Nason Creek: Upper White Pine Reach Restoration Plan

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INTRODUCTION

Nason Creek is a tributary to the Wenatchee River, which is part of the Upper Columbia River Basin located in central Washington (figure 1). Nason Creek contains the following Evolutionary Significant Unit (ESU) anadromous fish species listed for protection under the Endangered Species Act (ESA): Upper Columbia River spring Chinook salmon (*Oncorhynchus tshawysha*), Upper Columbia River steelhead (*Oncorhynchus mykiss*), and Columbia River bull trout (*Salvelinus confluentus*). Previous reports document impacts to riparian and streambank condition, channel function, floodplain connectivity, water quality, habitat diversity, and removal of large woody material as factors that have contributed to habitat degradation in Nason Creek (Andonaegui 2001; UCSRB 2007; UCRTT 2008; USBR 2008; USBR 2009). These conditions will persist into the future and are likely to continue to affect ESA-listed species if no action is taken to reverse these impacts. This restoration plan develops goals, measurable objectives, and actions that can be carried forward to improve the habitat conditions in Nason Creek. Further, the restoration plan will assist in working toward meeting tributary habitat commitments contained in the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008).

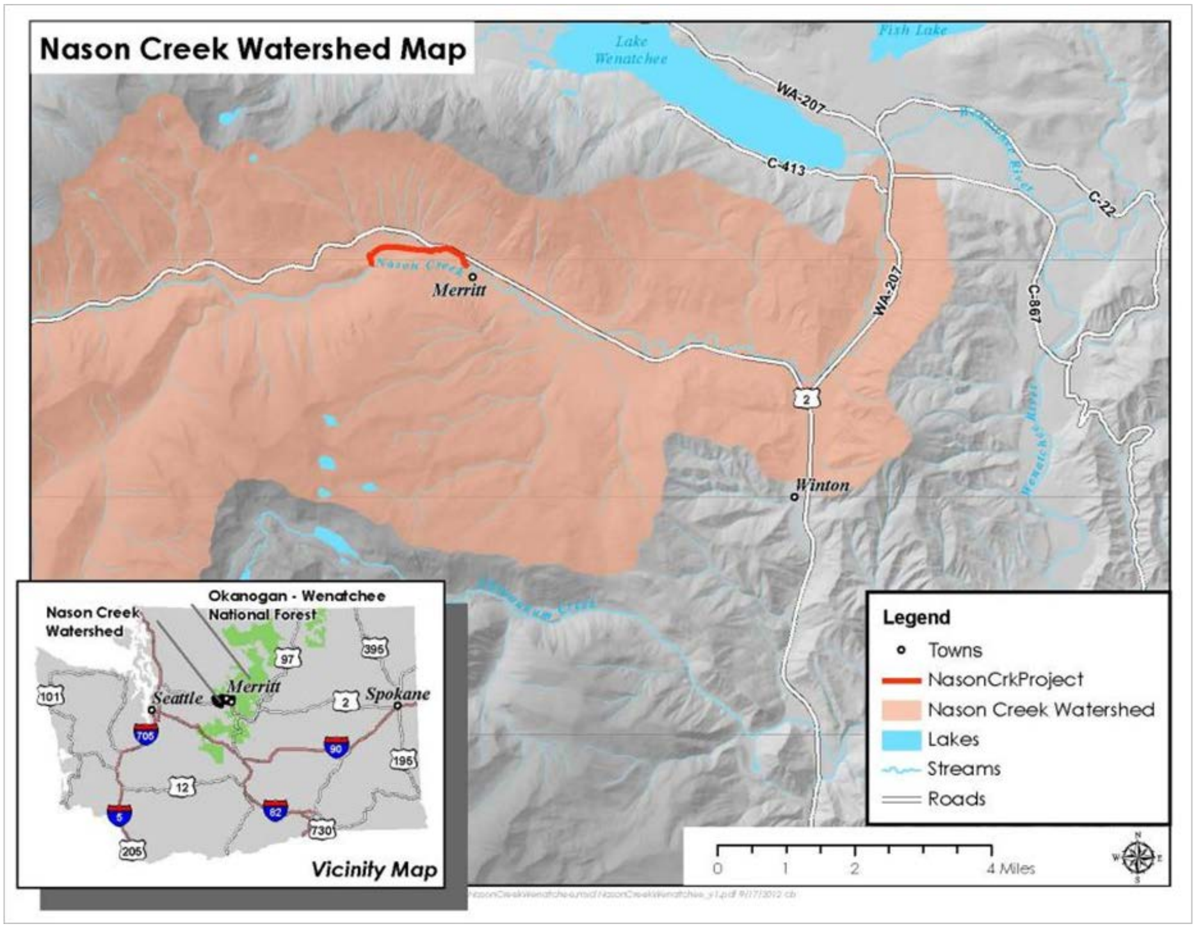

Figure 1. Location map of the Nason Creek watershed

Currently, the U.S. Bureau of Reclamation (USBR) and its partners are collaborating to develop a sequenced, reach-scale restoration approach on Nason Creek to restore salmonid habitat. This restoration plan focuses on the Upper White Pine Reach of Nason Creek, which encompasses a 2.25-mile-long segment of Nason Creek between river mile (RM) 14.25 and RM 12.0 as shown in figure 2.

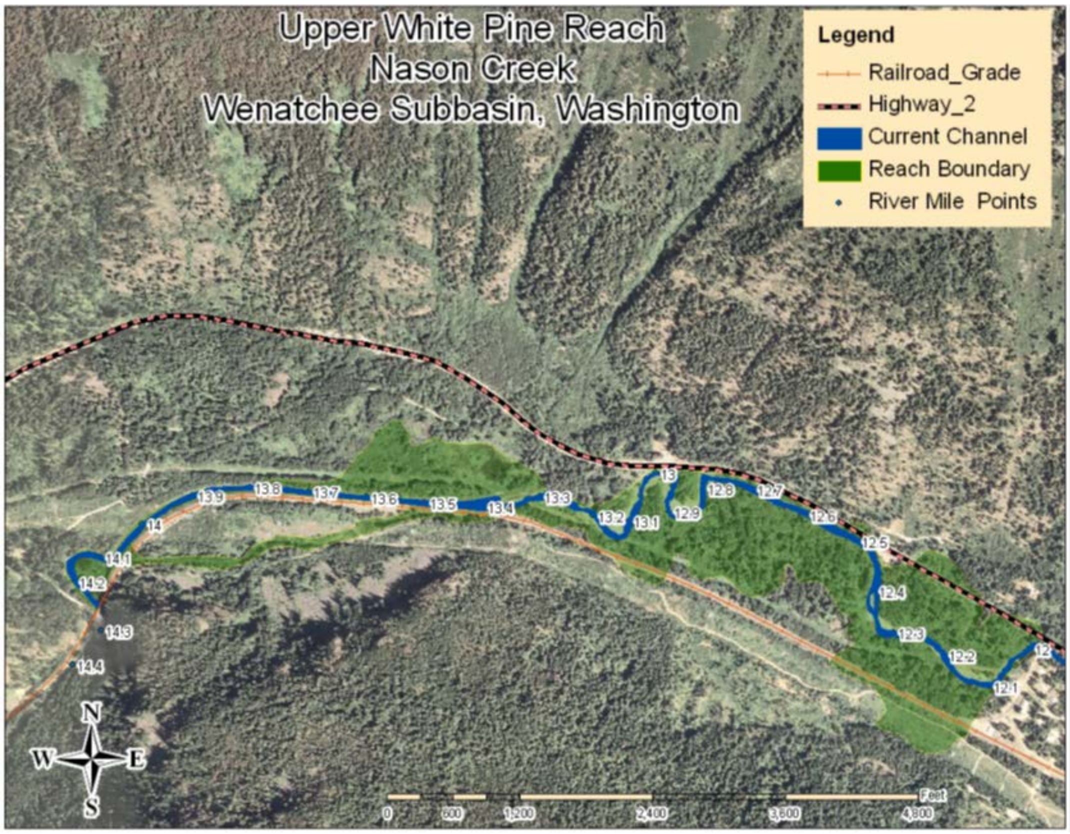

Figure 2. Location map of the Upper White Pine Reach of Nason Creek (USBR 2008)

To develop this restoration plan, the Upper White Pine project team, which includes USBR, Chelan County Natural Resources Department (CCNRD), the Yakama Nation, and the U.S. Forest Service, worked closely with a group of stakeholders and scientists to evaluate potential restoration actions in the Upper White Pine Reach. Key partners contributing to this evaluation included the Wenatchee Habitat Subcommittee (HSC) and an interdisciplinary team comprising regional experts and agency personnel. The project team conducted the assessment of the study area and restoration opportunities through an evaluation of geomorphic, hydraulic, and ecological processes, all of which are summarized in this plan. The restoration actions presented in this report will be vetted with private landowners, funders, and utilities through planning and permitting to determine the feasibility of project implementation.

Restoration Planning Context

The goal of this restoration plan is to support restoration and enhancement of aquatic habitat in the Upper White Pine Reach and the Nason Creek and Wenatchee Subwatersheds for ESA-listed salmon, steelhead trout, and bull trout.

The “Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan” (Recovery Plan, UCSRB 2007) identified Nason Creek as a category 2 watershed, meaning that it is a high priority for restoring ecosystem function and connectivity. The Recovery Plan, as well as the “Upper Columbia Regional Technical Team Biological Strategy” (UCRTT 2008), identified restoration priorities for Nason Creek. The 2008 Biological Strategy identified the following goals for the Upper White Pine Reach:

- Reconnect side channels, off-channels, wetlands, and floodplains to the stream where they have been disconnected.
- Increase habitat diversity and natural channel stability by increasing in-channel large wood complexes.
- Restore riparian vegetation conditions to reduce high water temperatures and to recover other lost riparian functions.

The USBR Tributary Assessment evaluated stream conditions in Nason Creek from river mile (RM) 4 to 14 (USBR 2008) and identified potential habitat restoration actions in the Upper White Pine Reach. The Upper White Pine Reach Assessment further prioritized habitat actions specific to RM 12 to 14.25 in the Upper White Pine Reach (USBR 2009). The following list summarizes all of the habitat actions that were identified for the reach:

- Protect and maintain wetlands and existing geomorphic, hydrologic, and riparian function.
- Conduct riparian rehabilitation to increase large woody debris (LWD) recruitment, canopy cover, and riparian composition by riparian planting within areas affected by powerlines, the railroad grade, roadways, or other cleared areas.
- Reconnect habitat units by modifying existing bank armoring and/or constructing LWD complexes to improve LWD retention, sediment retention, and habitat complexity and cover.
- Reconnect processes and isolated habitat by removing or modifying levees, the railroad grade, and U.S. Highway 2 to reconnect floodplains and wetlands, reconnect habitat-forming processes, and restore access to off-channel habitat.
- Reconnect processes by installing instream structures that will enhance floodplain connectivity.

We considered these previously identified goals and sub reach-level recommendations when developing the current restoration plan for the Upper White Pine Reach. We also conducted additional analysis and assessment of site limitations in order to develop restoration options.

THE PROJECT AREA

Nason Creek Watershed

Overview

The Nason Creek Watershed is located in the Cascade Mountains northwest of the town of Leavenworth, Washington. The Nason Creek Watershed is a 3rd-order basin that is approximately 69,000 acres in size. The Creek runs from the Cascade Crest near Stevens Pass to the Wenatchee River just downstream of Lake Wenatchee (Wenatchee RM 53.6). Elevations in the watershed range from 1,880 feet at the confluence with the Wenatchee River to 4,240 feet in the watershed headwaters. Nason Creek contributes 18 percent of the total flow to the Wenatchee River (WRIA 45 Planning Unit 2006). The channel of Nason Creek is confined throughout most of its length by either natural valley formations or by the Burlington-Northern Santa Fe Railway (BNSF) prism and/or U.S. Highway 2. Bonneville Power Administration (BPA) and Chelan County Public Utility District (PUD) utility lines also cross and/or run parallel to Nason Creek through several reaches. Approximately 400 acres of floodplain, side channels, and oxbows have been cut off from the mainstem of Nason Creek and over 5 percent of the mainstem channel has been armored by riprap and boulders (MCMCP 1998). Approximately 96 percent of the watershed is forested and land uses include timber harvest, rural residential, and recreation. The Forest Service manages approximately 78 percent of the watershed with the majority of private land being concentrated in the lower half of the watershed.

Despite impairments to stream habitat, Nason Creek is one of the more productive streams in the Wenatchee basin, providing habitat for all resident salmonids as well as for bull trout, cutthroat, and rainbow trout. Critical habitat for all three listed species extends through the mainstem for all species and into some tributaries for steelhead and bull trout. Existing fish habitat in Nason Creek are degraded from historic conditions, primarily as a result of floodplain development for transportation and power transmission as well as past timber harvest. The extent of upstream migration is near White Pine Creek for anadromous species (steelhead, Coho, and Chinook) and Mill Creek for bull trout. Migration for all fish in Nason Creek is blocked by a box canyon of bedrock falls and cascades approximately ½ mile above Mill Creek.

Past Land Use

Past land use activities included beaver trapping in the early to mid-1800s, construction and maintenance for U.S. Highway 2, private home building, campgrounds, recreation, power and transmission line maintenance, and railroad activities. The railroad was completed in 1892. U.S. Highway 2 was present in the early 1900s and was improved and relocated closer to Nason Creek in 1960. The powerlines were present on 1930s maps, but their initial construction date is unknown. Native Americans occupied the valley prior to the 1890s, and American pioneer settlements began with the railroad in the 1890s and increased thereafter (USBR 2008).

Upper White Pine Reach

The Upper White Pine Reach encompasses the stream channel and floodplain areas of Nason Creek from RM 12 just above Merritt, Washington to RM 14.25 where National Forest System (NFS) Road 6950 crosses under the White Pine Bridge. The Nason Creek stream channel in this area is currently bounded by U.S. Highway 2 to the north and the BNSF railroad prism to the south. Approximately 135 acres of floodplain and active channel are contained within the reach and U.S. Highway 2 and the BNSF railroad prism disconnect approximately 31 percent of the reach flood plain area (USBR 2009).

Mahar Creek is the only named tributary that enters Nason Creek within the Upper White Pine Reach on the north side of the channel between RM 14.1 and 14.2. Several other non-named ephemeral and intermittent tributaries enter Nason Creek primarily on the north side of the channel. Five perennial tributaries flow into the wetland near RM 13.5. During low flow conditions, these tributaries contribute 5 to 6 percent of flows to Nason Creek through the wetland area (refer to the wetland determination memo for more information).

Within the Upper White Pine Reach, the U.S. Forest Service is the primary landowner. Several additional small parcels are owned by either Chelan County or other private landowners. For a landowner map of the Upper White Pine project area, please contact the Chelan County Natural Resources Department in Wenatchee, Washington.

Subreaches

We established five subreach boundaries to define restoration actions (figure 3). Subreach boundaries were delineated based upon previous subreach units characterized in the Reach Assessment (USBR 2009, Table 10) and existing geomorphic conditions.

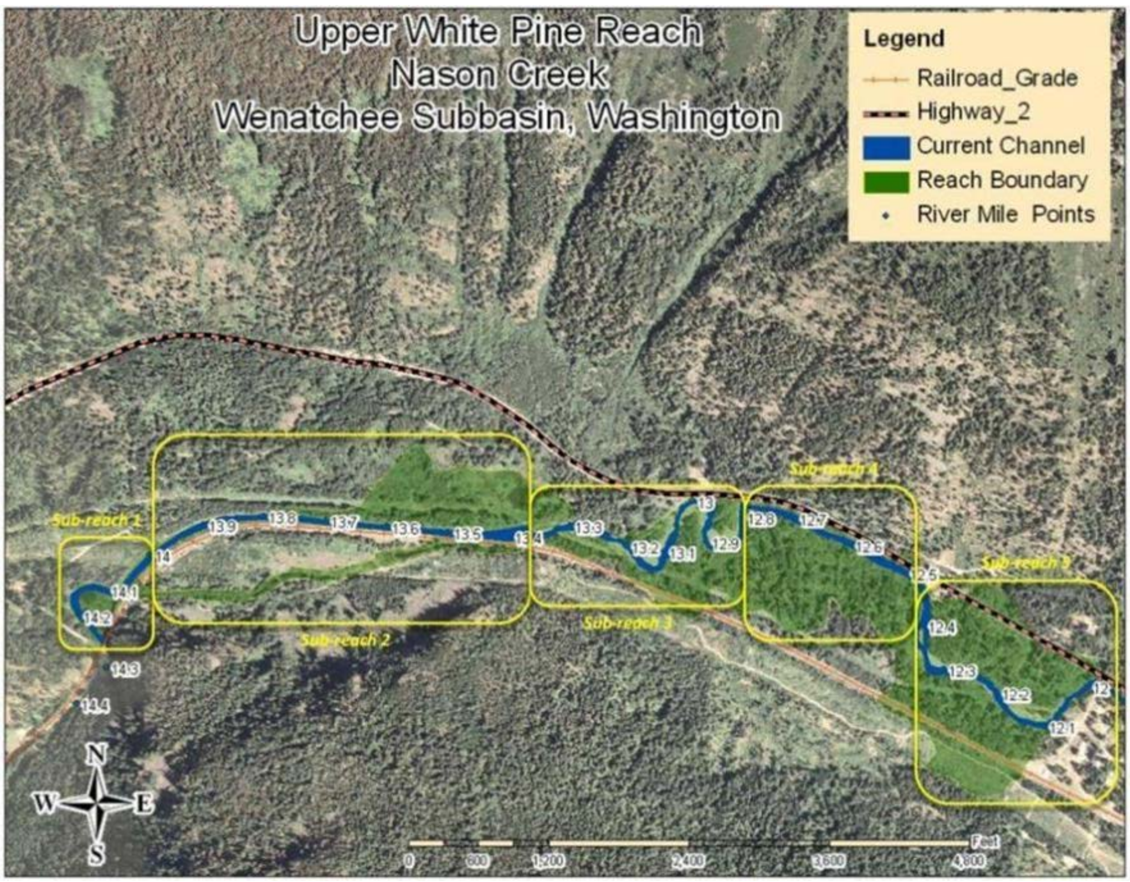

Figure 3. Location of the five subreach boundaries to be used for the Upper White Pine Reach Analysis (USBR 2008)

The following bullets define the five subreaches that will be used to describe potential restoration options for the Upper White Pine Reach of Nason Creek.

- **Subreach 1** begins at RM 14.25 where the BNSF Bridge crosses Nason Creek over the White Pine Road (FSR 6950) and it extends downstream to RM 14.0 where the BPA powerline crosses Nason Creek. This area includes UWP IZ-1 and UWP DIZ-1 from the Reach Assessment (Figure 8 of USBR 2009).
- **Subreach 2** starts near RM 14.0 where the BPA powerline crosses Nason Creek and extends downstream to RM 13.4 just upstream from where the PUD powerline crosses Nason Creek. This area includes UWP IZ-1, UW P IZ-2, UWP DOZ-1, UWP DIZ-1 (Figure 8 of USBR 2009).
- **Subreach 3** starts near RM 13.4 just upstream from where the PUD powerline crosses Nason Creek and extends downstream two meander bends to RM 12.8 where Nason Creek starts to flow adjacent to U.S. Highway 2. This area includes UWP IZ-2, UWP DOZ-1, UWP DOZ-2, UW OZ-1, and UW OZ-2 (Figure 8 of USBR 2009).
- **Subreach** 4 starts near RM 12.8 where Nason Creek begins to flow adjacent to U.S. Highway 2 and extends downstream to RM 12.5 where Nason Creek flows south from the U.S. Highway 2 prism near the abandoned fishing cabins. This area includes UWP IZ-3 and UWP OZ-1 (Figure 8 of USBR 2009).
- **Subreach 5** starts near RM 12.5 where Nason Creek leaves U.S. Highway 2 at the abandoned fishing cabins downstream to the reach end at RM 12.0, which is just upstream of the bridge in Merrit, Washington. This area includes UWP IZ-4, UWP OZ-3, UWP DOZ-4, UWP DOZ-5, and UWP DOZ-6 (Figure 8 of USBR 2009).

EXISTING CONDITIONS

Hydrology

Nason Creek drains high-elevation areas of the Chiwaukum Mountains and has a snowmelt-dominated hydrologic regime. Figure 4 (Malmon 2010) shows modeled median, high, and low exceedence flows for Nason Creek at RM 12.

Although peak flows typically occur because of snowmelt in the late spring or early summer, some of the largest floods have occurred from heavy late-fall rain events. Large past flood events occurred in May 1948, November 1959, November 1990, November 1995, and November 2006. Past floods have washed out U.S. Highway 2 and damaged bridges, houses, and other infrastructure.

We determined peak flow hydrology following the methods used by the USBR as part of planning for the Lower White Pine project located downstream. Although a Washington Department of Ecology gage has been operating near the mouth of Nason Creek since 2002, no long-term stream gage record is available on Nason to reliably estimate peak flows. For this reason, we estimated flood magnitudes using a comparison to peak flows estimated for the Icicle Creek gage (USGS Gage #12458000), which has over 60 years of peak flow records. A direct basin-size correction was used to apply the Icicle Creek flood volumes to RM 13 of Nason Creek, which is roughly the midpoint of the Upper White Pine Reach. The flood magnitudes are presented in table 1.

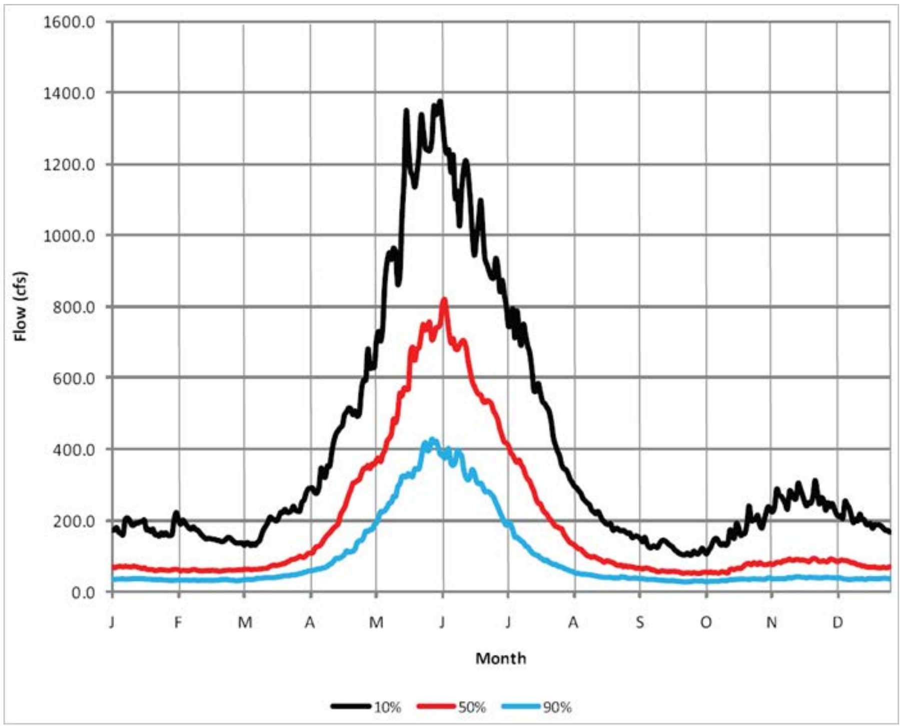

Figure 4. Modeled 10 percent, 50 percent, and 90 percent exceedance flows for RM 12 using data from 7 regional gages. Reprinted from Malmon (2010). Percentile flows represent the daily flow that is equaled or exceeded for the given percentage of time over the available period of record.

Table 1. Peak flow estimates for Nason Creek Upper White Pine Reach at RM 13. Flows were generated using a basin-size comparison with Icicle Creek Gage (USGS #12485000). Values are rounded to the nearest 100 cubic feet per second (cfs).

Recurrence Interval (years)	Estimated flow at RM 13 (cfs)
1.5	1,400
2	1,700
5	2,600
10	3,400
25	4,500
50	5,500
100	6,700
500	10,000

Geomorphology

The Upper White Pine Reach extends from RM 12 to 14.25 and comprises 135 acres of floodplain and active channel (USBR 2009). The reach lies within a U-shaped valley composed of alluvial and glacial deposits. Gradient is less than 2 percent and is mostly less than 0.5 percent except for at the upstream end (subreach 1). Figure 5 shows the longitudinal thalweg profile for the reach. The USBR (2009) determined that approximately 31 percent of the former active channel and floodplain have been "disconnected" from the existing active channel due to human actions that have re-located the channel or that reduce or completely eliminate the ability of flood flows to access the floodplain. One of the most significant human impacts to the reach was the relocation of the upstream portion of the channel (subreach 2) associated with the re-alignment of the BNSF railroad in the late 1950s or early 1960s.

Natural processes as well as past and contemporary land-use practices affect existing geomorphologic conditions. Human features within the study area that significantly influence geomorphology includes the BNSF railroad, U.S. Highway 2, powerline corridors (BPA and Clark Public Utility District), residential development, and floodplain fill. Figure 6 is a hillshaded relief map of the study area including the location of human features that affect geomorphic processes within the geomorphic low surface. Geomorphic descriptions and maps are provided below at the subreach scale.

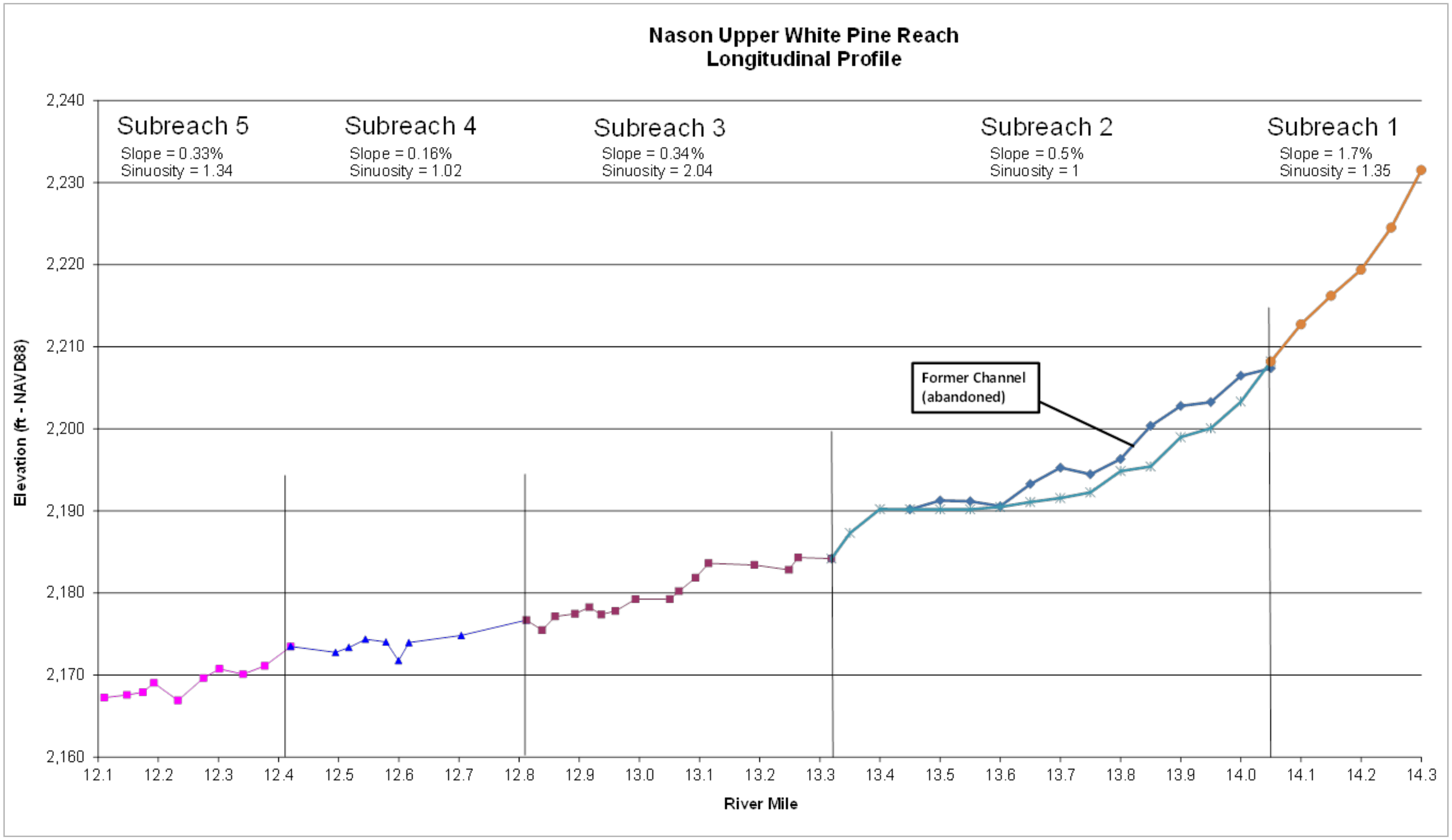

Figure 5. Longitudinal profile of the Upper White Pine Reach. Data for subreaches 1 and 2 was obtained from LiDAR and therefore represents water surface at the time of the LiDAR flight. Data for subreaches 3-5 is from bathymetric survey data and represents the channel thalweg.

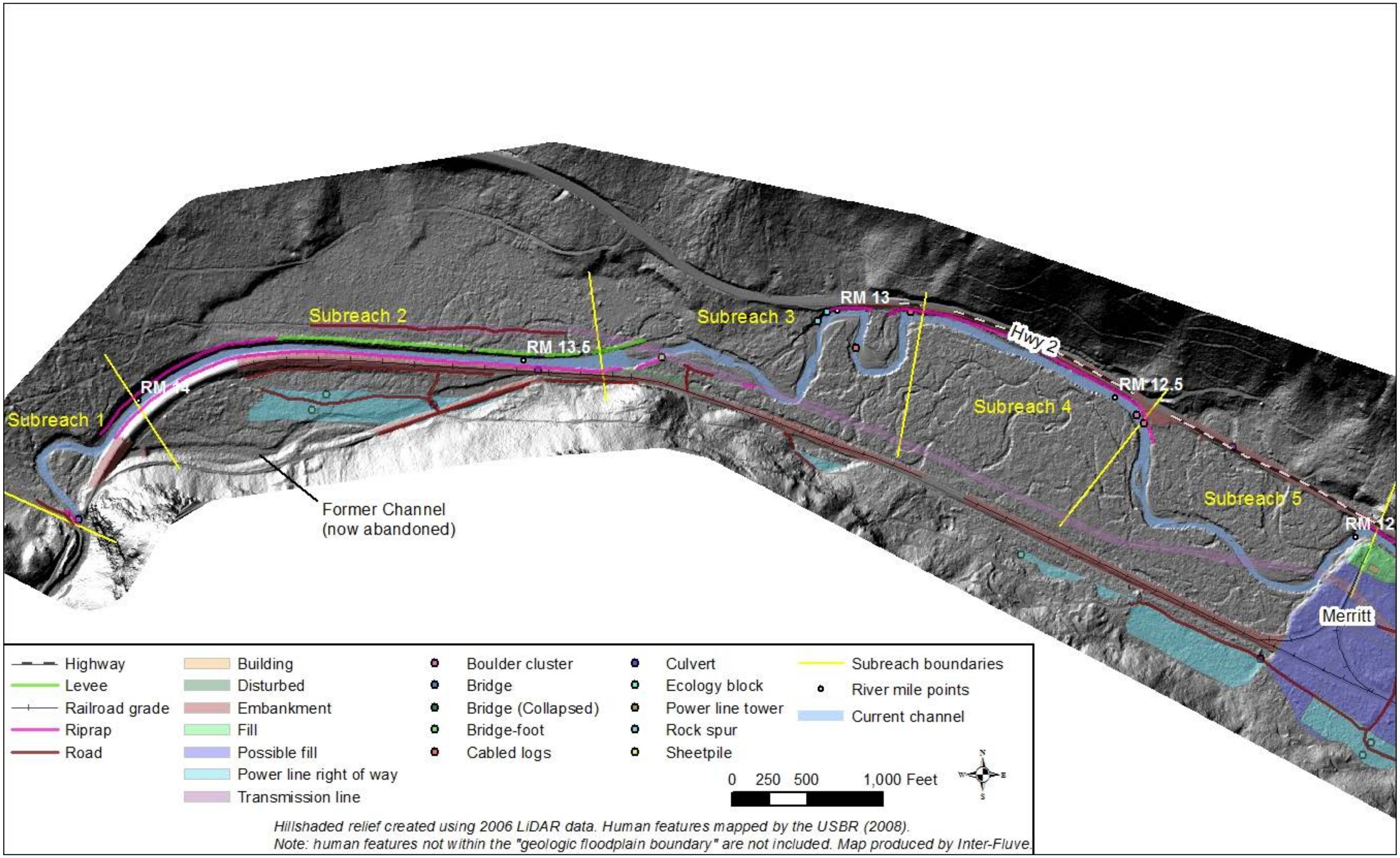

Figure 6. Hillshaded relief (from LiDAR) of the study area showing the subreach boundaries and man-made features

Subreach 1

In subreach 1, the channel and floodplain have been impacted by the construction of the railroad crossing and channelization or stream diversion resulting from the realignment of the rail corridor in the 1940s (figure 7). Channel characteristics are relatively steep, straight, highly entrenched with a few runs and riffle/cascades composed of boulder and cobble substrate (figure 8).

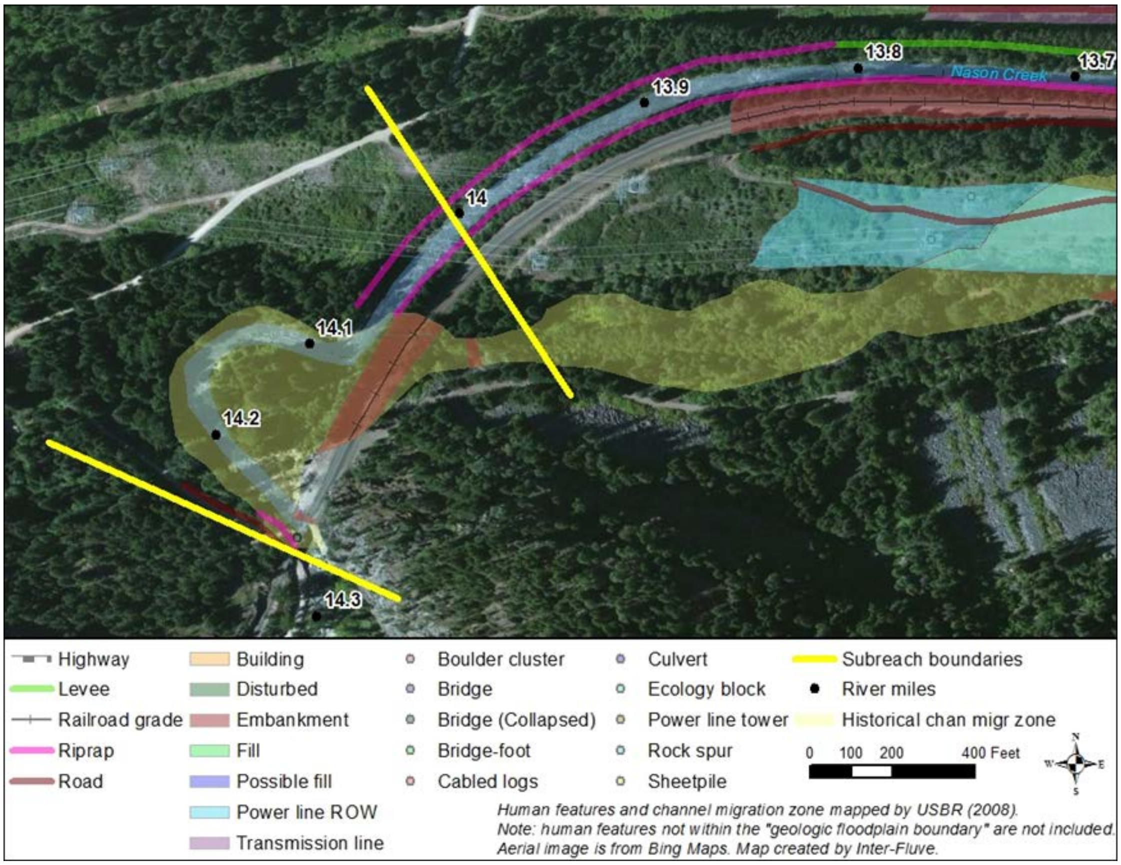

Figure 7. Subreach 1 showing the historical channel migration zone, current channel position, and man-made features as mapped by the USBR as part of the Nason Creek Tributary Assessment (USBR 2008)

Figure 8. View of subreach 1 just below the BNSF railroad bridge at RM 14.25. The channel has been straightened and riprapped through this area.

Subreach 2

The existing Nason Creek channel through subreach 2 was rerouted to the north to accommodate the realignment of the railroad. The creek is riprapped and dikes exist on both sides of the Nason Creek channel (figure 9, figure 10). The channel through subreach 2 is similar to subreach 1 in that it is incised and highly entrenched due to the rip-rap and dikes. However subreach 2 has a lower channel slope than subreach 1; Subreach 1 (1.7%) versus subreach 2 (0.5%). Due to the lower gradient, subreach 2 contains mostly glide habitat. Based on aerial photo interpretation (Appendix A), the stream channel throughout the entire analysis area was historically a response reach and migrated across the valley floor. The main channel from RM 14 through RM 13.5 occupied the southern extent of the valley prior to channelization. The existing realigned stream channel corridor in subreaches 1 and 2 was dredged to accommodate the realignment of the BNSF railroad prism. The historic riparian conditions that existed through subreaches 1 and 2 would have been similar to the reference areas upstream, which would have provided the reaches with essential fish habitat elements (large woody debris, pools, cover, shade, etc.). Presently, subreach 2 is a transport reach due to the confinement of the railroad prism and left bank levees. Therefore sediment is routed downstream to subreach 3 and beyond. Historically, before channel realignment, this reach was a depositional response reach similar to subreach 3.

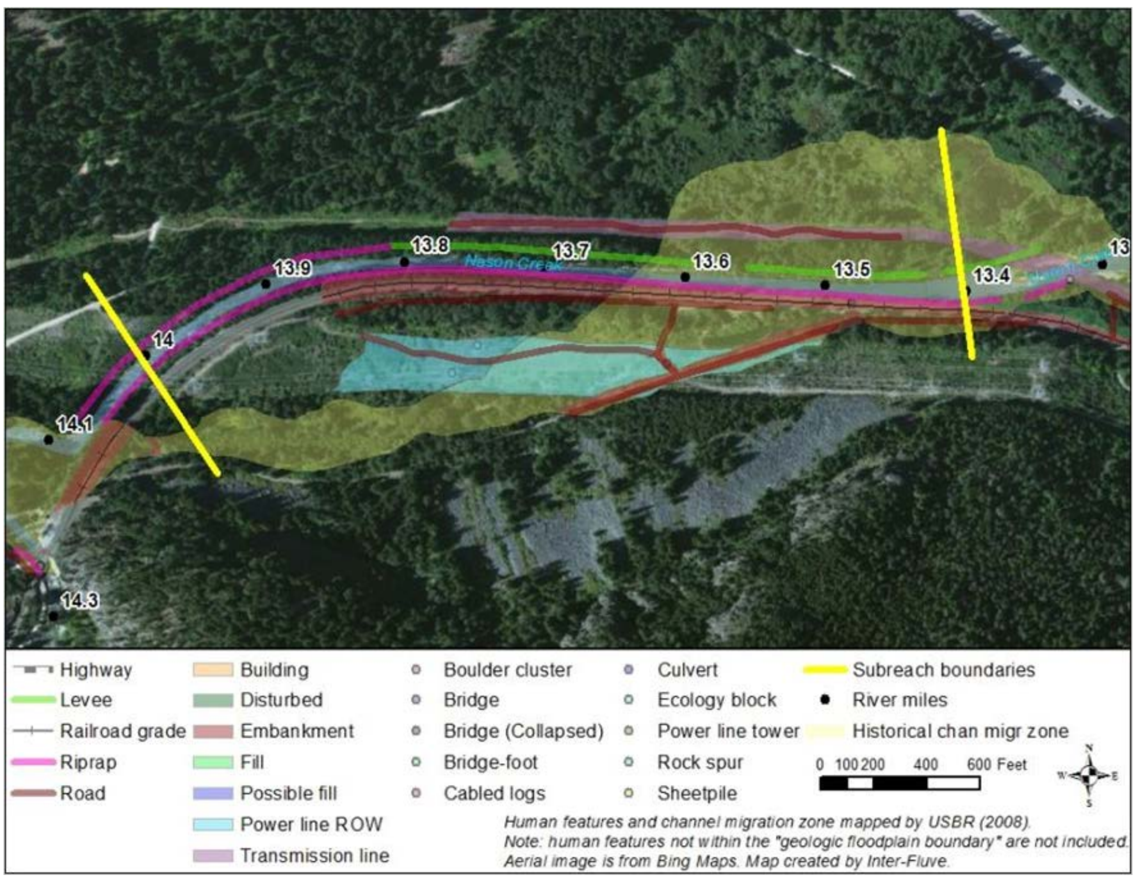

Figure 9. Subreach 2 showing the historical channel migration zone, current channel position, and man-made features as mapped by the USBR as part of the Nason Creek Tributary Assessment (USBR 2008)

Figure 10. Typical section of subreach 2 looking upstream. The railroad grade is located to the left and the levee that protects the CPUD powerlines is located to the right. Both banks are protected with riprap.

Subreach 3

Compared to upstream (subreach 2), Nason Creek through subreach 3 has less artificial confinement and is lower gradient and more alluvial (figure 11). It is a response reach, and much of the bedload material transported through the more confined upstream reaches is deposited in this section. A short but highly sinuous meander sequence comprises most of the section. The railroad embankment and armoring associated with a PUD powerline tower limit channel migration on the river-right at the upstream end.

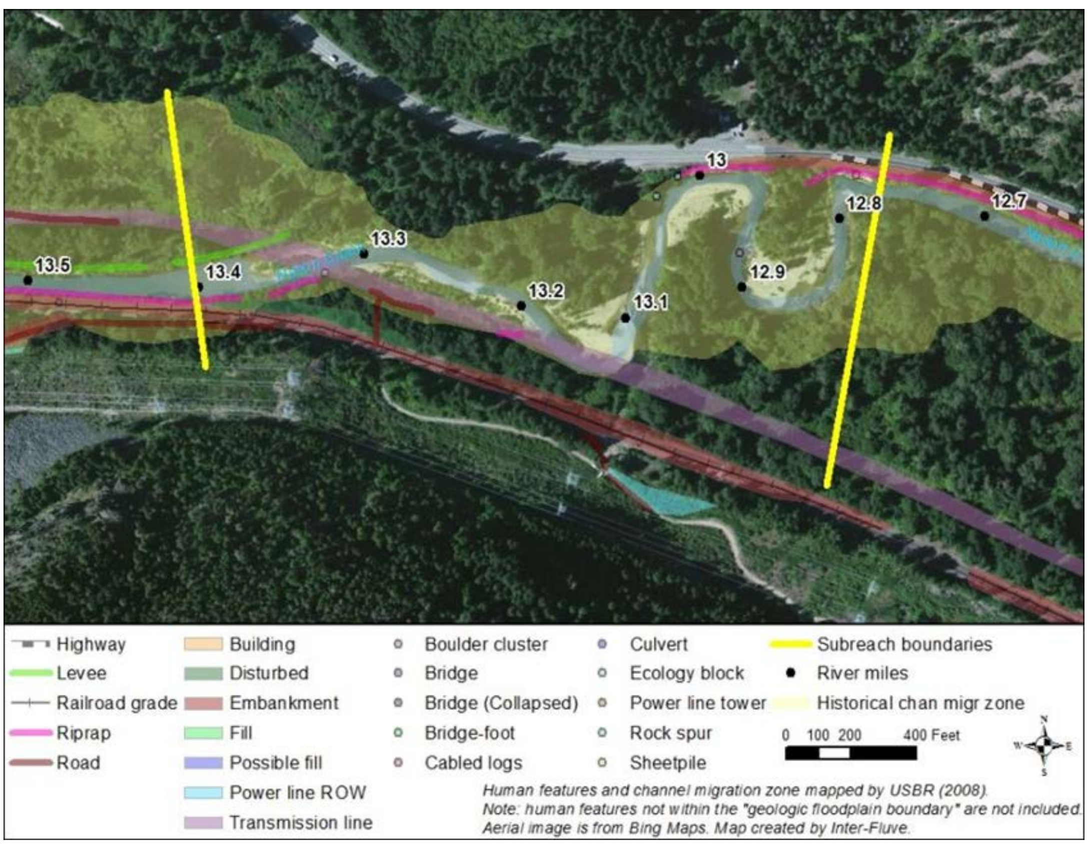

Figure 11. Subreach 3 showing the historical channel migration zone, current channel position, and man-made features as mapped by the USBR as part of the Nason Creek Tributary Assessment (USBR 2008)

There is a rapidly eroding streambank on the river-right near RM 13 due to riparian vegetation destabilization caused by the PUD powerline corridor (figure 12). This erosion currently threatens a power pole. U.S. Highway 2 abuts the stream on the left riverbank at the outside bends of the meanders at RMs 12.8 and 13. The highway and associated riprap banks limit natural bank erosion and impair riparian conditions. Meander scrolling and plan form changes have occurred over the course of the historical photo record. Significant scrolling of the upstream meander since 1970 (figure 13) is likely related to channelization of subreach 2, which has accelerated delivery of bedload material to this segment.

Figure 12. Power pole threatened by streambank erosion near RM 13

Figure 13. Illustration of changes to the migration pattern of the stream channel through subreach 3. Note that the blue line is interpreted from LiDAR data taken in 2006 and represents the approximate current stream channel. The aerial photo was taken in 1970.

Subreach 4

Subreach 4 extends from RM 12.8 downstream to RM 12.5. U.S. Highway 2 parallels this segment along the river-left bank, which is armored in several places with riprap (figure 14). The highway embankment has impacted riparian vegetation, has reduced the potential for large wood recruitment, and has narrowed the flood-prone area along the left bank. This segment has very low sinuosity but is also very low gradient. The segment is comprised of a mix of pools, riffles, and glides.

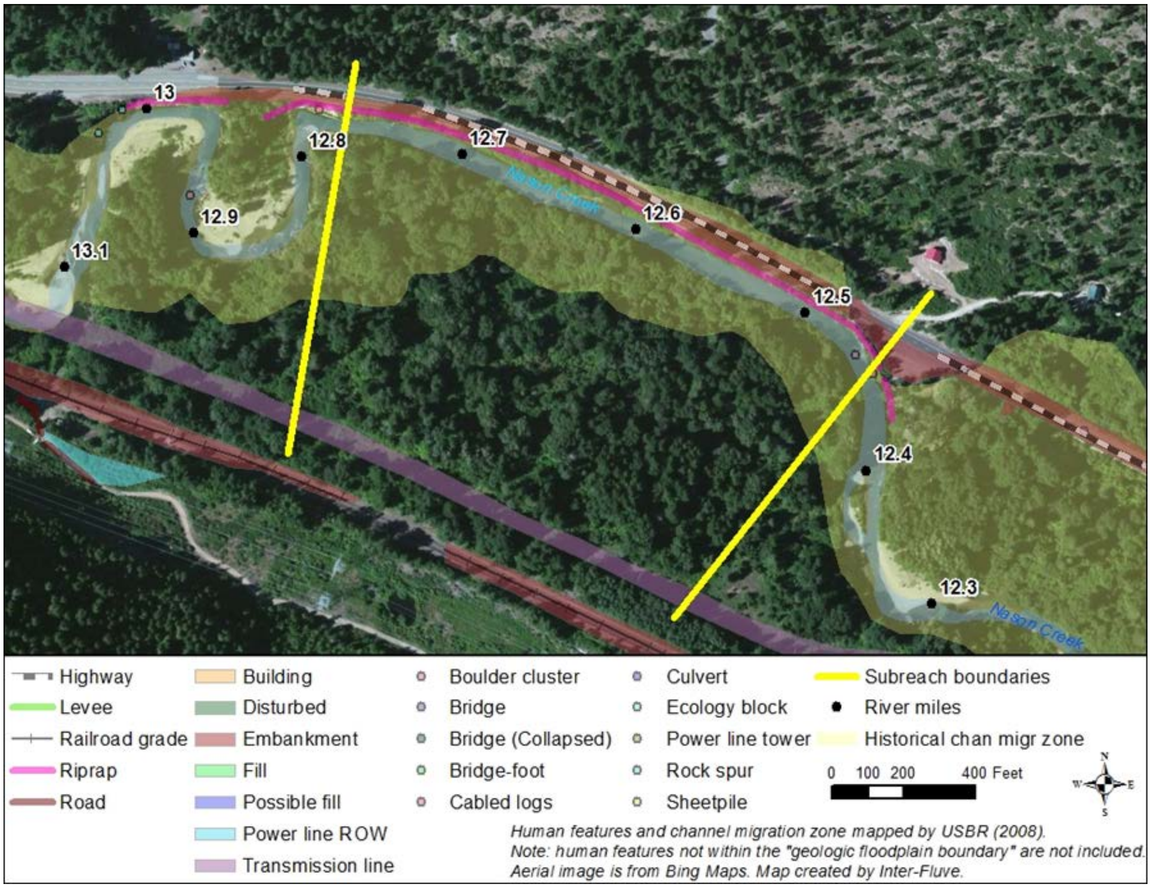

Figure 14. Subreach 4 showing the historical channel migration zone, current channel position, and man-made features as mapped by the USBR as part of the Nason Creek Tributary Assessment (USBR 2008)

Through subreach 4, the channel has remained in a relatively constant position over the reliable historical photo and map record (since 1932), except for a small segment at the downstream end of the subreach near RM 12.5, which includes a short (approximately 0.1 mile) portion of former channel that was filled, straightened, and shifted south as part of a highway upgrade project.

Overflow channel scars extending from subreach 3 are evident throughout the right-bank floodplain but their origin is unknown. These overflow channel scars, and the entire river-right floodplain surface, trend diagonally downward in elevation in a northeastward (i.e., down-valley and toward river-left) direction. It is possible that these features are related to a past disturbance, such as a large channel-occluding event (e.g., large wood jam, debris avalanche, or snow avalanche) within subreach 3 that initiated significant floodplain flow and overbank deposition. Underlying geologic processes may also be contributing to this condition. Under existing conditions, the channel appears to be moderately incised in its current location and does not access significant portions of the floodplain until large flood events (i.e., above the 10-year event; see the Hydraulics section below).

Subreach 5

Subreach 5 extends from RM 12.5 downstream to the reach end at RM 12.0 (figure 15). Subreach 5 has moderate sinuosity and pool-riffle morphology. There is a moderate amount of large wood. A logjam was located near RM 12.3 during field visits in 2011 (figure 16). There is evidence of past incision that may be recovering via lateral channel migration and bar formation. Instream and riparian habitat conditions appear to be relatively intact.

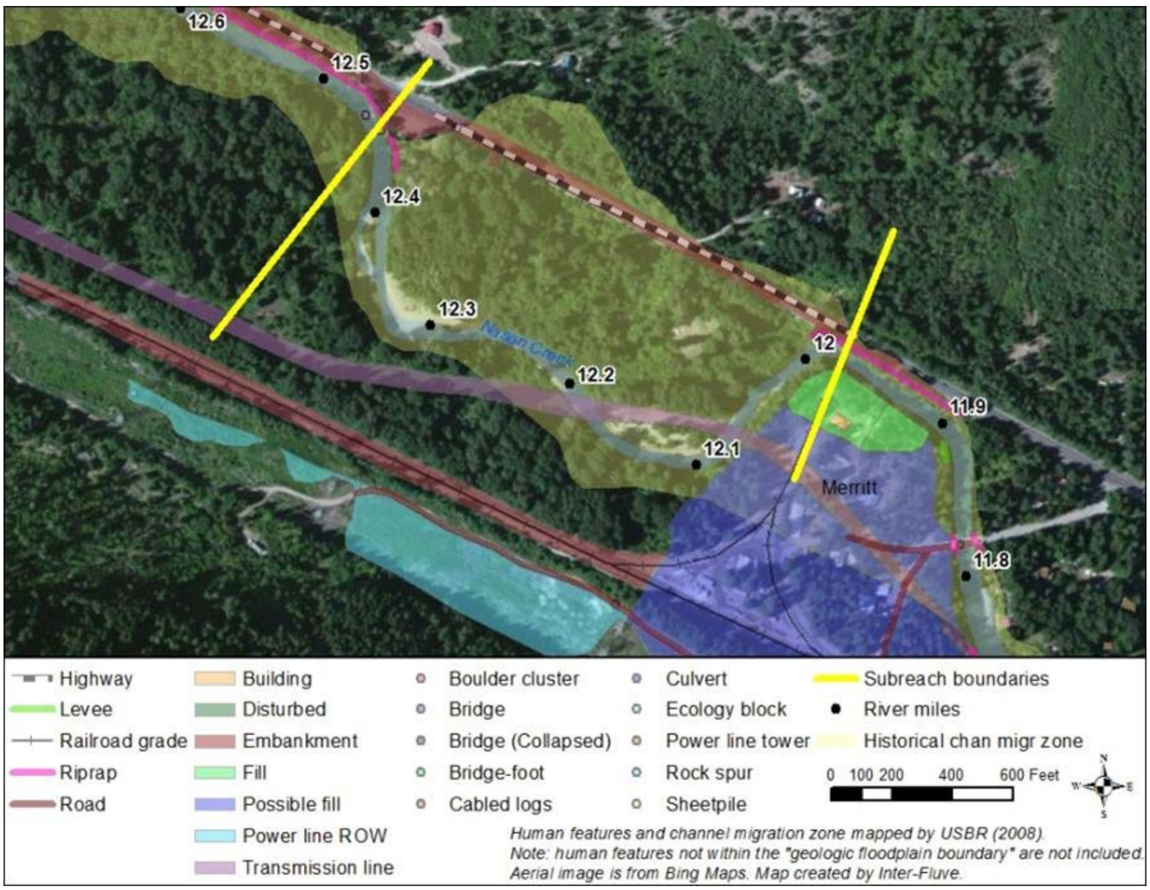

Figure 15. Subreach 5 showing the historical channel migration zone, current channel position, and man-made features as mapped by the USBR as part of the Nason Creek Tributary Assessment (USBR 2008)

As evidenced from 1932 maps and floodplain topography, the main channel was historically located to the north of its current alignment and ran adjacent to the left valley wall to the north of U.S. Highway 2. Construction associated with U.S. Highway 2 sometime between 1932 and 1949 disconnected this historical channel. The channel has been located more or less in its current alignment since at least 1949. Remnant relic channels remain within the left and right-bank floodplains within this segment.

Figure 16. Newly recruited cedar tree and associated logjam near RM 12.3 (photo taken in May 2011)

An unknown quantity of fill was placed downstream at the community of Merritt prior to 1900. This fill has decreased the extent and frequency of floodplain inundation and has likely led to local and upstream channel incision. However, there is little historical information on past conditions (prior to fill and prior to railroad) to compare to contemporary conditions.

Hydraulics

We conducted preliminary hydraulic modeling and analysis to characterize existing hydraulic and sediment transport conditions and to establish a baseline for evaluating hydraulic conditions under various restoration scenarios. We conducted one-dimensional, steady state hydraulic modeling using HEC-RAS and HEC-GeoRAS for inundation modeling. The hydraulic analysis helps to characterize flood inundation patterns, the distribution of stream energy throughout the study reach, and the potential for sediment scour and deposition.

Modeling Methods

We created a one-dimensional hydraulic model using the HEC GeoRAS framework to create the boundaries of the model system (stream centerline, bank stations, overbank flowpaths, and cross sections). These features were overlaid on a digital elevation model from which elevations were extracted for all components of the geometric data set. We created the digital elevation model using a combination of LiDAR data as well as 27 surveyed cross-sections of the bankfull channel between river miles 12.1 and 13.3 (subreaches 3 to 5). For RM 13.3 to 14.3 (subreaches 1 to 2), only LiDAR data was used, which means the cross-section data used in the model does not represent actual bathymetry but instead represents the water surface elevation at the time the LiDAR was collected (flow at the time of the LiDAR flight was 40 cfs at the Washington State Department of Ecology gage at the mouth of Nason Creek). Topography data used in the hydraulic model for subreaches 1 and 2 is therefore believed to be most appropriate for modeling higher discharges only (i.e., approximately a 2-year event or greater), and should be used with caution to evaluate conditions at lower flow levels.

Once the geometric data was developed, we exported the model from ArcGIS and brought it into HEC-RAS 4.1.0, a one-dimensional water surface profiling program. We input steady-flow data based on the flood frequency data, and modeled flows ranging from the 2-year to 100-year floods. For the purposes of this effort, we used a Manning's n value of 0.04 for the channel and 0.08 for overbank areas based on the average channel geometry and roughness characteristics.

We imported the HEC-RAS output back into ArcGIS and mapped flood inundation using HEC GeoRAS. This involves overlaying model output onto the digital terrain model to map inundation extents.

Results and Discussion

Inundation plots are included in figure 17, figure 18, and figure 19 for the 2-year, 10-year, and 100-year floods. During the 2-year event, most of the flow remains contained within the channel throughout the study area. Only low-lying portions of the floodplain, including primarily relic channel scars and some connected backwater areas become inundated. At the 10-year event, much of the flow continues to remain within the active channel except for portions of the lower end of subreach 2 (near RM 13.5) and in subreach 5 (RM 12 to 12.5). At the 100-year event, significant portions of the floodplain become inundated. Flows in subreach 2, which is artificially straightened and channelized, remain deep and narrow at all flow levels. Shallower flows occur in subreaches 3 and 5, which are less confined and have a greater degree of floodplain inundation at all flows. Floodplain inundation within the large left-bank floodplain in subreach 2 is a result of backwater inundation from downstream; this subreach is largely isolated from its floodplain at all flows due to the elevation of the channel bed relative to the floodplain and the left-bank levee system that extends from RM 13.5 to 13.9.

The historical hydraulic regime of the Upper White Pine Reach has been significantly altered by the construction of the BNSF railroad prism, U.S. Highway 2, straightening, diking, floodplain fill, and armoring of the Nason Creek channel. This is particularly evident in subreaches 1 and 2, but lesser impacts have also occurred in subreaches 3 to 5. Before these alterations, Nason Creek would have had more frequent floodplain inundation and would have inundated areas that are now isolated due to man-made infrastructure. These results help to characterize existing conditions at the site and are used to compare to future proposed conditions modeling to evaluate the effects of restoration scenarios.

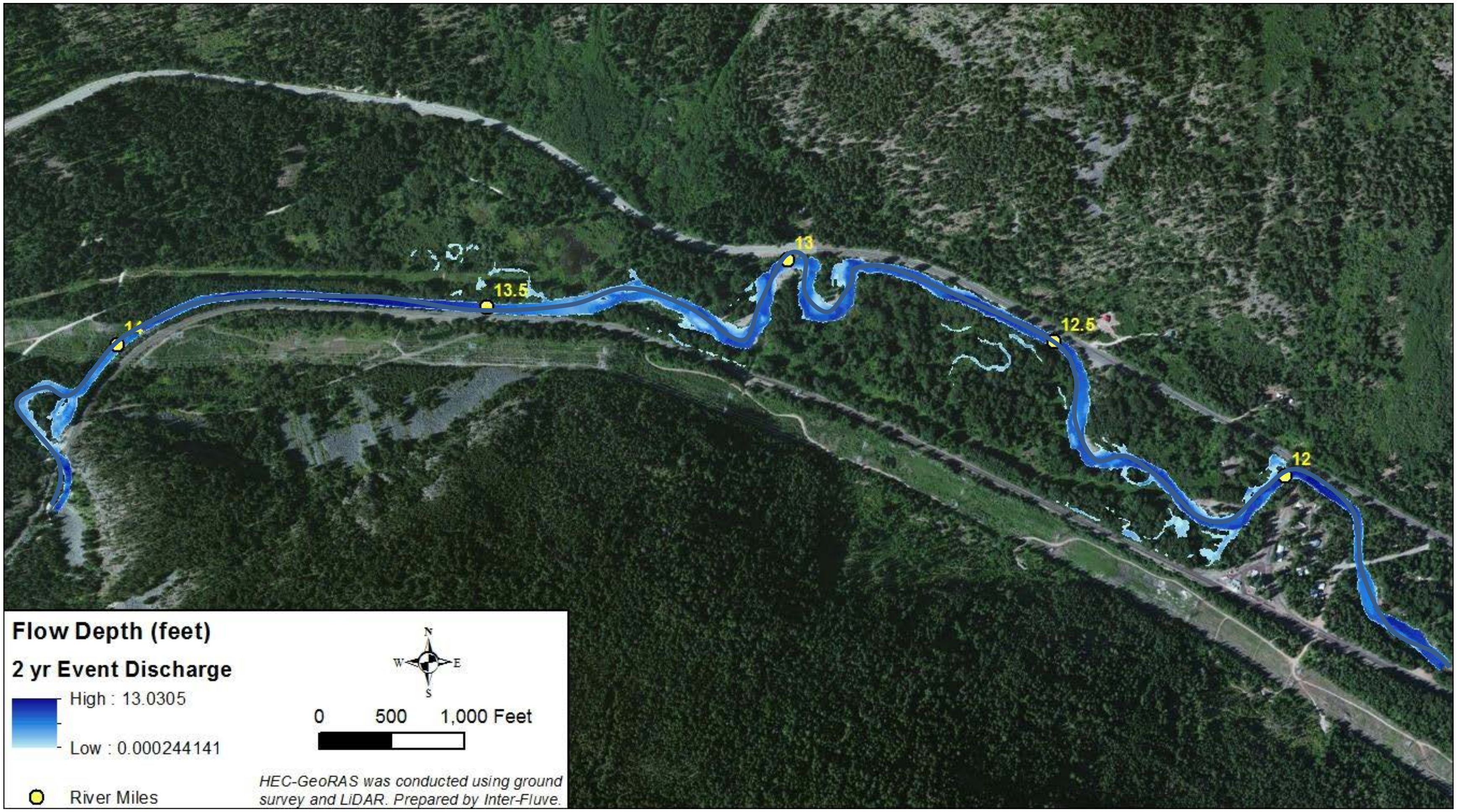

Figure 17. Existing water depth and inundation extent from the HEC GeoRAS model output for a 2-year flow event (Q_2 flow)

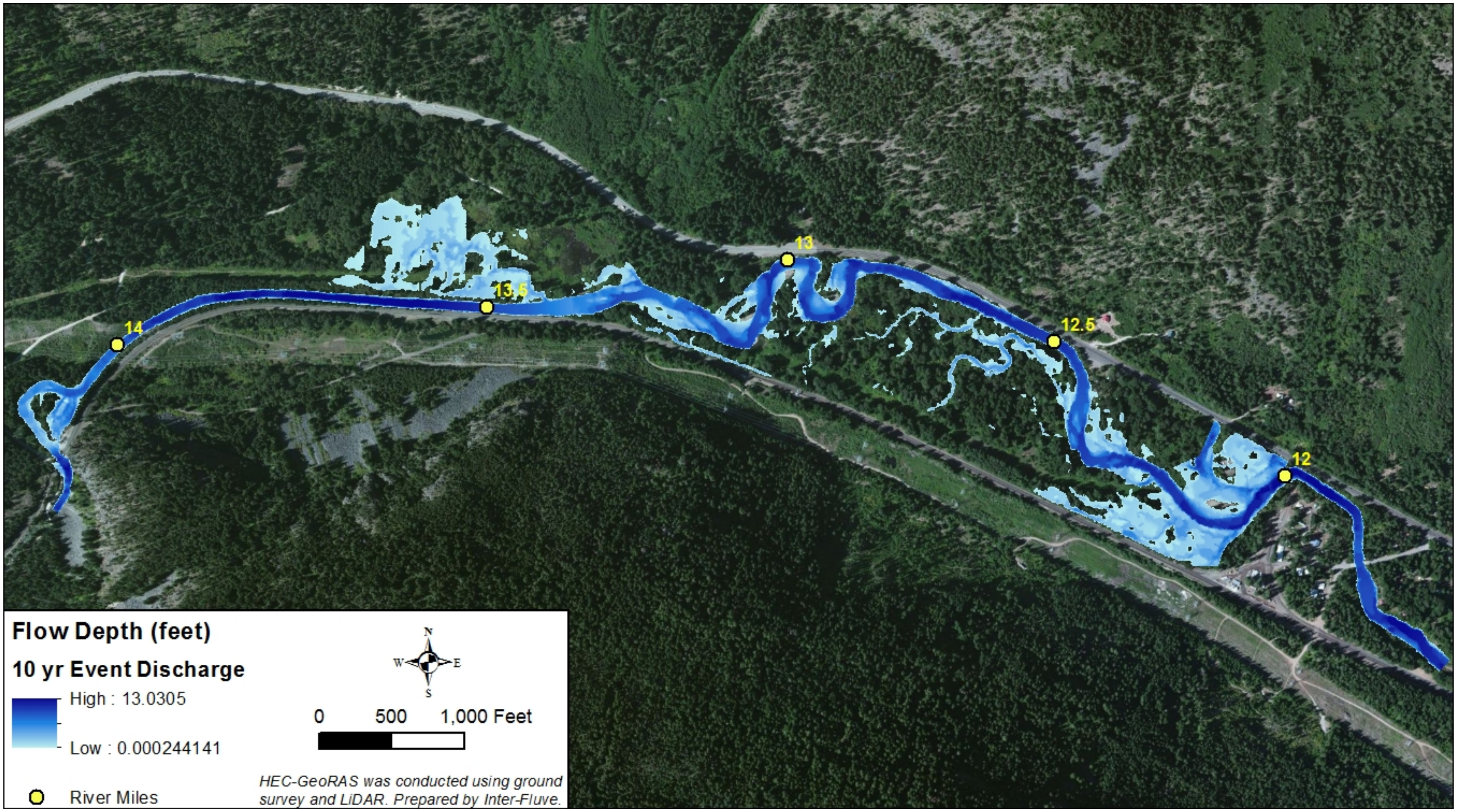

Figure 18. Existing water depth and inundation extent from the HEC GeoRAS model output for a 10-year flow event (Q_{10} flow)

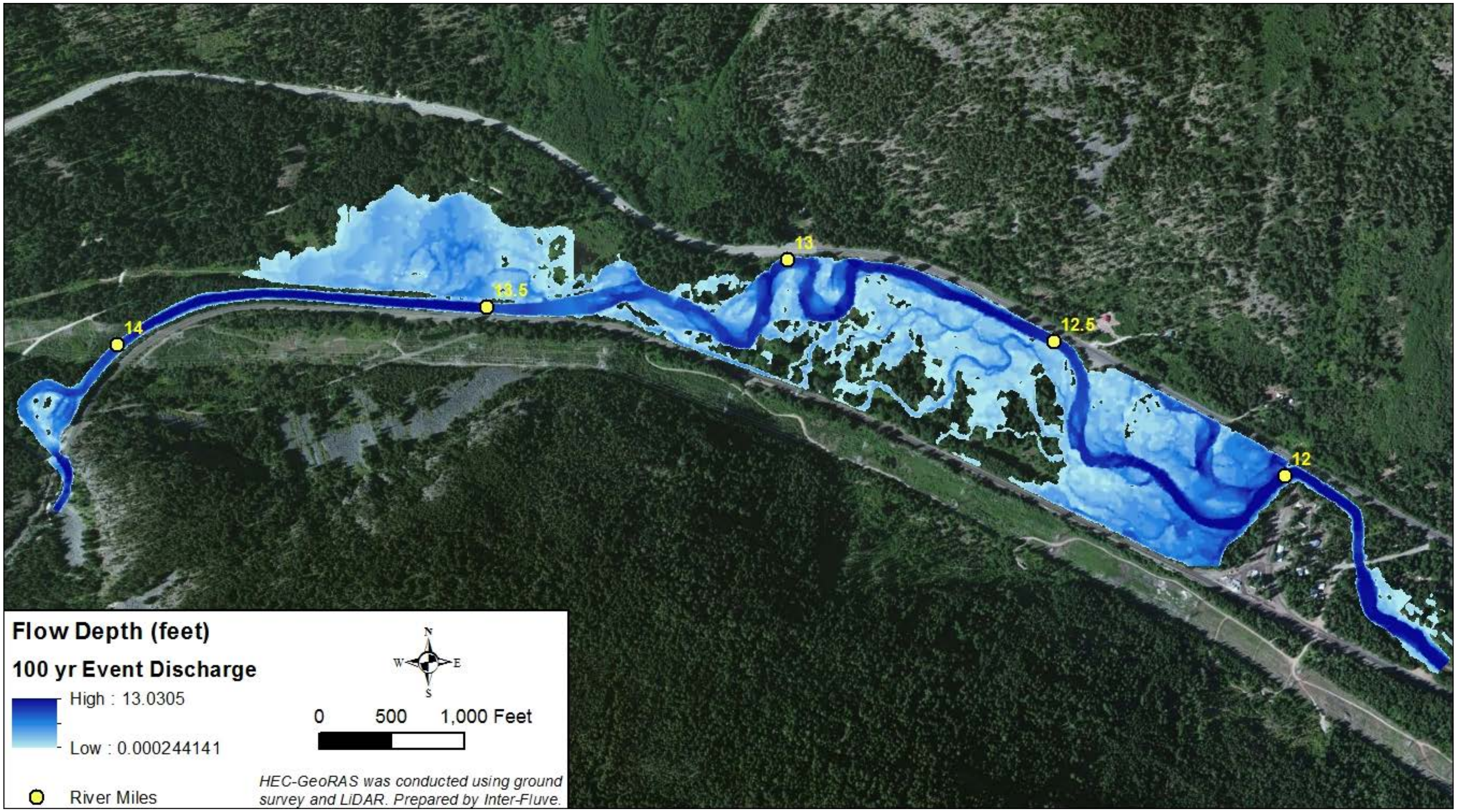

Figure 19. Existing water depth and inundation extent from the HEC GeoRAS model output for a 100-year flow event (Q_{100} flow)

Water Quality

Temperature

High stream temperature is considered a habitat-limiting factor in the Upper White Pine Reach (USBR 2009). The Washington State Department of Ecology (WDOE) has listed the upstream portion of the study area as a Category 4a or 5 stream on the state's 303(d) list of impaired waters since 2004 for violation of the stream temperature standard (listing ID No. 42923). The currently approved 303(d) listing for Nason Creek (2008) cites 31 excursions above critical temperatures for the 7-day average daily maximum temperature between June 25 and August 21, 2003. The Wenatchee River Total Maximum Daily Load (TMDL; WDOE 2005) suggests that stream-shading mechanisms (i.e., riparian cover) and connectivity to off-channel habitat contribute to temperature impairments. Thermal infrared imaging (FLIR) surveys of Nason Creek were performed in 2001 and 2003 (Watershed Sciences 2003). The 2001 results are included in figure 20 and figure 21. At the time of the 2001 FLIR survey, temperatures were in the 16 to 18 degrees Celsius range throughout the study area. The FLIR studies showed a local warming trend occurring between RM 15 (just upstream of the Upper White Pine Reach) down to RM 13.6 (midway through subreach 2), and then consistent temperatures down to near RM 10.5 (includes subreaches 3, 4, and 5), where a significant warming trend began.

The 2001 FLIR images show that the wetland area in the left-bank floodplain near RM 13.4 was considerably warmer than the mainstem (24 to 25 degrees Celsius versus 17 to 18 degrees Celsius) at the time of the FLIR flight. The backwater alcove (abandoned channel) on river-right between RM 13.5 and 13.6 was even warmer (25 to 26 degrees Celsius versus 17 to 18 degrees Celsius).

The Wenatchee River Ranger District of the Okanogan-Wenatchee National Forest has collected summer stream temperature data annually at three separate sites within the project area since 2009. Temperature data loggers were placed in the existing wetland (just north of RM 13.5 to 13.6) in subreach 2 and in the mainstem at approximately RM 14.2 (subreach 1) and 12.5 (subreach 4) from early July into October (see figure 22 for location of data logger placement). The Okanogan-Wenatchee Land and Resource Management Plan (1990 Forest Plan), which has a standard for class 2 waters such as Nason Creek, states:

- The maximum temperature will be less than or equal to 61 degrees Fahrenheit (16 °C) on any day and/or the average 7-day maximum temperature will be less than or equal to 58 degrees Fahrenheit (14 °C).
- Where streams naturally exceed the above standards, management activities will not cause further measurable temperature increase.

Table 2 shows the number of days when Okanogan-Wenatchee National Forest standards for temperature were exceeded from 2009 to 2011. These data indicate that off-channel and main channel temperatures regularly exceed standards in some years but not all years; and temperatures in the wetland area tend to be higher than the mainstem. These data validate the listing for impairment by the WDOE.

In general, the temperature data indicate that in some years, high temperatures may impair conditions for fish during the warm summer months. These data, and the recommendations in the TMDL report, underscore the importance of increasing riparian shading and increasing exchange with hyporheic flow, where possible. FLIR data and U.S. Forest Service monitoring suggest that off-channel areas in subreach 2 may have high summer temperatures that exceed standards for salmonid rearing, sometimes by a large degree. These data will need to be considered when planning and designing for off-channel habitat restoration work in the Upper White Pine Reach.

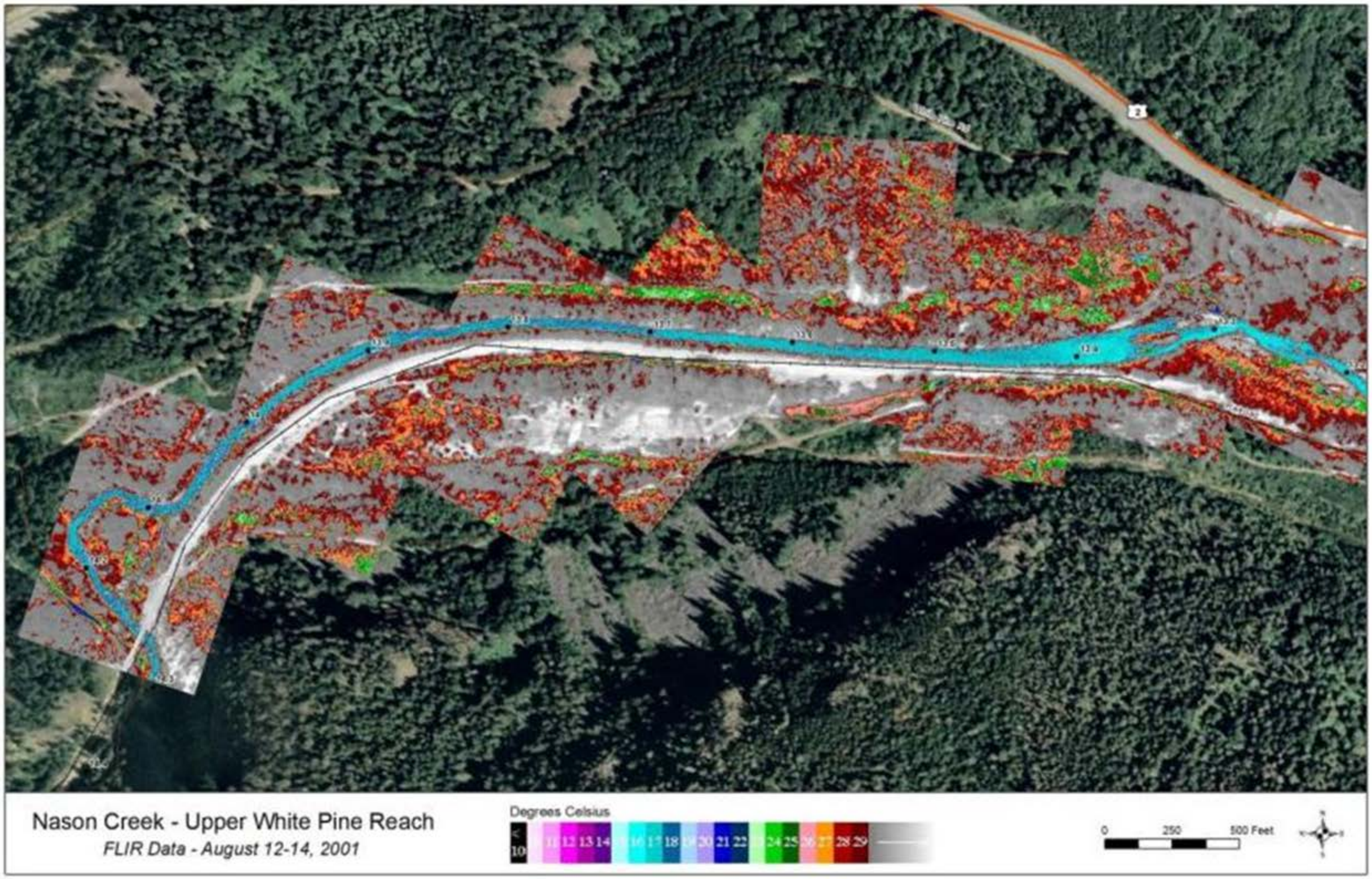

Figure 20. Thermal infrared survey for the Upper White Pine Reach of Nason Creek (subreach areas 1-2). Survey date August 12-14, 2001. Conducted for the Pacific Watershed Institute, by Watershed Sciences, LLC. Mapped by Inter-Fluve, Inc.

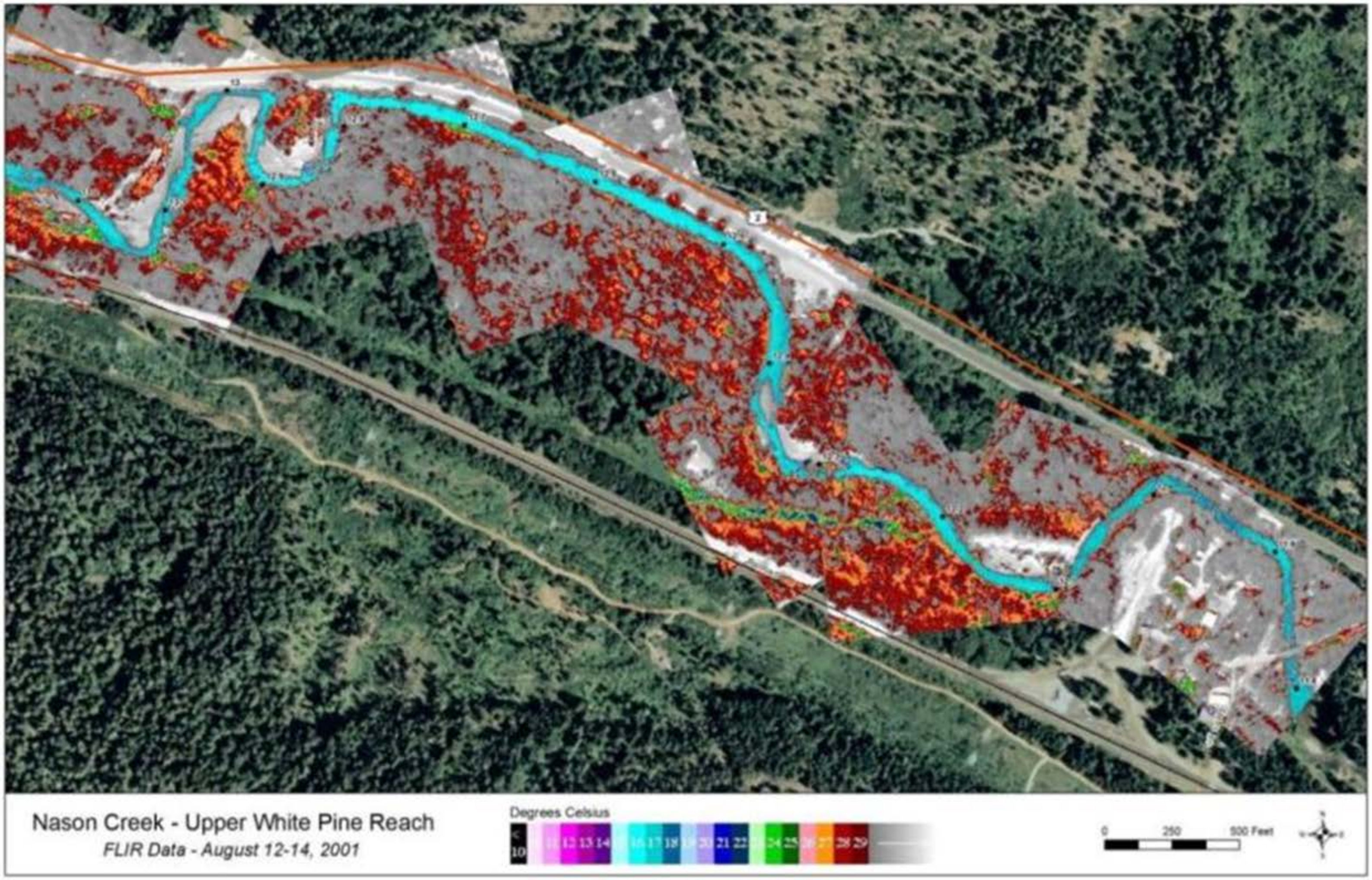

Figure 21. Thermal infrared survey for the Upper White Pine Reach of Nason Creek (subreach areas 3-5). Survey date August 12-14, 2001. Conducted for the Pacific Watershed Institute, by Watershed Sciences, LLC. Mapped by Inter-Fluve, Inc.

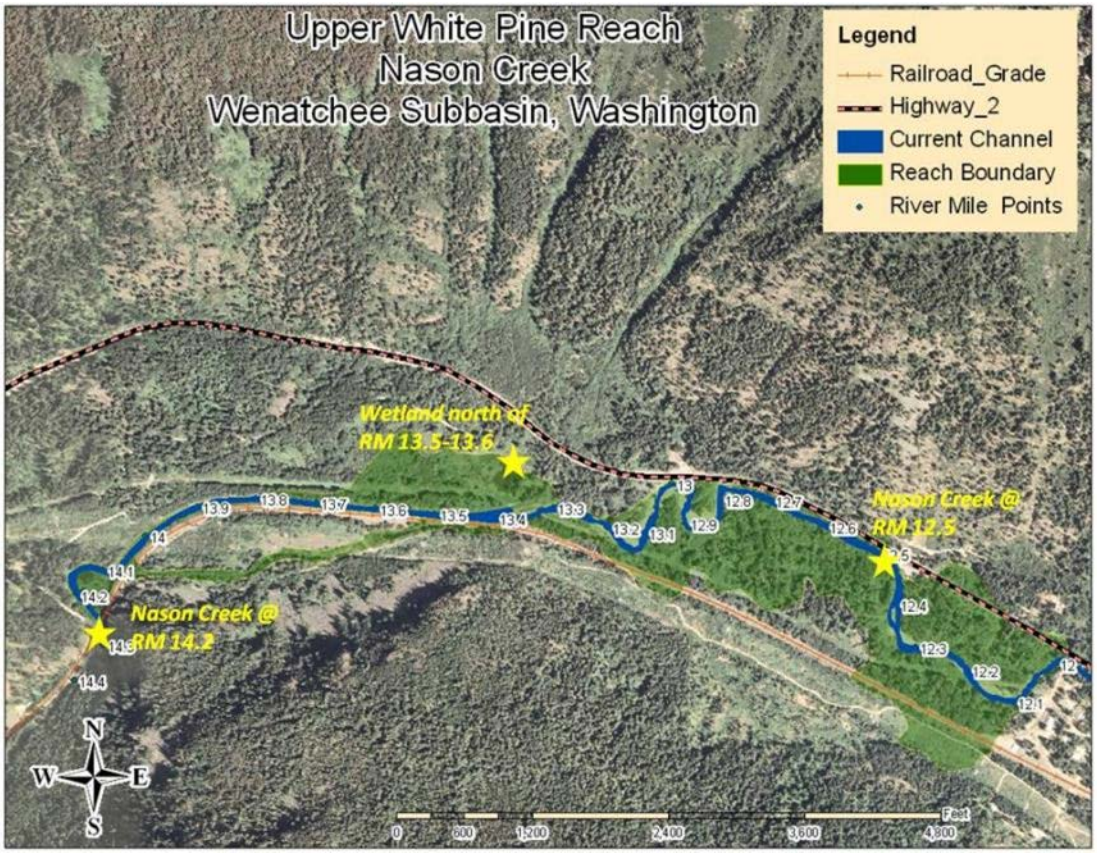

Figure 22. Location of temperature data loggers used by the Okanogan-Wenatchee National Forest to collect water temperature data from 2009 through 2011 within the Upper White Pine Reach

Table 2. Number of days that Nason Creek temperatures exceeded the forest plan standards and guidelines from 2009-2011

	Days recorded above 61 °Fahrenheit (16.1 °C)			Exceedances above the 7-day maximum daily temperature of 58 °Fahrenheit (14.4 °C)		
Data Logger Location	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**
Wetland north of RM 13.5-13.6	69	0	6	73	0	17
Nason Ck. @ RM 14.2	21	2	25	42	2	32
Nason Ck. @ RM 12.5	21	2	0	43	4	4

Source: USDA Forest Service 2009, 2010, 2011

Nutrients

Historically, large runs of anadromous salmonids in the summer and fall months would have introduced large but relatively short-lived quantities of nutrients to Nason Creek, and would have provided much of the nutrient base for juvenile salmonids as they entered the winter months. Nutrient retention (i.e., the length of time any given nutrient is held within the system, thus increasing its availability to be utilized by biota) in Nason Creek was probably high due to the large amount of woody material that would have been present within the channel. In-stream primary productivity (including the growth of algae, bacteria, and fungus), which forms the basis for the growth of fish and other aquatic organisms, was likely regulated by a dense riparian canopy, limited sunlight availability, and low water temperatures. In-stream habitat complexity from large woody debris complexes, off-channel stream habitat, and beaver ponds would have added to the productivity of Nason Creek by providing summer and winter rearing areas for juvenile fish.

Riparian Forest

Past and ongoing man-made alterations impact riparian and floodplain vegetation within the Upper White Pine Reach. Anthropogenic impacts to vegetation include U.S. Highway 2, the railway, levees, residential impacts, and BPA and Chelan PUD powerline corridors. These features have altered the character of the riparian forest and have limited important riparian functions such as bank cover and complexity, shading, large wood recruitment, groundwater infiltration, flow mediation, nutrient supply and storage, and sediment and pollutant capture and storage.

In August 2011, the USDA Forest Service, TEAMS Enterprise Unit surveyed the Upper White Pine Reach to determine existing riparian vegetation conditions versus a selected reference reach approximately 420 feet downstream of the Nason and White Pine Creek confluence (RM 15.4). See Appendix B for detailed methods and analysis. Based on the data collected, there is a greater diversity of native species in the reference reach compared to any of the Upper White Pine Subreach areas. Over 30 native plant species were found within the reference reach, whereas the greatest native plant composition in any of the project areas was 22. Invasive species presence was highest in subreach 3, where six invasive species were present, compared to two in the reference area. Nine tree species were found in the reference reach, whereas six, at most, were found in any one of the subreaches. Generally, the amount of riparian forest per mile is well below that found in reference reaches upstream due to the presence of man-made features (see Appendix B). About 22 percent of the floodplain vegetation has been disturbed by way of clearing and/or modification to some degree (USBR 2009).

In addition to species composition, the structure and function of the riparian forest has been degraded. This is largely due to the presence of transportation and powerline corridors within the riparian buffer, which has led to vegetation removal and bank armoring. The reach has a lack of canopy cover (based on only 2 percent medium-large trees in the riparian zone), which suggests impaired stream shading (USBR 2009). A lack of canopy cover is also indicative of a lack of large wood recruitment available to the stream. Compared to reference reaches, there is considerably less large wood available for stream recruitment. Channelization in the upper portion of the Upper White Pine Reach and placement of riprap along subreaches 1 through 4 has impeded the growth and reestablishment of conifers and subsequent LWD recruitment. This occurs mainly as a result of the lack of floodplain connectivity within this portion of the stream channel and the terracing of banks that inhibit recruitment and establishment of riparian vegetation.

Fish Populations

Steelhead

Wenatchee River steelhead are inland (versus coastal) steelhead of the “stream maturing” reproductive ecotype (NMFS 1996). Steelhead begin to migrate up the Columbia River in June and July, arriving near their spawning grounds from August to November. Peak steelhead spawning in Nason Creek occurs between April and May. Juvenile rearing lasts approximately two to seven years prior to ocean emigration. Mean smolt age is 2.7 years with outmigration generally occurring from April through June with peak migration in early May (LaVoy 1992). Juvenile steelhead reside in Nason Creek year-round and outmigrate between April and November, with peak outmigration in the spring and fall. Steelhead populations are supplemented in the Wenatchee River by hatchery smolt releases, with a release target of 400,000 smolts per year from hatcheries.

Spawning survey data from the Washington Department of Fish and Wildlife (WDFW) show that numbers of steelhead redds within Nason Creek watershed have ranged from a low of 27 and a high of 412 (average 168) between 2001 and 2010 (Hillman et al. 2011). Steelhead in Nason Creek spawn primarily in the mainstem of Nason Creek but also spawn within Roaring Creek and an un-named tributary to Nason Creek. Based on redd counts and using an average spawner to redd ratio of 2.11, the average number of steelhead returning to Nason Creek for spawning averaged 354 fish between 2001-2010 (Hillman et al. 2011).

A total of 57 percent of steelhead in Nason Creek spawn between RM 8.3 and 13.2, which encompasses subreaches 3, 4, and 5 of the Upper White Pine Reach. Generally, only about 12 percent of spawning in Nason Creek occurs upstream of RM 13.2 (in subreach 1 and 2 and above). The average spawner density within the entire Upper White Pine reach has been 15 redds per mile over the past 10 years.

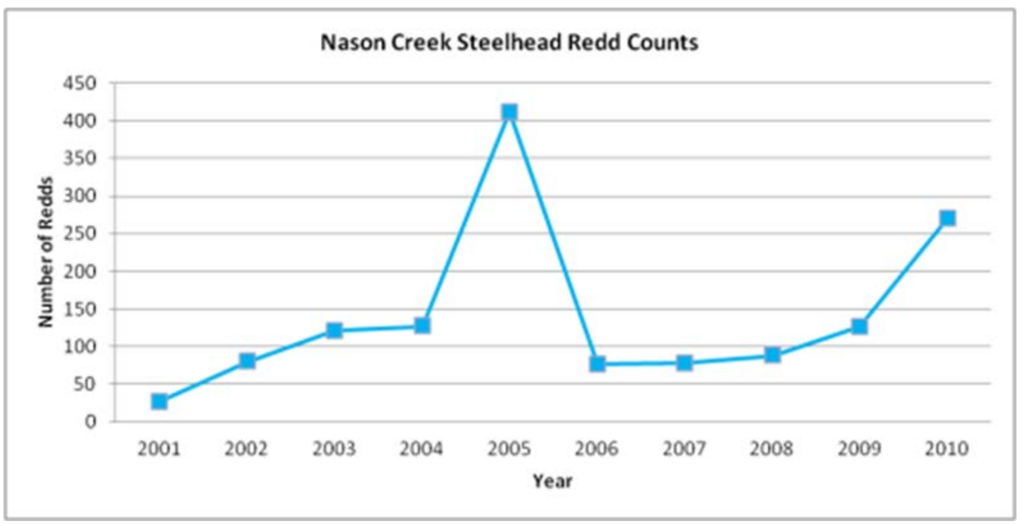

Figure 23. Redd counts of steelhead spawning in Nason Creek between 2001 and 2010 based on WDFW spawner surveys (Hillman et al. 2011)

Chinook Salmon

Adult spring Chinook salmon migrate into the Columbia River in the early spring (peak migration in mid-May), move into Upper Columbia river tributaries from April through July and hold until spawning begins in late summer (Upper Columbia Salmon Recovery Plan 2007). Adult spring Chinook salmon returning to the Wenatchee River system reside at sea from 2 to 3 years before maturing and returned to spawn (Mosey and Murphy 2000). In Nason Creek, spawning occurs from August through September. Spring Chinook salmon eggs remain in the gravel until hatching in December and fry emergence occurs between January and February (LaVoy 1992). Juveniles spend anywhere from a few months up to one year in fresh water before smolting and migrating to the Pacific Ocean. Outmigration from Nason Creek occurs year-round but peaks in April, July, and November. This indicates a diversity of life history strategies within the subpopulation.

From 1989 and 2010, returning spring Chinook in Nason Creek ranged from 15 to 1,174 adults with an average of 280 per year based on redd surveys and an average of 2.14 adults per redd (figure 24). Spring Chinook returns have increased since the extreme lows of the early 1990s; however, the current population is still considered to be at a high risk of extinction (Upper Columbia Salmon Recovery Plan 2007). Most spring Chinook spawning in Nason Creek occurs downstream of RM 13.2 with only 18 percent of spawning above RM 13.2 (above subreach 3) in 2010 (Hillman et al. 2011). Most of this spawning was upstream of the Upper White Pine Reach with little spawning occurring in subreaches 1 and 2. Spawner densities in Upper White Pine averaged 94 redds per mile over the past 10 years.

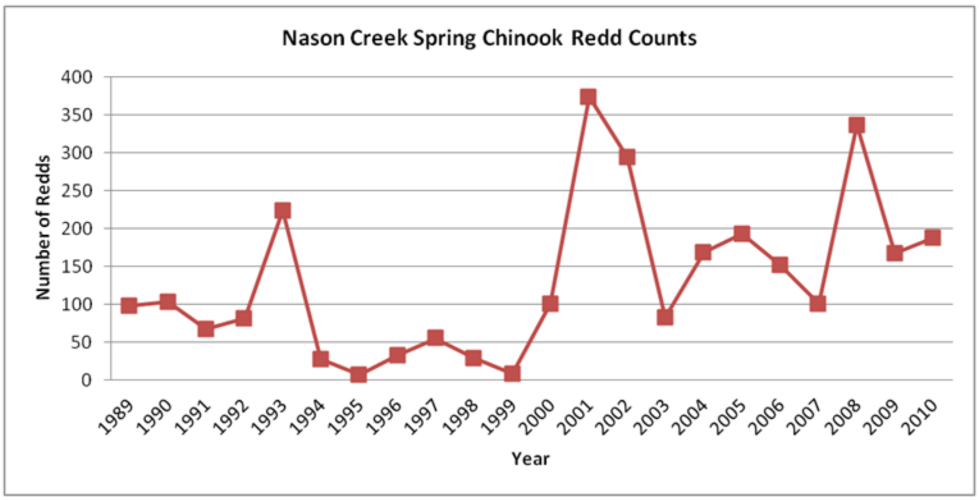

Figure 24. Redd counts of spring Chinook spawning in Nason Creek between 1989 and 2010 based on WDFW spawner surveys (Hillman et al. 2011)

Coho Salmon

Coho salmon are the rarest of the salmon species in Nason Creek and are primarily the offspring of an active reintroduction program run by the Yakama Nation. Between 2003 and 2010, there have been between 3 and 41 redds in Nason Creek with an average of 15 redds annually. These redds have been found throughout Nason, from the mouth to the confluence with White Pine Creek.

Bull Trout

During a recent study, Kelly Ringle and DeLaVergne (2005) identified three groups of bull trout with the Nason Creek population belonging to the Upper Wenatchee-Columbia River ESU (spawn in the Chiwawa River system and Nason Creek and over-winter in the Columbia River). Bull trout typically over-winter from December to May and migrate up the Wenatchee River to spawning grounds from May to mid-October (Kelly Ringle and DeLaVergne 2005). Bull trout are known to spawn in Nason Creek above the Upper White Pine Reach in the Mill Creek area (RM 20) upstream to a series of falls at RM 21.4 and in Mill Creek from the mouth to a barrier falls approximately 0.75 miles upstream. Bull trout have also been observed in Henry Creek, a tributary of Nason about 1 mile downstream of Mill Creek and may be able to access the lower reaches of Coulter, Roaring, Gill, and White Pine Creeks at certain flows. The bull trout population within the Nason Creek watershed is depressed and typically has less than 15 redds each year (based on USFWS and USFS surveys) (figure 25). Between 1996 and 2009 there was an average of 6.7 redds in Nason Creek watershed. Redd numbers reflect the size of the current year's spawning population and not the number of adults in the population since adult bull trout may not spawn every year and can spawn in multiple years (McIntyre and Rieman 1993). Spawning occurs from mid-September to November and adult bull trout migrate to over-wintering habitat from October to December (Kelly Ringle and DeLaVergne 2005). Bull trout utilize habitat within the Upper White Pine reach for holding, migration, and rearing.

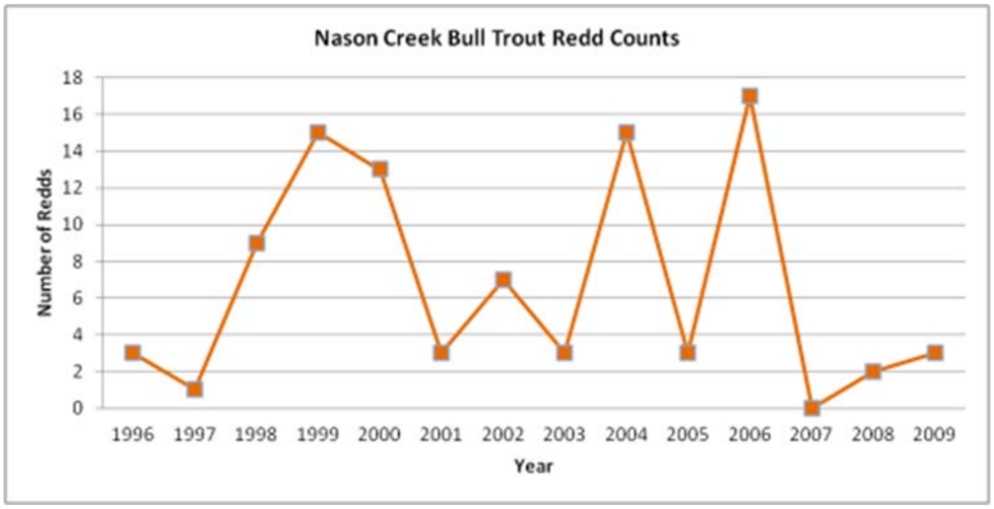

Figure 25. Redd counts of bull trout spawning between 1996 and 2009 in Nason Creek based on USFS and USFWS spawner surveys (USFS and USFWS unpublished data). Redd numbers reflect the size of the current years spawning population and not the number of adults in the population since adult bull trout may not spawn every year and can spawn in multiple years.

Fish Habitat

Human alterations have affected the quantity and quality of habitat conditions in numerous ways in the Upper White Pine Reach. In particular, channelization and floodplain fill associated with the railway, U.S. Highway 2, powerline corridors, and development at Merritt have resulted in direct habitat simplification as well as disruption of processes including rates of floodplain inundation, channel migration, and large wood recruitment. These impacts have reduced the quantity, quality, and access to stream and off-channel habitats. Habitat conditions and impacts are summarized in greater detail below.

Substrate

Salmonids require substrate of the appropriate size that is free of significant fines. Habitat surveys and observations suggest that fine sediment may be a concern in the lower portion of the Upper White Pine Reach. A pebble count conducted by the Forest Service in 2008 between RM 11.75 and 13.4 resulted in 19 percent fines (less than 6 mm). A pebble count between RM 13.4 and 14.2 resulted in only 7 percent fines. In the 2008 survey, substrate embeddedness was judged to be low and to not be a significant concern for salmonid spawning.

Although substrate is not the only driver of spawning suitability, it can be a limiting factor in areas such as the Upper White Pine Reach, which has been channelized, disconnected from its floodplain, and lacks gravel retaining features such as large woody debris (see below). Compared to the reference reach, the extent of spawning habitat is considerably less than what might be expected in the absence of human influence.

Large Woody Debris

Instream large wood supports many geomorphic and habitat functions including pool formation, nutrient retention, initiation of split-flow conditions, bank resistance, channel and floodplain roughness, spawning gravel retention, hiding cover, and velocity refuge. Large wood quantities and sizes are low in the Upper White Pine Reach compared to reference conditions. Wood is likely far below natural levels due to: (1) past removal of instream wood for flood control, (2) channel manipulations during the construction of U.S. Highway 2, the railroad, and the powerlines, (3) past clearing of riparian areas and the associated loss of recruitment sources, and (4) impaired recruitment and retention processes due to channelization and bank armoring. A comparison to reference conditions supports this conclusion. It should be noted that the reference site is also impacted by past clearing and the associated loss of recruitment sources; historical quantities are therefore assumed to have exceeded those found in the reference reach. Large wood quantities found in the reference reach were 41 pieces per mile (greater than 12 inches diameter). Large-sized woody debris (greater than 36 inches diameter) frequency in the reference reach was 12 pieces per mile.

Large wood is present in subreaches 3, 4, and 5, but is essentially absent from subreaches 1 and 2 except for a logjam in subreach 1 that diverts flow into the right-bank side channel. Only eight pieces of large woody debris were found in subreaches 1 and 2 and it was all less than 36 inches diameter. Future wood recruitment potential from the adjacent riparian corridor is poor due to the stream channelization and lack of riparian vegetation impeded by the railroad grade and powerline corridors.

In subreaches 3 through 5, wood quantities were greater but are assumed to be far below historical conditions. The 2007 habitat survey (USDA Forest Service 2008) counted 26 pieces per mile in this section and two logjams. Site visits in 2011 confirmed two logjams in this section, one at RM 12.3 and one at RM 12.9. A single large key piece (cottonwood) was located at RM 12.85 and other smaller pieces were located at the bend between RM 12.8 and 12.9. Other areas in subreaches 3 through 5 were largely devoid of wood.

Pool Frequency and Quality

Pool habitat is important for salmonid spawning, rearing, and migration. Pools provide habitat for adult holding, juvenile foraging, and flood refugia. Due to man-made alterations that have simplified and confined the channel, the Upper White Pine Reach is generally lacking deep pools with adequate cover. The reference reach had 12 pools per mile and a residual maximum pool depth that ranged from 4.8 to 6.1 feet.

Subreaches 1 and 2 have relatively few pools and pools are generally of poor quality. Only three pools exist in the 0.8 mile of subreach 2. A 1,350-foot-long pool/glide is located near the beginning of the reach and is formed by the constricted channel. Little or no wood is found in the pools and average maximum residual pool depths average 3.8 feet. No spawning gravel exists at the pool crests.

Pools in the lower part of the Upper White Pine Reach (subreaches 3 through 5) were comparable to reference site conditions, with approximately 15 pools per mile between RM 11.75 and 13.4 (USDA Forest Service 2008). Pools were of high quality, with an average maximum depth of 4.6 feet and an average residual depth of 3.6 feet. Pool habitat generally lacked complexity downstream of RM 12.8, but deep and complex pool habitat was observed in the meander bends between RM 12.8 and RM 13.3. An 800-foot-long portion of the channel along the U.S. Highway 2 between RM 12.4 and 12.6 was classified as pool habitat by the Forest Service in the 2007 survey, but was classified as mostly glide habitat by the USBR as part of the Nason Creek Tributary Assessment (USBR unpublished data). The bend at RM 12.45 does contain a deep pool with boulder cover, but the remainder of the section that parallels the highway (RM 12.45 to 12.8) is dominated by uniform riffle and glide habitat with very little depth or wood cover.

Off-Channel Habitat

Juvenile salmonids utilize off-channel habitat for rearing and flood refugia. Off-channel areas offer productive foraging opportunities and refuge from predators and high flows. Very little off-channel habitat exists in the reach due to both man-made impacts (i.e., dikes, riprap, and road fill) and natural confinement in the upper half of the reach. At low flows, only about 1 percent of the habitat area consists of side channels and off-channel habitat (USDA Forest Service 2008).

At the upstream end of subreach 1, there is a small active side channel on the river-right bank (east) between RM 14.1 and 14.2. The historic main channel of Nason Creek, which was cut off by the railroad and stream channel realignment, extends along the south side of the valley between RM 14.25 and 13.5. This channel scar is currently segmented by a series of powerline service roads. The lower end of the historic channel provides approximately 300 feet of off-channel habitat in subreach 2 where it re-enters Nason Creek through a culvert under the railroad at RM 13.5. This remnant channel is largely disconnected due to an undersized and plugged culvert but may provide some habitat at certain flows. Habitat within this off-channel area has been simplified by clearing for the railroad and the BPA powerlines. The off-channel area lacks cover, complexity, and shade; therefore, surface water temperatures are likely high.

There is a wetland complex within the north bank floodplain at the downstream end of subreach 2 near RM 13.4 (DOZ-1 in USBR 2009). There is beaver activity in this wetland and the wetland connects to the mainstem at high flows. It is likely used periodically for juvenile salmonid rearing but hydrologic connectivity with the mainstem has been affected by the left bank levee. A wetland determination was completed to estimate wetland boundaries, wetland classification, and wetland size (see Appendix C). A wetland determination is useful for planning purposes; however, a more detailed wetland delineation will be completed when proposed earthwork areas have been defined through later stages of design. The wetland delineation boundaries will be used for permitting to document any temporary and/or permanent impacts.

There is no off-channel habitat in subreaches 3 and 4. In subreach 5, there is an off-channel area within the former (pre-1949) mainstem channel location that is now a remnant channel scar and wetland area just south of the highway between RM 12 and 12.4. This channel has filled in and has limited connectivity to the mainstem at most flow levels.

Habitat Access

No physical barriers to upstream or downstream fish migration are present in the existing mainstem Nason Creek; however, the upper end of the historic Nason Creek stream channel has been totally blocked by the railroad prism and a partial barrier exists at the lower end of the historical channel located in subreach 2 (south at RM 13.5). The historical channel is currently functioning as an off-channel slough and is partially disconnected at low flows due to the size of the culvert under the railroad and accumulated gravel and debris in the culvert. The specific degree of connectivity and passage of this culvert warrants further investigation.

Competition and Predation

Brook trout influence the quality of fish habitat in Nason Creek through competition and predation of native salmonids. Although little is known about the size or distribution of the brook trout population in Nason Creek, it is likely that brook trout are competing with native species in the Upper White Pine Reach is impaired by the presence of this non-native species. They appear to easily outcompete anadromous salmon (Hutchison and Iwata 1997) and may be important predators of salmon eggs and juveniles (Johnson and Ringler 1979). One study in the Columbia Basin found that survival of Chinook in streams without brook trout was nearly double the survival in streams with brook trout (Levin et al. 2002). Just downstream in Nason Creek, in the Lower White Pine Reach, brook trout were found to be abundant during snorkel surveys in off-channel habitat (Yakama Nation, unpublished data 2011). Given their habitat preferences, brook trout likely occur in the remaining off-channel habitat in the Upper White Pine Reach and may be competing with native species.

Existing Condition Summary

Channel processes, hydraulics, vegetation, water quality, and aquatic habitat have been impacted from channel alterations and more than a century of land-use practices. The reach is currently constrained by civil infrastructure including U.S. Highway 2, the BNSF railway, powerline corridors, and floodplain fill. Forest management (e.g., timber harvest) has impacted geomorphic and biological processes in the area, specifically riparian health, and large woody debris recruitment. Because of these impairments, aquatic habitat throughout the reach is degraded compared to what would be expected under historical or unaltered conditions.

Following the methods described in Beechie et al. (2008), process impairments have been summarized and rated within each subreach according to their degree of impairment (see table 3). This framework helps to organize our knowledge of system impairments and leads to the development of restoration actions discussed later in this document. Impairments are described according to the underlying processes that have been altered as a result of human actions. These processes are known to affect aquatic habitat and fish populations in numerous ways.

Identifying impairment levels by subreach helps to focus actions on areas with the highest need for restoration. Each subreach is given a rating of high, moderate, or low with respect to the level of impairment for each identified process. The definitions for high, medium, and low are as follows:

- High (H) = impairment dominates a majority of the subreach.
- Moderate (M) = impairment affects a significant portion of the subreach.
- Low (L) = no impairment or impairment is limited to minor occurrences within the subreach.

The results of this summary table 3 highlight the degree of system impairments by subreach. As can be seen in table 3, subreach 2 is highly impaired with respect to all of the listed process impairments. This is due to past channel re-location and straightening, and the existing confinement from the railway and levee system. Subreach 4 has the next greatest amount of impairment, largely as a result of some past channel straightening and the presence of U.S. Highway 2 adjacent to the subreach. Subreaches 1, 3, and 5, which have had less direct impact from man-made alterations, generally have moderate impairments with some low ratings.

Table 3. Ratings of process impairment for each subreach within the Upper White Pine Reach

Process	Anthropogenic Cause of Process Impairment	Subreach Ratings				
		1	2	3	4	5
Stream Channel	Past incision related to channelization and reduced LWD reduces lateral channel dynamics and formation of secondary channels	M	H	M	H	M
Floodplain Connectivity	Infrastructure (e.g., levees, the railroad corridor, and U.S. Highway 2) reduce floodplain inundation extent and storage	M	H	L	L	M
Floodplain Connectivity	Past incision reduces connectivity to off-channel habitats	M	H	L	M	M
Sediment	Channelization and bank armoring increases sediment transport capacity and reduces storage	L	H	M	H	M
Riparian Vegetation	Streambank vegetation replaced with rock armoring	M	H	M	H	L
Riparian Vegetation	Floodplain forest cleared	L	H	M	L	L
Riparian Vegetation	Infrastructure (e.g., levees, the railroad corridor, and U.S. Highway 2) limit riparian vegetation quality, area and effectiveness	M	H	M	H	L
Large Woody Debris	Reduced large wood delivery due to decreased channel migration and degraded riparian areas	M	H	M	H	M
Large Woody Debris	Reduced large wood retention in the channel has led to simplified habitat	M	H	M	H	M
	Totals L=1, M=2, H=3	16	27	16	22	15

HISTORICAL AND REFERENCE CONDITIONS

Historical Conditions

Historically, the Upper White Pine Reach had greater sinuosity, less stream energy, greater access to its floodplain, and was more depositional than under contemporary conditions. The reach would have maintained a dynamic equilibrium with floodplain and lateral channel migration processes regularly creating new habitats over time (USBR 2009). Prior to timber harvest and agriculture, the floodplain forest would have produced diverse age classes and species of trees. The riparian forests would have provided shade, nutrients, and large woody debris to the channel, providing optimal habitat for native salmonids in Nason Creek.

The earliest reliable records available for the Upper White Pine Reach are State Highway Department and Chelan County PUD drawings from 1933 and 1932, respectively, and a 1949 aerial photo. The 1949 aerial photo is included in figure 26. Although these records do not show the area prior to human-caused disturbance, they do show the channel prior to the relocation of the railway in subreach 2. The 1932 drawings also show the channel prior to relocation and straightening due to U.S. Highway 2 in subreaches 4 and 5. This historical mapping and photo information demonstrates that the channel throughout the reach was more sinuous and had a greater degree of side-channel habitat compared to current conditions.

Figure 26. Aerial photo (1949) of the Upper White Pine Reach showing the approximate locations of the 1949 and 2012 (present day) stream channel alignments. The Burlington Northern Railroad is in its original alignment at the upper end of the reach. The floodplain near RM 13.5 appears to be in agricultural use. The CPUD powerline corridor is in a different alignment at the upper end of the reach.

The former (now abandoned) channel in subreach 2 still retains much of its historical signature on the landscape, even though portions of it have been filled and excavated as part of the relocation of the railway. Nevertheless, channel characteristics, including gradient, width, morphology, and substrate size can be estimated by taking measurements from the abandoned channel. These measurements can be used as one of several references for helping to establish design parameters for restoration work. The LiDAR map (figure 6) shows the former channel location and a longitudinal profile of the former channel is included in figure 5.

Reference Conditions

We measured channel, riparian, and floodplain conditions at a reference site upstream of the study reach. These conditions were used in combination with historical information, hydraulic modeling, and regional habitat targets to develop restoration objectives and design parameters. The reference site selection was based on having similar channel morphology, hydrology, sediment regime, and biota relative to the site to be restored (Upper White Pine Reach). The reference site exhibits much less direct human disturbance than the study reach and it contains some high functioning aquatic habitat conditions. However, it is considered a “disturbed” reference site as it has been impacted by some past and on-going man-made alterations including timber harvest and the nearby NFS road and railway that affect floodplain and riparian function.

In some cases, a “disturbed” reference reach is better suited for design than an undisturbed reference. In contrast to an undisturbed reference site, a disturbed site, such as the one selected for the Upper White Pine Reach, is capable of sustaining stable and high quality habitat under the same contemporary watershed conditions that also affect the study reach. The site is capable of routing current flood flows and sediment loads while still retaining high quality habitat. Disturbed reference sites provide valuable insight to how the channel can cope with an altered sediment budget, hydrology, and riparian biota. In addition, they provide an excellent time reference for recovery. For these reasons, developing design criteria from this disturbed reference site will afford a greater probability of success compared to reference conditions obtained from an undisturbed site that has a different set of watershed inputs.

The reference reach used for the Upper White Pine Reach is located upstream of the study area near RM 15 (figure 27). Data were collected at two sites; one at RM 14.9 (reference 1) and one at RM 15.1 (reference 2) upstream of the Upper White Pine Bridge (RM 14.25) in August 2011.

Cross-sections were measured at multiple locations within multiple habitat units to determine depths, widths, bankfull dimensions, flood-prone dimensions, and entrenchment. A longitudinal profile was measured to determine gradient. Riparian vegetation composition and structure were measured using linear and circular vegetation plots. Large woody debris counts were conducted and substrate was measured (Wolman pebble counts). In addition to field surveys, reference site data was measured using LiDAR, aerial photo interpretation, flood frequency analysis, hydraulic modeling, and hydraulic regime equations. Detailed analysis results of the reference conditions are located in Appendix E and summarized in table 4.

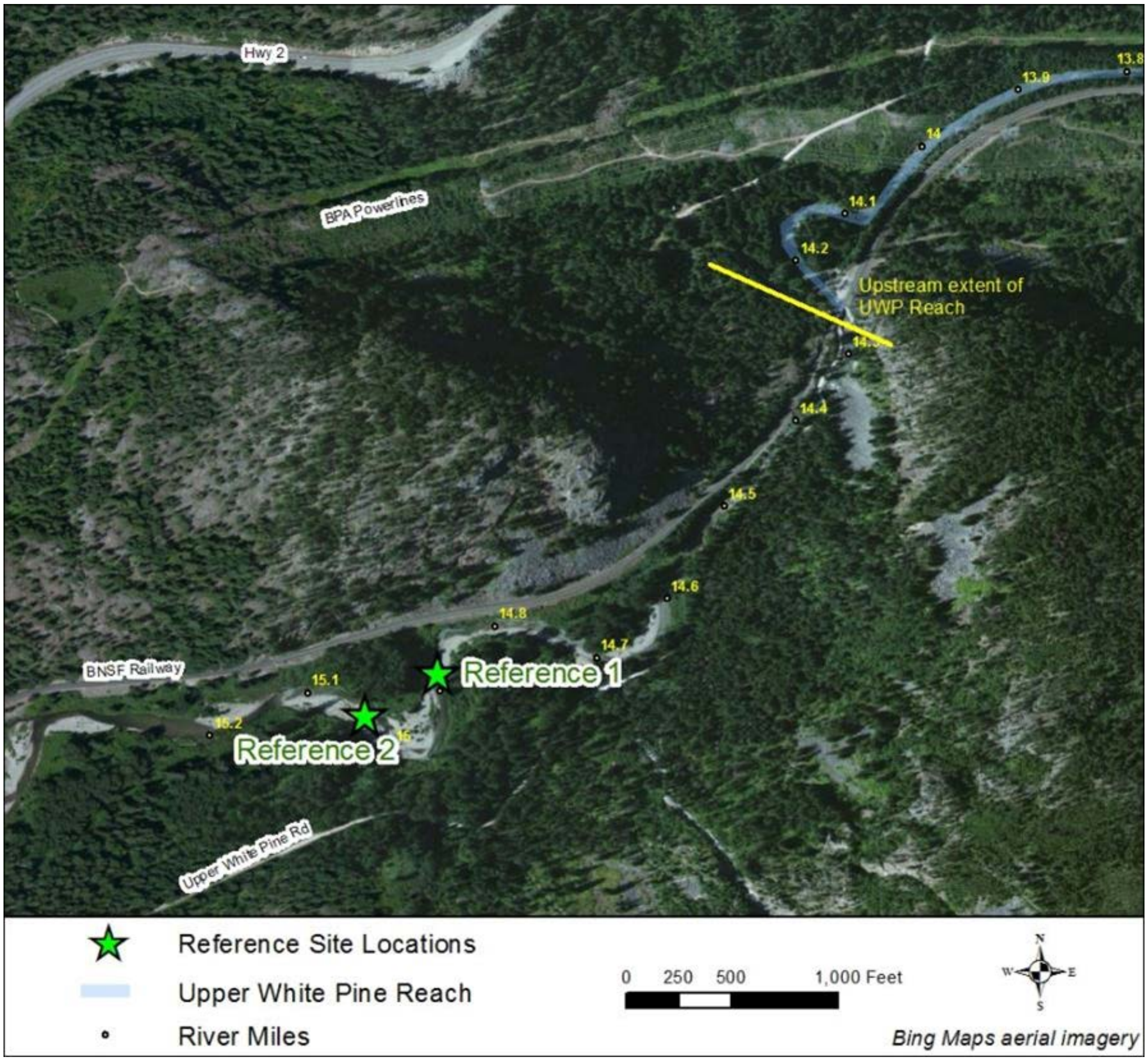

Figure 27. Location of reference sites in relation to the Upper White Pine Reach

Table 4. Reference reach measurements for the Upper White Pine Reach

Project Design Attributes	Reference Conditions
Riparian Area / River Mile (Acres)	76-214*
Riparian Trees Per Acre	368
Riparian Forest Large Tree Seral Class / Acre	26%
Number of Tree Species within Riparian Area	6
Flood Plain LWD / River Mile (Key Pieces >36" in Diameter)	18
Flood Plain LWD / River Mile (12"-35" in Diameter)	29
Flood Plain LWM / River Mile (<12" in Diameter) cubic yards	587
Flood Prone Width (ft.)	320-890*
Side Channels / River Mile (ft.)	1,721
Off-Channel Wetlands/ River Mile (Acres)	2
Flood Prone Area / River Mile Q2 (Acres)	12-42*
Flood Prone Area / River Mile Q10 (Acres)	56-110*
Flood Prone Area / River Mile Q100 (Acres)	78-216*
Entrenchment Ratio	3-9*
Meander Belt width(ft.)	600-800
Meander Wavelength(ft.)	574-910*
Sinuosity Range	1.2-1.7*
Thalweg Slope	0.9% (Upper), 0.5% (Lower)*
Average Bankfull Width (ft.)	125
Bankfull Average Depth (ft.)	3.4
Average Bank Full Width/Depth Ratio	37
Residual Maximum Pool/Scour Depth	4.8-6.1*
Average Low Flow Width (ft.)	38
Average Low Flow Depth (ft.)	2.4
Average Low Flow Width/Depth Ratio	15.8
LWM / River Mile (Key Pieces >36" in Diameter) pieces	12
LWM / River Mile (12"-35" in Diameter) pieces	29
LWM / River Mile (<12" in Diameter) cubic yards	711
Pools Per Mile	12
Spawning Area Per Mile (Square Yards)	3,220

* Range of values found within reference or project areas - otherwise average

Restoration Goals and Objectives

Desired Future Conditions

The following summarizes the desired conditions for the Upper White Pine Reach based on information from historical, reference, and site potential conditions.

Nason Creek has a hydrologic and sediment regime that functions within the range of natural variability, which contains a network of healthy riparian stream and forest vegetation that is resilient to disturbance.

Riparian areas contain plant communities that are diverse in species composition and structure. They provide summer and winter thermal regulation; nutrient filtering; and have appropriate rates of surface erosion, bank erosion, and channel migration.

Aquatic habitats support spawning, migration, and rearing of salmon and steelhead. They offer complex off-channel and marginal habitat; have a large amount of cover and complexity; have clean and abundant spawning gravel and cool water refugia.

Salmon and steelhead are productive, well distributed throughout the reach, and express diverse life histories.

Goals and Objectives

Overall Goal: Reestablish hydrogeomorphic connectivity between Nason Creek and its floodplain and restore and enhance stream channel, riparian, and wetland habitat functions for ESA-listed salmonids.

Floodplain and Channel Dynamics

Goal

Restore natural stream channel and floodplain structure and function to increase floodplain connectivity and promote habitat formation. Reconnect the stream channel to its historical floodplain and channel migration zone to allow for more frequent floodplain inundation, natural rates of channel migration and bank stability, and natural lateral channel dynamics to restore and support habitat-forming processes.

Objectives

1. Restore flood prone area by 20 acres through removal or modification of man-made features that constrain the channel or sever floodplain connections (short term less than 10 years).
2. Increase the 2-year recurrence interval floodplain inundation area to the maximum extent possible (greater than 10 acres per river mile) through restoration of floodplain and channel geometry and structure (short term less than 10 years).
3. Improve parameters of channel pattern, profile, dimension, and structure to be more consistent with habitat-forming processes that lead to pool creation, gravel recruitment, retention, and sorting, and large woody debris recruitment that are more characteristic of reference/historical conditions (short term less than 10 years).
4. Restore more natural rates of channel migration (e.g., 10 to 20 percent bank deformation and 25-year return avulsion interval) through removal/modification of bank armoring,

restoration of floodplain roughness, and restoration of streambank vegetation, structure, and complexity consistent with reference/historical conditions (short and long term).

Riparian Forest Condition

Goal

Restore and enhance riparian areas to promote a more complex and diverse floodplain that can respond to disturbance and provide habitat functions. Plant, manage, and protect riparian areas to enhance stream bank roughness and stability, increase stream shade and bank complexity, and ensure long-term recruitment of wood for streams and aquatic habitat.

Objectives

1. Restore species composition, seral stage, and structural complexity of riparian areas to be more consistent with the potential native community. Increase riparian tree densities to 350 to 375 trees per acre and increase late seral class (greater than 16 inches in diameter) to 20 to 30 percent per acre (long term greater than 10 years).
2. Increase riparian canopy cover from less than 50 percent to greater than 80 percent (long term greater than 10 years).

Aquatic Habitat

Goal

Rehabilitate and restore aquatic habitat to allow for the opportunity and capacity to support diverse life history strategies and increased growth and survival of fish. Restore the structure and function of Nason Creek in order to support and create high quality, complex, and diverse fish habitat that can support productive fish populations.

Objectives

1. Restore the quantity and distribution of rearing habitat by increasing large wood pieces (12 to 35 inches diameter; greater than 35 feet long) to greater than 29 pieces per mile and key pieces (greater than 36 inches diameter) to greater than 12 pieces per mile (41 pieces per mile total) while enhancing cover by 50 percent in all available off-channel rearing areas (short term less than10 years).
2. Restore channel dimensions and increase the quality and quantity of pools to over 12 pools per mile with average maximum residual pool depth greater than 4.8 inches to increase the availability and quality of adult holding, spawning and juvenile rearing habitat with adequate substrate, velocity, depth, and cover (short term less than 10 years).
3. Improve rearing potential by increasing seasonal off-channel and side channel habitat by 5 acres through active restoration and restored floodplain processes (short and long term).
4. Increase salmon and steelhead redd densities to above pre-implementation levels (over 15 per mile for steelhead and Chinook redd densities to greater than 94 per mile) within the project reach (long term – 10-year average after implementation).
5. Increase the number of steelhead juveniles to greater than 2.7 per square meter and Chinook to greater than 0.1 per meter within the project area (long term – 6-year average after implementation).

POTENTIAL RESTORATION PROJECT ELEMENTS

Numerous potential restoration project elements were identified and evaluated. Project elements span a variety of project types and locations and are sometimes focused on a discrete portion of the channel and in other cases span entire subreaches. Project elements were evaluated as to how well they meet the restoration objectives, biological benefits, feasibility, and compatibility with other elements (see Appendix G). Project elements that were believed to best achieve the goals and objectives were then packaged into a preferred reach-scale restoration scenario (with options), which are presented in the subsequent section ("Restoration Scenarios"). Each project element is described below.

Riparian Restoration

This action would potentially thin and or plant native and locally adapted species to achieve the stand density, large tree component, and canopy cover objectives. Accomplishing these objectives within the riparian area, floodplain, and channel migration zone would increase long-term riparian functions including stream bank and floodplain stability, stream shade, future large wood recruitment, and nutrient exchange. There would not be substantial short-term benefit with this action except for limited bank and soil stabilization.

Riparian enhancement would require a variety of techniques depending on the area. Areas along the channel boundary would be planted with deciduous riparian shrub and tree species including red-osier dogwood, willow, and cottonwood. Areas of riparian and floodplain that are currently dominated by shrub species would be under-planted with western red cedar and other shade-adapted species local to the site. Planting within shrub-dominated areas of the riparian area and floodplain would be challenging due to the dense cover of shrub vegetation in many areas and therefore site specific planting sites would need vegetation cut. Competition effects and additional thinning of riparian vegetation would need to be addressed as part of development of the riparian planting plan. Access for riparian work would be obtained via foot or ATV in order to minimize disturbance to existing vegetation or stream habitat, but some unavoidable impacts to existing vegetation should be anticipated.

Establishing native riparian plantings along the highway or railway embankments would be challenging. Revegetation of these areas would be difficult due to the presence of riprap and the narrow riparian buffer. It would be difficult to establish vegetation in these areas without widening the available buffer or significantly modifying the riprap. Some portions of the highway or railway embankment that currently contain a narrow riparian buffer and are not dominated by riprap may support alder, cottonwood, willow, Douglas fir, or Engelmann spruce.

The CPUD powerline realignment assessment (Appendix D) currently includes realignment options that would relocate the powerlines outside of the riparian area in subreach 2 and the upstream portion of subreach 3 (down to RM 13.2). If the powerlines are re-located, then riparian planting could occur within the previous cleared right-of-way. If the powerlines are not relocated from these areas, then tree planting would not be possible due to on-going clearing and maintenance requirements within the powerline corridor.

Riparian restoration activities could occur in all five subreaches. These are described as follows:

Subreach 1. Riparian conditions within subreach 1 are in relatively good condition (figure 28); subreach 1 contains five of the six riparian tree and shrub species and 18 percent of riparian stands are in the large tree seral class compared to 26 percent within the reference area. Therefore, riparian restoration opportunities are limited to under-planting of conifers and potentially inter-planting of rip-rip along the BNSF railroad corridor.

Figure 28. Aerial view of riparian conditions in subreach 1

Subreach 2. Subreach 2 has the potential to increase the active riparian area from an existing 6 acres to between 12 to 26 acres if the stream channel corridor were reconstructed and/or PUD powerline corridor relocated (figure 29).

Figure 29. Aerial view of potential riparian restoration areas in subreach 2; riparian revegetation would be limited to areas disturbed by restoration actions

Subreaches 3-5. In subreaches 3 to 5, riparian restoration could plant 23 acres with native and locally adapted species to achieve the tree density and canopy cover objectives (figure 30). Target areas currently have less than 25 percent coverage of the large tree seral class, which is the restoration objective based on reference reach conditions. Some of the target areas are cleared areas, with only herbaceous vegetation or bare ground due to man-made features and uses including the highway embankment and the CPUD powerline corridor. Other target areas are dominated by dense shrub species with little new recruitment of trees. Target areas were delineated using the results from the LiDAR-based vegetation analysis performed as part of the Tributary Assessment (USBR 2008). Target areas include areas mapped as herbaceous (1-3 feet tall) or shrubs, saplings, and small trees (3 to -40 feet tall). In subreaches 4 and 5, this action would require agreement of multiple landowners.

The implementation costs for riparian restoration would range from approximately $10,000 to $14,000 per acre (see Appendix F).

Large Woody Material Placement

This project element would place large woody material at strategic locations along the restoration corridor to provide numerous geomorphic and habitat functions including pool formation, initiation of split-flow conditions, bank resistance, channel and floodplain roughness, spawning gravel retention, hiding cover, and velocity refuge.

Logjams would increase wood quantities to achieve restoration objectives and target conditions. Construction of logjams would increase wood quantities in the study area from 22 pieces per mile to greater than 50 pieces per mile. Pool depth and quality would also be increased due to the streambed scour generated by the large wood structures. In addition, logjams would provide cover, complexity, and flood refuge for juvenile salmonid rearing.

Below are descriptions of the various types of large wood structures and potential locations for structure placements within the reach.

Large Wood Project Types

Bar Apex Logjams

This action includes the installation of bar apex logjams within the main Nason Creek channel at select locations (primarily subreaches 2 to 5). Apex logjams would be constructed to mimic the function of natural bar apex jams and would be ballasted using a combination of pilings, boulders, and partial burial.

Bar apex logjams would be located in areas where these types of logjams would be expected to naturally form, including depositional areas within the main Nason Creek channel and existing bar surfaces where logjams would activate side channels and create split-flow conditions. These jams would be intended to create a significant channel response that is not currently occurring due to low wood quantities and sizes compared to historical conditions. Apex jams would be designed and located to create scour at the face of the structure, induce split-flow conditions around the structure, and capture gravels (i.e., induce bar development) downstream of the structure.

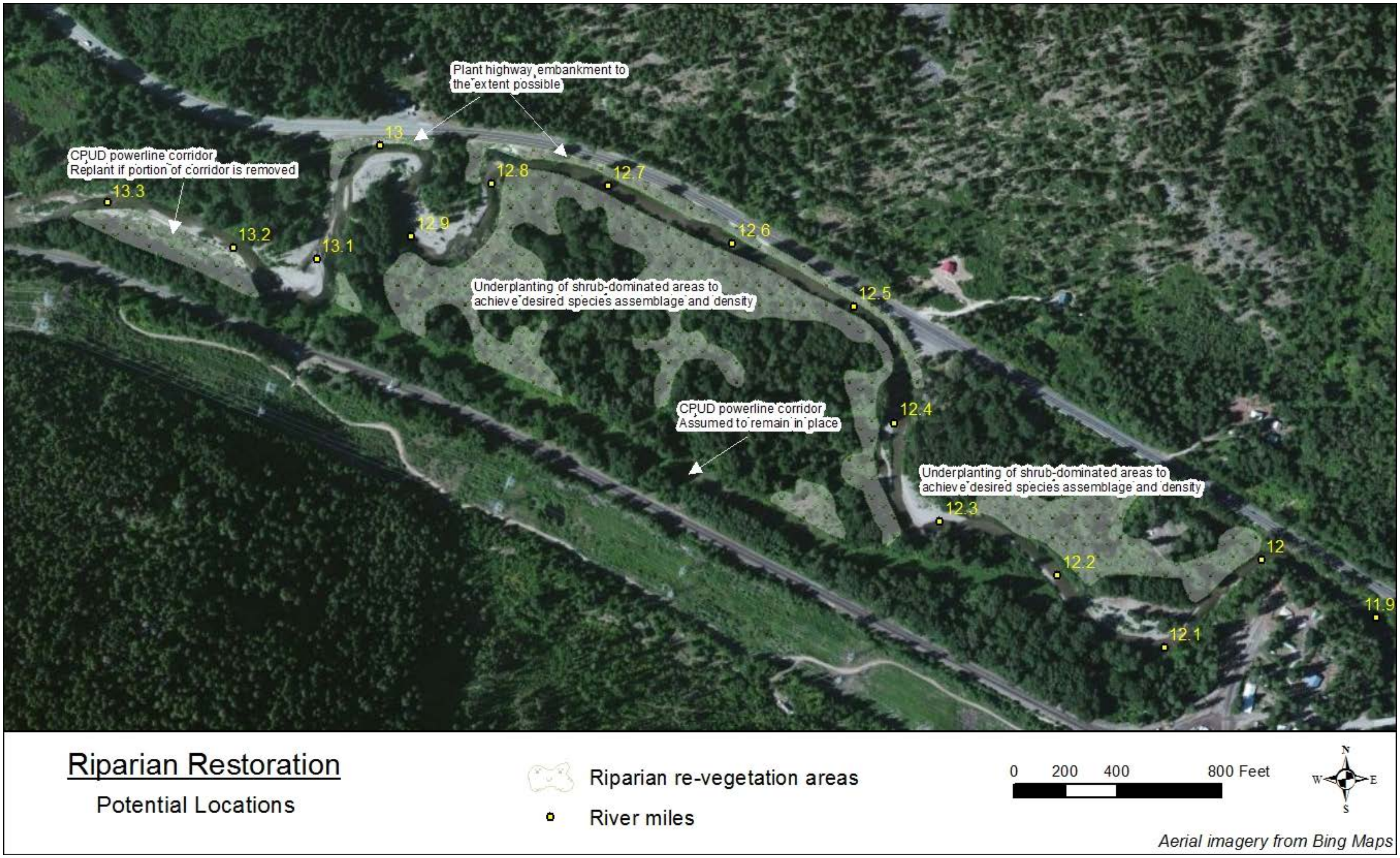

Figure 30. Potential riparian enhancement locations in subreaches 3 to 5

The primary benefit would be an increase in lateral channel dynamics that would increase side channel habitat availability and diversity. There would be an increase in channel margin habitat that would be expected to increase juvenile salmonid rearing habitat. Gravel capture would be expected to provide additional spawning habitat for salmonids.

Bar apex jams would also increase wood quantities and pool frequency to achieve restoration objectives and target conditions. Construction of bar apex jams would contribute to increasing wood quantities to greater than 50 pieces per mile; subreach 2 and subreaches 3 to 5 currently contain 2 and 26 pieces per mile respectively. Bar apex logjams would also help to increase pool frequency to greater than 18 pools per mile, with an increase in high quality pool habitat (depth and cover). In addition, bar apex logjams would provide cover, complexity, and flood refuge for juvenile salmonid rearing.

The construction cost of a bar apex logjam with 50 pieces of wood would range from approximately $80,000 to $110,000 (see Appendix F)

Meander Bend Logjams

This action includes the construction of meander bend logjams at specific stream margin areas designed to scour pools, reduce width to depth ratios, and provide hiding cover (figure 31). Meander bend logjams are also constructed as part of stream channel realignments and in areas where riparian vegetation and bank habitats have been degraded due to man-made alterations.

Meander bend jams would be constructed along the outside bends of the channel where they would create and maintain pool scour and would provide salmonid rearing cover and complexity within the pools. Meander bend logjams could be ballasted through a combination of burial within the bank, pilings, and boulder ballast.

The primary benefit would be to provide margin habitats that are more consistent with the natural conditions that would be expected in the absence of man-made alterations.

Meander bend logjams would be constructed as part of all stream channel realignment options within subreach 2 to maintain stream channel geometry and pools, provide hiding cover for fish, and protect regenerating vegetation.

The degraded areas, which are not currently properly functioning do not support quality aquatic habitats or natural bank migration rates. Impacts include: (1) clearing/lack of riparian vegetation due to powerline corridor maintenance or highway embankments, (2) rapid bank erosion due to lack of bank vegetation and instream wood, and (3) lack of margin complexity and cover due to bank armoring and fill.

At RM 13.15, where vegetation clearing associated with the CPUD corridor has increased erosion rates, a meander-bend jam would provide bank resistance to erosion while enhancing margin complexity. At RMs 13.05, 12.8, and 12.45, meander-bend jams would help to mitigate the habitat impacts of bank armoring associated with the highway embankment. These uniform, simplified habitats would be replaced with complex logjams habitats with high quality rearing cover. At RM 12.1, fill at Merritt has affected bank margin complexity and pool habitat. A meander-bend jam here would increase scour and rearing cover.

The construction cost of a meander-bend logjam with 50 pieces of wood would range from approximately $80,000 to $110,000 (see Appendix F).

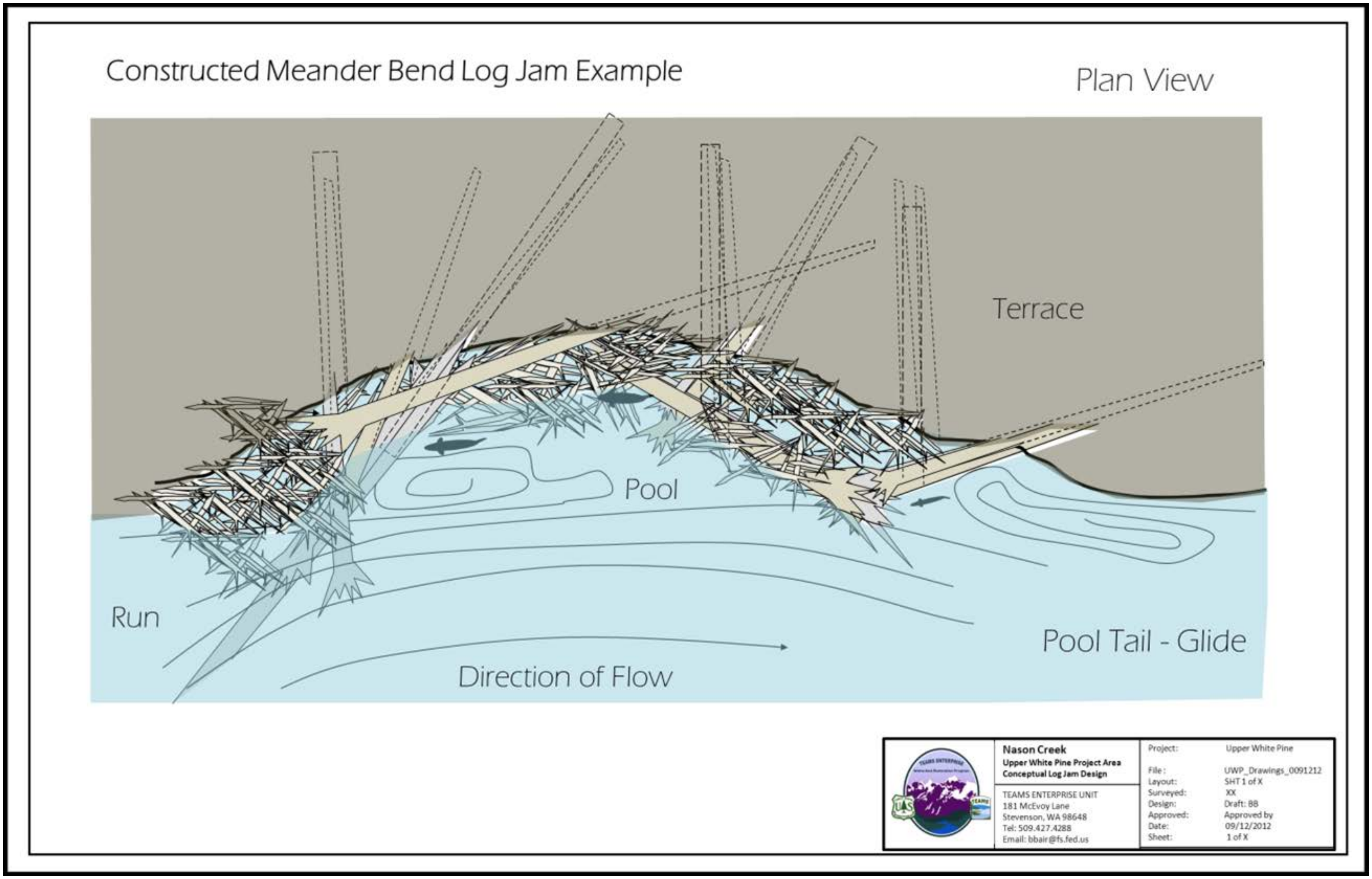

Figure 31. Conceptual drawing of a typical meander bend logjam

Channel Margin Complexity

This action includes placement of large wood (e.g. logs with rootwads) for margin complexity within subreaches 1 and 4 (figure 32). These placements would primarily be confined to channel margins only. Margin wood would consist of individual pieces or small jams (2 to 4 pieces) placed mostly parallel to the channel and secured through a combination of burial, securing/bracing using existing trees, pilings, and/or boulder ballast. Margin large wood placement in subreach 1 would be designed to scour pools, retain gravel for potential spawning and provide hiding cover for fish. Margin large wood placements in subreach 4 would be designed to avoid any potential negative effects on the existing spawning areas within the subreach and would enhance margin habitat where it has been simplified due to the highway embankment and the straight, uniform channel segment (figure 33). Juvenile salmonid rearing habitat complexity would be improved by increasing wood cover, velocity refuge, and maintenance of undercut banks. The construction cost of margin complexity using 50 pieces of wood would range from approximately $80,000 to $120,000 (see Appendix F).

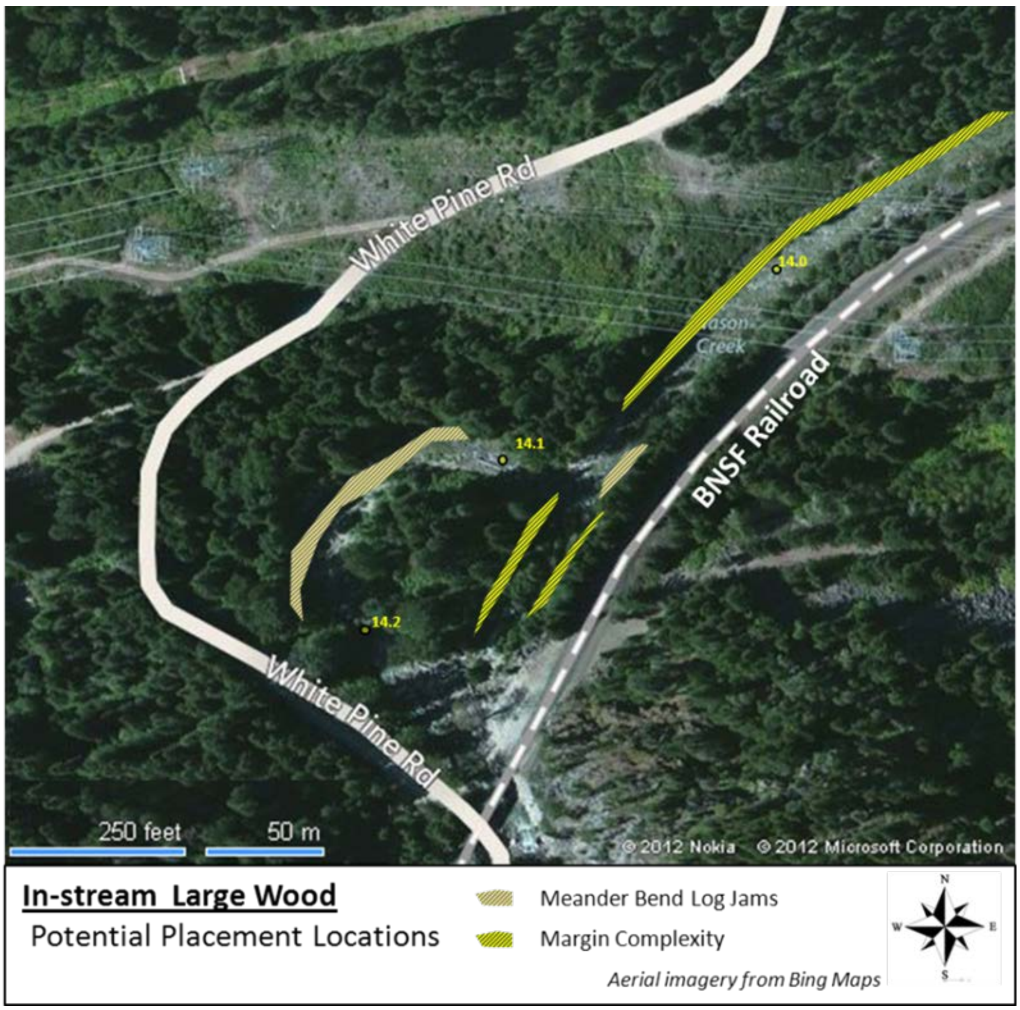

Figure 32. Potential sites for placement of meander bend logjams, and large wood margin complexity in subreach 1

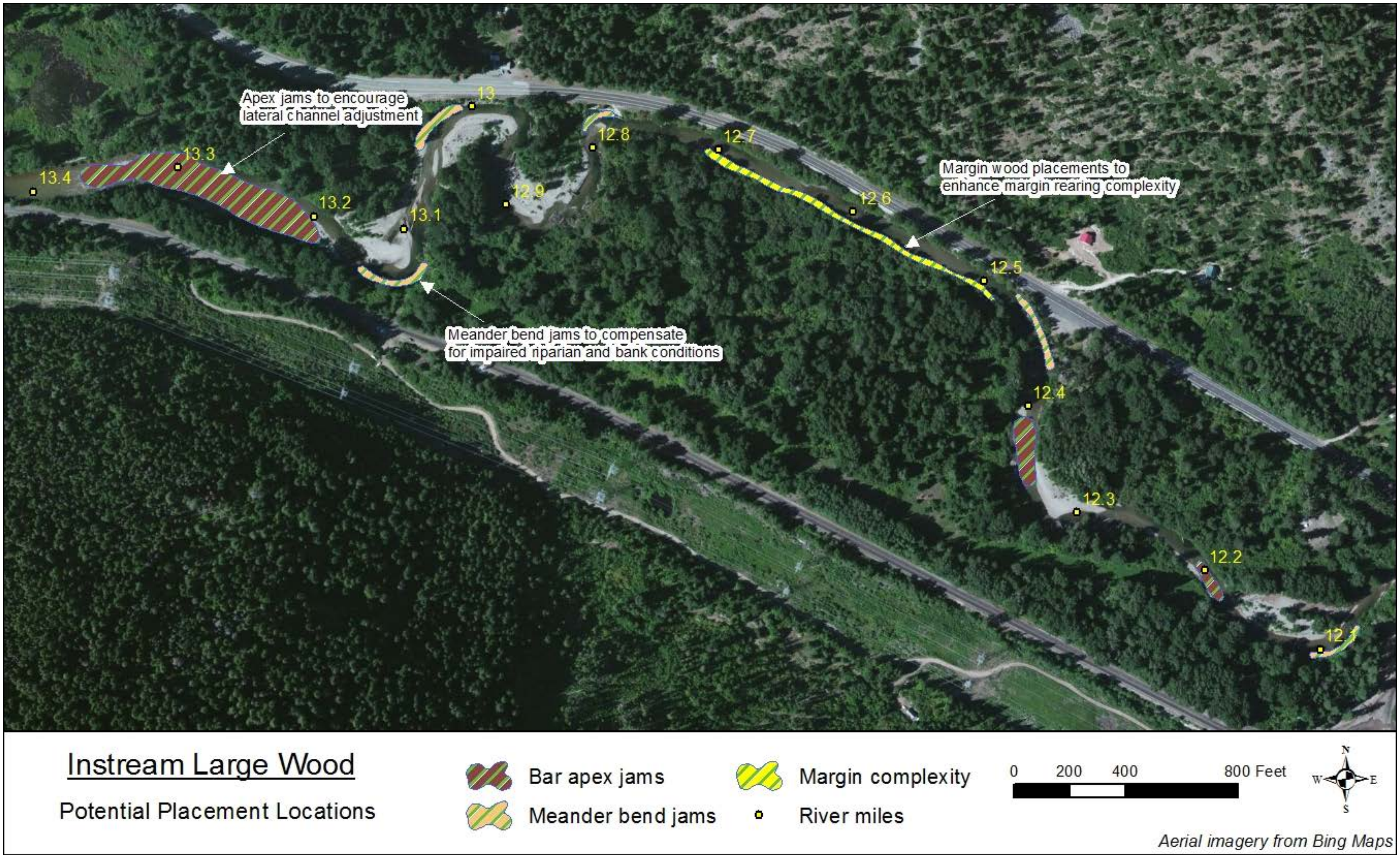

Figure 33. Potential sites for placement of bar apex jams, meander bend jams, and margin complexity in subreaches 3 to 5

Lateral Structures along U.S. Highway 2

This action would place one or two large stable logjam structures along the left (north) bank along the highway embankment in subreach 4 in order to force portions of the channel (up to 800 feet long) away from the highway. This action would reduce the negative impacts of the highway on margin habitat and would create more instream and riparian habitat diversity. Structures would be constructed as large ballasted logjams tied into the highway embankment. The number of structures used for this action would depend on additional design analysis. A location map assuming two structures is included in figure 34.

Figure 34. Potential sites for placement of lateral structures

Scour pools would be expected to form at the upstream face of the structures and lateral to the structures. Gravel deposition areas would form in the downstream velocity shadow of each structure. The structures would be designed to minimize potential erosion of the highway embankment and would include construction of additional protective measures for the highway if needed. The hydraulic model was revised to evaluate the potential impact of these structures on flood inundation and stream energy. An inundation map for the 2-year flow is included in figure 35. Preliminary modeling indicates that the project can be designed to not have a significant impact on inundation patterns or sediment continuity through the subreach. However, significant substrate scour would be expected to occur at the upstream face and lateral edges of the structures and gravel deposition (bar development) would be expected downstream of the structures.

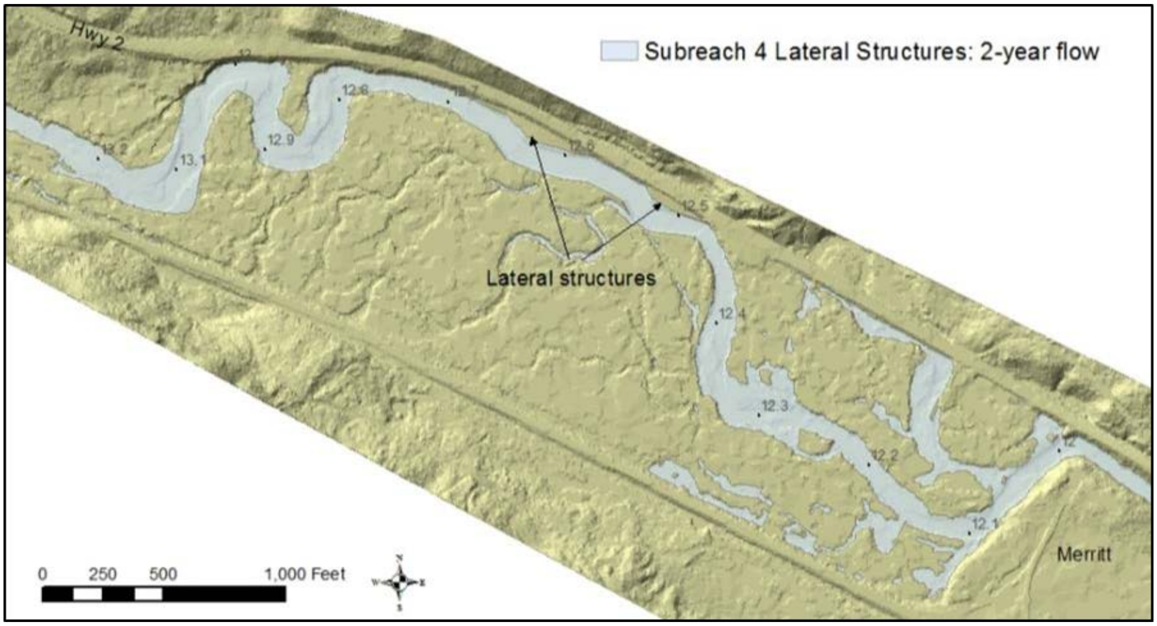

Figure 35. Inundation map for the subreach 4 lateral structures at the 2-year flow. Results generated using HEC GeoRAS. Results are preliminary and have been developed at a concept-level.

The habitat benefits for lateral jams would include: (1) creation and maintenance of lateral scour pool habitat associated with the structures, (2) increased channel complexity and cover compared to the existing riprap bank, and (3) increased riparian buffer width. These benefits would be expected to primarily benefit rearing conditions for juvenile salmon and steelhead while minimizing impacts to an existing high-use Chinook spawning area.

The construction cost of two lateral structures with 50 pieces of wood in each structure would range from approximately $290,000 to $440,000 (see Appendix F).

Floodplain Large Woody Material Placement

This action would place large woody material on floodplain gravel bars to promote channel roughness during high flow events. This action would only be implemented in conjunction with other actions that facilitate the need for floodplain wood placement. Figure 36 and figure 37 show a plan and cross sectional view of a typical floodplain large woody material structure.

Floodplain large wood placement would promote protection of pioneer riparian vegetation during peak flows, collection of organic and inorganic detritus, and slack water refuge for fish during peak flow events. It is expected that floodplain large woody material would last for 30 years or self-perpetuate (continue to collect additional sources of large woody debris) over time.

Floodplain wood placements would potentially occur associated with channel reconfigurations in subreaches 2, 3, and 4.

The cost of floodplain wood placements varies dramatically ($500 to $10,000 per structure construction costs) due to the objectives and complexity.

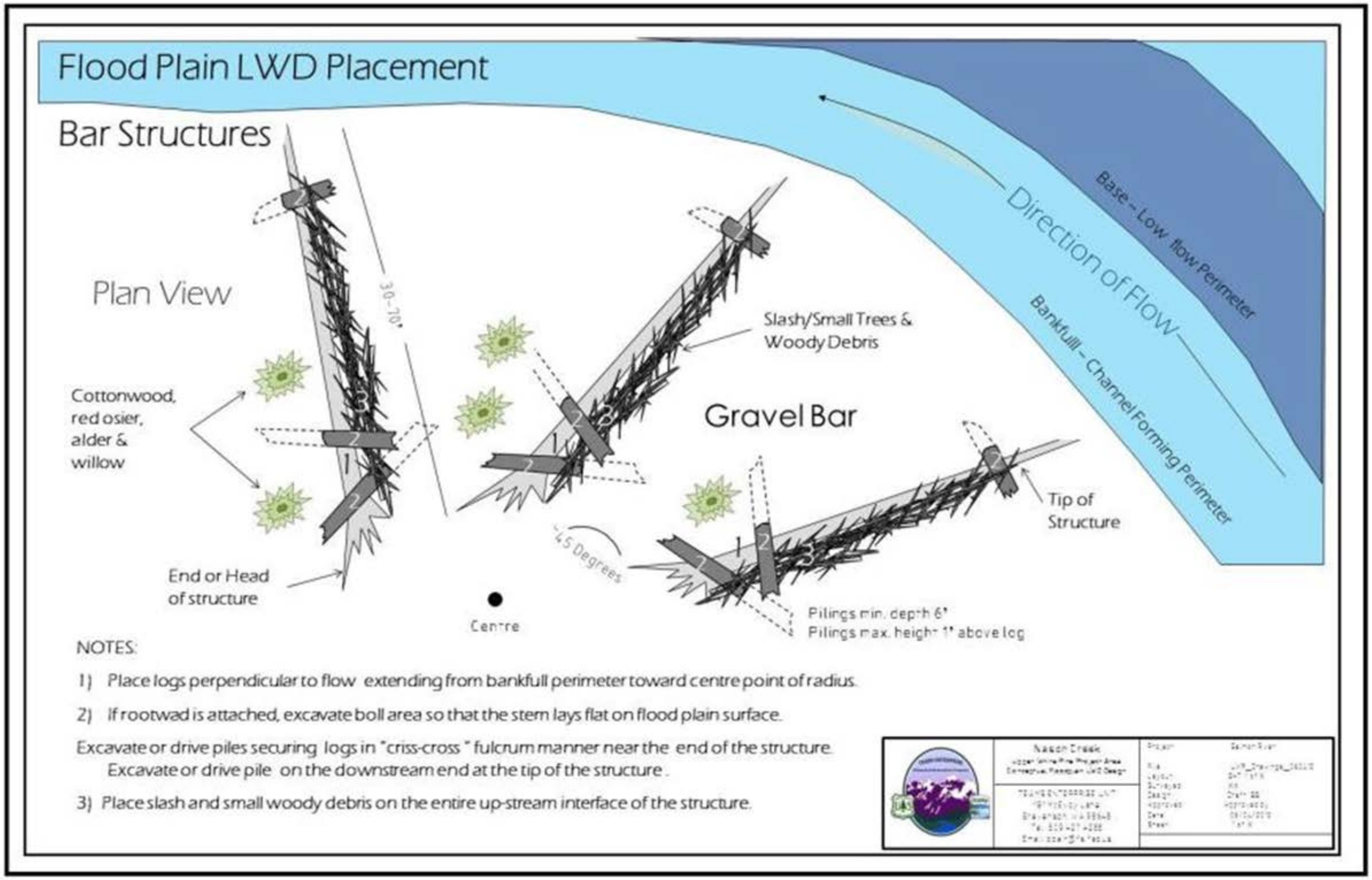

Figure 36. Typical flood plain large woody debris (LWD) placement plan view drawing

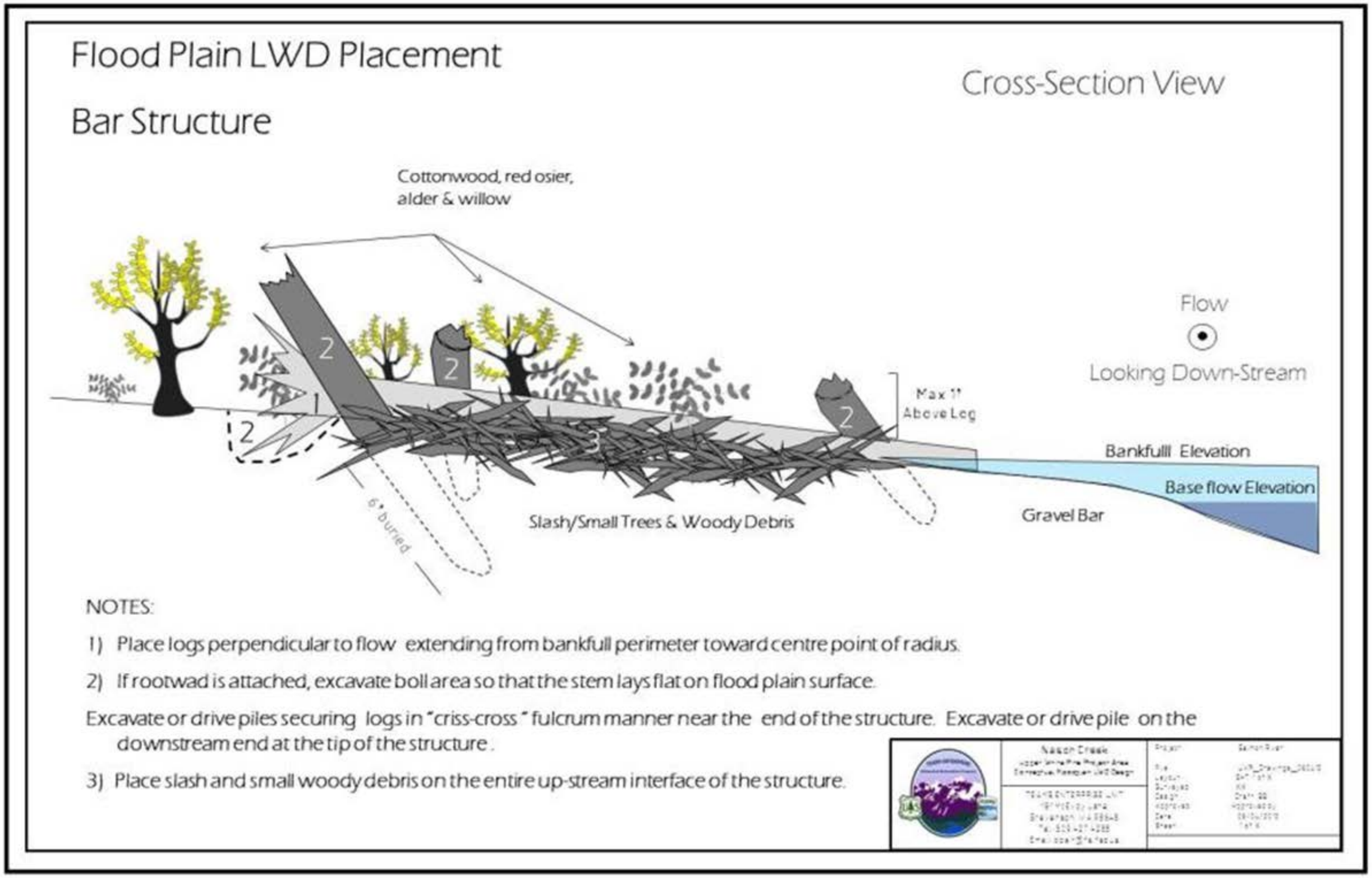

Figure 37. Typical flood plain large woody debris (LWD) placement cross section view drawing

Large Wood Feasibility and Safety Considerations

Logjams would be constructed using temporary coffer dams to isolate the portion of the channel being treated. Dewatering using pipes, pumps, or temporary diversion channels may be required. Turbidity generated during construction would need to be addressed through dewatering and pumping of turbid water to suitable land-application areas on the floodplain. The effectiveness and potential impacts of fish rescue would need to be addressed as part of project design and permitting. Temporary access roads would be located to minimize impacts on riparian trees but some impact to vegetation would occur for access. Potential site-specific feasibility issues are discussed below.

In subreach 3, apex jams located at the upstream end of the subreach would be potentially constrained by the CPUD powerline corridor between RM 13.2 and 13.3. If the corridor were to be moved away from the stream in this location, a sequence of large apex jams could be placed in this area to provide multiple split flow channels and bar development. If the powerlines were to remain in place, then smaller apex jams could be utilized to limit risk to the powerline corridor. A potential constraint would be constructing a logjam beneath the powerlines at RM 13.15. A potential constraint for jams along the highway embankment would be constructing the jams in close proximity to the highway and along the existing bank armoring. Staging areas and access may be challenging, especially at the RM 13.05 and 12.8 sites (bends). Constructing a jam at the RM 12.1 site (subreach 5) may be challenging due to the need to establish access through developed areas at Merritt or through heavily forested areas to the west.

In subreach 4, access for placement of lateral structures or margin complexity wood would pose constraints associated with construction adjacent to U.S. Highway 2. A staging area and access routes would have to be established from across the channel to minimize interaction with highway traffic. This would likely be accomplished via bridging of the Nason Creek channel with temporary log bridges. In addition, it will be necessary to ensure that constructed elements do not pose any potential risk to the structural integrity of the highway or other nearby infrastructure. This risk will be addressed as part of further analysis during the design phase, and habitat features will be designed accordingly.

For all large wood placements, there is a potential safety risk to river recreational users. Design would need to consider potential recreational uses of the river and would need to employ techniques that may be required to reduce potential river safety issues.

Levee Modification or Removal

This project element would breach or remove portions or all of the artificial levee that runs along the north side of the Nason Creek stream channel from River Mile 13.35 to 13.9 (2,900 feet) (figure 38). The levee, in conjunction with the BNSF railroad prism that runs along the south side of the channel, prevents channel migration of Nason Creek in subreach 2 and has greatly reduced flood plain inundation at higher flows. Spoils from the removed levee would be transported to a location that has yet to be determined.

Regardless of which levee section would be breached or removed, this element would only reconnect floodplain and wetland habitat during larger (greater than Q^{75}) peak flow events if constructed without channel raise or meander introduction. Levee removal would promote sediment deposition within subreach 2, which is currently a transport reach. The long-term benefits of this action depend of the extent of the flood plain recovered and frequency of inundation. It also depends on which combination of additional restoration actions would be implemented with this action. Full levee removal or partial breach are reflected as subreach 2 option A in the Scenario table (table 9 and the Action Evaluation Matrix in Appendix G). Figure 39 shows the estimated inundation of the Nason Creek channel should the artificial levee restoration action be implemented. There would be no change in floodplain inundation at the 2 year (Q^2) and 10 year (Q^{10}) events and an increase of approximately 18 acres (2 acres per river mile) at the 100 year (Q^{100}) event.

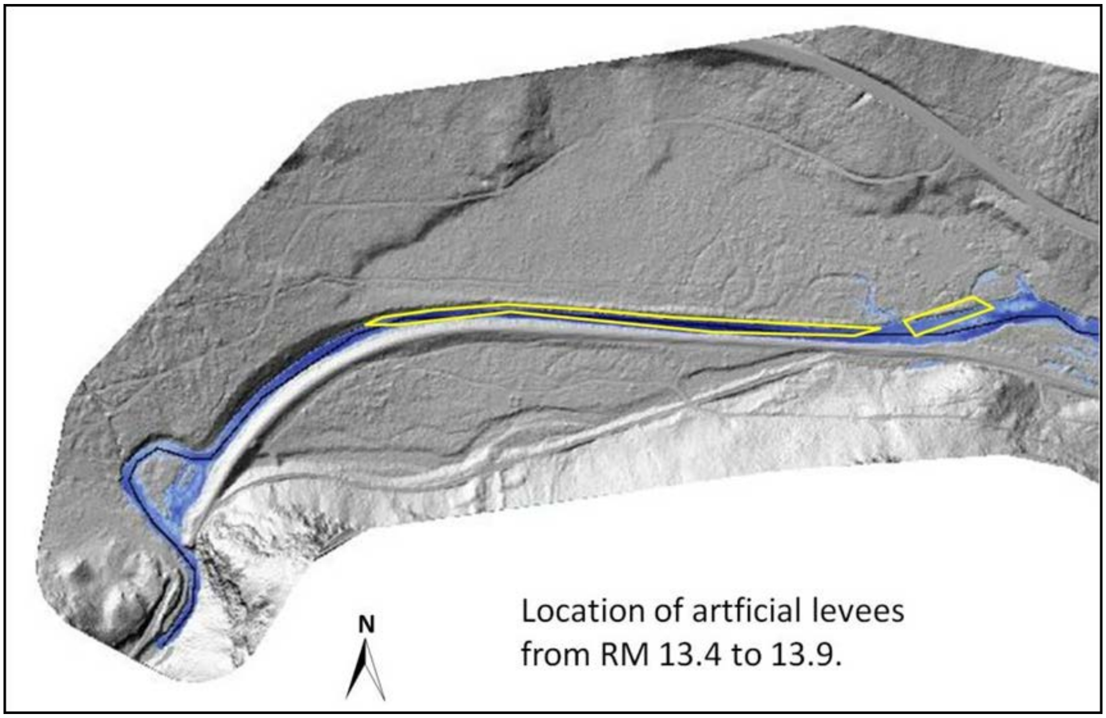

Figure 38. Approximate location of artificial levees present in subreach 2

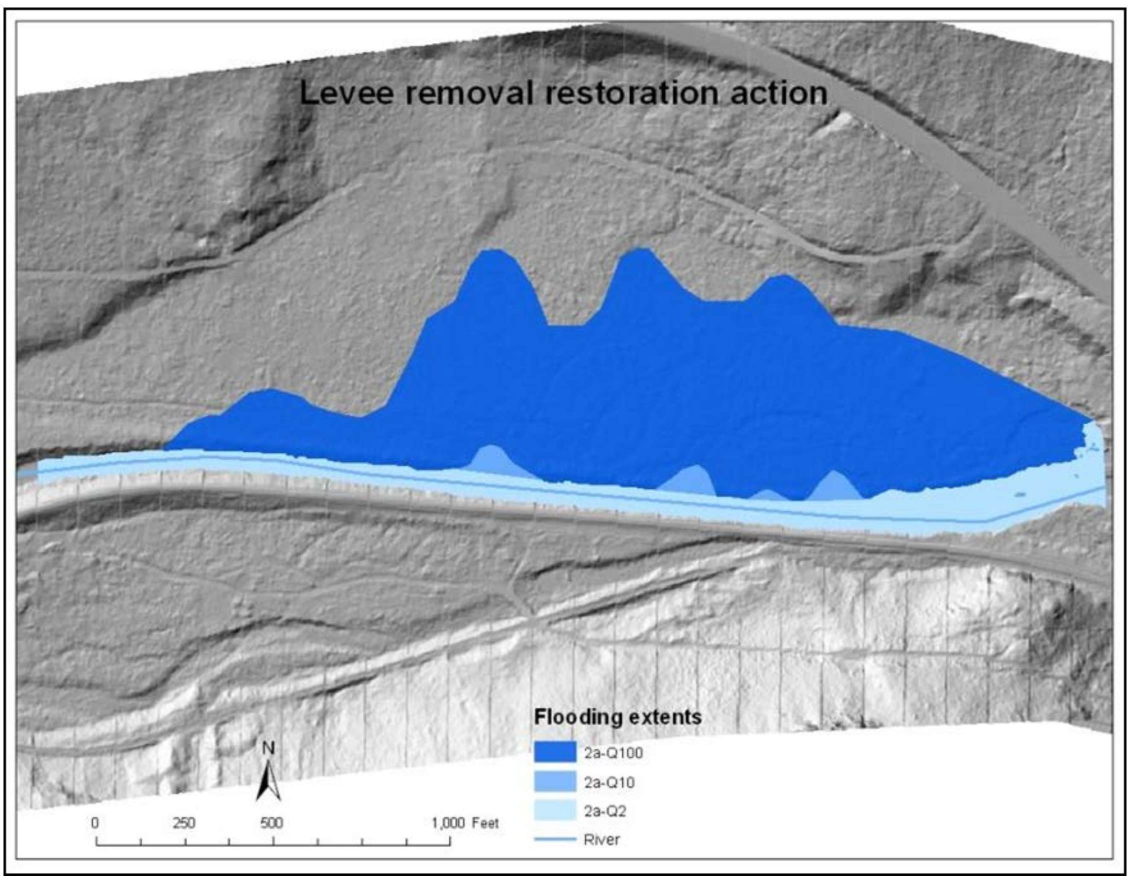

Figure 39. Inundation mapping for the 2-, 10-, and 100-year flood events after removing the artificial levee in subreach 2; modeling depicts full levee removal option

This action could impact access and maintenance of the PUD powerlines during flood events. Implementation staging and access to the area could occur on existing Forest Service and powerline maintenance road corridors. Determining a location where to dispose of the levee spoil would need to be determined.

This action would cost between $90,000 and $130,000 for levee breaching at RM 13.6 and between $300,000 and $440,000 for complete levee removal (see Appendix F).

Powerline Corridor Relocation

The CPUD McKenzie to Beverly 115kV line is located within the Upper White Pine project area. This line runs from CPUD Generation facilities to the top of Stevens Pass where it connects to the Puget Sound Energy transmission line, into the Seattle Grid system. Along the way, it serves the Burlington Northern Cascade Tunnel, Stevens Pass Ski resort and other residential services. It consists of wood poles in H-frame and/or 3 pole angle and dead-end configurations. Approximately 20 miles of the line are within USFS land ownership (14 miles on permit and 6 miles on easement). Within the Upper White Pine project area, the line is in an area under easement, which was obtained prior to USFS ownership. The easement is 100 feet wide and allows for construction of a second transmission line in this corridor.

The powerline poles are currently accessible and relatively easy to maintain. Structures 52/6 and 52/5 on the south side of Nason Creek are somewhat accessible even with some issues that arise from the surrounding terrain and railroad crossings, and in a few instances in the past the river was crossed to gain access to those structures. Pole 52/7 is submerged year-round resulting in access issues and making maintenance difficult. The rest of the structures, 52/8 and above, have good access with limited interruptions from spring runoff.

HDR Engineering, Inc. prepared an alternatives analysis to determine how to eliminate or minimize the impact of the McKenzie to Beverly-115kV Transmission Line on restoration actions in the Upper White Pine reach. The final technical memorandum is included as Appendix D. This text provides an overall summary of that analysis and describes how the findings pertain to restoration options.

Alternatives 1 and 2 reduce the number of poles located north of Nason Creek from RM 13.4 – 13.9 from six to five but the poles remain located within the current easement. Updates to the pole materials would allow for an increased span between poles and allow restoration actions to occur if all poles were accessible for maintenance. For example, the levee could be breached and a high flow channel could be created through the easement as long as there was a bridge or culvert to provide access to the lowest elevation pole in this area.

Alternative 3 proposes to relocate the six CPUD poles currently located within project area 2 to Upper White Pine road. This is the CPUD preferred alternative, however, CPUD has stated that they need to maintain an easement for these poles so that the future costs associated with a permit are not passed on to ratepayers.

Alternative 4 proposes to re-locate one or more poles outside of the easement to accommodate proposed restoration actions. This may also be feasible if maintenance access is provided, poles are located outside of the BNSF ROW, and if the poles remain on an easement.

The removal of the PUD powerline could potentially remove approximately 2,300 feet of powerline from its current location. This action would improve the riparian forest condition by allowing the vegetation to grow in the short and long term. Over the long term, this has the potential to improve the riparian species composition, structural complexity, cover, and large woody debris recruitment to Nason Creek. Depending on the additional restoration actions to be implemented in the area, floodplain inundation, stream channel dynamics, and aquatic habitat would all be improved to varying degrees.

In addition to the PUD powerline, U.S. Highway 2, the BNSF railroad prism, and the BPA powerline all pass through subreach 2. Complex land ownership including federal, county, and private complicate the relocation efforts as well as the cost, which ranges from $580,000 to $1.2 million for PUD powerline relocation Alternatives 1-4.

Stream Channel Realignment

Subreach 2 Realignment

This project element proposes three realignment options in subreach 2:

- **Option 2B** would rehabilitate the stream channel cross-section geometry and create meanders within the existing stream channel corridor between RM 13.85 and 13.45 (figure 40). This would involve the full extent of levee removal and introduction of stream channel meanders without re-alignment.
- **Option 2C** would reconstruct a new stream channel and fill in the existing Nason Creek stream channel between RM 13.85 and 13.35 (figure 42). This scenario is full level removal with stream channel relocation.
- **Option 2D** (preferred scenario) would be a variation and or combination of options 1 and 2. Between 2,000 to 2,630 feet of stream channel would be created with this action depending on the option selected. This action is a partial levee removal with mainstem relocation and/or creation of side channels through the floodplain.

Subreach 2 – Realignment or Channel Modification Option 2B

Option 2B proposes to remove the artificial levee between RM 13.4-13.9 and construct a new meandering stream channel along the current Nason Creek channel location. Modification of the stream channel would increase the streambed elevation to fully reconnect the floodplain. A side channel would be constructed at RM 13.55 connecting the newly constructed Nason Creek channel and the existing wetland complex. Large wood structures would be constructed throughout the reconstructed reach. Riparian plantings would occur on the areas between RM 13.4 and 13.9 where the levees were removed and new channel constructed. For a plan view of option 2B, see figure 40. Option 2B could also include installation of new culverts under the railroad prism at RM 13.5 and or 14.1, reconnecting and converting the historic stream channel into a side channel.

Rehabilitation of the stream channel cross-section geometry and construction of meanders within the existing stream channel corridor within subreach 2 could increase flood prone area from 6 acres to 9 acres at the 2 year discharge return interval and 12 acres to 24 acres at 100-year flood return interval. The amount of area restored is dependent on the level of restoration. For instance, if all levees are removed and the streambed invert elevation is increased by three feet similar to the full stream channel restoration option 2C, then 24 acres of flood prone area could be restored. However if the PUD powerline corridor remains in its current location, the flood plain area would likely be restricted due to maintenance access. If the stream channel corridor were expanded to the southern edge of the power poles with levee setbacks, flood prone area could be increased from 6 acres to 12 acres for the 2 year and 100 year flood return intervals. Under option 2B, the short and long-term biological benefits include reconnecting flood plain and wetland habitats during peak flow events and reducing peak flow pressure (streambed shear stress) which promotes sediment deposition. Further, option 2B would reestablishes flood plain connectivity (wetlands and side channel habitats), restore natural channel migration rates, rehabilitate stream channel cross-sections to reduce width-to-depth ratios, restore pool riffle sequences, and pool habitats (figure 51, page 68). Riparian restoration would increase stream shade and large woody debris recruitment, thus improving aquatic habitat.

Channel realignment cost would range from approximately $430,000 to $640,000 depending on level of channel modification, design and contracting methodology (see Appendix F).

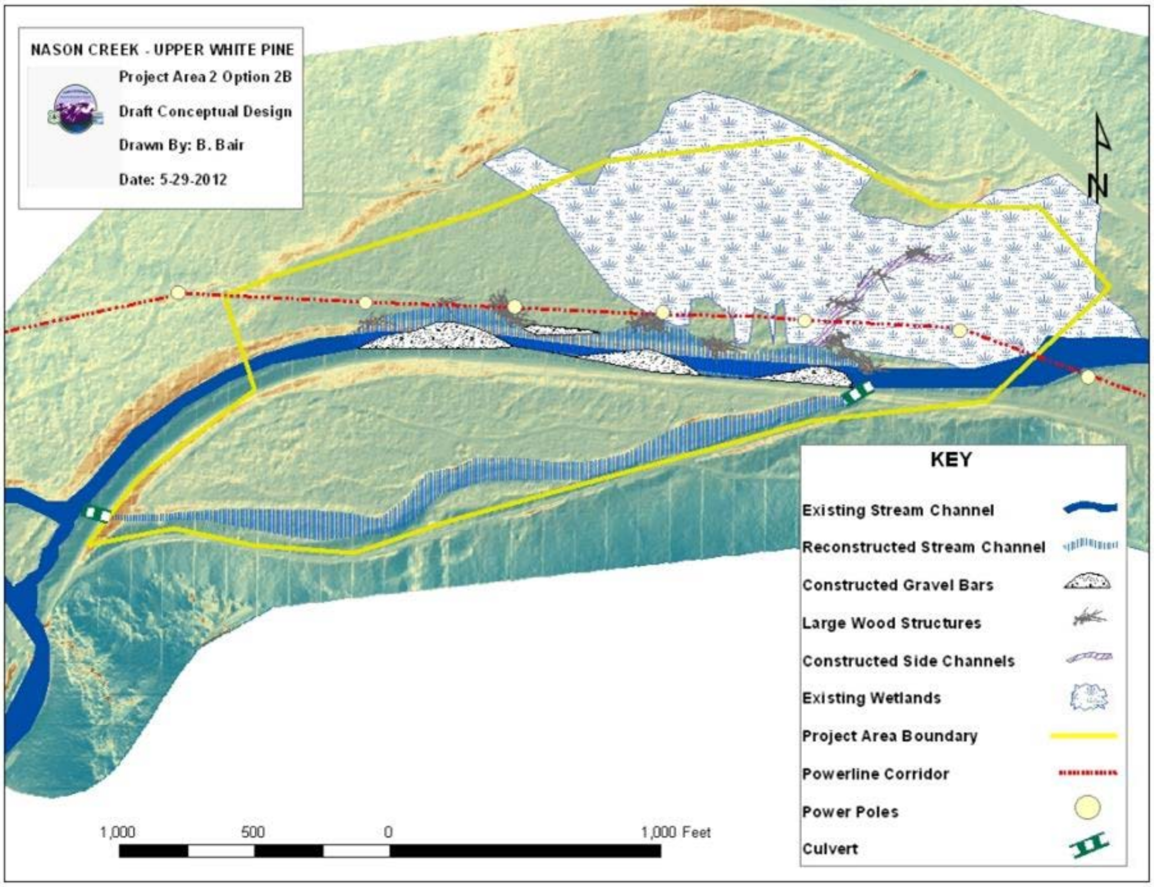

Figure 40. Conceptual design for option 2B (Nason Creek, RM 14.0 – 13.4)

Table 5. Changes to stream channel geometry, large woody material quantity, pool numbers, and spawning volume after implementation of option 2B

Design Attributes	Existing Condition	Condition after Option 2B Implementation
Entrenchment Ratio	1.0	1.2-2.0* after one year
Meander Beltwidth (ft.)	NA	200 after one year
Meander Wavelength(ft.)	NA	574 - 910* after one year
Sinuosity Range	1	1.2-1.7* after one year
Thalweg Slope	1.1% Upper- 0.5% Lower*	1.0% Upper- 0.5% Lower* after one year
Average Bankfull Width (ft.)	98	125 after one year
Bankfull Average Depth (ft.)	2.6	3.4 after one year
Average Bank Full Width/Depth Ratio	38	37 after one year
Residual Maximum Pool/Scour Depth	4.4	5-6 after one year
Average Low Flow Width (ft.)	56	38 after one year
Average Low Flow Depth (ft.)	0.6	2.4 after one year
Average Low Flow Width/Depth Ratio	93	16 after one year
LWM / River Mile (Key Pieces >36" in Diameter) pieces	0	12 after one year
LWM / River Mile (12"-35" in Diameter) pieces	4	29 after one year
LWM / River Mile (<12" in Diameter) cubic yards	198	711 after one year
Pools Per Mile	2	12 after one year
Spawning Area Per Mile (Square Yards)	880	2000 after one year

* Range of values found with reference or project areas - otherwise average

Subreach 2 - Realignment Option 2C

Option 2C would involve the following actions: levee removal (RM 13.3-13.9), powerline relocation, stream channel meander and floodplain reconstruction, off-channel wetland reconnection and creation, large wood restoration, riparian restoration. For a plan view of option 2C see figure 41. Option 2C could also include installation of new culverts under the railroad prism at RM 13.5 and or 14.1, reconnecting and converting the historic stream channel into a side channel.

Levee removal, powerline relocation and stream channel reconstruction would restore the greatest amount of flood prone area of any of the options. Option 2C would increase the flood prone area from 6 acres to 35 acres per river mile (482 percent increase) at the Q2 discharge, 11 acres to 43 acres per river mile (291 percent increase) at the Q10 discharge and 36 acres to 59 acres per river mile (57 percent increase) at the Q100 discharge. Entrenchment ratios (flood prone width / bankfull width) would increase from 1.0 to 3-9, with sinuosity being changed from 1.1 to 1.3. Furthermore, wetland habitat would be reconnected and an additional one acre of new wetland habitat would be constructed.

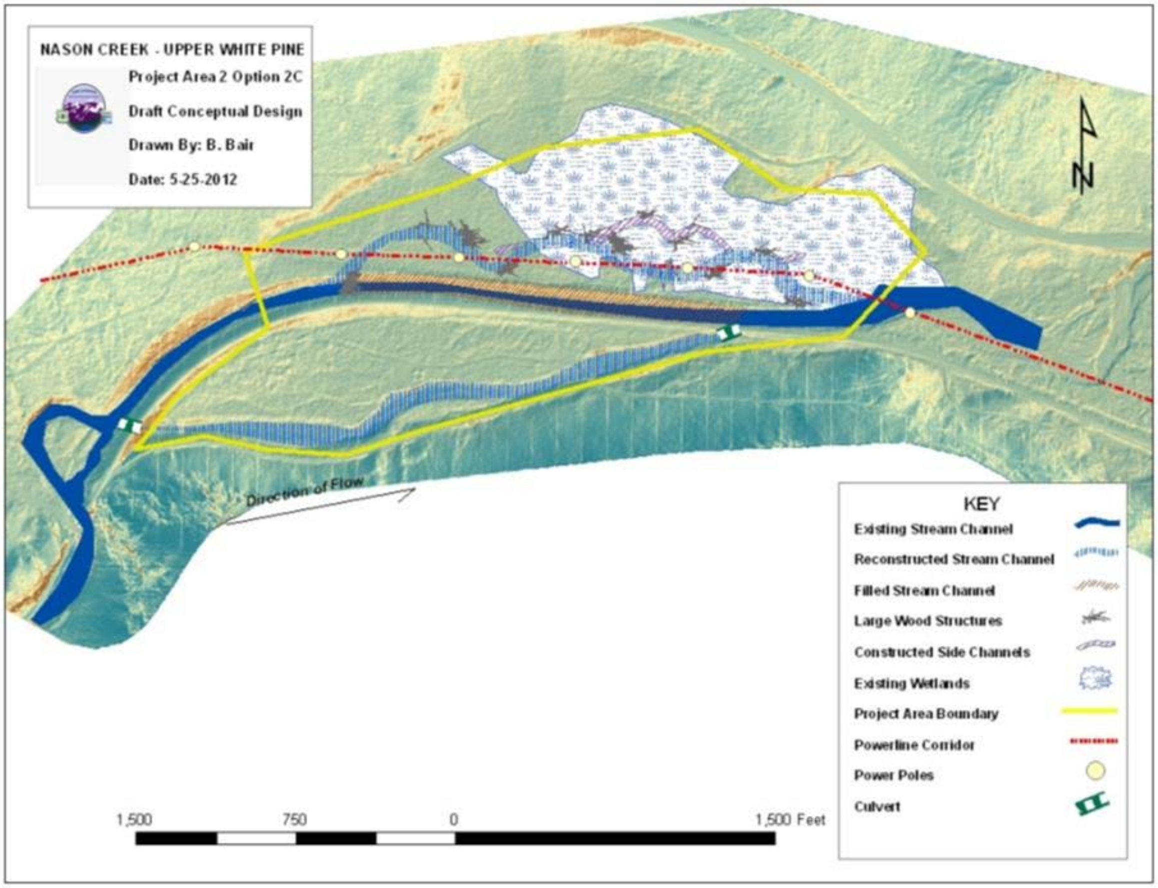

Figure 41. Conceptual design for option 2C (Nason Creek, RM 14.0 – 13.4)

Fish habitat would be significantly improved by increasing pools from 2 to 12 per river mile, increasing spawning area from 880 square yards to 3,000 square yards, decreasing low flow width to depth ratios from 94 to 16 and restoring large wood levels to greater than 50 trees per mile.

Relocating the powerline corridor would allow reforestation of the flood prone area increasing the effective riparian area from 16 acres to 26 acres per river mile. Floodplain large wood levels would also be restored to greater than 50 trees per mile, which would provide protection for pioneer and planted riparian vegetation.

Table 6 summarizes how implementation of option 2C would change stream channel geometry as well as large woody debris quantity, pool numbers and spawning area volume from the existing condition.

Table 6. Changes to stream channel geometry, large woody material quantity, pool numbers, and spawning volume after implementation of option 2C

Design Attributes	Existing Condition	Condition after Option 2C Implementation
Entrenchment Ratio	1.0	3-9 one year
Meander Beltwidth (ft.)	NA	600-800 one year
Meander Wavelength(ft.)	NA	500-1000 one year
Sinuosity Range	1	1.2-1.4 one year
Thalweg Slope	1.1% Upper- 0.5% Lower*	0.9% Upper- 0.5% Lower* one year
Average Bankfull Width (ft.)	98	125 one year
Bankfull Average Depth (ft.)	2.6	3.4 one year
Average Bank Full Width/Depth Ratio	38	37 one year
Residual Maximum Pool/Scour Depth	4.4	5-6 one year
Average Low Flow Width (ft.)	56	38 one year
Average Low Flow Depth (ft.)	0.6	2.4 one year
Average Low Flow Width/Depth Ratio	93	16 one year
LWM / River Mile (Key Pieces >36" in Diameter) pieces	0	12 one year
LWM / River Mile (12"-35" in Diameter) pieces	4	29 one year
LWM / River Mile (<12" in Diameter) cubic yards	198	711 one year
Pools Per Mile	2	12 one year
Spawning Area Per Mile (Square Yards)	880	3000 one year

* Range of Values found with Reference or Project Areas - Otherwise Average

The stream channel reconstruction action option in subreach 2 would reestablish floodplain connectivity (figure 42 on page61, figure 44 on page 62, and figure 45 on page 63), restore natural channel migration rates, rehabilitate stream channel cross-sections (figure 43 on page62), by reducing width-to-depth ratios, restoring pool-riffle-glide sequences (figure 51 on page 68), and off channel habitats.

Approximately 39,400 cubic yards of material would need to be excavated to remove the levee and construct a new stream channel. Approximately 48,400 cubic yards of fill would be needed to fill in the existing stream channel. Due to the fill deficits, sections of the existing stream channel could potentially be left unfilled and used as off-channel rearing. Material from excavated constructed wetland complexes could also be used to reduce the fill deficits.

The invert elevation of the new stream channel bed would need to be approximately three feet higher than the existing stream channel bed elevation in order to reestablish flood plain connectivity (see figure 43). This increase in streambed elevation and filling of the existing channel would create a pool approximately six feet deep (maximum depth) tapering upstream 110 feet to the pool head. The new stream channel segment would begin from the pool and transition into a spawning glide, riffle and then pool (see figure 45 on page 63). Seven new pool riffle sequences would be constructed; 850 feet of pools, 1,400 feet of riffle and 390 feet of spawning glides.

The upper 870 feet of conceptual new stream channel would serve as the transition from the steeper transport subreach 1 project area (1.1% thalweg slope) to the lower depositional subreach 2 (0.4% thalweg slope). Conceptual sinuosity for the upper transition would be 1.1 and 1.3 for the lower depositional area (see figure 46 on page 63).

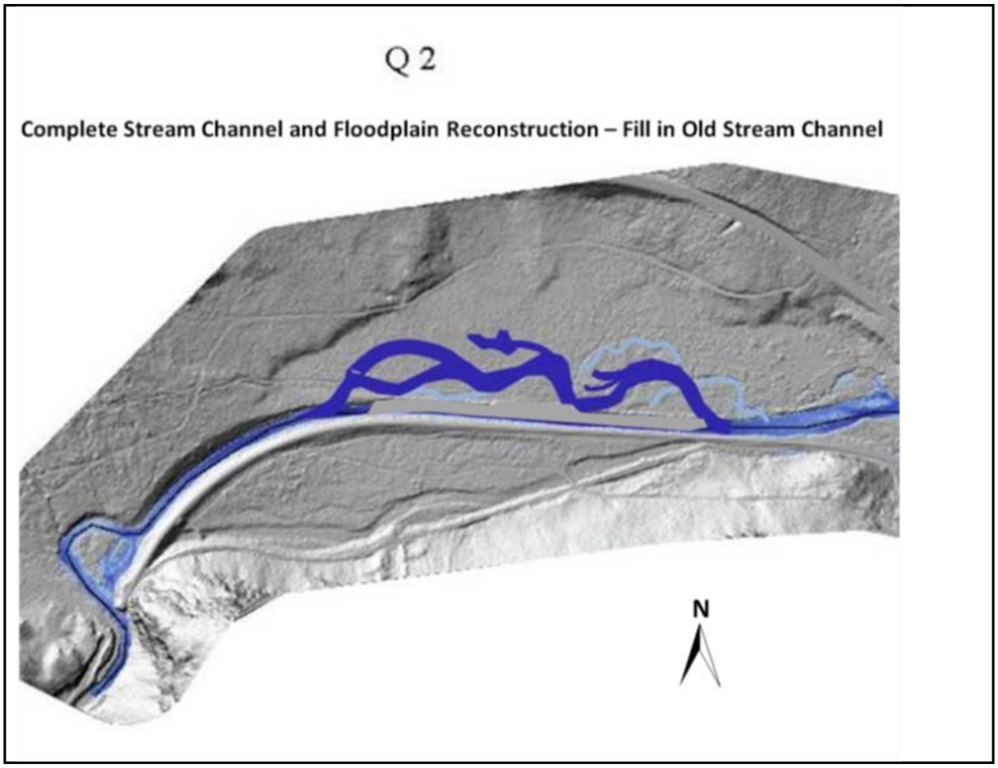

Figure 42. Plan view showing full channel and floodplain reconstruction between RM 13.85 and 13.35 at a 2-year (Q^2) flow

Restoring flood plain connectivity would provide off-channel rearing and foraging habitats and peak flow refuge for aquatic organisms from the creation of side channels and alcoves. This option replicates the natural reference stream channel conditions and would restore pool, riffle and spawning glide habitats. Restoring riffle and glide habitat would increase aquatic insect and fish productivity in the short and long term (greater than 30 years).

The primary issue and constraint for this action is the existence of the powerline corridor / location of power poles and cost. Implementation of option 2B is dependent on powerline and or power pole relocation, which would essentially double the cost. The entire subreach 2 project area exists on National Forest System lands. Staging and access to the area would be a non-issue as Forest Service and powerline maintenance roads already exist. Issues may arise regarding implementation of the stream construction restoration action as it relates to the existing wetland complex in subreach 2. The cost of this action (excluding powerline relocation) could range from approximately $620,000 to 930,000 depending on material accessibility, design, and contracting methodology.

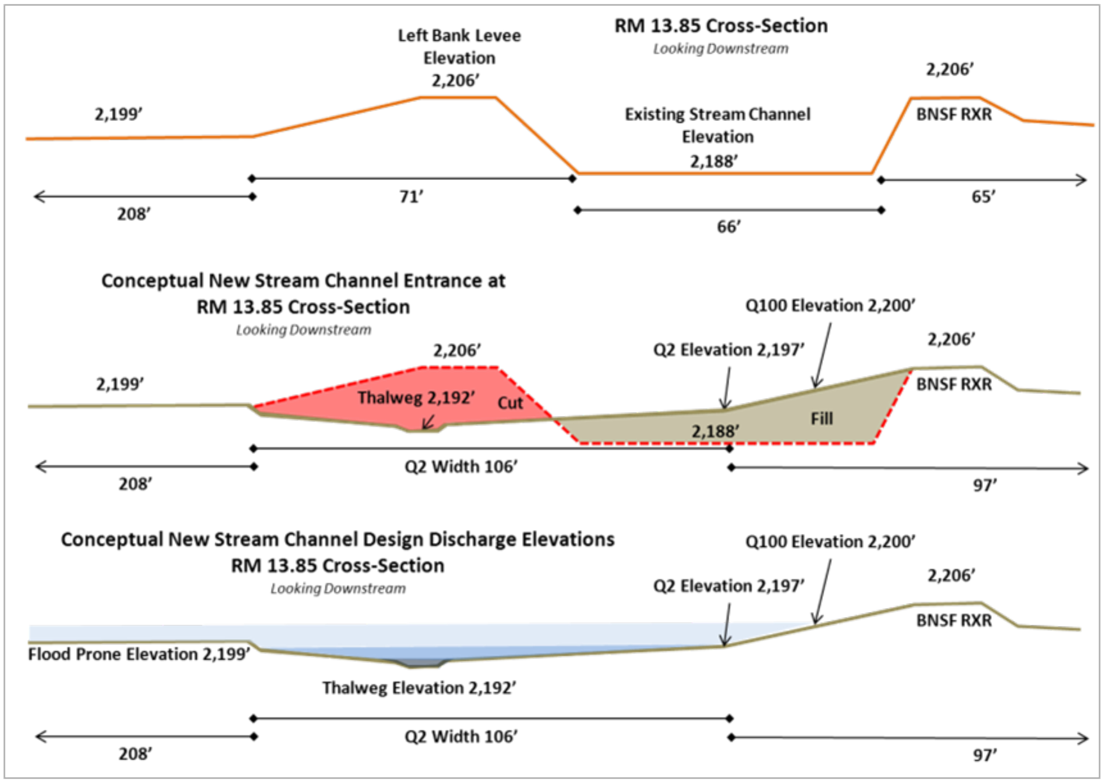

Figure 43. Cross-section views of conceptual new stream channel entrance

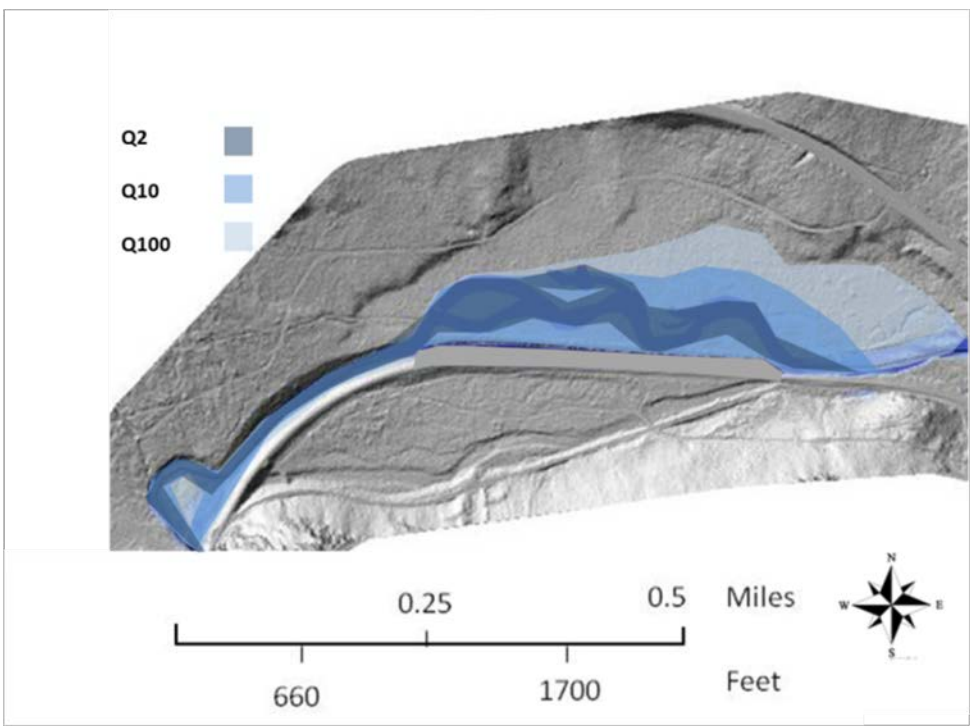

Figure 44. HEC RAS inundation mapping for the 2-, 10-, and 100-year flood events after complete channel and flood plain reconstruction in subreach 2

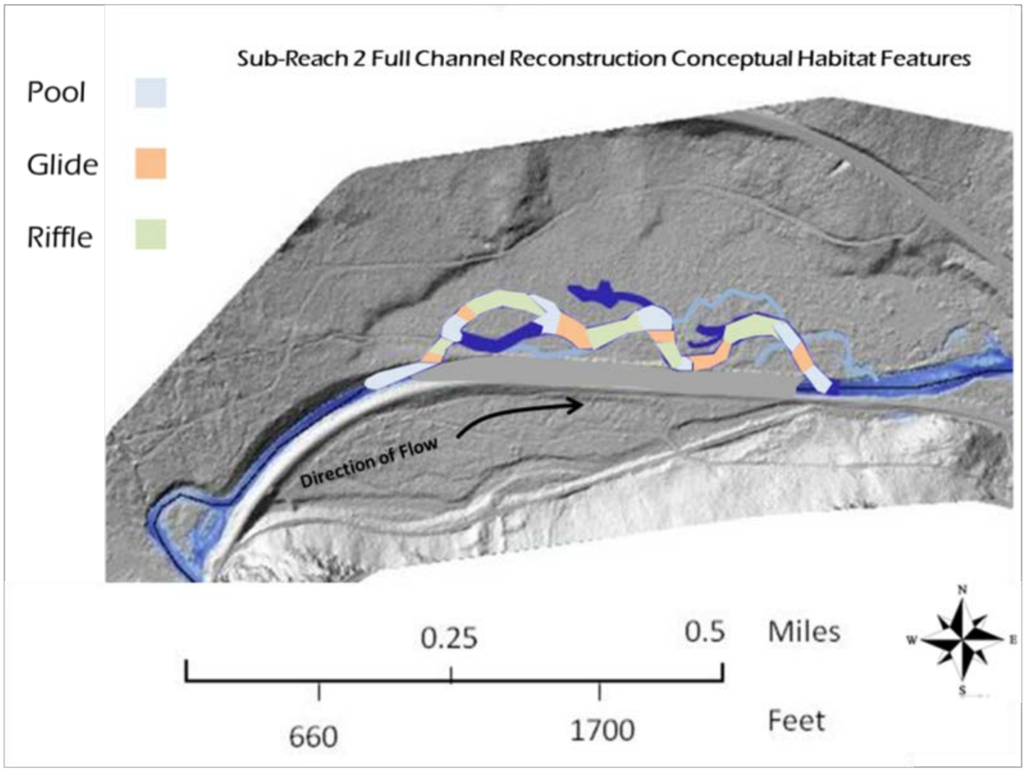

Figure 45. Subreach 2 full stream channel reconstruction conceptual habitat features

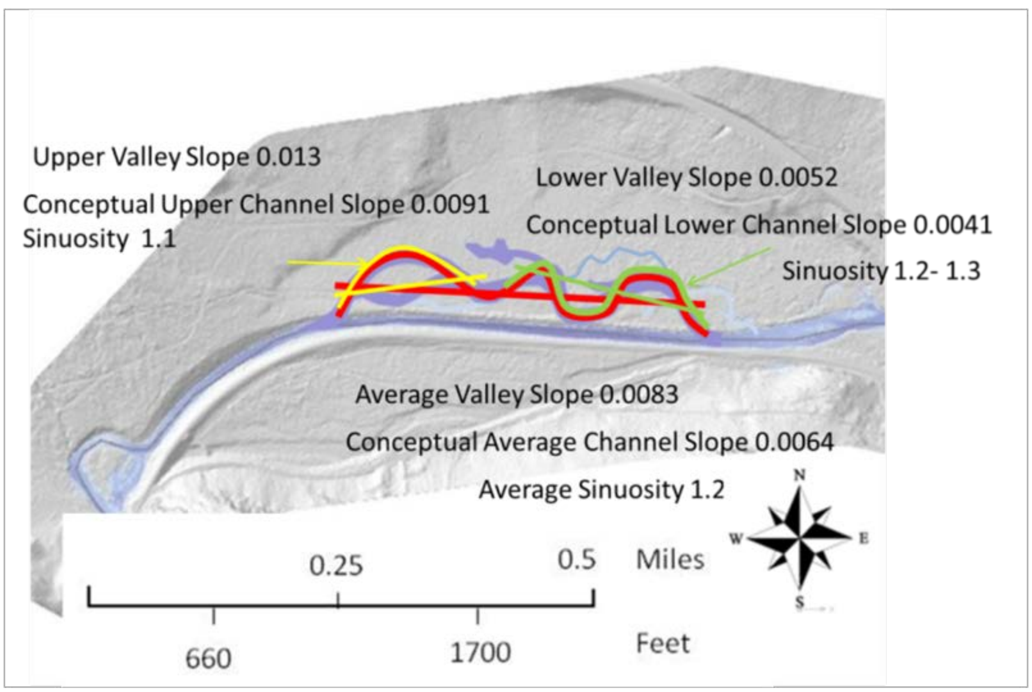

Figure 46. Conceptual slope and sinuosity for subreach 2 option 1 stream channel reconstruction

Subreach 2 - Realignment Preferred Option/Scenario 2D

Option 2D is a blend of options 2B and 2C, and is the preferred scenario. This alternative was developed based upon review of historic site conditions. It aims to restore the historic stream channel sinuosity present in this reach of Nason Creek. LIDAR review and the 1949 aerial photograph depict mainstem stream channel meanders near RM 13.3-13.65. Figure 44 depicts inundation modeling results from flows in Nason Creek, however, much of this floodplain area is already inundated during the 2 year event from tributary flows and the existing wetland. Therefore, the floodplain surface water connection will be even larger than depicted.

Option 2D would leave levees in place upstream of RM 13.65 and restore the stream channel similar to what is proposed in option 2B; rehabilitate stream channel cross-section and construct low amplitude meanders within the confines of the existing stream corridor. The lower 1,500 feet (between RM 13.3–13.65) would remove levees and reconstruct a new channel to the north of the existing channel similar to option 2C (see figure 41 on page 59). Option 2D could also include installation of new culverts under the railroad prism at RM 13.5 and 14.1, reconnecting and converting the historic stream channel into a side channel. Option 2D would involve the following actions: partial levee removal (RM 13.3–13.65), stream channel meander and floodplain reconstruction, off-channel wetland reconnection and creation, large wood restoration, riparian restoration. For a plan view of option 2D, see figure 47.

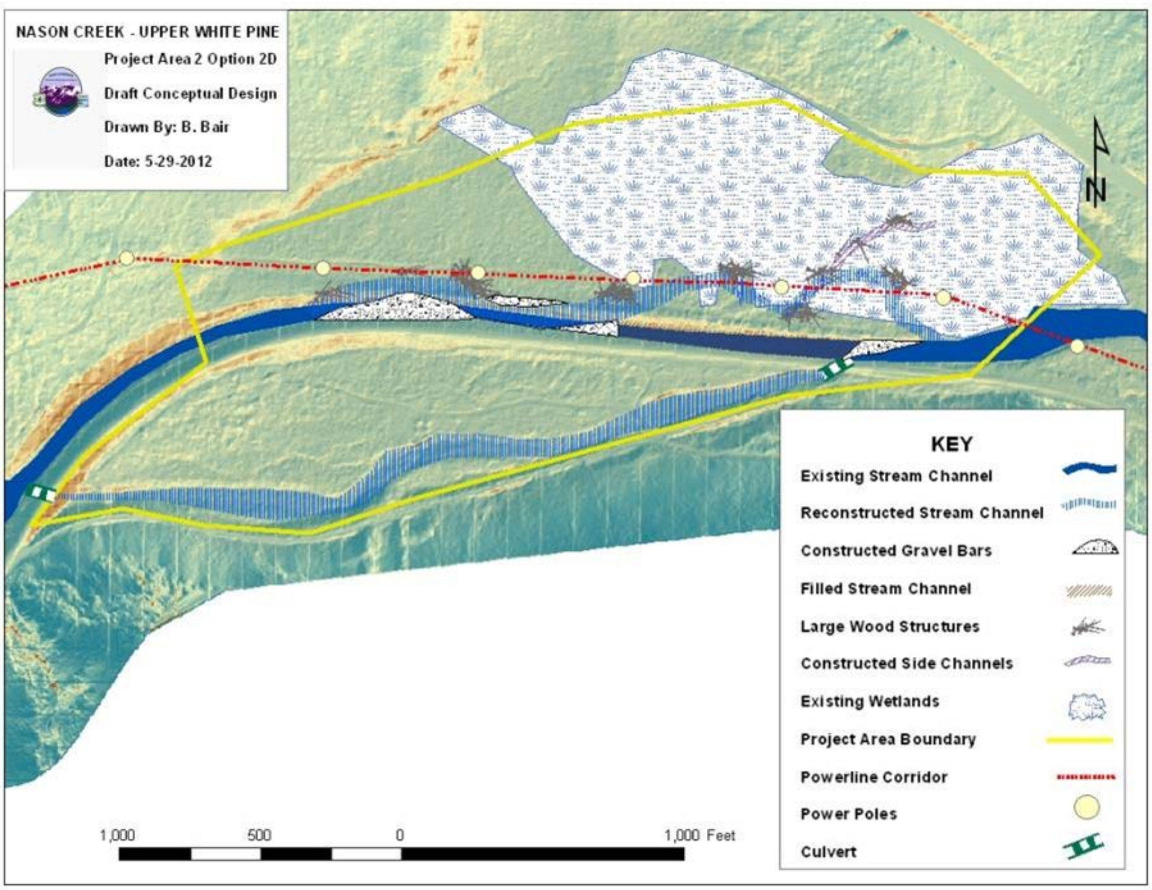

Figure 47. Conceptual design for option 2D (Nason Creek, RM 14.0 – 13.4)

Approximately 19,000 cubic yards of material would be excavated to remove the levee between RM 13.3 to 13.65. Depending on the level of floodplain connection, between 14,500 and 23,000 cubic yards of fill would be placed to fill the existing channel and to construct meanders and rehabilitate stream channel cross-section geometry within the existing stream corridor. Approximately 15,000 to 20,000 cubic yards of material would be excavated to construct the new stream channel.

Table 7. Changes to stream channel geometry, large woody material quantity, pool numbers and spawning volume after implementation of option 2D

Design Attributes	Existing Condition	Condition after Option 2D Implementation
Entrenchment Ratio	1.0	3 one year
Meander Beltwidth (ft.)	NA	150-600 one year
Meander Wavelength(ft.)	NA	500-1,000 one year
Sinuosity Range	1	1.1-1.2 one year
Thalweg Slope	1.1% Upper - 0.5% Lower*	1.0% Upper- 0.5% Lower* one year
Average Bankfull Width (ft.)	98	125 one year
Bankfull Average Depth (ft.)	2.6	3.4 one year
Average Bank Full Width/Depth Ratio	38	37 one year
Residual Maximum Pool/Scour Depth	4.4	5-6 one year
Average Low Flow Width (ft.)	56	38 one year
Average Low Flow Depth (ft.)	0.6	2.4 one year
Average Low Flow Width/Depth Ratio	93	16 one year
LWM (Key Pieces >36" in Diameter) pieces	0	12 one year
LWM (12"-35" in Diameter) pieces	4	29 one year
LWM (<12" in Diameter) cubic yards	198	711 one year
Pools	1	7 one year
Spawning Area (Square Yds.)	485	1,375 one year

Partial levee removal and stream channel reconstruction would restore the second greatest amount of flood prone area of all project area 2 options. Option 2D would increase the flood prone area from 6 acres to 28 acres at the Q2 discharge, 11 acres to 43 acres at the Q10 discharge, 21 acres to 49 acres at the Q50 discharge and 36 acres to 57acres at the Q100. Entrenchment ratios (flood prone width/bankfull width) from1.0 to 3, sinuosity would be increased from 1.0 to 1.2. Similar to option 2C, 1.8 acres of wetland habitat would be reconnected and an additional one acre of new wetlands would also be constructed.

Fish habitat would also be improved by increasing pools would be from 1 to 7, increasing spawning area from 485 square yards to 1,375 square yards and restoring large wood levels to greater than 50 trees per mile.

Without relocating the powerline corridor, riparian restoration would be limited in increasing the effective riparian area from 16 acres to 20 acres. Floodplain large wood levels would be restored to reference conditions that would also provide protection for pioneer and planted riparian vegetation during peak flow events.

The cost range for option 2D is $560,000 to $850,000 (cost estimates exclude installation of culverts). The estimated cost range does not include protection, removal or relocation of specific power poles. Option 2D is included in the preferred scenario description.

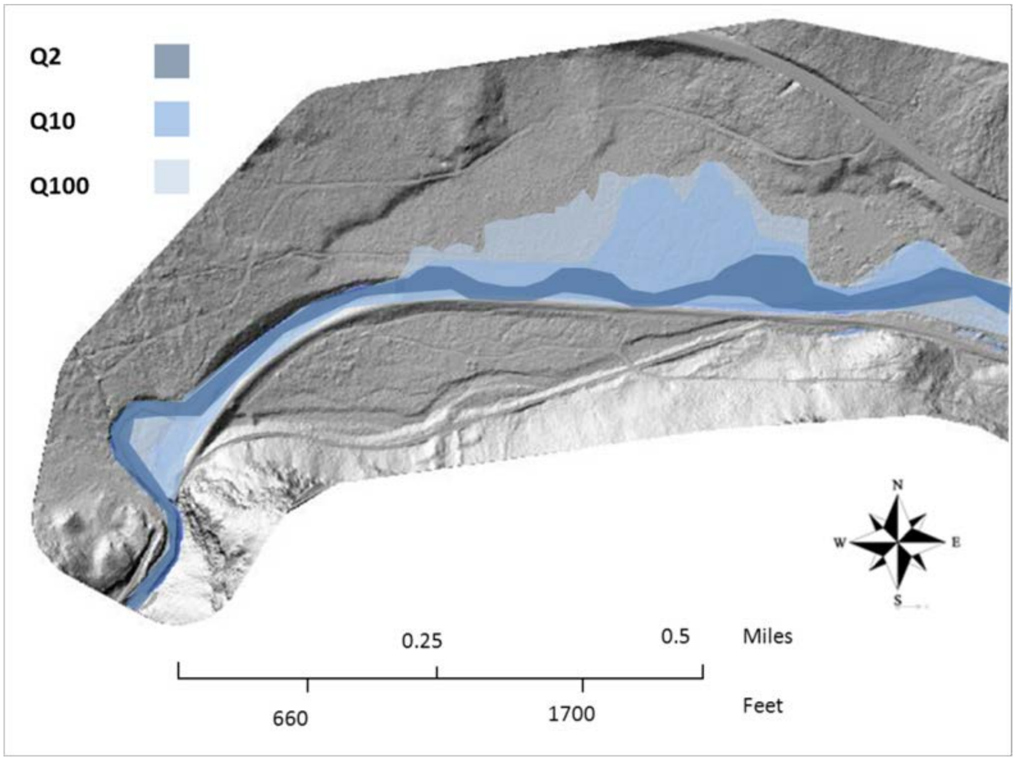

Figure 48. HEC RAS inundation mapping for the 2-, 10-, and 100-year flood events after stream channel cross-section rehabilitation and meander construction along the existing stream corridor in subreach 2

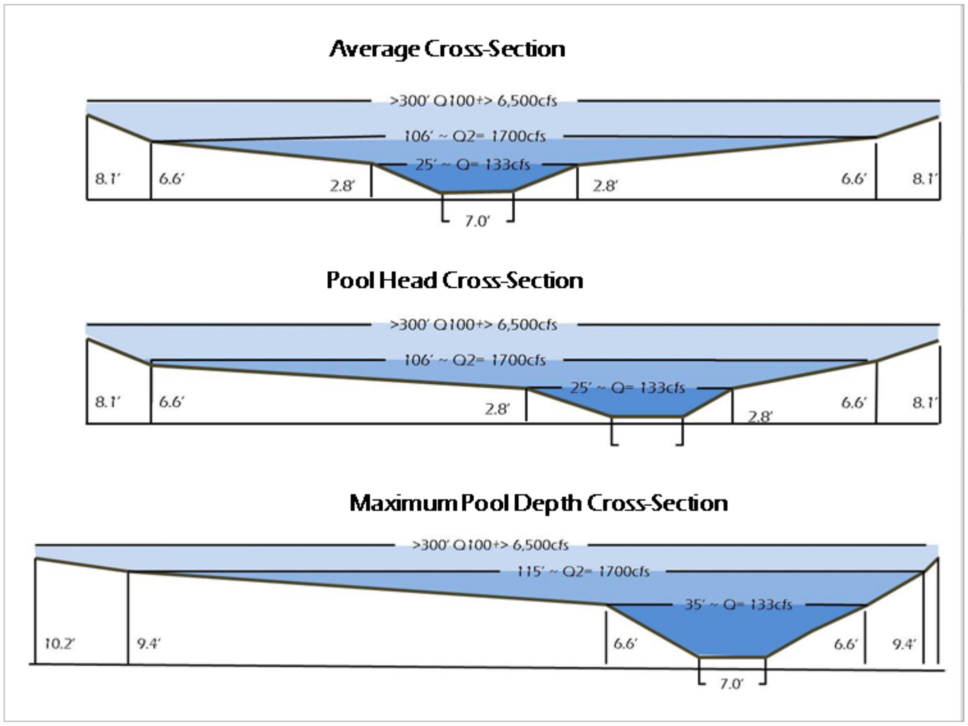

Figure 49. Average, pool head, and maximum pool depth cross section dimensions to be implemented for the stream channel and meander construction restoration action

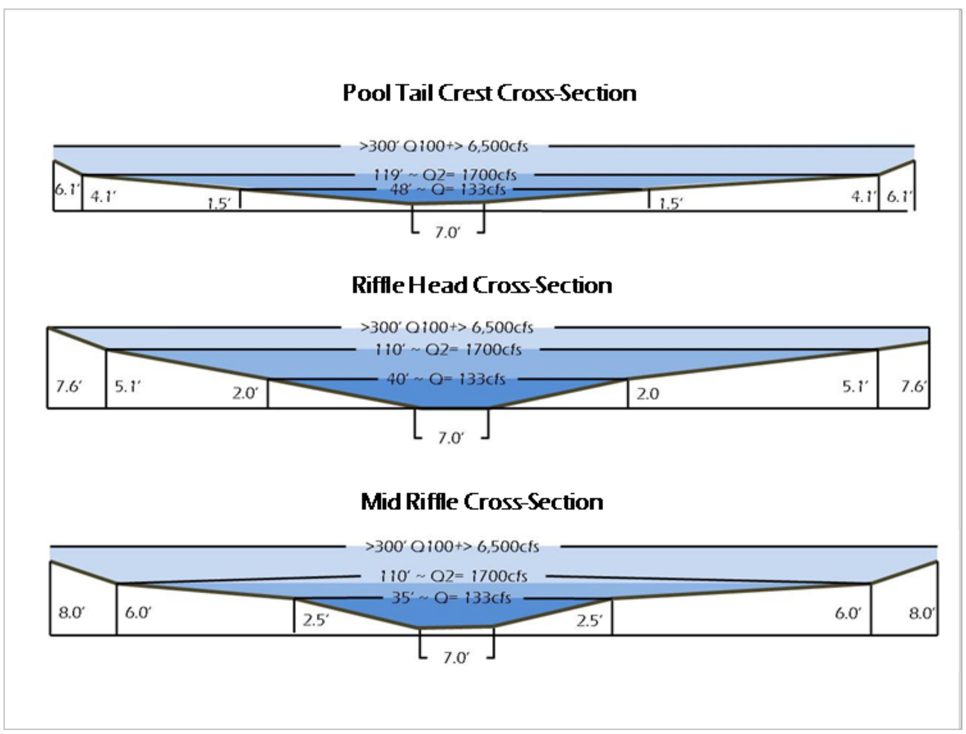

Figure 50. Pool tail crest, riffle head, and mid riffle cross section dimensions to be implemented for the stream channel and meander construction restoration action

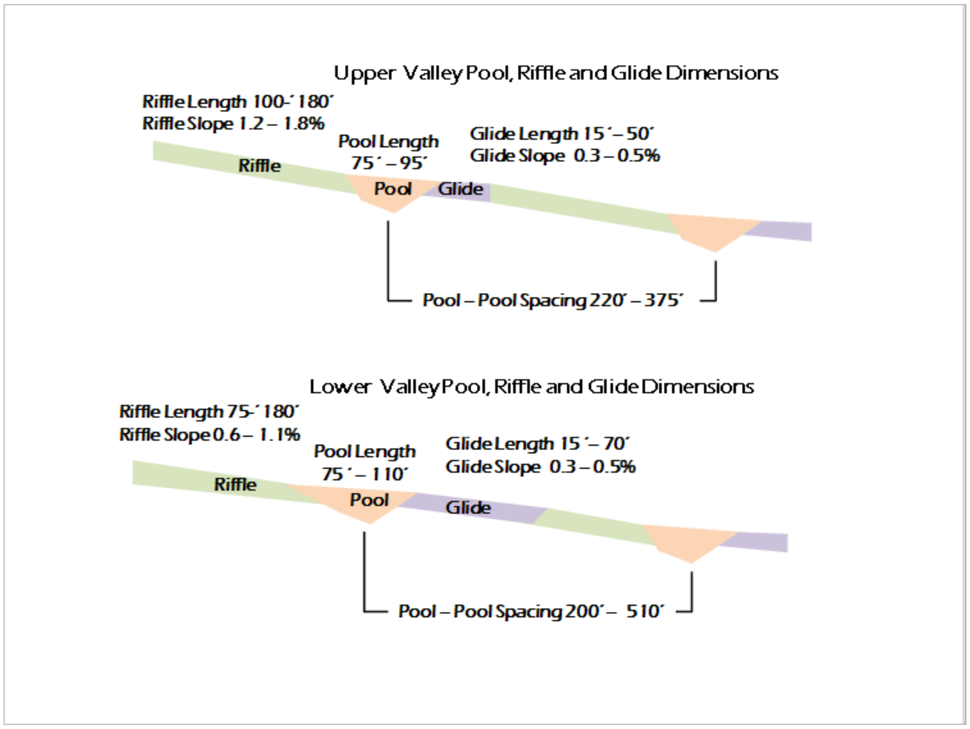

Figure 51. Proposed riffle, pool, and glide dimension for the stream channel reconstruction restoration action proposed in subreach 2

Subreach 3 Realignment

This project element involves two realignment options within subreach 3 that would shift the channel away from the armored banks along U.S. Highway 2. Realignment option 1 would involve a slight shift of the channel just enough to remove the influence of the armored banks. Realignment option 2 is a more aggressive approach that would shift the channel further from the highway. These are described below.

Subreach 3 - Realignment Option 1

This action includes moving the channel away from the highway embankment in subreach 3 (figure 52). The channel currently abuts the highway at two locations at the northern extents of the two meanders near RM 12.8 and 13. This action would shift the channel to the south approximately 50 feet at both locations in order to: (1) move the channel off of the existing riprap banks at these locations, (2) create a forested riparian and floodplain buffer (long term), and (3) enhance margin habitat complexity through placement of meander bend logjams. These actions would be expected to enhance cover for rearing juvenile salmon and steelhead on 500 lineal feet of channel and to enhance long-term riparian functions including wood recruitment, shade, and bank stability. The new channel would approximate the location of the early 1980s alignment as observed in the aerial photo record. The channel would be moved just enough to establish an adequate riparian buffer (~50 feet) but would retain existing high quality habitat that now exists within these meander bends, including pool-riffle habitat and a large meander bend logjam along the river-left bank near RM 12.95.

The new floodplain surface would be set at an elevation to overtop between a 1 and 2-year return interval flood event and would be planted with native riparian vegetation including deciduous and coniferous species. The existing riprap would remain in place and would not be altered other than to fill the lower elevation portions for construction of the new floodplain surface. Designed channel geometry would be based on existing channel geometry at the site, reference site channel geometry, and geometry required to achieve floodplain inundation at the 1 to 2-year event. This element was modeled using HEC-GeoRAS. An inundation map of this element is included in figure 53.

Figure 52. Plan view of subreach 3 realignment, option 1

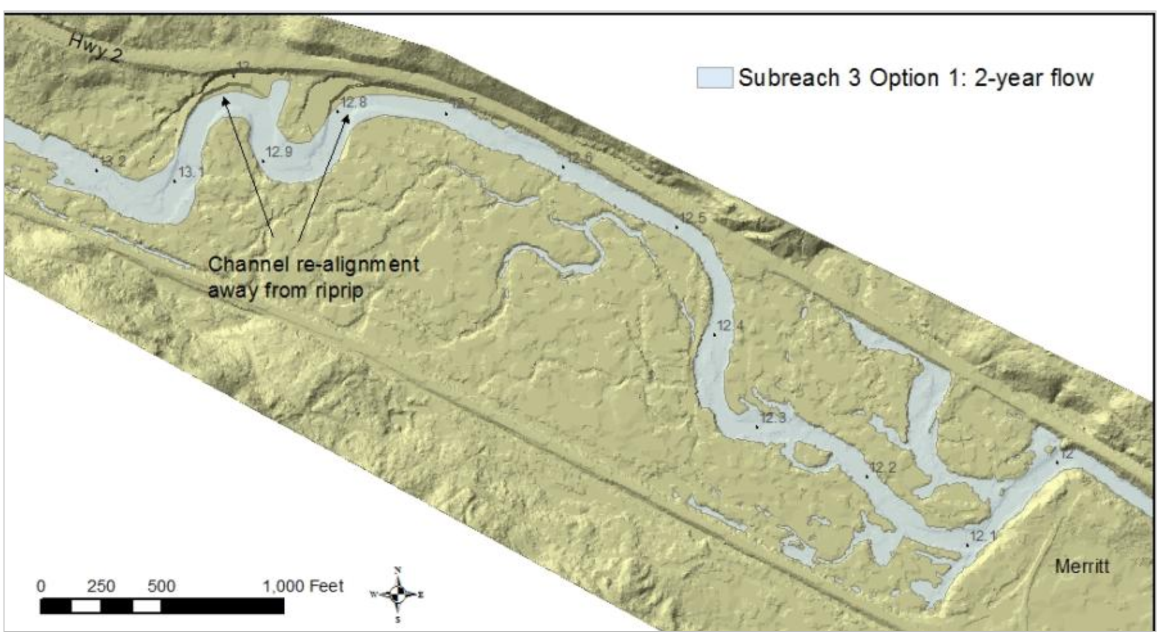

Figure 53. Inundation map for the subreach 3 option 1 at the 2-year flow. Results generated using HEC GeoRAS. Results are preliminary and have been developed at a concept level.

This action would provide the minimal disruption necessary to remove the interaction between the river's channel migration zone and the highway embankment. Channel migration would be expected to continue over time in this subreach in keeping with the geomorphic setting and historical trends. There are potential constraints associated with construction adjacent to U.S. Highway 2. A staging area and access routes would have to be established to minimize interaction with highway traffic. Channel realignment would require moving approximately 500 feet of existing channel. Fish rescue would be required prior to dewatering. The effectiveness and potential impacts of fish rescue would need to be addressed as part of project design and permitting. The stream would be routed (piped) around the construction areas during construction of the realignments. There is significant potential for turbidity generation during construction that would need to be addressed through dewatering and pumping of turbid water to suitable land-application areas on the floodplain. Some of the construction would need to occur from the south bank due to the proximity of U.S. Highway 2.

The primary costs would be associated with excavation of the new channel alignment, creation of the new floodplain surface, and construction of logjams. Establishing access, dewatering, and erosion control would also be significant costs. It is anticipated that all of the material excavated for the new alignment could be accommodated onsite for the new floodplain surface. The concept level construction cost estimate ranges from $410,000 to $610,000 (see Appendix F).

Subreach 3 - Realignment Option 2

This action includes moving the channel into a new alignment between RM 12.7 and 13.1 in subreach 3 (figure 54). The new alignment would approximate the 1949 alignment and would result in reduced channel sinuosity. This action would accomplish the following: (1) move the channel off of the existing riprap banks at RM 12.8 and 13, (2) significantly reduce the potential for a channel avulsion at the existing bends in the short-term, and (3) provide for off-channel habitat in the former channel location. Meander bend logjams would be used to provide interim stability in the newly constructed channel to compensate for impacts to riparian vegetation as part of construction activities.

The former channel would be enhanced as off-channel habitat with two off-channel units created in the portions of the meanders that are relocated. These off-channel areas would be connected to the new mainstem channel. These off-channel habitats would have only downstream connection points (i.e., they would not be flow-through side-channels), which would be located at RM 12.75 and 12.95. Fill would be placed at the upstream ends to block mainstem flow from re-occupying the former channels. The existing logjam at RM 12.95 would become part of the upstream off-channel habitat unit. Habitat along the existing riprap banks would be enhanced through wood placements and riparian plantings.

Designed channel geometry would be based on existing channel geometry at the site, reference site channel geometry, and geometry required to achieve floodplain inundation at the 1 to 2-year event. An inundation map of the proposed action is included in figure 55.

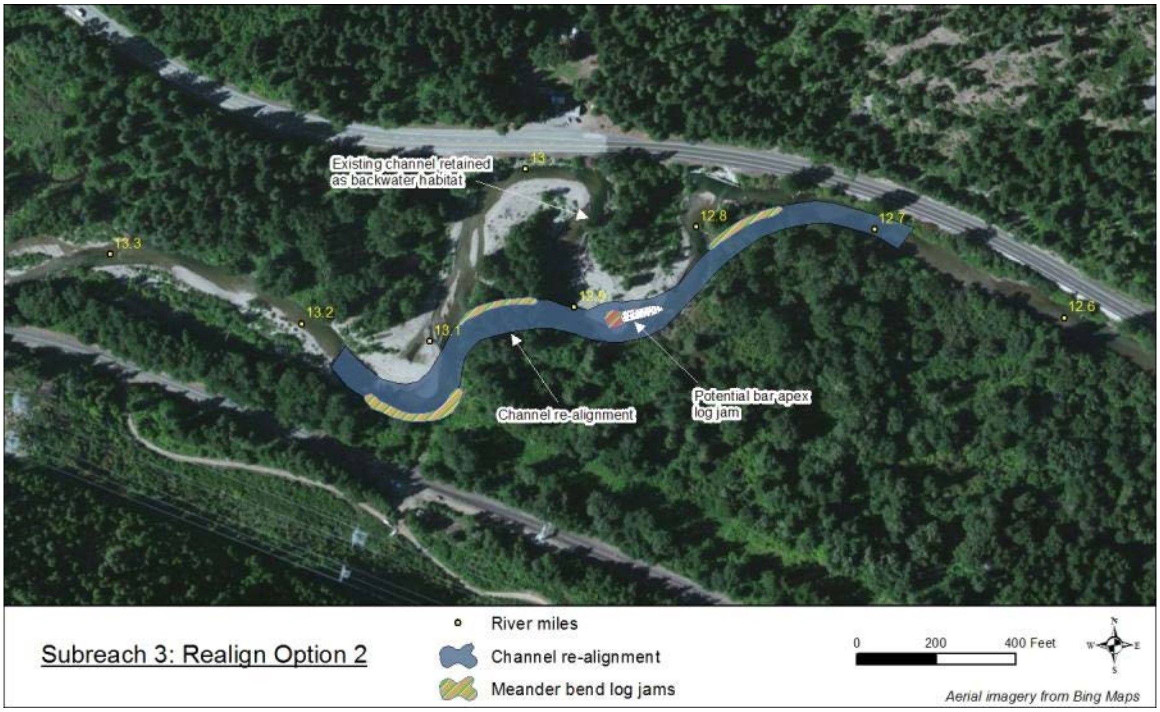

Figure 54. Plan view of subreach 3 realignment, option 2

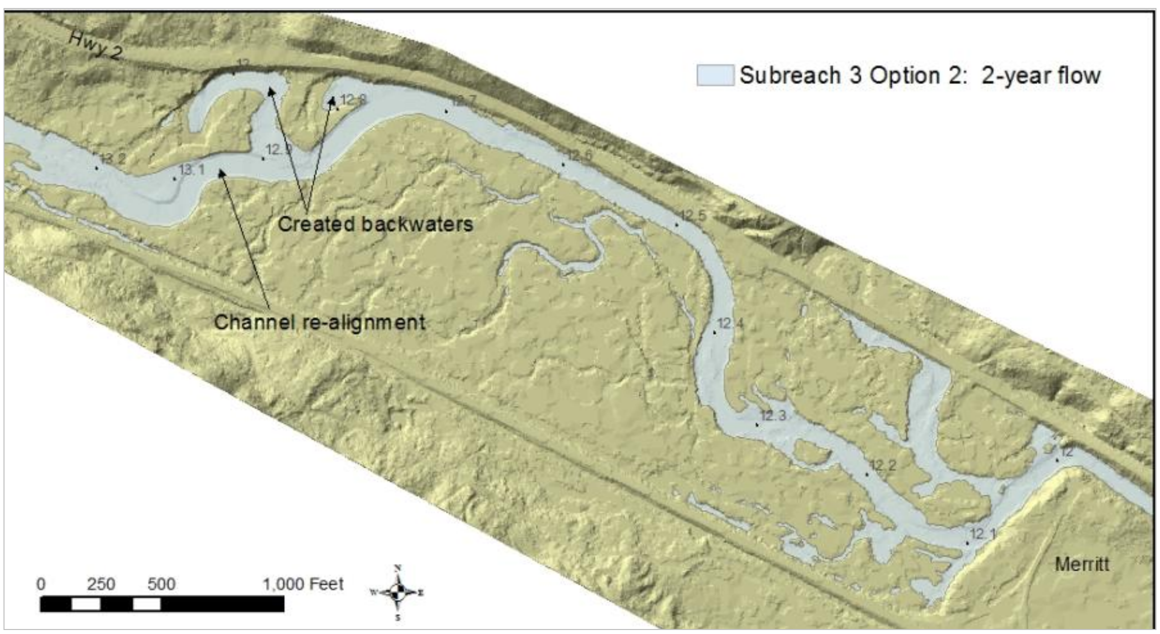

Figure 55. Inundation map for the subreach 3 option 2 at the 2-year flow. Results generated using HEC GeoRAS. Results are preliminary and have been developed at a concept-level.

The primary benefits to this action would be moving the channel away from the riprap banks and creation of new off-channel habitat. As in option 1, moving the channel away from the riprap banks would enhance margin complexity on 500 lineal feet of channel. This action would also create approximately 1.5 additional acres of off-channel habitat, which would have benefits to juvenile rearing and flood refuge. Reduced channel width-to-depth and increased bedload transport competency (due to increased gradient) may benefit habitat formation locally and in subreach 4 over the long term.

A potential habitat impact would be the loss of high quality habitat in portions of the existing meander bends that would be relocated. This includes pool and riffle habitats as well as the large existing logjam at RM 12.95 (this logjam would be retained as habitat within the new off-channel area, but would not have the same habitat benefits as in the mainstem channel). An additional impact would be the clearing of mature riparian and floodplain forest (~1 acre) that would be required for the relocation; this material could be used as placed wood habitat in the new channel but would reduce the overall extent of floodplain and riparian forest at the site.

Fish rescue would be required since channel realignment would require moving approximately 1,400 feet of existing channel into 800 feet of new channel. Some of the former channel would be retained as backwater habitat and may not require full fish rescue. Most of the new channel would be constructed in isolation from Nason Creek by leaving soil plugs and using temporary coffer dams. Fish rescue would be required at the least along the approximately 400 feet of channel where the main channel would be blocked (upstream ends of the two relocated sections). The effectiveness and potential impacts of fish rescue would need to be addressed as part of project design and permitting.

The primary costs would be associated with excavation of the new channel alignment and construction of logjams. Establishing access, dewatering, and erosion control would also be significant costs. It is anticipated that all of the material excavated for the new alignment could be accommodated onsite or at a nearby disposal area to be determined. The concept level construction cost estimate ranges from $490,000 to $740,000 (see Appendix F).

Off Channel Creation, Enhancement, or Reconnection

Off-channel habitat creation would increase the amount of available off-channel habitat, which has been lost throughout lower Nason Creek as a result of man-made alterations including stream channel dredging and realignment, straightening, levees, bank armoring, and floodplain filling.

In the short term, off-channel wetlands would provide off-channel rearing / foraging habitat and peak flow refuge for aquatic organisms. In the long term, wetland habitat can become isolated by loss of inlet and or outlet channel. Therefore, longevity varies greatly (1 to greater than 30 years).

Off-channel habitat work could occur in subreaches 1, 2, 4, or 5. Potential work elements in these subreaches are discussed below:

Subreach 1

Off channel creation in subreach 1 would involve installing a culvert under the BNSF railroad prism at RM 14.15. The culvert would provide an upstream connection to the historic channel creating flow-through access to 2,900 feet of the historic stream channel. Depending upon the culvert size and invert elevation, this reconnection may create up to seven acres of seasonal habitat availability. The cost of constructing a culvert under the existing railway and rehabilitation of the historic stream channel would range from $600,000 -$3,500,000. The wide cost range is due to the type of stream channel crossing installed (bridge versus culvert) and the extent of rehabilitation of the historic stream channel.

Other than cost, there are other concerns associated with an upstream connection to the historic channel. This culvert connection appears to be located on private property and BNSF has indicated that they are not supportive of this upstream connection. In addition, due to the site topography, this culvert would need to be almost 200 feet long. Thus, providing fish passage would be difficult to design, expensive to install, and not likely supported by BNSF.

Subreach 2

Installation of a larger culvert under the BNSF prism at the downstream end of the historic channel would provide off-channel habitat within subreach 2. The existing culvert provides some off channel rearing habitat under the BNSF railway at RM 13.55. However, if this culvert could be replaced with a larger structure along with wetlands/historic stream channel modification and enhancement this would provide up to 7 acres of off-channel habitat. There may be some concern about water temperatures in the downstream end of the historic channel because of vegetation maintenance under the BPA powerlines. However, the intent of the improved downstream connection would be to create high flow refugia and spring and winter rearing habitat. Thus, the time that fish would have access to this area would not be during low water and high temperature seasons. Temperature monitoring conducted in 2011 and 2012 in the historic channel have documented temperatures below 16C in the early summer season.

Subreach 2 also proposes to construct between 300 or 700 feet of side channel habitat that would connect existing wetland habitat. This action is contingent on implementation of the stream channel and meander construction restoration action. The cost of this action could range from approximately $32,000 for minor modifications of the existing structure to over 1 million for replacement of obstruction (see Appendix F).

Subreaches 4 and 5

Potential locations for off-channel creation and enhancement in Subreaches 4 and 5 are included in figure 57. Locations for potential off-channel projects in Subreaches 4 and 5 are based on where these types of habitats would naturally form and where existing floodplain depressions would help to facilitate construction. Off-channel areas would be created through excavation of floodplain material. In most cases, the off-channel habitats would have only one connection point with the mainstem, and would be placed in areas where groundwater contributions would be expected to maintain suitable water temperature conditions throughout the year. There is also the potential to create a flow-through side-channel (including both an upstream and downstream connection) along the north boundary of the floodplain in Subreach 5. In general, off-channel habitats would be designed to be accessible to juvenile salmonids throughout the year, providing both high flow refuge from fall through spring as well as temperature refuge in the summer. Large wood would be placed in off-channel areas for complexity and cover. A total of approximately 4 acres of potential off-channel habitat creation have been identified. The concept level construction cost estimate for subreaches 4 and 5 ranges from $110,000 to $160,000 per acre (see Appendix F).

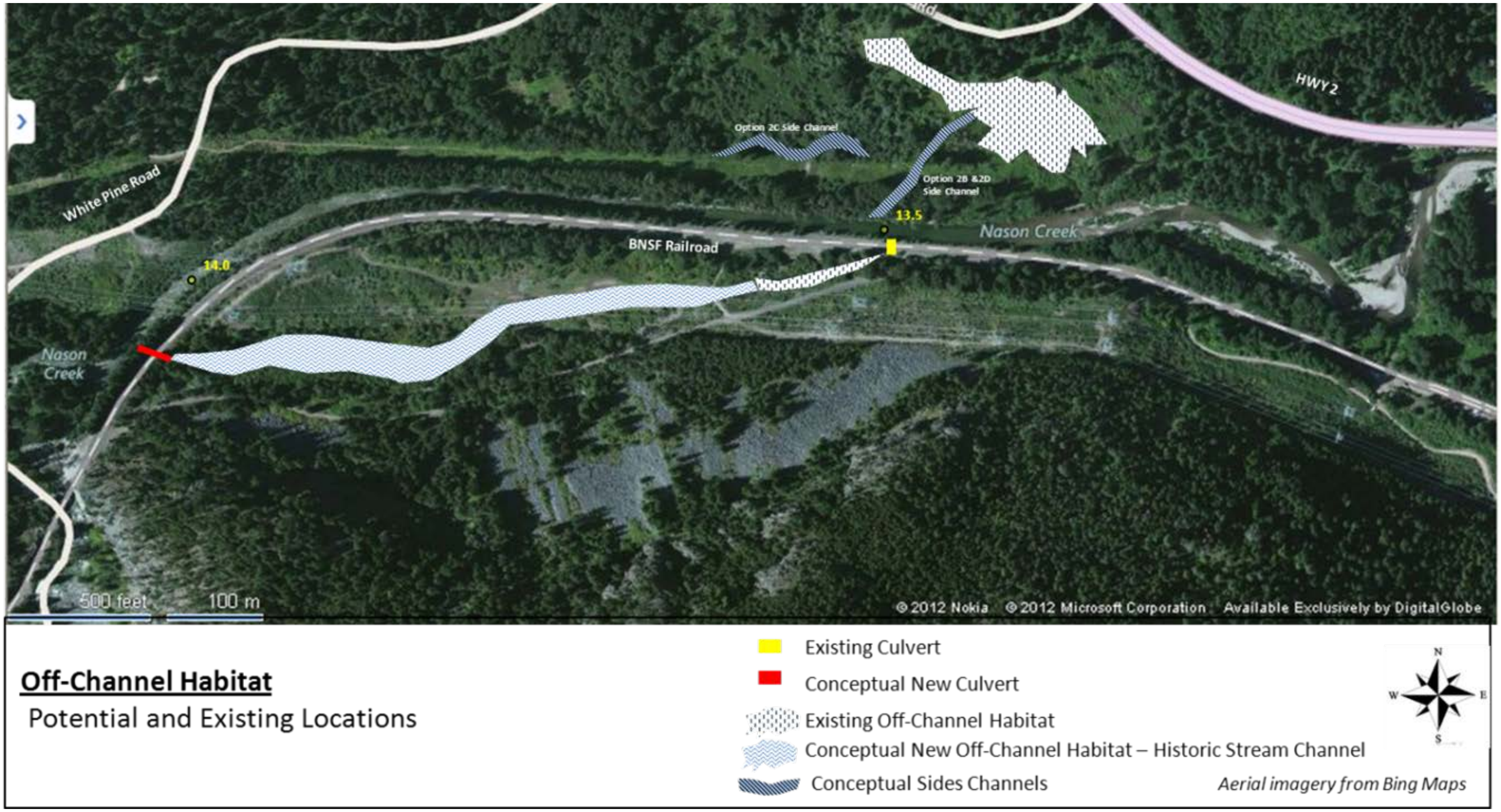

Figure 56. Off-channel opportunities in subreaches 1 and 2

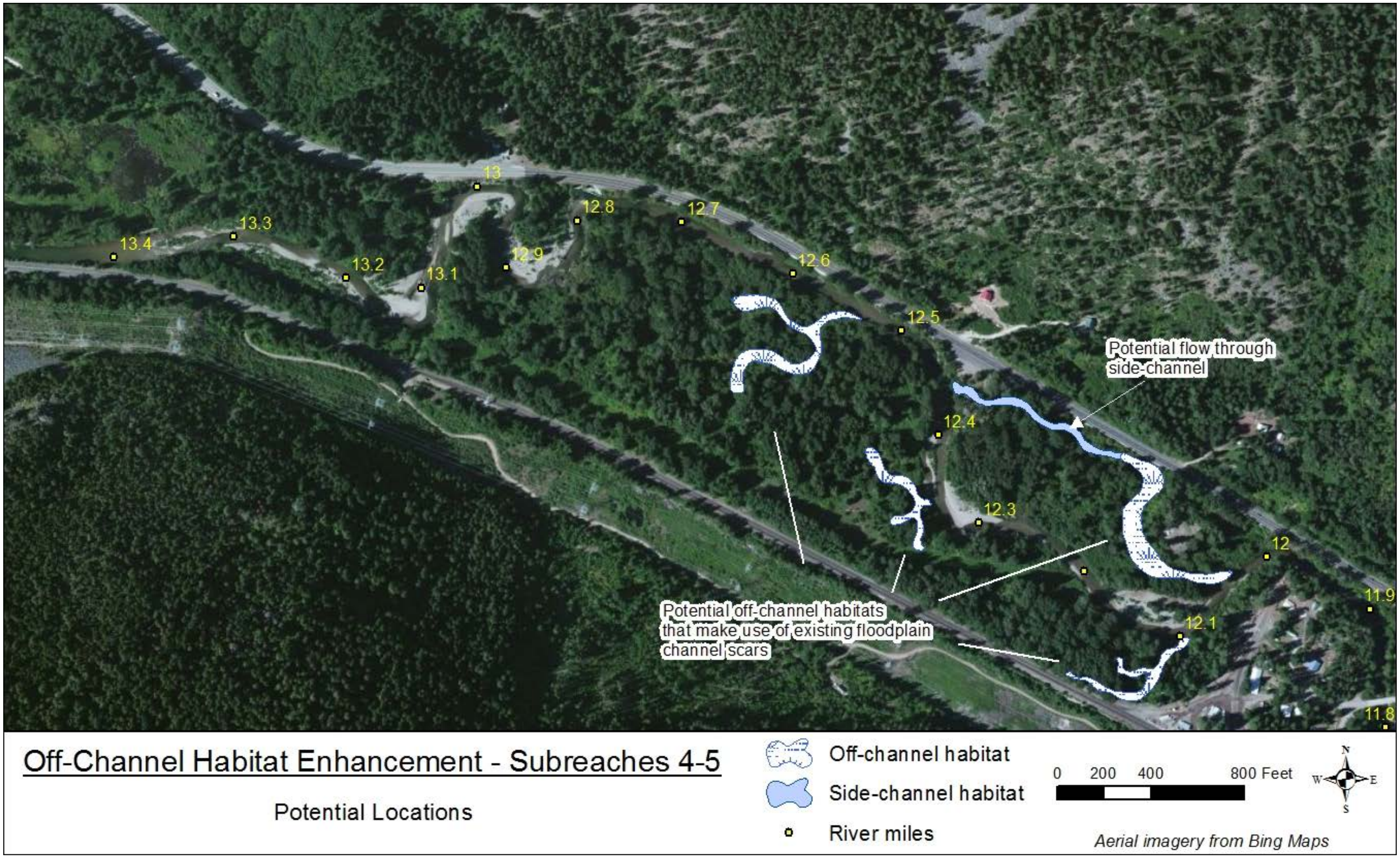

Figure 57. Off-channel enhancement opportunities in subreaches 4 and 5

RESTORATION SCENARIOS

Based on the evaluation of the potential restoration elements, a preferred restoration scenario for the entire Upper White Pine Reach was developed. This scenario includes a combination of the restoration elements that will work collectively to best accomplish the project goals and objectives. Also included are several options that could potentially modify the preferred alternative depending on on-going feasibility and cost-benefit evaluations.

Table 9 on page 82 lists the primary elements in the preferred scenario, and the scenario options, by subreach. Descriptions of the preferred scenario and options are included below. Greater detail for specific elements is included above in the project element descriptions. Elements that were not included in the preferred scenario, or as options, are discussed at the end of this section ("Elements Considered but Dropped from Further Analysis").

Preferred Scenario

Description

The preferred scenario includes no actions in subreach 1.

In subreach 2, approximately 0.35 mile of the left bank levee (~1,500 feet) would be removed and the channel would be moved into a new, meandering alignment within the left bank floodplain area. The specific realignment configuration would be partially dependent on the range of options available for reconfiguration of the CPUD powerlines, which is still being evaluated. Also within subreach 2, the culvert under the BNSF prism would be replaced on the right bank at RM 13.5. This would reconnect up to 7 acres (2,900 linear feet) of the historical mainstem channel alignment. Culvert replacement would be combined with habitat enhancements within the historic channel (riparian planting, excavation, and large wood additions).

In subreach 3, large wood jams could potentially be placed in the upstream portion of the subreach between RM 13.2 and 13.3. These jams would primarily function to provide habitat cover and local pool scour and would not be designed to create significant channel planform changes. Further analysis will be conducted during the design phase to determine if wood placements at this location are appropriate given the proximity to the powerline corridor and other project elements upstream and downstream.

A meander-bend logjam would be placed on the eroding right bank at RM 13.15 at the CPUD powerline corridor. Channel re-alignment would occur to move the mainstem channel away from the riprap bank at the RM 13 meander bend (realignment option 1), but not at the RM 12.8 meander bend. Realignment at the 12.8 bend was dropped due to a lesser degree of habitat impairment and concerns with impacts to existing vegetation.

In subreach 4, single large wood pieces or small jams (2-4 pieces) would be placed selectively along the south-bank channel margin. An off-channel habitat complex connected to the mainstem at all flow levels would be created within existing floodplain channel scars in the right bank floodplain.

In subreach 5, meander bend and bar apex logjams would be placed at select locations. Off-channel habitat would be created at 3 locations within existing floodplain channel scars. Locations include the right bank at RM 12.35 and 12.1 and the left bank at RM 12.05. This left bank off-channel habitat area could potentially have an upstream (flow-through) connection near RM 12.45.

Figure 58 shows the location of elements that make up the preferred scenario.

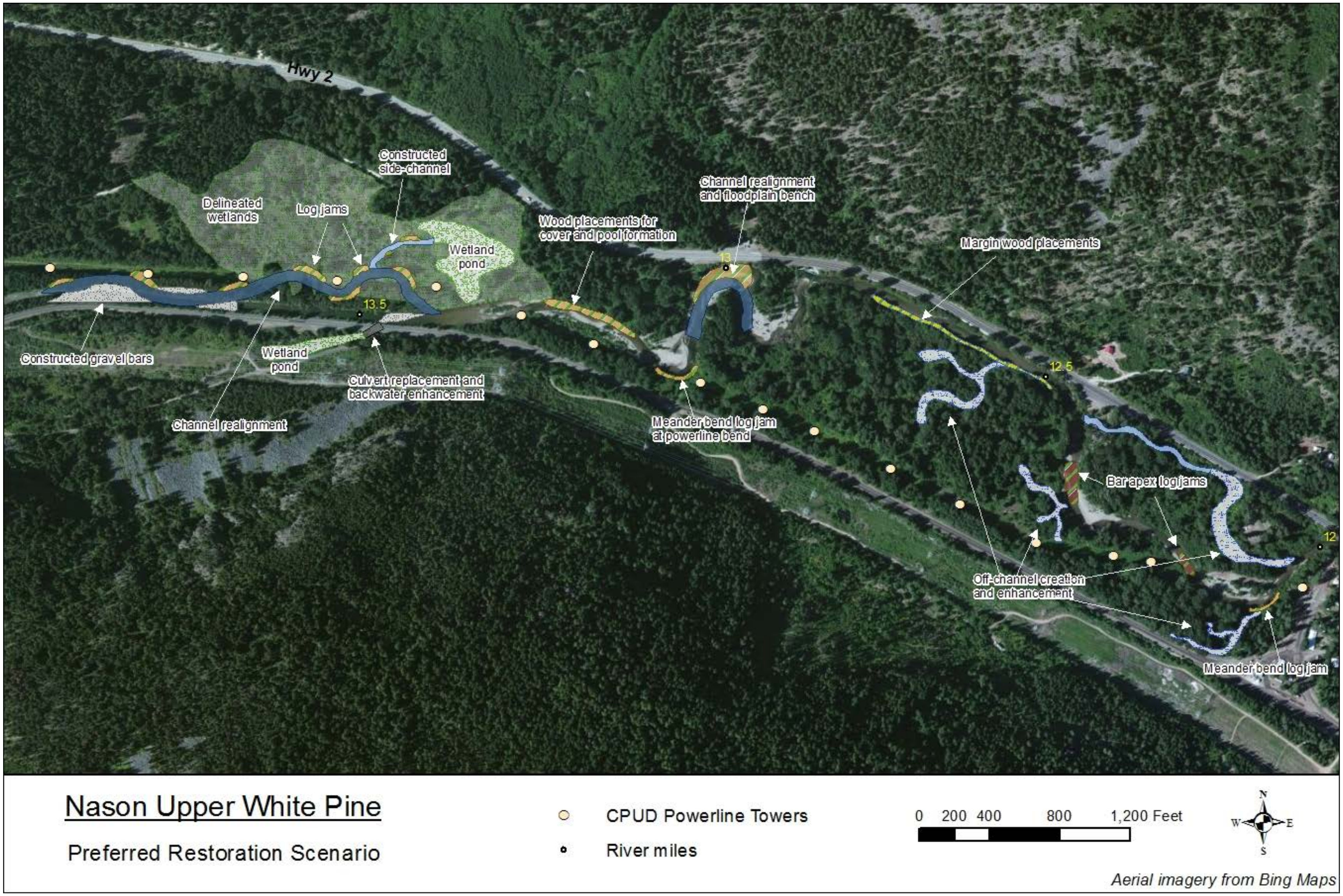

Figure 58. Preferred restoration scenario for the Upper White Pine Reach. Note: wetlands have not been delineated for subreaches 3-5.

Benefits

In subreach 2, stream channel rehabilitation (RM 13.65-13.85) would consist of modifying stream channel cross-section geometry and construct low amplitude meanders within the confines of the existing stream corridor restoring pool riffle and glide sequences. Restoration of pool riffle and glide habitat would restore resting and hiding cover for juvenile and adult fish, restore riffle macro-invertebrate productivity and increase available spawning habitat for native fishes.

The lower 2,000 feet of subreach 2 (between RM 13.3–13.65) would remove levees and reconstruct a new channel; these actions would restore pool, riffle and glide sequences and provide the previously discussed biological benefits. Sinuosity would be increased from 1.0 to 1.2, pool and spawning habitat would be increased from 1 pool to 7 pools and 485 yd^2 to 1,375 yd^2 respectively, the average low flow width to depth ratios would be reduced from 93 to 16 within the reach. In addition to restoration of in-stream habitat, removal of the levees and reconstruction of the stream channel would reconnect 22 acres of existing wetland complexes at the two year return discharge. Wetland reconnection within subreach 2 would involve construction of approximately 1 acre of new off-channel wetland habitat to the north. Levee removal and reconnection of floodplain and wetland habitat north of Nason Creek is contingent upon relocation of at least one power pole. In addition, approximately ¼ acre of off-channel wetland habitat to the south of the BNSF railway would also be connected by modifying or replacing the existing culvert at RM 13.5. The reconnection of existing wetlands and creation of an additional 1.25 acres of wetlands would provide over-winter and off-channel peak flow refuge for juvenile fish.

The preferred scenario for subreach 2 also proposes to construct approximately 400 feet of perennial side channel habitat that would connect existing wetlands. The constructed side channel would provide additional off-channel refuge and potential spawning habitat for native fish.

Large wood structures placed within subreach 2 would also help to maintain pools and provide hiding cover for adult and juvenile fish. In addition, large wood placed within the stream channel and on the floodplain would provide help to increase macroinvertebrate production through the collection and retention of organic detritus.

In subreach 3, wood placements between RM 13.2 and 13.3 would provide pool scour, complexity, and habitat cover for rearing juvenile salmonids as well as high flow refuge habitat for juveniles and adults. Wood placements would help to accomplish the wood loading objective. The meander bend logjam at the powerline corridor (RM 13.15) would: (1) reduce the lateral instability created by vegetation clearing, (2) create pool scour, complexity, and cover for salmonid rearing and holding, and (3) help to accomplish the wood loading target. Channel realignment at the bend at RM 13 would enhance channel margin habitat, riparian conditions, off-channel habitat availability, and would help to accomplish the wood loading targets.

In subreach 4, channel margin wood would be expected to enhance juvenile salmonid rearing cover and high flow refuge for juveniles and adults. Wood placements would be placed to not alter existing spawning areas within the subreach. Wood additions would also help to accomplish the wood quantity objectives. Off-channel habitat in subreach 4 would increase the availability of off-channel juvenile salmonid rearing habitat throughout the year and would also help to accomplish the off-channel habitat objective.

In subreach 5, logjams would enhance lateral channel dynamics and provide pool scour, complexity, and habitat cover for rearing juvenile salmonids. Jams would also provide high flow refuge habitat for juveniles and adults. Wood placements would help to accomplish the wood loading objective. Off-channel habitat in subreach 5 would increase the availability of off-channel juvenile salmonid rearing habitat throughout the year and would help to accomplish the off-channel habitat objective.

Level of Effort/Cost

Estimated costs are presented in table 8 for the preferred scenario. These costs are based upon the cost estimates generated for the individual project elements presented earlier in this report and in Appendix F. In some cases, costs have been further modified to account for alterations to the original restoration element or to account for cost savings achieved due to implementation of multiple combined elements.

Table 8. Estimated construction costs, by element, for the preferred scenario

Subreach	Preferred Scenario Element	Cost Estimate Range
1	None	$0
2	Levee removal and channel realignment (does not include powerline re-configuration)	$560,000 - $850,000
	Off-channel enhancement at RM 13.5 (right bank)	$32,000 - $1,000,000
3	Wood placements RM 13.2 - 13.3	$80,000 - $110,000
	Meander bend logjam at CPUD powerlines (RM 13.15)	$80,000 - $110,000
	Channel realign option 1 (except only at RM 13 bend – assumed 2/3 cost of element)	$270,000 - $410,000
4	Margin wood placement	$80,000 - $120,000
	Off-channel habitat creation (1 acre)	$110,000 - $160,000
5	Bar apex and meander bend logjams (3 jams)	$230,000 - $340,000
	Off-channel habitat creation and enhancement (3 acres)	$330,000 - $490,000
	Total Cost Estimate	$1,772,000 - $3,590,000

Scenario Options

Subreach 2 Option A – Levee breech at RM 13.6

This option would create a breech in the existing levee at RM 13.6. This scenario would only reconnect floodplain and wetland habitat during larger (greater than Q^{75}) peak flow events. This scenario would promote sediment deposition within subreach 2 and provide off channel habitat during larger flow events. Riparian conditions through subreach 2 would not be improved to the extent that water temperature would be expected to improve to State and Forest standards over time. This action would cost between $90,000 and $130,000 and could not be included with the preferred scenario due to the channel realignment elements involved.

Subreach 2 Option B – Channel rehabilitation within existing channel footprint with power line relocation

This option was described in detail starting on page 56.

Subreach 2 Option C – Full Channel Rehabilitation Outside of Existing Channel Footprint with Powerline Relocation

This option was described in detail starting on page 58.

Subreach 2 Option E- Instream Enhancement via Large Woody Debris and Boulder Placement

This option would use large woody material and boulder placement to provide in stream roughness and habitat in subreach 2. This would provide increased channel complexity and habitat for fish. However, the artificial levee in subreach 2 would remain, thus limiting the potential for off channel habitat creation, riparian improvement and sediment storage capability. Water temperature is not expected to improve under this option. Riparian growth would be limited by the rip rapped channel margins and sediment would still be transported downstream to subreach 3 and beyond. This option could be included with subreach 2 option A. All other subreach 2 options involve removing the levee and reconstructing the stream channel. Cost of this option ranges between $25,000 and $75,000.

Subreach 3 Option A - Channel Realignment at RM 12.8 Meander Bend

This option would add in channel realignment at the RM 12.8 meander bend as described as part of project element "Subreach 3 – Realignment Option 1." It is compatible with the preferred scenario and would simply be an added element. This was not included in the preferred scenario because habitat conditions here are less impaired and there may be significant impacts to existing vegetation to realign the channel. This option could be added into the preferred scenario depending on further analysis of impacts and/or could be accomplished as a follow-up phase of restoration once the effects of implementation at the upstream bend have been evaluated. This option would increase the overall cost by an estimated $140,000 to $200,000.

Subreach 3 Option B - Channel Realignment Option 2 (to 1949 location)

This option was not included in the preferred scenario due to concerns with construction impacts to existing vegetation, loss of habitat associated with the existing logjam at RM 12.9, and uncertainty with benefits beyond what could be accomplished under option A (realignment option 1). This option may be exercised pending additional hydraulic and geomorphic analysis. Substitution of this option for subreach 3 realignment option 1 would increase the overall cost by an estimated $90,000 - $130,000.

Subreach 4 Option A - Lateral Structures along U.S. Highway 2

This option was not included in the preferred scenario due to concerns with impacts to existing spawning grounds and costs versus habitat benefits. This option will be further evaluated with hydraulic, geomorphic, and fish use evaluations. This option would increase the overall cost by an estimated $290,000 to $440,000.

Elements Considered but Dropped from Further Analysis

The following elements were considered but dismissed due to concerns with feasibility, costs, uncertainty, or questionable benefit given potential construction-related impacts.

- Riparian restoration in subreaches 3 to 5, except as it would be associated with other projects and revegetation within the disturbance limits of those projects. Riparian work on the south side interior is believed to entail too much impact on existing vegetation. Riparian work along the highway embankment is believed to be too ineffective.
- Meander bend logjams along the left-bank at the bends at RM 12.45, 12.8, and 13, assuming no channel realignment were to occur. It was determined that the value that would be gained by simply adding wood to these armored banks would not be worth the effort and impact required for construction.

Table 9. Elements included within the preferred scenario, including scenario options,* by subreach

Scenario	Subreach				
	1	**2**	**3**	**4**	**5**
Preferred Scenario (Subreach 2 Option D)	None	• Channel raise and rehabilitation of cross-sections and pool-riffle-glide sequences (RM 13.85-13.65) – leave levee • Levee removal (13.65-13.3) and channel realignment (includes powerline reconfiguration) • Modify or install new culvert for off-channel enhancement at RM 13.5 (right bank)	• Wood placements RM 13.2 - 13.3 • Meander bend logjam at CPUD powerlines (RM 13.15) • Channel realign option 1 (except only at RM 13 bend)	• Margin wood placement • Off-channel habitat creation and enhancement	• Bar apex and meander bend logjams • Off-channel habitat creation and enhancement
Subreach 1 Option A	Instream enhancement via LWD placement				
Subreach 2 Option A		Levee breach near RM 13.6			
Subreach 2 Option B		Levee removal (13.85-13.3) with channel raise and rehabilitation of cross-sections and pool-riffle-glide sequences (no realignment - channel remains in existing corridor); and full relocation of powerlines.			
Subreach 2 Option C		Levee removal (13.85-13.3) with full stream channel realignment; full relocation of powerlines.			
Subreach 2 Option E		Instream enhancement via LWD and boulder placement			
Subreach 3 Option A			Channel realign at RM 12.8 meander bend		
Subreach 3 Option B			Channel realign option 2 (to 1949 location)		
Subreach 4 Option A				Lateral structures along U.S. Highway 2	

*Option 2C was dropped from further consideration

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Appendix A – Aerial Photos Used for Upper White Pine Analysis

Figure 59. Aerial photo of the Upper White Pine Reach taken in 1949

Figure 60. Aerial photo of the Upper White Pine Reach taken in 1962

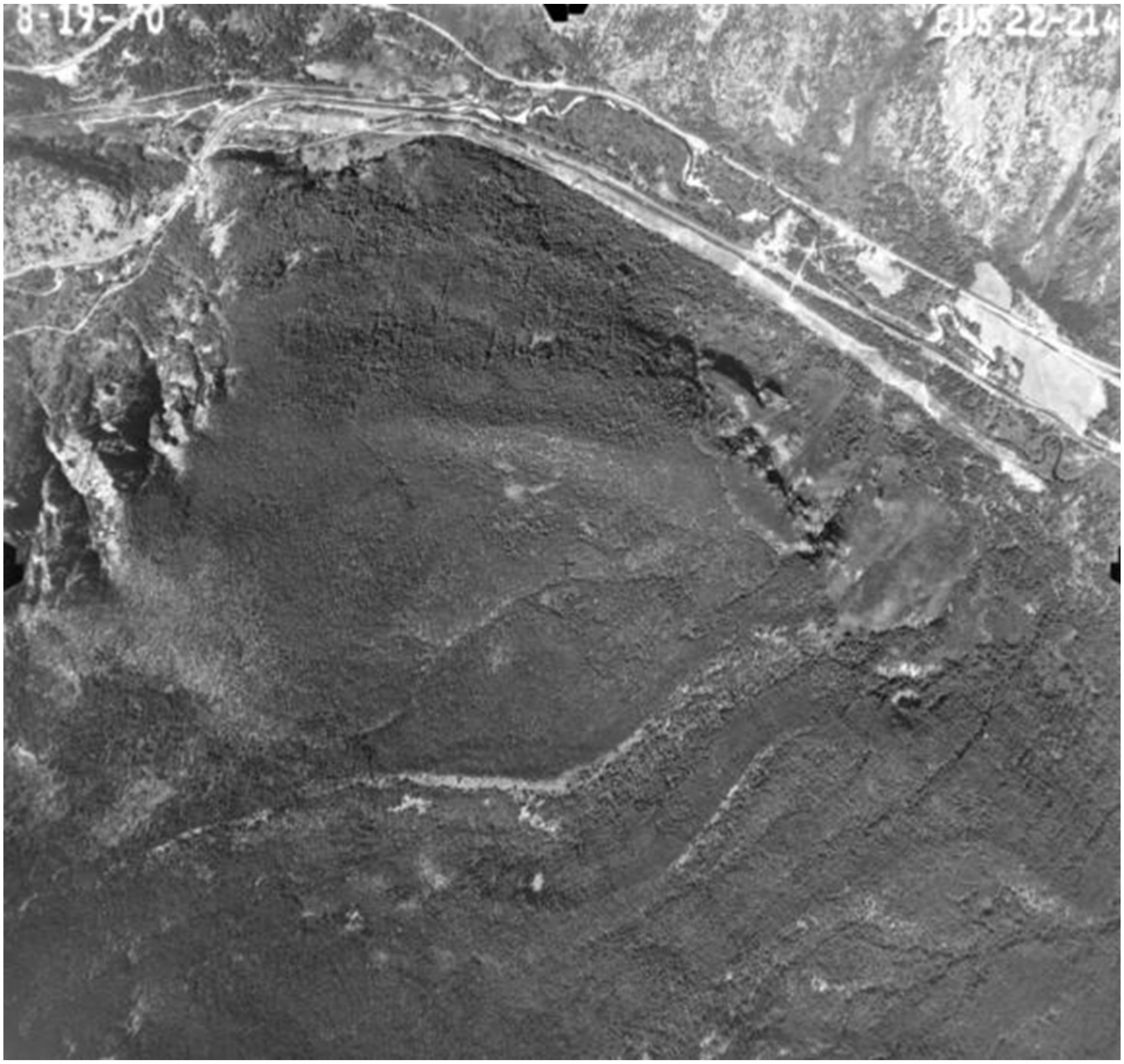

Figure 61. Aerial photo of the Upper White Pine Reach taken in 1970

Figure 62. Aerial photo of the Upper White Pine Reach taken in 1975

Figure 63. Aerial photo of the Upper White Pine Reach taken in 2006

APPENDIX B – UPPER WHITE PINE REACH RESTORATION PLAN-VEGETATION SURVEY

Upper White Pine Reach Restoration Plan, Vegetation Survey

Prepared By:
Melissa Lanza
TEAMS Enterprise Unit

I. Introduction

The U.S. Forest Service TEAMS Enterprise Unit (TEAMS) has entered into an agreement with the U.S. Bureau of Reclamation (USBR) to develop a Restoration Plan (Plan) for the Upper White Pine Reach of Nason Creek. The Upper White Pine Reach encompasses Nason Creek from RM 12.0 near Merritt, WA upstream to RM 14.3 at the White Pine Road Bridge.

A riparian vegetation survey was conducted within the Upper White Pine project area to characterize riparian vegetation within the five subreach areas and compare it to reference reach conditions, identify native plant species appropriate for use in restoration of stream channels in the region, and provide recommendations for restoration of riparian vegetation within the entire project area.

II. Survey Methods

Methods used to survey project areas were adapted to specific characteristics of each subreach area. Methods used include; Peet et al. methodology, a polygon methodology and a general grid methodology. The Peet et al. methodology establishes a 50m transect with up to 5, 10m x 10m² plots surveyed along the transect. This methodology is appropriate for most types of vegetation, flexible in intensity and time commitment, is compatible with other data types from other methods, and provides information on species across spatial scales (Peet et al. 1998). Four of the five subreach areas were surveyed using the most appropriate method for each area. Because of private property access issues and similarities between the vegetation structure of subreach area 4 and subreach area 5 a survey was not conducted in subreach area 5.

III. Riparian Vegetation Description

Subreach Area 1

Subreach area 1 has been impacted by the construction of the railroad crossing and apparent channelization / stream diversion resulting from the construction of the rail corridor. A Peet et al. methodology was used to survey this area for a total area surveyed of 1000m². A plot was established on the left bank terrace of Nason Creek within the flood plain. The survey was conducted 2 m from the active stream channel. A dense canopy is present shading out most understory herbaceous and shrub species. Large conifers line the bank and are scattered throughout the terrace. There is little diversity of species and little presence of invasive species along the riverbanks. Invasive species are present along Upper White Pine Road, which runs adjacent to subreach area 1. Trees found in the survey area include, in order of abundance; *Acer circinatum* (vine maple), *Populus balsamifera* ssp. *Trichocarpa* (black cottonwood), *Pseudostuga mensizii* (Douglas-fir), *Abies grandis* (grand fir), and *Thuja Plicata* (western red cedar). Black Cottonwood was the most abundant tree representing 25-50 percent vegetation cover with Vine maple, Douglas fir, Grand fir and Western red cedar following. Size class structure was 21 percent seedling/sapling (0-15 cm), 21 percent pole (15-30 cm), 39 percent small trees (31-41 cm), and 18 percent large trees (<41 cm).

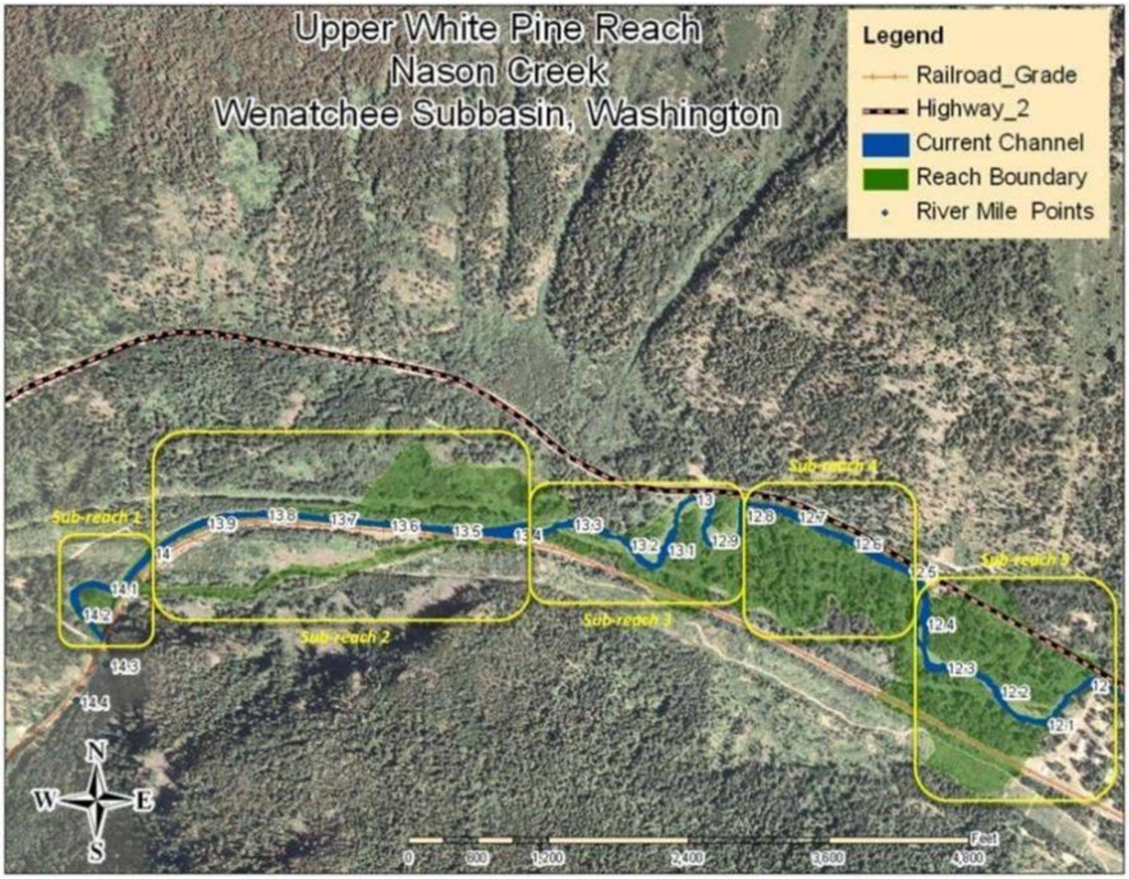

Figure 1. Map showing the breakdown of subreach areas within the Upper White Pine Reach of Nason Creek RM 12.0-14.3

Subreach Area 2

Subreach area 2 encompasses the Upper White Pine Reach from RM 14.0 downstream to RM 13.4. Three surveys were conducted in this area; a survey in a wetland complex, a survey on the berm along the left bank of Nason that protects the powerlines and the railroad corridor, and a survey underneath the powerlines.

Wetland Complex, Plot A

The wetlandcomplex provides important habitat for both aquatic and terrestrial wildlife. A species list was compiled using a polygon grid survey within an area of significant vegetation cover for a total area surveyed of 2,745m². The survey was conducted in the corner of the large disconnected zone, upstream from where the wetland empties into Nason Creek. Large cottonwoods stand between Nason Ck. and the wetland area. Larger conifers are present further upland from the creek on the edge of the wetland. This area had the highest diversity present in any single plot with 54 species recorded. Trees present in the plot include: black cottonwood, vine maple, alder, grand fir, and *Salix sp.* (willow). Invasive species recorded in the plot are the common tansy, oxeye daisy, and curly dock; all in relatively low abundance. This area had the highest concentration of sedges and grasses of any plot surveyed.

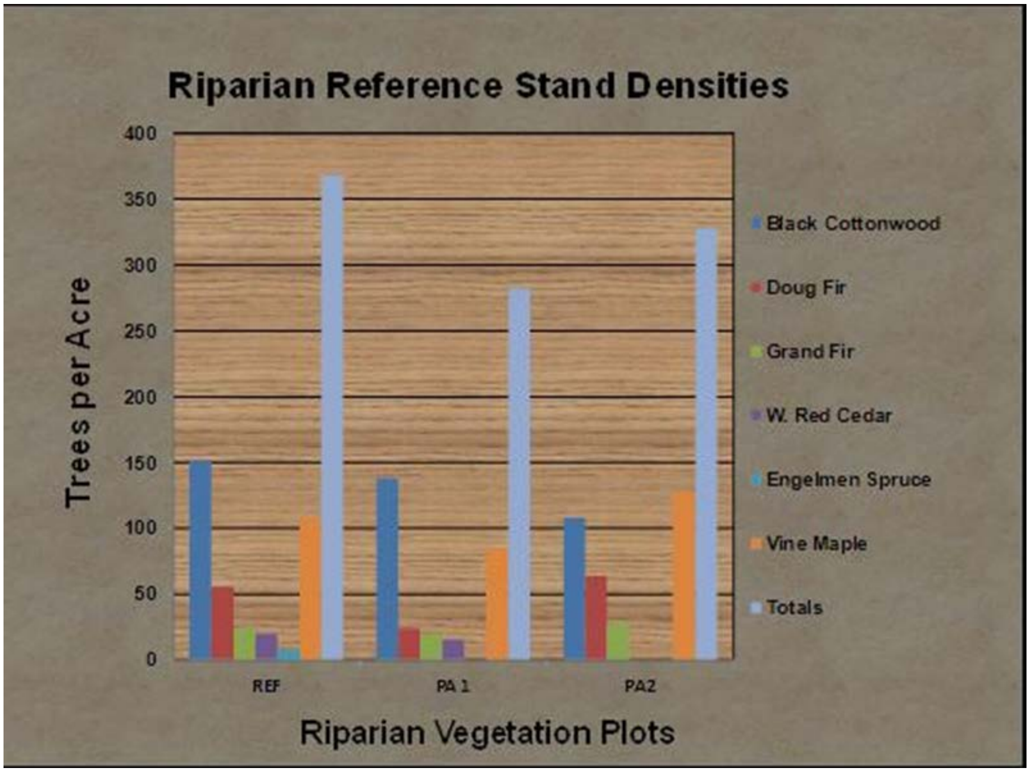

Figure 2. Vegetation densities of the reference area (REF), subreach area 1 (PA1), and subreach area 2(PA2) on the berm

Berm, Plot B

The section of channel where the berm is located was constructed to protect the railroad infrastructure to the south. The banks of the creek are rip-rapped and a berm/dike exists on both sides of the Nason Creek channel. Large shady conifers grow on top of the berm and provide good in-stream shade. A Peet et al. plot was established on top of the berm and all species within the plots were recorded for a total area surveyed of 1,000m². Trees present include; Black cottonwood, Douglas-fir, grand fir, vine maple, *cornus sericea* ssp. *sericea* (redosier dogwood), and *Acer glabrum* (Rocky Mountain maple). The most abundant tree species was vine maple with 128 trees per acre in this project subreach, followed closely by black cottonwood with 108 trees per acre, Douglas-fir with 64 and grand fir with 28. Species size class structure was made up of 33 percent seedling/sapling size (0-15cm), 18 percent pole (15-30cm), 33 percent small trees (31-41cm), and 16 percent large trees (<41cm).

Powerlines, Plot C

Due to alternatives A and B in the Upper White Pine Draft Alternatives Report we were interested in the current species composition of this area. Alternatives A and B propose to relocate the PUD lines to restore the creek to historic sinuosity and connect to the existing wetland complex. By order of a Federal powerline regulatory agency no trees or shrubs can grow within 30 feet of any PUD line or severe fines are imposed. A general species list was compiled in the area below power pole 52/9. Trees include; *Populus tremuloides* (Aspen), vine maple, *Crataegus douglasii* (hawthorne), *cornus sericea* ssp. *sericea.* Shrubs include; *Symphoricarpos Albus* (Snowberry), *Spirea douglasii* (Spirea), *and Rubus parviflorus* (Thimbleberry). There was zero presence of large conifers under the powerlines due to the restrictions on the height of plants in place.

Subreach Area 3

Subreach area 3 encompasses the Upper White Pine Reach from RM 13.4 downstream to RM 12.8. The survey was conducted on the left bank of Nason Creek on the terraced flood plain. The area went from terraced at the far end of the survey to a lower terrace at the bend in the river and exhibited severe bank erosion. A polygon/grid methodology was used for a total area surveyed of 2,400m². Old mining equipment was discovered in the survey area and this area was found to have the highest concentration of invasive species found in any survey area. Conifers present showed mature growth and were abundant. Overall the area lacked much species diversity or complexity. Trees present include; cottonwood, *g*rand fir, *pinus ponderosa* (ponderosa pine), Doulas-fir, Rocky Mountain maple, Redosier dogwood, *acer macrophylum* (Big leaf maple), *v*ine maple. Invasive species found include; *Centaurea maculosa* (spotted knapweed) , *Tanaecetum vulgare* (tansy), *Verbascum Thapsus* (mullein), *Leucanthemum vulgare* (oxeye daisy), *Arctium lappa* (greater burdock), and *Hypericum perforatum* (St. Johns wort).

Subreach Area 4

Subreach area 4 encompasses the Upper White Pine Reach from RM 12.8 downstream to RM 12.5. Subreach area 4 is located along the road fill for U.S. Highway 2. The highway right of way has impacted riparian vegetation and large wood recruitment on the north bank of the project area. The survey was conducted downstream from the sharp bend in the creek where the stream begins to flow directly adjacent the highway. This stretch of Nason has been channelized and rip-rap lines the left bank of the creek protecting the highway. The survey was conducted on a terrace and there was little to no access to the floodplain by the creek. No large conifers were present in our survey plot only a very small Grand Fir was discovered and one very large old cottonwood. A general polygon/grid survey was conducted for a total area surveyed1443m². Trees present include; cottonwood, grand fir, vine maple, Rocky Mountain maple, redosier dogwood), and hawthorne.

Subreach Area 5

Subreach area 5 encompasses the Upper White Pine Reach from RM 12.5 downstream to the reach end at RM 12.0. Subreach area 5 starts where the channel leaves the U.S. Highway 2 road fill and ends just upstream of the bridge at Merritt. The channel geometry, floodplain connectivity and riparian conditions within this project area are qualitatively in good shape and appear to be functioning and recovering from past perturbations well. However, there is a lack of large wood and channel roughness as a result of the U.S. Highway 2 fill slope impact on riparian vegetation. A survey was not conducted in the subreach 5 area due to similarities in vegetation structure to Subreach area 4 and private property access issues at the time of the survey.

Historic Remnant Channel

A survey was completed in the abandoned historic channel of Nason Creek that was relocated years ago to protect the railroad corridor. Many of the same tree species were present in this area as other project areas. Invasive species in this area were very high in abundance. A general species list was compiled in the area and can be found in the Table and Appendices section of this report.

Reference Reach

A reference reach was surveyed to try and capture a stable vegetation community that the project areas could be compared with. The reference reach was located upstream of the project area on Nason Creek approximately 140 yards downstream from the confluence of Nason and White Pine

Creek. A polygon grid methodology was employed to survey the reference reach for a total area surveyed of just over 1000 m². The area exhibited a very diverse floodplain community with large mature trees species. Fire scars were found on large woody debris (LWD) in the survey area. The flood plain exhibited many remnant side channels with large cobble covered in a thick spongy moss. The banks contained both fine and coarse sediments. LWD occurred within the floodplain as well as in the remnant channels further up on the floodplain. By far this area exhibited the most diverse vegetation community of any area surveyed. Trees found in the plot include; *Populus balsamifera* (cottonwood), *abies grandis* (grand fir), *Pseudotsuga menziesii* (Douglas-fir), *Thuja picata* (red cedar), *Picea engelmanii* (Engelmann spruce), *Acer circinatum* (vine maple), *cornus sericea ssp. sericea* (redosier dogwood), *Alnus incana* (alder), and *Salix sp*.(willow). Cottonwood accounted for 25-50 percent of cover in the survey plot. Grand fir, Douglas-fir, and western red cedar covered roughly 2-5 percent of plot area and Alder covered 25-50 percent of the plot area. Willow was found to cover 1-3 percent and dogwood and vine maple covered 5-25 percent. Species size class structure was made up of 37 percent seedling/sapling (0-15cm), 22 percent pole (15-30cm), 16 percent small trees (31-41cm), and 24 percent large trees (<41cm).

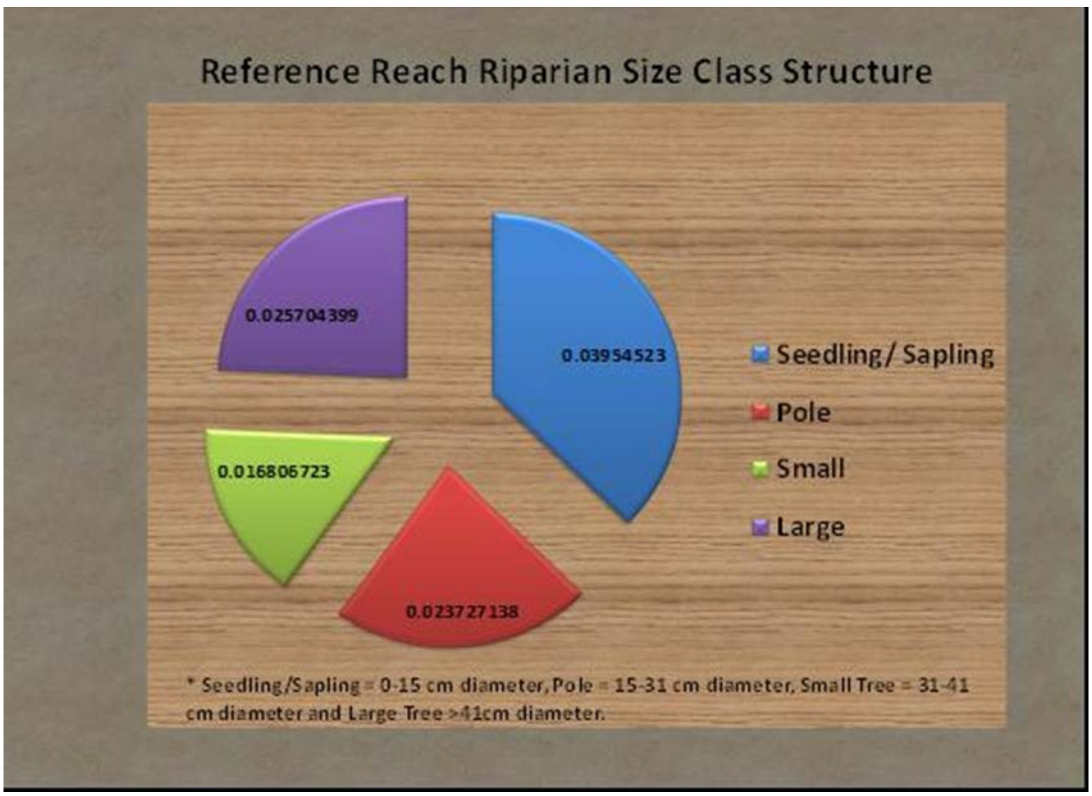

Figure 3. Size class structure in the reference reach survey area, Nason Creek Vegetation Survey, WA.

IV. Comparison of Project Reach and Reference Reach Conditions Diversity

Vegetation within the project areas has been heavily altered due to past disturbances and diversity of the vegetation is limited due to these disturbances. Based on the data collected there is a greater diversity of species in the reference reach compared to any of the project areas. Over 30 native plant species were found within the reference reach while the greatest native plant composition in any of the project areas was only 22. Invasive species presence was highest in Subreach Area 3 with six invasive species present while only two were found in the reference area. Nine different tree species were found in the reference reach while at most only 6 were found in any one of the project areas. LWD found within the reference plot totaled 7. However, no LWD was present in any of the four project areas surveyed. The lack of LWD in the project area is a direct result of the disturbances that have occurred on Nason Creek. Channelization through the creation of berms and dikes along the stream corridor to protect powerlines and the railroad has impeded the growth and reestablishment of conifers and in effect LWD recruitment. This occurs mainly as a result of the lack of floodplain connectivity within this portion of the stream channel and the terracing of banks that inhibit recruitment and establishment of riparian vegetation.

V. Planting Prescriptions

Non-Native and Invasive Species Management and Eradication

Invasive plant species are described as characteristically adaptable, aggressive, and have a high reproductive capacity (Invasive Species Information Center.org) An invasive species is a non-native species whose introduction does or is likely to cause economic or environmental harm or harm to human, animal, or plant health (ISIC.org). The presence and abundance of non-native/invasive species poses a challenge to any restoration re-vegetation effort. Before planting begins at the project site it is critical to begin the process of eradicating weeds that are established on site. The success of the restoration of the site depends on it. Spotted knapweed , oxeye daisy, and common tansy are present in some project areas. Invasive species presence in project areas is surprisingly low; however there are areas of high concentration of invasive species. These areas include the old remnant channel, the area underneath the 52/9 PUD powerlines, and parts of Subreach area 3. The low level of invasive species colonization in project areas will ensure eradication is not a terribly difficult task but still a topic any riparian vegetation restoration project will need to consider.

Planting

By identifying restoration objectives first it becomes easier to select appropriate plant species to fill the desired ecological functions of a project. Managers need to consider the characteristics of the site such as, soil drainage, elevation, disturbance patterns, and weeds that may compete with newly planted vegetation. Once restoration projects have been decided upon, a more comprehensive planting scheme may be developed according to the location of structures and new bankfull and flood prone elevations.

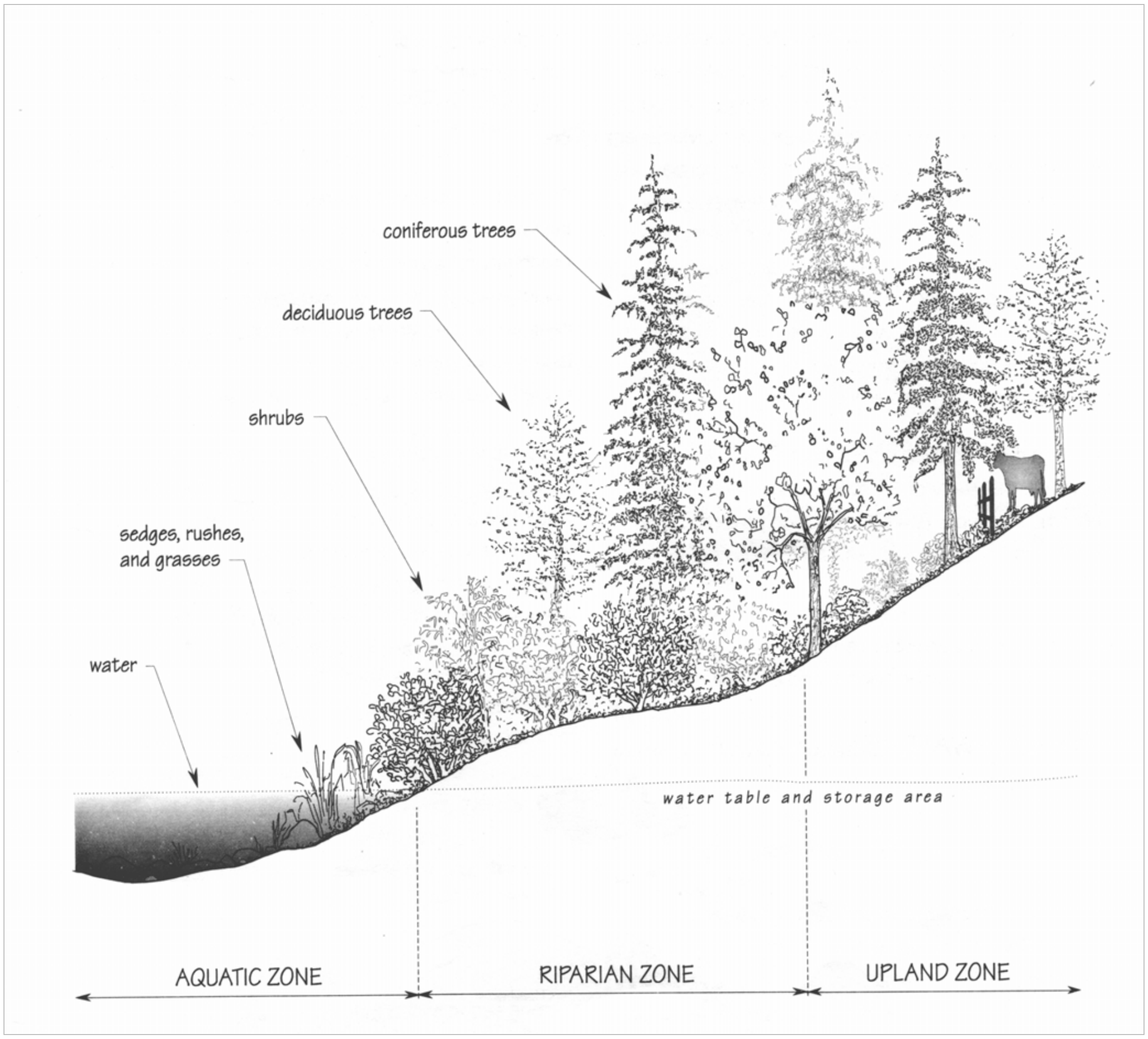

Figure 4. Planting zones in a riparian vegetation community (source: Streamside Planting Guide for Western Washington)

Plants should be chosen that are tolerant of specific site conditions such as shade, drought in summer months, and flood frequency.

Streamside riparian shrubs should be planted with spacing of 4 feet by 4 feet with upland plants spaced 6 feet by 6 feet. Shrubs and riparian tree species should be planted in the streamside riparian zone. Conifers should be planted in the upland to avoid mortality from high flows.

Plant Sources

Plants used for the project should be selected based on the geographic region and from local native sources as close to the project site as possible. Species that are well adapted to the sites should be chosen. Local containerized and bare root stock should be used when possible as these types of plantings may have a higher success rate. Local biotypes are better adapted to site conditions and have a better vigor and hardiness (Witthrow-Robinson et al. no date). This helps plants compete better with non-native and invasive species. Seed collecting within the project reach can be cost effective and ensure local stock but can be very time consuming. Cuttings of local willow and cottonwood can also be used. Follow instructions for propagating native plants from cuttings listed in the reference section. Some local native plants that can be started from cuttings include: cottonwoods, willow, dogwoods, and snowberry. Cuttings should be done in the spring or fall and live stakes should be planted as early as possible in the winter for the best chance of survival. See Table 1 for a list of possible appropriate species.

Number of Plants

The number of plants needed depends on many factors. Before the exact number of plants can be decided a clear design scheme must be developed showing the location of in-stream structures and future physical habitat of the creek after restoration. Mortality of plantings is possible in any revegetation project. To account for this possibility, at times more than one tree can be placed in the same area and a higher total number of plants can be used to ensure planting success. Many shrub species will establish rapidly and this will help to reduce the number of extra plantings necessary and shade out weeds. When plants are planted away from the creek or above the water table supplemental watering may be needed and this should be considered in the design.

Distribution of Plantings

See Table 1 and Streamside Planting Guide for Western Washington in the reference section that provides pertinent information on the design, selection, planting, and maintenance of trees in riparian areas. Spacing of plantings is important. Bennett and Ahrens (2007) suggest using an upland planting scheme of 10 x 10 or 12 x 12 in riparian areas. Closer spacing can be used to ensure more rapid dominance of planted trees over other vegetation. Shrubs can be planted much closer to one another than trees (Bennett and Ahrens 2007). See listed references for more guidelines on tree distribution and spacing.

VI. Conclusion

Implementation and effectiveness monitoring will be important to determine success of weed control, restoration plantings, and bank stabilization techniques. Through riparian plantings we can enhance existing riparian habitat, which is the key to restoring natural stream functions and aquatic habitats. The benefits to salmon recovery efforts are increased riparian habitat, channel stabilization, improved water quality, increased stream shading, which reduces water temperatures, improved wildlife and fish populations and improved aesthetics. Planting riparian areas prevents erosion and the undercutting of banks and slows water runoff from the spring melt and seasonal weather events.

Tables and Appendices

Table 1. Tree and shrub species chart detailing species, method of propagation, habitat value, form and size, rooting regime, and culture (Streamside Planting Guide for Western Washington)

Tree Species	Propagation Method	Habitat Value	Form & Size	Rooting	Culture
Bigleaf Maple *Acer macropyllum*	Seedling	squirrels, finches, and evening grosbeaks eat the seeds	trees to 100 feet	shallow roots	moist, dry soil, sun-part shade
Black Cottonwood *Populus trichocarpa*	cuttings	eagles and osprey perch and nest in branches	trees to 80 feet	shallow, fibrous roots	wet-moist soil; sun
Douglas-fir *Pseudotsuga menziesii*	seedling	black bears eat sap of young trees	trees to 340 feet	shallow roots	moist-dry soil; sun
Red Alder *Alnus rubra*	Seedling; cuttings, suckers	birds eat seeds	trees up to 80 feet	shallow, strong, lateral roots	moist-dry soil; sun-shade
Western Hemlock *Tsuga heterophylla*	Seedling	deer browse foliage	Trees from 100–160 feet	shallow roots	moist soil; shade
Western Red cedar *Thuja plicata*	seedling	raccoons and skunks den in cavities made by root buttresses	Trees from 150–200 feet	shallow roots	moist-wet soil; shade
Shrub Species					
Black Twinberry *Lonicera involucrata*	cuttings	many species of wildlife eat the berries	spreading shrub to 10 feet	shallow, spreading roots	wet-moist soil; shade
Douglas spirea *Spiraea douglasii*	divisions; root cuttings, cuttings	birds and small mammals use for cover	dense shrub to 7 feet	extensive fibrous roots	wet sites, sun or shade
Indian Plum *Oemleria cerasiformis*	seed; cuttings	many wildlife species eat the fruit	sparse shrubs to 15 feet	shallow, spreading roots	moist dry soil; sunshade
Red Elderberry *Sambucus racemosa*	cuttings from 2nd year wood; root cuttings; seed	many bird species eat the berries and use branches for cover	shrub to 20 feet	fibrous. strong adventitious roots	moist-dry soil, sun-shade
Red-Osier Dogwood *Cornus stolonifera*	cuttings; layers	many birds eat the berries	shrub to 20 feet	spreads by shallow, strong rootstocks	wet-well drained soil, sun shade
Salmonberry *Rubus spectabilis*	cuttings, rooted cuttings	many bird species eat the berries	ground cover and shrubs to 10 feet shallow, fibrous, trailing branches	set roots	wet-dry soil; sun-shade
Serviceberry *Amelanchier alnifolia*	suckers; seedlings	many bird species eat the berries	shrub or small tree to 30 feet	deep, spreading roots	well drained dry soil, sun

Tree Species	Propagation Method	Habitat Value	Form & Size	Rooting	Culture
Sitka Alder *Alnus sinuata*	seedlings, cuttings	goldfinches eat the berries	shrub to 25 feet	shallow, extensive roots	moist soil; sun
Snowberry *Symphoricarpos albus*	suckers; cuttings	dense cover for birds and rodents dense shrub to 3 feet;	extensive branching,	fibrous roots;	moist-well drained soil; sun-shade
Tall Oregon Grape *Berberis aquifolium*	cuttings; layers	deer browse foliage	shrub to 7 feet	deep roots	well drained soil, sun-shade
Wild Rose *Rosa nutkana*	stem cuttings, root cuttings	provides good nest sites and food for birds	sparse to dense shrub to 4 feet	poor for erosion control	dry-moist soil; sun-partial shade
Willows *Salix* spp.	cuttings	rabbits and deer eat twigs, birds use for cover	shrubs or trees to 40 feet	shallow, extensive roots	moist-wet soils, sun

Table 2: Subreach Area 1 Species Lists

Scientific Name	Common Name
Thuja plicata	Western red cedar.
Abies grandis	Grand fir
Populous balsamifira ssp. *trichocarpa*	Black cottonwood
Acer circinatum	Vine maple
Psedotsuga menziesii	Douglas fir
Pachistima myrsinites	Mountain lover
Maianthemum racemosa (smilacina)	Treacleberry
Maianthemum stellata	Starry false lily of the valley
Clintonia uniflora	Brides bonnet
Cornus sericea ssp *sericea*	Redosier dogwood
Trillium ovatum	Pacific trillium
Oplopanax horridum	Devils club
Rubus parviflorus	Thimbleberry
Species outside of plot	
Pinus ponderosa	Ponderosa Pine
As arum caudatum	Ginger
Sambucus racemosa	Red elderberry
Acer glabrum	Rocky mountain maple
Arceuthobrum douglasii	Douglas fir-dwarf mistletoe
Athyrium filix femina	Ladyfern
Pteridium aquilinum	Bracken fern
Viola glabella	Pioneer violet
Chimaphita menziesii	Little princes pine
Gallium triflorum	Ribes

Scientific Name	Common Name
Epilobium angustifolium	Fireweed
Rubus spectabilis	Salmonberry

Table 3. Subreach Area 2; Wetland Complex, Plot A

Scientific Name	Common Name
Abies grandis	Grand fir
Populus balsamifera	Cottonwood
Cornus sericea ssp. *sericea*	Dogwood
Crataegus douglasii	Hawthorne
Alnus	Alder
Acer Circinatum	Vine Maple
Salix sp.	Willow
Epilobium glaberrimum	Willowherb
Lycopus asper	Rough bugleweed
Gallium	Sweet woodruff
Athyrium filix-femina	Common lady-fern
Lonicera involucrate	Twinberry honeysuckle
Spirea douglasii	Rose spirea
Soladego Canadensis	Goldenrod
Piperia greeni	Bog orchid
Lysichitom americanum	Yellow skunk cabbage
Leucanthemum vulgare	Oxeye daisy
Tanaecetum vulgare	Tansy
Rubus parvifloris	Thimbleberry
Maianthemum stellata	Starry false lily of the valley
Symphoriocarpos albus	Snowberry
Rubus Idaeus	Red raspberry
Lathyrus sp.	Field pea
Thalictrum occidentale	Meadow rue
Heracleum lanatum	Cow parsnip
Trifolium sp.	Clover
Anaphalis margaritacea	Western pearly everlasting
Osmorhiza chilensis	Sweet cicely
Maianthemum racemose (smilacina)	Treacleberry
Equisitium sp.	Horsetail
Aruncus Sylvester	Goats beard
Amelanchier	Serviceberry
Stachys cooleyae	Cooleys hedgenettle
Rosa nutkana	Wild rose
Achillea millefolium	Yarrow
Plantago lanceolata	Narrowleaf plantain
Scirpus macrocarpus	Panicled bulrush

Scientific Name	Common Name
Phleum pretense	Timothy grass
Dactylis glomerata	Orchardgrass
Agrostis ssp.	Bentgrass
Pteridium aquilinum	Bracken fern
(Disporum) prosartes hookeri	Hookers fairy bells
Rumex crispus	Curly dock
Silene noctiflora	Nightflowering silene
Mimulus moschatus	Muskflower
Juncus effusis	Common rush
Phalaris arundinaceae	Reed canarygrass
Glyceria grandis	American mannagrass
Carex stipata	Awlfruit sedge
Puccinellia pauciflora	Pale false mannagrass
Carex vesicaria	Blister sedge
Carex retrorsa	Knotsheath sedge

Table 4. Subreach Area 2; Berm, Plot B

Scientific Name	Common Name
Psedotsuga menziesii	Douglas fir
Populous balsamifera ssp trichocarpa	Black cottonwood
Abies grandis	Grand fir
Pinus monticola	White pine
Acer circinatum	Vine maple
Acer glabrum	Rocky mountain maple
Amelanchier arnifolia	Serviceberry
Cornus sericea ssp *sericea*	Redosier dogwood
Symphoricarpus albus	Common snowberry
Rubus parviflorus	Thimbleberry
Spirea douglasii	Western spirea
Sambucus racemosa	Red elderberry
Maianthemum stellata	Star flowered
Mahonia nervosa	Dwarf Oregon grape
Penstemon serrulatus	Cascade penstemon
Osmorhiza chilensis	Sweetcicely
Solidago Canadensis	Goldenrod
Maianthemum racemosa (smilacina)	Traecleberry
Gallium triflorum	Fragrant bedstraw
Lathyrus sp.	Field pea
Heracleum lanatum	Cow parsnip

Table 5. Subreach Area 2; Powerlines, Plot C

Scientific Name	Common Name
Populous tremuloides	Quacking Aspen
Acer circinatum	Vine maple
Crataegus douglasii	Hawthorne
Symphoricarpus Albus	Common snowberry
Spirea douglasii	Western spirea
Rubus parviflorus	Thimbleberry
Stachys cooleyae	Cooleys hedgenettle
Heracleum lanatum	Cow parsnip
Solidago Canadensis	Goldenrod
Aster sp.	Aster
Maianthemum stellata	Starry false lily of the valley
Osmorhiza chilensis	Sweetcicely
Athyrium filix-femina	Common lady-fern
Rubus leucodermis	Blackcap raspberry
Gallium triflorum	Fragrant bedstraw
Viola glabella	Yellow wood violet
Sorbus scopulina	Greene's mountain ash
Leucanthemum vulgare	Oxeye daisy
Lathyrus	Pea sp.
Species on Fringe	
Cornus sericea ssp. *sericea*	Redosier dogwood
Psedotsuga menziesii	Douglas fir
Populous balsamifera	Cottonwood
Cornus sericea	Redosier dogwood
Abies grandis	Grand fir

Table 6. Subreach Area 3

Scientific Name	Common Name
Populous balsamifera	Cottonwood
Acer glabrum	Douglas maple
Cornus sericea	Redosier dogwood
Pinus ponderosa	Ponderosa pine
Acer macrophylum	Big leaf maple
Abies grandis	Grand Fir
Acer circinatum	Vine maple
Pseudotsuga mensizzi	Douglas fir
Symphoriocarpus albus	Snowberry
Centaurea maculosa	Spotted knapweed
Tanaecetum vulgare	Tansy

Scientific Name	Common Name
Verbascum thapsus	Mullein
Leucanthemum vulgare	Oxeye daisy
Mainanthemum stellata	Starry false lily of the valley
Rubus parviflorus	Thimbleberry
Mananthem racemosa smilicina	Traecleberry
Sambucus racemosa	Red elderberry
Arctium lappa	Greater burdock
Osmorhiza chilensis	Sweetcicely
Penstemon serrulatus	Cascade penstemon
Rubus ursinus	California blackberry
Hypericum perforatum	St. Johns Wort
Phacelia hastate	Silverleaf phacelia
Trillium ovatum	Pacific triflorum
Rubus leucodermus	Blackcap raspberry

Table 7. Subreach Area 4

Scientific Name	Common Name
Populus balsamifira	Cottonwood
Acer circinata	Vine maple
Acer glaburlum	Douglas maple
Cornus sericea	Redosier dogwood
Crataegus douglasii	Hawthorne
Abies grandis	Grand fir
Pachistima myrsinites	Boxwood
Mahonia nervosa	Oregon grape
Mahonia aqquifolium	Cascade Oregon grape
Mianthemum racemosa smilicina	False Salmon Seal
Mianthemum stellata	False star flower
Silene menziesii	Menzie's campion
Disporum hookeri	Fairy bell's
Rubus ursinus	California blackberry
Viola glabella	Yellow wood violet
Gallium triflorum	Fragrant bedstraw
Symphoricarpus albus	Snowberry
Polystichum munitum	Western swordfern
Heracleum lanatum	Cow parsnip
Stachys cooleyae	Cooleys hedgenettle
Osmorizha chilensis	Sweetcicely
Dicentra Formosa	

Table 8. Reference reach

Scientific Name	Common Name
Populous balsamifera	Cottonwood
Abies grandis	Grand fir
Pseudotsuga mensizzi	Douglas fir
Thuja Picata	
Picea englemanii	Engelmann spruce
Tsuga heterophylla	Western hemlock
Acer circinatum	Vine maple
Cornus sericea ssp sericea	Redosier dogwood
Alnus incana	Gray alder
Salix sp.	Willow
Rubus parviflorus	Thimbleberry
Ribes viscosissimum	Sticky currant
Pachistima myrsinites	Boxwood
Lonicera involucrate	Twinberry honeysuckle
Sambucus racemosa	Red elderberry
Maianthemum stellata	Starry false lily of the valley
Mertensia paniculata	Tall bluebells
Chimaphila menziesii	Little prince's pine
(pyrola) Orthilia secunda	Sidebells wintergreen
Thalictrum occidentale	Western meadowrue
Osmorhiza chilensis	Sweetcicely
Pyrola asarifolia	Bog wintergreen
Holodiscus discolor	Ocean spray
Equisetum sp.	Horsetail
Maianthemum racemosa	Feathery false lily of the valley
Epilobium angustifolium	Fireweed
Tanaecetum vulgare	Tansy
Leucanthemum vulgare	Oxeye daisy
Prunella vulgaris	Heal all
Anaphalis margaritacea	Western pearly everlasting
Hieracium	Hawkweed
Acer glabrum	Rocky mountain maple

Table 9. Old historic channel area; species list

Scientific Name	**Common Name**
Populus balsamifera	Cottonwood
Salix sp.	Willow
Abies grandis	Grand fir
Pseudotsuga mensizii	Douglas fir
Cornus serecea	Redosier dogwood
Lonicera invulocrata	Twinberry honeysuckle
Alnus incana	Speckled alder
Epilobium	Fireweed
Pachistima myrsinitis	Mountain lover
Rubus ersinus	California blackberry
Thalictrum occidentalis	Western meadow-rue
Mertensia paniculata	Tall lungwort
Maianthemum stellata	Starry false lily of the valley
Rubus parviflorus	Thimbleberry
Spirea douglasii	Spirea
Stachys coolege	Cooleys hedgenettle
Acer macrophyllum	Big leaf maple
Alnus rubra	Red alder
Centaurea maculate	Spotted knapweed
Hypericum perforatum	St Johns wort
Leucanthimum	Ox-eye daisy
Cirsium arvensis	Canada thistle
Verbascum thapsis	Mullein
Soledago Canadensis	Golden rod
Achilea milifolium	Yarrow

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APPENDIX C – WETLAND DETERMINATION AND CLASSIFICATION AT UPPER WHITE PINE

Memo

To: Upper White Pine Project File

From: Jennifer Goodridge, CCNRD

Date: 9/4/2012

Re: Wetland Determination and Classification at Upper White Pine

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This technical memorandum summarizes the wetland determination for Upper White Pine site which is located near Merritt in Chelan County. The wetland is located south of Upper White Pine road and Hwy 2 and north of Nason Creek near RM 13.4. The purpose of this wetland determination is to identify the approximate wetland boundaries, acreage, habitat types, and classification to aid with the planning and design of the Upper White Pine stream habitat restoration project.

The following maps were reviewed prior to the site visit (see attached): Figure 1 Vicinity map, Figure 2 Lidar, Figure 3 County Soil survey, and Figure 4 National wetland inventory (NWI). The County soil survey maps hydric soils (aequic fluvaquents) throughout most of the study area. There is a small amount of Saska stony sandy loam towards Upper White Pine. The tributaries flow into the wetland through steep slopes (30-75%) consisting of the entic haplumbrepts soils. The NWI map indicates that there is a palustrine scrub shrub wetland in the vicinity of the project area. However, the polygon appears to be shifted over and undersized compared to the actual wetland on site; this is not uncommon since the NWI maps were generated from aerial photo interpretation and digitized without ground truthing.

CCNRD staff Matt Shales and Jennifer Goodridge conducted a site visit to verify map findings on July 11, 2012. Figure 5 depicts the approximate wetland boundaries, location of tributaries and Nason creek within the study area. Data plots 1 - 4 document the site conditions. The northern and eastern wetland boundary are somewhat defined by site topography. There is a wetland mosaic along the southern boundary under the CPUD lines that was not mapped in detail as part of this wetland determination.

Hydrology sources to this wetland include surface and groundwater flows from the slopes to the north. It also appears that water holds in this wetland due to the series of beaver dams at the downstream end of the wetland. There is also a berm located on the south side of the wetland between the wetland and Nason Creek. This berm also appears to have an effect on wetland hydrology. There are 1 – 2 channels through the berm that provide a hydrologic connection between the wetland and Nason Creek during high water levels, Nason Creek is hydrologically connected to the wetland at elevations above the level of the beaver dams during spring to early summer high flows.

There are five perennial tributaries that flow into the wetland and their location is noted on Figure 5. Tributary flows and temperature have been collected twice a month by CCNRD staff from June 6, 2012 through August 30, 2012 using a Sontek flow tracker ADV and mid-section method. Flows in tributary 3 were too low to use this device so they have been measured using the float method. Table 1 provides additional information about each tributary.

Low flows in Nason Creek (late August) are typically around 50 - 60 cfs (based upon data collected at the Merritt bridge for the Lower White Pine project in 2010 and 2012 and based upon the WADOE gauge ID 45J070 Nason Creek near the mouth). Therefore, during low flow periods, these tributaries contribute approximately 5-6% of the flows to Nason Creek. Temperature measurements in the wetland generally track the temperature of the tributaries. The temperature in Nason Creek was 10.8° on August 30, 2012 and the typical range for temperatures in mainstem Nason Creek ranges from 9-14° (based upon the two sources listed above). Thus, the tributaries and wetland appear to have the potential to provide cold water refugia during the summer low flow period.

Table1. Temperature and flow data in tributaries to Nason Creek

Tributary #	Temperature range* (C)	2012 maximum flow recorded* (cfs)	2012 minimum flow recorded to date* (cfs)
1	6.8 – 9.2	2.41	1.53
2	6.3 – 9.1	1.26	.41
3	Not recorded	.2	.1
4	6.6 – 8.7	.48	.28
5	5.9 – 8.8	1.23	.78
Totals	5.9 – 9.1	5.58 cfs	3.1

*Tributary flows and temperatures may be higher or lower outside of the June – August 2012 data collection period.

The total wetland area is approximately 28.5 acres and includes the following Cowardin wetland types:

Palustrine forested (1.6 acres) – dominant forested species include Quaking aspen (*Populus tremuloides*), black cottonwood (*Populus balsamifera*), and western red cedar (*Thuja plicata*).
Palustrine scrub-shrub (21.4 acres) – dominant species include hardhack (*Spirea douglassii*), willows (*Salix spp*.), hawthorne (*Crategus douglassii*), and red osier dogwood (*Cornus sericea*)
Palustrine emergent and open water (5.5 acres) – dominant species include reed canarygrass (under the powerlines) (*Phalaris arundinaceae*), sedges (*Carex spp*.), and mannagrass (*Glyceria sp*.).

The wetland contains two Hydrogeomorphic classes, slope and riverine. The wetland is located at the base of the slope and the primary source of hydrology comes from subsurface flow and discharging groundwater. There is some backwater effect from Nason Creek, however, that is limited to higher water events.

According to the Washington State Department of Ecology (DOE) Wetland Rating System, this wetland ranks as a Category II wetland using the wetland functions scoring. However, this may be considered a Category I wetland due to the small clumps of aspen within the forested areas and/or the listed species present. The DOE wetland classification category will need to be finalized as part of the wetland delineation report.

This wetland determination documents that there are wetlands on site and it characterizes the approximate wetland area and type. Prior to earthwork on site, the wetland boundaries will need to be delineated (flagged and surveyed) to more accurately measure the volume and area of earthwork proposed in wetlands as part of the stream restoration project. This wetland determination and any future wetland delineation map and report is considered preliminary prior to review and approval by Washington State Department of Ecology and/or the US Army Corps of Engineers.

Attachments: Figure 1: Aerial Photograph
Figure 2: LIDAR Topography
Figure 3: County Soil Survey
Figure 4: National Wetland Inventory
Figure 5: Wetland Determination Map
Data Sheets 1- 4

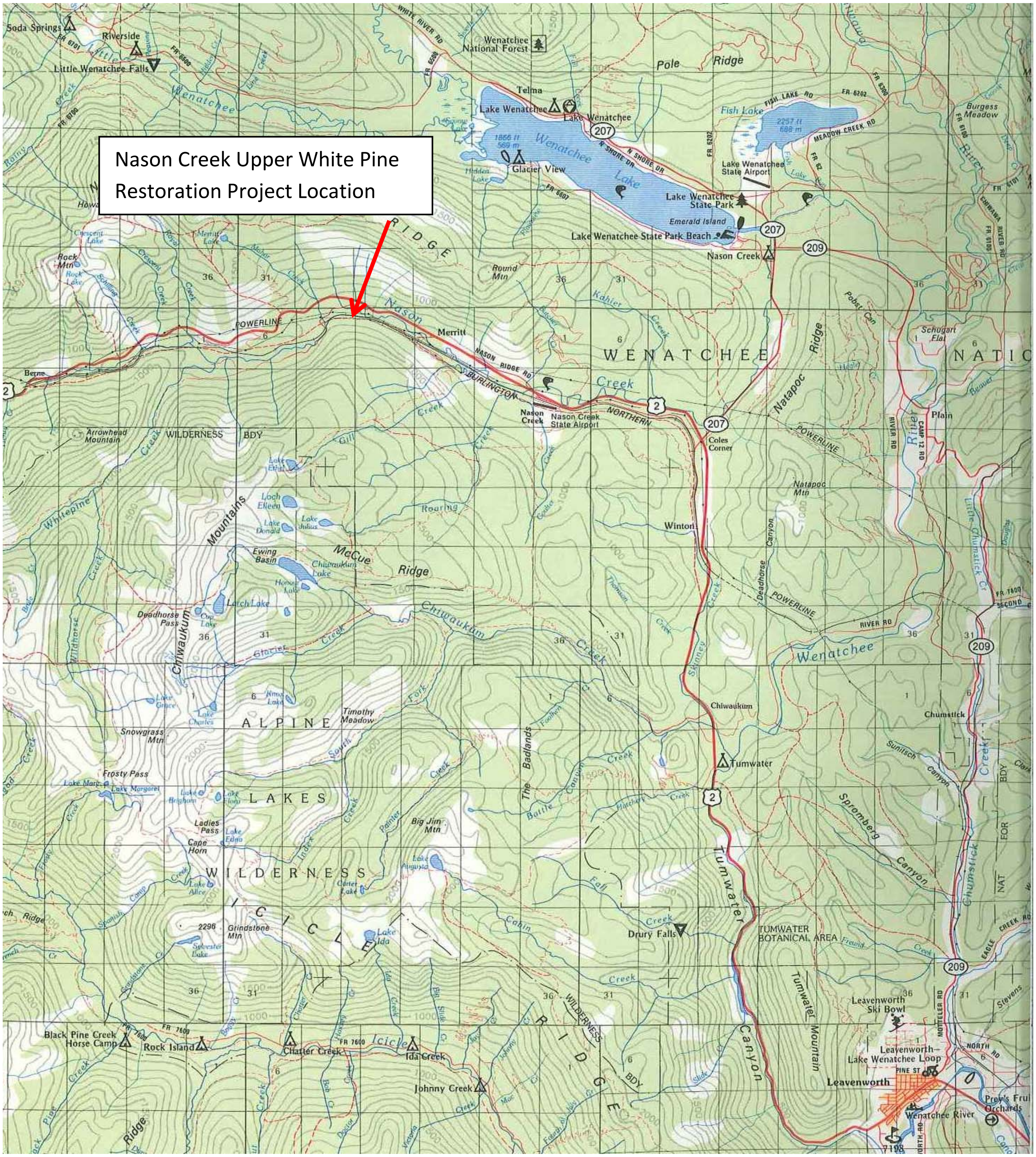


Figure 1: Vicinity map for the Nason Creek Upper White Pine Stream Habitat Restoration project

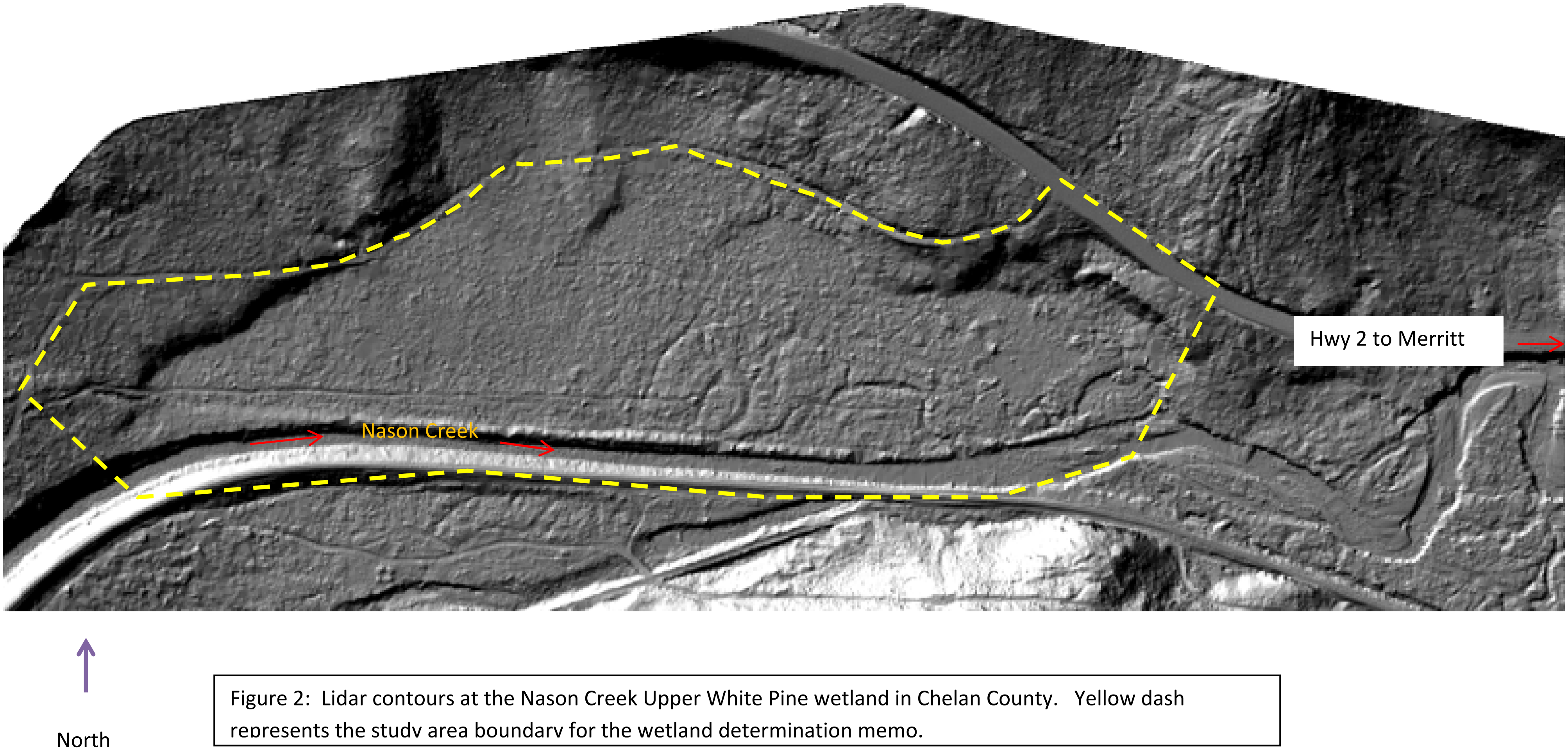


Figure 2: Lidar contours at the Nason Creek Upper White Pine wetland in Chelan County. Yellow dash represents the study area boundary for the wetland determination memo.

Legend:

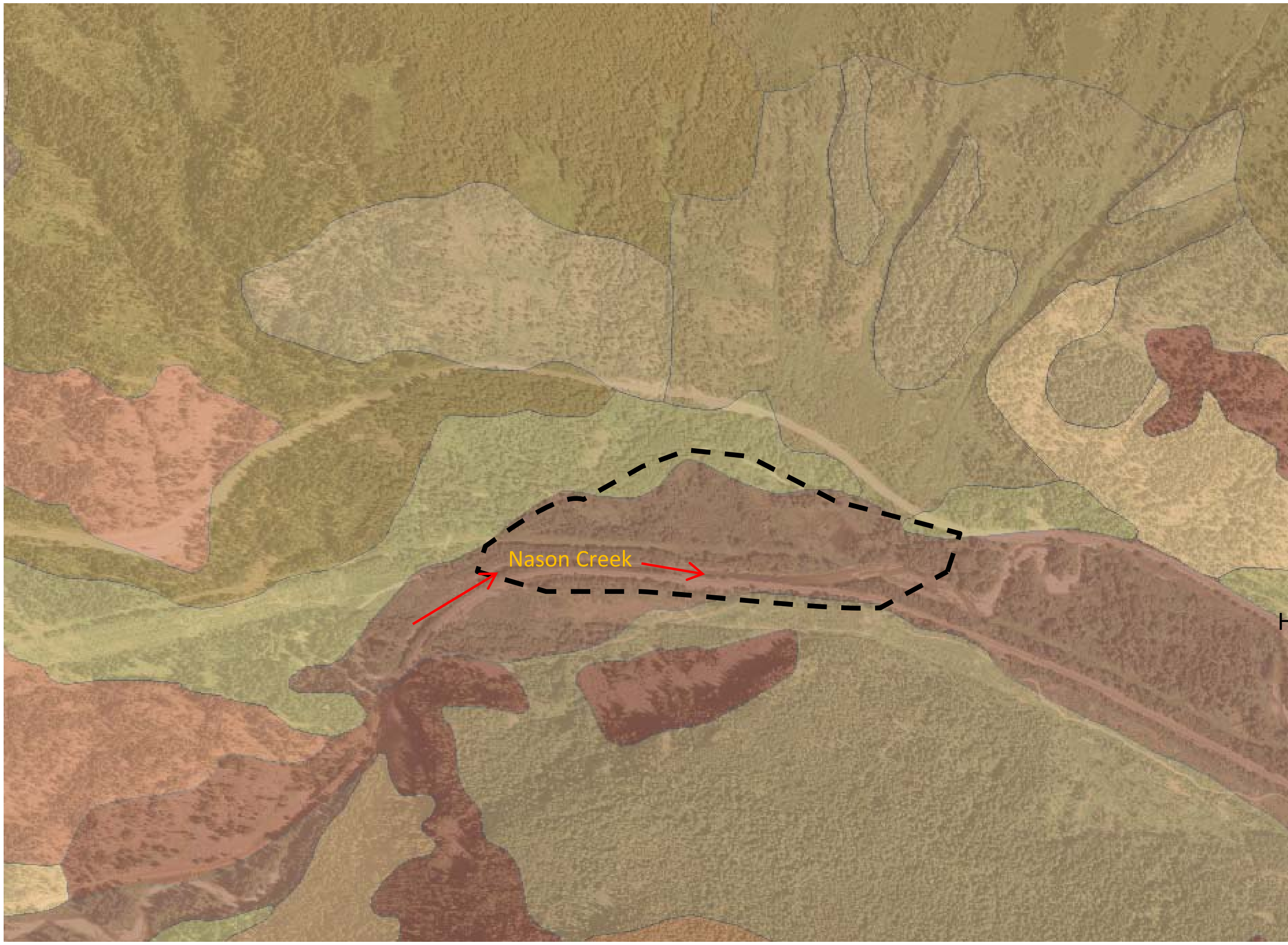
Study Area Boundary

Saska stony sandy loam 3-30% slopes

Aequic fluvaquents, hydric

Entic haplumbrepts 30-75% slopes

North



Hwy 2 to Merritt

Figure 3: Chelan County Soil survey for the Nason Creek Upper White Pine wetland.

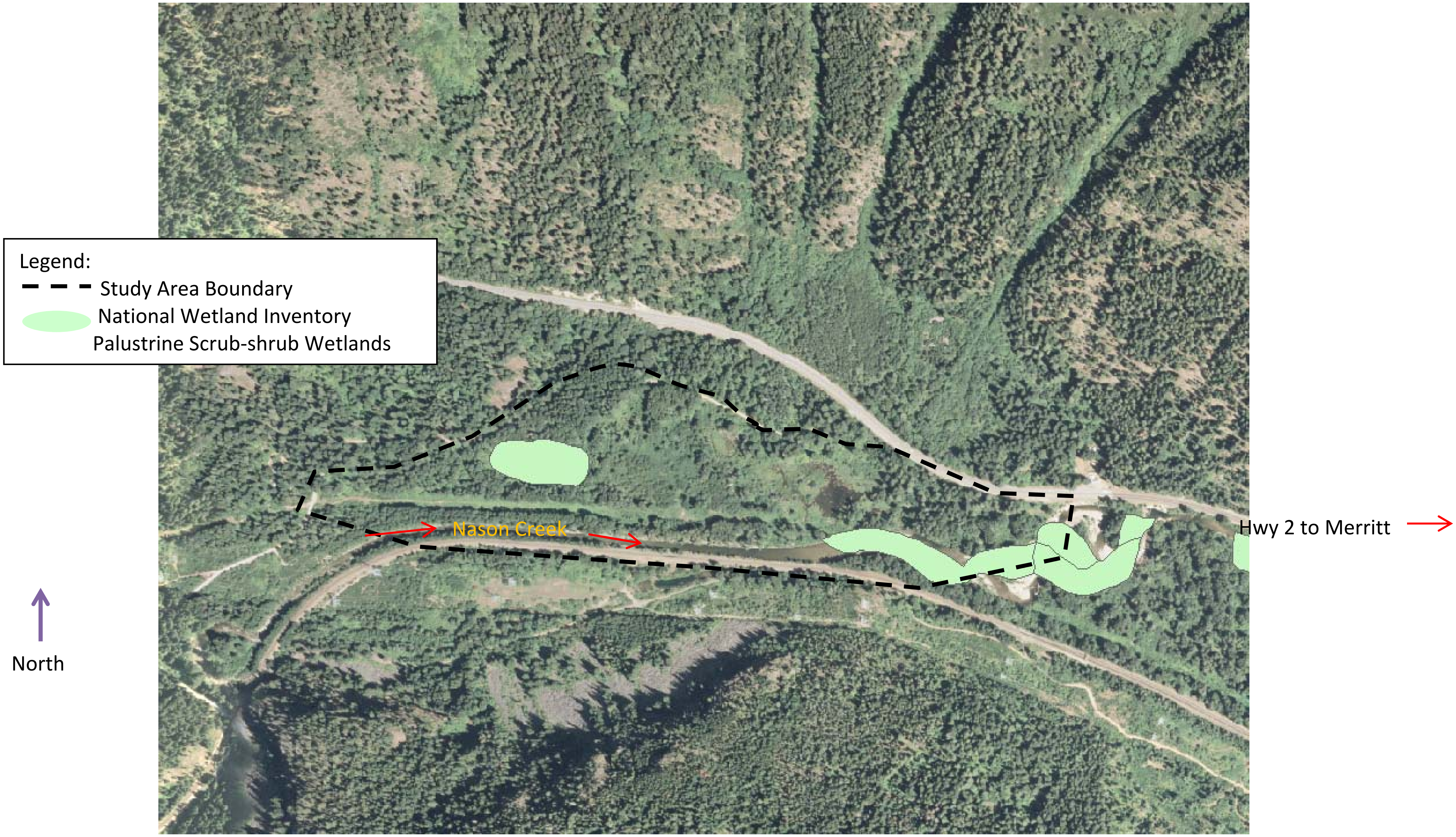


Figure 4: National Wetland Inventory at the Nason Creek Upper White Pine wetland in Chelan County.

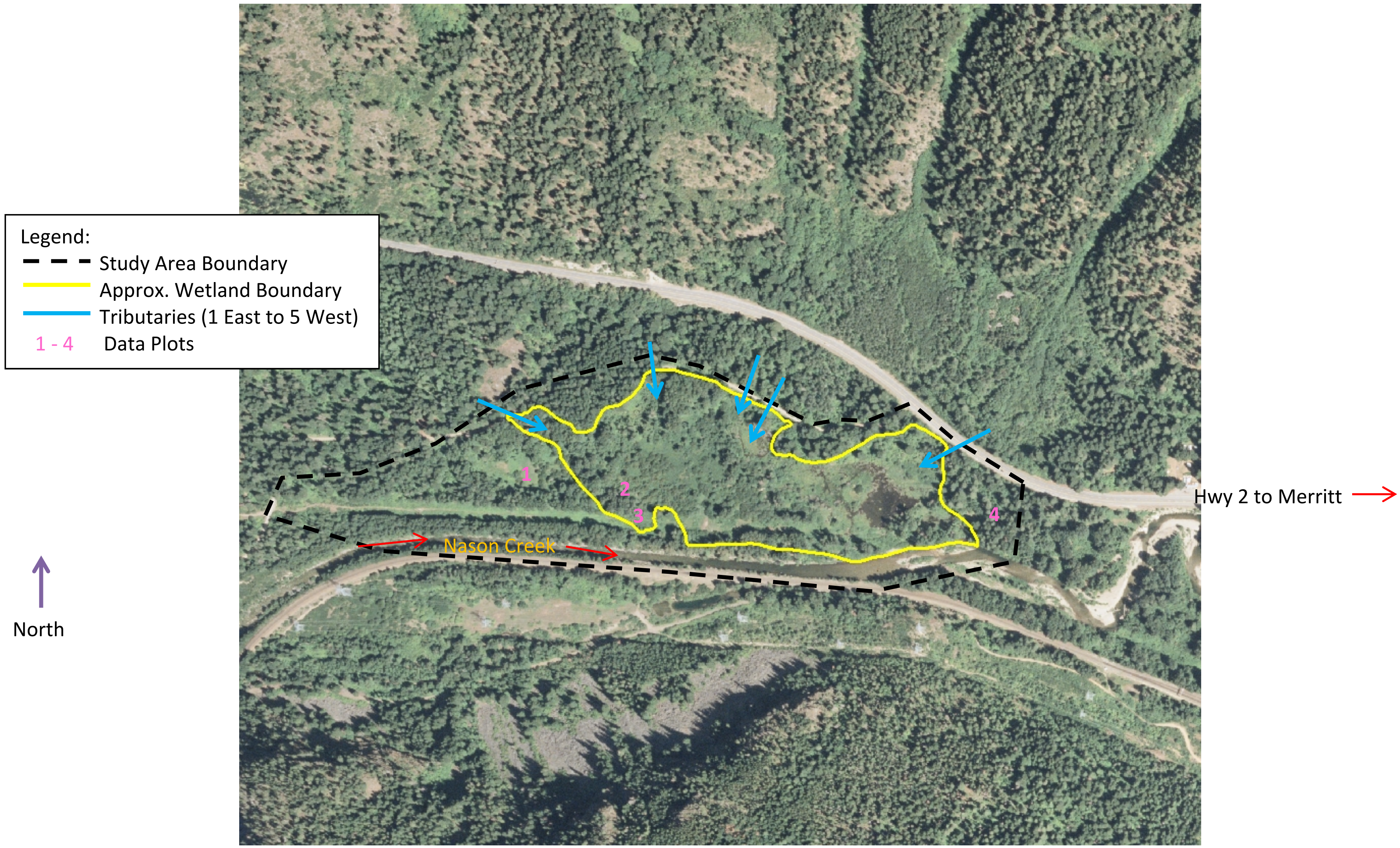


Figure 5: Wetland determination boundaries, study area boundary, data plot location, and location of tributaries at the Nason Creek Upper White Pine wetland in Chelan County.

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: Upper White Pine City/County: Chelan Sampling Date: 7-11-12

Applicant/Owner: Chelan County State: WA Sampling Point: 1

Investigator(s): Jennifer Goodridge Section, Township, Range: 26N 16E Section 5, 5, 33

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): ______ Slope (%): ______

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: ______ NWI classification: ______

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ___ (If no, explain in Remarks.)

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ___ No X	Is the Sampled Area within a Wetland? Yes ___ No X
Hydric Soil Present?	Yes ___ No X	
Wetland Hydrology Present?	Yes ___ No X	

Remarks:

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
= Total Cover			
Sapling/Shrub Stratum (Plot size: ______)			
1.			
2.			
3.			
4.			
5.			
= Total Cover			
Herb Stratum (Plot size: ______)			
1. Achillea millefolium	10		NL
2. Carex sp.	10		FACU-OBL
3. Agropyron repens	30	*	FAC-
4. Solidago canadensis	20	*	FACU
5. Vicia or Lathyrus	Trace		
6. Rumex acetosella	10		FACU+
7. Phleum pratense	5		FAC-
8. Microsteris gracilis	2		FACU
9. Tragopogon pratensis	2		NL
10. Pteridium aquilinum	10		FACU
11.			
= Total Cover			
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
= Total Cover			
% Bare Ground in Herb Stratum ______			

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 50 (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

- ___ 1 - Rapid Test for Hydrophytic Vegetation
- ___ 2 - Dominance Test is >50%
- ___ 3 - Prevalence Index is ≤3.0[1]
- ___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
- ___ 5 - Wetland Non-Vascular Plants[1]
- ___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ___ No X

Remarks:

SOIL

Sampling Point: 1

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR 2/2						SL	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) **(except MLRA 1)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes ___ No X

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) **(except MLRA 1, 2, 4A, and 4B)**
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- ___ Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) **(LRR A)**
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) **(MLRA 1, 2, 4A, and 4B)**
- ___ Drainage Patterns (B10)
- X Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) **(LRR A)**
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ______

Water Table Present? Yes ___ No X Depth (inches): ______

Saturation Present? (includes capillary fringe) Yes ___ No X Depth (inches): ______

Wetland Hydrology Present? Yes ___ No X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: Upper White Pine City/County: Chelan Sampling Date: 7-11-12

Applicant/Owner: Chelan County State: WA Sampling Point: 2

Investigator(s): Jennifer Goodridge Section, Township, Range: 26N 16E 5

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): ______ Slope (%): ______

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: ______ NWI classification: ______

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ___ (If no, explain in Remarks.)

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes X No ___	Is the Sampled Area within a Wetland? Yes X No ___
Hydric Soil Present?	Yes X No ___	
Wetland Hydrology Present?	Yes X No ___	

Remarks: North of Pole 9

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1. Populus balsamifera	25	*	FAC
2.			
3.			
4.			
		= Total Cover	
Sapling/Shrub Stratum (Plot size: ______)			
1. Cornus sericea	20	*	FACW
2. Crategus douglassii	10		FAC
3. Salix sp.	20	*	FAC-OBL
4. Spirea douglassii	10		FACW
5.			
		= Total Cover	
Herb Stratum (Plot size: ______)			
1. Bidens frondosa	5		FACW+
2. Geum macrophyllum	5		FACW-
3. Carex spp.	10		FACU-OBL
4. Agrosti exarata	5		FACW
5. Poa sp.	5		
6. Epilobium sp.	Trace		
7.			
8.			
9.			
10.			
11.			
		= Total Cover	
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 100% (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation
___ 2 - Dominance Test is >50%
___ 3 - Prevalence Index is ≤3.0[1]
___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)
___ 5 - Wetland Non-Vascular Plants[1]
___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes X No ___

Remarks:

SOIL

Sampling Point: 2

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR2/1							

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- X Histosol (A1)
- __ Histic Epipedon (A2)
- __ Black Histic (A3)
- __ Hydrogen Sulfide (A4)
- __ Depleted Below Dark Surface (A11)
- __ Thick Dark Surface (A12)
- __ Sandy Mucky Mineral (S1)
- __ Sandy Gleyed Matrix (S4)
- __ Sandy Redox (S5)
- __ Stripped Matrix (S6)
- __ Loamy Mucky Mineral (F1) **(except MLRA 1)**
- __ Loamy Gleyed Matrix (F2)
- __ Depleted Matrix (F3)
- __ Redox Dark Surface (F6)
- __ Depleted Dark Surface (F7)
- __ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- __ 2 cm Muck (A10)
- __ Red Parent Material (TF2)
- __ Very Shallow Dark Surface (TF12)
- __ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ____

Depth (inches): ____

Hydric Soil Present? Yes X No ____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- X Surface Water (A1)
- X High Water Table (A2)
- X Saturation (A3)
- __ Water Marks (B1)
- __ Sediment Deposits (B2)
- __ Drift Deposits (B3)
- __ Algal Mat or Crust (B4)
- __ Iron Deposits (B5)
- __ Surface Soil Cracks (B6)
- __ Inundation Visible on Aerial Imagery (B7)
- __ Sparsely Vegetated Concave Surface (B8)
- __ Water-Stained Leaves (B9) **(except MLRA 1, 2, 4A, and 4B)**
- __ Salt Crust (B11)
- __ Aquatic Invertebrates (B13)
- __ Hydrogen Sulfide Odor (C1)
- __ Oxidized Rhizospheres along Living Roots (C3)
- __ Presence of Reduced Iron (C4)
- __ Recent Iron Reduction in Tilled Soils (C6)
- __ Stunted or Stressed Plants (D1) **(LRR A)**
- __ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- __ Water-Stained Leaves (B9) **(MLRA 1, 2, 4A, and 4B)**
- __ Drainage Patterns (B10)
- __ Dry-Season Water Table (C2)
- __ Saturation Visible on Aerial Imagery (C9)
- __ Geomorphic Position (D2)
- __ Shallow Aquitard (D3)
- __ FAC-Neutral Test (D5)
- __ Raised Ant Mounds (D6) **(LRR A)**
- __ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes X No ____ Depth (inches): 4"

Water Table Present? Yes ____ No ____ Depth (inches): ____

Saturation Present? (includes capillary fringe) Yes X No ____ Depth (inches): Surface

Wetland Hydrology Present? Yes X No ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: Upper White Pine City/County: Chelan Sampling Date: 7-11-12

Applicant/Owner: Chelan County State: ______ Sampling Point: 3

Investigator(s): Jennifer Goodridge Section, Township, Range: 26N 16E S

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): ______ Slope (%): ______

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: ______ NWI classification: ______

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ___ (If no, explain in Remarks.)

Are Vegetation ___, Soil ___, or Hydrology ___ significantly disturbed? Are "Normal Circumstances" present? Yes X No ___

Are Vegetation ___, Soil ___, or Hydrology ___ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present? Yes ___ No ___	Is the Sampled Area within a Wetland?	Yes X No ___
Hydric Soil Present? Yes ___ No ___		
Wetland Hydrology Present? Yes ___ No ___		

Remarks: 25' North of Pole 9

VEGETATION – Use scientific names of plants.

	Absolute % Cover	Dominant Species?	Indicator Status
Tree Stratum (Plot size: ______)			
1. Populus tremuloides	25	*	FAC
2.			
3.			
4.			
	___ = Total Cover		
Sapling/Shrub Stratum (Plot size: ______)			
1. Spirea douglasii	20	*	FACW
2. Symphoricarpos albus	10		FACU
3. Rubus parviflorus	20	*	FAC
4.			
5.			
	___ = Total Cover		
Herb Stratum (Plot size: ______)			
1. Stachys cooleyae	5		NI
2. Solidago canadensis	10		FACU
3. Heracleum lanatum	10		FAC+
4. Phalaris arundinaceae	5		FACW
5.			
6.			
7.			
8.			
9.			
10.			
11.			
	___ = Total Cover		
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
	___ = Total Cover		

% Bare Ground in Herb Stratum ______

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 100% (A)

Total Number of Dominant Species Across All Strata: ______ (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: ______ (A/B)

Prevalence Index worksheet:

Total % Cover of:	Multiply by:
OBL species ______	x 1 = ______
FACW species ______	x 2 = ______
FAC species ______	x 3 = ______
FACU species ______	x 4 = ______
UPL species ______	x 5 = ______
Column Totals: ______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ 5 - Wetland Non-Vascular Plants[1]

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes X No ___

Remarks:

SOIL

Sampling Point: 3

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR3/2		10YR3/6					

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

- ___ Histosol (A1)
- ___ Histic Epipedon (A2)
- ___ Black Histic (A3)
- ___ Hydrogen Sulfide (A4)
- ___ Depleted Below Dark Surface (A11)
- ___ Thick Dark Surface (A12)
- ___ Sandy Mucky Mineral (S1)
- ___ Sandy Gleyed Matrix (S4)
- ___ Sandy Redox (S5)
- ___ Stripped Matrix (S6)
- ___ Loamy Mucky Mineral (F1) **(except MLRA 1)**
- ___ Loamy Gleyed Matrix (F2)
- ___ Depleted Matrix (F3)
- ___ Redox Dark Surface (F6)
- ___ Depleted Dark Surface (F7)
- ___ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

- ___ 2 cm Muck (A10)
- ___ Red Parent Material (TF2)
- ___ Very Shallow Dark Surface (TF12)
- ___ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ___________

Depth (inches): ___________

Hydric Soil Present? Yes X No ___

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

- ___ Surface Water (A1)
- ___ High Water Table (A2)
- ___ Saturation (A3)
- ___ Water Marks (B1)
- ___ Sediment Deposits (B2)
- ___ Drift Deposits (B3)
- ___ Algal Mat or Crust (B4)
- ___ Iron Deposits (B5)
- ___ Surface Soil Cracks (B6)
- ___ Inundation Visible on Aerial Imagery (B7)
- ___ Sparsely Vegetated Concave Surface (B8)
- ___ Water-Stained Leaves (B9) **(except MLRA 1, 2, 4A, and 4B)**
- ___ Salt Crust (B11)
- ___ Aquatic Invertebrates (B13)
- ___ Hydrogen Sulfide Odor (C1)
- X Oxidized Rhizospheres along Living Roots (C3)
- ___ Presence of Reduced Iron (C4)
- ___ Recent Iron Reduction in Tilled Soils (C6)
- ___ Stunted or Stressed Plants (D1) **(LRR A)**
- ___ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

- ___ Water-Stained Leaves (B9) **(MLRA 1, 2, 4A, and 4B)**
- ___ Drainage Patterns (B10)
- X Dry-Season Water Table (C2)
- ___ Saturation Visible on Aerial Imagery (C9)
- ___ Geomorphic Position (D2)
- ___ Shallow Aquitard (D3)
- ___ FAC-Neutral Test (D5)
- ___ Raised Ant Mounds (D6) **(LRR A)**
- ___ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ___

Water Table Present? Yes ___ No X Depth (inches): ___

Saturation Present? (includes capillary fringe) Yes ___ No X Depth (inches): ___

Wetland Hydrology Present? Yes X No ___

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Plot is near SW wetland boundary in an aspen patch

WETLAND DETERMINATION DATA FORM – Western Mountains, Valleys, and Coast Region

Project/Site: Upper White Pine City/County: Chelan Sampling Date: 7-11-12

Applicant/Owner: Chelan County State: WA Sampling Point: 4

Investigator(s): Jennifer Goodridge Section, Township, Range: 26N 16E 4

Landform (hillslope, terrace, etc.): ______ Local relief (concave, convex, none): ______ Slope (%): ______

Subregion (LRR): ______ Lat: ______ Long: ______ Datum: ______

Soil Map Unit Name: ______ NWI classification: ______

Are climatic / hydrologic conditions on the site typical for this time of year? Yes X No ______ (If no, explain in Remarks.)

Are Vegetation ______, Soil ______, or Hydrology ______ significantly disturbed? Are "Normal Circumstances" present? Yes X No ______

Are Vegetation ______, Soil ______, or Hydrology ______ naturally problematic? (If needed, explain any answers in Remarks.)

SUMMARY OF FINDINGS – Attach site map showing sampling point locations, transects, important features, etc.

Hydrophytic Vegetation Present?	Yes ______ No X	Is the Sampled Area within a Wetland? Yes ______ No X
Hydric Soil Present?	Yes X No ______	
Wetland Hydrology Present?	Yes ______ No X	

Remarks:

VEGETATION – Use scientific names of plants.

Tree Stratum (Plot size: ______)	Absolute % Cover	Dominant Species?	Indicator Status
1. Pseudotsuga menziesii	80	*	FACU
2. Populus balsamifera	20	*	FAC
3.			
4.			
		= Total Cover	
Sapling/Shrub Stratum (Plot size: ______)			
1. Acer circinatum	70	*	FAC-
2. Symphoricarpus albus	20	*	FACU
3. Rubus parviflorus	10		FAC-
4.			
5.			
		= Total Cover	
Herb Stratum (Plot size: ______)			
1. Osmorhiza occidentalis	S		NL
2. Streptopus sp. (twistedstalk)	S		FAC-
3. Galium sp.	S		
4. Bare ground (duff)	60%		
5.			
6.			
7.			
8.			
9.			
10.			
11.			
		= Total Cover	
Woody Vine Stratum (Plot size: ______)			
1.			
2.			
		= Total Cover	

% Bare Ground in Herb Stratum ______

Remarks:

Dominance Test worksheet:

Number of Dominant Species That Are OBL, FACW, or FAC: 2 (A)

Total Number of Dominant Species Across All Strata: 4 (B)

Percent of Dominant Species That Are OBL, FACW, or FAC: 50% (A/B)

Prevalence Index worksheet:

Total % Cover of:		Multiply by:
OBL species	______	x 1 = ______
FACW species	______	x 2 = ______
FAC species	______	x 3 = ______
FACU species	______	x 4 = ______
UPL species	______	x 5 = ______
Column Totals:	______ (A)	______ (B)

Prevalence Index = B/A = ______

Hydrophytic Vegetation Indicators:

___ 1 - Rapid Test for Hydrophytic Vegetation

___ 2 - Dominance Test is >50%

___ 3 - Prevalence Index is ≤3.0[1]

___ 4 - Morphological Adaptations[1] (Provide supporting data in Remarks or on a separate sheet)

___ 5 - Wetland Non-Vascular Plants[1]

___ Problematic Hydrophytic Vegetation[1] (Explain)

[1]Indicators of hydric soil and wetland hydrology must be present, unless disturbed or problematic.

Hydrophytic Vegetation Present? Yes ______ No X

SOIL

Sampling Point: 4

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox %	Type[1]	Loc[2]	Texture	Remarks
0-12	10YR2/1						gra lo	

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

__ Histosol (A1)
__ Histic Epipedon (A2)
__ Black Histic (A3)
__ Hydrogen Sulfide (A4)
__ Depleted Below Dark Surface (A11)
__ Thick Dark Surface (A12)
__ Sandy Mucky Mineral (S1)
__ Sandy Gleyed Matrix (S4)
__ Sandy Redox (S5)
__ Stripped Matrix (S6)
__ Loamy Mucky Mineral (F1) **(except MLRA 1)**
__ Loamy Gleyed Matrix (F2)
__ Depleted Matrix (F3)
__ Redox Dark Surface (F6)
__ Depleted Dark Surface (F7)
__ Redox Depressions (F8)

Indicators for Problematic Hydric Soils[3]:

__ 2 cm Muck (A10)
__ Red Parent Material (TF2)
__ Very Shallow Dark Surface (TF12)
__ Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if present):

Type: ______

Depth (inches): ______

Hydric Soil Present? Yes X No ___

Remarks:
dark colored organic forest soils

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one required; check all that apply)

__ Surface Water (A1)
__ High Water Table (A2)
__ Saturation (A3)
__ Water Marks (B1)
__ Sediment Deposits (B2)
__ Drift Deposits (B3)
__ Algal Mat or Crust (B4)
__ Iron Deposits (B5)
__ Surface Soil Cracks (B6)
__ Inundation Visible on Aerial Imagery (B7)
__ Sparsely Vegetated Concave Surface (B8)
__ Water-Stained Leaves (B9) **(except MLRA 1, 2, 4A, and 4B)**
__ Salt Crust (B11)
__ Aquatic Invertebrates (B13)
__ Hydrogen Sulfide Odor (C1)
__ Oxidized Rhizospheres along Living Roots (C3)
__ Presence of Reduced Iron (C4)
__ Recent Iron Reduction in Tilled Soils (C6)
__ Stunted or Stressed Plants (D1) **(LRR A)**
__ Other (Explain in Remarks)

Secondary Indicators (2 or more required)

__ Water-Stained Leaves (B9) **(MLRA 1, 2, 4A, and 4B)**
__ Drainage Patterns (B10)
__ Dry-Season Water Table (C2)
__ Saturation Visible on Aerial Imagery (C9)
__ Geomorphic Position (D2)
__ Shallow Aquitard (D3)
__ FAC-Neutral Test (D5)
__ Raised Ant Mounds (D6) **(LRR A)**
__ Frost-Heave Hummocks (D7)

Field Observations:

Surface Water Present? Yes ___ No X Depth (inches): ______
Water Table Present? Yes ___ No X Depth (inches): ______
Saturation Present? (includes capillary fringe) Yes ___ No X Depth (inches): ______

Wetland Hydrology Present? Yes ___ No X

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

Appendix D – Chelan PUD Transmission Line Relocation Detailed Alternative Analysis

Technical Memorandum

HDR

To: **Jennifer Goodridge (CCNRD), Jeff Osborn (CPUD), Becky Jaspers (CPUD), Chad Bowman (CPUD), Jim Caldwell (CPUD),**

From: **Jason F. Brunner, P.E. (HDR), Ben McKinsey (HDR)**

Date: **July 31, 2012**

Subject: **Chelan PUD Transmission Line Relocation Detailed Alternative Analysis due to Nason Creek Reconnection**

Background:

Nason Creek is a tributary to the Wenatchee River in Chelan County, Washington. Nason Creek contains spawning, rearing, and migration habitat for cutthroat and redband trout as well as ESA listed Spring Chinook, steelhead trout, and bull trout. The location of highways, railroad and power line corridors adjacent to Nason Creek have confined and straightened the channel in places. Timber harvest, road development and conversion of the floodplain to residential uses in Nason Creek and its tributaries have degraded and reduced spawning and rearing habitat in the watershed. The Upper Columbia Spring Chinook and Steelhead Recovery Plan identifies restoration plans to restore viable and sustainable salmon and steelhead runs to the Upper Columbia basin. Restoring natural stream processes in river mile 12-14 on Nason Creek, the Upper White Pine reach, has been identified as a high priority action for fish habitat restoration actions to recover salmon populations in the Wenatchee watershed. Restoration actions within this stream reach will need to address the Chelan PUD transmission lines that travel through the project area.

Existing Conditions:

The existing affected transmission line is the Chelan PUD McKenzie to Beverly 115kV line. It currently runs from CPUD Generation facilities to the top of Stevens Pass where it connects to the Puget Sound Energy transmission line, into the Seattle Grid system. Along the way it serves the Burlington Northern Cascade Tunnel, Stevens Pass Ski resort and other residential services. It consists of wood poles in H-frame and/or 3 pole angle and deadend configurations. Approximately 20 miles of the line reside within forest service land. Fourteen miles of the Right of Way were obtained through permits with the USFS, and 6 miles were easements from private land owners. The section of the line proposed to be relocated is an area under easement which was obtained prior to USFS ownership. The easement is 100 feet wide and allows for construction of a second transmission line in this corridor.

The existing structures are currently accessible and relatively easy to maintain. Structures 52/6 and 52/5 are both h-frame structures on the south side of Nason Creek and are typically accessible even with some issues that arise from the surrounding terrain and railroad crossings, and in a few instances in the past the creek was crossed to gain access to these structures. 52/7, a 3-pole, transposition deadend structure with guying, is submerged year-round resulting in access issues and making maintenance difficult. The rest of the structures, h-frame tangent structures 52/8 to 52/11 and structure 53/1, a 3 pole running angle structure with guying, have good access with limited interruptions from spring runoff. See attached map of existing structures for reference.

CPUD Comments:
The CPUD does not desire to exchange the easement rights for permits or franchises. Permits and franchises can carry short term or annual fees, potential relocation at the PUD's cost and potential for changes in terms as the permit or franchise expires and needs to be renewed. Currently the District has only one transmission line within its corridor, however, the easement and terrain allows for construction of a second line. The District wants to preserve the ability to construct a second line within any new alignment.

Currently most of the structures are accessible year around. The District needs to be able to access the structures year around for maintenance purposes and in case of an emergency. In addition to drivable access, a working pad needs to be maintained for the trucks to set up and deploy booms and outriggers. If the area around the poles is flooded, a drivable route and working pad will need to be provided to all pole locations. At times a conductor becomes frayed or damaged and must be repaired. If the area between the structures is flooded, provisions should be made for limited access to the transmission line corridor for cases such as these.

Scope:

The purpose of this project is to develop alternatives to eliminate or minimize the impact of the McKenzie to Beverly-115kV Transmission Line on restoration actions in the Upper White Pine reach. The critical relocation area is from structures 52/5 to 53/1. Multiple preliminary relocation/renovation options within the project area were analyzed based on advantages and disadvantages as well as a relative cost analysis for each option. These options were reviewed by the Chelan County Natural Resource Department (CCNRD) and the Chelan County Public Utility District to determine two to four favorable options. CCNRD routed this analysis to other stakeholders for review including US Forest Service, Regional Technical Team, and restoration project funders (current and potential future).

The following is a more detailed analysis based on the alternatives picked as the most likely rebuild/relocation options from the preliminary report. The alternatives include a description of feasibility, including advantages and disadvantages, estimated construction schedule, and a more accurate cost analysis. The updated analysis will be delivered to involved parties to aid in future decisions regarding the Nason Creek Upper White Pine Restoration Project.

Alternative Options:

Alternatives Based on Existing Alignment
Alternative 1A: Replace with fewer, taller steel poles using H-frame construction.
Alternative 1B: Replace with fewer, taller steel poles using single pole construction.
Alternative 2A: Replace with steel-concrete hybrid structures using H-frame construction.
Alternative 2B: Replace with steel-concrete hybrid structures using single pole construction.

Alternatives Based on Realignments
Alternative 3A: Realign along White Pine Road using H-frame construction.
Alternative 3B: Realign along White Pine Road using single pole construction.
Alternative 4A (new): Realign through existing river bed based on river relocation Option 2C.
Alternative 4B (new): Realign through existing river bed based on river relocation Option 2D.

Alternatives Based on Existing Alignment

Route:

These options would require the removal of approximately 6 structures over 0.6 miles of existing line from structure 52/6 to structure 53/1. The new line would remain on the existing alignment and altered as described in each alternative. See attached plan and profile drawings for more information.

Overall Advantages:

1. No new Right of Way would need to be acquired. This also would greatly reduce the permitting (highway/water) phase of planning, which would also reduce costs and the overall project timeline.
2. This would not disturb highway traffic during construction.
3. This route would be less impactful to the surrounding area and less visible to the public, therefore reducing complaints of visual impact.
4. New overhead transmission structures along the existing route would be built from fire resistant materials. Chelan PUD has had issues in the past with fires destroying wood pole lines.

Overall Disadvantages:

1. Maintenance along the existing route would be difficult due to reduced access after habitat rehabilitation and could be disruptive to the reintroduced aquatic species. Additional water hazards and the risk of damaging the habitat would make maintenance far more difficult than the existing conditions unless access is built into the habitat, which would complicate the restoration.
2. Initial construction would be an issue depending on the time of year and specialized equipment would have to be used to minimize terrain destruction.

Alternative 1: Replace the critical section with fewer, taller steel poles.

Design:

Structure 52/6 will be moved east away from the bank of the existing riverbed. Existing structures, 52/6 and 53/1 will be replaced with three pole deadend structures. Wood would be an adequate material for these two structures since the structure locations are outside of the proposed wetland area. Structure 52/7, an existing deadend transposition structure, will be replaced with a single, vertical running angle, steel pole structure with a concrete pier foundation to accommodate the required phase changes. From 52/8 to 52/10, the structures will be replaced with tangent structures. New 636 kcmil 26/7 Strand "Grosbeak" ACSR conductor will be installed through the new section. See attached plan and profile drawing for more information regarding structure placement.

Structure Type:

Alternative 1A: Direct embedded, H-frame steel pole structures would be used through the wetland area for the tangent structures. A culvert backfilled with concrete would be installed around the buried portion of the steel poles to help prevent corrosion.

Alternative 1B: Direct embedded, single steel pole structures would be used through the wetland area for the tangent structures. A culvert backfilled with concrete would be installed around the buried portion of the steel poles to help prevent corrosion.

Construction Timeline:

Alternative	Install	Removal of Existing
Alternative 1A	5 Weeks	4 Weeks
Alternative 1B	5 Weeks	4 Weeks

Additional Advantages:

1. This type of structure would be low maintenance, reducing CPUD interaction with restored habitat.
2. This type of structure is fire resistant. Chelan PUD has had issues in the past with fires destroying wood pole lines.
3. This steel pole option is less impactful to the habitat with fewer structures in the new spawning zone.
4. Using wood for the deadend structures will reduce total structure costs.
5. Applicable to Alternative 2B: Single pole construction will minimize line impact through the wetland area.

Additional Disadvantages:

1. Foundations would be installed at critical structure locations. Culverts with concrete backfill would be installed at all other structure locations through the wetland area. Specialized treatments would have to be applied to protect against corrosion without impacting the spawning environment.
2. Taller poles would increase the chance of visibility for the reconstructed area to be seen from the highway. This could create public issues.
3. Taller poles make CPUD maintenance more difficult. Larger trucks and/or equipment may be required which may require larger access and working (landing) areas.
4. The angled deadend wood structures require guying which could potentially increase necessary vegetation clearing.

CPUD Comments:

The District would consider replacement of the existing structures with taller steel poles, however with taller poles the working pads and roadways may have to be a bigger to allow for larger maintenance vehicles. Additionally, longer spans allow the conductor to swing more in the wind. This may result in additional tree removal to provide required clearances.

Cost:

Alternative 1A:

The estimated labor and material cost of the overhead transmission line is:

Construction	\$555K - \$755K
Permitting	Up to \$50K
Total	\$605K - \$805K

Alternative 1B:

The estimated labor and material cost of the overhead transmission line is:

Construction	\$530K - \$730K
Permitting	Up to \$50K
Total	\$580K - \$780K

Alternative 2: Replace the critical section with steel-concrete hybrid structures.

Design:
Structure 52/6 will be moved east away from the bank of the existing riverbed. Existing structures, 52/6 and 53/1 will be replaced with three pole deadend structures. Wood would be an adequate material for these two structures since the structure locations are outside of the proposed wetland area. Structure 52/7, an existing deadend transposition structure, will be replaced with a single, vertical running angle, steel pole structure with a concrete pier foundation to accommodate the required phase changes. From 52/8 to 52/10, the structures will be replaced with 3 tangent structures. New 636 kcmil 26/7 Strand "Grosbeak" ACSR conductor will be installed through the new section. See attached plan and profile drawing for more information regarding structure placement.

Structure Type:
Alternative 2A: H-frame concrete hybrid pole construction would be used through the wetland area for the tangent structures.
Alternative 2B: Single pole concrete hybrid construction would be used through the wetland area for the tangent structures.

Construction Timeline:

Alternative	Install	Removal of Existing
Alternative 2A	5 Weeks	4 Weeks
Alternative 2B	5 Weeks	4 Weeks

Additional Advantages:
1. This type of structure would be low maintenance, reducing CPUD interaction with restored habitat.
2. This type of structure was designed to be able to handle poor soil conditions and wetland areas. This type of structure does not need a pier or mat foundation which would help minimize habitat disturbance.
3. According to Valmont-Newmark Inc. the pole assembly can be accomplished in one day.
4. Using wood poles for the deadend structures will reduce total structure costs.
5. Applicable to Alternative 2B: Single pole construction will minimize line impact through the wetland area.

Additional Disadvantages:
1. This non-standard, new technology type of structure can be very expensive.
2. Shipping cost could add expense.
3. This structure type requires custom design and specialized installation techniques. This would include the use of expensive specialized equipment and trained professionals to complete.
4. This type of pole is new to the market. Therefore, long term deficiencies and other problems have not been discovered.
5. Angled deadend wood structures require guying which could potentially increase necessary vegetation clearing.

CPUD Comments:
The District has not evaluated this type of structure. A detailed evaluation would be required before determining if this would be acceptable. Additionally, longer spans allow the conductor to swing more in the wind. This may result in additional tree removal to provide required clearances.

Cost:
Alternative 2A:
The estimated labor and material cost of the overhead transmission line is:

Construction	\$620K - \$820K
Permitting	Up to \$50K
Total	\$670K - \$870K

Alternative 2B:
The estimated labor and material cost of the overhead transmission line is:

Construction	\$570K - \$770K
Permitting	Up to \$50K
Total	\$620K - \$820K

Alternatives Based on Realignment

Alternative 3: Realign along White Pine Road.

Removal and Realignment:

Design Route:
This option would require the removal of 8 structures over 0.75 miles of existing line from structure 52/5 to structure 53/1. From structure 52/5, the line would head north for approximately 600 ft. The line then turns north-west towards White Pine Road. Once the line intersects with White Pine Road it will follow within the Right of Way of the road as much as possible. White Pine Road is a less prominent road and has many curves. It would be inefficient to follow the road completely. The new alignment would merge with the original line at structure 53/1. Structures 52/5 and 53/1 will be reconfigured as three pole deadend structures. Structure 52/6 will be replaced with a single pole, vertical running angle transposition structure to provide a required phase change. New 636 kcmil 26/7 Strand "Grosbeak" ACSR conductor will be installed through the new section. The length of this relocation is approximately 4530ft. See attached for more information on structure locations and proposed alignment.

Structure Type:
Alternative 3A: H-frame wood pole construction would be used for all tangent structures. Angle structures will be three pole guyed structures.
Alternative 3B: Single pole construction would be used for all tangent and angled structures except as noted above at structures 52/5 and 53/1.

Construction Timeline:

Alternative	Install	Removal of Existing
Alternative 3A	6 Weeks	4 Weeks
Alternative 3B	6 Weeks	4 Weeks

Additional Advantages:

1. This option would remove the transmission line from the future floodplain area.
2. CPUD standard wood pole structures would be utilized. These structure types would be a less expensive option relative to other proposed materials.
3. Acquiring permits to construct the line within the Right of Way of the road should be more reasonable than another currently undeveloped route.
4. Having the line located along a road would provide an accessible environment for construction and maintenance purposes.
5. This would not disturb the highway traffic during construction. However, White Pine Road would have to potentially be shut down.
6. This route would be less visible than some of the other options.

Disadvantages:

1. Permits would have to be obtained for the entire relocation.
2. New Right of Way and/or easements would need to be obtained. Chelan PUD currently has a Right of Way of 100 feet and the option of adding an additional transmission line on their current Right of Way. Any realignment could possibly lead to a loss of these future line considerations.
3. Initial construction would be an issue depending on the time of year and specialized equipment would have to be used to minimize terrain destruction.
4. The White Pine Road has a lot of short, tight curves which will make it difficult for the transmission line to follow the road exactly, creating some structures with more difficult access for maintenance and requiring additional Right of Way.
5. A considerable amount of vegetation would be removed to obtain a proper Right of Way and could become a public issue.
6. Angle and deadend wood structures require guying which could potentially increase necessary vegetation clearing.

CPUD Comments:

This is the preferred alternative by the District if a replacement easement could be provided and the structures are provided with acceptable access provisions.

Cost:

Alternative 3A:

The estimated labor and material cost of the overhead transmission line is:

Construction	\$625K - \$825K
Permitting	\$100K - \$125K
Total	\$725K - \$950K

Alternative 3B:

The estimated labor and material cost of the overhead transmission line is:

Construction	\$590K - \$790K
Permitting	\$100K - \$125K
Total	\$690K - \$915K

Alternative 4: Realign through the existing riverbed based on various river relocation options.

Design Route Alternative 4A:
This option would replace structures 52/5 through 53/1. This route would remain on the existing alignment for new structures 52/5 and 52/6. Structure 52/5 would be replaced with a 3 pole wood deadend. Structure 52/6 would be replaced with a single steel pole, vertical running angle structure with a concrete pier foundation to accommodate the required phase changes and span the creek to the proposed filled area based on relocation option 2C. The line would continue to head west between the new proposed creek and railroad tracks until the creek and railroad tracks begin to turn south. At this point the new line would cross the creek again and connect back to the existing line at structure 53/1, which will be replaced with a 3 pole, steel deadend on a concrete pier foundation. New 636 kcmil 26/7 Strand "Grosbeak" ACSR conductor will be installed through the new section. See attached for more information on structure locations and proposed alignment.

Structure Type:
Direct embedded, H-frame steel poles would be used through the wetland area for the tangent structures. A culvert backfilled with concrete would be installed around the buried portion of the steel pole to help prevent corrosion.

Design Route Alternative 4B:
This option would replace structures 52/5 through 53/1. All of the structures would remain on the existing alignment except for one. Structure 52/7 would be relocated south beyond the existing easement along the bank of the existing river bed just north of the BNSF Right of Way. Structure 52/5 would be replaced with a 3 pole wood deadend. Structure 52/6 would be replaced with a single steel pole, vertical running angle structure with a concrete pier foundation to accommodate the required phase changes and span the creek to the proposed filled area based on relocation option 2D. The line would continue to head north-west crossing the creek again and reconnect with the existing Right of Way 175 feet west of existing structure 52/9. New structures will be installed along the corridor up to structure 53/1. Structure 53/1 would be replaced with a 3 pole, steel deadend on a concrete pier foundation. New 636 kcmil 26/7 Strand "Grosbeak" ACSR conductor will be installed through the new section. See attached for more information on structure locations and proposed alignment.

Structure Type:
Single steel pole, vertical running angle structures on pier foundations will be installed through the wetland area. A single directly embedded, H-frame steel pole will be installed with a culvert backfilled with concrete to help prevent corrosion along the existing Right of Way.

Construction Timeline:

Alternative	Install	Removal of Existing
Alternative 4A	6 Weeks	4 Weeks
Alternative 4B	6 Weeks	4 Weeks

Advantages:

1. This would not disturb highway traffic during construction.
2. This route would be less impactful to the surrounding area and less visible to the public, therefore reducing complaints of visual impact.
3. This type of structure would be low maintenance, reducing CPUD interaction with restored habitat.
4. This type of structure is fire resistant. Chelan PUD has had issues in the past with fires destroying wood pole lines
5. This steel pole option is less impactful to the habitat with fewer structures in the new spawning zone.
6. Using wood for the deadend structures will reduce total structure costs.
7. Less clearing of existing vegetation should be needed based on relocation to the riverbed area.
8. Applicable to Alternative 2B: Single pole construction will minimize line impact through the wetland area.

Disadvantages:

1. Compared to wood poles, this would be a more expensive option.
2. Depending on location of existing easements, new Right of Way would have to be obtained for the relocated area.
3. Installing structures in recently filled/relocated terrain along the existing creek route could cause concern for the integrity of ground bearing capacity. Additional costs could be incurred to bury poles/foundations deeper to ensure stability.
4. Final alignment will be affected by proximity to the existing railroad and required horizontal clearances. Could lead to encroachment on wetland to avoid railroad as well as increased costs.
5. Foundations would be installed at every structure location which could be exposed to running or standing water after habitat rehabilitation. Specialized treatments would have to be applied to protect against corrosion without impacting the spawning environment. Specifically, structure 52/6 would require a deeper foundation due to the fact that it will be installed in recently disturbed soil.
6. Initial construction would be an issue depending on the time of year and specialized equipment would have to be used to minimize terrain destruction.
7. The angled deadend wood structures require guying which could potentially increase necessary vegetation clearing.
8. Applicable to Alternative 4A: The alignment in the old riverbed would more than likely be in BSNF Right of Way which will make it extremely difficult to be permitted. The entire alignment would more than likely need to be shifted to the north 50+ feet to get out of the BNSF Right of Way and allow for blowout clearances. This would eliminate some of the area for Creek restoration and increase the vegetation clearing necessary for the new transmission alignment
9. Applicable to Alternative 4B: Maintenance of the newly installed structures on the existing alignment may be difficult and disruptive to aquatic habitat if the mainstem relocation is located west of existing structure 52/9. Additional water hazards and the risk of damaging the habitat would make maintenance far more difficult than the existing conditions unless access is built into the habitat, which would complicate the restoration.

CPUD Comments:
The District considers this option feasible if the following items are addressed: Access would have to be provided to all stretches of the line; the final line location would have to be in an easement outside of the railroad ROW; poles in the filled areas would need sufficient compaction and testing prior to placement.

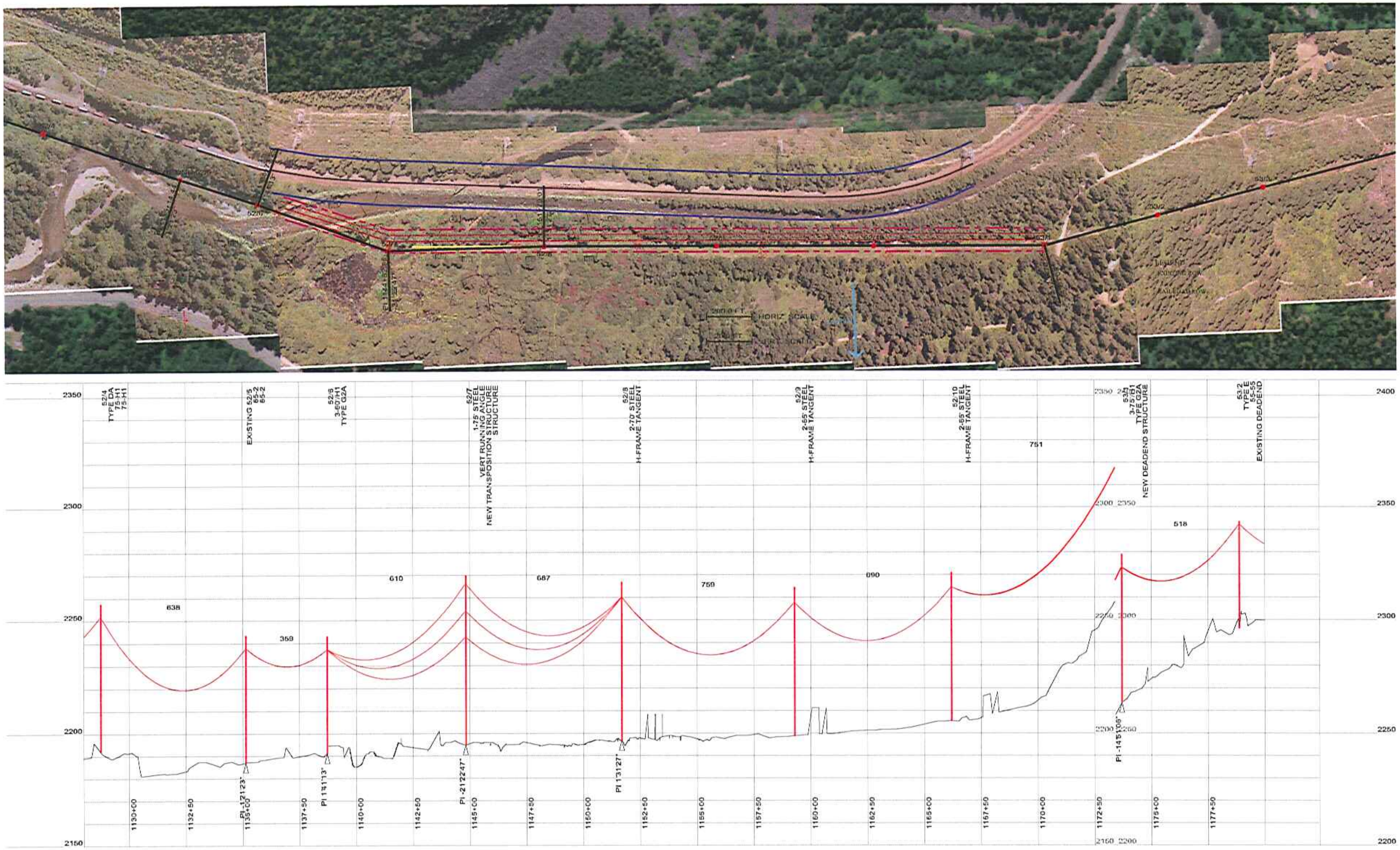
Cost:
Alternative 4A:
The estimated labor and material cost of the overhead transmission line is:

Construction	$835K – $1.05 mil
Permitting	$75K – $100K
Total	$910K – $1.15 mil

Alternative 4B:
The estimated labor and material cost of the overhead transmission line is:

Construction	$740K – $940K
Permitting	$50K – $75K
Total	$790K – $1.02 mil

PLS-CADD DRAWING



HDR HDR ENGINEERING, INC.	CONSULTANT	PRIM. ENG.	CHELAN PUD NO.1	SCALE	VERIFY SCALE BAR IS ONE INCH ON ORIGINAL DRAWING 0 — 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY WENATCHEE, WASHINGTON P.U.D. CHELAN COUNTY	NASON CREEK RELOCATION ALTERNATIVE 1A/2A H-FRAME STEEL/HYBRID POLES ALONG EXISTING ROW
		2ND ENG.	PRIM. ENG.				SHEET OF
		DESIGNER	2ND ENG.				REVISION
		APPROVAL	PROJ. MGR.	REV / DATE	REVISION / REQ. BY / DRFT		DATE / DWG.

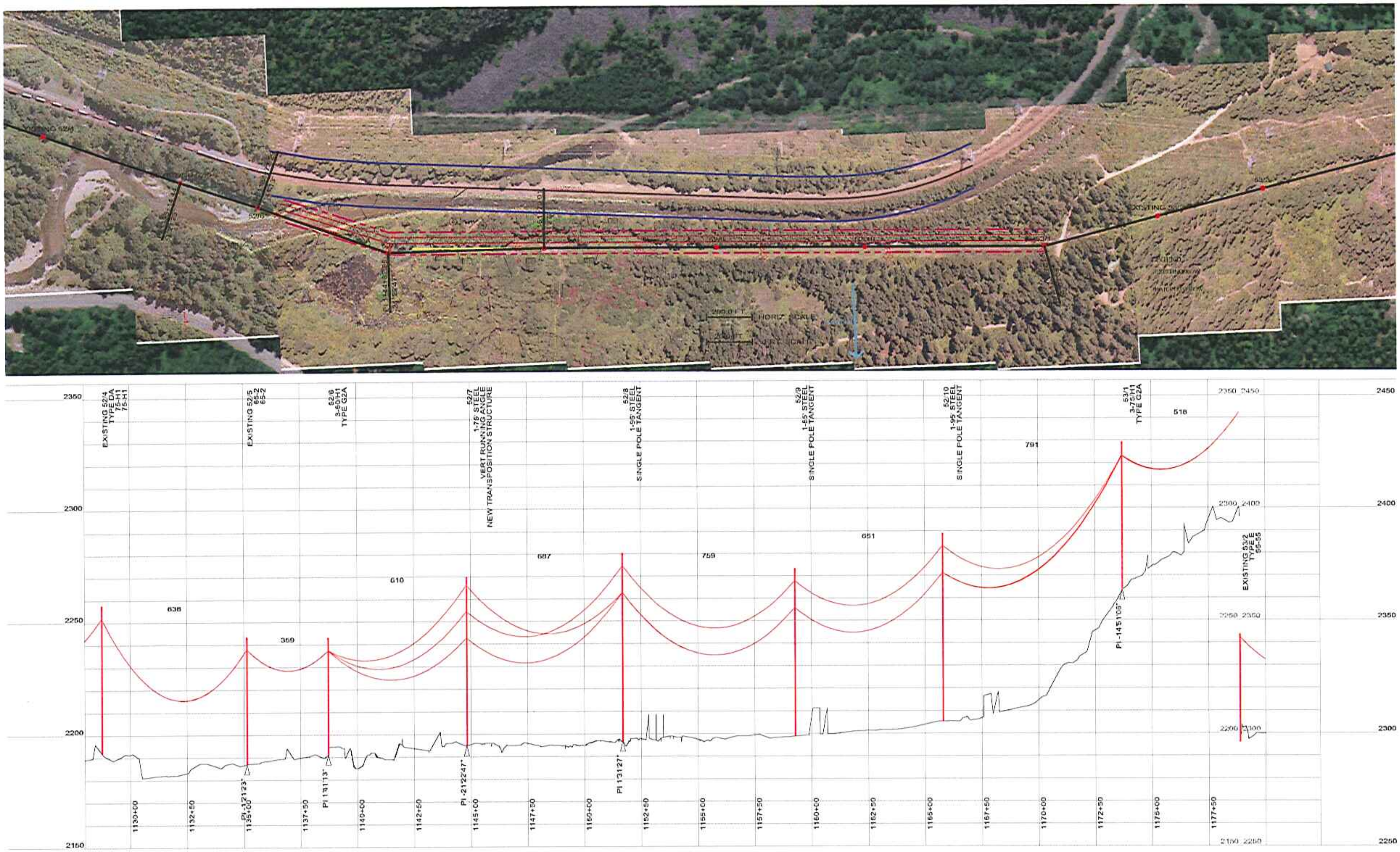
ORIG. DRAWN

ORIG. DATE

DOCUMENT CLASS:

ORIGINAL DWG. #:

PLS-CADD DRAWING



HDR HDR ENGINEERING, INC.	CONSULTANT	PRIM. ENG.	CHELAN PUD NO.1	SCALE	VERIFY SCALE BAR IS ONE INCH ON ORIGINAL DRAWING. 0 —— 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.
		2ND ENG.	PRIM. ENG.		
		DESIGNER	2ND ENG.		
		APPROVAL	PROJ. MGR.	REV / DATE	REVISION / REQ. BY / DRFT

PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY
WENATCHEE, WASHINGTON
P.U.D. CHELAN COUNTY

NASON CREEK RELOCATION

ALTERNATIVE 1B/2B
SINLGE STEEL/HYBRID POLES ALONG EXISTING ROW

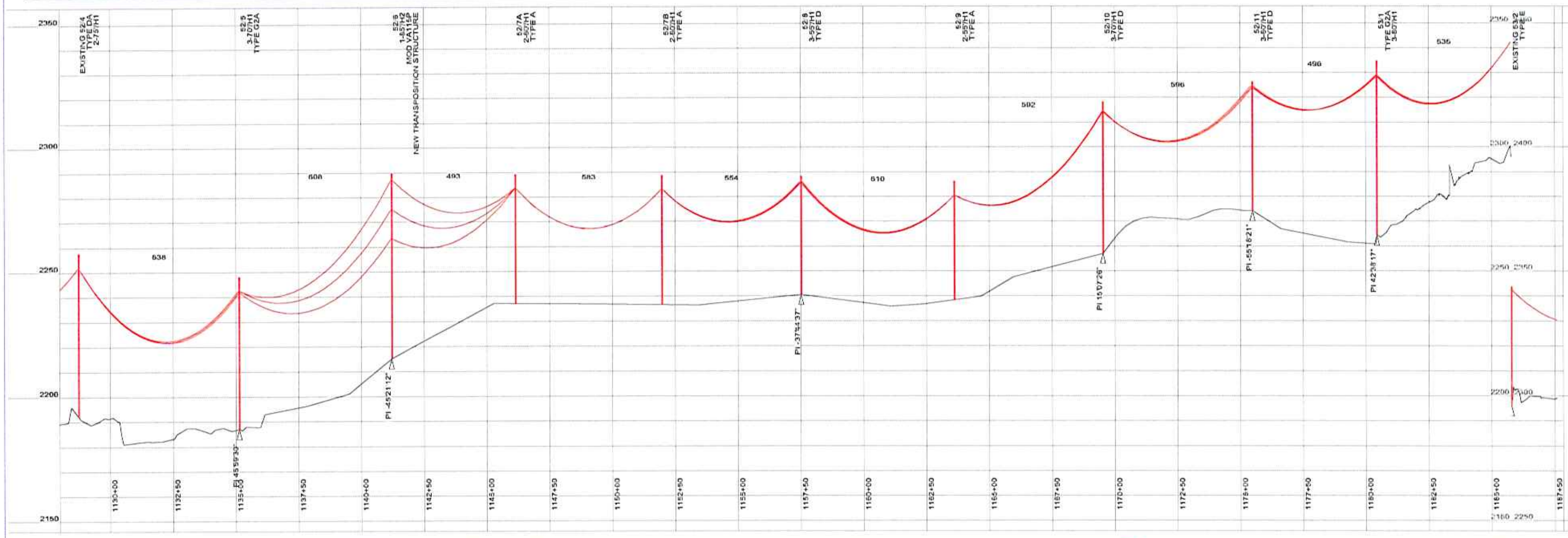
SHEET OF
REVISION
DATE
DWG.

DOCUMENT CLASS:

ORIGINAL DWG. #:

ORIG. DRAWN

ORIG. DATE



HDR	CONSULTANT	PRIM. ENG.	CHELAN PUD NO.1	SCALE	VERIFY SCALE	PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY	NASON CREEK RELOCATION	SHEET OF
HDR ENGINEERING, INC.		2ND ENG.	PRIM. ENG.		BAR IS ONE INCH ON ORIGINAL DRAWING 0 —— 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.	WENATCHEE, WASHINGTON	ALTERNATIVE 3A	REVISION
		DESIGNER	2ND ENG.			P.U.D. CHELAN COUNTY	H-FRAME WOOD POLES ALONG WHITE PINE ROAD	DATE
		APPROVAL	PROJ. MGR.	REV DATE	REVISION REQ. BY DHFT			DWG.

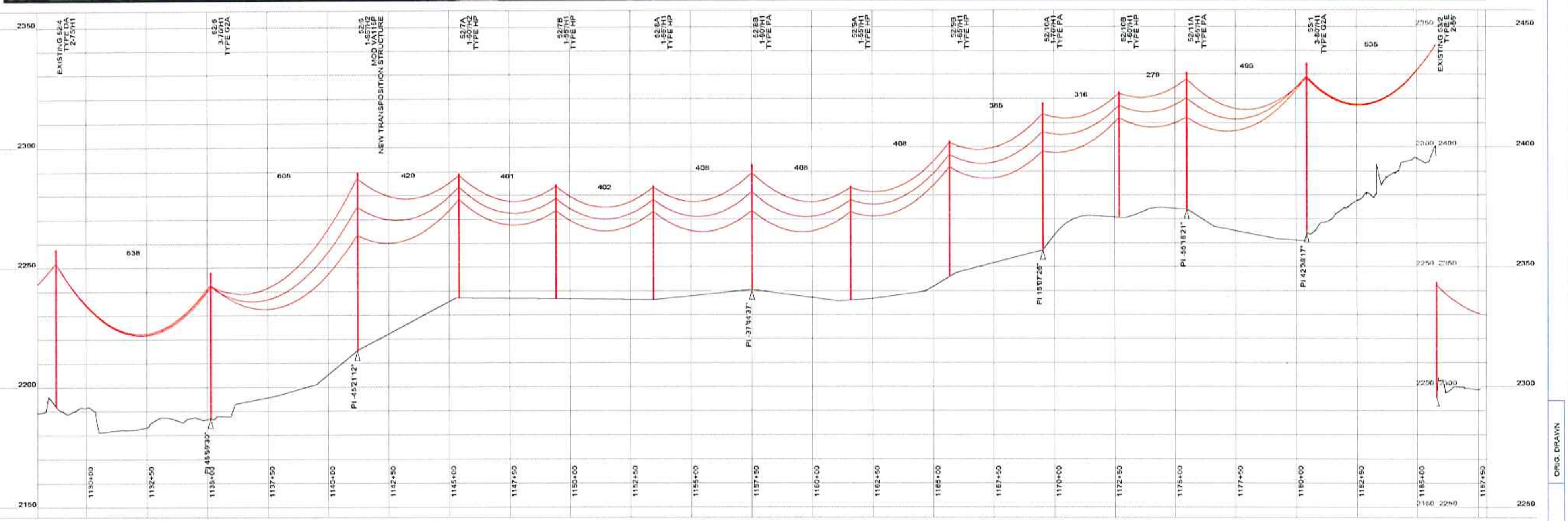
DOCUMENT CLASS:

ORIGINAL DWG. #:

ORIG. DRAWN

ORIG. DATE

PLS-CADD DRAWING



HDR HDR ENGINEERING, INC.	CONSULTANT	PRIM. ENG.	CHELAN PUD NO.1	SCALE	VERIFY SCALE BAR IS ONE INCH ON ORIGINAL DRAWING 0 —— 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.	PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY WENATCHEE, WASHINGTON P.U.D. CHELAN COUNTY	NASON CREEK RELOCATION ALTERNATIVE 3B SINGLE WOOD POLES ALONG WHITE PINE ROAD	SHEET OF
		2ND ENG.	PRIM. ENG.					REVISION
		DESIGNER	2ND ENG.					DATE
		APPROVAL	PROJ. MGR.	REV / DATE	REVISION / REQ. BY / DRFT			DWG.

DOCUMENT CLASS:

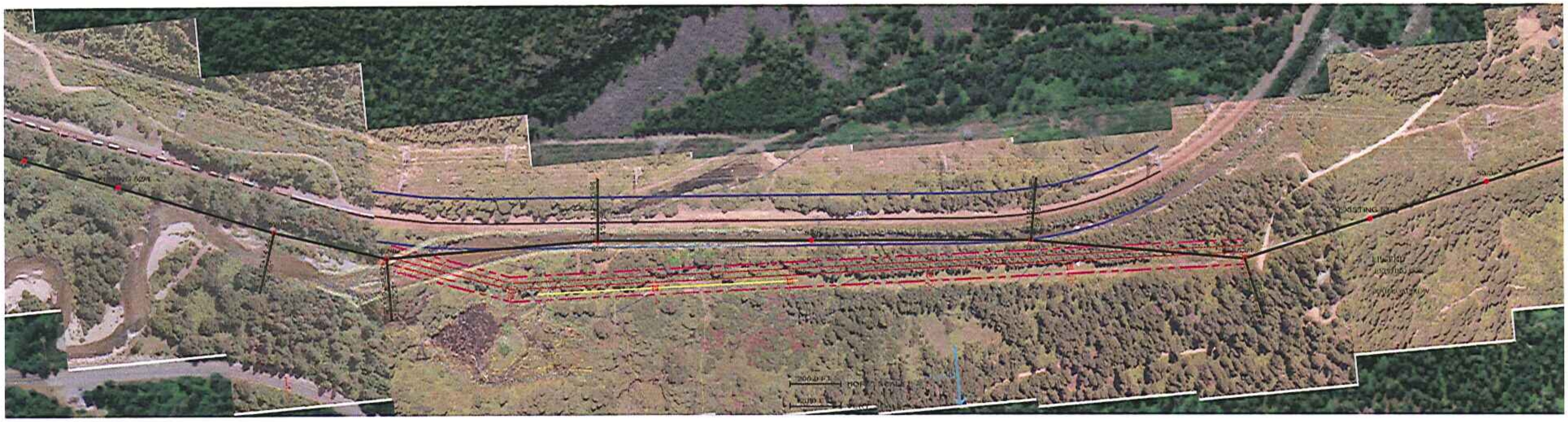
ORIGINAL DWG. #:

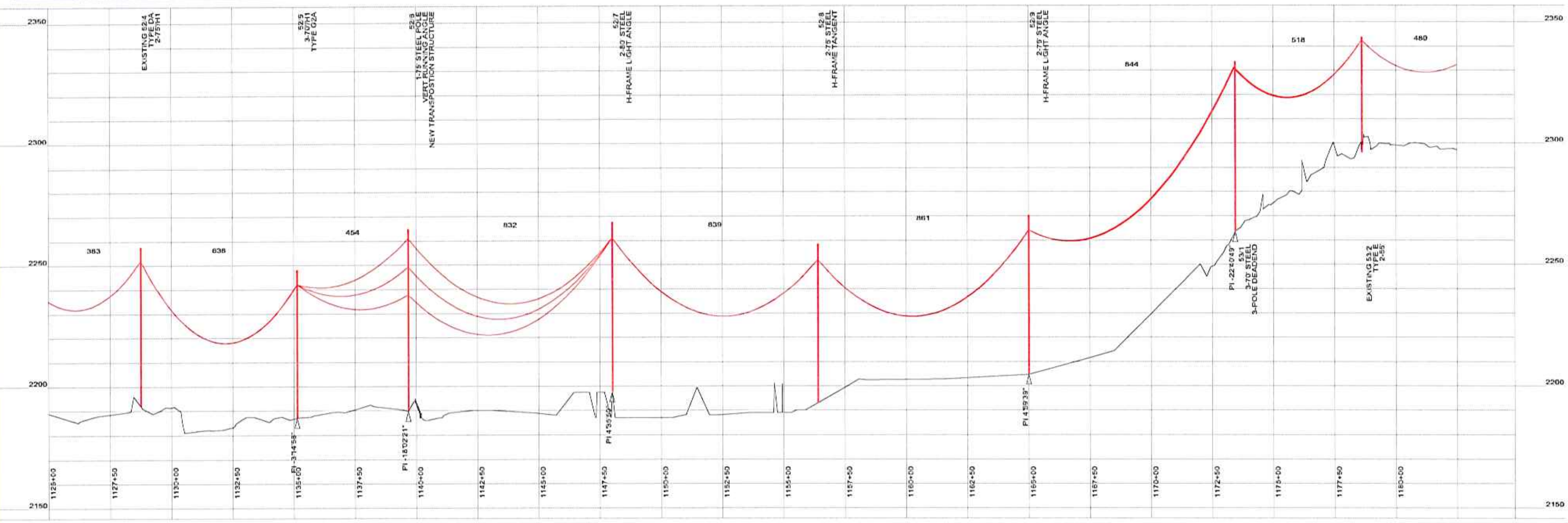
ORIG. DRAWN

ORIG. DATE

RIVER BED OPTION 2C
7/31/2012
PAGE 1/1

PLS-CADD DRAWING





HDR
HDR ENGINEERING, INC.

CONSULTANT
PRIM. ENG.
2ND ENG.
DESIGNER
APPROVAL

CHELAN PUD NO.1
PRIM. ENG.
2ND ENG.
PROJ. MGR.

SCALE

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING
0 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

REV | DATE | REVISION | REQ. BY | DRFT

PUBLIC UTILITY DISTRICT NO. 1
OF CHELAN COUNTY
WENATCHEE, WASHINGTON
P.U.D.
CHELAN COUNTY

NASON CREEK RELOCATION

ALTERNATIVE 4A
RIVERBED RELOCATION BASED ON CREEK ROUTE 2C

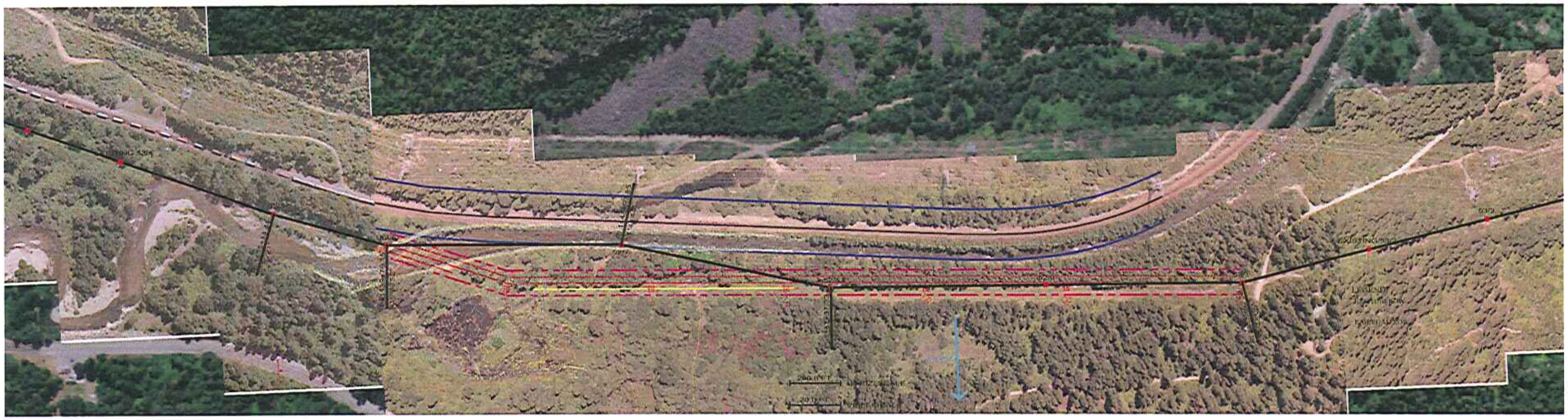
SHEET OF
REVISION
DATE
DWG.

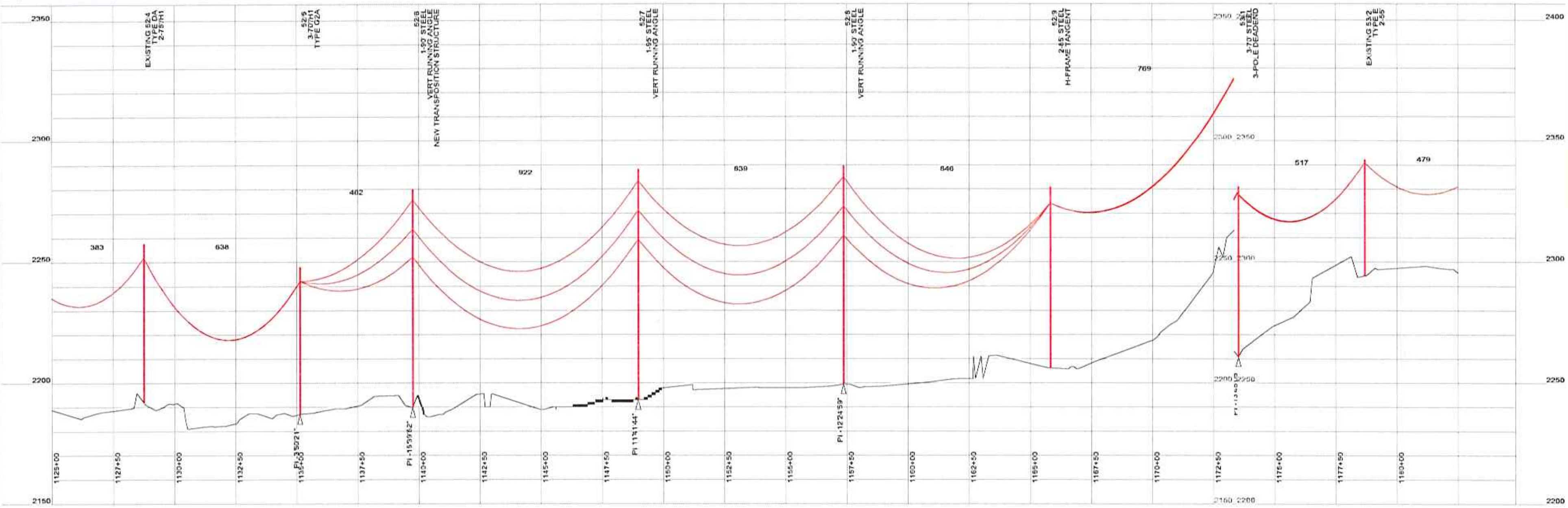
ORIG. DRAWN
ORIG. DATE

DOCUMENT CLASS:
ORIGINAL DWG. #:

RIVER BED OPTION 2D
7/31/2012
PAGE 1/1

PLS-CADD DRAWING





HDR ENGINEERING, INC.	CONSULTANT	PRIM. ENG.	CHELAN PUD NO.1	SCALE	VERIFY SCALE	
		2ND ENG.	PRIM. ENG.		BAR IS ONE INCH ON ORIGINAL DRAWING 0 ——— 1" IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.	
		DESIGNER	2ND ENG.			
		APPROVAL	PROJ. MGR.	REV / DATE	REVISION	REQ. BY / DRFT

PUBLIC UTILITY DISTRICT NO. 1 OF CHELAN COUNTY
WENATCHEE, WASHINGTON

P.U.D. CHELAN COUNTY

NASON CREEK RELOCATION

ALTERNATIVE 4B
RIVERBED RELOCATION BASED ON CREEK OPTION 2D

SHEET OF
REVISION
DATE
DWG.

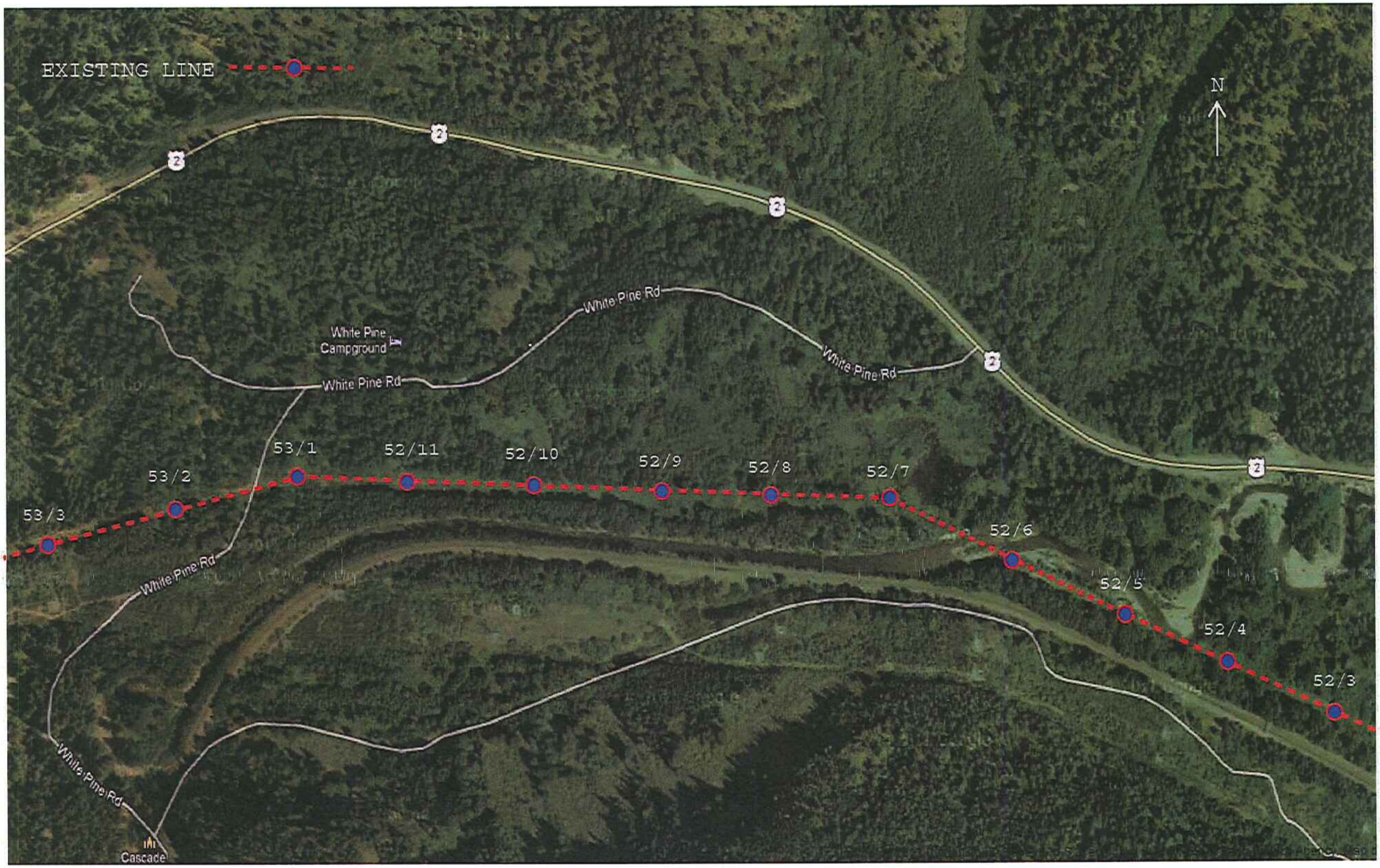
ORIG. DRAWN
ORIG. DATE

DOCUMENT CLASS:

ORIGINAL DWG. #:

Existing Alignment:

HDR



APPENDIX E – REFERENCE REACH DATA

Hydraulic Equations

Regime Equations version 4.0

Along with field data, the following hydraulic equations taken from: STREAM Modules: Spreadsheet Tools for River Evaluation, Assessment and Monitoring (Dan Mecklenburg, Ohio Department of Natural Resources & Andy Ward, Ohio State University 2004) were used to evaluate existing channel dimensions in subreaches 1 and 2 as well as the reference conditions collected by TEAMS shown in Figure 27.

A = bankfull cross-sectional area, Wbnk = bankfull width, D = bankfull mean depth, Lm = meander wavelength, Lb = along-channel bend length, B = meander belt width, Rc = loop radius of curvature, K = channel sinuosity, m = meters, ft = feet)

$Lm = 1.25\ Lb$

$Lm = 1.63\ B$

$Lm = 4.53\ Rc$

$Lb = 0.8\ Lm$

$Lb = 1.29\ B$

$Lb = 3.77\ Rc$

$B = 0.61\ Lm$

$B = 0.78\ Lb$

$B = 2.88\ Rc$

$Rc = 0.22\ Lm$

$Rc = 0.26\ Lb$

$Rc = 0.35\ B$

$A = 0.0094\ Lm^{1.53}$

$A = 0.0149\ Lb^{1.53}$

$A = 0.021\ B^{1.53}$

$A = 0.117\ Rc^{1.53}$

$W_{bnk} = 0.19\ Lm^{0.89}$

$W_{bnk} = 0.26\ Lb^{0.89}$

$W_{bnk} = 0.31\ B^{0.89}$

$W_{bnk} = 0.81\ Rc^{0.89}$

$D = 0.04\ Lm^{0.66}$

$D = 0.054\ Lb^{0.66}$

$D = 0.055\ B^{0.66}$

$D = 0.127\ Rc^{0.66}$

$Lm = 21\ A^{0.65}$

$Lb = 15.4\ A^{0.65}$

$B = 12.6\ A^{0.65}$

$Rc = 4.1\ A^{0.65}$

$Lm = 6.5\ W_{bnk}^{1.12}$

$Lb = 4.4\ W_{bnk}^{1.12}$

$B = 3.7\ W_{bnk}^{1.12}$

$Rc = 1.3\ W_{bnk}^{1.12}$

$Lm = 129\ D^{1.52}$

$Lb = 86\ D^{1.52}$

$B = 80\ D^{1.52}$

$Rc = 23\ D^{1.52}$

$W = 12.5\ D^{1.45}$

$D = 0.17\ W_{bnk}^{0.69}$

$W_{bnk} = 73\ D^{1.23}$

K-2.35

$D = 0.15\ W_{bnk}^{0.59}$ K1.46

The following tables show the design parameters used by TEAMS for the Upper White Pine analysis.

Table 10. TEAMS Enterprise design parameters

Flow Ranges for Nason Creek – Upper White Pine Project Area	Discharge (cfs)	Source
base flow	40	USDI - BLM
Q1.2 (Calculated from Est. Bankfull X-Sec) n 0.05 & 0.07	1,455-2,000	TEAMS
Calculated Q (8-18-2011) n 0.07	99.6	TEAMS
Q1.2 Extrapolated Gage Data	1151	Kopp 2011
Initial Q2 Estimated Range	1,500-2,000	TEAMS
Q2 Extrapolated Gage Data	1,700 – 1,700	Kopp 2011 - BOR 2008
Q5 Extrapolated Gage Data	2,606 – 2,700	Kopp 2011 - BOR 2008
Q 10	3,400 – 3,400	Kopp 2011 - BOR 2008
Q25	4,500 – 4,300	Kopp 2011 - BOR 2008
Q50	5,500 – 5,400	Kopp 2011 - BOR 2008
Q100	6,700 – 6,500	Kopp 2011 - BOR 2008
Q200	8,000	Kopp 2011
Q500	10,000	Kopp 2011

Geomorphology for Nason Cr – Upper White Pine Project Area	Design Parameters	Notes/Comments
Valley Slope (subreach 2)	0.71% (1.0% Upper - 0.5% Lower)	Measured from elevations - LiDAR data
Valley Slope (Reference Areas)	1.10%	Measured from elevations - LiDAR data
Sinuosity Range	1.2-1.7	Estimated from reference reach and remnant channels
Low Flow Width (disturbed reference; ft)	25-55	Data from 8-2011 TEAMS survey
Bankfull Width (disturbed reference ; ft)	107-183	Data from 8-2011 TEAMS survey
Bankfull Width (GIS; ft)	94-110	Measured from bare earth LiDAR
Bankfull Width (hydraulic equations; ft)	92, 106, 123*	Min, Average, Max from multiple hydraulic equations.
Bankfull Average Depth (disturbed reference; ft)	2.2-4.0	Data from 8-2011 TEAMS survey
Bankfull Average Depth (hydraulic equations; ft)	2.5, 3.5, 4.4*	Min, Average, Max from multiple hydraulic equations.
Residual Maximum Pool Depth - Scour Depth	4.8 - 6.1	Data from 8-2011 TEAMS survey
Glide Slope	0.3-0.5%	Glide slope range of references surveyed on 8-2011

Geomorphology for Nason Cr – Upper White Pine Project Area	**Design Parameters**	**Notes/Comments**
Riffle Slope	1.3-1.6%	Riffle slope range of references surveyed on 8-2011
Flood Prone Width (ft)	320 - 890	Estimated from bare earth LiDAR of remnant channels.
Entrenchment Ratio (Flood Prone Width/Bankfull Width)	>3	Estimated from bare earth LiDAR of remnant channels.
Meander Beltwidth (ft)	600-800	Estimated from reference reach and remnant channels
Meander Beltwidth (ft)	350, 546, 852*	Min, Average, Max from multiple hydraulic equations.
Meander Wavelength (ft)	630-780	Estimated from bare earth LiDAR of remnant channels.
Meander Wavelength (ft)	574, 910, 1260*	Min, Average, Max from multiple hydraulic equations.

Nason Creek - Upper White Pine Reach Habitat Dimensions and Design Parameters	**Design Parameters (ft)[†]**
Pool Head (Run) - Low Flow Width	25
Pool Head (Run) - Bankfull Width	106.5,110.5,114.5*
Pool Head (Run) - Flood Prone Width	520
Pool Head (Run) - Average Low Flow Depth	2.6
Pool Head (Run) - Average Bankfull Depth	4.0
Pool Head (Run) Low Flow W/D	10
Pool Head (Run) Bankfull W/D	28
Run Length	20-46
Pool Head / Run - Thalweg to Low Flow El.	1.5, 2.8, 4.1*
Pool Head / Run - Thalweg to Bankfull Flow El.	4.6, 6.6, 8.6*
Pool Head / Run - Thalweg to Flood Prone El.	6.8, 8.1, 9.2*
Pool Head / Run - Entrenchment Ratio	4.7
Pool Max - Low Flow Width	38
Pool Max - Bankfull Width	114.5,117.5,121*
Pool Max - Flood Prone Width	540
Pool Max - Average Low Flow Depth	3.9
Pool Max - Average Bankfull Depth	2.9
Pool Max Low Flow W/D	10
Pool Max Bankfull W/D	39
Pool Length	74 - 93
Pool Max - Thalweg to Low Flow El.	6.6
Pool Max - Thalweg to Bankfull Flow El.	9.4

Nason Creek - Upper White Pine Reach Habitat Dimensions and Design Parameters	Design Parameters (ft)†
Pool Max - Thalweg to Flood Prone El.	10.2
Pool Max - Entrenchment Ratio.	4.7
Sub-Pavement / Bar Samples D16	0.9-5mm
Sub-Pavement / Bar Samples D50	8-12mm
Sub-Pavement / Bar Samples D84	23-27mm
Pool Tail Crest Low Flow Width	37
Pool Tail Crest Bankfull Flow Width	119
Pool Tail Crest - Flood Prone Width	480
Pool Tail Crest - Average Low Flow Depth	0.9
Pool Tail Crest - Average Bankfull Flow Depth	2.2
Pool Tail Crest Low Flow W/D	41
Pool Tail Crest - Bankfull W/D	54
Pool Tail Crest Length	13 - 93
Pool Tail Crest - Thalweg to Low Flow El.	1.2
Pool Tail Crest - Thalweg to Bankfull Flow El.	4.2
Pool Tail Crest - Thalweg to Flood Prone El.	6.1
Pool Tail Crest - Entrenchment Ratio	4.0
Pool Tail Crest D16	23-34mm
Pool Tail Crest D50	47-60mm
Pool Tail Crest D84	88-110mm
Riffle Low Flow Width	43,54,65*
Riffle Bankfull Flow Width	127,155,183*
Riffle - Flood Prone Width	617
Riffle - Average Low Flow Depth	1.2
Riffle - Average Bankfull Flow Depth	2.6
Riffle Low Flow W/D	36
Riffle Bankfull W/D	48.8
Riffle Length	74 - 174
Riffle - Thalweg to Low Flow El.	0.9, 1.4, 1.8*
Riffle - Thalweg to Bankfull Flow El.	3.6, 4.2, 5.1*
Riffle - Thalweg to Flood Prone El.	5.7, 6.1, 7.6*
Riffle - Entrenchment Ratio	4.7
1.3% Riffle D16	23mm
1.6 % Riffle D16	32mm
1.3% Riffle D50	51mm
1.6 % Riffle D50	77mm
1.3% Riffle D84	91mm
1.6 % Riffle D84	130mm

† data from 8-2011 TEAMS survey

* min, avg., max.

Nason Creek -Upper White Pine Reach Disturbed Reference X-Sections

Bankfull - Pool Max Depth X-Section									
n	Wbnk	Dbnk	Abnk	R=A/P	S	Pbnk	Qbnk	Vbnk	W/D
0.03	114	2.9	330.6	7.1	0.0005	46.3	1340.1	4.1	39
0.04	114	2.9	330.6	7.1	0.0005	46.3	1005.1	3.0	
0.05	114	2.9	330.6	7.1	0.0005	46.3	804.1	2.4	
0.06	114	2.9	330.6	7.1	0.0005	46.3	670.1	2.0	
0.07	114	2.9	330.6	7.1	0.0005	46.3	574.3	1.7	
Base Flow - Pool Max Depth X-Section									
n	Wlow	Dlow	Alow	R=A/P	S	Plow	Qbase	Vlow	W/D
0.03	38	3.9	148.2	5.7	0.0005	26.1	516.4	3.5	10
0.04	38	3.9	148.2	5.7	0.0005	26.1	387.3	2.6	
0.05	38	3.9	148.2	5.7	0.0005	26.1	309.9	2.1	
0.06	38	3.9	148.2	5.7	0.0005	26.1	258.2	1.7	
0.07	38	3.9	148.2	5.7	0.0005	26.1	221.3	1.5	
Bankfull - Pool Head X-Section									
n	Wbnk	Dbnk	Abnk	R=A/P	S	Pbnk	Qbnk	Vbnk	W/D
0.03	111	4	444.0	8.1	0.0005	54.6	1961.1	4.4	28
0.04	111	4	444.0	8.1	0.0005	54.6	1470.8	3.3	
0.05	111	4	444.0	8.1	0.0005	54.6	1176.6	2.7	
0.06	111	4	444.0	8.1	0.0005	54.6	980.5	2.2	
0.07	111	4	444.0	8.1	0.0005	54.6	840.5	1.9	

Base Flow - Pool Head X-Section									
n	Wlow	Dlow	Alow	R=A/P	S	Plow	Qbase	Vlow	W/D
0.03	25	2.6	65	2.9	0.0005	22.6	144.6	2.2	10
0.04	25	2.6	65	2.9	0.0005	22.6	108.4	1.7	
0.05	25	2.6	65	2.9	0.0005	22.6	86.7	1.3	
0.06	25	2.6	65	2.9	0.0005	22.6	72.3	1.1	
0.07	25	2.6	65	2.9	0.0005	22.6	62.0	1.0	
Bankfull- Pool Tail X-Section									
n	Wbnk	Dbnk	Abnk	R=A/P	S	Pbnk	Qbnk	Vbnk	W/D
0.03	119	2.2	261.8	5.8	0.004	45	2622.0	10.0	54
0.04	119	2.2	261.8	5.8	0.004	45	1966.5	7.5	
0.05	119	2.2	261.8	5.8	0.004	45	1573.2	6.0	
0.06	119	2.2	261.8	5.8	0.004	45	1311.0	5.0	
0.07	119	2.2	261.8	5.8	0.004	45	1123.7	4.3	
Base Flow - Pool Tail X-Section									
n	Wlow	Dlow	Alow	R=A/P	S	Plow	Qbase	Vlow	W/D
0.03	37	0.9	33.3	1.2	0.004	28	117.0	3.5	41
0.04	37	0.9	33.3	1.2	0.004	28	87.7	2.6	
0.05	37	0.9	33.3	1.2	0.004	28	70.2	2.1	
0.06	37	0.9	33.3	1.2	0.004	28	58.5	1.8	
0.07	37	0.9	33.3	1.2	0.004	28	50.1	1.5	

Bankfull - Mid Riffle X-Section									
n	Wbnk	Dbnk	Abnk	R=A/P	S	Pbnk	Qbnk	Vbnk	W/D
0.03	127	2.6	330.2	5.6	0.006	59	3948.0	12.0	49
0.04	127	2.6	330.2	5.6	0.006	59	2961.0	9.0	
0.05	127	2.6	330.2	5.6	0.006	59	2368.8	7.2	
0.06	127	2.6	330.2	5.6	0.006	59	1974.0	6.0	
0.07	127	2.6	330.2	5.6	0.006	59	1692.0	5.1	
Base Flow - MidRiffle X-Section									
n	Wlow	Dlow	Alow	R=A/P	S	Plow	Qbase	Vlow	W/D
0.03	43	1.2	51.6	1.6	0.006	32.2	270.3	5.3	36
0.04	43	1.2	51.6	1.6	0.006	32.2	202.7	3.9	
0.05	43	1.2	51.6	1.6	0.006	32.2	162.2	3.2	
0.06	43	1.2	51.6	1.6	0.006	32.2	135.1	2.6	
0.07	43	1.2	51.6	1.6	0.006	32.2	115.8	2.3	

n= Manning's Roughness Coe.
Wbnk= Width @ Bankfull
Wlow= Width @ Base Flow
Dbnk= Average Depth @ Bankfull
Dlow= Average Depth @ Base Flow
Abnk= Area @ Bankfull
Alow= Area @ Base Flow
R= Hydraulic Radius
S= Slope
Pbnk= Wetted Perimeter @ Bankfull
Plow= Wetted Perimeter @ Base Flow
Qbnk= Discharge @ Bankfull
Qlow= Discharge @ Base Flow
Vbnk= Velocity @ Bankfull
Vlow= Velocity @ Base Flow
W/D = Width to Depth Ratio

Nason Ck. Pebble Counts (Disturbed Reference) 08/18/11 Reference 1

Pool Tail Crest		
<2	4	
2	1	
2.8	1	
4	1	
5.6	0	
8	2	
11	3	
16	4	
22.6	14	
32	17	
45	28	
64	19	
90	13	
128	2	
180	0	
	109	
	Percent	**mm**
d16	11.08421	17.800
d50	47.75516	49.800
d84	99.77102	49.800

Mid-Riffle		
<2	4	
2	0	
2.8	0	
4	1	
5.6	0	
8	2	
11	1	
16	8	
22.6	8	
32	18	
45	23	
64	19	
90	15	
128	1	
180	0	
	100	
	Percent	**mm**
d16	11.55386	19.500
d50	53.04860	55.300
d84	99.74433	167.500

Sub-Pavement		
<2	24	
2	3	
2.8	5	
4	4	
5.6	8	
8	7	
11	11	
16	7	
22.6	12	
32	9	
45	4	
64	6	
90	1	
128	0	
180	0	
	101	
	Percent	**mm**
d16	64.96909	19.500
d50	91.20534	55.300
d84	100.00000	167.500

Nason Ck. Pebble Counts (Un-Disturbed Reference #1) 08/19/11 Reference 2

Glide		
<2	0	
2	0	
2.8	0	
4	0	
5.6	0	
8	0	
11	2	
16	6	
22.6	6	
32	18	
45	20	
64	17	
90	23	
128	7	
180	1	
	100	
	Percent	**mm**
d16	2.91896	17.800
d50	35.96583	49.800
d84	98.11364	174.500

Mid-Riffle		
<2	5	
2	0	
2.8	0	
4	0	
5.6	0	
8	0	
11	1	
16	6	
22.6	3	
32	12	
45	15	
64	20	
90	24	
128	14	
180	5	
	105	
	Percent	**mm**
d16	8.25276	19.500
d50	32.56770	55.300
d84	91.64871	167.500

Sub-Pavement		
<2	4	
2	0	
2.8	3	
4	6	
5.6	11	
8	13	
11	18	
16	22	
22.6	21	
32	10	
45	8	
64	0	
90	0	
128	0	
180	0	
	116	
	Percent	**mm**
d16	51.97061	17.800
d50	94.71830	49.800
d84	100.00000	174.500

APPENDIX F – RESTORATION OPTION COST ESTIMATES

The following information provides preliminary cost estimates for planning purposes. Actual costs for design and construction activities may vary substantially from these estimates. Assumptions for time requirements and material quantities have been made based on limited information that is available for the site. Information obtained during additional site investigations will be needed to determine actual quantities and costs. Estimates based on 2012 costs.

Subreach 2 - Levee Breach Option A1

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$6,000	$6,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	0.5	$4,000	$2,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	0.3	$50,000	$15,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	0.5	$5,000	$2,500	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	7,890	$10	$78,900	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Revegetation	AC	0.2	$10,000	$2,000	Assumes revegetation of new floodplain and all disturbed areas - site restoration.
	Construction Subtotal				$106,400	
	Concept Level Construction Cost Range			**- 20%**	**$90,000**	
				+ 20%	**$130,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre

Subreach 2 - Full Levee Removal Option A2

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$21,000	$21,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$10,000	$10,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	0.5	$50,000	$25,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	0.5	$5,000	$2,500	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	31,000	$10	$310,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Revegetation	AC	0.2	$10,000	$2,000	Assumes revegetation of new floodplain and all disturbed areas - site restoration.
	Construction Subtotal				$370,500	
	Concept Level Construction Cost Range			**- 20%**	**$300,000**	
				+ 20%	**$440,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre

Subreach 2 - Realignment Option B

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$30,000	$30,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$4,000	$4,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	1	$50,000	$50,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	2	$5,000	$10,000	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	31,000	$10	$310,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	120	$1,000	$120,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
7	Boulder Ballast (purchased, delivered, installed)	TN	50	$100	$5,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	4	$2,000	$8,000	Assumes revegetation of new floodplain and all disturbed areas - site restoration.
	Construction Subtotal				$537,000	
	Concept Level Construction Cost Range			**- 20%**	**$430,000**	
				+ 20%	**$640,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 2 - Realignment Option C

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$44,000	$44,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$4,000	$4,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	1	$50,000	$50,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	2	$5,000	$10,000	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	42,000	$10	$420,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	220	$1,000	$220,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
7	Boulder Ballast (purchased, delivered, installed)	TN	100	$100	$10,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	9	$2,000	$18,000	Assumes revegetation of new floodplain and all disturbed areas - site restoration
	Construction Subtotal				$776,000	
	Concept Level Construction Cost Range			**- 20%**	**$620,000**	
				+ 20%	**$930,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 2 - Realignment Option D

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$40,000	$40,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$4,000	$4,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	1	$50,000	$50,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	2	$5,000	$10,000	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	39,000	$10	$390,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	190	$1,000	$190,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
7	Boulder Ballast (purchased, delivered, installed)	TN	70	$100	$7,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	7	$2,000	$14,000	Assumes revegetation of new floodplain and all disturbed areas - site restoration
	Construction Subtotal				$705,000	
	Concept Level Construction Cost Range			**- 20%**	**$560,000**	
				+ 20%	**$850,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 2 – Large Woody Debris and Boulder Structures Option E

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$9,000	$9,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$6,000	$6,000	Includes access establishment and staging (single jam).
3	Environmental Protection Measures	LS	2	$10,000	$20,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	1	$5,000	$5,000	Includes clearing and grubbing of all disturbance areas.
5	Large Woody Debris Installation	EA	100	$1,000	$100,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached. Assumes 1 jam at 50 pieces per jam.
6	Boulder Ballast (purchased, delivered, installed)	TN	200	$100	$20,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
7	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance.
Construction Subtotal					$165,000	
Concept Level Construction Cost Range				**- 20%**	**$130,000**	
				+ 20%	**$200,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
AC = Acre
EA = Each
TN = Ton

Subreach 3 - Realignment Option A

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$29,000	$29,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$10,000	$10,000	Includes access establishment and staging. Assumes a temporary bridge across Nason Creek is not required.
3	Environmental Protection Measures	LS	1	$50,000	$50,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	0.5	$5,000	$2,500	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Re-grading	CY	13,000	$10	$130,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	200	$1,000	$200,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
7	Boulder Ballast (purchased, delivered, installed)	TN	800	$100	$80,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of new floodplain bench and all disturbed areas. Includes follow up maintenance.
	Construction Subtotal				$506,500	
	Concept Level Construction Cost Range			**- 20%**	**$410,000**	
				+ 20%	**$610,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 3 - Realignment Option B

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$35,000	$35,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$10,000	$10,000	Includes access establishment and staging. Assumes a temporary bridge across Nason Creek is not required.
3	Environmental Protection Measures	LS	1	$50,000	$50,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	1	$5,000	$5,000	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Re-grading	CY	23,000	$10	$230,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	200	$1,000	$200,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
7	Boulder Ballast (purchased, delivered, installed)	TN	800	$100	$80,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance
Construction Subtotal					$615,000	
Concept Level Construction Cost Range				**- 20%**	**$490,000**	
				+ 20%	**$740,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 4 - Lateral Structures

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$21,000	$21,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$10,000	$10,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	1	$40,000	$40,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	0.5	$5,000	$2,500	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Re-grading	CY	15,000	$10	$150,000	Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	100	$1,000	$100,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached. Assumes 250 logjams.
7	Boulder Ballast (purchased, delivered, installed)	TN	400	$100	$40,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance.
Construction Subtotal					$368,500	
Concept Level Construction Cost Range				**- 20%**	**$290,000**	
				+ 20%	**$440,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Subreach 4-5 - Off-Channel Creation and Enhancement

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$8,000	$8,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$2,000	$2,000	Includes access establishment and staging (per acre).
3	Environmental Protection Measures	LS	1	$10,000	$10,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs (assumes 10K per acre).
4	Clearing and Grubbing	AC	1	$5,000	$5,000	Includes clearing and grubbing of all disturbance areas.
5	Common Excavation/Regrading	CY	6,500	$10	$65,000	Assumes 1 acre of off-channel creation. Assumes an average of 4 feet excavation. Final design criteria and analysis will likely alter these estimates up or down. Assumes disposal or accommodation of material on-site using off-road trucks.
6	Large Woody Debris Installation	EA	30	$1,000	$30,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached. Assumes 30 pieces per acre.
7	Boulder Ballast (purchased, delivered, installed)	TN	120	$100	$12,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
8	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance
	Construction Subtotal				$137,000	
	Concept Level Construction Cost Range			**- 20%**	**$110,000**	
				+ 20%	**$160,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
CY = Cubic Yard
AC = Acre
EA = Each
TN = Ton

Logjams

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$5,000	$5,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$2,000	$2,000	Includes access establishment and staging (single jam).
3	Environmental Protection Measures	LS	1	$10,000	$10,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Clearing and Grubbing	AC	0.5	$5,000	$2,500	Includes clearing and grubbing of all disturbance areas.
5	Large Woody Debris Installation	EA	50	$1,000	$50,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached. Assumes 1 jam at 50 pieces per jam.
6	Boulder Ballast (purchased, delivered, installed)	TN	200	$100	$20,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
7	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance.
Construction Subtotal					$94,500	
Concept Level Construction Cost Range				**- 20%**	**$80,000**	
				+ 20%	**$110,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
AC = Acre
EA = Each
TN = Ton

Subreach 4 - Margin Complexity

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Mobilization and Demobilization	LS	1	$6,000	$6,000	Calculated at 6% of construction subtotal. Rounded to the nearest $1,000.
2	Site Access Measures	LS	1	$10,000	$10,000	Includes access establishment and staging.
3	Environmental Protection Measures	LS	1	$10,000	$10,000	Includes stream diversion/dewatering, fish relocation, and erosion control BMPs.
4	Large Woody Debris Installation	EA	50	$1,000	$50,000	Purchased, delivered, installed. Assumes 30% delivered with root wads attached.
5	Boulder Ballast (purchased, delivered, installed)	TN	200	$100	$20,000	Purchased, delivered, installed. Estimate 4 tons per log (full submerged logs). Boulder ballast requirements may be able to be reduced depending on hydraulics analysis.
6	Revegetation	AC	0.5	$10,000	$5,000	Assumes revegetation of disturbed areas and follow up maintenance.
Construction Subtotal					$101,000	
Concept Level Construction Cost Range				**- 20%**	**$80,000**	
				+ 20%	**$120,000**	*Range of costs are rounded to the nearest $10,000

LS = Lump Sum
TN = Ton
AC = Acre
EA = Each

Riparian Enhancement

No.	Description	Unit	Quantity	Unit Cost	Total Cost	Design and Quantity Assumptions
1	Site Access Measures	AC	1	$2,000	$2,000	Includes establishing access for riparian work.
2	Revegetation	AC	1	$10,000	$10,000	Assumes 1 acre of riparian revegetation work.
Construction Subtotal					$12,000	
Concept Level Construction Cost Range				**- 20%**	**$10,000**	
				+ 20%	**$14,000**	*Range of costs are rounded to the nearest $10,000

AC = Acre

APPENDIX G – UPPER WHITE PINE EVALUATION MATRIX

This matrix describes and evaluates the degree to which potential restoration actions satisfy the restoration objectives. A narrative discussion is included for each action and objective, followed by an interpretation ("Interp") of how well the action satisfies the objective based on the available quantitative or qualitative information, depending on the objective. A 'Low' rating is given for actions that serve to accomplish the objective to a minimal degree; a 'High' rating is given if the action serves to accomplish the objective to a large degree. See the color coding key for the ratings included at the bottom of the table.

Color Coding Key: Low | Low/Moderate | Moderate | Moderate/High | High

	Floodplain and Channel Dynamics				Riparian Forest Condition		Aquatic Habitat				
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 1 Meander-bend Jams and Margin Wood Placements	Floodprone area is significantly affected by the levee to the Railroad grade to theWest and Channelization of the stream. The railroad grade would not be removed or modified. LWD would have no effect on channelization. **Interp: Low/NA**	No significant impact to floodplain inundation expected from the addition of LWD. **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Low/Moderate**	Restores streambank complexity that is more characteristic of reference/historical conditions however will have no effect on channel migration. **Interp: Low/Moderate**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of meander-bend log jams. Wood quantities increased from 2 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool area and quality (depth and cover) at 6 pool locations. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool depth, hiding cover, and velocity refuge is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate/High**
Subreach 2a - Full levee removal or breaching	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be removed. **Interp: High**	The levee would be removed however only the larger peak flow events would inundate the floodplain: Q2 = 0 acre increase from existing condition, Q10= 0 acre increase from existing condition, Q50 = 8 acre increase from existing condition, Q100 = 18 acre increase from existing condition, **Interp: Low/Moderate**	Removing the levee would not help to restore channel pattern and structure. **Interp: Low**	Removing the levee in itself would not restore channel migration or stream banks; the majority of the streambanks are rip-rapped. **Interp: Low**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Large wood would not be increased as a result of implementation of this element. **Interp: Low/NA**	Stream channel and pool habitat would not be rehabilitated as a result of implementation of this element. **Interp: Low/NA**	Off-channel habitat would not be restored as a result of implementation of this element. **Interp: Low/NA**	Spawning habitat would not be increased. **Interp: Low**	No significantincrease in juvenile rearing densities are expected as a result of removing levees. **Interp: Low**

	Floodplain and Channel Dynamics				Riparian Forest Condition		Aquatic Habitat				
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 2b - Full levee removal and stream meanders	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be partially removed and modified. **Interp: Moderate**	The levee would be would be removed and the stream channel cross-section would be modified and streambed elevation would be raised increasing floodplain inundation by the following: Q2 = 3 acre increase from existing condition Q10= 8 acre increase from existing condition Q50 = 18 acre increase from existing condition Q100 =24 acre increase from existing condition **Interp: Moderate/High**	Minor increases in sinuosity. Restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology. **Interp: Moderate**	Approximately 2,000 ft of stream would be rehabilitated. Increased bank complexity (veg and wood in place of riprap and along newly constructed banks). Channel migration would remain impeded to the South by the railroad grade and to a lesser extent to the North from protection of the powerline access corridor. **Interp: Low/Moderate**	Three acre increase in effective riparian area. Existing non-vegetated riprap bank converted to 50-ft wide riparian buffer planted with native species communities at 370 trees/ac **Interp: High (long-term)**	Approximately 50% of the existing non-vegetated riprap bank converted to 50-ft wide native riparian buffer. Planting of native conifers expected to result in future canopy cover >80%. **Interp: High**	This Option includes installation of a series of meander-bend log jams and margin wood placements. Wood quantities increased from 4 pieces per mile to >50 pieces per mile **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased significantly; pools will be increased from 2 pools to 6 within Sub-reach 2. **Interp: High**	Action would potentially reconnect 2 acres of off-channel habitat **Interp: Moderate/High**	This Option has the potential to increase spawning habitat area from 880 square yards to approximately 2,000 square yards. **Interp: High**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 2c - Full levee removal (.5 mile) and full stream channel re-location	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be completely removed and a new stream channel would be constructed. **Interp: High**	The levee would be would be removed and the stream channel & floodplain would be reconstructed. Floodplain inundation by the following: Q2 = 29 acre increase from existing condition Q10= 32 acre increase from existing condition Q50 = 28 acre increase from existing condition Q100 =24 acre increase from existing condition **Interp: High**	This Option restores sinuostiy and natural stream channel migration zone, restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology. **Interp: High**	Approximately 2,600 ft of stream would be reconstructed. Stream banks and complexity would be restored. Channel migration would emulate reference conditions. **Interp: High**	Ten acre increase in effective riparian area. Existing non-vegetated riprap bank converted to 50-ft wide riparian buffer planted with native species communities at 370 trees/ac **Interp: High (long-term)**	Existing non-vegetated riprap bank converted to 100-200-ft wide native riparian buffer. Planting of native conifers expected to result in future canopy cover >80%. **Interp: High**	This Option includes installation of a series of meander-bend and point bar log jams and margin wood placements. Wood quantities increased from 4 pieces per mile to >50 pieces per mile. **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased significantly; pools will be increased from 2 pools to 7 within Sub-reach 2. **Interp: High**	Action would reconnect 2 acres of wetlands, construct an additional 0.8 acre of wetland habitat and approximately 700 feet of side channels. **Interp: High**	This Option has the potential to increase spawning habitat area from 880 square yards to approximately 3,000 square yards. **Interp: High**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: High**

	Floodplain and Channel Dynamics				Riparian Forest Condition		Aquatic Habitat				
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 2d - Preferred Scenario partial levee removal (.3 acre) and partial channel restoration	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The lower 900 feet of the levee would be removed and modified. **Interp: Moderate/High**	The levee would be would be removed and the stream channel & floodplain would be reconstructed *at the lower end of the reach.*. Floodplain inundation by the following: Q2 = 22 acre increase from existing condition Q10= 32 acre increase from existing condition Q50 = 28 acre increase from existing condition Q100 =24 acre increase from existing condition **Interp: High**	This Option restores sinuostiy and natural stream channel migration zone in the lower 900 feet of the Sub-reach. This Option restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology throughout the Sub-reach. **Interp: High**	Approximately 900 ft of stream would be reconstructed, 1,700 ft would be rehabilitated. Stream banks and complexity would be restored in the lower half of the Sub-reach. The upper section of Sub-reach 2 would have increased bank complexity (veg and wood in place of riprap and along newly constructed banks). Channel migration would remain impeded to the South by the railroad grade and to a lesser extent to the North from protection of the powerline access corridor. **Interp: Moderate**	Five acre increase in effective riparian area. Existing non-vegetated riprap bank converted to 50-ft wide riparian buffer planted with native species communities at 370 trees/ac **Interp: High (long-term)**	Approximately 50% of the existing non-vegetated riprap bank converted to 50-ft wide native riparian bufferin the upper section; the lower 900 ft would be restrored to a 100 ft riparian buffer. Planting of native conifers expected to result in future canopy cover >80%. **Interp: High**	This Option includes installation of a series of meander-bend and point bar log jams and margin wood placements. Wood quantities increased from 4 pieces per mile to >50 pieces per mile. **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased significantly; pools will be increased from 2 pools to 7 within Sub-reach 2. **Interp: High**	Action would reconnect 2 acres of wetlands and construct approximately 300 feet of side channels. **Interp: High**	This Option has the potential to increase spawning habitat area from 880 square yards to approximately 3,000 square yards. **Interp: High**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: High**
Subreach 2e Margin LWD and Boulder Placements	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would not be removed or modified as a result of this element. **Interp: Low/NA**	No significant impact to floodplain inundation expected from the addition of LWD. **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Low/Moderate**	Restores streambank complexity that is more characteristic of reference/historical conditions however will have no effect on channel migration. **Interp: Low/Moderate**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of margin LWD. Wood quantities increased from 4 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool area and quality (depth and cover) at 8 pool locations. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool depth, hiding cover, and velocity refuge is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate/High**
Subreach 2 - Off-channel Habitat	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation and off-channel habitat would only be increased as a result of implementation of one of the stream channel realignment emlements or modification or replacement of culverts. **Interp: Moderate**	Increases reach-scale off-channel habitat up to 7 acres **Interp: Low/Moderate**	No significant impact on channel migration or streambanks **Interp: Low/NA**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action will include placement of wood cover in constructed off-channel areas. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Will include creation of new side-channel and off-channel pool habitat **Interp: Moderate**	Includes addition of up to 5 acres of new off-channel and side-channel habitat. **Interp: High**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Created off-channel habitat would be expected to significantly increase juvenile rearing capacity **Interp: High**
Subreach 3 - Realign Option 2	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant increase in 2-yr floodplain inundation. **Interp: Low/Moderate**	Restores circa 1983 alignment (500 ft of 1,500 ft of channel relocated). Retains existing high quality pool-riffle morphology and log jam **Interp: Moderate/High**	Approximately 500 ft of stream moved away from highway. Increased bank complexity (veg and wood in place of riprap). Restoration of long-term migration without interaction with highway embankment (<25-yr return interval avulsion potential). **Interp: Moderate/High**	Existing non-vegetated riprap bank converted to 50-ft wide riparian buffer planted with native species communities at 400 trees/ac **Interp: High (long-term)**	Existing non-vegetated riprap bank converted to 50-ft wide native riparian buffer. Planting of native conifers expected to result in future canopy cover >80%. **Interp: High**	Action includes installation of meander-bend log jams at RM 12.8 and 13. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased. No significant increase in pool frequency. **Interp: Moderate**	Action would create new off-channel habitat in former [relocated] channel area (<0.5 acres) **Interp: Moderate**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**

	Floodplain and Channel Dynamics				Riparian Forest Condition		Aquatic Habitat				
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 3 - Realign Option 2	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation increased by >1 acre, primarily due to off-channel habitat creation **Interp: Moderate**	Restores circa 1949 alignment (800 ft of 1,500 ft of channel relocated). Interaction with existing log jam and some existing high quality habitat is eliminated. **Interp: Moderate**	Approximately 500 ft of stream moved away from highway. Increased bank complexity (veg and wood in place of riprap). Restoration of long-term migration without interaction with highway embankment (<25-yr return interval avulsion potential). **Interp: Moderate/High**	Stream moved away from non-vegetated riprap bank into alignment with existing and planted native riparian buffer. Re-planted at 400 trees/ac. **Interp: High (long-term)**	Stream moved away from non-vegetated riprap bank. Existing and planted trees expected to provide future canopy cover >80%. **Interp: High**	Action includes installation of meander-bend log jams at outside bends of new constructed channel, and possibly a bar apex jam. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased. No significant increase in pool frequency. **Interp: Moderate**	Action would create new off-channel habitat in former [relocated] channel area (~1.5 acres) **Interp: Moderate/High**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool cover and depth is expected in new channel but loss of existing habitat limits total benefits. **Interp: Low/Moderate**
Subreach 4 - Lateral Structures	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant increase in 2-yr floodplain inundation. **Interp: Low/Moderate**	No significant change in pattern from historical conditions. Enhanced pool-riffle morphology. **Interp: Moderate**	Lateral dynamics enhanced with structures (sinuosity increased from 1.00 to 1.04). Streambank moved away from highway for approximately 500-800 lineal ft. Improved bank complexity. **Interp: Moderate/High**	Stream moved away from sparsely vegetated highway embankment for 500-800 lineal feet. Re-planted with native riparian species at 400 trees/ac except on new bar surfaces, which would be expected to naturally recruit willow and cottonwood. **Interp: High (long-term)**	Stream moved away from sparsely vegetated highway embankment for 500-800 lineal feet. Re-planted with native riparian species at 400 trees/ac except on new bar surfaces, which would be expected to naturally recruit willow and cottonwood. Long-term increase in canopy cover assumed to be >50%. **Interp: Moderate/High (long-term)**	Action includes installation of one or two log jam structures between RM 12.4 and 12.7. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Pool frequency will be increased through addition of 1-2 new pools with high quality depth (>5 ft) and cover (wood) habitat. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	Capture, retention, and sorting of gravels in the lee of jams is expected to increase spawning habitat availability and quality, but existing high degree of observed spawning reduces the potential for added benefits **Interp: Low/Moderate**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 3 & 5 Bar Apex Jams	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Moderate**	Enhances lateral channel dynamics (bank deformation) that is more characteristic of reference/historical conditions (>10-20% bank deformation at 25-yr event) **Interp: Moderate/High**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of bar apex log jams. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool frequency to greater than 18 pools/mile and will create high quality pool habitat (depth and cover). **Interp: High**	Apex jams would increase split-flow conditions and formation of side-channels in some locations **Interp: Moderate**	Capture, retention, and sorting of gravels in the lee of jams is expected to increase spawning habitat availability and quality **Interp: Moderate/High**	Increased channel margin (via split-flow around jams) and enhanced pool depth, hiding cover, and velocity refuge is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: High**
Subreach 3-5 Meander-bend Jams	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Moderate**	Restores streambank structure and complexity that is more characteristic of reference/historical conditions **Interp: Moderate**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of meander-bend log jams. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool area and quality (depth and cover) at 5 pool locations. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool depth, hiding cover, and velocity refuge is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate/High**

	Floodplain and Channel Dynamics				Riparian Forest Condition		Aquatic Habitat				
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 4 - Margin Complexity	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Enhances margin structure along 1,500 ft of stream but no significant geomorphic effects **Interp: Low**	Enhances streambank structure and complexity along 1,500 ft of stream **Interp: Low/Moderate**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of channel margin wood. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Pool quality will be increased through increased depth and cover. No significant increase in pool frequency. **Interp: Low/Moderate**	No significant impact on off-channel habitat **Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced cover and margin complexity is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 4-5 - Off-channel Habitat	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation increased by approximately 5 acres due to creation of new off-channel habitats **Interp: Moderate**	Increases reach-scale off-channel availability to be more in-line with historical patterns **Interp: Low/Moderate**	No significant impact on channel migration or streambanks **Interp: Low/NA**	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action will include placement of wood cover in constructed off-channel areas. Wood quantities increased from 26 pieces per mile to >50 pieces per mile. **Interp: High**	Will include creation of new side-channel and off-channel pool habitat **Interp: Moderate**	Includes addition of up to 5 acres of new off-channel and side-channel habitat. **Interp: High**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Created off-channel habitat would be expected to significantly increase juvenile rearing capacity **Interp: High**
Subreach 3-5 - Riparian Enhancement	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Long-term benefits to channel pattern and structure through enhanced bank stability, roughness, and wood recruitment **Interp: Low/Moderate (long-term)**	Long-term benefits to floodplain roughness, streambank vegetation, structure (i.e. wood recruitment), and complexity **Interp: Low/Moderate (long-term)**	Significant impact on riparian species communities. Increase large tree seral class proportion from <10% per acre to 20-30% per acre **Interp: High**	Significant impact on riparian and floodplain canopy cover. Increase of riparian tree canopy cover from <50% to >80% in target areas. **Interp: High**	Riparian plantings are expected to increase LW loading over the long-term **Interp: Moderate (long-term)**	Riparian plantings are expected to increase long-term pool frequency and quality through LW loading over the long-term. **Interp: Moderate (long-term)**	No significant impact on off-channel habitat **Interp: Low**	Riparian plantings are expected to increase long-term LW loading that would retain spawning gravels **Interp: Low/Moderate (long-term)**	Riparian plantings are expected to increase long-term LW loading that would enhance juvenile rearing habitat quantity and quality **Interp: Moderate/High (long-term)**

Color Coding Key:	**Low**	**Low/Moderate**	**Moderate**	**Moderate/High**	**High**

This matrix describes and evaluates how potential restoration actions satisfy the restoration objectives. A narrative discussion is included for each action and objective, followed by an interpretation ("Interp") of how well the action satisfies the objective based on the available quantitative or qualitative information. A 'Low' rating is given for actions that serve to accomplish the objective to a minimal degree; a 'High' rating is given if the action serves to accomplish the objective to a large degree.

	Floodplain and Channel Dynamics			
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**
Subreach 1 Meander-bend Jams and Margin Wood Placements	Floodprone area is significantly affected by the levee to the Railroad grade to the West and Channelization of the stream. The railroad grade would not be removed or modified. LWD would have no effect on channelization. **Interp: Low/NA**	No significant impact to floodplain inundation expected from the addition of LWD. **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Low/Moderate**	Restores streambank complexity that is more characteristic of reference/historical conditions however will have no effect on channel migration. **Interp: Low/Moderate**
Subreach 2a - Full Levee Removal or breaching	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be removed. **Interp: High**	The levee would be removed however only the larger peak flow events would inundate the floodplain: Q2 = 0 acre increase from existing condition, Q10= 0 acre increase from existing condition, Q50 = 8 acre increase from existing condition, Q100 = 18 acre increase from existing condition, **Interp: Low/Moderate**	Removing the levee would not help to restore channel pattern and structure. **Interp: Low**	Removing the levee in itself would not restore channel migration or stream banks; the majority of the streambanks are rip-rapped. **Interp: Low**
Subreach 2b- Levee Removal and Stream Meanders	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be partially removed and modified. **Interp: Moderate**	The levee would be would be removed and the stream channel cross-section would be modified and streambed elevation would be raised increasing floodplain inundation by the following: Q2 = 3 acre increase from existing condition, Q10= 8 acre increase from existing condition, Q50 = 18 acre increase from existing condition, Q100 =24 acre increase from existing condition **Interp: Moderate/High**	Minor increases in sinuosity. Restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology. **Interp: Moderate**	Approximately 2,000 ft of stream would be rehabilitated. Increased bank complexity (veg and wood in place of riprap and along newly constructed banks). Channel migration would remain impeded to the South by the railroad grade and to a lesser extent to the North from protection of the powerline access corridor. **Interp: Low/Moderate**
Subreach 2c - Full Levee Removal (O.5 mile) and Stream relocation	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would be completely removed and a new stream channel would be constructed. **Interp: High**	The levee would be would be removed and the stream channel & floodplain would be reconstructed. Floodplain inundation by the following:Q2 = 29 acre increase from existing condition, Q10= 32 acre increase from existing condition, Q50 = 28 acre increase from existing condition, Q100 =24 acre increase from existing condition **Interp: High**	This Option restores sinuosity and natural stream channel migration zone, restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology. **Interp: High**	Approximately 2,600 ft of stream would be reconstructed. Stream banks and complexity would be restored. Channel migration would emulate reference conditions. **Interp: High**
Subreach 2d - Preferred Scenario - Partial Levee removal (0.3 mile) and partial stream channel restoration	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The lower 900 feet of the levee would be removed and modified. **Interp: Moderate/High**	The levee would be would be removed and the stream channel & floodplain would be reconstructed *at the lower end of the reach.*. Floodplain inundation by the following: Q2 = 22 acre increase from existing condition, Q10= 32 acre increase from existing condition, Q50 = 28 acre increase from existing condition, Q100 =24 acre increase from existing condition **Interp: High**	This Option restores sinuostiy and natural stream channel migration zone in the lower 900 feet of the Sub-reach. This Option restores stream channel cross-section width to depth ratios, riffle-pool-glide morphology throughout the Sub-reach. **Interp: High**	Approximately 900 ft of stream would be reconstructed, 1,700 ft would be rehabilitated. Stream banks and complexity would be restored in the lower half of the Sub-reach. The upper section of Sub-reach 2 would have increased bank complexity (veg and wood in place of riprap and along newly constructed banks). Channel migration would remain impeded to the South by the railroad grade and to a lesser extent to the North from protection of the powerline access corridor. **Interp: Moderate**
Subreach 2e Margin LWD and Boulder Placements	Floodprone area is significantly affected by the levee to the North and Railroad grade to the South. The levee would not be removed or modified as a result of this element. **Interp: Low/NA**	No significant impact to floodplain inundation expected from the addition of LWD.**Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Low/Moderate**	Restores streambank complexity that is more characteristic of reference/historical conditions however will have no effect on channel migration. **Interp: Low/Moderate**
Subreach 2 - Off-channel Habitat	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation and off-channel habitat would only be increased as a result of implementation of one of the stream channel realignment elements or modification or replacement of culverts. **Interp: Moderate**	Increases reach-scale off-channel habitat up to 7 acres **Interp: Low/Moderate**	No significant impact on channel migration or streambanks. **Interp: Low/NA**

This matrix describes and evaluates the degree to which potential restoration actions satisfy the restoration objectives. A narrative discussion is included for each action and objective, followed by an interpretation ("Interp") of how well the action satisfies the objective based on the available quantitative or qualitative information, depending on the objective. A 'Low' rating is given for actions that serve to accomplish the objective to a minimal degree; a 'High' rating is given if the action serves to accomplish the objective to a large degree.

	Floodplain and Channel Dynamics			
Element	**Remove / modify floodplain alterations**	**Increase floodplain inundation**	**Restore natural channel pattern and structure**	**Restore channel migration and streambanks**
Subreach 3 - Realign Option 2	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant increase in 2-yr floodplain inundation. **Interp: Low/Moderate**	Restores circa 1983 alignment (500 ft of 1,500 ft of channel relocated). Retains existing high quality pool-riffle morphology and log jam **Interp: Moderate/High**	Approximately 500 ft of stream moved away from highway. Increased bank complexity (veg and wood in place of riprap). Restoration of long-term migration without interaction with highway embankment (<25-yr return interval avulsion potential). **Interp: Moderate/High**
Subreach 3 - Realign Option 2	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation increased by >1 acre, primarily due to off-channel habitat creation **Interp: Moderate**	Restores circa 1949 alignment (800 ft of 1,500 ft of channel relocated). Interaction with existing log jam and some existing high quality habitat is eliminated. **Interp: Moderate**	Approximately 500 ft of stream moved away from highway. Increased bank complexity (veg and wood in place of riprap). Restoration of long-term migration without interaction with highway embankment (<25-yr return interval avulsion potential). **Interp: Moderate/High**
Subreach 4 - Lateral Structures	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant increase in 2-yr floodplain inundation. **Interp: Low/Moderate**	No significant change in pattern from historical conditions. Enhanced pool-riffle morphology. **Interp: Moderate**	Lateral dynamics enhanced with structures (sinuosity increased from 1.00 to 1.04). Streambank moved away from highway for approximately 500-800 lineal ft. Improved bank complexity. **Interp: Moderate/High**
Subreach 3 & 5 Bar Apex Jams	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Moderate**	Enhances lateral channel dynamics (bank deformation) that is more characteristic of reference/historical conditions (>10-20% bank deformation at 25-yr event) **Interp: Moderate/High**
Subreach 3-5 Meander-bend Jams	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Restores channel structure that will enhance pool creation, gravel recruitment, gravel retention, and gravel sorting that is more characteristic of reference/historical conditions **Interp: Moderate**	Restores streambank structure and complexity that is more characteristic of reference/historical conditions **Interp: Moderate**
Subreach 4 - Margin Complexity	Floodprone area is not significantly affected by human features.**Interp: Low/NA**	No significant impact to floodplain inundation expected**Interp: Low/NA**	Enhances margin structure along 1,500 ft of stream but no significant geomorphic effects **Interp: Low**	Enhances streambank structure and complexity along 1,500 ft of stream**Interp: Low/Moderate**
Subreach 4-5 - Off-channel Habitat	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	2-yr floodplain inundation increased by approximately 5 acres due to creation of new off-channel habitats **Interp: Moderate**	Increases reach-scale off-channel availability to be more in-line with historical patterns **Interp: Low/Moderate**	No significant impact on channel migration or streambanks **Interp: Low/NA**
Subreach 3-5 - Riparian Enhancement	Floodprone area is not significantly affected by human features. **Interp: Low/NA**	No significant impact to floodplain inundation expected **Interp: Low/NA**	Long-term benefits to channel pattern and structure through enhanced bank stability, roughness, and wood recruitment **Interp: Low/Moderate (long-term)**	Long-term benefits to floodplain roughness, streambank vegetation, structure (i.e. wood recruitment), and complexity **Interp: Low/Moderate (long-term)**

This matrix describes and evaluates the degree to which potential restoration actions satisfy the restoration objectives. A narrative discussion is included for each action and objective, followed by an interpretation ("Interp") of how well the action satisfies the objective based on the available quantitative or qualitative information, depending on the objective. A 'Low' rating is given for actions that serve to accomplish the objective to a minimal degree; a 'High' rating is given if the action serves to accomplish the objective to a large degree.

	Riparian Forest Condition		Aquatic Habitat				
Element	**Restore riparian species communities**	**Increase riparian canopy cover**	**Increase large wood**	**Restore stream channel and pool habitat**	**Restore off-channel habitat**	**Increase redd densities**	**Increase juvenile rearing densities**
Subreach 3 - Realign Option 2	Existing non-vegetated riprap bank converted to 50-ft wide riparian buffer planted with native species communities at 400 trees/ac. **Interp: High (long-term)**	Existing non-vegetated riprap bank converted to 50-ft wide native riparian buffer. Planting of native conifers expected to result in future canopy cover >80%. **Interp: High**	Action includes installation of meander-bend log jams at RM 12.8 and 13. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased. No significant increase in pool frequency. **Interp: Moderate**	Action would create new off-channel habitat in former [relocated] channel area (<0.5 acres) **Interp: Moderate**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 3 - Realign Option 2	Stream moved away from non-vegetated riprap bank into alignment with existing and planted native riparian buffer. Re-planted at 400 trees/ac. **Interp: High (long-term)**	Stream moved away from non-vegetated riprap bank. Existing and planted trees expected to provide future canopy cover >80%. **Interp: High**	Install meander-bend log jams at outside bends of new constructed channel, and possibly a bar apex jam. Wood quantities increased from 26/mile to >50/mile **Interp: High**	The quality of pool habitat with respect to depth and cover will be increased. No significant increase in pool frequency. **Interp: Moderate**	Action would create new off-channel habitat in former [relocated] channel area (~1.5 acres) **Interp: Mod/High**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool cover and depth is expected in new channel but loss of existing habitat limits total benefits. **Interp: Low/Moderate**
Subreach 4 - Lateral Structures	Stream moved away from sparsely vegetated highway embankment for 500-800 lineal feet. Replanted with native riparian species at 400 trees/ac except on new bar surfaces, which would be expected to naturally recruit willow and cottonwood. **Interp: High (long-term)**	Stream moved away from sparsely vegetated highway embankment for 500-800 lineal feet. Re-plant native riparian species at 400 trees/ac; new bar surfaces would naturally recruit willow and cottonwood. Increase in canopy cover assumed to be >50%. **Interp: Mod/High (long-term)**	Action includes installation of one or two log jam structures between RM 12.4 and 12.7. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Pool frequency will be increased through addition of 1-2 new pools with high quality depth (>5 ft) and cover (wood) habitat. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	Capture, retention, and sorting of gravels in the lee of jams will increase spawning habitat availability and quality, but existing high degree of observed spawning reduces the potential for added benefits **Interp: Low/Moderate**	Enhanced pool cover and depth is expected to increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 3 & 5 Bar Apex Jams	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of bar apex log jams. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool frequency to greater than 18 pools/mile and will create high quality pool habitat (depth and cover). **Interp: High**	Apex jams would increase split-flow conditions and formation of side-channels in some locations **Interp: Moderate**	Capture, retention, and sorting of gravels in the lee of jams is expected to increase spawning habitat availability and quality **Interp: Moderate/High**	Increased channel margin (via split-flow around jams) and enhanced pool depth, hiding cover, and velocity refuge will increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: High**
Subreach 3-5 Meander-bend Jams	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action includes placement of meander-bend log jams. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Will increase pool area and quality (depth and cover) at 5 pool locations. **Interp: Moderate**	No significant impact on off-channel habitat **Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced pool depth, hiding cover, and velocity refuge will increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Mod/High**
Subreach 4 - Margin Complexity	No significant impact on riparian species communities**Interp: Low/NA**	No significant impact on riparian canopy cover**Interp: Low/NA**	Action includes placement of channel margin wood. Wood quantities increased from 26 pieces per mile to >50 pieces per mile **Interp: High**	Pool quality will be increased through increased depth and cover. No significant increase in pool frequency.**Interp: Low/Moderate**	No significant impact on off-channel habitat**Interp: Low**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Enhanced cover and margin complexity will increase the availability of high quality juvenile rearing habitat for Chinook and steelhead **Interp: Moderate**
Subreach 4-5 - Off-channel Habitat	No significant impact on riparian species communities **Interp: Low/NA**	No significant impact on riparian canopy cover **Interp: Low/NA**	Action will include placement of wood cover in constructed off-channel areas. Wood quantities increased from 26 pieces per mile to >50/ mile **Interp: High**	Will include creation of new side-channel and off-channel pool habitat **Interp: Moderate**	Includes addition of up to 5 acres of new off-channel and side-channel habitat. **Interp: High**	No significant impact of spawning habitat availability is expected. **Interp: Low**	Created off-channel habitat would be expected to significantly increase juvenile rearing capacity **Interp: High**
Subreach 3-5 - Riparian Enhancement	Significant impact on riparian species communities. Increase large tree seral class proportion from <10% per acre to 20-30% per acre **Interp: High**	Significant impact on riparian and floodplain canopy cover. Increase of riparian tree canopy cover from <50% to >80% in target areas. **Interp: High**	Riparian plantings are expected to increase LW loading. **Interp: Mod (long-term)**	Riparian plantings will increase long-term pool frequency and quality through LW loading. **Interp: Mod (long-term)**	No significant impact on off-channel habitat **Interp: Low**	Riparian plantings will increase LW loading that would retain spawning gravels. **Interp:Low/Mod (long-term)**	Riparian plantings are expected to increase long-term LW loading that would enhance juvenile rearing habitat quantity and quality **Interp: Mod/High (long-term)**