Natural Systems Design
Stream & Riparian
Resource Management
P.O. Box 15609
Seattle, WA 98115

June 4th, 2015

Nooksack Tribe
Natural Resource Department
P.O. Box 157 5016
Deming Rd Deming WA 98244

Attention: Treva Coe, Eric Stover

Subject: South Fork Nooksack Nesset's Reach - Preliminary Basis of Design Report

PROJECT BACKGROUND

The South Fork Nooksack River (South Fork) historically supported a healthy population of anadromous fish that included spring Chinook, coho, chum, pink, and sockeye salmon as well as winter and summer-run steelhead, coastal cutthroat and bull trout. Currently, three of these species are listed as threatened or endangered under the Endangered Species Act (ESA). Human actions such as timber harvest, removal of natural logjams, clearing of floodplain forests, channel confinement, bank armoring, and installation of road crossing structures have led to a general simplification of habitat within the Nooksack watershed and are attributed to the recent decline in salmon abundance in the Nooksack watershed (WRIA 1 2005).

The Nooksack Indian Tribe (NIT) has identified the Nesset's Reach of the South Fork as a candidate location for habitat restoration. The proposed restoration reach is between river mile (RM) 12 (upstream end) and RM 10.3 (downstream end). This reach was targeted by NIT for restoration following the recommendations put forth in the WRIA I Recovery Plan (WRIA 1 2005) for the entire South Fork Nooksack.

RESTORATION GOALS AND OBJECTIVES

Restoration concepts utilized a general approach to achieve the following goals;

A. Reduce reach-level constraints to habitat formation (i.e. riprap)
B. Achieve habitat targets in near-term while promoting (or at least not precluding) long-term restoration of habitat-forming processes

Specific near term or immediate restoration objectives for the project reach include:

1. Enhance habitat in cool water refuges
2. Increase local floodplain connectivity
3. Reduce redd scour
4. Increase habitat unit diversity
5. Increase wood formed pools
6. Improve fish passage to Rothenbuhler Slough

Specific longer term restoration objectives for the project reach include:

7. Increase reach floodplain connectivity through channel bed aggradation
8. Improve/increase base flow in lower Hutchinson Creek

Increases in these key habitat metrics would address limiting factors in the reach to ESA listed spring Chinook salmon, as well as other salmonids (WRIA 1 2005) that use the reach. Many of the project objectives would be met by increasing the number of stable accumulations of large wood material (LWM)in the form of engineered logjams (ELJs)In addition to these improvements, higher LWD loading would provide additional hydraulic complexity leading to sorting of spawning gravels, reducing channel energy through stress partitioning, greater instream cover, and potentially bed aggradation.

RESTORATION RECOMMENDATIONS

Habitat conditions within the project reach are degraded in large part due to reach and watershed scale disturbances in the South Fork watershed. Historic disturbances include clearing of riparian forests, removal of in-stream wood, local confinement of the river at the City of Bellingham (COB) water pipeline crossing (RM 10.45), all of which have cumulatively contributed to channel incision as much as 5-feet in the last 30-years (Appendix A). These impacts have in-turn disconnected the river from its floodplain, reduced LWD loading and associated habitat, increased channel migration rates (reduced bank cohesion), limited channel migration at the COB pipeline crossing, and simplification of the channel form. The lack of stable large wood in the river has been a major contributing factor to channel incision throughout the South Fork, as well as contributing to a reduction in the number of pools, amount and quality of complex cover, number of forested islands and side channels, and total channel length (sinuosity and anabranching). Channel incision within the project reach has also dramatically reduced the off-channel habitat available to salmonids. The loss of functional and stable wood and logjams, effective in partitioning shear stress and reducing stream energy, has resulted in more energy available for channel migration and incision. The slower velocities associated with the pre-disturbance condition would have also resulted in a finer substrate more suitable for spawning salmonids, and higher water surface elevations for any given flow due to backwatering from instream LWM would have resulted in greater floodplain and side channel connectivity. Without countermeasures focusing on re-introduction of stable LWM loading of sufficient frequency to roughen the channel and partition shear stresses, ongoing incision will continue to further degrade habitat conditions within the project reach. A geomorphic, hydrologic, and hydraulic assessment was completed (Appendix A) and provides additional information on historic disturbances, geomorphic response and current hydraulic conditions within the project reach.

The proposed restoration actions are primarily focused on increasing stable LWM in the form of engineered logjams (ELJs) within the project reach to meet the restoration objectives. Increasing stable LWM within the channel is anticipated to promote geomorphic responses listed below, which in turn will address limiting factors.

Geomorphic Response to ELJs	Restoration Goal(s) Met
Primary and secondary pool formation with complex cover	1, 4, 5
Sediment deposition downstream in lee of ELJ	2, 3, 7
Increased water surface elevations (locally)	2, 6, 7, 8
Sediment grain size sorting	3, 4
Reach level bed aggradation	2, 6, 7, 8
Split flow into multiple channels & stable island development	3, 4, 5

In addition to these habitat benefits from re-introducing stable LWM, reducing reach level constraints to habitat formation provide significant habitat improvements. The removal and/or modification of existing bank protection and levees will improve habitat conditions related to these features. The channel and habitat conditions adjacent to these structures is considerably simplified due to lack of complexity from instream LWM, rock lined banks providing limited habitat value and restricting channel migration and the

recruitment of trees, and levees that decrease the magnitude and frequency of overbank floodwaters on adjacent floodplains.

CONCEPTUAL DESIGN DEVELOPMENT

The conceptual restoration designs for the Nesset's Reach on the South Fork were developed to meet the restoration objectives and informed by the geomorphic, hydrologic, and hydraulic analyses completed (Appendix A). Consideration of meeting FEMA and Whatcom County "no-rise" requirements were incorporated into each of the 3 design alternatives developed. Reporting and analyses to support local floodplain regulations will be prepared and submitted to Whatcom County separately.

The 3 conceptual restoration design alternatives were developed for the Nesset's Reach, and are differentiated by the number, types, and locations of proposed ELJs, restoration actions along the COB water pipeline levee, and side channel improvement strategies. These options provide a range of anticipated habitat benefits and implementation costs for consideration to reach consensus on a preferred alternative.

PROJECT COMPONENTS

The proposed restoration elements include ELJs constructed with a core of structural logs partially embedded into the channel and arranged to induce a desired hydraulic and geomorphic effect. Each ELJ includes a large volume of smaller logs packed on the upstream end and flanks of the ELJ to provide complex interstitial cover for fish, and additional stability to the structure by forcing scour away from the core structure. Existing natural logjams within the project reach and historic logjams formed by old growth trees were used to size the proposed structures, as well as mimic the ecological and geomorphic function contributing to beneficial habitat within the Nesset's reach. Based on these criteria, 4 structure architectures are proposed, each unique in the geomorphic and habitat benefits provided. The developed structure types are as follows:

- Type 1 ELJ – Type 1 ELJs are the largest proposed structures with a width and length of 85- and 100-feet, respectively. Type 1 ELJs will mimic the geomorphic, ecologic and hydraulic function once provided by large old growth trees that once lined the banks and were recruited into the channel of the South Fork. These structures are intended to force primary pool formation on the upstream end, promote stable forested island development downstream, increase instream cover, sort spawning sized gravels, and with a sufficient number of structure densely spaced, will decrease overall basal shear stresses reach-wide to promote bed aggradation to improve floodplain and side channel connectivity. Type 1 ELJs will be excavated into the channel bed to protect the structure from scour and will be post supported.
- Type 2 ELJ – Type 2 ELJs are a medium sized structure with a width and length of 55- and 80-feet, respectively. Type 2 ELJs will provide similar geomorphic, ecologic, and hydraulic benefits as the Type 1 ELJs, but at a smaller scale. The Type 2 structures have been strategically placed to function with adjacent ELJs to increase habitat benefits while providing cost savings. Type 2 structures will be excavated into the channel bed to protect the structure from scour, is post supported, and cost less than Type 1 structures.
- Type 3 ELJ – Type 3 ELJs are a large structure with a width and length of 75- and 35-feet, respectively. Type 3 ELJs will provide similar geomorphic, ecologic, and hydraulic benefits as the Type 1 ELJs, but at a much lower cost. To reduce construction costs, Type 3 structures will be excavated to a nominal depth into the channel, are post supported, and uses a smaller number of key pieces. To have its intended effect, the Type 3 structure relies on trapping mobile wood

moving through the project reach to create a large stable wood accumulation over time. Minimizing the excavation depth and number of key pieces results in significant cost savings, but also results in a less robust structure in the short-term. Stability will increase over time as additional logs rack onto the structure keeping scour from the core. Locations for Type 3 structure were chosen that are lower energy or have less severe hydraulic conditions where natural LWD would be likely to deposit and where the structure is at a lower risk of becoming unstable.

- Type 4 ELJ – Type 4 ELJs are small sized structures with a width and length of 40- and 60-feet, respectively. Type 4 ELJs are similar in size and function to the Type 2 ELJs, however they are designed such that they can more easily be constructed in the flowing channel via helicopter or ground based construction methods. The structures will not be excavated into the channel bed, but rather placed on top of the existing channel bed, reducing water management and excavation costs. Buoyant, lateral, and scour stability is achieved using rock collars, with stability increasing over time as scour causes the structure to settle and become embedded into the channel.

In addition to the proposed ELJs, restoration of the existing right bank levee near the COB water supply pipeline is proposed to improve habitat conditions. The COB water supply pipeline crosses the South Fork at RM 10.45 and is protected in part by levees on either side of the river. These levees are primarily intended to restrict channel migration and avulsions that could threaten the pipeline, rather than flooding of property which is more typical of levees. Restoration is focused on improving habitat conditions where levees are present, while maintaining the intent of the structure in protecting the pipeline by reducing the height of the levee and constructing two gaps along the levee alignment. Actions to improve habitat conditions along the existing levees are discussed for each concept design alternative in the following section of this report.

Several side channels, including Rothenbuhler Slough, were identified for potential restoration actions to improve off channel habitat conditions. To counteract off-channel habitat loss due to ongoing incision, the inlets to remnant side channels were evaluated for deepening using a track mounted excavator. The proposed side channel excavation elevations were evaluated using the existing conditions hydraulic results for the 1-year flow, with inverts set to be 2-feet below the 1-year water surface elevation (WSEL) or approximate ordinary high water mark (OHWM) at the inlet location. Clearing of underbrush along the side channels was also evaluated to reduce roughness to accelerate flows and further development of the side channels given the additional flow from the lowered inlet. Increasing the frequency and magnitude of side channels was also evaluated in helping to alleviate reach-scale increases in flood elevations (for "no rise" requirements) due to other project elements.

CONCEPTUAL RESTORATION DESIGN ALTERNATIVE 1

The restoration approach for alternative 1 (Figures 1 and 2) is to improve channel and habitat stability, habitat quality and quantity, and develop forested islands and an anabranching planform through the creation of stable accumulations of LWD by constructing 31 ELJs at strategic locations. The locations were developed to have both individual habitat benefits associated with each ELJ, and to cumulatively influence hydraulics and geomorphic processes to restore historic habitat conditions. The added roughness to the channel and partitioning of shear stresses associated with the cumulative effects of the ELJs is anticipated to initiate reach scale aggradation that will further increase floodplain and side channel connectivity. The number of proposed ELJs in alternative 1 is considered the minimum necessary to influence geomorphic processes over the long term to ensure habitat benefits realized will be maintained.

To increase conveyance capacity of existing but disconnected side channels by decreasing roughness, clearing of underbrush is proposed (Figure 1). Activation of these existing side channels proposed for clearing is expected to increase due to increased WSE from proposed ELJs, and clearing of vegetation would increase flow velocity and promote channel development to accommodate the additional flow. A secondary

anticipated benefit is to assist in achieving "no rise" compliance by lowering the reach scale WSEL due to the additional conveyance capacity. A total of 5,400-feet are proposed for side channel clearing, with all material removed to be incorporated into the proposed ELJs as racking and slash. Preliminary hydraulic assessments indicated that the reduced roughness from clearing the side channels was insignificant in reducing reach scale flood elevations.

Habitat conditions along the existing right bank levee will be improved by partial or complete removal of the levee and rock facing, and installation of 3 Type 2 ELJs adjacent to where the levee is completely removed (Figure 2). Sections of the levee proposed for complete removal (red hatch) (Figure 2) include removal of all rock facing, and removal of the levee down to the river bed (607-ft total). Partial removal (yellow hatch) (Figure 2) of the levee includes removal of the rock facing and levee down to the ordinary high water mark (OHWM) (1,594-ft total). Two sections of levee are proposed for restoration, including the right bank levee from RM 10.55 to 10.82 (1,549-ft), and left bank levee from RM 10.4 to 10.5 (652-ft) immediately upstream of the COB pipeline. The right bank levee is completely removed (red hatch) at the inlet and outlet of the old channel that was cut-off when the levee was constructed (416-ft total). Removal of the top portion of the levee will increase the magnitude and frequency of overbank flooding on the adjacent floodplains, increasing off channel refugia and result in reach scale reductions in WSE to assist in achieving "no-rise" compliance. The proposed ELJs will increase cover and complexity along these simplified banks, while retaining the rock armor below OHWM will continue to provide protection to the pipeline.

CONCEPTUAL RESTORATION DESIGN ALTERNATIVE 2

The restoration approach for alternative 2 (Figures 3 and 4) is to improve channel and habitat stability, habitat quality and quantity, and develop forested islands and an anabranching planform through the creation of stable accumulations of LWD by constructing 41 ELJs at strategic locations. The locations were developed to have both individual habitat benefits associated with each ELJ, and to cumulatively influence hydraulics and geomorphic processes to restore historic habitat conditions. The added roughness to the channel and partitioning of shear stresses associated with the cumulative effects of the ELJs is anticipated to initiate reach scale aggradation that will further increase floodplain and side channel connectivity. The number of ELJ in alternative 2 will provide the necessary influence to geomorphic processes over the long term to ensure habitat benefits realized will be maintained.

To increase conveyance capacity of existing but disconnected side channels, clearing of underbrush and limited excavation at the side channel inlets is proposed (Figure 3). Activation of these existing side channels proposed for clearing and grading is expected to increase due to increased WSE from proposed ELJs, lowering the inlet invert elevation, and clearing of vegetation would cumulatively increase flow velocity and promote channel development to accommodate the additional flow. A secondary anticipated benefit is to assist in achieving "no rise" compliance by lowering the reach scale WSE due to the additional conveyance capacity. A total of 3,193-feet are proposed for side channel clearing and 2,900-feet for grading, with all material removed to be incorporated into the proposed ELJs as racking and slash. Preliminary hydraulic assessments indicated that the reduced roughness from clearing the side channels and lowering of the inlet elevations was insignificant in reducing reach scale WSE.

Habitat conditions along the existing right bank levee will be improved by partial or complete removal of the levee and rock facing, and installation of 3 Type 2 ELJs adjacent to where the levee is completely removed (Figure 4). Sections of the levee proposed for complete removal (red hatch) (Figure 4) include removal of all rock facing, and removal of the levee down to the river-bed (850-ft total). Partial removal (yellow hatch) (Figure 4) of the levee includes removal of the rock facing and levee down to the ordinary high water mark (OHWM) (1,350-ft total). To increase the complexity and cover along the entire levees, a matrix of rock collar ballasted logs with rootwads, similar to that built upstream in the Saxon Reach, is proposed were the levee is partially removed. The matrix of rock and logs would be constructed on top of

the existing rock revetment, ensuring protection of the pipeline, while improving habitat conditions in this simplified reach of the South Fork.

Two sections of levee are proposed for restoration, including the right bank levee from RM 10.4 to 10.5 (1,550-ft), and left bank levee from RM 10.55 to 10.82 (650-ft) immediately upstream of the COB pipeline. The right bank levee is completely removed (red hatch) at the inlet and outlet of the old channel that was cut-off when the levee was constructed. Removal of the top portion of the levee will increase the magnitude and frequency of overbank flooding on the adjacent floodplains, increasing off channel refugia and result in reach scale reductions in WSE to assist in achieving "no-rise" compliance. The proposed ELJs will increase cover and complexity along these simplified banks, while retaining the rock armor below OHWM will continue to provide protection to the pipeline.

CONCEPTUAL RESTORATION DESIGN ALTERNATIVE 3

The restoration approach for alternative 3 (Figures 5 and 6) is to improve channel and habitat stability, habitat quality and quantity, and develop forested islands and an anabranching planform through the creation of stable accumulations of LWD by constructing 42 ELJs at strategic locations. The locations were developed to have both individual habitat benefits associated with each ELJ, and to cumulatively influence hydraulics and geomorphic processes to restore historic habitat conditions. The added roughness to the channel and partitioning of shear stresses associated with the cumulative effects of the ELJs is anticipated to initiate reach scale aggradation that will further increase floodplain and side channel connectivity. The number of ELJ in alternative 3 will provide the necessary influence to geomorphic processes over the long term to ensure habitat benefits realized will be maintained.

To increase conveyance capacity of existing but disconnected side channels, clearing of underbrush and limited excavation at the side channel inlets is proposed (Figure 5). Activation of these existing side channels proposed for clearing and grading is expected to increase due to increased WSE from proposed ELJs, lowering the inlet invert elevation, and clearing of vegetation would cumulatively increase flow velocity and promote channel development to accommodate the additional flow. A secondary anticipated benefit is to assist in achieving "no rise" compliance by lowering the reach scale WSE due to the additional conveyance capacity. A total of 3,193-feet are proposed for side channel clearing and 2,894-feet for grading, with all material removed to be incorporated into the proposed ELJs as racking and slash. Preliminary hydraulic assessments indicated that the reduced roughness from clearing the side channels and lowering of the inlet elevations was insignificant in reducing reach scale flood elevations.

Habitat conditions along the existing right bank levee will be improved by partial removal of the levee and rock facing, and installation of 2 Type 4 ELJs and 1 Type 2 ELJ adjacent to where the levee is partially removed (Figure 6). Partial removal (yellow hatch) (Figure 6) of the levee includes removal of the rock facing and levee down to the ordinary high water mark (OHWM) (1,700-ft total). Removal of the top portion of the levee will increase the magnitude and frequency of overbank flooding on the adjacent floodplains, increasing off channel refugia and result in reach scale reductions in WSEL to assist in achieving "no-rise" compliance. To increase the complexity and cover along the entire levees, a matrix of rock collar ballasted logs with rootwads, similar to that built upstream in the Saxon Reach, is proposed. The matrix of rock and logs would be constructed on top of the existing rock revetment, ensuring protection of the pipeline, while improving habitat conditions in this simplified reach of the South Fork.

PREFERRED CONCEPT DESIGN

Based on NIT and stakeholder comments, a preferred alternative was selected based on the habitat benefits and costs. ELJ types and placement locations were taken from alternative 2 and modified to maximize habitat benefits. It was decided that no clearing or grading be proposed for the left bank side channels, but the 2 short excavations at the upstream end of the project reach from alternatives 2 and 3 remain. The

restoration actions along the existing levees at the downstream end of the project reach were chosen from alternative 1, including a combination of partial and complete removal of the levees. The selected preferred alternative was used to further design development into the preliminary design.

STAKEHOLDER CONSULTATION

NIT staff have contacted all landowners in the reach to inform them that restoration project designs are underway. In addition, Tribal staff have met with the following landowners and documented any concerns:

- Whatcom County Parks. Parks Director Michael McFarlane has been notified of the project, but Tribal staff have not yet met with him to discuss any constraints.
- Claire Galbraith Family LLC. Gail Everett and Sandy Luke are co-owners; Randy Luke (Sandy's husband) is taking the lead in any decision making. They have expressed that they are not interested in full-scale channel migration, but they are not concerned with a little more flooding behind the levee. Some bank deformation and scalloping at the bank would be acceptable, but they would like it to be controlled. They are supportive of the concept of lowering and notching the levee, and constructing log jams along it.
- Clare and Virginia Hellyer. Claire passed on, and Tribal staff have contacted Reed Hellyer, one of the heirs and a cousin of Gail and Sandy Everett (co-owners of the Claire Galbraith Family LLC property). He indicated his feedback on the project would likely be similar to theirs. Reed also needs to discuss any decisions with his siblings.
- Nicholas Guilford and Amy Pospisil are generally supportive of the project and would allow access if needed. They do have concerns about the South Fork eroding into the left bank just upstream of their house and flooding near his home.
- The Whatcom Land Trust is very supportive of restoration in the reach. They have expressed concerns about clearing of existing floodplain vegetation to promote floodplain channel connectivity.
- Lawson Curtis and Valerie Lloyd are very supportive of restoration in the reach. They do keep livestock, and they are amenable to accessing the reach through their property as long as we call in advance, ensure gates remain closed and limit number of trips to the extent possible. Their access road will likely need to be improved for larger equipment.
- City of Bellingham. Staff contacted Clare Fogelsong, Natural Resources Policy Manager. They are not concerned with increased flooding but with lateral migration and/or downcutting that would comprise the City's water pipeline that crosses under the South Fork at the lower end of the reach.
- Donald and Lois Thorndike's property was recently sold to Jeff Rainey. Tribal staff have not yet contacted Jeff Rainey, but he generally supports salmon habitat restoration that does not negatively impact his business (i.e. through erosion of land in production).
- Jean Rothenbuhler is in assisted living, and her niece Lois has power of attorney. Lois and her husband are generally supportive of restoration. The farm has been leased to Jeff Rainey, and he plans to install elk fencing on the property, so any access through the property will need to be coordinated.

While tubing is prevalent in the South Fork downstream, this reach is closed to "limb-propelled devices". There is, however, recreational use by swimmers and occasional boaters during summer, as well as wading and boating during other times of the year. Potential recreation impacts were considered during design process and minimized to the extent possible. Safety signage will be installed on each structure and at known access points and area stores and restaurants. Applying for the Washington State Department of

Natural Resources Aquatic Lands Conservation License requires the completion of the *DNR Public Safety Checklist for Large Woody Debris Projects*.

PRELIMINARY DESIGN DEVELOPMENT

The preliminary design (Appendix B) was developed based on the selected preferred concept design, with additional design including refinement of the preferred alternative details, and determining access, staging, and temporary erosion and sediment control (TESC) measures. Proposed ELJ locations were modified where adjustments would maximize the geomorphic response and habitat benefits, while meeting the permit requirements. Due to the size of the reach and number of proposed restoration elements, the project reach was divided into 3 distinct phases to facilitate funding the project over several years and the short in-stream construction period on the South Fork. The site sequence was chosen to start with the furthest upstream Phase 1, and work downstream to Phase 3.

PHASE 1 PROJECT AREA

The Phase 1 project area is located 0.9 miles downstream of the Saxon Road Bridge, and extends 0.6 miles downstream to RM 11.4 (Appendix B, sheet 5). The restoration approach for Phase 1 is to re-establish an anabranching planform through the creation of stable accumulations of LWM. These accumulations will be established by constructing ELJs that will split flows over a range of discharges, forming stable forested islands in the lee of the structure over time. Restoring an anabranching planform will reduce channel widths and increase depths compared to the current channel, and the ELJs will maintain pools as downward vortices are created as flow impinges on the structures. The proposed ELJs are located across the active channel width, increasing the probability that multiple structures are engaged with the channel over time as it migrates across the floodplain and anabranching planform is developed. The placement of ELJs is such that when flow is deflected around structures it is then directed toward downstream ELJs, increasing the likelihood of engagement with the channel, and inducing reach-scale increases in water surface elevations (increased floodplain and side channel connection) and decreases in velocity and shear stress to promote bed aggradation and channel stability.

The proposed ELJs are laid out in strategic locations to maximize their hydraulic, geomorphic and habitat forming benefits both immediately following construction and in the long-term. The ELJs function individually and cumulatively to meet the project objectives. Individually, the proposed ELJs will provide pool and cover habitat, locally increase water surface elevations when engaged with flow, trap mobile LWM during floods, and increase instream roughness. The cumulative function of the ELJs impacts a much larger area, and can begin to restore broader objectives of floodplain and side channel connectivity, improved channel stability through shear stress partitioning, and maintaining stable habitat features over time.

Specific descriptions for each structure placement within this site are as follows;

1. ELJs 1-3-1, 1-3-2, 1-3-3, and 1-3-4 are all Type 3 structures that are designed to obstruct the current channel and deflect flows toward the right and form multiple flow splits. Minor excavations on the left and right of ELJ 1-3-1 will encourage these flow splits into existing high flow channels and toward other proposed ELJs downstream. The split of flow at these structures will also reduce active bank erosion on the left side of the channel downstream of ELJ 1-3-3, where a narrow riparian buffer exists between the channel and a cleared pasture. This group of structures will also trap large trees currently being recruited into the channel from ongoing migration of the upstream left bank. Primary pools interacting with the main channel are anticipated with each of these structures.

2. ELJs 1-3-5, 1-3-9, and 1-3-11 are all Type 3 structures designed to interact with the additional flow down the right side of the channel resulting from the cluster of ELJs upstream (ELJs 1-3-1, 1-3-2, 1-3-3, 1-3-4). These structures will help to limit the possibility of the channel capturing Nesset Creek, which flows just beyond the right active channel margin. Initially, secondary pools are anticipated with each of these structures, however development of the flow split upstream could convert these to primary pools interacting with the new channel thread.
3. ELJs 1-3-6, 1-3-7, and 1-3-8, are all Type 3 structures placed to split flows and rack large trees recruited into the channel from erosion of the left bank immediately upstream. Forested islands are expected to develop in the lee of these structures and around flow splits, increasing overall channel length and edge habitat. Initially, primary pools are anticipated for ELJ 1-3-7 adjacent to the current channel, with secondary pools associated with ELJs 1-3-6 and 1-3-8. As the site evolves over time, there could be a shift in which of these ELJs have primary versus secondary pools.
4. ELJs 1-3-10 and 1-3-12 are both Type 3 structures designed to impinge on the channel and deflect flows to the left toward ELJ 1-3-17. Their location downstream of the actively eroding left bank upstream sets these structures in a location to recruit mobile LWM due to this erosion. The local increase in WSE and deflection of flow toward the left will also increase the magnitude and frequency of activation of the side channel whose inlet is immediately upstream of ELJ 1-3-17. A primary pool is anticipated to develop adjacent to 1-3-10 and secondary pool at ELJ 1-3-12.
5. ELJ 1-3-17 is a Type 3 structures located to interact with additional flow down the left side of the channel (due to ELJs 1-3-10 and 1-3-12) creating a secondary pool, and to locally increase WSEL to further increase the magnitude and frequency of activation of the side channel immediately upstream of the structure.
6. ELJs 1-3-13, 1-3-15, and 1-3-16 are Type 3 structures, and ELJ 1-4-14 a Type 4 structure, designed to obstruct the channel and split and deflect flows toward the left and away from the right bank where the channel is currently located. The combined effect of these structures is to roughen the current channel alignment to promote a split(s) toward the center of the active channel and toward ELJ 1-3-18. The significant obstruction of the channel will increase WSE at the reach scale to improve floodplain and side channel connection. Primary pools are anticipated with ELJs 1-3-13, 1-4-14, and 1-3-16, and secondary pool with ELJ 1-3-15. As the site evolves over the long-term, pool types associated with each ELJ may change as the channel adjusts and new channels are formed.
7. ELJ 1-3-20, is a Type 3 structure, and 1-4-19, a Type 4 structure, located on either side of the active channel to constrict flow and induce a flow split to the left toward downstream ELJs 1-3-21 and 1-3-22 and side channel inlets. The confinement and narrowing of the channel will maintain deep primary pools associated with each of these structures, and significantly increase WSE to improve floodplain and side channel connectivity.
8. ELJ 1-3-18 is a Type 3 structure located to interact with flows along the left bank introduced from flow deflections and overall increases in WSEL from upstream structures. This structure will create a secondary pool and deflect flows toward the downstream ELJ 1-3-22.
9. ELJs 1-3-21 and 1-3-22 are both Type 3 structures designed to deflect and split flows within the active channel and toward the inlet to adjacent side channel inlets on the left bank floodplain immediately upstream of ELJ 1-3-22. The close proximity of the structures will induce a significant increase in WSE upstream of the structures, further increasing the frequency and

magnitude of discharge into the adjacent side channel inlet. Secondary pools are anticipated to form with each structure, however these may evolve into primary pools as the site develops over time.

TABLE 1 – PHASE 1 RESTORATION ELEMENT SUMARY

RESTORATION ELEMENT	TYPE	PRIMARY RESTORATION OBJECTIVES ACHIEVED*
ELJ 1-3-1	3	2, 3, 4, 5, 7
ELJ 1-3-2	3	2, 3, 4, 5, 7
ELJ 1-3-3	3	2, 3, 4, 5, 7
ELJ 1-3-4	3	2, 3, 4, 5, 7
ELJ 1-3-5	3	1, 2, 4, 5
ELJ 1-3-6	3	2, 4, 5
ELJ 1-3-7	3	2, 4, 5
ELJ 1-3-8	3	2, 4, 5
ELJ 1-3-9	3	1, 2, 4, 5
ELJ 1-3-10	3	2, 4, 5
ELJ 1-3-11	3	1, 2, 4, 5
ELJ 1-3-12	3	2, 4, 5
ELJ 1-3-13	3	2, 4, 5
ELJ 1-4-14	4	2, 4, 5
ELJ 1-3-15	3	2, 4, 5
ELJ 1-3-16	3	2, 4, 5
ELJ 1-3-17	3	1, 2, 4, 5
ELJ 1-3-18	3	1, 2, 4, 5
ELJ 1-4-19	4	1, 2, 4, 5
ELJ 1-3-20	3	2, 4, 5
ELJ 1-3-21	3	2, 4, 5
ELJ 1-3-22	3	1, 2, 4, 5

** numbers correspond to list of restoration objectives on pages 1*

PHASE 2 PROJECT AREA

The Phase 2 project area extends from RM 11.4 – 11.0 (Appendix B, sheet 6). The restoration approach for Phase 2 is to significantly roughen and obstruct the main stem channel throughout the sub-reach to improve floodplain and side channel connection, promote conditions that will lead to long-term aggradation, and increase instream complexity and cover through the creation of stable accumulations of LWM. These accumulations will be established by constructing ELJs that will split flows over a range of discharges, forming stable forested islands in the lee of the structure over time. The increased roughness in the channel and obstruction to flow will increase flow depths compared to the current channel, and the ELJs will maintain pools as downward vortices are created as flow impinges on the structures. The

proposed ELJs are located across the active channel width, increasing the probability that multiple structures are engaged with the channel over time as it migrates across the floodplain and anabranching planform is developed. The placement of ELJs is such that when flow is deflected around structures it is then directed toward downstream ELJs, increasing the likelihood of engagement with the channel, and inducing reach-scale increases in water surface elevations (increased floodplain and side channel connection) and decreases in velocity and shear stress to promote bed aggradation and channel stability. The structures are also located to improve the low-flow connection with the cold water refugia found in Pond Creek.

The proposed ELJs are laid out in strategic locations to maximize their hydraulic, geomorphic and habitat forming benefits both immediately following construction and in the long-term. The ELJs function individually and cumulatively to meet the project objectives. Individually, the proposed ELJs will provide pool and cover habitat, locally increase water surface elevations when engaged with flow, trap mobile LWM during floods, and increase instream roughness. The cumulative function of the ELJs impacts a much larger area, and can begin to restore broader objectives of floodplain and side channel connectivity, improved channel stability through shear stress partitioning, and maintaining stable habitat features over time. Specific descriptions for each structure placement within this site are as follows;

10. ELJs 2-1-23 and 2-1-24 are both Type 1 structures that are designed to obstruct the current channel and constrict flows to significantly increase WSE upstream. Constriction and the associated backwatering at this location will increase the magnitude and activation frequency of the floodplain and side channel upstream of ELJ 2-1-24. Primary pools interacting with the main channel are anticipated with each of these structures.

11. ELJs 2-4-25, 2-4-26, and 2-4-27 are all Type 4 structures designed to be constructed in the low-flow channel and provide immediate primary pool and cover habitat. This section of the South Fork is a plane bed channel lacking complexity and cover. These proposed structures constructed out in the middle of the channel will provide immediate complexity within this section of the South Fork by deflecting flows and forcing scour adjacent to the structures. The deflected flows will likely initiate local bank erosion on the left side of the channel, adding additional complexity from recruited trees. Backwatering due to these structures will increase WSE and activation magnitude and frequency of the adjacent left bank floodplain.

12. ELJ 2-3-28 is a Type 3 structure designed to split and deflect flows toward the Pond Creek confluence downstream. A forested island is expected to develop in the lee of this structure, increasing the overall channel length and edge habitat. Due to its location in the center of the active channel, a primary pool is expected to be maintained at this structure.

13. ELJ 2-2-29 is a Type 2 structure located at the confluence with Pond Creek and is designed to interact with flows along the right bank introduced from flow deflection from ELJ 2-3-28. This structure will maintain a secondary pool at the confluence with Pond Creek, a known cold water refugia. As the site evolves this pool may be converted to a primary pool as the additional flow from the ELJ 2-3-28 deflection shifts more of the channel directed toward the structure.

14. ELJ 2-3-30 is a Type 3 structure designed to split and deflect flows toward the downstream ELJ 2-2-31. A forested island is expected to develop in the lee of this structure, increasing the overall channel length and edge habitat. Due to its location in the center of the active channel, a primary pool is expected to be maintained at this structure.

15. ELJ 2-2-31 is a Type 2 structure designed to obstruct flow in the main channel to induce formation of a primary pool. The structure will receive additional flow due to deflection

upstream from ELJ 2-3-30. Local increases in WSE due to flow obstruction from this structure will increase the activation magnitude and frequency of the adjacent left bank floodplain.

TABLE 2 – PHASE 2 RESTORATION ELEMENT SUMARY

RESTORATIO N ELEMENT	TYPE	PRIMARY RESTORATION OBJECTIVES ACHIEVED*
ELJ 2-1-23	1	2, 3, 4, 5, 7
ELJ 2-1-24	1	2, 3, 4, 5, 7
ELJ 2-4-25	4	2, 4, 5
ELJ 2-4-26	4	2, 4, 5
ELJ 2-4-27	4	2, 3, 4, 5, 7
ELJ 2-3-28	3	2, 3, 4, 5, 7
ELJ 2-2-29	2	1, 2, 3, 4, 5, 7
ELJ 2-3-30	3	1, 2, 4, 5
ELJ 2-2-31	2	2, 4, 5

** numbers correspond to list of restoration objectives on pages 1*

PHASE 3 PROJECT AREA

The Phase 3 project area extends from RM 11 – 10.3 (Appendix B, sheet 7). The restoration approach for Phase 3 is to significantly roughen and obstruct the main stem channel to increase instream complexity and cover through the creation of stable accumulations of LWM, and improve floodplain and side channel connection to improve off-channel refugia by partially removing the existing levee and associated rock revetment. The LWM accumulations will be established by constructing ELJs that will split flows over a range of discharges and maintain primary and secondary pools. The increased roughness in the channel and obstruction to flow will increase flow depths compared to the current channel, and the partial removal of the levees and rock protection will dramatically increase overbank activation of the adjacent floodplains. Modifications to the existing levees includes the removal of the top portion of the levee extending above the pre-levee floodplain, removal of bank armor above OHWM, and breaching the levee at select locations to engage off-channel floodplain habitat during normal and low flows. Breaches in the levee will be armored using the salvaged rock removed elsewhere on the levee above OHWM (Appendix B, sheet 8). These levee modifications will improve hydrologic connection with the Hutchinson Creek floodplain and Rothenbuhler Slough over a range of discharges. Nearly ⅓ of the structures are proposed along the existing levees where rock armoring creates a much simplified channel margin. The remaining ELJs are located adjacent to the low-flow channel to disrupt flow patterns and improve hydraulic and habitat complexity in this simplified reach of the South Fork.

Specific descriptions for each structure placement within this site are as follows;

16. ELJs 3-3-32 and 3-3-33 are both Type 3 structures that are designed to obstruct the current channel and constrict flows to significantly increase WSE upstream. Constriction and the associated backwatering at this location will increase the magnitude and activation frequency of the floodplain upstream in the Phase 2 reach. Primary pools interacting with the main channel are anticipated with each of these structures.
17. ELJs 3-3-34 and 3-3-35 are both Type 3 structures that are designed to obstruct and deflect the current channel, and constrict flows to significantly increase WSE upstream. High flows will

be deflected from ELJ 3-3-34 toward ELJ 3-3-35, increasing complexity and available primary pool habitat at ELJ 3-3-35. A secondary pool is anticipated associated with ELJ 3-3-34.

18. ELJ 3-2-36 is a Type 2 structure, ELJs 3-4-37, 3-4-38, 3-4-39, 3-4-41 are Type 4 ELJs, and ELJ 3-3-43 a Type 3 structure, all of which are located along existing rock armoring associated with levees constructed to protect the COB water pipeline. These structures will increase habitat complexity along this simplified channel margin by forcing local scour and pool formation, as well as provide instream cover and sediment sorting adjacent to the structures. Local increases in WSE due to flow obstruction from these structures will increase the activation frequency and magnitude of overbank flooding on adjacent floodplains.
19. ELJ 3-3-40 is a Type 3 structure designed to split and deflect flows toward the downstream ELJ 3-4-41 and ELJ 3-3-42. A forested island is expected to develop in the lee of this structure, increasing the overall channel length and edge habitat. Due to its location in the center of the active channel, a primary pool is expected to be maintained at this structure.
20. ELJ 3-3-42 is a Type 3 structure designed to obstruct flow in the main channel to induce formation of a secondary pool. The structure will receive additional flow due to deflection upstream from ELJ 3-3-40. Local increases in WSE due to flow obstruction from this structure will increase the activation magnitude and frequency of the adjacent left bank floodplain.
21. ELJs 3-3-44 and 3-3-45 are both Type 3 structures that are designed obstruct and deflect the current channel, forming flow splits and an anabranching channel planform. Flows will be deflected from ELJ 3-3-44 toward ELJ 3-3-45, increasing complexity and available primary pool habitat at both structures.
22. Bank armor removal above OHWM will allow some channel adjustment locally and provide space for riparian edge establishment to improve cover and shade. Rock removed will be incorporated into other project elements to reduce costs. Due to the presence of the COB water pipeline downstream, rock below OHWM will remain to continue to provide protection to the pipeline from channel migration.
23. Removal of the upper portion of the levee that extends above the pre-levee floodplain elevation will increase the activation magnitude and frequency of overbank flooding over a range of discharges, dramatically increasing off-channel refugia during high flows. Breaches in the levee will be located to introduce lower discharges access to the floodplain, and will be protected from widening and/or lowering by incorporating rock removed from the banks (Appendix B, sheet 8).

TABLE 3 – PHASE 3 RESTORATION ELEMENT SUMARY

RESTORATIO N ELEMENT	TYPE	PRIMARY RESTORATION OBJECTIVES ACHIEVED*
ELJ 3-3-32	3	1, 2, 4, 5
ELJ 3-3-33	3	2, 4, 5
ELJ 3-3-34	3	2, 4, 5
ELJ 3-3-35	3	1, 2, 4, 5
ELJ 3-2-36	2	2, 4, 5, 8
ELJ 3-4-37	4	2, 4, 5, 8
ELJ 3-4-38	4	2, 4, 5, 8

RESTORATION ELEMENT	TYPE	PRIMARY RESTORATION OBJECTIVES ACHIEVED*
ELJ 3-4-39	4	2, 4, 5, 7, 8
ELJ 3-3-40	3	2, 4, 5, 7, 8
ELJ 3-4-41	4	2, 4, 5, 7, 8
ELJ 3-3-42	3	2, 4, 5, 6
ELJ 3-3-43	3	2, 4, 5, 6
ELJ 3-3-44	3	2, 4, 5, 8
ELJ 3-3-45	3	2, 4, 5, 8
Remove Rock below OHWM		1, 3, 4
Remove levee above pre-levee floodplain		2, 7, 8

** numbers correspond to list of restoration objectives on pages 1*

SITE ACCESS

The Phase 1 project area has two existing access roads from the west via Saxon Road allowing left bank access at RM 11.9 and a private driveway at RM 11.5 (Appendix B, sheet 14). A temporary bridge crossing near RM 11.75 will be constructed to enable access to the right bank staging site and restoration elements.

The Phase 2 project area has one existing access road from the west via a private driveway and provides left bank access at RM 11.5 (Appendix B, sheet 15). An additional access route from this driveway to the left bank at RM 11.0 will require some clearing and grubbing of vegetation. Temporary bridge crossings at RM 11.4 and RM 11.0 will enable access to right bank restoration elements and the gravel bar staging area at RM 11.1 (Appendix B, sheet 15).

The Phase 3 project area has an existing access route from the east at RM 10.6 via the COB right of way maintenance road for the water pipeline (Appendix B, sheet 16). This route provides access to right bank restoration elements and the levee adjustments as well as the right bank staging area at RM 10.8. Two other access routes from the west at RM 10.9 and RM 10.5 originate from private driveways and will require some clearing of vegetation (Appendix B, sheet 16).

Depending on the location of the low flow channel during construction, the number and locations of the proposed temporary bridge locations may vary. Access routes follow exposed unvegetated gravel bars where possible to minimize impacts to adjacent riparian vegetation and to avoid known existing LWM. Woody material from clearing will be utilized as racking material in the restoration elements and revegetation of cleared access routes will be included in replanting plans. The location of access routes will be verified prior to construction and modified to accommodate future channel migration and/or redistribution of LWM on bars.

SPAWNING IMPACTS

Spawning redd locations for endangered salmonids were considered in the placement of proposed restoration elements. Spawning redd data from 2000 to 2012 for the project area was provided by the NIT and the Lummi Nation Natural Resources Department in GIS format. Redd locations were overlaid with proposed ELJ, access road, and temporary bridge locations to ensure these elements did not interfere with recently observed redd locations. With the exception of the pit excavation for ELJ 1-3-3, no restoration elements interfere with known spawning locations. All structures to be constructed in the wetted channel

will be reviewed by a permitting agency and NIT biologist prior to construction starting to ensure that recent redds are not disturbed. If any redd or significant fish activity is observed in the immediate structure location, that structure will either not be constructed or relocated at the direction of the NSD engineer of record.

To further reduce impacts to the endangered salmonids, proposed ELJs will be constructed during the allowable in-stream construction window and temporary erosion and sediment control measures will be implemented in accordance with Department of Ecology Stormwater Management Regulations and Best Management Practices for Western Washington. Based upon the distance to observed redd locations, construction period, construction methods, and results from the hydraulic model, the proposed ELJ locations are not anticipated to adversely affect know spawning locations. Furthermore, the location of proposed ELJs proximal to observed redd locations are anticipated to create scour holes and adult holding habitat for spawning salmonids that will enhance these locations over time.

PROPOSED CONDITION HYDRAULICS

A proposed conditions hydraulic model was developed by modifying the existing conditions model (Appendix A) to evaluate the hydraulic effects of proposed restoration elements. The existing conditions model was modified to be representative of proposed conditions by adjusting the elevations within the footprint of the proposed structures to the design elevations of the individual ELJs (Appendix B), and adjusting the roughness value within the footprint of the proposed ELJ. Existing logjams (natural and constructed) are represented as well by higher roughness values in the existing and proposed hydraulic models. All discharges modeled for existing conditions (1-yr and 100-yr peak flows) were modeled for the proposed condition to evaluate the performance of specific project elements over a range of discharges. All model runs were performed in a steady state (discharge does not vary with time) and non-deformable bed (no adjustments for scour, sediment transport, erosion, and deposition). A detailed description of the hydraulic model setup, including data used in its development and parameters used, is provided in the geomorphic and hydraulic assessment (Appendix A). Reach and site scale figures of the proposed hydraulic model outputs are provided in Appendix C for the 1- and 100-year flow simulations.

The results of the proposed conditions hydraulic modeling demonstrate how the design achieves the project objectives by altering the hydraulic conditions during the 1- and 100-year flood. One of the important project objective is to reconnect floodplain and side channel habitat. Improving floodplain connectivity will help to meet several of the project objectives (2, 3, 5). Under existing conditions for the 1-year flood, the right bank side channels adjacent to RM 11.9 are not connected to the mainstem channel at the upstream inlets. Proposed condition hydraulic results suggest a 1-2 ft depth increase in these side channels for the 1-year flood (Figure 7). The reconnection of these side channels results in an increase in wetted channel length and edge habitat available, as well as partitioning shear stress in the main channel. The reduction in flow velocities upstream of the Phase 1 ELJ structures is expected to result in decreased sediment transport capacity, leading to long term aggradation and fining of the channel bed to more suitable spawning sized gravels (Figure 8). The results are also useful in predicting anticipated channel response to the proposed ELJs, where areas of increased velocity likely indicating an increased chance of channel migration, and areas of decreased velocity predictive of areas that will aggrade. The significant backwater formed by the proposed ELJs slows 1-year flood flows down by up to 7 ft/sec, with an average reduction of 3 ft/sec throughout the reach, indicating that aggradation is to be expected in this area (Figure 8).

Engagement of structures during the 1-year flow event is important to create and maintain stable pool habitat, and to trap mobile wood moving through the reach. All of the proposed ELJs are engaged with the

1-year flow (Figure 7), and are anticipated to create and maintain stable pool habitat with complex cover, and help increase residence time of mobile wood within the reach by trapping debris.

For the 100-year flood event, average flow depths across the project reach are increased between 0.5-1 ft, with local increases greater than 5-ft (Figure 9). These increases in flow depth demonstrate greater floodplain and side channel connectivity within the project reach, another important goal of the project. These increases in depth are accompanied by decreases in channel velocities driven by the increased channel roughness added by the ELJs. Most of the area projected to have increased velocity is floodplain inundated area that has low velocities under both the existing and proposed condition (Appendix C). These results are consistent with that shown for the 1-year flood event, demonstrating that the habitat benefits realized by the project occur over a wide range of flow conditions.

GEMORPHIC CHANNEL RESPONSE

The restoration of the Nesset's Reach is focused on the re-introduction of stable large wood accumulations in the form of ELJs. These structures will influence hydraulic conditions within the reach, and trigger a response in the channel as a result. Anticipated geomorphic responses to the ELJs include:

24. Local scour pool formation on the upstream side and flanks of ELJs
25. Constriction scour and pool formation between ELJs that are closely spaced
26. Channel bifurcation where flows are deflected around ELJs
27. New channel development resulting from bifurcated flow
28. Side channel development resulting from increased activation magnitude and frequency of flow over a range of discharges
29. Local aggradation in lee of structures
30. Reach-scale aggradation resulting from cumulative effect of ELJs increasing channel roughness
31. Local bank erosion and recruitment of trees where ELJs deflect flows toward channel banks

The geomorphic response of specific ELJs will change spatially and temporally as the South Fork adjusts to the structure placements. Structures placed in the current channel location may form scour pools and split flows immediately following construction, however the South Fork may migrate away from the structure over time and impinge on another ELJ that is constructed away from the current channel. The structures have been located such that they span the active channel, increasing the likelihood of engagement with ELJs over time as the channel migrates. The anticipated geomorphic response following construction is described for each structure in the Phase 1, 2, and 3 project area descriptions previously in this report. Over time as the channel adjusts to the structures, these anticipated processes will likely change for individual ELJs. The timing of high flow events following construction will dictate the rate of change in the reach, as more frequent high flow events will precipitate more geomorphic change relative to lower flows.

SCOUR ANALYSIS

A scour analysis was performed to ensure the ELJ structures are designed and constructed to withstand the scour that may occur during severe flood events. For each ELJ type, only the ELJ experiencing the most severe hydraulic conditions (highest velocity and flow depth) was evaluated. The scour analysis was performed using empirical equations developed to predict scour and results from the 100-year proposed condition hydraulic analysis. The scour potential for all ELJs was evaluated following the procedures outlined in FHWA HEC-18, Fourth Edition (Richardson and Davis 2001), FHWA HEC-20, Third Edition

(Lagasse et al., 2001), and Scientific Investigation Report 2004-5111 (Chase and Holnbeck, 2004). Scour estimates were performed for the 100-year discharge and considered long-term degradation, contraction scour, and pier scour components. Scour related to long-term degradation and contraction scour was determined to be negligible for this project. Pier scour for this project was determined using the Simplified Chinese Equation developed by Landers and Mueller (1996). The results of the scour analysis for each structure type are shown in Table 4, below. To withstand the estimated scour, the bottom elevations of proposed ELJs will be placed below the estimated scour elevation and coarse channel material will placed in front of each structure to inhibit scour that could destabilize the ELJ. The project will directly address general scour by reducing the river's sediment transport capacity and the predicted bed aggradation induced by the project will reduce the risks associated with scour. This scour assessment conservatively assumes that no racking logs are present on the upstream face of the ELJ, and that scour would initiate directly upstream of the ELJ face. All of the proposed ELJ types will be constructed with racking logs installed on the upstream face (minimum 10-ft thick) that will force scour initiation away from the ELJ core. Mobile LWD within the project reach is expected to rack onto proposed ELJ, further pushing scour away from the ELJ core. Burial depth of the Type-1 and Type-3 ELJ does not exceed the maximum potential scour predicted (Table 4), however the analysis does not account for abundant racking logs on the upstream face of the structure that will push scour away from the structure and prevent undermining during scouring floods. The Type-4 ELJ is a self-settling structure and thus, scour is not a concern for the success and stability of the structure.

TABLE 4 – SUMMARY OF SCOUR ANALYSIS FOR 100-YR PEAK DESIGN EVENT

STRUCTURE TYPE	MAXIMUM POTENTIAL SCOUR* (FT)	DESIGN SCOUR DEPTH (FT)**
TYPE 1 (2-1-24)	18.9	17
TYPE 2 (2-2-31)	14.7	16
TYPE 3 (3-3-40)	16.9	11
TYPE 4 (2-4-25)	16.9	N/A

** Scour depths presented are for the worst case for each structure type*

*** Design scour depth is representative of embedment depth of vertical posts below the channel bed*

STABILITY ANALYSIS

A stability analysis was performed to ensure the ELJ structures are designed and constructed to withstand the hydraulic forces that occur during severe flood events. For each ELJ type, only the ELJ experiencing the most severe hydraulic conditions (highest velocity and flow depth) was evaluated. The stability analysis was performed using force balance equations developed to predict buoyant and lateral (sliding) forces, results from the 100-year proposed condition hydraulic analysis, and material properties for the specific ELJ components. The stability for all ELJs evaluated followed the procedures outlined in D'Oust and Millar (2000), Abbe (2000), Shields et al. (2000), and Brauderick and Grant (2000). Stability estimates were performed for the 100-year recurrence discharge and considered destabilizing forces related to the buoyancy of large wood and sliding force caused by the streamflow velocities and the stabilizing forces related to alluvium ballast, and the friction between the bottom of the ELJ and the channel. The results of the stability analysis in terms of the factor of safety (resisting forces/destabilizing forces) for each structure type are shown in Table 5, below. Type 1, 2, and 3 structures were designed to withstand buoyant and lateral forces using excavated timber posts and alluvium backfill. Type-4 structures were designed to withstand

buoyant forces using rock collars. Although the factor of safety for the lateral forces does not meet the recommended minimum of 1.5, these structures are still considered stable because the calculations do not account for the settling of the structure into the bed due to scour and the deposition of alluvium behind the structure due to decreased flow velocities. Estimates are considered conservative since channel aggradation will result in a reduction of drag forces (by decreasing area of wood exposed to flow), an addition of surcharge (log burial), a reduction in basal shear stress (by reducing hydraulic gradients and flow depths), and a reduction in effective shear stress acting on wood by the cumulative effect of the ELJs in partitioning basal shear stress.

TABLE 5 – SUMMARY OF STABILITY ANALYSIS FOR 100-YR PEAK DESIGN EVENT

STRUCTURE TYPE	BOUYANCY FS*	LATERAL FS*
TYPE 1 (2-1-24)	9.6	5.4
TYPE 2 (2-2-31)	10.2	3.9
TYPE 3 (3-3-40)	4.7	2.1
TYPE 4 (2-4-25)	1.5	0.3

** FS presented are for the worst case for each structure type*

CONSTRUCTION COST ESTIMATES

The construction cost estimate presented for this project (Appendix D) is largely based on our professional judgment, consultation with construction contractors and recent experience with similar projects. Cost data for large wood was determined from recent project experience within the watershed. Quantity estimates are considered approximate but are sufficiently accurate for the preliminary design phase.

Construction costs were calculated in a single Microsoft Excel workbook, using consistent unit costs for each construction element or quantity. Construction quantities for each element were multiplied by their respective unit costs, and the resulting products totaled into a construction sub-total for each phase, as well as an overall project sub-total. Additional fees for taxes, contingencies, and incidentals were accounted for as a percentage of the construction sub-total. The construction sub-total was then increased by the percentages of the additional fees to estimate the total construction cost. The construction costs do not include engineering and permitting fees.

RISK ASSESSMENT

The proposed restoration design is intended to improve channel stability and habitat quantity and quality throughout the project reach. The introduction of ELJs will also result in changes to water surface elevations that meet the goal of improving side channel and floodplain connectivity, but this change must be balanced so as not to put existing habitat, forest, and local infrastructure at risk. Thus it is critical to evaluate the hydraulic effect of the proposed ELJs to ensure they have no undesired impacts. A risk assessment was conducted to evaluate potential impacts of the proposed restoration actions and to document that no adverse effects to habitat relative to the existing condition are predicted.

Risk is a function of the probability of a hazard occurring (such as structure failure/washout, flood inundation, or boater entanglement) and the consequences of that event (e.g., habitat loss, property damage, or injury). If an event has little or no consequence then the associated risk would be relatively low, whereas a high negative consequence coupled with a high probability of occurrence results in a high risk factor. Rivers and natural systems have evolved to function within a wide range of conditions, however

these processes are not always consistent with human needs and expectations. The South Fork is a dynamic river in its current condition and high flows pose risks to nearby infrastructure, developing riparian forest, and recreational users. The primary natural hazards for the project area are related to flood and erosion risks, including lateral bank erosion (channel migration/avulsion), sediment delivery from mass wasting events upstream, riparian woody debris recruitment, and in-stream LWD. Non-natural hazards include failure of in-stream structures, creation of boating hazards, changes in inundation/channel forming processes, the establishment of non-native vegetation, and construction impacts. Longer-term hazards such as climate change were not addressed as part of this assessment. This risk assessment establishes due diligence in evaluating the proposed design for the Nesset's Reach restoration and consists of the following elements:

32. Assessment of short-term risk associated with construction activities
33. Assessment of potential impacts to habitat
34. Assessment of potential impacts to infrastructure
35. Description of how ELJs will influence channel migration
36. Description of how ELJs will influence flooding
37. Assessment of potential impacts of ELJs for recreational users of the river
38. Description of risks of a no-action alternative

Short-Term Risks from Construction Activities

Several hazards have been identified related to construction activities that pose potential risks to construction delays, water quality, and habitat during construction. Construction activities included in this risk assessment are:

- Earthmoving
- Re-vegetation
- Water management
- In-stream structures

Earthmoving

Primary earthmoving activities included in the design are excavation of ELJ placements and scour pits as well as backfill of excavated material into ELJs. Grading associated with staging and stockpile areas, and establishment of proposed access routes is anticipated to be minimal. Any areas that are excavated or filled during construction will require clearing, and will remain exposed in the short-term as vegetation re-establishes naturally or as a result of planting. The proposed design plans incorporate re-vegetation in some areas, thus the risk associated with earthmoving is very low.

Re-Vegetation

Following construction the backfilled ELJs and any disturbed areas above the ordinary high water line (access routes, staging areas where applicable) will be planted and/or seeded to initiate establishment of native vegetation. Habitats to be formed include coniferous forest and riparian deciduous forest. The primary risk to establishment of the plantings is from flood erosion in the growth period following construction and available root water following installation. Selection of appropriate native vegetation and installation to sufficient depths will be used to mitigate any risk to the success of re-vegetation efforts.

Water Management

Some of the proposed ELJ locations will infringe on the low flow channel during construction, requiring water management techniques to isolate the work area and divert water elsewhere. Prior to the initiation of isolation and construction of each structure, the wetted channel bed will be inspected for recent fish usage, including redds. Should a recent redd be present within the area proposed to be isolated, the proposed ELJ location will be changed to avoid impacts to fish usage. If no fish usage is documented, the area will be isolated using bulk bags or other agency approved method. Water will be pumped from the isolated area and diverted from the work area prior to starting excavation for the proposed ELJ. Water diverted from the isolated work area will be diverted onto the adjacent floodplains in a location such that it infiltrates into the ground completely prior to re-entering the river. If diverted water remains as turbid surface flow as is re-enters the river, BMPs will be employed to slow the flow, filter suspended sediment, and/or otherwise keep turbidity in the river below the threshold set by permit applications. Periodic sampling for turbidity in the river downstream of the isolated work area and re-entry point of diverted waters will be conducted to ensure turbidity is maintained within levels permitted. Should turbidity remain above threshold levels, work will stop until BMPs are employed to manage turbidity below allowable levels.

In-Stream Structures

The project design includes in-stream ELJs (Appendix B). Construction of these design elements will be performed when low-flow conditions exist. The primary risk to project elements during construction is from flooding of the work area. Due to the hydrologic regime and work occurring during low-flow conditions, the risk from flooding is very low. Should inundation of the work area occur during construction, construction would be halted immediately until the water subsides.

Potential Impacts to Habitat

Improving habitat quality and quantity throughout the project reach is the main goal of the proposed restoration design. By activating additional side channels and reconnecting the floodplain, habitat will be created through the engagement of habitat features more frequently by increasing water elevations and local deflection into side channel inlets. Engaging these areas is regarded as an improvement relative to existing habitat conditions, but it may also result in decreased flow depths and velocities in the current channel that could negatively impact existing habitat. However, any anticipated reductions in mainstem flow will benefit the project objectives of countering channel incision and reducing migration potential by partitioning shear stress in the project reach, resulting in bed aggradation in the main channel, reach scale elevated water surface elevations, and thus enhanced floodplain and side channel connectivity. Under the modeled conditions, flow conditions are not expected to result in fish stranding or passage barriers (Appendix C). In addition to reducing flow velocities in the existing channel, the proposed structures will create holding areas for adult fish and cover for juveniles. The risk to existing habitat associated with the proposed project work is low.

Potential Impacts to Infrastructure

Levees and revetments along the left and right banks from RM 10.4 to 10.8 currently restrict channel migrations that would pose risks to the COB pipeline crossing. The right bank levee was not designed to prevent inundation of the adjacent floodplain, which is currently subject to inundation during peak flow events. The proposed restoration includes modifications to the levee that will enhance edge and floodplain habitat in the Phase 3 project reach, while maintaining protection of the pipeline. Riprap below OHWM will remain where the levee is partially removed, maintaining toe protection from scour and limiting channel migration. Locations where the levee is completely removed will have salvaged rock placed at depth to prevent widening and/or deepening of the removed section of levee. The water pipeline along the

right bank at RM 10.45 is projected to have increased water surface elevations of 0.2 – 1 ft during the 100-year flood. However, it is not anticipated that these increases will put the water infrastructure at risk due to the low velocities projected in this floodplain (Appendix C). The pipeline crossing lies approximately 6 feet below the channel bed (Earth Tech 2002). The bed is projected to aggrade throughout the project reach due to the channel roughness added by the proposed ELJs, thus reducing the risk of incision into the pipeline crossing.

ELJ Impacts on Channel Migration

Existing natural wood accumulations have effectively diverted flow when jams form, causing unchecked channel migration due to the limited amount of stable large wood in the South Fork. The quantity and distribution of the proposed ELJs is intended to encourage habitat and pool formation while reducing the potential for future channel migrations that may pose risks to forest development and available fish habitat. The project reach currently has a high potential for channel migration and full or partial avulsions, as evidenced by the historic channel alignments previously assessed (Appendix A). The short-term channel response to ELJ placements is likely to include bank erosion and bed scour adjacent to the structures due to deflection of flows. The additional sediment and wood from bank erosion is expected to accumulate in the lee of ELJs, backwater areas of reduced velocity, and on downstream structures. Short term, localized changes at each structure may be amplified as the channel adjusts to the flow alignments encouraged by the ELJs and sediment and wood are redistributed. In the long term, the design collectively makes channel-forming processes more predictable by partitioning flows, lengthening the channel, and introducing roughness, reducing stream power throughout the reach. The stable hard points created will also allow for the development of forested islands in the lee of ELJs, providing shade, wildlife habitat, and vegetative bank stability. Phase 2 and 3 of the Nesset's project are intended to balance aggradation throughout the reach, reducing the risk of avulsion.

ELJ Impacts on Flooding

The risk associated with flooding inundation and erosion is very low for the project area during construction given anticipated low-flows during the proposed construction time frame. Construction areas that are within the wetted channel during construction will be isolated using temporary cofferdams where applicable to minimize inundation risk. All materials and equipment will be stored above/outside of the ordinary high water line to minimize risk from unlikely high flows during construction.

The addition of ELJs to the mainstem channel will result in increases in water surface elevations. While these rises result in the reconnection of floodplain and side channel habitat, they may also result in increased inundation in undesirable locations. To reduce this risk, changes to 100-yr water surface elevations were extracted from the proposed condition hydraulic model (Figure 10). These changes are not anticipated to increase flood risk to adjacent property or infrastructure. The Phase 3 levee modifications are projected to increase flood inundation of the right bank floodplain downstream of RM 10.8 by 0.2 – 1 ft for the 100-year flow event. The projected change in inundation is not expected to increase erosion of public and private properties.

Potential Impacts to Recreational Users

Due to the dynamic nature of the river and mass delivery of sediment and large wood upstream of the project reach, the South Fork is moderately dangerous under existing conditions. Channel migrations are part of the river's current geomorphic regime. The dynamic response of the river to these changes makes recreational safety and boater navigation slightly unpredictable at present. Although the proposed work includes large wood additions to the channel, these structures are not projected to become mobilized under the range of flows in the South Fork. Wood debris jams are considered natural features in western

Washington fluvial systems. Large wood presence in the South Fork poses a hazard to recreational users regardless of the restoration work. The efficiency of ELJs in capturing additional wood may increase the risk for inexperienced boaters; however, the structures will increase the overall stability and predictability of the channel form relative to existing conditions. The addition of ELJ structures will enhance channel complexity, requiring boaters to be more aware of obstructions and flow patterns. Wood placements will also create areas of slow moving backwater, which may increase boater response times and the number of available pullouts.

Tubing and other recreational activities on the South Fork are primarily from Acme to Strand Road or Potter Road, with put-in sites downstream of the project reach. Public outreach regarding the proposed work should be implemented to aid boaters in understanding any changes in safety and channel form. Posting warning signs on each engineered wood placement may help boaters recognize and navigate around flow obstructions. Warning signs can be placed at known launch points upstream or within the project reach that indicate the river has natural and engineered wood debris that should be avoided. The same signage can also note facts about the restoration project and other conditions that may pose a hazard such as areas of constricted, fast-moving water. Correspondence and public meetings with river guides and recreational groups known to use the river can also improve safety by educating users and thus reduce risk.

Risks of a No-Action Alternative

Due to historic losses of riparian forest and the removal of large wood from the South Fork, the project reach is subject to frequent disturbances and rapid channel incision (Appendix A). The proposed restoration is intended to expedite the system's recovery and reverse historic trends in channel incision, rapid channel migration, and avulsions, in order to create a more stable river and higher quality habitat. Without restoration, the South Fork is expected to continue incising, lowering the water surface and further disconnecting floodplain and side channel habitats. As the channel becomes more entrenched in a simplified channel, stream power is expected to increase, exacerbating incision and erosional processes. In the project reach, channel instability will result in the ongoing loss of developing riparian forest as the channel continues to migrate in the absence of stable hard points and forested islands. The recruitment of young successional forest will not limit channel migration rates, or contribute to stable wood accumulations. There is also a risk of continued loss of spawning gravels, pools, and edge habitat due to the increased shear stress associated with an incised channel.

FINAL DESIGN DEVELOPEMENT

The final design for Phase 1 (submitted separately) was developed based on comments received from CRT/ SRFB technical reviewers on the preliminary designs and adjustments in channel planform during the 2014/2015 winter high flows. Changes to the preliminary design within the Phase 1 area were minor and consisted off the following;

- Removal ELJs 1-14-14 and 1-4-19 due to concerns over potential impacts to existing bedrock pools,
- Slight shifting of ELJs 1-3-1, 1-3-2, 1-3-3, and 1-3-4 due to adjustments in channel planform during the 2014/2015 winter high flows,
- The addition of 4 logs with rootwads to Type 3 ELJs to improve immediate complexity and cover,
- Substitution of chain lashings instead of cable
- Removal of 1 temporary access road to access 1-3-3 requiring an addition temporary bridge

Changes reflected in the Phase 1 final design plans do not significantly change the intent of the project and resulted in less than a 1% increase in total cost.

LIMITATIONS

We have prepared this report for the Nooksack Tribe, their authorized agents and regulatory agencies responsible for the South Fork Nesset's Reach restoration project. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices for river restoration and the engineered placement of wood in this area at the time this report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, expressed or implied, should be understood.

We appreciate this opportunity to be of service to the Nooksack Tribe for this project and look forward to continuing to work with you. Please call if you have any questions regarding this report, or if you need additional information.

Sincerely,

Natural Systems Design, Inc.

R. Leif Embertson, MS, PE, CFM
Senior River Engineer

Tim Abbe, PhD, PEG, PHG
Principal Geomorphologist

Attachments:

Figure 1 – Conceptual Restoration Design Alternative 1 (upstream)
Figure 2 – Conceptual Restoration Design Alternative 1 (downstream)
Figure 3 – Conceptual Restoration Design Alternative 2 (upstream)
Figure 4 – Conceptual Restoration Design Alternative 2 (downstream)
Figure 5 – Conceptual Restoration Design Alternative 3 (upstream)
Figure 6 – Conceptual Restoration Design Alternative 3 (downstream)
Figure 7 – Change in Depth for 1-year Flow
Figure 8 – Change in Velocity for 1-year Flow
Figure 9 – Change in Depth for 100-year Flow
Figure 10 – Change in WSE for 100-year Flow

Appendix A – Geomorphic, Hydrologic, and Hydraulic Assessment
Appendix B – Preliminary Design Drawings
Appendix C – Proposed Hydraulic Model Results
Appendix D – Preliminary Design Cost Estimate
Appendix E – Responses to CRT/SRFB Review Comments

REFERENCES

Abbe, T.B. 2000. Patterns, mechanics, and geomorphic effects of wood debris accumulations in a forest river system. Ph.D. dissertation, University of Washington, Seattle, WA, 219pp.

Brauderick, C.A., Grant, G.E., 2000. When do logs move in rivers? Water Resources Research, Vol 36, pp 571-83.

Chase, K. and S. Holnbeck. 2003. Evaluation of Pier-Sour Equations for Coarse-Bed Streams. US Geological Survey Scientific Investigations report 2004-5111.

D'Oust, S.G.D. and Millar, R.G. 2000. Stability of ballasted woody debris habitat structures. Journal of Hydraulic Engineering, Vol 126, pp. 810-17

Earth Tech. 2002. Evaluation of Impact of South Fork Nooksack River Rip Rap Removal on Water Supply Pipeline. Unpublished report to City of Bellingham Public Works Operations.

Lagasse, P., J. Schall, E. Richardson. 2001. Stream Stability at Highway Structures, third Edition. Federal Highways Administration HEC-20 Manual.

Landers, M.N., Mueller, D.S., 1996. Channel scour at bridges in the United States. US Department of Transportation, Federal Highways Administration Publication FHWA RD-95-184, 140p.

Richardson, E. and S. Davis. 2001. Evaluating Scour at Bridges, Fourth Edition. Federal Highways Administration HEC-18 Manual.

Shields, F.D., Knight, S.S. et al. 2000. Large woody debris structures for incised channel rehabilitation. Proceedings of ASCE 2000 joint conference on water resources engineering and water resources planning and management. Reston, VA ASCE.

WRIA 1. 2005. WRIA 1 Salmon Recovery Plan. Whatcom County, WA.

APPENDIX A

GEOMORPHIC, HYDROLOGIC, AND HYDRAULIC ASSESSMENT

Natural Systems Design

P.O. Box 15609, Seattle, WA 98105 T: (206) 834-0175

Natural Systems Design
Stream & Riparian
Resource Management
P.O. Box 15609
Seattle, WA 98115

July 31, 2014

Nooksack Indian Tribe
5016 Deming Rd
Deming, WA 98244

Attention: Treva Coe, Erica Capuana

Subject: South Fork Nooksack River - Nesset Reach Geomorphic, Hydrologic, and Hydraulic Assessment

PROJECT BACKGROUND

The South Fork Nooksack River (South Fork) historically supported a healthy population of anadromous fish that included spring Chinook, coho, chum, pink, and sockeye salmon as well as coastal cutthroat and bull trout. Currently, many of these species are listed as threatened or endangered under the Endangered Species Act (ESA). Human actions such as timber harvest, removal of natural logjams, clearing of floodplain forests, channel confinement, bank armoring, and installation of road crossing structures have led to a general simplification of habitat within the Nooksack watershed and are attributed to the recent decline in salmon abundance in the Nooksack watershed (WRIA1, 2005).

The Nooksack Indian Tribe (NIT) has identified the Nesset Reach of the South Fork as a candidate location for habitat restoration (Figure 1). The proposed restoration reach is between river mile (RM) 12 (upstream end) and RM 10.3 (downstream end). This reach was targeted by NIT for restoration following the recommendations put forth in the WRIA I Recovery Plan (WRIA 1 2005) for the entire South Fork Nooksack. The restoration goals for the project reach include:

1. Reduce reach-level constraints to habitat formation (e.g. remove bank hardening, levees)
2. Reconnect existing habitat (floodplains and side channels)
3. Increase habitat unit diversity (complex wood cover in low-flow channel, habitat unit diversity)
4. Increase key habitat quantity (number and depth of pools in low-flow channel – especially primary pools greater than 1 meter residual depth)
5. Increase availability of temperature refuges
6. Improve the stability of channel and habitat features

Increases in these key habitat metrics would address limiting factors in the reach to ESA listed spring Chinook salmon, as well as other salmonids (pink, sockeye, fall Chinook, and coho) (WRIA 1 2005) that use the reach. Many of the project goals would be met by increasing the number of stable accumulations of large wood debris (LWD) in the river. In addition to these improvements, higher LWD loading would provide additional hydraulic complexity leading to sorting of spawning gravels, reducing channel energy through stress partitioning, greater instream cover, and potentially bed aggradation.

Field surveys were conducted on August 18th and October 3rd, 2013 to evaluate the current geomorphic processes active within the project reach and how they contribute to the existing habitat conditions. In addition, the geomorphic responses from historic disturbances were evaluated to assess how the current condition reflects the impacts of these past events, and how these disturbances would have impacted habitat conditions. These findings will be used to inform the development of conceptual restoration actions that would improve the existing habitat conditions by re-establishing processes that contribute to increases in the key habitat metrics identified as goals for this project.

PROJECT REACH CHARACTERISTICS

The project reach is located 0.9 miles downstream of the Saxon Road Bridge, and extends 1.7 miles downstream to the confluence with Hutchinson Creek. The drainage area for the project reach is 133-square miles, with a vertical relief of 6,680-feet between the headwaters and the valley bottom (Figure 1). Mean annual precipitation is 90.2-inches and mean annual discharge is 765 cubic feet per second (cfs) with peak discharges ranging from 3,600-cfs to nearly 22,500-cfs. The project reach on the South Fork lies on the eastern side of a broad alluvial plain with land use dominated by agriculture, rural residential, and managed forest lands. The average channel gradient is 0.32-percent and average valley gradient is 0.41-percent. The river's current (2013) mean unvegetated bankfull width is 330 ft (varying from 200-600 ft) and is set within a historic migration zone and floodplain about 1,500 ft in width. The river's current sinuosity is 1.28, meander wavelengths range from 1,600-2,300 ft, and radius of curvature ranges from 600-800 ft (at RM 10.4 artificial revetments force channel into a 90 degree turn where the radii of curvature is about 500 ft). The dominant substrate types in the reach range from coarse gravel to cobble, with pockets of finer sand and gravels. The channel is characterized by a broad meandering pool-riffle morphology and large gravel point bars bisected with chute channels that are inundated during bankfull flows but dry most of the year. Pools are infrequent within the project reach, and are typically forced by key logs within the low-flow channel, and deepest where flow abuts exposed bedrock.

HISTORIC ANTHROPOGENIC DISTURBANCE

Major human disturbance within the project reach began with early European settlement in the late 1800's (Collins and Sheikh 2004). Historic logging of the floodplain forest and adjacent hillslopes, and the removal of LWD and logjams from large rivers, were the first impacts from these early settlers. The cleared floodplains were converted to agriculture, requiring drainage in low-lying areas. The early logging and clearing activities contributed to salmonid habitat degradation by destabilization of the landscape and removal of habitat forming wood from the river. The large native trees (diameters 6-9 ft, heights over 150 ft) formed stable snags and logjams that dissipated the river's energy by adding roughness and dispersing flow into an array of complex flow paths or anabranches. Through this process wood reduced the effective shear stress available for erosion and sediment transport, which in turn increased sediment trapping and storage within the valley (river bed aggradation). The influence of wood extends well up into the channel network and historic removal would have released lots of stored sediment (e.g., Montgomery et al. 1996).

Early timber harvests cleared everything, including trees on riparian floodplains and unstable steep slopes (Brown and Maudlin 2007). Industrial logging continues within the watershed but current regulations prohibit harvest on streambanks, channel migration zones or unstable slopes. The impacts from this historic disturbance are recorded throughout the project reach, as periods of channel instability (increased channel migration rates, channel avulsions, channel aggradation) due to high sediment inputs and the loss of key pieces in the river, and subsequent downcutting through the aggraded sediments and historic alluvium as sediment inputs have recently decreased. The loss of wood in low order channels within the watershed would have further increased sediment supply to the river y incision certainly contributed

The loss of a mature forested floodplain has eliminated the source of stable "key" pieces which take over a hundred years to grow, dramatically influencing the recovery time of the system. This is further compounded by higher channel migration rates that occur in areas with smaller trees (<21 inches in diameter, Abbe et al 2003) resulting in riparian areas are being reset more frequently and fewer trees reaching maturity. Large trees (> 4-ft in diameter and 125-ft long) are key in creating the conditions that allow trees to mature in this dynamic landscape (Abbe and Montgomery 1996, 2003a, b; Abbe 2000; Montgomery and Abbe 2006; Collins et al. 2012). The reduction in logjams and key pieces increased the river's effective shear stress available for sediment transport and reach scale bed scour. The removal of channel spanning logjams and channel straightening and confinement further increased the river's erosive

energy, and together caused the river to cut deeper into its valley. This downcutting or incision has disconnected the river from its historic floodplain and dramatically reduced aquatic habitat (described in more detail in this report).

Channel incision not only disconnects aquatic habitat, but it can aggravate downstream flooding by reducing flood storage capacity and undermining infrastructure such as pipeline crossings. The City of Bellingham's water diversion pipeline crosses the South Fork at the downstream end of the project reach (near RM 10.42). The 40-in concrete pipeline installed in 1961 was periodically exposed due to scour and bank erosion over the following 30 years (NHC 1991). Within a year (1962) about 100 ft of the pipeline was exposed in the right bank due to lateral channel migration. Bank armoring along both banks was completed by 1967. Concern regarding channel incision is reflected in 1968 construction of a concrete sill that extended 60 ft out into channel from the left bank, immediately downstream of the pipeline in 1968 (NHC 1991). Exposure of the pipeline on the right bank was observed in 1975 prompted emergency construction of a rock apron that extended from right bank across the channel to the 1968 concrete sill (NHC 1991). Maintenance of the bank armoring continued between 1977 and 1983, and was extended for 300-ft upstream on the left bank to prevent flanking of the river. A 1991 survey found the pipeline was exposed for approximately 60-ft on the left bank and since no evidence of the concrete sill (1968) or rock apron (1975) were found, it was presumed they had been washed out (NHC 1991). To protect the pipeline, the city deepened the crossing in 1992, replacing an 880-ft long section with a 42-in ductile iron pipeline buried about 9 ft deeper than the original (Earth Tech 2002). The new crossing was located about 25-ft upstream of the original (1962). In 2004 an additional 1,100 ft of the pipeline within the right bank floodplain (north or downstream of rock revetment) replaced and lowered. Analysis of alluvial surfaces in this study indicates the river has cut down about 10 ft in the last century and 4-5 ft in the last 30 yrs (1980-2011). This incision may have been tempered by the un-naturally high sediment inputs associated with timber practices, which would have contributed to channel aggradation. Assuming current timber management practices are being effective to reduce the sediment supply, incision is likely to continue and underscores the importance of wood in checking and reversing incision (e.g., Abbe and Brooks 2011). Within the 1.7 mile project reach, recruitment of large native cedar trees (X-ft diameter) was only observed along a 0.1 mile section of the river's left bank at RM 11.8.

RECENT RESTORATION ACTIONS

The Lower South Fork has been a focus of numerousrecent restoration actions, including recent projects within and immediately up and downstream of the Nesset project reach. The first of these projects was Lower Hutchinson (RM 10.13 - 10.25), completed in 2006 and lead by Lummi Natural Resources (Maudlin and Coe 2011). In 2008 the Lummi Natural Resources Department (LNRD) completed the Nesset's Reach Project, located within the current Nesset project reach (RM 10.5 - 11.5) (Maudlin and Coe 2011). The upstream Saxon Reach Project (RM 12.1 – 12.6), lead by LNRD, was completed during the summers of 2011 and 2012. Also during the summer of 2012, the phase 1 of the Downstream of Hutchinson project (RM 9.5 – 10.1), lead by NIT, was completed.

At the time of construction, the Lower Hutchinson Creek Project was the second engineered logjam (ELJ) in the Nooksack watershed, and included 6 ELJs and levee setback (approximately 500 ft). The project is located at the confluence of Hutchinson Creek (known cool water tributary) and the South Fork. The lower 500 ft of right bank levee was removed and replaced with 2 ELJs, with a 3rd ELJ constructed at the downstream end of the remaining levee (Maudlin and Coe 2011). These 3 ELJs provide all of the habitat benefits (primary and secondary pools, instream cover) resulting from the project (Maudlin and Coe 2011). The remaining 3 ELJs were built on the right bank floodplain to encourage side channel development and limit avulsion risk (Maudlin and Coe 2011). The setback levee was constructed at the downstream end of the project on the right bank, and is intended to allow side channel formation around the 3 floodplain ELJs and to limit flooding and avulsion risk to the north (Maudlin and Coe 2011).

The 2008 Nesset's Reach Project was the first restoration project within the current Nesset project reach, and involved stabilization of existing LWD accumulations and logjams. A total of 8 locations were stabilized using excavated and driven piles (averaging 10.5-ft deep, 16-ft max depth, 5-ft min depth) and additional LWD placed above for additional ballast (Maudlin and Coe 2011). By 2011, three of the locations had washed out (Maudlin and Coe 2011). Field surveys in 2013 found that 5 locations remained of the 8 stabilized. Channel migration between 2009 and 2011 resulted in destabilizing the 3 locations that washed away, and also moved the low-flow channel away from 2 of the remaining 5 locations. The 3 locations that washed out and the 2 locations where the channel moved away were all constructed adjacent to the 2008 low-flow channel.

The Saxon Reach Project, upstream of the Nesset reach, was constructed in 2011 and 2012. During the summer of 2011, 2 ELJs and 630 ft of complex log revetment were constructed, along with pile reinforcement of an existing logjam and excavation of a chute side channel coming off the existing logjam (Ericsson et al. 2011). All the 2011 work was on the left bank of the river. The remaining 5 ELJs and additional chute channel excavation were completed during the summer 2012. The project goal was to increase instream complexity by providing stable hardpoints in the active channel that will retain mobile LWD, leading to forested islands and instream cover. In order to achieve stability, the ELJs required excavation below scour depth, limiting their proximity to the low-flow channel (Ericsson et al. 2011). Engagement of the ELJs is anticipated to occur following future channel migration, and their locations were selected based in part on migration trends. The complex log revetment was constructed to improve cover along an actively eroding bank, and limit channel migration into adjacent private property (Ericsson et al. 2011). The river splits into two low-flow channels upstream of the revetment. The revetment has created excellent hydraulic refugia and cover during all flows and has thus far stopped any bank erosion. During the 2013 field surveys it was observed that the 2 downstream most ELJs (constructed in 2011) have sustained pools and deflected more flow toward the eroding right bank which has recruited several large cottonwood trees that are currently working their way through the Nesset reach.

Phase 1 of the "Downstream of Hutchinson project" (downstream of Hutchinson Creek confluence at RM 9.9.) was completed in 2012, and consisted of 9 ELJs immediately downstream of the 2008 Lower Hutchinson Creek Project (RM 10). The project was designed to increase pool frequency and depths, instream cover, and greater channel length (Element Solutions 2011). Depending on their locations, 3 ELJs types were constructed on or adjacent to the low-flow channel. 2 of the ELJs were constructed along the right bank side of the low-flow channel, 6 along the left bank low-flow channel, and 1 in the low-flow channel (Element Solutions 2011). During the 2013 summer field surveys, LWD was observed to have racked onto several of the ELJs following completion, likely during the previous winter.

GEOMORPHIC ASSESSMENT

SOUTH FORK GEOLOGY

The South Fork orginates within the Northwest Cascade System complex of Paleozoic and Mesozoic nappes, emplaced exotic terrains thrust over existing basement rocks (Tabor et al 2003). These nappes typically include metamorphosed oceanic and volcanic rock formed along the Cascadia Subduction Zone, and subsequently thrust upon the basement rocks to the east. The older Paleozoic terrains generally lie in the eastern side of the upper watershed, and age decreases toward the west (Tabor et al 2003) (Figure 2). The Paleozoic Excelsior Nappe includes the Cultus Formation and Chilliwack Group, composed of metasedimentary, and partially metamorphosed basaltic and andesitic volcanic rocks. The Welker Peak thrust Fault separates the Paleozoic Excelsior Nappe from the Mesozoic terrains to the west. These Mesozoic terrains include the Triassic-Jurassic Welker Peak Nappe and Jurassic Easton Metamorphic Suite. The Welker Peak Nappe exposes the Twin Sisters dunite (Tabor et al 2003), named after the prominent

range in the upper South Fork watershed. The Jurassic Easton Metamorphic Suite includes the Darrington Phyllite, composing much of the basement along the eastern margin of the Lower South Fork valley (Blue Mountain) (Lapen 2000).

Quaternary glacial deposits emplaced during the Vashon Stade and Everson interstade of Frasier Glaciation (10-20 ka) (Lapen 2000) over-ride these older Paleozoic and Mesozoic bedrock rock units. In general, glacial drift (Qgd) deposits are located on the higher terrain in the upper watershed, with outwash (Qgo) and till (Qgt) deposits located in the lower watershed along the valley bottom and margins (Lapen 2000) (Figure 2). More recent Holocene alluvium (Qa) occupies the Lower South Fork valley, with landslide (Qls) and alluvial fan (Qaf) deposits on the valley margins.

The Lower South Fork valley (defined as the mapped Quaternary alluvium (Qa) and alluvial fan deposits (Qaf)) starts near RM 15.5 and widens to 6,000 ft by RM 11.5. Downstream of RM 11.5 the valley rapidly widens to 9,300 ft, and is alluvium (Qa) with alluvial fans (Qad) at the valley margin where larger tributaries enter the valley bottom (Lapen 2000). A mantle of glacial outwash (Qgo) lies unconformably upon the Darrington Phyllite along the eastern valley margin within the project reach (Figure 2), and an alluvial fan is mapped where Hutchinson Creek enters the valley bottom at the downstream end of the project reach. Exposures of the Darrington Phyllite were observed during field surveys along the right (east) bank between RM 10.9 and 11.5, forming a barrier to channel migration (Figure 3).

TERRAIN ANALYSIS

As part of the geomorphic assessment for the reach, a terrain analysis was performed to evaluate the elevations of the floodplains and side channels relative to the main stem channel (Figure 4). The methods used for this analysis were adapted from Jones (2006), and utilized the LiDAR terrain surface (bare earth digital elevation model) (collected April 1st, 2013, 1,330 cfs daily average discharge at USGS station South Fork Nooksack at Saxon Road Bridge) for the analysis. The resultant relative elevation map (REM) depicts elevations of floodplain and instream features relative to the water surface elevation of the channel at the time when the 2013 LiDAR was collected (Figure 4). The results were field verified during the 2013 field surveys by comparing the bank heights with that predicted from the terrain analysis, and were found to be accurate to within 1 ft. The REM is useful in identifying side channels, potential avulsion (new channel) pathways, presence of terraces, and relic channel scars. Avulsion is the rapid abandonment of a river channel and the formation of a new river channel. Avulsions occur as a new channel forms creating a straighter path through the landscape, typically during large floods in areas where the new channel slope is greater than that of the old channel. Active side channels (both perennial and intermittent) are shown as shades of blue, with darker blues more frequently inundated (lower relative elevation). Similarly, floodplains that are inundated more frequently are shades of blue, with darker blues indicating more frequent inundation. Floodplains that are shades of green are inundated less frequently, with lighter greens to light yellow only inundated during high flow events. Areas of yellow to orange are higher alluvial areas lying above the 100 yr flood inundation. The distribution of these features indicates areas where side channels are present and floodplains are relatively low (good floodplain connection), compared to areas where there are no side channels and floodplains are relatively high (disconnected floodplain).

HISTORIC AERIAL PHOTOGRAPH & CHANNEL ANALYSIS

In addition to the terrain analysis performed, historic active (unvegetated) channel positions (Figure 5), low-flow centerlines, and aerial photographs (provided by NIT) were reviewed to document geomorphic processes (channel migration, avulsions, incision, sinuosity, and planform changes) and anthropogenic disturbances within the Nesset project reach over the historic record (1880 – present). Channel sinuosity was measured from RM 10.3 to RM 12 using the historic channel centerlines provided by NIT, and digitized by NSD from historic aerials provided by NIT. The historic active channel areas were clipped to the same project reach (RM 10.3 – 12), and their area calculated. For each date with historic channel area

and low-flow centerline information, the channel area was divided by the centerline length, providing a reach-averaged channel width. The reach scale changes in sinuosity and average active channel width from 1933 to 2011 are provided in Figure 6. Major clearing and channel alterations had occurred by 1933 so the record doesn't provide any information regarding the river's natural or pre-European condition. There is a general trend of channel narrowing through the historic record, widths reducing from 560 ft in 1933 to 330 ft in 2013. The trend is interrupted between 1985 and 1998 when channel width went from about 340 ft to 500 ft, coming back down to about 290 ft in 2001 (Figure 6). There is also a general trend of decreasing sinuosity since 1938, resulting periodic avulsions and channel confinement. The decreasing trend in sinuosity is most pronounced in the sub-reach from RM 10.9 to 11.6 where a longer section of the river has gradually become locked against bedrock on the eastside of the valley (Figure 4). The river historically meandered in this subreach but now occupies a nearly straight channel.

The REM (Figure 4) and historic channel alignments (Figure 5) were used to evaluate historic channel incision by identifying the elevations of historic channel paths. Cross sections were extracted from the 2013 LiDAR and the most recent active channel trace occupying each section of the cross section were combined to evaluate the relative position of historic channel alignments. This allows characterization in both horizontal (lateral bank erosion and avulsions) and vertical (aggradation and erosion) changes over time (Figures 7 -10). This analysis does not account for overbank/floodplain sedimentation, and thus provides maximum incision rates. At the lower end of the project (RM 10.5) there is about 10 ft of relief in historic alluvial surfaces with consistent incision through the 93 year record of 0.10 ft/yr (Figure 7). At RM 10.9 the 1885 channel surface was identified, providing a 126 year record over which there has also been 10 ft of incision averaging about 0.08 ft/yr (Figure 8). At RM 11.3 only the 17 years of record (1994-2011) could be used due to channel migration reoccupying previous channels. Total relief is 2.5 ft over the record, showing a higher incision rate (0.15 ft/yr) in the last 10-20 years (Figure 9). The previous sites downstream also show higher rates of incision in recent decades, 0.3 ft/yr at RM 10.9 (Figure 8) and 0.14 ft/yr at RM 10.5 (Figure 7). The upstream most cross-section at RM 11.7 reveals a more complicated story (Figure 10). Starting in 1943 the river was 5 ft above its position in 2011, translating into an incision rate of 0.07 ft/yr. But the 1933 channel was only half a foot above the 2011 channel, 4.5 ft below the 1948 channel. Based on Figure 10, this portion of the river experienced a period of dramatic aggradation from 1933 to 1948, and is corroborated by accounts from Tom Nesset with NIT staff describing widespread channel aggradation and pool filling following WWII. Given the elevation of the 1885 channel at RM 10.9, it can be inferred that there was a major avulsion prior to 1933 that dramatically shortened the river's length and resulted local incision. This is consistent with the river's shorter length 1933, as reflected by the low sinuosity (Figure 6). An avulsion causing localized changes is also supported by fact that the 1933 channel at RM 10.9 is at a similar elevation to the 1943 channel (Figure 8), and it is 2.5 ft above the 1943 channel at RM 10.3 (Figure 7). Prior to European colonization in the 1800s, the river would have naturally experienced variable sediment and wood loading as the channel locally eroded banks and islands. This local erosion would have introduced sediment and large wood into the river, creating stable logjams and deflecting flows away from the erosing bank. The general trend would have been aggradation interrupted by periods of local incision (Abbe et al. 2003a, Montgomery and Abbe 2006). Over the long-term, the system would reach an equilibrium grade where aggradation and erosion maintained a relatively constant grade. The variability introduced by stable wood would define how "dynamic" that equilibrium would be. Removing stable wood from the channel and floodplain results in a distinct trend of incision that would eventually reach an equilibrium state in which dynamic variability would be governed only by variations in channel planform associated with channel migration, wood loading, and sediment supply. The result of this incision has been a dramatic loss of floodplain connection, further reducing off-channel habitat and focusing stream energies toward the channel bed.

These terrain, historic air photo, and historic channels analyses, coupled with reference literature and field data collected during the 2013 field surveys, provides the foundation for this geomorphic characterization of the project reach.

GEOMORPHIC HISTORY AND PROCESSES CHARACTERIZATION

The South Fork flows through unconsolidated Holocene alluvium within the Nesset reach, however it encounters exposures of the Darrington Phyllite along the right bank between RM 10.9 and 11.5 (Figure 3). These bedrock exposures limit channel migration and create a relatively smooth high shear stress boundary. Deep scour pools (6-12 ft) have formed where the river flows directly into bedrock banks or where bedrock protrudes into the channel. The thin mantle of Pleistocene glacial outwash overlying the Darrington Phyllite along the right valley margin is erodible, and does not significantly limit channel migration. The Holocene alluvium found elsewhere in the valley bottom is readily erodible by the South Fork, except where bank armoring has been installed to limit channel migration. Levees constructed within the project reach have also influenced geomorphic processes by confining high flows, resulting in more erosive flows where confined, and backwater conditions upstream that reduce stream power. The mature forests that once covered the valley for thousands of years had the most a profound influence on the river's character by delivering trees large enough to redirect or even impound the river when recruited into the channel. These geologic, ecological and man-made controls have influenced the geomorphic evolution of the South Fork within the project reach.

Prior to European settlement in the Nooksack valley, the South Fork had a more pronounced anabranching morphology, characterized by multiple narrow and deep channel threads lined with predominately with alder and larger cedar and fir (Collins and Sheikh 2004). Large logjams were common on the South Fork, due to the abundance of large conifers lining the banks of sufficient size to act as key logs once recruited into the channel. These key logs captured mobile LWD, forming large logjams that initiated local channel adjustments (channel migration, avulsions, aggradation, pool formation) and created stable hardpoints within the channel migration zone. Habitat conditions were maintained through these processes of recruitment of key logs, subsequent formation of large logjams, and channel response resulting in further recruitment of key logs. A dynamic stability was maintained where large trees both induced (through flow deflection and avulsions) and limited (creation of stable hard points, partitioning shear stress, and bank stability from root cohesion) geomorphic processes. Based on the valley's gradient and sediment supply, without wood or artificial constraints, the river is anticipated to continue to develop into a single stem meandering channel that will cut down to a lower grade and then gradually build a new inset floodplain through channel migration.

By the early 1900's, logging, the conversion of forested floodplains to agriculture, and the clearing of logjams and snags in the channel had resulted in a loss of channel stability once provided by large trees (Collins and Sheikh 2004). Between 1880 and 1910, the South Fork planform changed from anastomosing to single thread (Figure 5), and by 1933 had significantly widened at the upstream and downstream ends of the project reach (500 – 600 ft expansion). This channel widening observed in the earliest available air photo (1933) was accompanied by an avulsion between RM 11.1 and 11.5 in the middle of the project reach, when compared to the 1918 active channel alignment (Figure 5). This avulsion corresponds to previous discussion of channel changes at RM 11.7 (Figure 10). The peak flow record does not extend prior to 1934 (USGS Wickersham), so correlation between these processes and peak flows is unavailable.

Channel migration continued from 1933 to 1947 at the upstream end of the project reach (RM 11.9 – 12) at a rate of 30-40 ft/yr. and at the downstream end between RM 10.4-10.6 at 20-30 ft/yr. Where the channel remained stable, vegetation established and progressed in side channels and on gravel bars. The net result of this channel migration was an initial increase in sinuosity, and a narrowing of the channel's unvegetated width (Figure 6). Incision appears to have been rapid during this time period, as channel surfaces from 1933 and before are 2.5 to 5 ft above the 1940's channel (Figures 7 - 8).

Several high peak flows (1947, 1949 and 1951) (between 14,000 - 15,800 cfs) (2 - 5 year recurrence interval) likely contributed to the avulsion at the upstream end of the project reach (between RM 12-12.3) and additional channel migration elsewhere that occurred between 1947 and 1955. 2 channel meanders migrating between 25-40 ft/yr in the middle of the project reach (10.95 – 11.6), and an additional meander at the downstream end of the project reach (RM 10.4 - 10.7) added channel length, but less than that which was lost from the avulsion between RM 12.1 and 12.3. Between 1955 and 1967 avulsions occurred at the downstream end (RM 10.5-10.8) and middle (RM 11.4-11.7) of the project reach, dramatically decreasing sinuosity, similar to that which occurred in 1933, however there was not a similar dramatic widening of the channel (Figure 6). The 4th highest recorded peak flow occurred in 1955 (19,300 cfs; 10 - 25 yr recurrence interval), which may have been the impetus for this avulsion. Vegetation continued to grow in side channels and old channel locations, indicating incision occurred related to these avulsion during this time.

The appearance of the pipeline crossing at RM 10.41 near the downstream end of the project reach in the 1967 air photo, and levee with revetment by the 1980 air photo, have a significant impact on channel migration within the reach. From the first appearance of the water pipeline in 1967 to the most current air photo (2011), there is no further significant channel migration in the downstream end of the project reach (Figure 5). The levee and associated revetment along the right bank from RM 10.55 to 10.85 is first visible in the 1980 air photo, however the lack of channel migration along this bank in the interim indicates these structures were constructed shortly after 1967.

Channel migration between 1967 and 1980 was limited to between RM 11.1 and 11.4 (averaging 30 ft/yr) resulting in increased sinuosity (Figure 6), while vegetation developed and matured in side channels and average channel width deceased (indicating incision). Continued channel migration at this location through 1994 (averaging near 40 ft/yr) ultimately lead to an avulsion that is first apparent in the 1998 air photo. Peak flow events in 1995 (16,900 cfs) and 1997 (16,000 cfs) likely contributed to this avulsion, and dramatically reduced sinuosity and increased average channel widths (Figure 6). Comparing the floodplain elevations to historic channel locations where this avulsion occurred (Figure 9) shows the incision has continued to the present day. A total of 2.5 ft of incision has occurred (Figure 9), and the rate of incision has decreased from 0.28 ft/yr (between 1994 – 1998) to 0.06 ft/yr (2004 – 2011).

Additional channel migration at the upstream end of the project reach led to an avulsion (from RM 11.8 to 12) between 1980 and 1986; however there is a gap in the historic peak flow record (between 1978 and 1988) so no correlation to peak flows can be made with this avulsion. This avulsion resulted in dramatic shortening of the channel upstream in the Saxon Reach, however the reduction in sinuosity is not reflected in Figure 6 as it occurred outside of the Nesset Reach. The net result of this avulsion and the older avulsion (1947 and 1955) at the upstream end of the project reach has resulted in 5 ft of degradation.

From 1998 to 2006 all of the significant channel migration in the reach occurred at the upstream end, and at a rate ranging from 25 to 125 ft/yr. This re-meandering of the channel following the avulsion increased sinuosity, however vegetation colonization and maturation on gravel bars and relic channel locations decreased average channel widths during the same time period. This indicates that although channel migration and re-meandering occurred following the avulsion, incision was the dominant processes following the avulsion within the project reach.

GEOMORPHIC ASSESSMENT SUMMARY

Historic disturbances dating back more than a century have governed the geomorphic evolution of the South Fork within the project reach. The clearing of logjams and LWD from the South Fork, and logging of riparian forests destabilized the river corridor by removing the backbone of the system. Large trees once common in the South Fork (Collins and Sheikh 2004) had a significant influence on channel grade and bank erosion rates (Wolff 1916; Abbe 1996, 1999, 2000; Abbe and Montgomery 1996a, 1996b; Montgomery et al. 1996; Abbe and Montgomery 2003; Brummer et al. 2006; Abbe and Brooks 2011).

Channel spanning logjams and buried LWD would have provided natural grade control, maintaining side channel and floodplain connection, while deflecting flow into channel banks. This deflected flow would have initiated bank erosion and recruitment of large riparian trees. These recruited trees would subsequently provide protection from further bank erosion by deflecting flow away from the eroding bank, resulting in a more stable channel planform over time. Remnants of large ancient snags are occasionally exposed in the river bed (Figure 11). Currently there are few riparian trees large enough to create stable snags in the South Fork Nooksack. Based on cottonwood snags the river moved several hundred feet in 2012-2013, functional wood would need to have a basal stem diameter of greater than 3 ft, a rootwad diameter greater than 10 ft and a stem length over 60 ft. The stable cedar snags we observed had two or more stems attached to a single large rootwad and were over 130 ft long (Figures 12 and 13).

In addition to the removal of wood from the river, the installation and maintenance of the water pipeline has significantly impaired geomorphic processes and associated habitat in the vicinity of the pipeline. Bank armoring and construction of the levees intended to limit channel migration has locked the channel in place and simplified habitat conditions along the chanel margins. The restricted channel migration potential has limited LWM recruitment where the banks have been armored, and the levees have redced the magnitude and frequency of overbank flooding, reducing off channel refugia. Historic incision documented by actions taken to lower the pipeline, provide further evidence that channel adjustments to watershed and hydrologic conditions have resulted in channel incision, as the channel is restricted from migrating laterally.

Our assessment describes the geomorphic response to the historic disturbances within the project reach, and the resultant simplified system that currently exists. Soon after logging and clearing of the channel of LWD, the channel widened significantly, and changed from an anastomosing planform to a single thread channel. Following this initial widening, channel incision became the dominant process. Incision has gradually decreased channel widths from their historic high in the early 20th century, as lateral bars re-vegetate due to decreased flooding frequency. Sinuosity, floodplain and side channel activation frequency have all decreased over time, a trend that is consistent with incision. These adjustments are primarily attributed to the historic logging and removal of LWD from the channel, and any restoration action should focus on restoring the function key logs once provided. LWD loading should roughen the channel and increase channel length (by splitting flow) enough to reduce effective shear stress throughout the reach and aggrade the riverbed. These changes will increase water elevations during moderate floods, re-engaging adjacent floodplain and side channel habitat.

HYDROLOGIC ANALYSIS

NSD conducted a hydrologic analysis of the South Fork to determine appropriate stream flow values for use as part of hydraulic analysis necessary for habitat enhancement project design. Flood events that are expected to be equaled or exceeded once on average during any 1.01-, 2-, 10-, and 100-year period (recurrence interval) have a special significance for river design projects. These events are commonly referred as the 1-, 2-, 10-, and 100-year floods. Recurrence intervals represent a long term, average period between floods of a specific magnitude. However, it is important to note that autocorrelation within hydrologic records suggests that low-frequency, or rare floods, could occur at shorter intervals or even with the same year, rather than on a predictable cycle as may be suggested by average values. For habitat enhancement project design purposes, the primary recurrence interval of interest are the 1-, 2- and 10-year flows due to their influence on habitat and geomorphic conditions.

PEAK FLOWS

The United State Geological Survey (USGS) maintains an active streamflow gauge 12210000 directly upstream of the project reach at the Saxon Road Bridge (drainage area of 129 mi^2). This USGS gauge has only been active since 2009. In order to increase the available years of record, streamflow records from the Saxon Road Bridge gauge were used in combination with values generated based on the USGS gage number 12209000, near Wickersham. The Wickersham gauge is located upstream of the project reach and upstream of the Skookum Creek hatchery facilities (drainage area of 103 mi^2). By combining values for the Saxon Road Bridge and Wickersham gauge a 66-year period of record was created and provides estimates of peak flows the South Fork Nooksack River, beginning in 1934. The top ten peak flows from both gauges are shown below in Table 2.

TABLE 2 – SF NOOKSACK AT SAXON BRIDGE (USGS 12210000) TOP TEN PEAK FLOWS

RANK	DATE	FLOW (CFS)*
1	11/23/1990	22400
2	12/12/2011	20500
3	11/9/1989	20200
4	11/3/1955	19300
5	10/17/2003	18500
6	1/8/2009	18400
7	12/2/1975	17200
8	11/29/1995	16900
9	3/19/1997	16000
10	11/6/2006	16000

* At gauge location

Peak discharge estimates for the combined gauge records were evaluated utilizing a Log Pearson Type III and following using USGS Bulletin #17B procedures (USGS, 1982). Following recommendations by Knowles and Sumioka (2001) this analysis was scaled to the project reach. Results from the peak flow and exceedance flow analysis are shown below in Table 3. The regional regression estimates (Knowles and Sumioka 2001) are about 29% greater than the peak flow analysis. Given the gage location, we believe the peak flow estimates from gage record to be more accurate. Two tributaries enter the river within the project reach downstream of the Saxon bridge gage, both on the right bank: Nesset Creek at RM 12 and Pond Creek at RM 11.1. Discharge from the creeks would slightly increase flows in Table 3.

Seven of the highest discharges for the South Fork have occurred within the past 20-years and are associated with rainfall dominated events between November and January. In an examination of changes in precipitation patterns and intensity within the North Fork Nooksack watershed, Hyatt (2007) discusses evidence that the warming climate may be influencing the frequency of large magnitude flood events. Other regional studies support the case that the magnitude and frequency of peak flows are likely to increase in Western Washington as a result of the warming climate (e.g., Mote 2006; Hamlet and Lettenmaier 2007; Abbe et al. 2008; Mote et al. 2008, Lee and Hamlet 2011; Neiman et al. 2011). The limited historic data for the South Fork Nooksack is insufficient to determine a statistically significant trend or climatic influence. Based on current climate change predictions for the western Cascades, over the next 80 years the South Fork Nooksack could experience a 20-25% increase in its 100 year flood discharge and a more moderate increase in lower magnitude, higher frequency events. Regardless, all predictions indicate some

sort of increase in peak flows and decrease in base flows. These changes could increase the duration in which the river moves bed material, and the magnitude of alluvium in transport, resulting in more rapid channel migration and incision,, further isolating off-channel habitat. Restoration actions that reduce stream energy through shear stress partitioning, reducing incision and lateral erosion rates, and promote bed aggradation and re-connection with historic floodplain and side channel habitats will help to moderate the expected impacts of a changing climate (Beechie et. al. 2012).

TABLE 3 – SF NOOKSACK PEAK FLOWS

RECURRENCE INTERVAL (YEARS)	GAUGE 1221000 GAUGE AT SAXON BRIDGE* (CFS)	FROM REGIONAL RECESSION CURVES** (CFS)
1	3400	4400
2	10300	13200
5	14500	18600
10	17100	22000
25	20200	26000
50	22500	28800
100	25200	32400

** Estimated peak flows in the South Fork Nooksack based on combined gauge records*

*** Estimated peak flows for Nesset reach based upon basin scaling methods from Knowles and Sumioka (2001)*

HYDRAULIC ASSESSMENT

The primary objective of NSD's hydraulic analysis was to evaluate flow patterns, hydraulic parameters, and inundation extents to characterize current riverine conditions and evaluate the effects of the proposed alternatives. Hydraulic models were created representative of existing conditions using Hydronia's RiverFLO-2D v3 and Aquaveo SMS v11.1 computer software. RiverFLO-2D is a two-dimensional, finite element computer model that provides depth-averaged hydraulic parameters at nodes within a triangular model mesh domain. RiverFLO-2d determines depth-averaged hydraulic parameters by solving the shallow water equations resulting from the integration of the Navier-Stokes equation. The Navier Stokes equation is derived from applying Newton's Second Law (Force=mass*acceleration) to fluid motion, and is generally expressed as:

$$\overbrace{\rho\Big(\underbrace{\frac{\partial \mathbf{v}}{\partial t}}_{\text{Unsteady acceleration}} + \underbrace{\mathbf{v}\cdot\nabla\mathbf{v}}_{\text{Convective acceleration}}\Big)}^{\text{Inertia (per volume)}} = \overbrace{\underbrace{-\nabla p}_{\text{Pressure gradient}} + \underbrace{\mu\nabla^2\mathbf{v}}_{\text{Viscosity}}}^{\text{Divergence of stress}} + \underbrace{\mathbf{f}.}_{\text{Other body forces}}$$

Where ρ = fluid density
μ = dynamic viscosities
p = pressure
∇ = del operator (abbreviation for derivative (gradient)of 3D vector field)
f = term representing body forces acting on the fluid (per unit volume)

SMS is a GIS based program that creates the triangular model mesh, model input files, and displays model results. The following sections provide more in-depth information on specific components of our hydraulic analysis, data development, and results.

METHODS

The existing-condition hydraulic analysis was completed to inform the understanding of current hydraulic and geomorphic processes within the project area, and to compare results with proposed condition modeling to evaluate the effects of proposed restoration elements. The existing hydraulic analysis was conducted for the 1-year and 100-year peak flow discharges. All model runs were performed in steady state (discharge does not vary with time) with a non-deformable bed (no adjustments for scour, sediment transport and deposition).

Model Topography

Hydraulic models developed for this project utilize a combination of topography data sources that include LiDAR, channel bathymetry, and ground survey. LiDAR data used for this project was acquired in 2013 for the Nooksack Indian Tribe and the Puget Sound LiDAR Consortium (PSLC) by Watershed Sciences, Inc. Channel bathymetry data used for this project was obtained from a cross-sectional survey completed in 2004 provided by the NIT. A composite digital terrain model (DTM) was developed in AutoCAD Civil3D by extrapolating dimensions of the wetted channel from the 2004 survey, and merging this generalized channel with the lidar, replacing portions of the LiDAR data which was classified as water surface.

The 2004 survey data was recorded based on the NAD83 UTM Zone 10N horizontal coordinate system, vertically referencing NAVD29. This data was then converted to match the 2013 LiDAR utilizing the horizontal and vertical datum Washington State Plane Coordinates North Zone NAD83/CORS96 (feet) and NAVD 88 (feet), respectively.

Mesh

A mesh or wireframe is a key component to any 2D hydraulic model. The model derives one depth averaged flow velocity (direction and magnitude) at each node of the 2D (x-y) mesh. Predicting vertical variations in flow within the water column requires a 3D model. The mesh is composed of nodes and elements that are coded with elevation and roughness values needed to run the computational routine. RiverFlo-2D utilizes a flexible tri-angular mesh to solve for volume conservation and momentum in the x and y directions at each node (representing depth average). The model mesh begins near the intersection with the Rothenbuhler Slough at RM 10.2 and extends upstream 2.6 miles just downstream of Saxon Road Bridge at RM 12.9. For this project the model mesh utilized approximately 115,000 triangular elements and 57,500 nodes. The governing equations are applied at each node in an iterative routine until converging on a solution that achieves conservation of mass and energy to within an acceptable error.

To create the model mesh, a map consisting of arcs and regions delineating the channel, floodplain features, and material types was developed using Aquaveo's Surface-water Modeling System (SMS) software. Polylines (referred to as arcs in SMS) were drawn along significant topographic features (top of bank, bars, side channels, roadways) and changes in roughness (forests, pastures, sloughs, logjams, cleared areas). These arcs function as breaklines during the mesh creation process to ensure the model mesh is an accurate representation of the channel/floodplain topography, and to create regions within the map having individually assigned roughness values. The spacing of nodes along an arc also functions to affect the density or refinement of the model mesh. The level of refinement of a model mesh is an important consideration during 2D modeling, as a finer (more dense) mesh creates more accurate representation of

the channel and floodplain topography, reduces model instability issues, but increases model computation time. For this project, the spacing of nodes in areas of interest were set at 10-feet intervals. (such areas included the main channel, adjacent side channels, and gravel bars) and reduced to 20, 40, and 80-feet intervals in ancillary regions becoming lense dense toward the extent of the model boundaries. In this way, the model mesh was optimized to provide detailed information in areas of interest while reducing computational time and real time needed to model all the individual scenarios for this analysis.

Roughness

Hydraulic analyses require an assessment of the resistance (drag force) the ground surface and other physical features exert against movement of water. This drag force is commonly referred to as roughness. The most accepted method to assess roughness uses the Manning's n resistance factor (Chow, 1959). Common factors that affect roughness values include: channel sediment size, gradation, and shape; channel shape, channel meandering, both bank and floodplain vegetation, obstructions to flow, channel planform, flow depth, and flow rate. The energy loss by these drag forces . are factored by the Manning's value. However, in one-dimensional models, other energy losses to channel flow include gradation, channel shape, and channel meandering, losses also accounted for by increasing the Manning's factor. Conversely, these momentum losses from channel dimensions, meandering, and floodplain topography are explicitly calculated in 2D hydraulic models explicitly calculate momentum losses caused by channel shape, meandering, and floodplain topography not normally accounted for in 1D hydraulic models. As such, Manning's n values in 2D models are generally lower (up to 30-50%) than those normally used for 1D hydraulic models (Belleudy, 2000).

Manning's n values for this project were set for different roughness types accessing land use types seen in recent aerial photographs, and in accordance with standard hydraulic reference manuals (Chow, 1959; Barnes, 1967; Hicks and Mason, 1998). These values were then further reduced by 40% from typical 1D model values after comparing model results from initial iterations with observed water surface elevations. Model roughness values are shown in Table 5.

TABLE 5 – MODEL ROUGHNESS VALUES

ROUGHNESS TYPES	MANNNG'S N VALUE*
Channel, main	0.018
Channel, side	0.028
Gravel bar	0.028
Gravel bar_vegetated	0.042
Forest (conifer,deciduous, mixed, dead, clearcut)	0.072
Pasture/clearing	0.030
Logjam	0.090
Road_Paved	0.010
Riprap	0.014
Slough	0.048

* Effective n value used in the 2D modeling after the 40% reduction

Boundary Conditions

All hydraulic models for subcritical flow require a known boundary condition at the upstream and downstream extents to begin the computational routine. The boundary conditions for each model flow are shown in Table 6, below.

Upstream conditions for the 1-year flow event were estimated from gage analysis adjusted per change in drainage area. Downstream water surface elevation for the 1-year event was estimated from a normal depth analysis of flow accounting for roughness and a mean channel gradient of 0.003 ft/ft using HEC-RAS.

The 100-year flow event utilized both flow values and water surface elevations from the South Fork Nooksack River FIS study and model, both completed by Northwest Hydraulic Consultants in 2009. Flow for the 100-yr event was taken from the regulated existing condition model output at the upstream boundary of the model mesh. Downstream water surface elevations for this analysis were taken from the regulated existing conditions model output at the downstream boundary of the model mesh (downsteam of the Rothenbuhler Slough).

TABLE 6 – UPSTREAM BOUNDARY CONDITIONS

FLOW EVENT	DISCHARGE (CFS)	SOURCE
1-YEAR PEAK	4,400	1-yr flow estimated from gage data adjusted per change in drainage area. See Hydrology section, Table 3.
100-YEAR PEAK	30,844.3	Flow taken from Hec-RAS model* at DS extents XSEC 52338.8 combined with split from Hutch (RAS flow on the Hutch tributary: 4807.12 cfs; RAS flow on Mainstem: 26037.23 cfs. Combined flow = 30844.35 cfs).

* HEC-RAS model completed by NHC for the South Fork Nooksack River FIS study, 2009

TABLE 7 – DOWNSTREAM BOUNDARY CONDITIONS

FLOW EVENT	DOWNSTREAM WATER SURFACE ELEVATION (NAVD88 FT)	SOURCE
1-YEAR PEAK	312.16	WSEL determined through normal depth analysis of XSEC 52174.19* at S=0.003
100-YEAR PEAK	317.41	WSEL taken from HEC-RAS model* at DS extents XSEC 52338.8

* HEC-RAS model completed by NHC for the South Fork Nooksack River FIS study, 2009

EXISTING CONDITIONS RESULTS

Results from the existing conditions model runs are attached to this report as Appendix A. Completed model runs were initially reviewed in SMS to verify accuracy of results and then exported to GIS compatible data files. GIS compatible data files include data for each node and hydraulic parameters within the model mesh (water surface elevation, flow depth, flow velocity, shear stress, etc.) to facilitate importing into GIS to develop raster grids of the model results. Key observations of the model results are described below.

- The right bank side channel complex at RM 11.8 near Nesset Creek receives some slow moving backwater during the 1-year flow but is not connected to mainstem channel at the upstream inlets

(Figure 14). The right bank floodplain is inundated with pooled water with depths up to 2 ft and velocities < 0.3 ft/sec (Figures 14 & 15).

- The left bank side channels at RM 11.6 are inundated during the 1-year flow event and convey 380 cfs (9 percent of total discharge), with flow depths up to 3.5 ft and velocities up to 3 ft/sec (Figures 14 & 15). Average velocity in these side channels is 1 ft/sec, with an average depth of 1 ft. The floodplain between the side channels is inundated with shallow water 0.5 ft deep.
- Deep pools with depths up to 8 and 15 ft occur in the thalweg along the outer banks in the meanders at RM 11.6, RM 10.9, 10.7, and 10.3 for the 1- and 100-year flows, respectively (Figures 14 & 16).
- 1-year flow velocities exceed 12 ft/sec in confined areas and in meander bends, with 100-year flows reaching velocities up to 17.5 ft/sec (Figures 15 & 17).
- The mean depth for the mainstem during the 1-year flow is 4.5 ft, with an average velocity of 6 ft/sec. Reach wide averages for the 1-year flow are 3 ft and 2.5 ft/sec (Figures 14 & 15). During the 100-year flood mainstem depth and velocities approach 10-ft and upwards of 10-ft/s.
- The existing right bank levee from RM 10.5 to 10.9 is not overtopped during the 1-year flow event; however flow velocities adjacent to the levee reach 11 ft/sec. Scour pools near the levee are 8 ft deep.
- Areas of slow moving backwater occur during the 1-year at RM 11.2 in an old meander channel and in the Hutchinson Creek outlet at RM 10.3 (Figure 14).
- Gravel bars along the mainstem channel are inundated with water up to 1 ft in depth during the 1-year flow and much of the floodplain is inundated during the 100-yr flow event (Figures 14 & 16).
-
- Rothenbuhler is not actively connected at the inlet or outlet locations during the 1-year flow. During the 100-year flow Rothenbuhler Slough conveys approximately 750-cfs with depths up to 6 ft and velocities of 1.5 ft/s.

TABLE 8 – TYPICAL EXISTING HYDRAULIC CONDITIONS

LOCATION (RM)	1-YR DEPTH/VELOCITY	100-YR DEPTH/VELOCITY
11.8	2.5 – 6 ft/3 – 9 ft/s	6 – 11 ft/6 – 10.5 ft/s
11.3	1.5 – 5.5 ft/3 – 10 ft/s	6 – 12 ft/4 – 15 ft/s
10.8	2 – 8 ft/3 – 9 ft/s	9 -14 ft/4 – 12 ft/s
10.4	3 – 7 ft/2 – 8 ft/s	8 – 12 ft/4 – 16 ft/s

LIMITATIONS

We have prepared this report for Nooksack Indian Tribe, their authorized agents and regulatory agencies responsible for the Nesset Reach restoration project. Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices for geomorphology and hydrology in this area at the time this report was prepared. The conclusions, recommendations, and opinions presented in this report are based on our professional knowledge, judgment and experience. No warranty or other conditions, expressed or implied, should be understood.

We appreciate this opportunity to be of service to Nooksack Indian Tribe for this project and look forward to continuing to work with you. Please call if you have any questions regarding this report, or if you need additional information.

Sincerely,

Natural Systems Design, Inc.

R. Leif Embertson, MS, PE, CFM
Senior River Engineer

Tim Abbe, PhD, PEG, PHG
Principle Geomorphologist

Attachments:

Figure 1 – Project area location map
Figure 2 – Geologic map
Figure 3 – Bedrock exposure
Figure 4 – Relative elevation map
Figure 5 – Historic channels map (1880 - 1967) (1980 – 2011)
Figure 6 – Changes in channel sinuosity and width
Figure 7 – Historic incision (RM 10.5)
Figure 8 – Historic incision (RM 10.9)
Figure 9 – Historic incision (RM 11.3)
Figure 10 – Historic incision (RM 11.7)
Figure 11 – Large snag buried in riverbed
Figure 12 – Recent wood recruitment within Nesset Reach
Figure 13 – Key log recently recruited into river within Nesset Reach
Figure 14 – Existing conditions 1 year flow depth map
Figure 15 – Existing conditions 1 year flow velocity map
Figure 16 – Existing conditions 100 year flow depth map
Figure 17 – Existing conditions 100 year flow velocity map

REFERENCES

Abbe, T.B. and D.R. Montgomery. 1996. Large woody debris jams, channel hydraulics, and habitat formation in large rivers. *Regulated Rivers: Research and Management* 12, 201-221.

Abbe, T., 1999. Engineered Log Jam Habitat Enhancement Report Site Conditions, Geomorphic Analysis, Project Objectives, and Design Proposal for the Larson's Bridge Reach of the South Fork Nooksack River. Report submitted to Lummi Indian National Department of Natural Resources, 2616 Kwina Road, Bellingham, WA 98227-9298. Tim Abbe, Seattle, WA.

Abbe, T.B. 2000. Patterns, mechanics, and geomorphic effects of wood debris accumulation in a forest river system. Ph.D. dissertation. University of Washington. Seattle, WA. 211 p.

Abbe, T., J. Bountry, L. Piety, G. Ward, M. McBride and P. Kennard. 2003a. Forest influence on floodplain development and channel migration zones. *Geological Society of America Abstracts with Programs*, Cordilleran Section, 28(5), 41.

Abbe, T.B. and D.R. Montgomery. 2003b Patterns and processes of wood debris accumulation in the Queets River Basin, Washington. *Geomorphology* 51, 81-107.

Abbe, T., Kennard, P., Park, J., and Beason, S. 2008. Alluvial landscape response to climate change in glacial rivers and the implications to transportation infrastructure. National Hydraulic Engineering Conference, Federal Highways Administration. Portland, ME.

Abbe, T. and A. Brooks. 2011. Geomorphic, Engineering and Ecological Considerations When Using Wood in River Restoration. In Simon, A., Bennett, S.J. and Castro, J.M. (Editors), Stream Restoration in Dynamic Fluvial Systems: Scientific Approaches, Analyses and Tools. American Geophysical Monograph Series 194. Washington D.C. pp.419-451.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Pess, P. Roni, J. Kimball, J. Stanform, P Kiffney, N. Mantua. 2012. Restoring salmon habitat for a changing climate. *River Research Applications*. 29 939-960.

Brown, M. and M. Maudlin. 2007. Upper South Fork Nooksack River Habitat Assessment. Lummi Natural Resources Department.

Brummer, C.J., Abbe, T.B., Sampson, J.R., and Montgomery, D.R. 2006. Influence of vertical channel change associated with wood accumulations on delineating channel migration zones, Washington, USA. *Geomorphology* 80, 295-309.

Collins, B. and A. Sheikh. 2004. Historical riverine dynamics and habitats of the Nooksack River. Nooksack Natural Resources Department.

Collins, B. D., Montgomery, D. R., Fetherston, K. L., and Abbe, T. B. 2012. The floodplain large-wood cycle hypothesis: A mechanism for the physical and biotic structuring of temperate forested alluvial valleys in the North Pacific coastal ecoregion. Geomorphology, 139, 460-470.

Earth Tech. 2002. Evaluation of Impact of South Fork Nooksack River Rip Rap Removal on Water Supply Pipeline. Unpublished report to City of Bellingham Public Works Operations.

Element Solutions. 2011. South Fork Nooksack Reach-scale Geomorphic Analysis for the proposed Downstream Hutchinson Restoration Project. Unpublished report to Nooksack Tribe Natural Resources.

Ericsson, M., T. Abbe, and J. Bjork. 2011. Basis of Design Report – South Fork Nooksack River Saxon Reach Restoration Project. Unpublished report for Lummi Natural Resources Department prepared by Cardno-Entrix, Inc..

Hamlet, A. F., and D. P. Lettenmaier. 2007. Effects of 20th century warming and climate variability on flood risk in the western U.S., Water Resour. Res., 43, W06427, doi:10.1029/2006WR005099.

Hyatt, T. 2007. Lower North Fork Nooksack: Reach Assessment and Restoration Recommendations. June 29, 2007. Nooksack Tribe Natural Resource Department. Deming, WA.

Jones, J. 2006. SC Mapping and Fish Habitat Suitability Analysis using LiDAR Topography and Orthophotography. Photogrammetric Engineering & Remote Sensing. Vol 71, No. 11.

Knowles, S.M. and S.S. Sumioka. 2001. The national flood-frequency program- Methods for estimating flood magnitude and frequency in Washington. U.S. Geological Survey Fact Sheet FS-016-01.

Lapen, T. 2000. Geologic Map of the Bellingham 1:100,000 Quadrangle, Washington. OFR 2000-5. Washington State Department of Natural Resources, Division of Geology and Earth Resources.

Lee, S., A.F. Hamlet, 2011: Skagit River Basin Climate Science Report, a summary report prepared for Skagit County and the Envision Skagit Project by the Department of Civil and Environmental Engineering and The Climate Impacts Group at the University of Washington.

Maudlin, M., T. Coe. 2011. Effectiveness Monitoring of South Fork Nooksack Instream Habitat Projects, Summer 2011. Nooksack Tribe, Natural Resources Department. Deming, WA.

Montgomery, D. R., T.B. Abbe, N.P. Peterson, J.M. Buffington, K.M. Schmidt, and J.D. Stock. 1996. Distribution of Bedrock and Alluvial Channels in Forested Mountain Drainage Basins, *Nature*, v. 381, 587-589.

Montgomery, D. R., and Abbe, T. B. 2006. Influence of logjam-formed hard points on the formation of valley-bottom landforms in an old-growth forest valley, Queets River, Washington, USA. Quaternary Research, 65(1), 147-155.

Mote, P.W., 2006. Climate-driven variability and trends in mountain snowpack in western North America. J. Climate, 19, 6209-6220.

Mote, P.W., A.F. Hamlet, E. Salathé, 2008: Has spring snowpack declined in the Washington Cascades? Hydro. Earth Syst. Sci., 12, 193-206.

Neiman, Paul J., L. J. Schick, F. M. Ralph, M. Hughes, G. A. Wick, 2011: Flooding in Western Washington: The Connection to Atmospheric Rivers. Journal of Hydrometeorology, 12, 1337–1358.

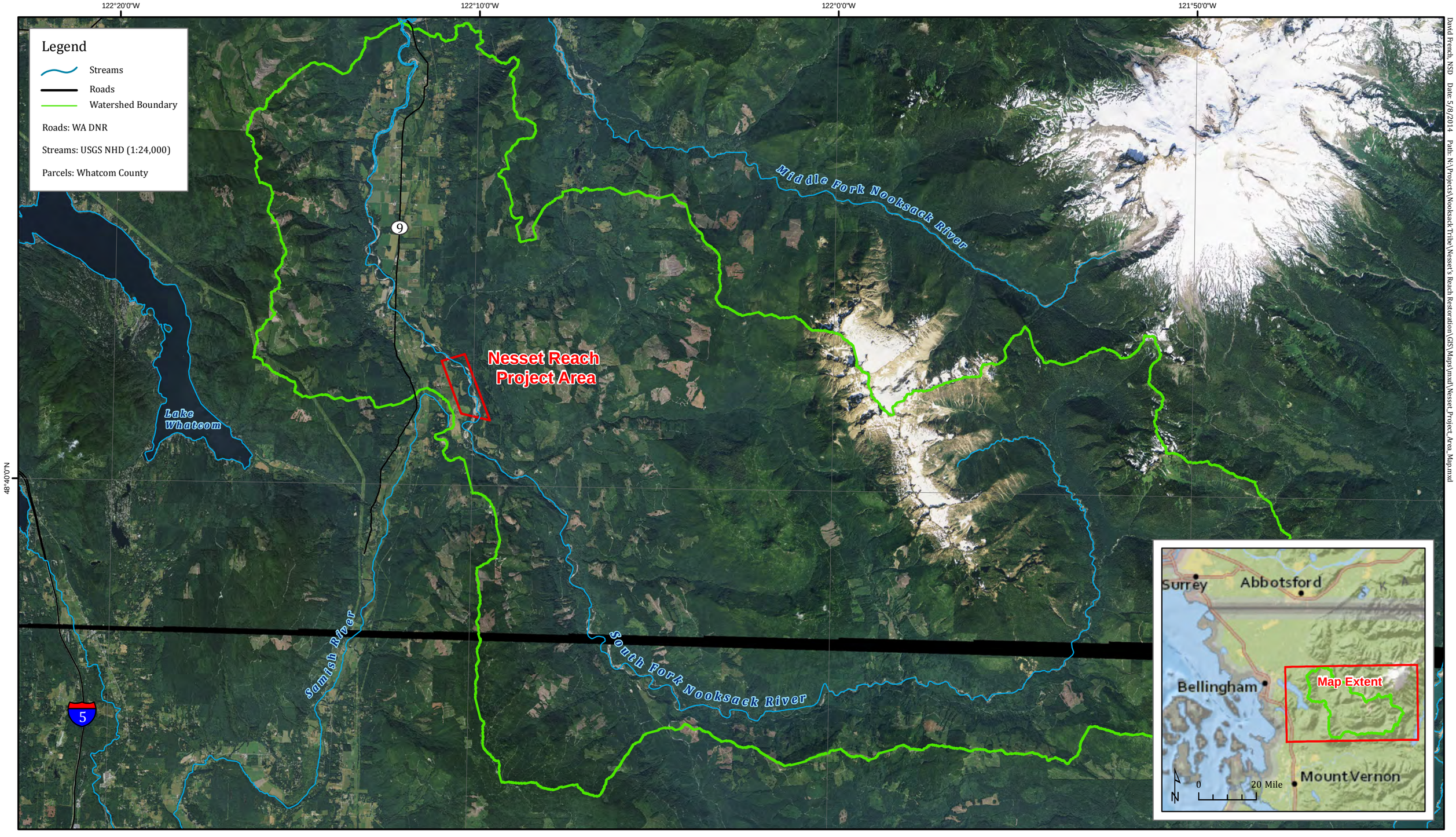
Northwest Hydraulic Consultants Inc. 1991. South Fork Nooksack River Pipeline Crossing. Unpublished report to City of Bellingham Public Works Department.

Tabor, R., R. Haugerud, W. Hildreth, E. Brown. 2003. Geologic Map of the Mount Baker 30- by 60- Minute Quadrangle, Washington. USGS Geologic Investigation Series I-2660

US Geological Survey. 1982. Guidelines for Determining Flood Flow Frequency. Bulletin #17B of the Hydrology Subcommittee, Interagency Advisory Committee on Water Data. Reston, VA.

WRIA 1. 2005. WRIA 1 Salmon Recovery Plan. Whatcom County, WA.

Wolff, H.H. 1916. The design of a drift barrier across the White River, near Auburn, Washington. *Transactions of the American Society of Civil Engineers* 16, 2061-2085. Paper No.1377.



South Fork Nooksack River - Nesset Reach Habitat Restoration

Figure 1 - Project Area Location Map

Topographic data source: February 2009 LiDAR DEM (Puget Sound LIDAR Consortium)

N

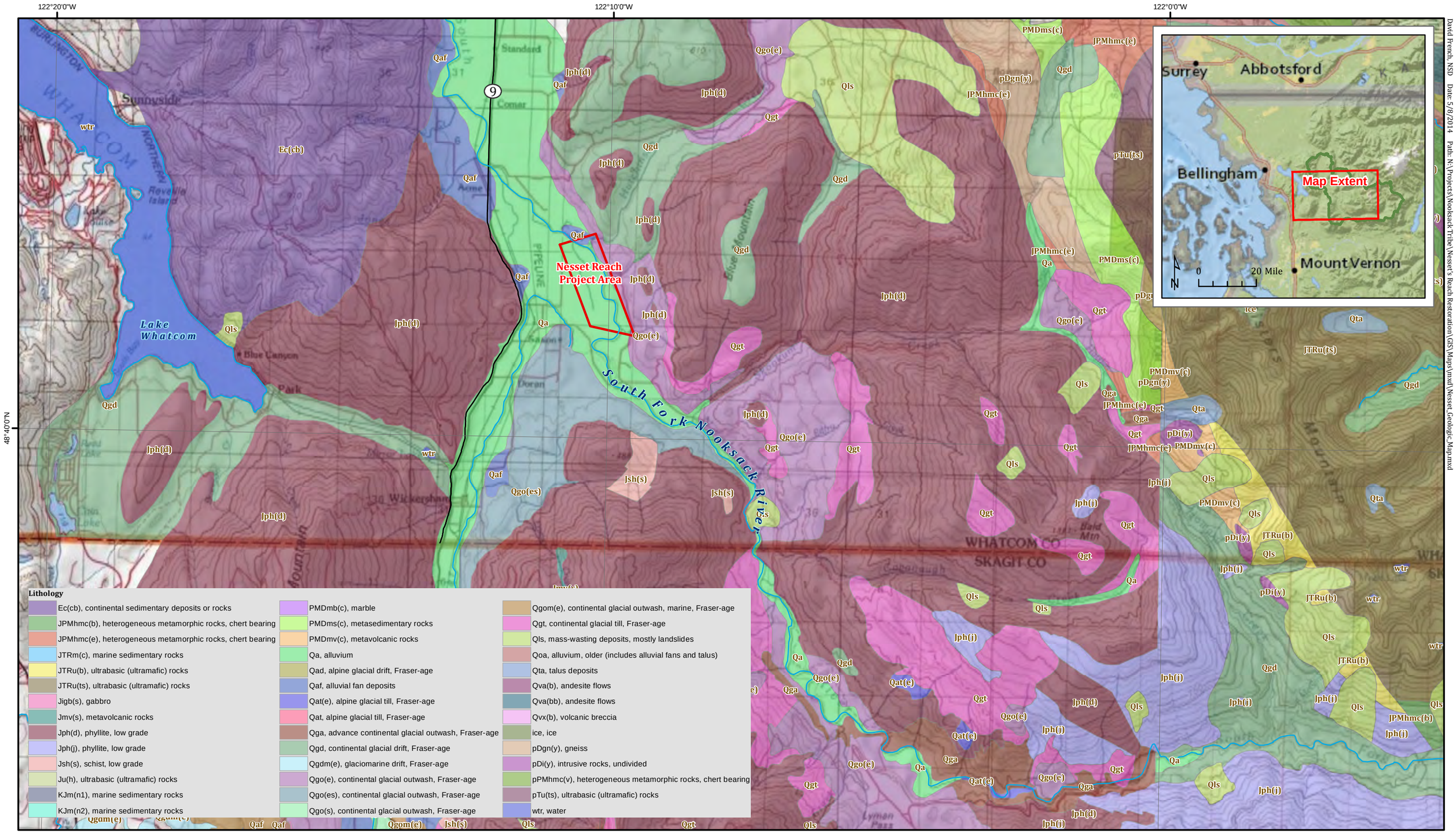
0 1 2 3 4 Miles

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 5/8/2014 Path: N:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\Nesset_Project_Area_Map.mxd



South Fork Nooksack River - Nesset Reach Habitat Restoration

Figure 2 - Geologic Map

1:100,000 Scale Surface Geology for Washington State; Department of Natural Resources
Roads: WA DNR
Streams: USGS NHD (1:24,000)
Topography: USGS

N

0 1 2 3 4 Miles

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

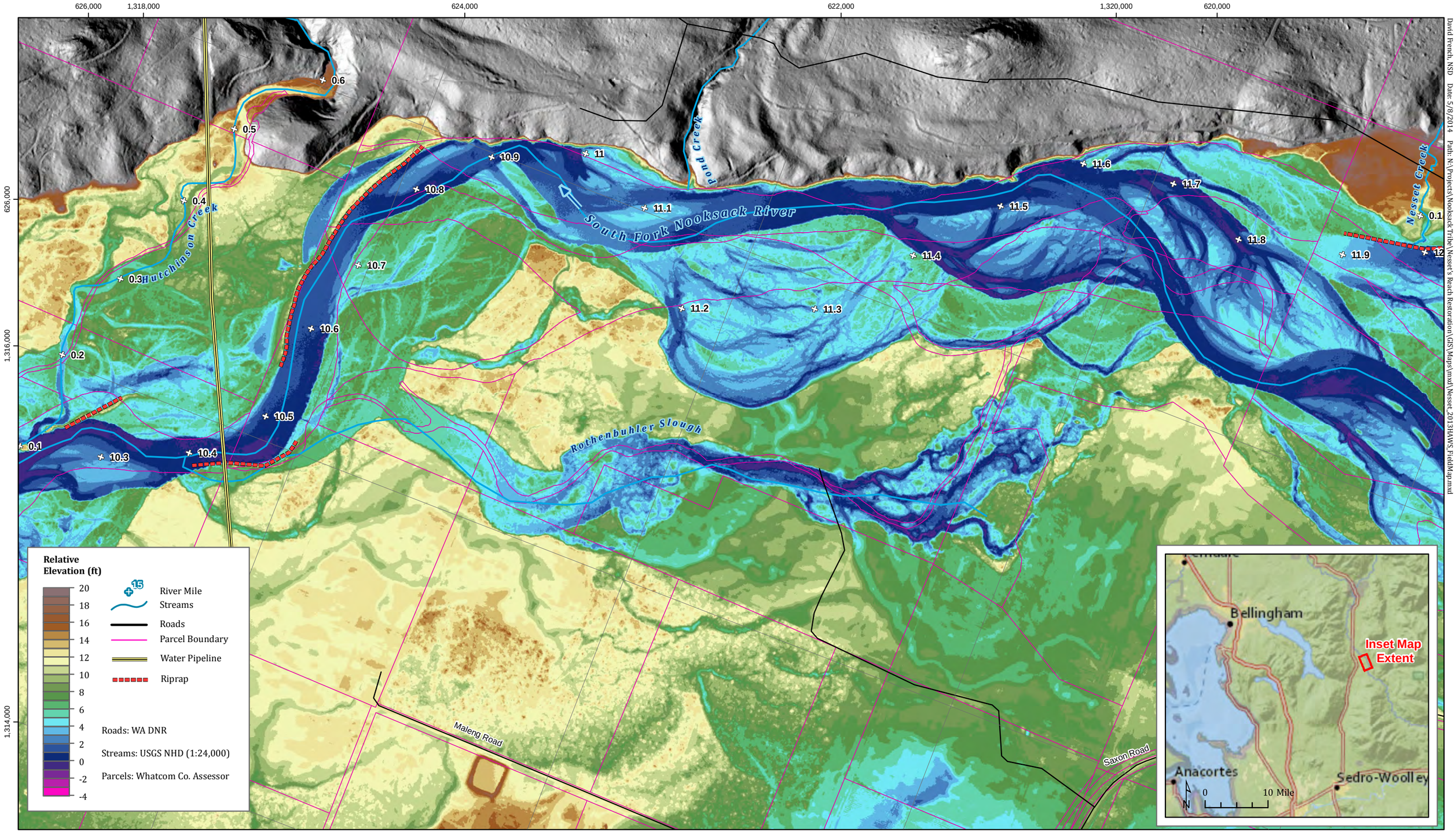
Streams
Roads
Project Area

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 5/8/2014 Path: N:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\Nesset_Geologic_Map.mxd

Figure 3. Exposure of Darrington Phyllite on right bank of SF Nookasck River at RM 11.5. A 12 foot deep pool has formed at the base of the bedrock exposure, locally known as Preacher's Rock.



0 500 1,000 1,500 2,000 Feet

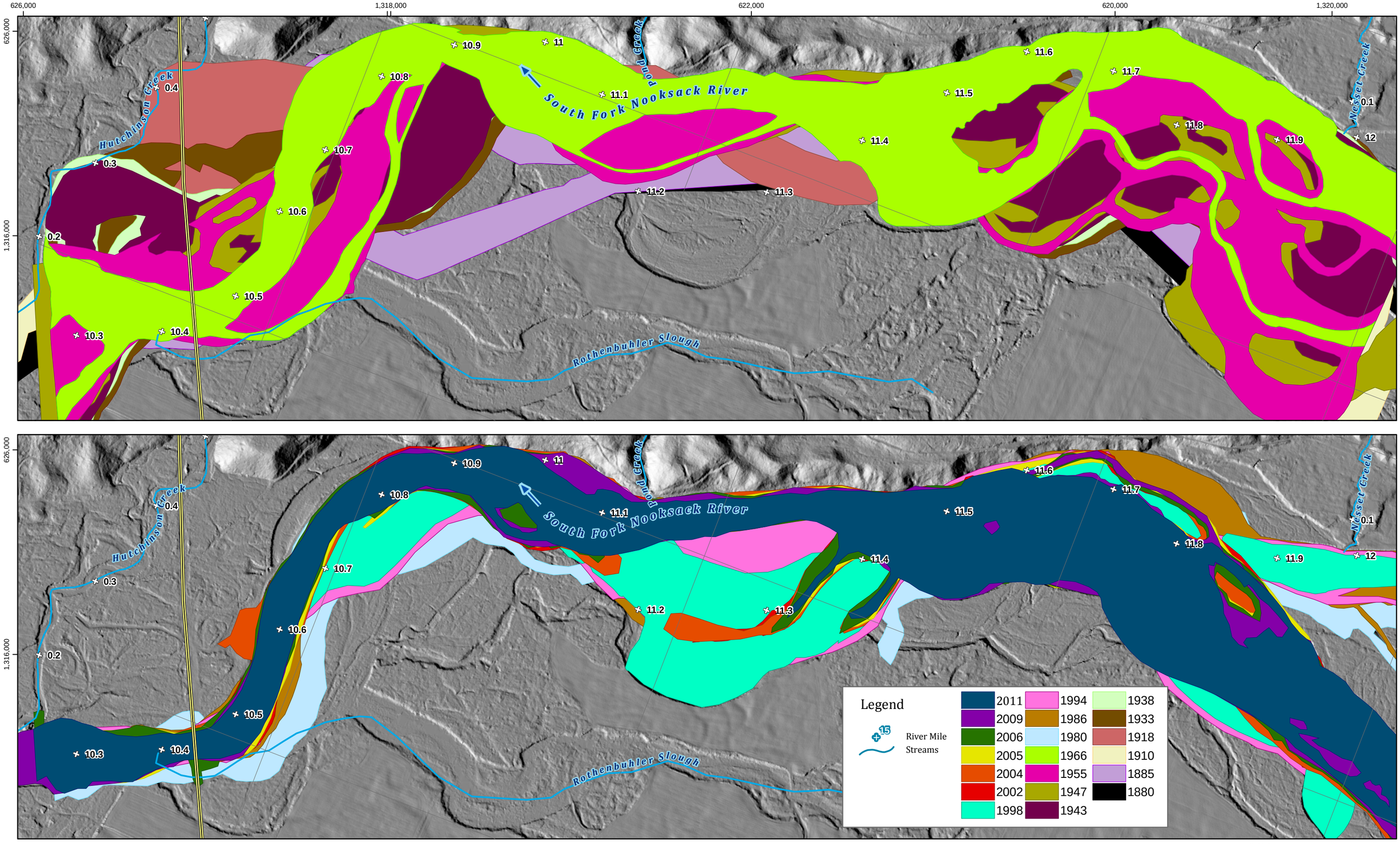
Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

South Fork Nooksack River - Nesset Reach Habitat Restoration

Figure 3 - Relative Elevation Map

Topographic Data Source: February 2013 LiDAR (Nooksack Tribe)
Relative elevation is derived as the difference between bare earth elevations and a reference plane representing the low flow water surface.

David French, NSD Date: 5/8/2014 Path: N:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\Nesset_2013HAWS_FieldMap.mxd



South Fork Nooksack River - Nesset Reach Habitat Restoration

Figure 4 - Historic Channels Map

Topographic Data Source: February 2013 LiDAR (Nooksack Tribe); Channels from Collins and Sheikh (2004) and digitized from aerial imagery by NSD (2014)

0 500 1,000 1,500 2,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 5/8/2014 Path: N:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\Figure_HistoricActiveChannels.mxd

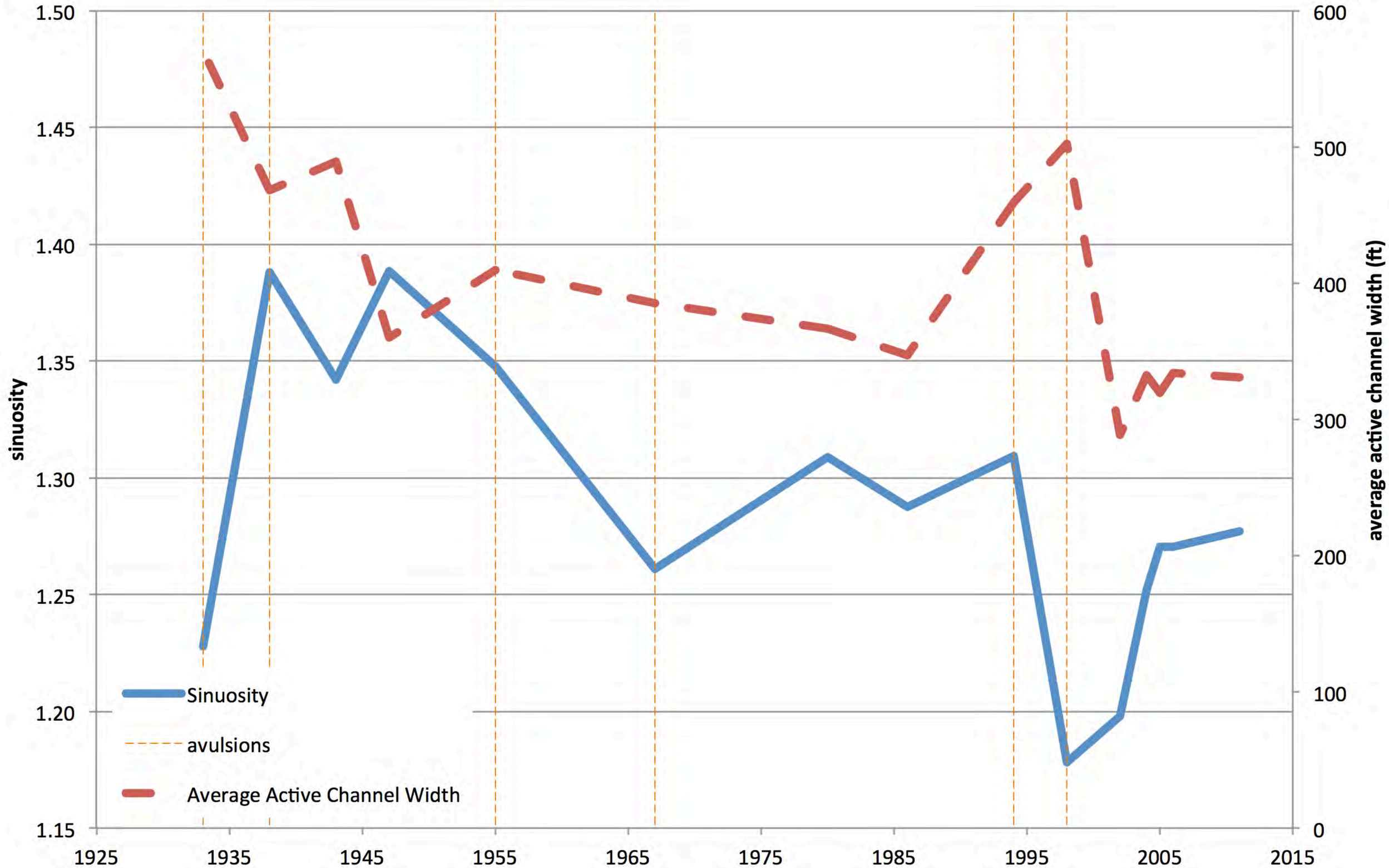
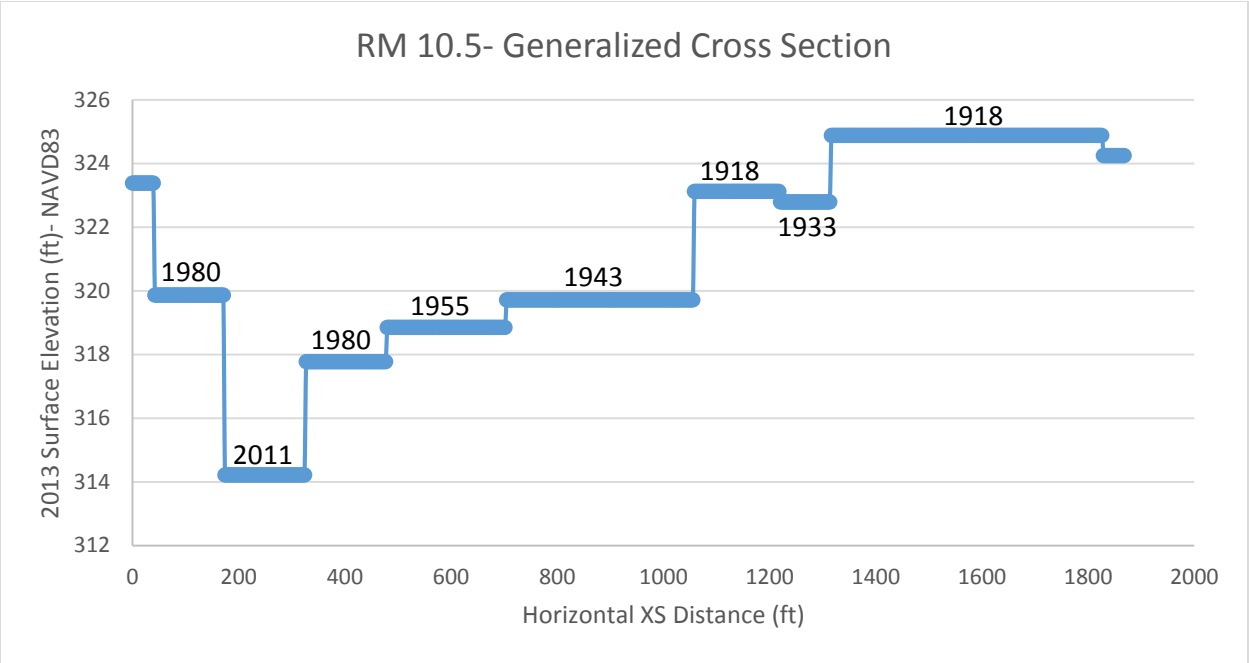
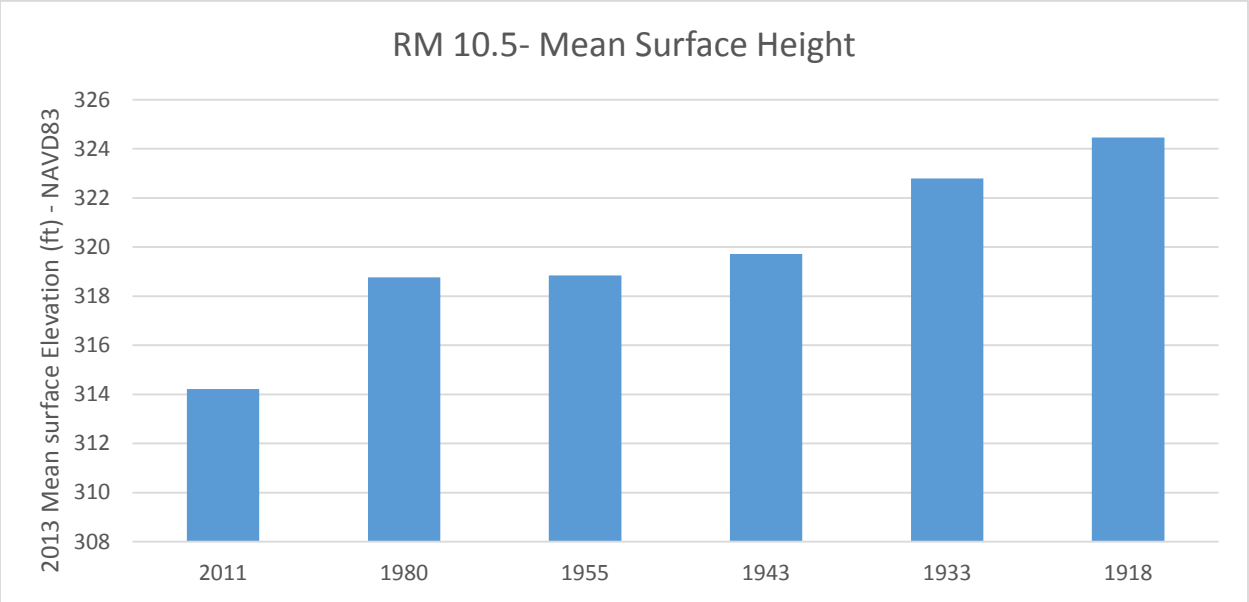


Figure 6. Changes in channel sinuosity and width (1933 - 2011)





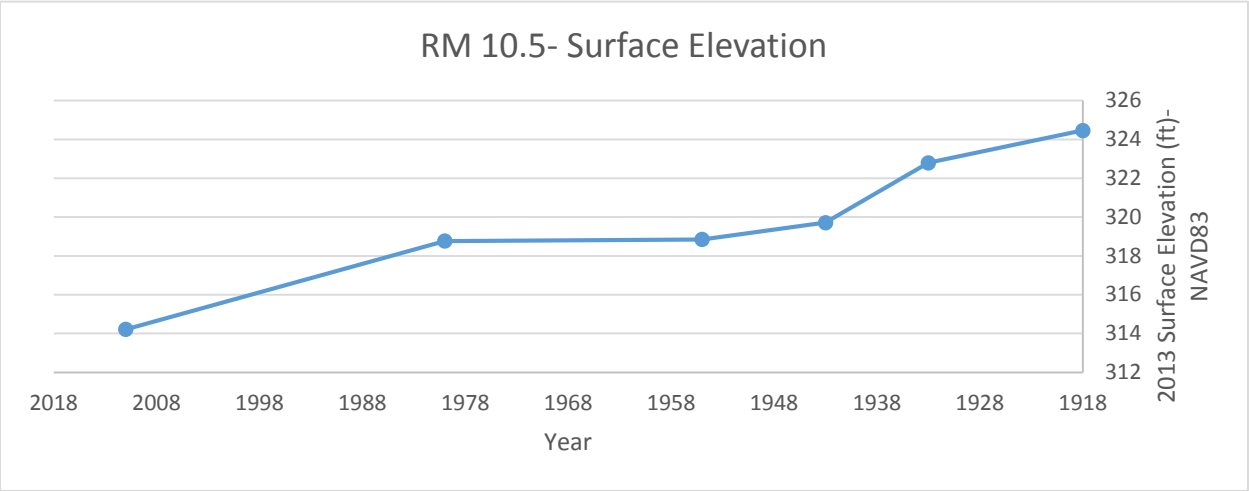
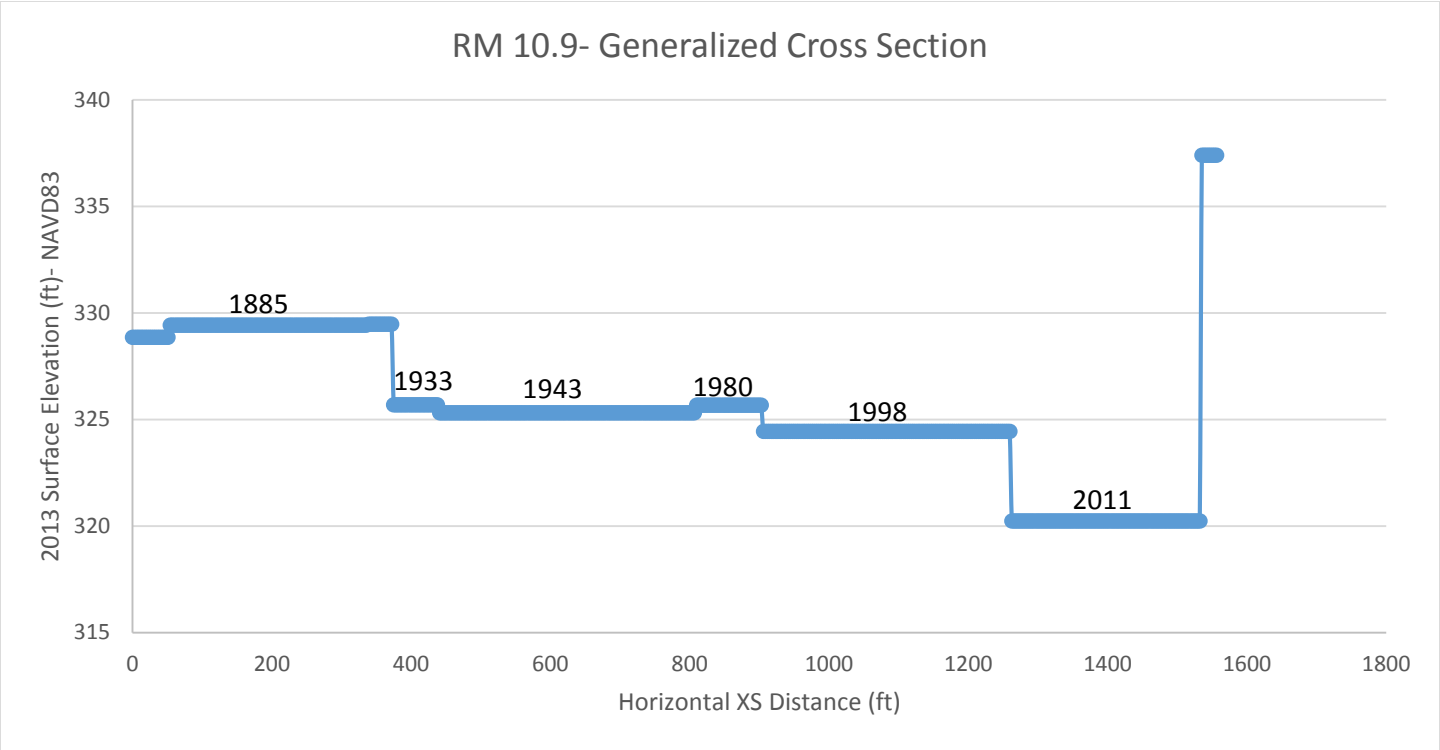
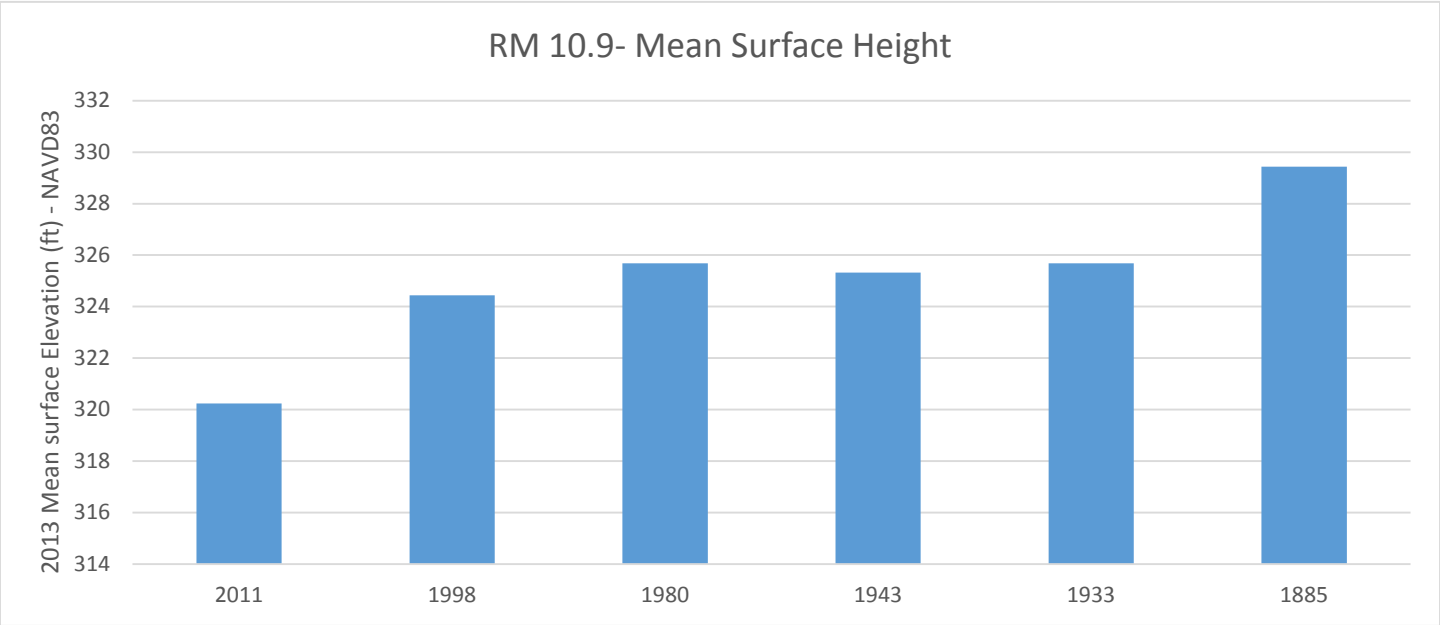


Figure 7. Surface elevations and corresponding year most recently occupied at RM 10.5, documenting historic and ongoing incision within the Nesset Reach.





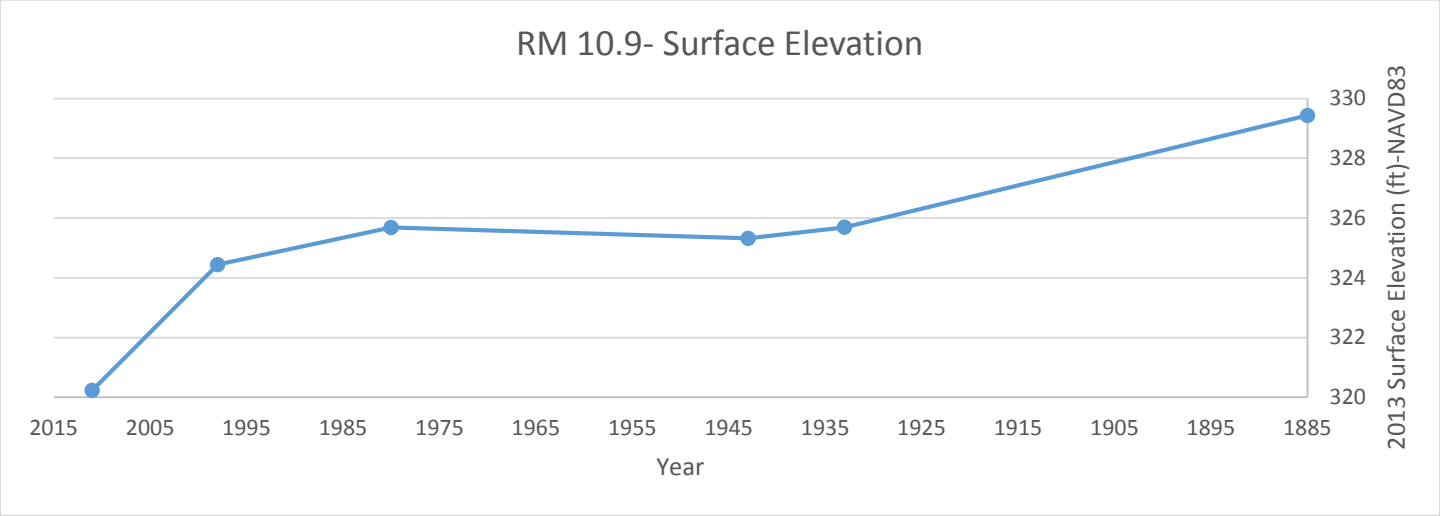
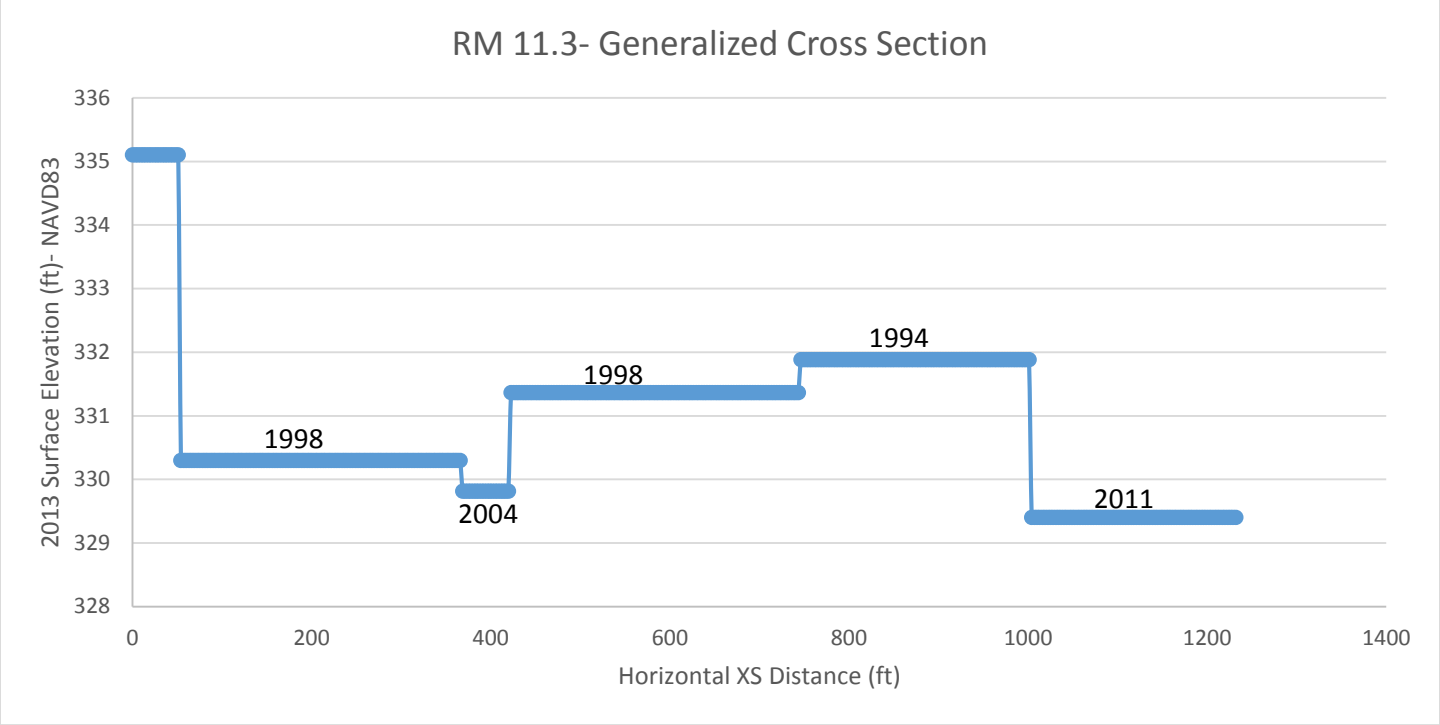
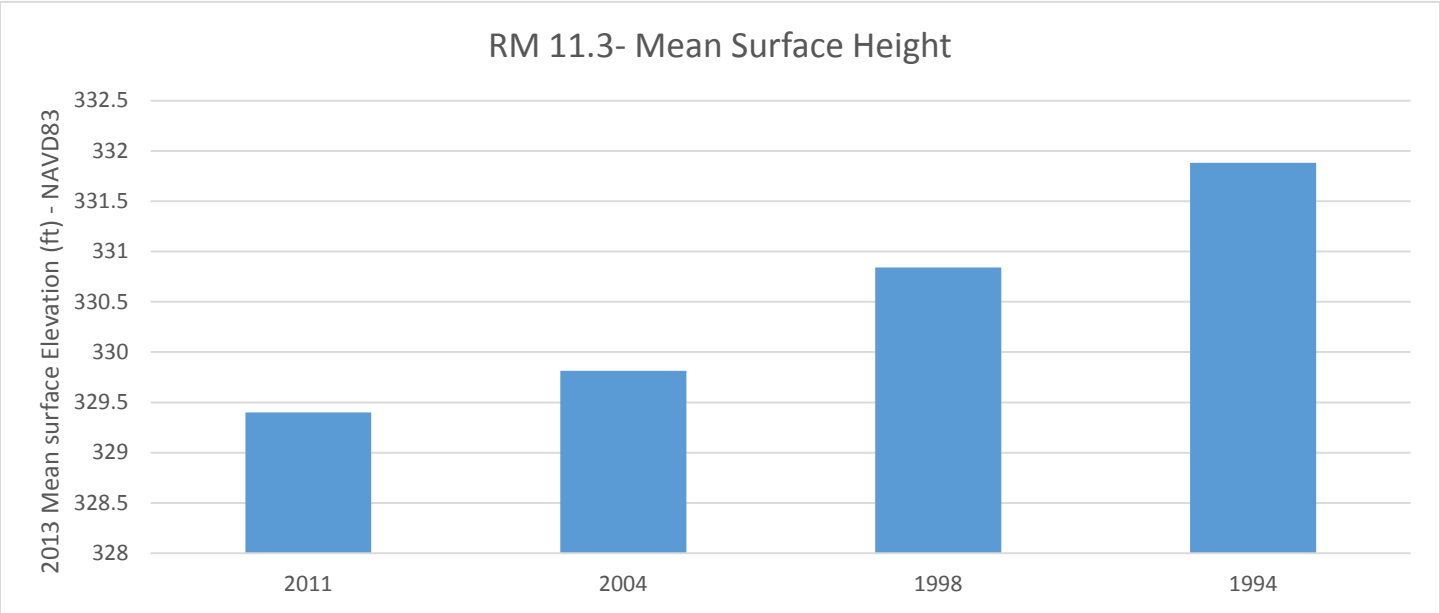


Figure 8. Surface elevations and corresponding year most recently occupied at RM 10.9, documenting historic and ongoing incision within the Nesset Reach.





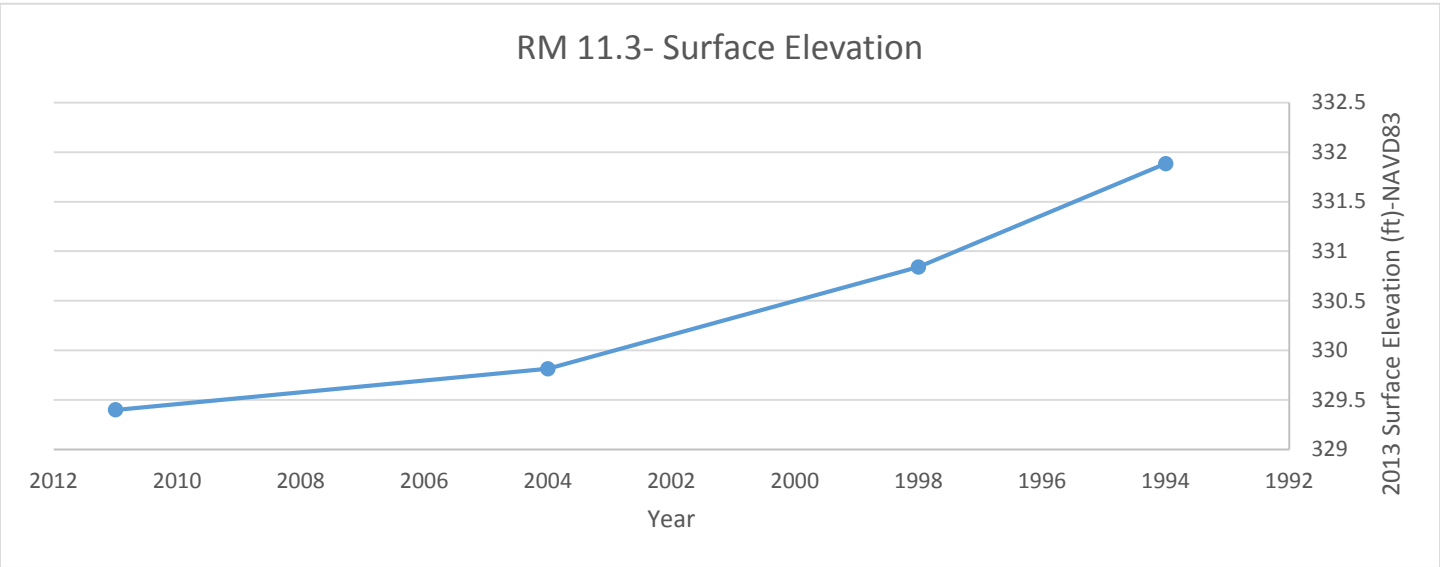
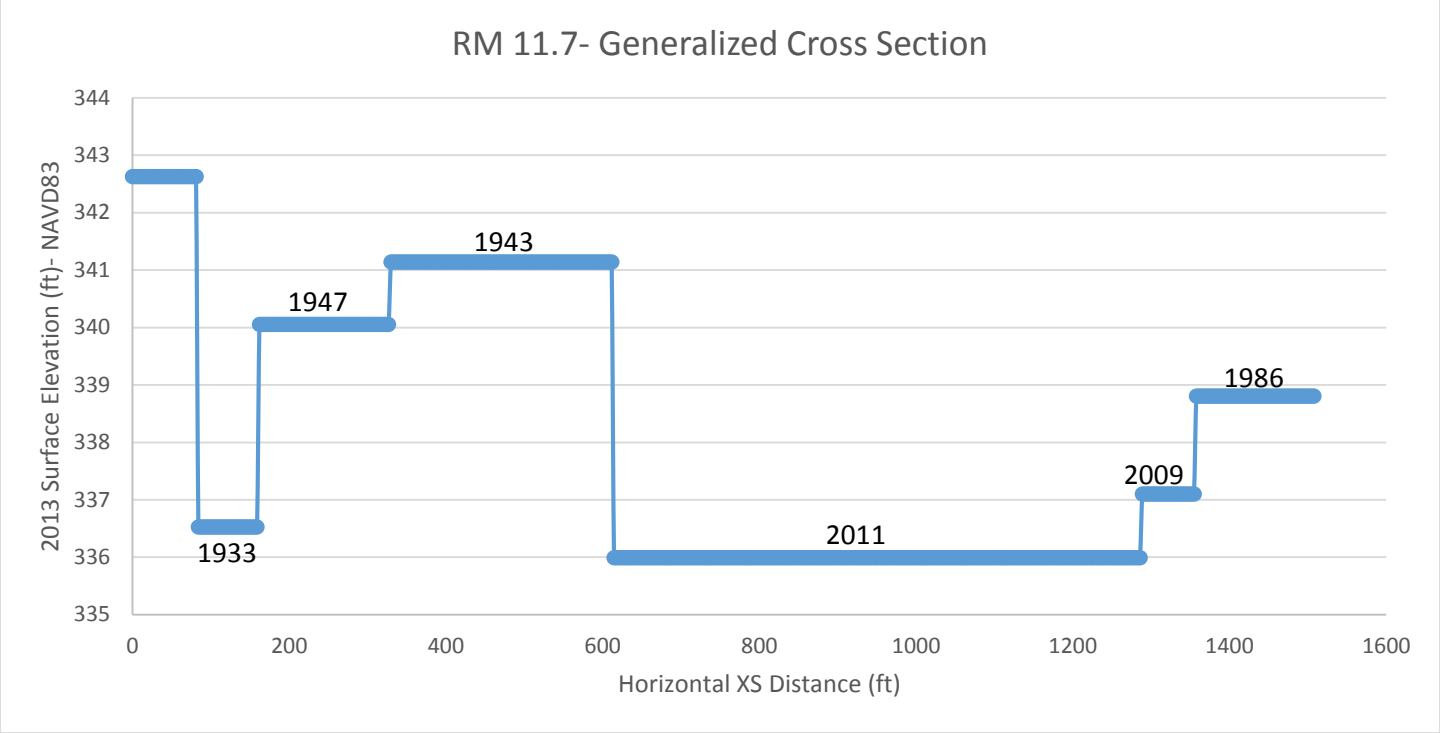
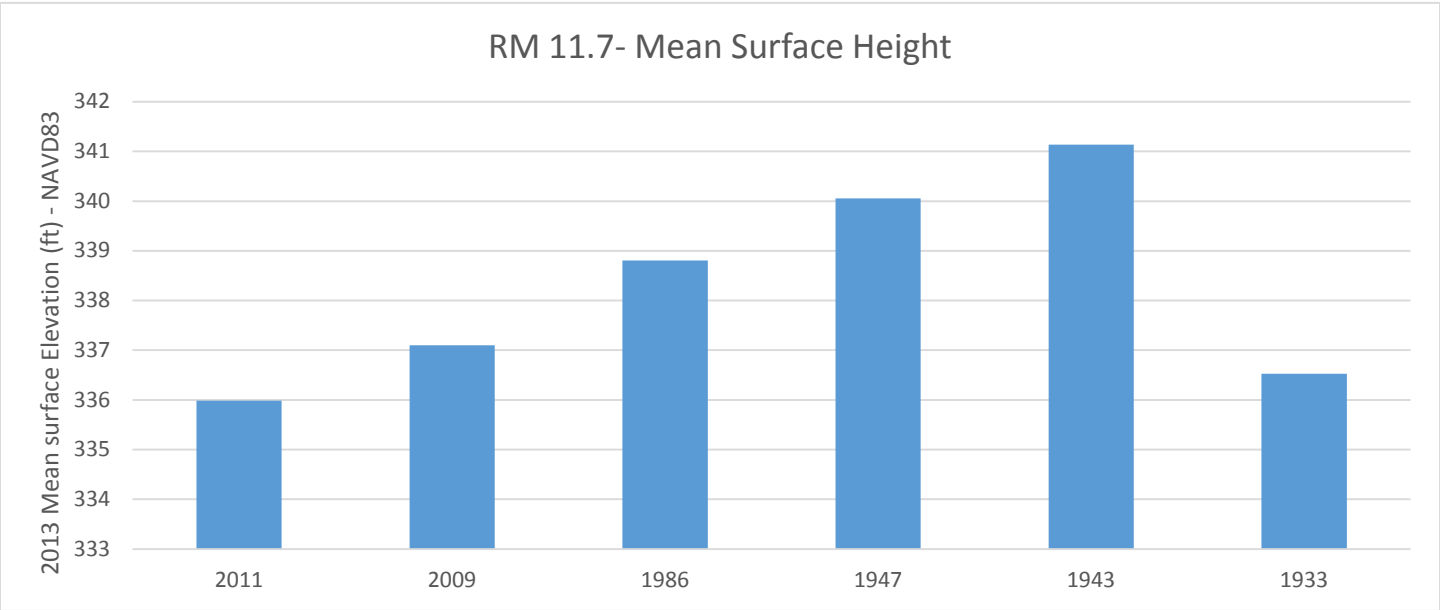


Figure 9. Surface elevations and corresponding year most recently occupied at RM 11.3, documenting historic and ongoing incision within the Nesset Reach.





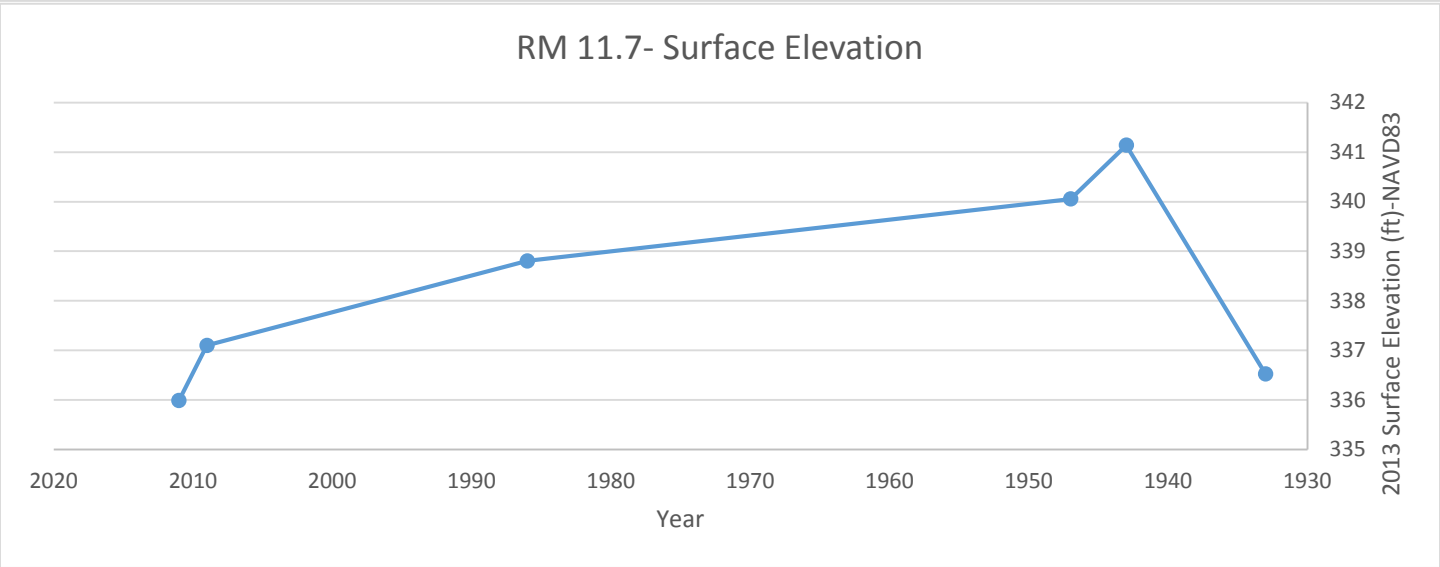


Figure 10. Surface elevations and corresponding year most recently occupied at RM 11.7, documenting historic and ongoing incision within the Nesset Reach.

Figure 11. Large ancient snag (> 4 ft in diameter) exposed in river bed at RM 11.54 at toe of left bank gravel bar.

Figure 12. Segment of Nesset Reach in SF Nooksack where riparian forest is sufficient to provide functional or key pieces to the river. In August 2013 survey, 4 distinct snags were observed in low-flow channel from RM 11.8 to 11.9. Each snag consisted of multiple large trees attached to same rootwad.

Figure 13. Rare example of stable snag recently recruited to South Fork from eroding left bank at RM 11.82, observed in August 2013. This snag is two cedar boles (~2.5-3.5 ft diameters) attached to single rootwad about 10-15 ft in diameter. Total length is approximately 140 ft. This snag does not appear to have moved from where it entered river between 2009 and 2011.

APPENDIX B

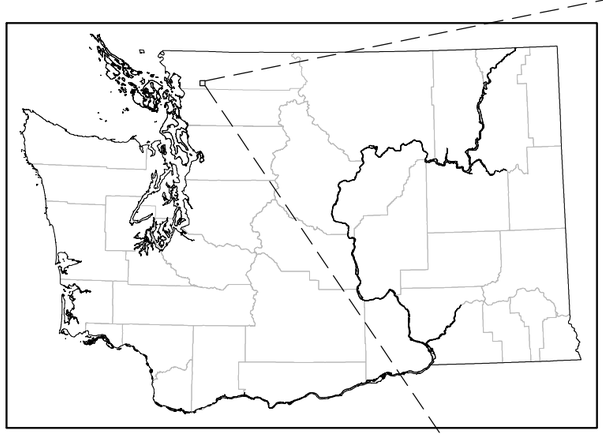
PRELIMINARY DESIGN DRAWINGS

Natural Systems Design

P.O. Box 15609, Seattle, WA 98105 T: (206) 834-0175

SOUTH FORK NOOKSACK RIVER

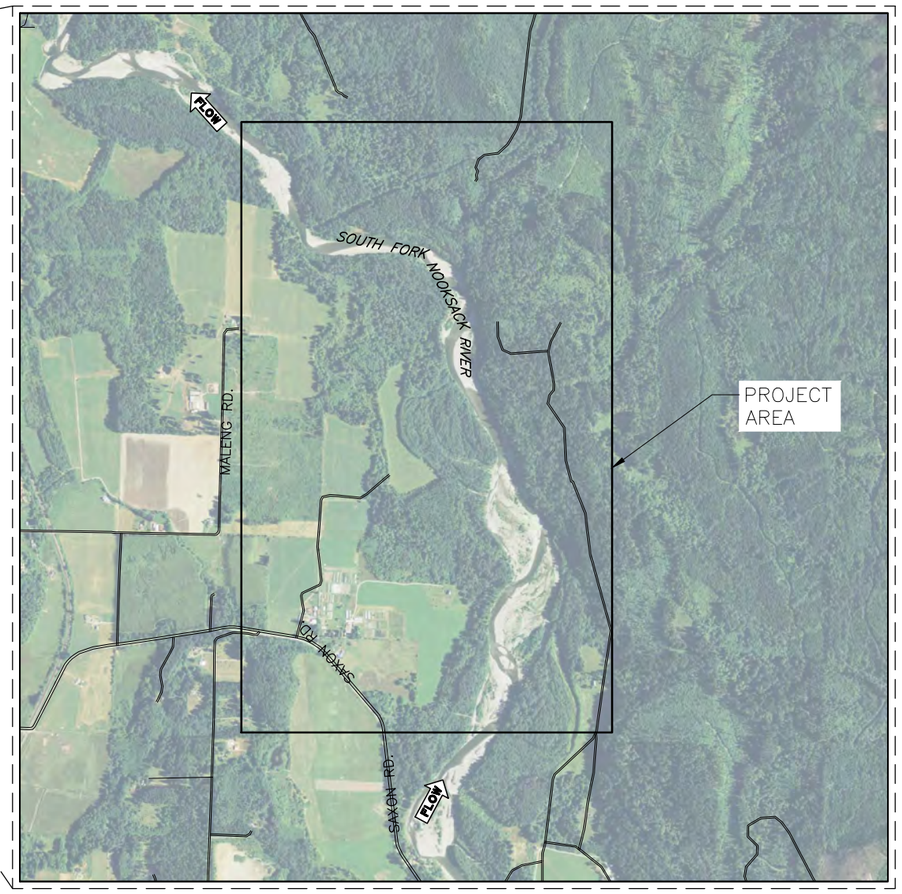
NESSET'S REACH RESTORATION



WASHINGTON STATE

SCALE: 1"=50 MILES

50 25 0 50 100



VICINITY

SCALE: 1" = 1000'

Sheet List Table	
Sheet Number	Sheet Title
1	COVER SHEET
2	GENERAL NOTES
3	LEGEND
4	SITE PLAN
5	PHASE 1 SITE PLAN
6	PHASE 2 SITE PLAN
7	PHASE 3 SITE PLAN
8	PHASE 3 SECTION AND DETAILS
9	TYPE 1 ELJ
10	TYPE 2 ELJ
11	TYPE 3 ELJ
12	TYPE 4 ELJ
13	RESTORATION DETAILS
14	PHASE 1 TESC PLAN
15	PHASE 2 TESC PLAN
16	PHASE 3 TESC PLAN
17	TESC DETAILS

CONTACT INFORMATION

NATURAL SYSTEMS DESIGN, INC

1900 N NORTHLAKE WAY, SUITE 211
SEATTLE, WA 98103
(206) 834-0175

NOOKSACK INDIAN TRIBE

5016 DEMING ROAD
DEMING, WA 98244
(360) 592-5176

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS -- CURRENT\COVER SHEET.DWG Corvey 5/1/2013 9:26:19 AM

State of Washington Licensed Geologist 1981 Timothy B. Abbe

R. LEIF EMERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

0 Ø 1

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

COVER SHEET

SHEET 1 OF 17

GENERAL NOTES

1. THESE PLANS HAVE BEEN PREPARED FOR THE EXCLUSIVE USE OF NOOKSACK INDIAN TRIBE, HEREAFTER REFERRED TO AS "OWNER" AND THEIR AUTHORIZED AGENTS.

2. NATURAL SYSTEMS DESIGN HEREAFTER REFERRED TO AS "ENGINEER" IS RESPONSIBLE FOR THE PREPARATION OF THESE ORIGINAL PLANS AND ASSOCIATED SPECIFICATIONS AND WILL NOT BE RESPONSIBLE FOR, OR LIABLE FOR UNAUTHORIZED CHANGES TO OR USES OF THESE PLANS. ANY USE WHICH INCLUDES ALTERATION, DELETION, OR EDITING OF THIS DOCUMENT WITHOUT EXPLICIT WRITTEN PERMISSION FROM THE ENGINEER, IS STRICTLY PROHIBITED. ANY OTHER UNAUTHORIZED USE OF THIS DOCUMENT IS PROHIBITED.

3. MINOR MODIFICATIONS ARE EXPECTED TO SUIT JOB SITE DIMENSIONS OR CONDITIONS. SUCH MODIFICATIONS SHALL BE INCLUDED AS PART OF THE WORK. THE OWNER, ENGINEER AND APPROPRIATE REGULATORY AGENCIES WILL BE NOTIFIED OF ANY OWNER–AUTHORIZED CHANGE RESULTING IN MORE THAN A 10% DESIGN CHANGE OF PROPOSED FOOTPRINT OR SIGNIFICANTLY AFFECTING THE INTENDED BENEFIT OR FUNCTION OF A PROJECT ELEMENT.

4. THE LOCATION OF ALL FEATURES SHOWN IS APPROXIMATE.

5. THE CONTRACTOR AGREES TO ASSUME SOLE AND COMPLETE RESPONSIBILITY FOR JOB SITE CONDITIONS DURING THE COURSE OF CONSTRUCTION OF THIS PROJECT, INCLUDING SAFETY OF ALL PERSONS AND PROPERTY, AND FURTHER AGREES THAT THIS REQUIREMENT SHALL APPLY CONTINUOUSLY AND NOT BE LIMITED TO NORMAL WORKING HOURS IN ACCORDANCE WITH THE PROVISIONS OUTLINED BY THE PROJECT CONTRACT AND SPECIFICATIONS.

6. ALL IMPROVEMENTS SHALL BE ACCOMPLISHED UNDER THE APPROVAL, INSPECTION, AND TO THE SATISFACTION OF THE OWNER. IMPROVEMENT CONSTRUCTION SHALL COMPLY WITH THESE PLANS AND THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT) STANDARD PLANS FOR CONSTRUCTION OF ROAD, BRIDGE, AND MUNICIPAL CONSTRUCTION, CURRENT EDITION UNLESS NOTED OTHERWISE. ALL REFERENCES TO THE "STANDARD SPECIFICATIONS" SHALL MEAN THE WASHINGTON STATE DEPARTMENT OF TRANSPORTATION (WSDOT) STANDARD SPECIFICATIONS FOR CONSTRUCTION OF LOCAL STREETS AND ROADS, CURRENT EDITION. CONSTRUCTION NOT SPECIFIED ON THESE PLANS SHALL CONFORM TO THE REQUIREMENTS OF THE STANDARD SPECIFICATIONS. THE CONTRACTOR IS OBLIGATED TO BE FAMILIAR WITH APPLICABLE SECTIONS OF THE STANDARD SPECIFICATIONS NOT DISCUSSED IN THE GENERAL NOTES. THE CONTRACT SPECIAL PROVISIONS SHALL SUPERSEDE THOSE OF THE STANDARD SPECIFICATIONS WHERE DISCREPANCIES OCCUR.

7. IT IS THE RESPONSIBILITY OF THE CONTRACTOR AND HIS SUBCONTRACTOR(S) TO EXAMINE THE PROJECT SITE PRIOR TO THE OPENING OF BID PROPOSALS. THE CONTRACTOR SHALL BECOME FAMILIAR WITH THE CONDITIONS UNDER WHICH THE WORK IS TO BE PERFORMED, SUCH AS THE NATURE AND LOCATION OF THE WORK AND THE GENERAL AND LOCAL CONDITIONS, PARTICULARLY THOSE AFFECTING THE AVAILABILITY OF TRANSPORTATION, THE DISPOSAL, HANDLING, AND STORAGE OF MATERIALS, AVAILABILITY OF LABOR, WATER, ELECTRICITY, ROADS, THE UNCERTAINTIES OF WEATHER, THE CONDITIONS OF THE GROUND, SURFACE AND SUBSURFACE MATERIALS, GROUNDWATER, THE EQUIPMENT AND FACILITIES NEEDED FOR AND DURING THE PERFORMANCE OF THE WORK, AND THE COSTS THEREOF. ANY FAILURE BY THE CONTRACTOR AND SUBCONTRACTOR(S) TO ACQUAINT THEMSELVES WITH ALL THE AVAILABLE INFORMATION WILL NOT RELIEVE THE CONTRACTOR AND SUBCONTRACTOR(S) FROM RESPONSIBILITY FOR PROPERLY ESTIMATING THE DIFFICULTY AND COST OF SUCCESSFULLY PERFORMING THE WORK.

8. THE CONTRACTOR IS RESPONSIBLE FOR REVIEWING THE CONTRACT DOCUMENTS AND FOR ALL SUBMITTALS REQUIRED TO THE OWNER FOR REVIEW AND ACCEPTANCE.

PERMIT NOTES

1. EVERY REASONABLE EFFORT SHALL BE MADE TO CONDUCT THE ACTIVITIES SHOWN IN THESE PLANS, IN A MANNER THAT MINIMIZES THE ADVERSE IMPACT ON WATER QUALITY, FISH AND WILDLIFE, AND THE NATURAL ENVIRONMENT.

2. ALL WORK WILL BE IN COMPLIANCE WITH PERMIT CONDITIONS ISSUED BY VARIOUS REGULATORY AGENCIES. IT IS THE CONTRACTOR'S RESPONSIBILITY TO HAVE COPIES OF ALL PERMITS ON THE JOB SITE, UNDERSTAND AND COMPLY WITH ALL PERMIT CONDITIONS.

3. ALL WORK THAT DISTURBS THE SUBSTRATE, BANK, OR SHORE OF A WATERS OF THE STATE THAT CONTAINS FISH LIFE SHALL BE CONDUCTED ONLY DURING THE WORK PERIOD FOR THAT WATERBODY AS INDICATED IN THE MOST RECENT ALLOWABLE WORK PERIODS FOR HYDRAULIC PROJECTS IN FRESHWATER FOR THE PROJECT AREA. THOSE PORTIONS OF THE PROJECT WORK THAT OCCUR OUTSIDE OR ABOVE THE ORDINARY HIGH WATER MARK (ABOVE THE CORPS JURISDICTIONAL LINE) ARE NOT SUBJECT TO THE WORK PERIODS DESCRIBED ABOVE UNLESS SPECIFIED IN THE RELEVANT PERMITS.

4. ALL ACTIVITIES THAT INVOLVE WORK ADJACENT TO OR WITHIN THE WETTED CHANNEL SHALL, AT ALL TIMES, REMAIN CONSISTENT WITH ALL APPLICABLE WATER QUALITY STANDARDS, EFFLUENT LIMITATION AND STANDARDS OF PERFORMANCE, PROHIBITIONS, PRETREATMENT STANDARDS, AND MANAGEMENT PRACTICES ESTABLISHED PURSUANT TO THE CLEAN WATER ACT OR PURSUANT TO APPLICABLE STATE AND LOCAL LAW.

5. IF AT ANY TIME, AS A RESULT OF PROJECT ACTIVITIES, FISH ARE OBSERVED IN DISTRESS, A FISH KILL OCCURS, OR WATER QUALITY PROBLEMS DEVELOP (INCLUDING EQUIPMENT LEAKS OR SPILLS), OPERATIONS SHALL CEASE AND THE OWNER SHALL BE NOTIFIED IMMEDIATELY.

6. IF, DURING CONSTRUCTION, ARCHAEOLOGICAL REMAINS ARE ENCOUNTERED, CONSTRUCTION IN THE VICINITY SHALL BE HALTED, AND THE STATE OFFICE OF HISTORIC PRESERVATION AND THE OWNER SHALL BE NOTIFIED IMMEDIATELY.

SURVEY NOTES

1. UNLESS NOTED OTHERWISE ON THE PLANS, THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE PROTECTION OF ALL EXISTING SURVEY MONUMENTS AND OTHER SURVEY MARKERS DURING CONSTRUCTION.

2. THE CONTRACTOR SHALL MAINTAIN A SET OF PLANS ON THE JOB SHOWING "AS–CONSTRUCTED" CHANGES MADE TO DATE. UPON COMPLETION OF THE PROJECT, THE CONTRACTOR SHALL SUPPLY TO OWNER A SET OF PLANS, MARKED UP TO THE SATISFACTION OF THE OWNER, REFLECTING THE AS–CONSTRUCTED MODIFICATIONS.

3. ELEVATIONS SHOWN ON THE PLANS FOR PIPE INVERTS, TOPS OF BANKS, THALWEG, GRADE CONTROLS, ETC., ARE BASED UPON THE TOPOGRAPHIC INFORMATION SHOWN ON THE PLANS. THE CONTRACTOR SHALL VERIFY ALL NECESSARY SURFACE ELEVATIONS IN THE FIELD AND NOTIFY THE OWNER OF ANY DISCREPANCIES, WHICH MIGHT AFFECT PROPER OPERATION OF THE NEW FACILITIES BEFORE BREAKING GROUND AND PRIOR TO FACILITY INSTALLATION. THE OWNER SHALL BE CONTACTED IN THE EVENT ELEVATIONS ARE INCORRECT SO THAT THE PROPER ADJUSTMENTS CAN BE MADE BY ENGINEER PRIOR TO THE INSTALLATION OF THE FACILITIES, AS SET FORTH IN THE SPECIAL PROVISIONS.

4. LIDAR FOR THIS PROJECT WAS PROVIDED BY PUGET SOUND LIDAR CONSORTIUM BY WATERSHED SCIENCES, INC. AND IS REPRESENTATIVE OF 2013 CONDITIONS. THE VERTICAL DATUM IS NAVD 88 (FT) GEOID03. THE HORIZONTAL DATUM IS NAD 83 (HARN) WASHINGTON STATE PLANE NORTH FIPS 4601, US SURVEY FT. AERIAL IMAGERY IS A 2013 NAIP.

EROSION, SEDIMENT CONTROL AND WATER MANAGEMENT NOTES

1. THE CONTRACTOR SHALL BE RESPONSIBLE FOR IMPLEMENTING ALL TEMPORARY EROSION CONTROL MEASURES. THE EROSION CONTROL MEASURES SHALL BE IN ACCORDANCE WITH ALL FEDERAL, STATE, AND LOCAL REQUIREMENTS. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE MAINTENANCE AND PERFORMANCE OF THE TEMPORARY EROSION CONTROL MEASURES THROUGHOUT THE DURATION OF THE PROJECT.

2. A SEDIMENT AND EROSION CONTROL PLAN WILL BE DEVELOPED BY THE CONTRACTOR AND SUBMITTED FOR APPROVAL BY OWNER AND/OR THE ENGINEER BEFORE ANY CONSTRUCTION MAY BEGIN. THE SEDIMENT AND EROSION CONTROL PLAN WILL IDENTIFY BEST MANAGEMENT PRACTICES TO ENSURE THAT THE TRANSPORT OF SEDIMENT TO SURFACE WATERS, DRAINAGE SYSTEMS, AND ADJACENT PROPERTIES IS MINIMIZED.

3. ACTIVITIES SHALL BE DESIGNED AND CONSTRUCTED TO AVOID AND MINIMIZE ADVERSE IMPACTS TO WATERS OF THE UNITED STATES TO THE MAXIMUM EXTENT PRACTICAL THROUGH THE USE OF PRACTICAL ALTERNATIVES. ALTERNATIVES THAT SHALL BE CONSIDERED INCLUDE THOSE THAT MINIMIZE THE NUMBER AND EXTENT OF IN–WATER WORK AND EQUIPMENT CROSSINGS OF WETTED CHANNELS.

4. AT NO TIME SHALL SEDIMENT–LADEN WATER BE DISCHARGED OR PUMPED DIRECTLY INTO THE SUBJECT RIVER, STREAM, OR WETLAND. WATER SHALL BE DISCHARGED IN ACCORDANCE WITH REQUIREMENTS SET FORTH IN THE PROJECT PERMITS AND / OR SPECIFICATIONS.

5. IF HIGH WATER LEVEL CONDITIONS THAT CAUSE SILTATION OR EROSION ARE ENCOUNTERED DURING CONSTRUCTION, WORK SHALL STOP UNTIL THE WATER LEVEL SUBSIDES.

6. PERMIT CONDITIONS CONTAIN SPECIFIC REQUIREMENTS FOR THE CONTROL OF EROSION AND TURBIDITY FROM PROJECT OPERATIONS. TURBIDITY WILL BE MONITORED ON A FREQUENT BASIS BY THE PROJECT MANAGEMENT AND INSPECTION STAFF ON–SITE. TURBIDITY AMOUNTS IN EXCESS OF THE PERMITTED CONCENTRATIONS AND/OR DURATIONS WILL CAUSE WORK TO BE STOPPED UNTIL IMPROVED PRACTICES ARE IN EFFECT AND THE PROBLEMS CONTROLLED. THE CONTRACTOR IS COMPLETELY RESPONSIBLE FOR ANY PROJECT DELAYS THAT OCCUR BY NATURE OF THIS FAILURE TO ADEQUATELY CONTAIN SEDIMENT ON–SITE.

7. CONTRACTOR SHALL LIMIT MACHINERY MOVEMENT TO CONSTRUCTION AREAS DEFINED ON SITE PLAN OR IDENTIFIED AS ACCEPTABLE BY THE ENGINEER OR OWNER.

8. ALL EXTERNAL GREASE AND OIL SHALL BE PRESSURE–WASHED OFF THE EQUIPMENT PRIOR TO TRANSPORT TO THE SITE.

9. THE CONTRACTOR IS RESPONSIBLE TO ENSURE THAT NO PETROLEUM PRODUCTS, HYDRAULIC FLUID, SEDIMENTS, SEDIMENT–LADEN WATER, CHEMICALS, OR ANY OTHER TOXIC OR DELETERIOUS MATERIALS ARE ALLOWED TO ENTER OR LEACH INTO THE SUBJECT RIVER, STREAM, OR WETLAND.

10. THE CONTRACTOR SHALL HAVE AN EMERGENCY SPILL KIT ONSITE AT ALL TIMES.

11. NO TREES OR WETLAND VEGETATION SHALL BE REMOVED UNLESS THEY ARE SHOWN AND NOTED TO BE REMOVED ON THE PLANS OR AS DIRECTLY SPECIFIED ON–SITE BY THE PROJECT MANAGEMENT STAFF. ALL TREES CONFLICTING WITH GRADING SHALL BE REMOVED. NO GRADING SHALL TAKE PLACE WITHIN THE DRIP LINE OF TREES NOT TO BE REMOVED UNLESS OTHERWISE APPROVED.

12. FOLLOWING CONSTRUCTION, SITE RESTORATION WILL INCLUDE ESTABLISHING LONG–TERM EROSION PROTECTION MEASURES. THESE MEASURES WILL INCLUDE PLANTINGS, EROSION CONTROL FABRIC, SEED, AND MULCH. EQUIPMENT AND EXCESS SUPPLIES WILL BE REMOVED AND THE WORK AREA WILL BE CLEANED. MAINTENANCE ACTIVITIES FOR THE NEWLY CONSTRUCTED RESTORATION PROJECTS ARE ANTICIPATED TO OCCUR PERIODICALLY.

CONSTRUCTION NOTES

1. CONTRACT DOCUMENTS REFER TO THESE PLANS.

2. CONTRACTOR SHALL FURNISH ALL MATERIALS, EQUIPMENT, AND LABOR NECESSARY TO COMPLETE ALL WORK AS INDICATED IN THE CONTRACT DOCUMENTS.

3. CONSTRUCTION HOURS SHALL BE WEEKDAYS BETWEEN 7:00 A.M. AND 6:30 P.M. UNLESS PRIOR APPROVAL IS RECEIVED FROM THE OWNER.

4. ANY DISCREPANCIES ARE TO BE BROUGHT TO THE ATTENTION OF THE OWNER PRIOR TO PROCEEDING WITH THE WORK.

5. THE CONTRACTOR SHALL INSTALL ALL EQUIPMENT AND MATERIALS IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS UNLESS SPECIFICALLY INDICATED OTHERWISE BY THE OWNER OR WHERE LOCAL CODES OR REGULATIONS TAKE PRECEDENCE.

6. ALL WORK PERFORMED AND MATERIALS INSTALLED SHALL BE IN STRICT ACCORDANCE WITH ALL APPLICABLE CODES, REGULATIONS, AND ORDINANCES.

7. THE CONTRACTOR SHALL SUPERVISE AND DIRECT THE WORK USING THE BEST SKILLS AND ATTENTION. THE CONTRACTOR SHALL BE SOLELY RESPONSIBLE FOR ALL CONSTRUCTION MEANS, METHODS, TECHNIQUES, SEQUENCES, AND PROCEDURES AND FOR COORDINATING ALL PORTIONS OF THE WORK UNDER THIS CONTRACT.

8. THE CONTRACTOR SHALL MAKE ALL NECESSARY PROVISIONS TO PROTECT EXISTING IMPROVEMENTS, ROADWAY, DRAINAGE WAYS, PRIVATE BRIDGE, CULVERTS, AND VEGETATION UNTIL SUCH ITEMS ARE TO BE DISTURBED OR REMOVED AS INDICATED ON THE CONTRACT DOCUMENTS.

9. THE CONTRACTOR SHALL KEEP THE JOB SITE CLEAN AND HAZARD FREE. CONTRACTOR SHALL DISPOSE OF ALL DIRT, DEBRIS, AND RUBBISH FOR THE DURATION OF THE WORK. UPON COMPLETION OF WORK, CONTRACTOR SHALL REMOVE ALL MATERIAL AND EQUIPMENT NOT SPECIFIED AS REMAINING ON THE PROPERTY.

10. NOTES AND DETAILS ON THE PLANS SHALL TAKE PRECEDENCE OVER GENERAL NOTES HEREIN.

11. DIMENSIONS CALLOUTS SHALL TAKE PRECEDENCE OVER SCALES SHOWN ON THE PLANS.

12. THE PLANS REPRESENT THE FINISHED STRUCTURE. THEY DO NOT INDICATE THE METHOD OF ALL CONSTRUCTION. THE CONTRACTOR SHALL PROVIDE ALL MEASURES NECESSARY TO PROTECT THE STRUCTURES, WORKS, AND THE PUBLIC DURING CONSTRUCTION.

13. MATERIAL SHALL NOT BE STORED OUTSIDE OF IDENTIFIED STAGING AREAS. THE CONTRACTOR SHALL USE ONLY DESIGNATED SPECIFIC SITES FOR STORAGE OF EQUIPMENT AND MATERIALS AS SHOWN ON THESE PLANS. THE CONTRACTOR SHALL BE RESPONSIBLE FOR THE SECURITY OF ALL EQUIPMENT AND MATERIALS.

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\NOTES AND LEGEND.DWG Garvey 5/1/2013 9:26:19 AM

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

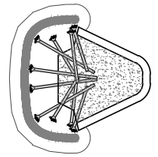
NESSET'S REACH RESTORATION

GENERAL NOTES

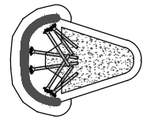
2

GENERAL LEGEND

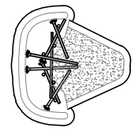
- PROPERTY LINE
- PHASE LINE
- ROW — ROW — RIGHT OF WAY LINE
- EXISTING ROAD
- CL — CL — CLEARING LIMIT
- GL — GL — GRADING LIMIT
- 10 — EXISTING MAJOR CONTOUR
- 2 — EXISTING MINOR CONTOUR
- 10 — PROPOSED MAJOR CONTOUR
- 2 — PROPOSED MINOR CONTOUR
- LOW FLOW CHANNEL
- > — EXISTING FLOW
- OHWM — EXISTING OHWM
- OHWM — PROPOSED OHWM
- MHHW — MEAN HIGHER HIGH WATER
- MHW — MEAN HIGH WATER
- MLLW — MEAN LOWER LOW WATER
- 2-YR — 2-YEAR FLOOD BOUNDARY
- 100-YR — 100-YEAR FLOOD BOUNDARY
- SD — EXISTING STORM SEWER
- SS — EXISTING SANITARY SEWER
- WL — EXISTING WETLAND
- WL — PROPOSED WETLAND
- W — EXISTING WATER
- W — PROPOSED WATER
- CONTROL POINT LOCATION
- MINOR EXCAVATION



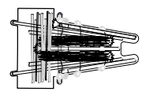
ENGINEERED LOGJAM TYPE 1, SEE SHEET 9



ENGINEERED LOGJAM TYPE 2, SEE SHEET 10



ENGINEERED LOGJAM TYPE 3, SEE SHEET 11



ENGINEERED LOGJAM TYPE 4, SEE SHEET 12

- NATIVE ALLUVIUM
- STREAMBED GRAVEL
- RIPRAP
- STEEL CABLE
- RM 2.8 — RIVER MILE

TEMPORARY EROSION CONTROL LEGEND

- SB — SB — SILT BOOM
- BN — BN — BLOCK NETS
- SF — SF — SILT FENCE
- SW — SW — STRAW WATTLE
- PROPOSED STREAM BYPASS
- PROPOSED STAGING AREA
- BULK BAG COFFERDAM
- TEMPORARY ACCESS ROAD
- PUMP OUTLET LOCATION

DETAIL AND SECTION REFERENCING

- 1 — NOTE REFERENCING NUMBER
- 4/6 — DETAIL REFERENCE NUMBER; SHEET ON WHICH DETAIL APPEARS
- 4/2 — DETAIL REFERENCE NUMBER; SHEET ON WHICH DETAIL APPEARS
- (TYP) — SPECIFIES THAT DETAIL IS UNIFORMLY TYPICAL THROUGHOUT PROJECT EXCEPT WHERE OTHERWISE NOTED
- (VAR) — SPECIFIES THAT DETAIL WAS TAKEN FROM SEVERAL SHEETS
- A / A32 — SECTION A–A IS SHOWN ON SHEET 32
- SECTION A–A 32 (SCALE: NTS) — SECTION A–A IS SHOWN ON SHEET 32

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS — CURRENT\NOTES AND LEGEND.DWG Garvey 5/17/2013 9:26:19 AM

State of Washington — Licensed Geologist — 1181 — Timothy B. Abbe

R. LEIF EMBERTSON — STATE OF WASHINGTON — 45447 — REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

LEGEND

3

SHEET 3 OF 17

EXISTING REVETMENT

EXISTING HUTCHINSON CREEK ELJ'S

SAXON ROAD

ROTHENBUHLER SLOUGH

PRIVATE DRIVE

HUTCHINSON CREEK

CITY OF BELLINGHAM WATERLINE

LEVEE BREACH 2

LEVEE TRIM

EXISTING LEVEE

LEVEE BREACH 1

EXISTING SAXON PROJECT ELJ

SOUTH FORK NOOKSACK RIVER

POND CREEK

PHASE 1

PHASE 2

PHASE 3

FLOW

OHWM

WMHO

0+00 2+00 4+00 6+00 8+00 10+00 12+00 14+00 15+42

LIDAR FOR THIS PROJECT IS REPRESENTATIVE OF 2013 CONDITIONS AND AERIAL IMAGERY IS A 2013 NAIP.

250' 125' 0 250' 500'

SCALE: 1"=250'-0"

N

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD\DWGS — CURRENT\SITE PLAN.DWG Gainey 5/1/2013 9:26:19 AM

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

0 Ø 1

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

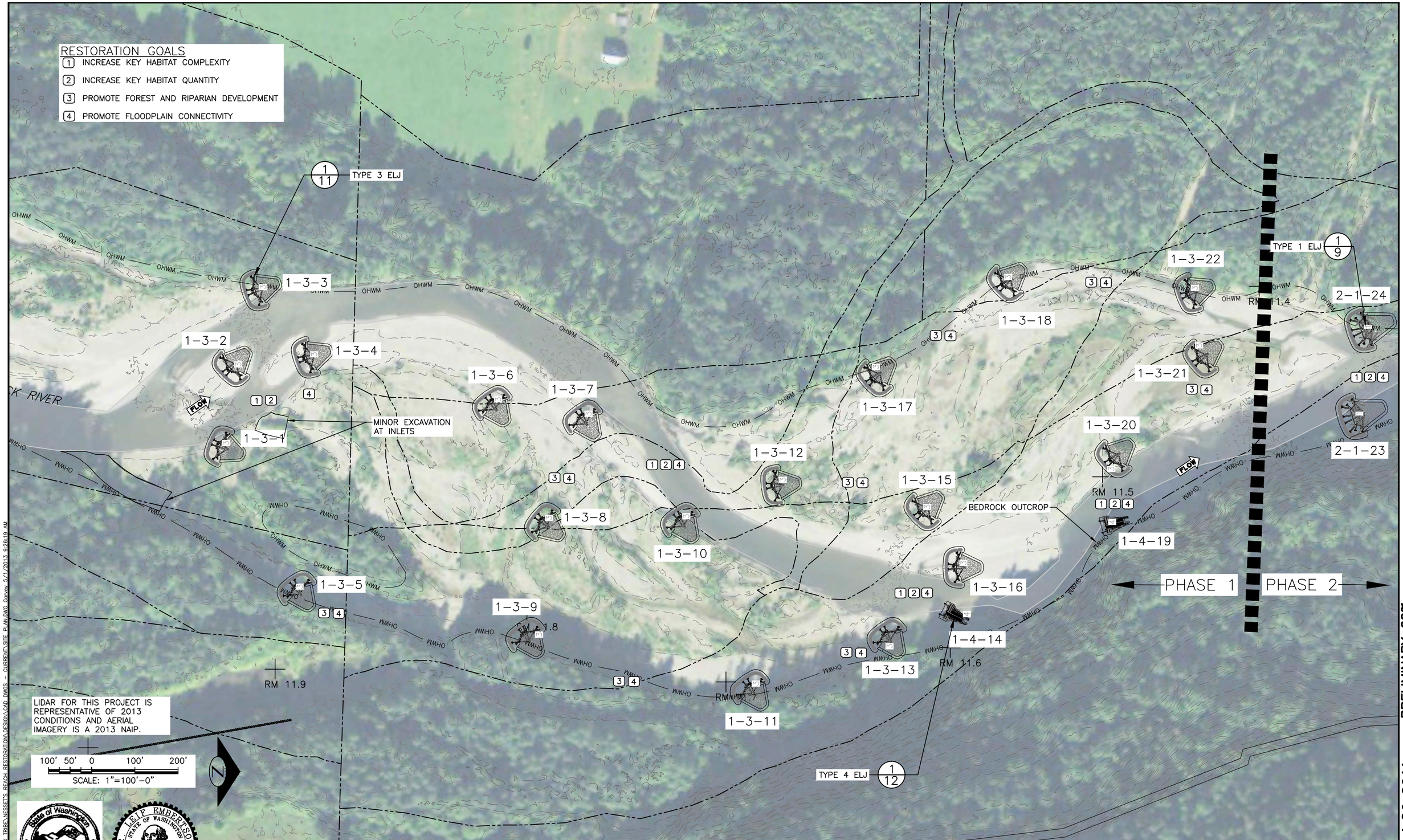
NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

SITE PLAN

4

SHEET 4 OF 17



PRELIMINARY 60%

Jul-30-2014

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

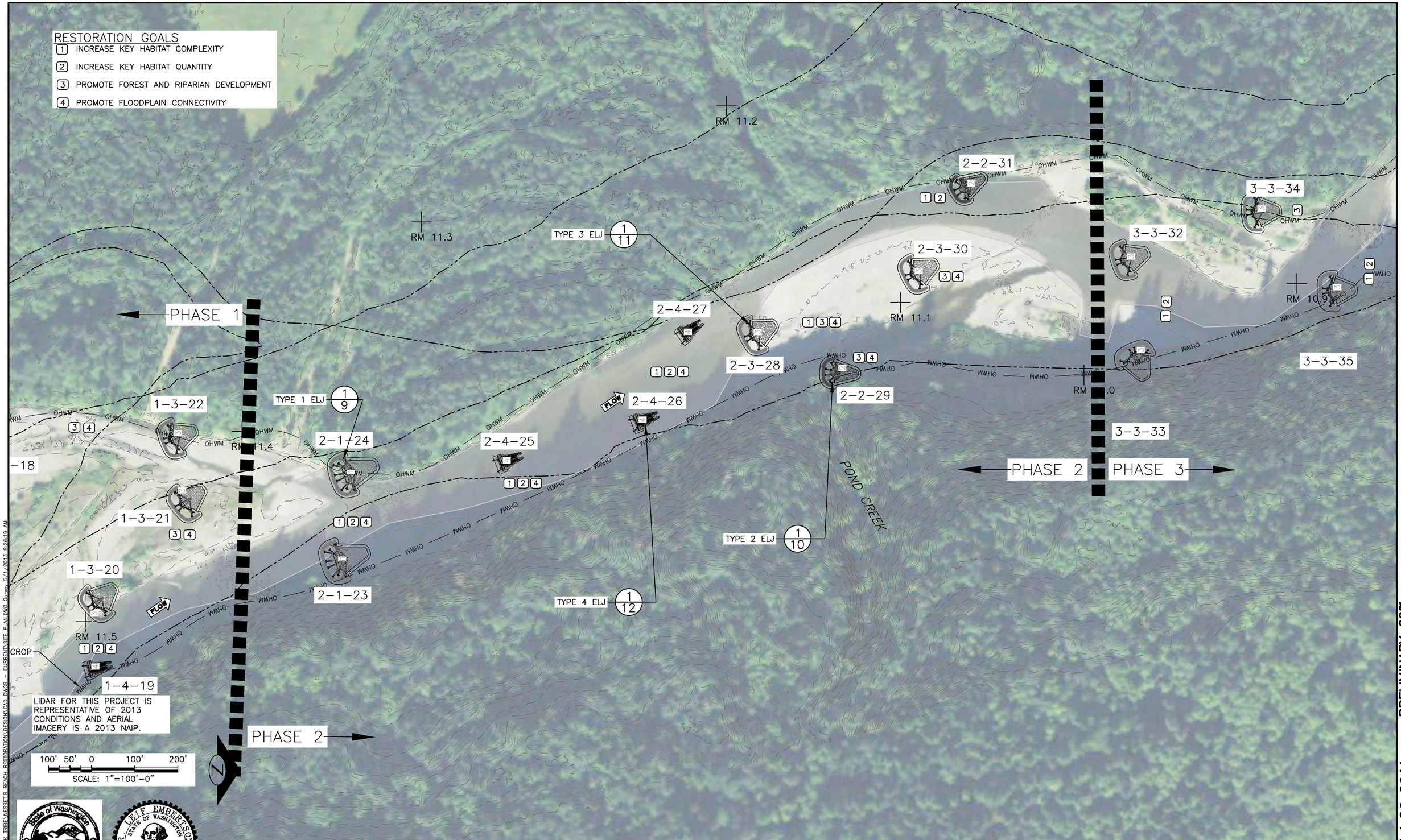
NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 1 SITE PLAN

SHEET 5 OF 17

N:\PROJECTS\NOOKSACK_TRIBE\NESSET'S_REACH_RESTORATION\DESIGN\CAD_DWGS_-_CURRENT\SITE_PLAN.DWG Gurney 5/1/2013 9:26:19 AM



State of Washington Licensed Geologist 1151 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 2 SITE PLAN

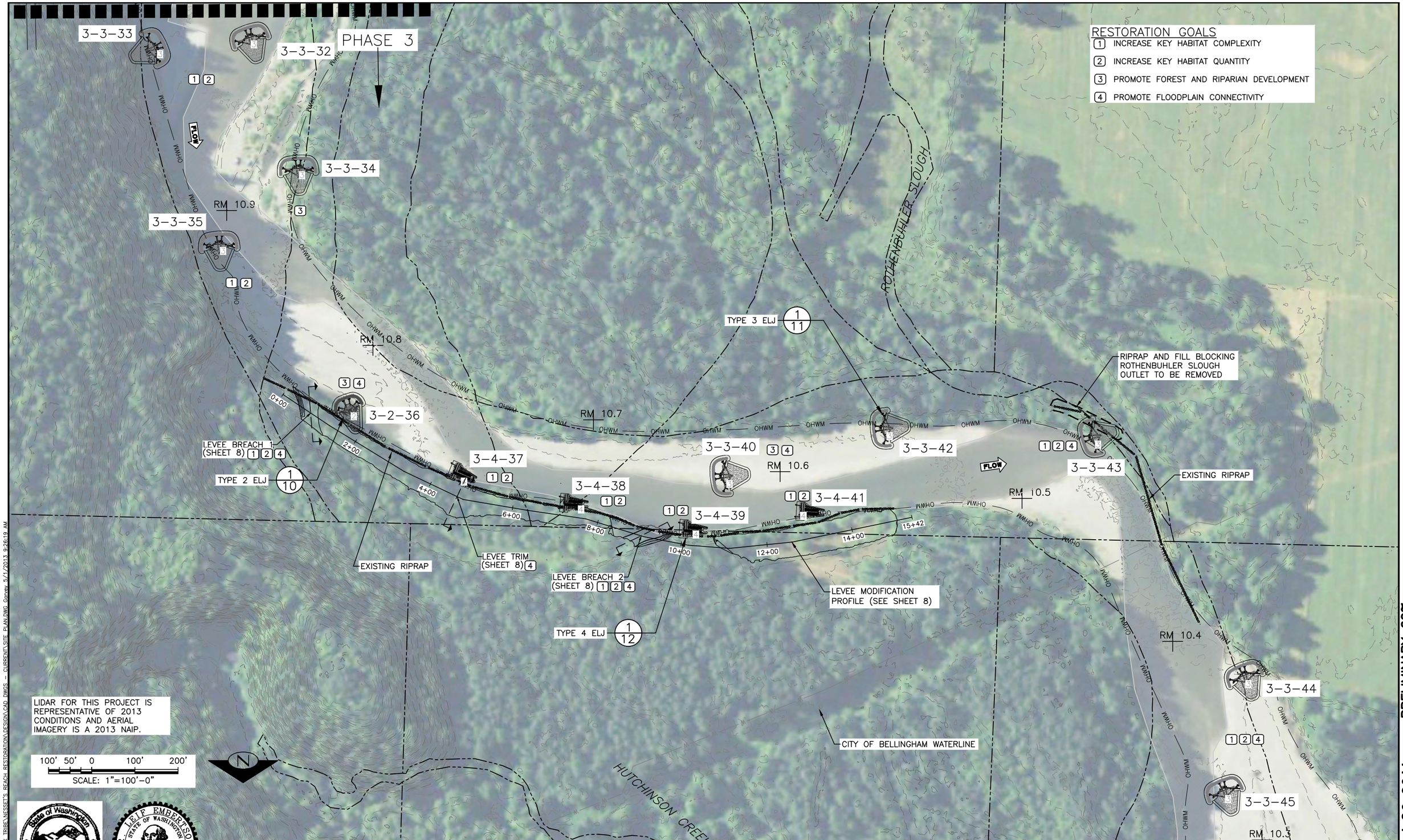
6

SHEET 6 OF 17

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\SITE PLAN.DWG Garvey 5/1/2013 9:26:19 AM



State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 3 SITE PLAN

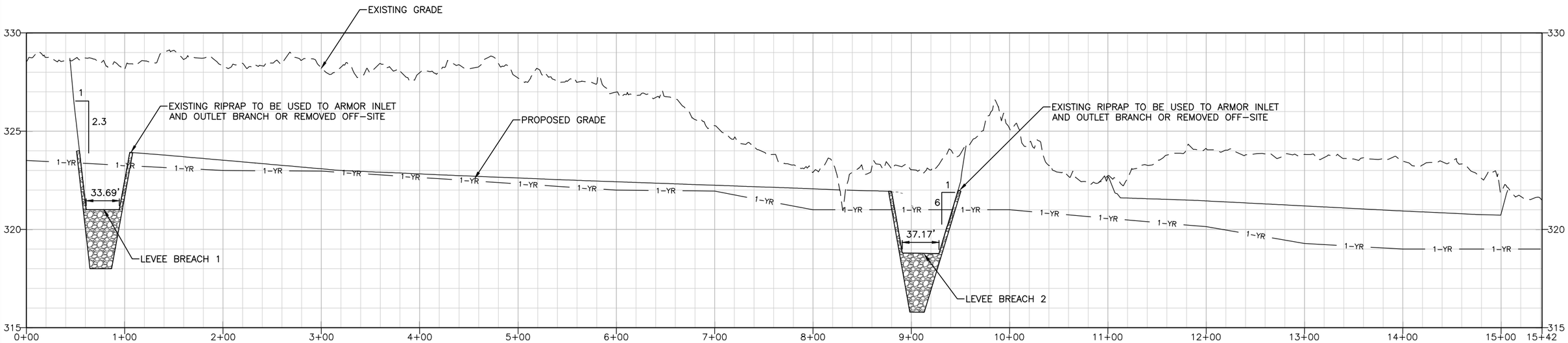
7

SHEET 7 OF 17

PRELIMINARY 60%

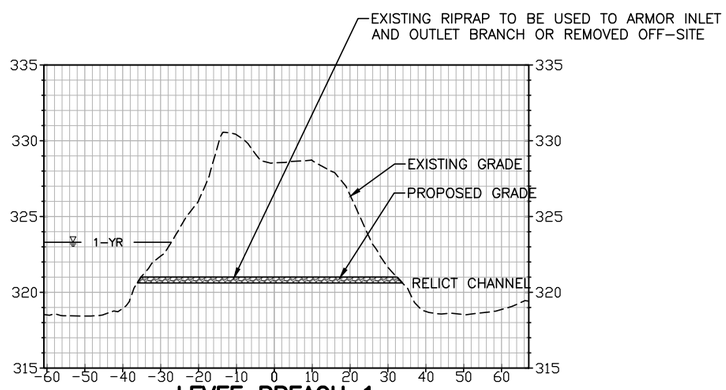
Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS — CURRENT\SITE PLAN.DWG Ginney 5/1/2013 9:28:19 AM



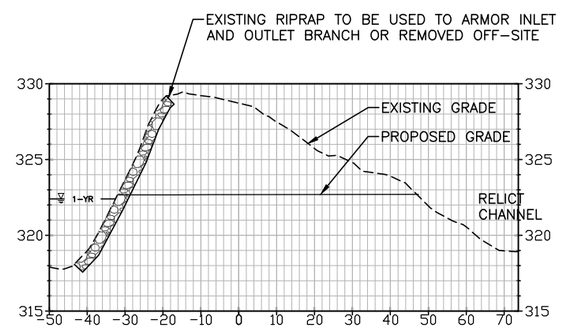
LEVEE MODIFICATION PROFILE

(HORZ: 1" = 50' | VERT: 1" = 2.5" | VERT EXAGG: 1:20)



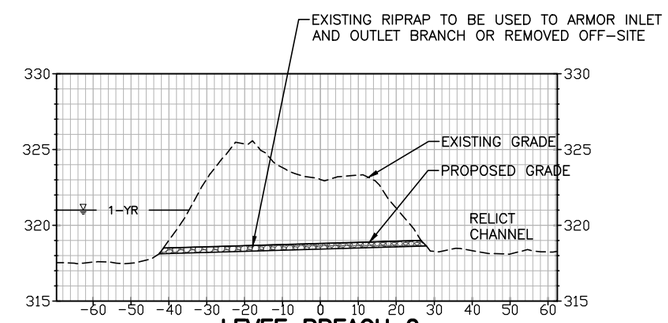
LEVEE BREACH 1

(HORZ: 1" = 20' | VERT: 1" = 5")



LEVEE TRIM

(HORZ: 1" = 20' | VERT: 1" = 5")



LEVEE BREACH 2

(HORZ: 1" = 20' | VERT: 1" = 5")

PRELIMINARY 60%

Jul-30-2014

Timothy B. Abbe

0 Ø 1

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

Natural Systems Design

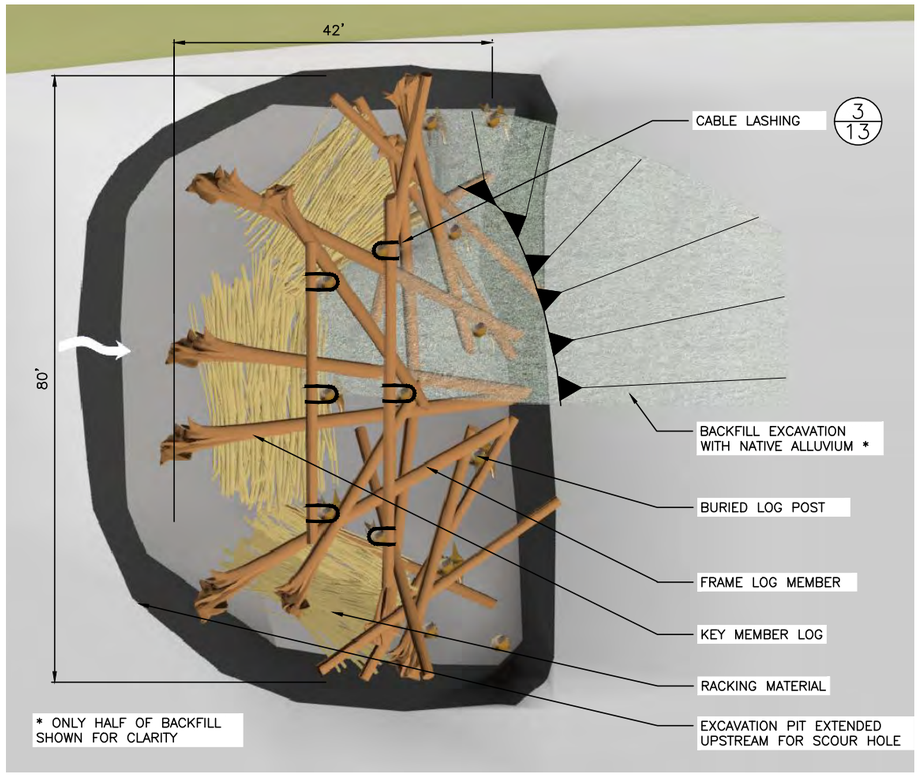
NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 3 SECTION AND DETAILS

SHEET 8 OF 17

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS - CURRENT\PHASE 3 SECTION DETAILS.DWG Gonzey 5/17/2013 9:26:19 AM



TYPE 1 ELJ PLAN (1/4)

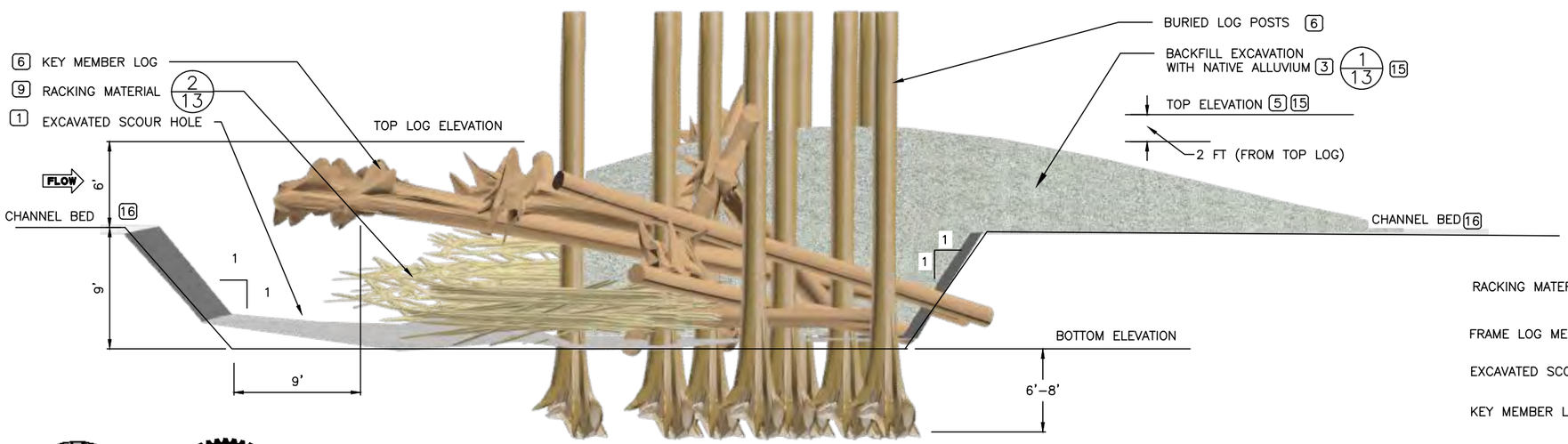
SCALE: 1"=10'

TYPE 1 ELJ STRUCTURE SCHEDULE

STRUCTURE LABEL*	**	**	**	**	**	**	**	**	**
STRUCTURE LENGTH, (ft)	**	**	**	**	**	**	**	**	**
MINIMUM FRAME LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
MINIMUM KEY LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
TIMBER POST DIAMETER, (in)	**	**	**	**	**	**	**	**	**
GROUND ELEVATION AT STRUCTURE, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE BOTTOM ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
TOP LOG ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE TOP ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
MINIMUM PILE TIP ELEVATIONS, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
AVERAGE SEPTEMBER WATER SURFACE ELEVATION (ft-NAVD 88)	**	**	**	**	**	**	**	**	**
** Label format, Phase-ELJ Type-ELJ Number*									
***TBD - To be determined and verified at final design phase*									

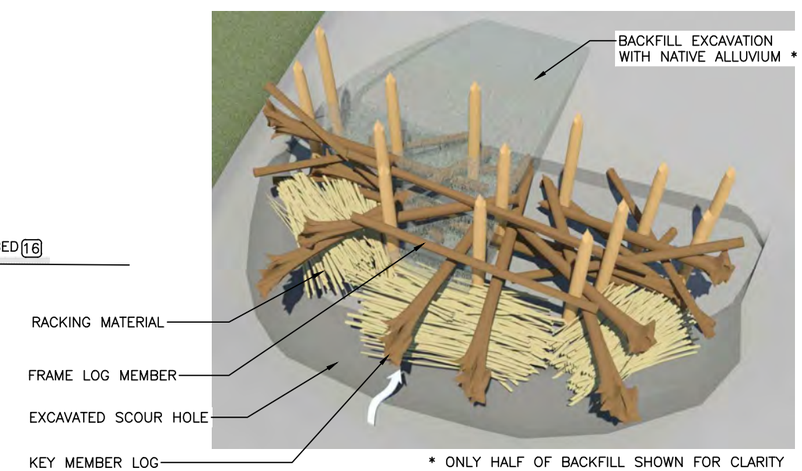
TYPE 1 ELJ STRUCTURE NOTES

1. EXCAVATE IN FRONT OF LOGJAM FOR PLACEMENT OF RACKING MATERIAL. EXCAVATION AREA SHALL NOT BE BACKFILLED WITH ALLUVIUM, BUT LEFT AS A SCOUR HOLE.
2. EXCAVATION SPOILS SHALL BE STAGED ACCORDING TO THE SWPPP. SPOILS SHALL ALSO BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. BACKFILL EXTENTS MAY VARY AND TO BE CONSTRUCTED WITH NATIVE ALLUVIUM FROM EXCAVATION SPOILS.
4. BACKFILL EACH STRUCTURE LAYER WITH NATIVE ALLUVIUM FLUSH WITH THE CURRENT LAYER PRIOR TO PLACEMENT OF THE SUBSEQUENT LAYER.
5. FINAL ELJ HEIGHT TO BE ACHIEVED AS SPECIFIED REGARDLESS OF ACTUAL LOG DIAMETERS USED OR STACKING ARRANGEMENT.
6. ALL LARGE WOOD DIMENSIONS DO NOT INCLUDE BARK THICKNESS.
7. COVER TOP OF BACKFILL AREA AND BASE OF STRUCTURES 6–12 INCHES WITH LOOSE WOOD DEBRIS AND CHIPS.
8. CABLE FRAME LOG MEMBERS PER INSTRUCTIONS ON LAYERING PLAN TO VERTICAL POSTS WITH 1/2 INCH GALVANIZED STEEL CABLE AND 4 CABLE CLAMPS PER LASHING. STAPLES WILL NOT BE USED TO FASTEN CABLE ENDS TOGETHER. ALL CLAMPS AND HAND SPLICING SHALL BE PER THE MANUFACTURER SPECIFICATIONS TIGHTEN CABLE TO APPROXIMATELY 500–POUNDS TENSION.
9. RACKING MATERIAL SHALL CONSIST OF APPROXIMATELY 150 CU. YDS PER STRUCTURE WITH 6" – 12" DIA DBH AND A MINIMUM OF 5–FEET LENGTH. RACKING PLACEMENT SHALL OCCUR WITH EACH LAYER PLACEMENT TO ENSURE RACKING MATERIAL EXTENDS THROUGH STRUCTURE AND PINNED IN PLACE BY SUBSEQUENT LAYERS.
10. THE CONTRACTOR SHALL FIELD VERIFY WITH THE OWNER REPRESENTATIVE OR ENGINEER ALL STRUCTURE LOCATIONS, PILE LOCATIONS, LENGTHS, WIDTHS AND ELEVATIONS PRIOR TO EXCAVATION, ASSEMBLY AND INSTALLATION OF EACH STRUCTURE.
11. LOCATIONS FOR ALL STRUCTURE PLACEMENTS WILL BE STAKED IN FIELD BY THE ENGINEER OR OWNER REPRESENTATIVE PRIOR TO START OF CONSTRUCTION.
12. EXCAVATION LIMITS SHALL BE FIELD VERIFIED BY THE OWNER REPRESENTATIVE OR ENGINEER PRIOR TO EXCAVATION COMMENCING AND PLACEMENT OF ANY LARGE WOOD.
13. LOG TYPE IDENTIFICATION SHALL BE PAINTED ON ALL LOGS BY THE CONTRACTOR IN A PLACE VISIBLE FOR FIELD VERIFICATION PRIOR TO PLACEMENT WITH LEAD–FREE, BLAZE–ORANGE SURVEY MARKING PAINT.
14. THE WOOD LAYER PLACEMENT IN EACH LOGJAM LAYER SHALL BE FIELD VERIFIED BY ON–SITE OWNER REPRESENTATIVE PRIOR TO BACKFILLING.
15. BACKFILL NOT TO EXCEED TOP ELEVATION. EXCESS BACKFILL TO BE PLACED DOWNSTREAM OF FINISHED ELJ.
16. CHANNEL BED ELEVATION IS REPRESENTATIVE OF A LOCAL AVERAGE CHANNEL BED AT RIFFLES. CHANNEL BED ELEVATION SHOULD NOT BE TAKEN IN POOLS.



TYPE 1 ELJ PROFILE (2/4)

SCALE: 1"=5'



TYPE 1 ELJ PERSPECTIVE (3/4)

NOT TO SCALE

State of Washington Licensed Geologist 1181 Timothy B. Abbe

RALF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

TYPE 1 ELJ

9

SHEET 9 OF 17

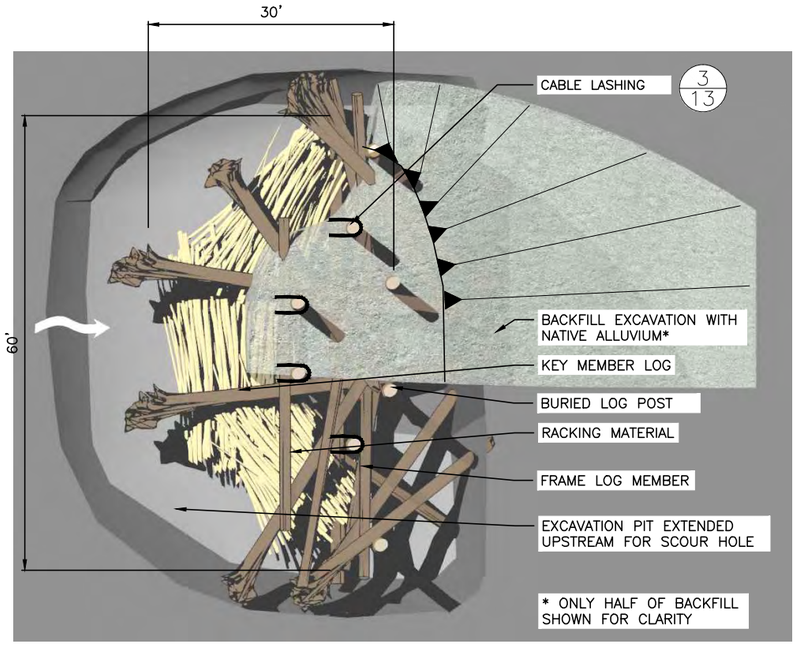
PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK_TRIBE\NESSET'S_REACH_RESTORATION\DESIGN\CAD_DWGS – CURRENT\TYPE 1 ELJ.DWG Survey 5/1/2013 9:26:19 AM

TYPE 2 ELJ STRUCTURE SCHEDULE

STRUCTURE LABEL*	**	**	**	**	**	**	**	**	**
STRUCTURE WIDTH, (ft)	**	**	**	**	**	**	**	**	**
STRUCTURE LENGTH, (ft)	**	**	**	**	**	**	**	**	**
MINIMUM FRAME LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
MINIMUM KEY LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
TIMBER POST DIAMETER, (in)	**	**	**	**	**	**	**	**	**
GROUND ELEVATION AT STRUCTURE, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE BOTTOM ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
TOP LOG ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE TOP ELEVATION, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
MINIMUM PILE TIP ELEVATIONS, (ft-NAVD88)	**	**	**	**	**	**	**	**	**
AVERAGE SEPTEMBER WATER SURFACE ELEVATION (ft-NAVD 88)	**	**	**	**	**	**	**	**	**
** Label format, Phase-ELJ Type-ELJ Number*									
***TBD - To be determined at final design phase*									

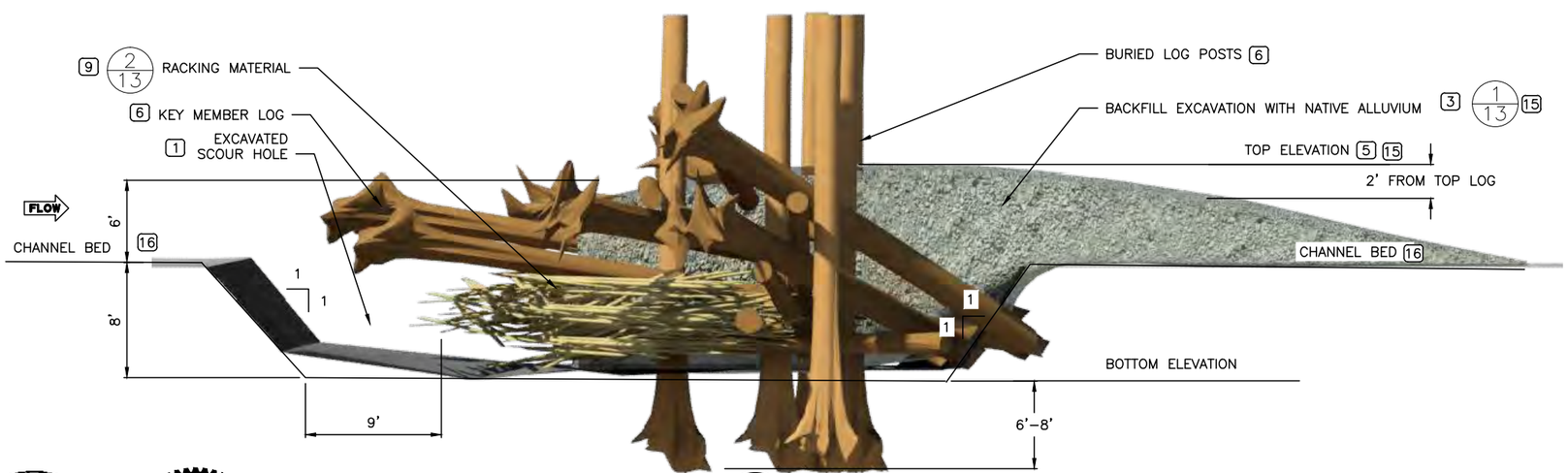


TYPE 2 ELJ PLAN (1/4)

SCALE: 1"=10'

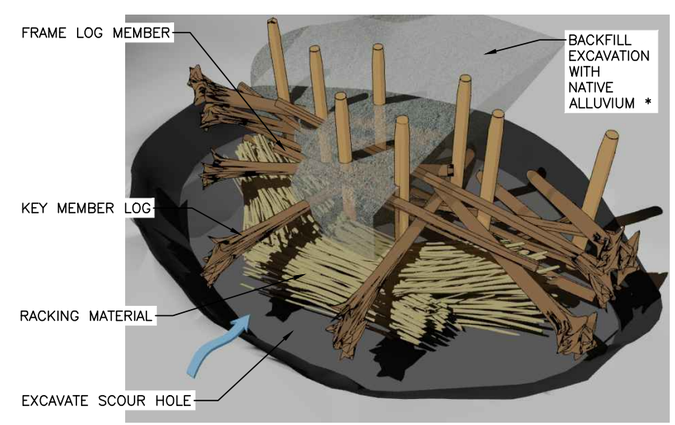
TYPE 2 ELJ STRUCTURE NOTES

1. EXCAVATE IN FRONT OF LOGJAM FOR PLACEMENT OF RACKING MATERIAL. EXCAVATION AREA SHALL NOT BE BACKFILLED WITH ALLUVIUM, BUT LEFT AS A SCOUR HOLE.
2. EXCAVATION SPOILS SHALL BE STAGED ACCORDING TO THE SWPPP. SPOILS SHALL ALSO BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. BACKFILL EXTENTS MAY VARY AND TO BE CONSTRUCTED WITH NATIVE ALLUVIUM FROM EXCAVATION SPOILS.
4. BACKFILL EACH STRUCTURE LAYER WITH NATIVE ALLUVIUM FLUSH WITH THE CURRENT LAYER PRIOR TO PLACEMENT OF THE SUBSEQUENT LAYER.
5. FINAL ELJ HEIGHT TO BE ACHIEVED AS SPECIFIED REGARDLESS OF ACTUAL LOG DIAMETERS USED OR STACKING ARRANGEMENT.
6. ALL LARGE WOOD DIMENSIONS DO NOT INCLUDE BARK THICKNESS.
7. COVER TOP OF BACKFILL AREA AND BASE OF STRUCTURES 6–12 INCHES WITH LOOSE WOOD DEBRIS AND CHIPS.
8. CABLE FRAME LOG MEMBERS PER INSTRUCTIONS ON LAYERING PLAN TO VERTICAL POSTS WITH 1/2 INCH GALVANIZED STEEL CABLE AND 4 CABLE CLAMPS PER LASHING. STAPLES WILL NOT BE USED TO FASTEN CABLE ENDS TOGETHER. ALL CLAMPS AND HAND SPLICING SHALL BE PER THE MANUFACTURER SPECIFICATIONS TIGHTEN CABLE TO APPROXIMATELY 500–POUNDS TENSION.
9. RACKING MATERIAL SHALL CONSIST OF APPROXIMATELY 110 CU YARDS PER STRUCTURE WITH 6" – 12" DIA DBH AND A MINIMUM OF 5–FEET LENGTH. RACKING PLACEMENT SHALL OCCUR WITH EACH LAYER PLACEMENT TO ENSURE RACKING MATERIAL EXTENDS THROUGH STRUCTURE AND PINNED IN PLACE BY SUBSEQUENT LAYERS.
10. THE CONTRACTOR SHALL FIELD VERIFY WITH THE OWNER REPRESENTATIVE OR ENGINEER ALL STRUCTURE LOCATIONS, PILE LOCATIONS, LENGTHS, WIDTHS AND ELEVATIONS PRIOR TO EXCAVATION, ASSEMBLY AND INSTALLATION OF EACH STRUCTURE.
11. LOCATIONS FOR ALL STRUCTURE PLACEMENTS WILL BE STAKED IN FIELD BY THE ENGINEER OR OWNER REPRESENTATIVE PRIOR TO START OF CONSTRUCTION.
12. EXCAVATION LIMITS SHALL BE FIELD VERIFIED BY THE OWNER REPRESENTATIVE OR ENGINEER PRIOR TO EXCAVATION COMMENCING AND PLACEMENT OF ANY LARGE WOOD.
13. LOG TYPE IDENTIFICATION SHALL BE PAINTED ON ALL LOGS BY THE CONTRACTOR IN A PLACE VISIBLE FOR FIELD VERIFICATION PRIOR TO PLACEMENT WITH LEAD–FREE, BLAZE–ORANGE SURVEY MARKING PAINT.
14. THE WOOD LAYER PLACEMENT IN EACH LOGJAM LAYER SHALL BE FIELD VERIFIED BY ON–SITE OWNER REPRESENTATIVE PRIOR TO BACKFILLING.
15. BACKFILL NOT TO EXCEED TOP ELEVATION. EXCESS BACKFILL TO BE PLACED DOWNSTREAM OF FINISHED ELJ.
16. CHANNEL BED ELEVATION IS REPRESENTATIVE OF A LOCAL AVERAGE CHANNEL BED AT RIFFLES. CHANNEL BED ELEVATION SHOULD NOT BE TAKEN IN POOLS.



TYPE 2 ELJ PROFILE (2/4)

SCALE: 1"=5'



* ONLY HALF OF BACKFILL SHOWN FOR CLARITY

TYPE 2 ELJ PERSPECTIVE (3/4)

NOT TO SCALE

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

TYPE 2 ELJ

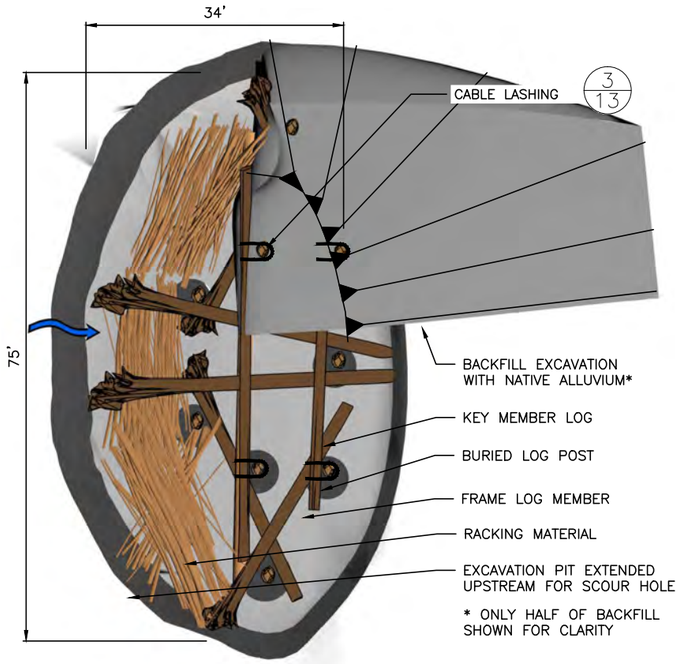
PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\TYPE 2 ELJ.DWG Gonzey 5/1/2013 9:26:19 AM

TYPE 3 ELJ STRUCTURE SCHEDULE

STRUCTURE LABEL*	**	**	**	**	**	**	**	**	**
STRUCTURE WIDTH, (ft)	**	**	**	**	**	**	**	**	**
STRUCTURE LENGTH, (ft)	**	**	**	**	**	**	**	**	**
MINIMUM FRAME LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
MINIMUM KEY LOG DIAMETER, (in)	**	**	**	**	**	**	**	**	**
TIMBER POST DIAMETER, (in)	**	**	**	**	**	**	**	**	**
GROUND ELEVATION AT STRUCTURE, (ft–NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE BOTTOM ELEVATION, (ft–NAVD88)	**	**	**	**	**	**	**	**	**
TOP LOG ELEVATION, (ft–NAVD88)	**	**	**	**	**	**	**	**	**
STRUCTURE TOP ELEVATION, (ft–NAVD88)	**	**	**	**	**	**	**	**	**
MINIMUM PILE TIP ELEVATIONS, (ft–NAVD88)	**	**	**	**	**	**	**	**	**
AVERAGE SEPTEMBER WATER SURFACE ELEVATION (ft–NAVD 88)	**	**	**	**	**	**	**	**	**
* Label format, Phase–ELJ Type–ELJ Number									
**TBD – To be determined at final design phase									

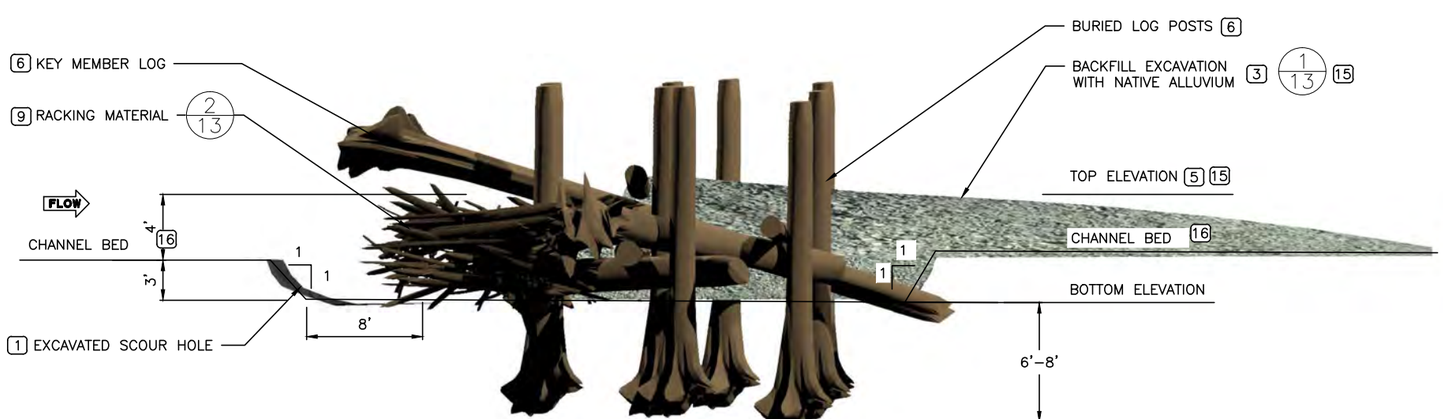


TYPE 3 ELJ PLAN 1/4

SCALE: 1"=10'

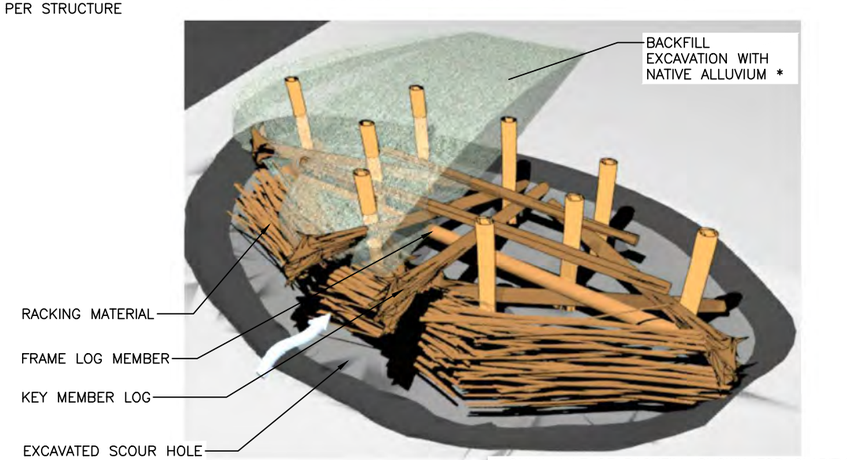
TYPE 3 ELJ STRUCTURE NOTES

1. EXCAVATE IN FRONT OF LOGJAM FOR PLACEMENT OF RACKING MATERIAL. EXCAVATION AREA SHALL NOT BE BACKFILLED WITH ALLUVIUM, BUT LEFT AS A SCOUR HOLE.
2. EXCAVATION SPOILS SHALL BE STAGED ACCORDING TO THE SWPPP. SPOILS SHALL ALSO BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. BACKFILL EXTENTS MAY VARY AND TO BE CONSTRUCTED WITH NATIVE ALLUVIUM FROM EXCAVATION SPOILS.
4. BACKFILL EACH STRUCTURE LAYER WITH NATIVE ALLUVIUM FLUSH WITH THE CURRENT LAYER PRIOR TO PLACEMENT OF THE SUBSEQUENT LAYER.
5. FINAL ELJ HEIGHT TO BE ACHIEVED AS SPECIFIED REGARDLESS OF ACTUAL LOG DIAMETERS USED OR STACKING ARRANGEMENT.
6. ALL LARGE WOOD DIMENSIONS DO NOT INCLUDE BARK THICKNESS.
7. COVER TOP OF BACKFILL AREA AND BASE OF STRUCTURES 6–12 INCHES WITH LOOSE WOOD DEBRIS AND CHIPS.
8. CABLE FRAME LOG MEMBERS PER INSTRUCTIONS ON LAYERING PLAN TO VERTICAL POSTS WITH 1/2 INCH GALVANIZED STEEL CABLE AND 4 CABLE CLAMPS PER LASHING. STAPLES WILL NOT BE USED TO FASTEN CABLE ENDS TOGETHER. ALL CLAMPS AND HAND SPLICING SHALL BE PER THE MANUFACTURER SPECIFICATIONS TIGHTEN CABLE TO APPROXIMATELY 500–POUNDS TENSION.
9. RACKING MATERIAL SHALL CONSIST OF APPROXIMATELY 150 CU. YDS PER STRUCTURE WITH 6" – 12" DIA DBH AND A MINIMUM OF 5–FEET LENGTH. RACKING PLACEMENT SHALL OCCUR WITH EACH LAYER PLACEMENT TO ENSURE RACKING MATERIAL EXTENDS THROUGH STRUCTURE AND PINNED IN PLACE BY SUBSEQUENT LAYERS.
10. THE CONTRACTOR SHALL FIELD VERIFY WITH THE OWNER REPRESENTATIVE OR ENGINEER ALL STRUCTURE LOCATIONS, PILE LOCATIONS, LENGTHS, WIDTHS AND ELEVATIONS PRIOR TO EXCAVATION, ASSEMBLY AND INSTALLATION OF EACH STRUCTURE.
11. LOCATIONS FOR ALL STRUCTURE PLACEMENTS WILL BE STAKED IN FIELD BY THE ENGINEER OR OWNER REPRESENTATIVE PRIOR TO START OF CONSTRUCTION.
12. EXCAVATION LIMITS SHALL BE FIELD VERIFIED BY THE OWNER REPRESENTATIVE OR ENGINEER PRIOR TO EXCAVATION COMMENCING AND PLACEMENT OF ANY LARGE WOOD.
13. LOG TYPE IDENTIFICATION SHALL BE PAINTED ON ALL LOGS BY THE CONTRACTOR IN A PLACE VISIBLE FOR FIELD VERIFICATION PRIOR TO PLACEMENT WITH LEAD–FREE, BLAZE–ORANGE SURVEY MARKING PAINT.
14. THE WOOD LAYER PLACEMENT IN EACH LOGJAM LAYER SHALL BE FIELD VERIFIED BY ON–SITE OWNER REPRESENTATIVE PRIOR TO BACKFILLING.
15. BACKFILL NOT TO EXCEED TOP ELEVATION. EXCESS BACKFILL TO BE PLACED DOWNSTREAM OF FINISHED ELJ.
16. CHANNEL BED ELEVATION IS REPRESENTATIVE OF A LOCAL AVERAGE CHANNEL BED AT RIFFLES. CHANNEL BED ELEVATION SHOULD NOT BE TAKEN IN POOLS.



TYPE 3 ELJ PROFILE 2/4

SCALE: 1"=5'



TYPE 3 ELJ PERSPECTIVE 3/4

NOT TO SCALE

State of Washington Licensed Geologist 1161 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

TYPE 3 ELJ

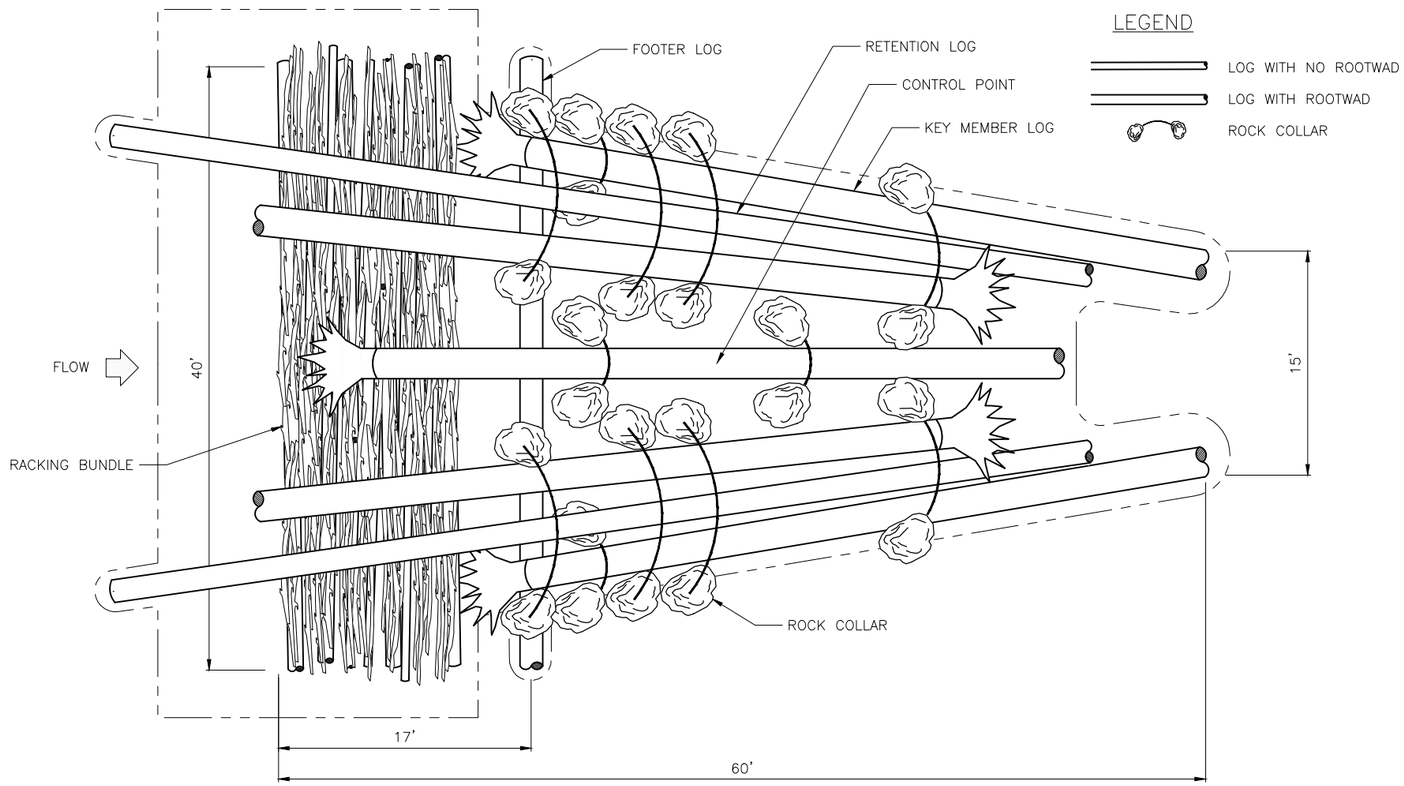
11

SHEET 11 OF 17

PRELIMINARY 60%

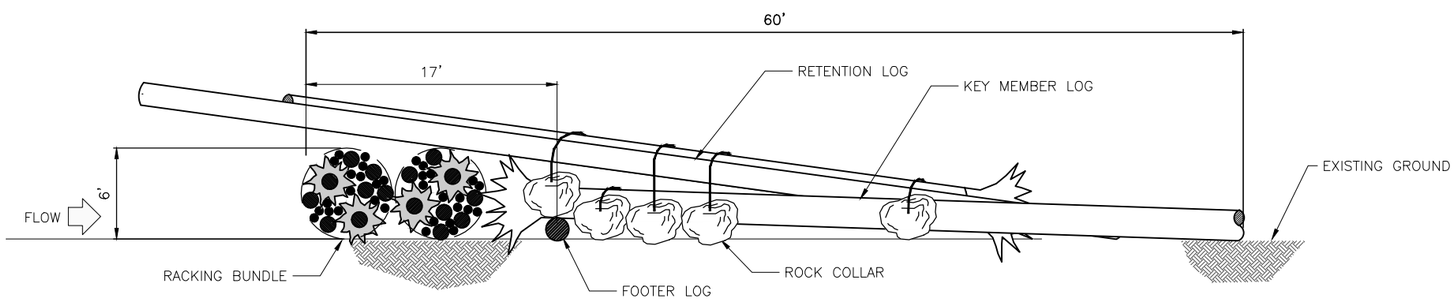
Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\TYPE 3 ELJ.DWG Garvey, 5/1/2013 9:26:19 AM



TYPE 4 ELJ PLAN (1/4)

SCALE: 1"=5'



TYPE 4 ELJ PROFILE (2/4)

SCALE: 1"=5'

TYPE 4 STRUCTURE SCHEDULE

STRUCTURE LABEL*			
STRUCTURE WIDTH, (FT)			
STRUCTURE LENGTH, (FT)			
SCOUR DEPTH, (FT)			
MINIMUM FRAME LOG DIAMETER, (IN)			
MINIMUM KEY LOG DIAMETER, (IN)			
TIMBER POST DIAMETER, (IN)			
GROUND ELEVATION AT STRUCTURE, (FT–NAVD88)			
STRUCTURE BOTTOM ELEVATION, (FT–NAVD88)			
TOP LOG ELEVATION, (FT–NAVD88)			
STRUCTURE TOP ELEVATION, (FT–NAVD88)			
MINIMUM PILE TIP ELEVATIONS, (FT–NAVD88)			
AVERAGE SEPTEMBER WATER SURFACE ELEVATION (FT–NAVD 88)			
* LABEL FORMAT, PHASE–ELJ TYPE–ELJ NUMBER			
**TBD – TO BE DETERMINED AND VERIFIED AT FINAL DESIGN PHASE			

TYPE 4 STRUCTURE NOTES:

1. EXCAVATE IN FRONT OF LOGJAM FOR PLACEMENT OF RACKING MATERIAL. EXCAVATION AREA SHALL NOT BE BACKFILLED WITH ALLUVIUM, BUT LEFT AS A SCOUR HOLE.
2. EXCAVATION SPOILS SHALL BE STAGED ACCORDING TO THE SWPPP. SPOILS SHALL ALSO BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. BACKFILL EXTENTS MAY VARY AND TO BE CONSTRUCTED WITH NATIVE ALLUVIUM FROM EXCAVATION SPOILS.
4. BACKFILL EACH STRUCTURE LAYER WITH NATIVE ALLUVIUM FLUSH WITH THE CURRENT LAYER PRIOR TO PLACEMENT OF THE SUBSEQUENT LAYER.
5. FINAL ELJ HEIGHT TO BE ACHIEVED AS SPECIFIED REGARDLESS OF ACTUAL LOG DIAMETERS USED OR STACKING ARRANGEMENT.
6. ALL LARGE WOOD DIMENSIONS DO NOT INCLUDE BARK THICKNESS.
7. COVER TOP OF BACKFILL AREA AND BASE OF STRUCTURES 6–12 INCHES WITH LOOSE WOOD DEBRIS AND CHIPS.
8. CABLE FRAME LOG MEMBERS PER INSTRUCTIONS ON LAYERING PLAN TO VERTICAL POSTS WITH 1/2 INCH GALVANIZED STEEL CABLE AND 4 CABLE CLAMPS PER LASHING. STAPLES WILL NOT BE USED TO FASTEN CABLE ENDS TOGETHER. ALL CLAMPS AND HAND SPLICING SHALL BE PER THE MANUFACTURER SPECIFICATIONS TIGHTEN CABLE TO APPROXIMATELY 500–POUNDS TENSION.
9. RACKING MATERIAL SHALL CONSIST OF APPROXIMATELY 500 INDIVIDUAL LOGS PER STRUCTURE WITH 6" – 12" DIA DBH AND A MINIMUM OF 5–FEET LENGTH. RACKING PLACEMENT SHALL OCCUR WITH EACH LAYER PLACEMENT TO ENSURE RACKING MATERIAL EXTENDS THROUGH STRUCTURE AND PINNED IN PLACE BY SUBSEQUENT LAYERS.
10. THE CONTRACTOR SHALL FIELD VERIFY WITH THE OWNER REPRESENTATIVE OR ENGINEER ALL STRUCTURE LOCATIONS, PILE LOCATIONS, LENGTHS, WIDTHS AND ELEVATIONS PRIOR TO EXCAVATION, ASSEMBLY AND INSTALLATION OF EACH STRUCTURE.
11. LOCATIONS FOR ALL STRUCTURE PLACEMENTS WILL BE STAKED IN FIELD BY THE ENGINEER OR OWNER REPRESENTATIVE PRIOR TO START OF CONSTRUCTION.
12. EXCAVATION LIMITS SHALL BE FIELD VERIFIED BY THE OWNER REPRESENTATIVE OR ENGINEER PRIOR TO EXCAVATION COMMENCING AND PLACEMENT OF ANY LARGE WOOD.
13. LOG TYPE IDENTIFICATION SHALL BE PAINTED ON ALL LOGS BY THE CONTRACTOR IN A PLACE VISIBLE FOR FIELD VERIFICATION PRIOR TO PLACEMENT WITH LEAD–FREE, BLAZE–ORANGE SURVEY MARKING PAINT.
14. THE WOOD LAYER PLACEMENT IN EACH LOGJAM LAYER SHALL BE FIELD VERIFIED BY ON–SITE OWNER REPRESENTATIVE PRIOR TO BACKFILLING.

State of Washington Licensed Geologist 1981 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

TYPE 4 ELJ

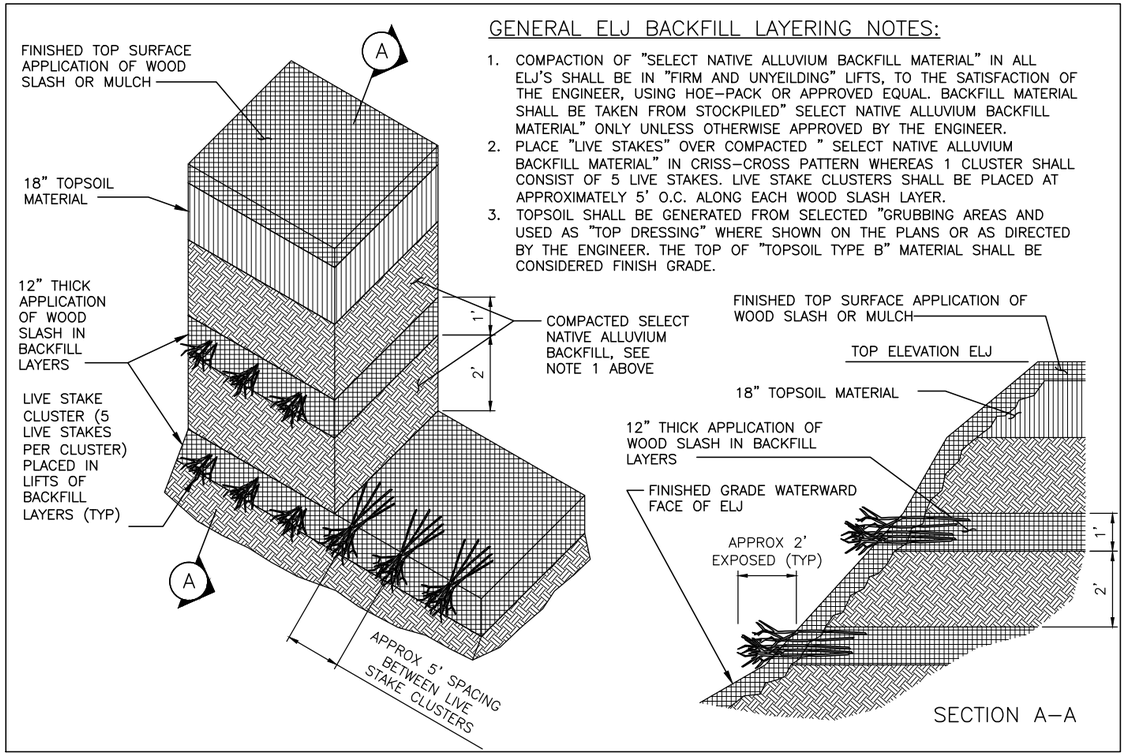
PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\ TYPE 4 ELJ.DWG Garvey 5/1/2013 9:26:19 AM

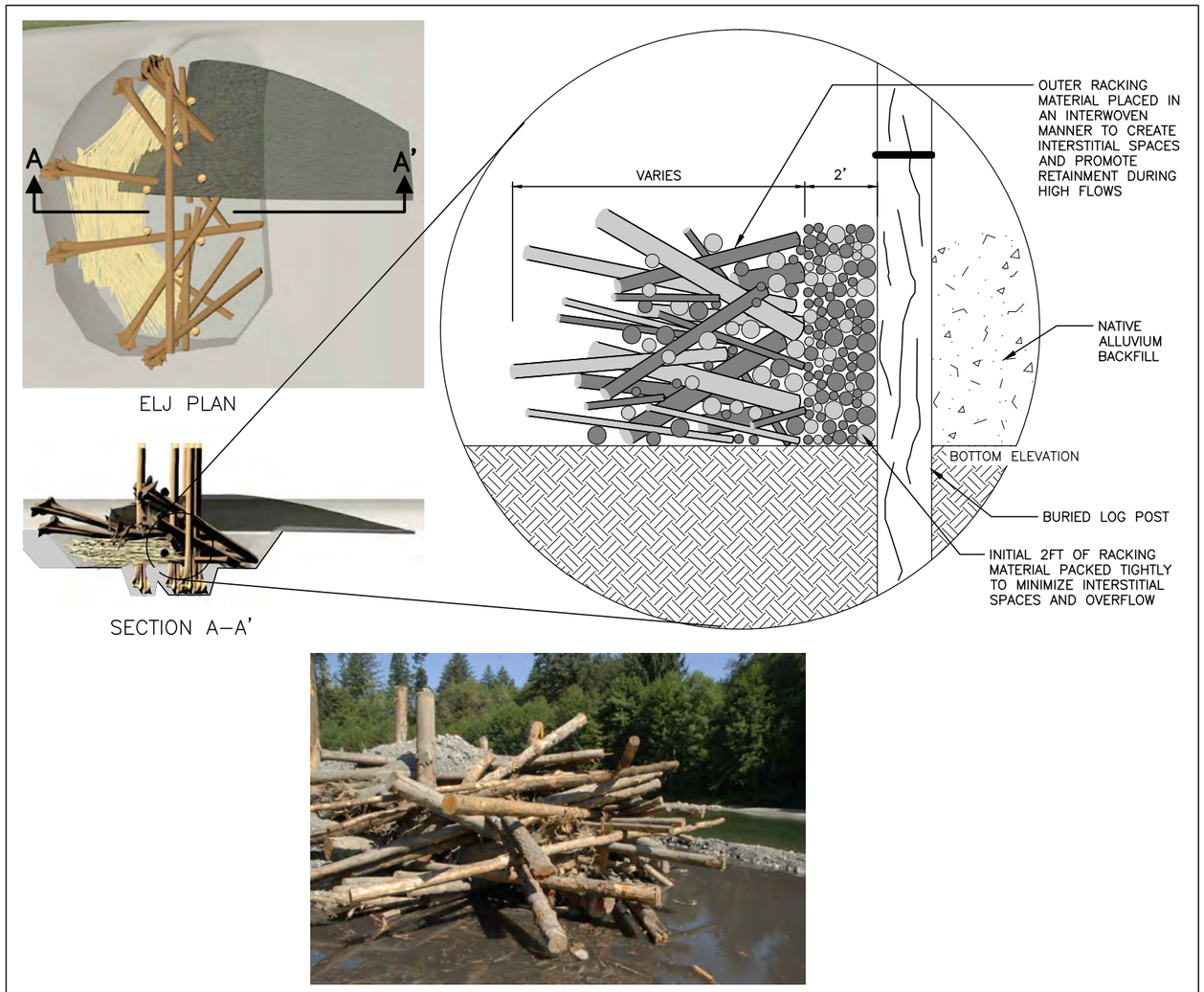
GENERAL ELJ BACKFILL LAYERING NOTES:

1. COMPACTION OF "SELECT NATIVE ALLUVIUM BACKFILL MATERIAL" IN ALL ELJ'S SHALL BE IN "FIRM AND UNYEILDING" LIFTS, TO THE SATISFACTION OF THE ENGINEER, USING HOE-PACK OR APPROVED EQUAL. BACKFILL MATERIAL SHALL BE TAKEN FROM STOCKPILED" SELECT NATIVE ALLUVIUM BACKFILL MATERIAL" ONLY UNLESS OTHERWISE APPROVED BY THE ENGINEER.
2. PLACE "LIVE STAKES" OVER COMPACTED " SELECT NATIVE ALLUVIUM BACKFILL MATERIAL" IN CRISS-CROSS PATTERN WHEREAS 1 CLUSTER SHALL CONSIST OF 5 LIVE STAKES. LIVE STAKE CLUSTERS SHALL BE PLACED AT APPROXIMATELY 5' O.C. ALONG EACH WOOD SLASH LAYER.
3. TOPSOIL SHALL BE GENERATED FROM SELECTED "GRUBBING AREAS AND USED AS "TOP DRESSING" WHERE SHOWN ON THE PLANS OR AS DIRECTED BY THE ENGINEER. THE TOP OF "TOPSOIL TYPE B" MATERIAL SHALL BE CONSIDERED FINISH GRADE.



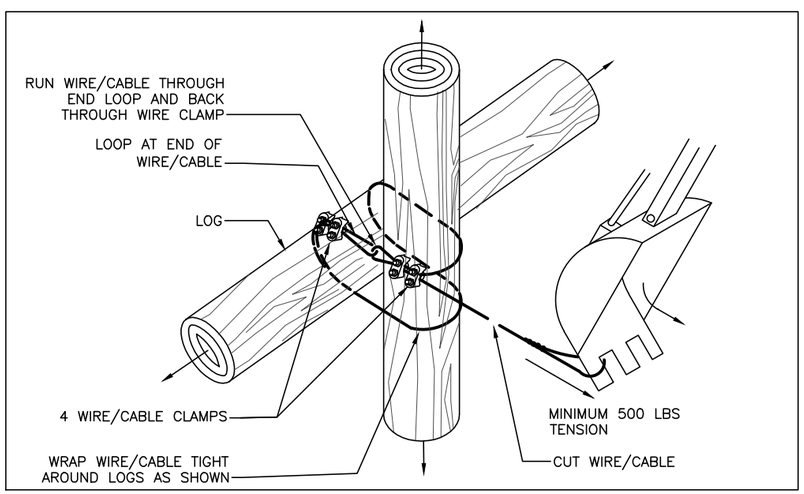
ELJ BACKFILL LAYERING DETAIL (1/13)

NOT TO SCALE



RACKING MATERIAL DETAIL (2/13)

NOT TO SCALE



CABLE LASHING (3/13)

NOT TO SCALE

State of Washington Licensed Geologist 1161 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

RESTORATION DETAILS

13

SHEET 13 OF 17

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS -- CURRENT\RESTORATION DETAILS.DWG Gurney 5/1/2013 9:28:19 AM

SAXON ROAD

SAXON ROAD

EXISTING ACCESS ROAD (FROM SAXON ROAD)

PRIVATE DRIVE

ROTHENBUHLER SLOUGH

EXISTING ACCESS ROAD (FROM PRIVATE DRIVE)

RM 11.2

RM 11.3

4/17 TEMPORARY BAR ACCESS

EXISTING SAXON PROJECT ELJ

2/17 TEMPORARY BRIDGE

SOUTH FORK NOOKSACK RIVER

FLOW

RM 11.4

RM 11.5

RM 11.6

RM 11.8

RM 11.9

RM 12.1

12.0

PHASE 2

PHASE 1

OHWM

WMHO

LIDAR FOR THIS PROJECT IS REPRESENTATIVE OF 2013 CONDITIONS AND AERIAL IMAGERY IS A 2013 NAIP.

150' 0 150' 300'

SCALE: 1"=150'-0"

N

NOTES:

1. LOG STAGING, EQUIPMENT REFUELING, AND STAGING AREA.
2. ELJ TO BE ASSEMBLED IN WETTED CHANNEL. FINAL DETERMINATION TO BE COMPLETED PRIOR TO CONSTRUCTION BY OWNER AND PERMITTING BIOLOGIST. ASSEMBLY TO BE COMPLETED BY MACHINERY LOCATED ON DRY GRAVEL BAR.
3. ELJ TO BE CONSTRUCTED FROM BANK USING LONG REACH EXCAVATOR AND TEMPORARY LOG CROSSING, AS SHOWN ON TESC DETAILS. AT NO TIME SHALL EQUIPMENT WALK IN LOW FLOW CHANNEL.
4. LOW FLOW CHANNEL APPROXIMATE AND TO BE VERIFIED PRIOR TO CONSTRUCTION.
5. MINOR WATER ISOLATION OF WORK AREA USING TEMPORARY COFFERDAM MAYBE REQUIRED DEPENDING ON LOCATION OF LOW FLOW CHANNEL AND STREAMFLOW STAGE AT THE TIME OF CONSTRUCTION.

PRELIMINARY 60%

Jul-30-2014

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS - CURRENT\TESC PLAN.DWG Gonzey 5/1/2013 9:26:19 AM

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

0 Ø 1

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

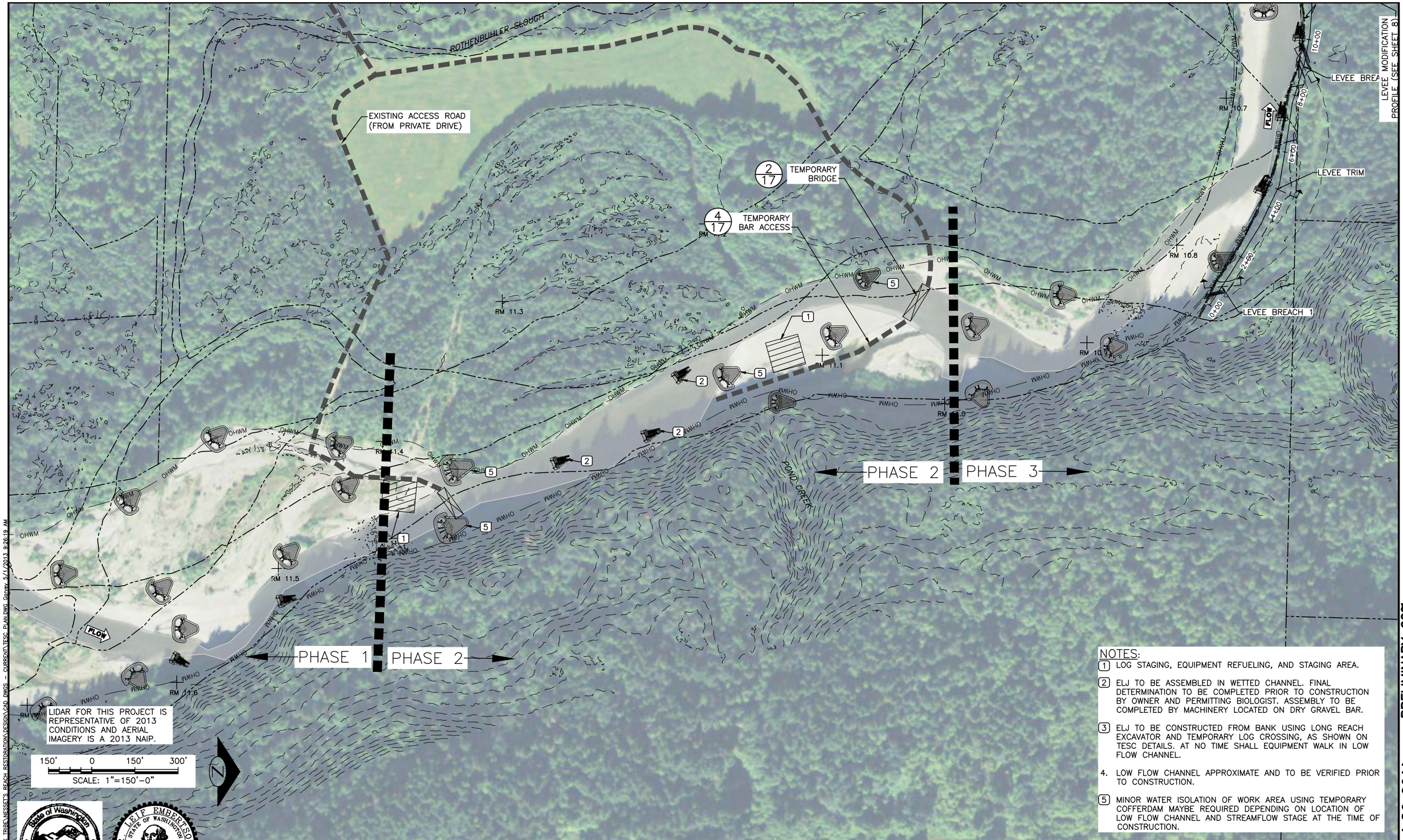
NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 1 TESC PLAN

14

SHEET 14 OF 17



NOTES:

1. LOG STAGING, EQUIPMENT REFUELING, AND STAGING AREA.
2. ELJ TO BE ASSEMBLED IN WETTED CHANNEL. FINAL DETERMINATION TO BE COMPLETED PRIOR TO CONSTRUCTION BY OWNER AND PERMITTING BIOLOGIST. ASSEMBLY TO BE COMPLETED BY MACHINERY LOCATED ON DRY GRAVEL BAR.
3. ELJ TO BE CONSTRUCTED FROM BANK USING LONG REACH EXCAVATOR AND TEMPORARY LOG CROSSING, AS SHOWN ON TESC DETAILS. AT NO TIME SHALL EQUIPMENT WALK IN LOW FLOW CHANNEL.
4. LOW FLOW CHANNEL APPROXIMATE AND TO BE VERIFIED PRIOR TO CONSTRUCTION.
5. MINOR WATER ISOLATION OF WORK AREA USING TEMPORARY COFFERDAM MAYBE REQUIRED DEPENDING ON LOCATION OF LOW FLOW CHANNEL AND STREAMFLOW STAGE AT THE TIME OF CONSTRUCTION.

PRELIMINARY 60%

Jul-30-2014

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

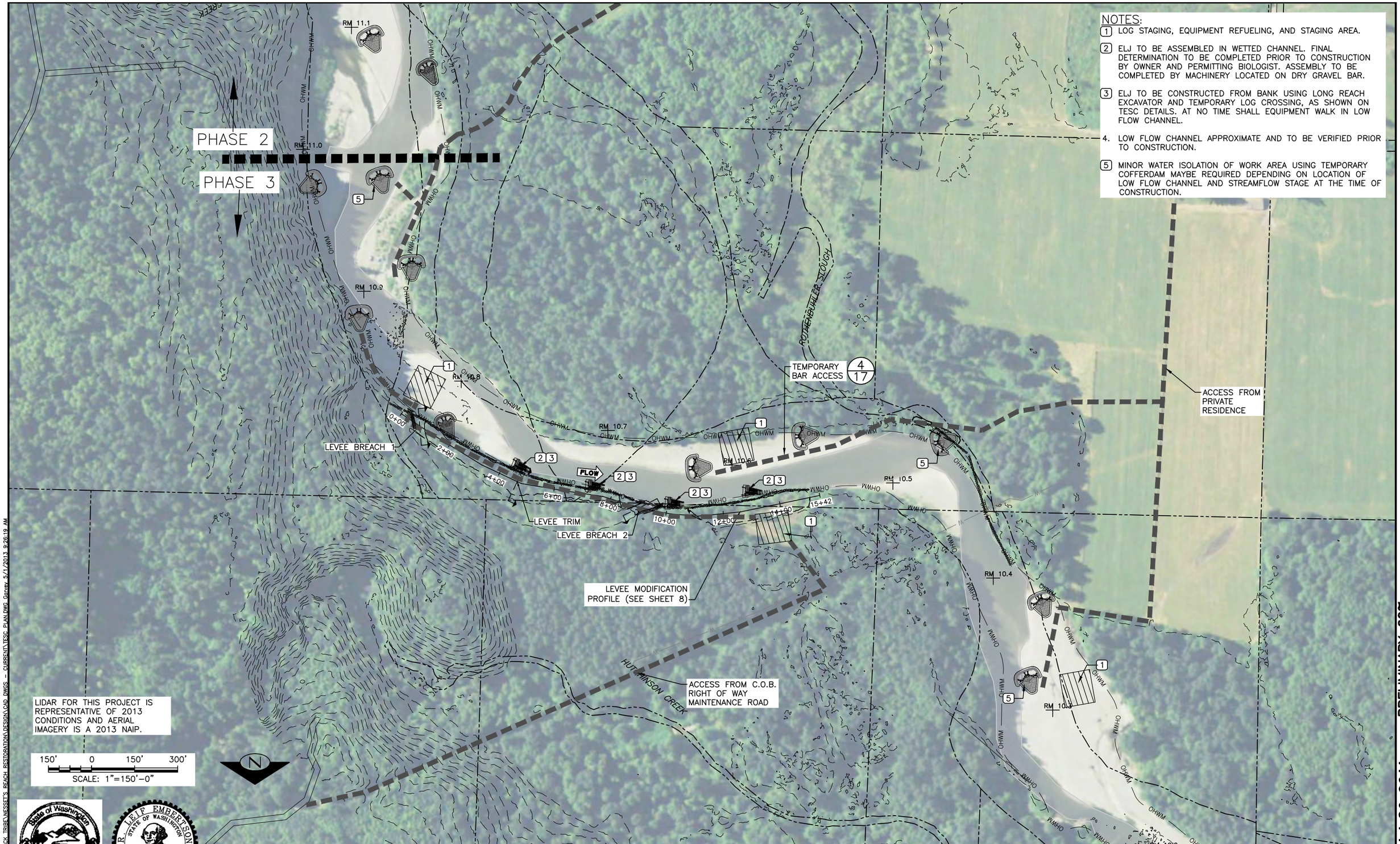
PHASE 2 TESC PLAN

SHEET 15 OF 17

N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS — CURRENT\TESC PLAN.DWG Gpvey 5/1/2013 9:26:19 AM

NOTES:

1. LOG STAGING, EQUIPMENT REFUELING, AND STAGING AREA.
2. ELJ TO BE ASSEMBLED IN WETTED CHANNEL. FINAL DETERMINATION TO BE COMPLETED PRIOR TO CONSTRUCTION BY OWNER AND PERMITTING BIOLOGIST. ASSEMBLY TO BE COMPLETED BY MACHINERY LOCATED ON DRY GRAVEL BAR.
3. ELJ TO BE CONSTRUCTED FROM BANK USING LONG REACH EXCAVATOR AND TEMPORARY LOG CROSSING, AS SHOWN ON TESC DETAILS. AT NO TIME SHALL EQUIPMENT WALK IN LOW FLOW CHANNEL.
4. LOW FLOW CHANNEL APPROXIMATE AND TO BE VERIFIED PRIOR TO CONSTRUCTION.
5. MINOR WATER ISOLATION OF WORK AREA USING TEMPORARY COFFERDAM MAYBE REQUIRED DEPENDING ON LOCATION OF LOW FLOW CHANNEL AND STREAMFLOW STAGE AT THE TIME OF CONSTRUCTION.



LIDAR FOR THIS PROJECT IS REPRESENTATIVE OF 2013 CONDITIONS AND AERIAL IMAGERY IS A 2013 NAIP.

150' 0 150' 300'
SCALE: 1"=150'-0"

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

PHASE 3 TESC PLAN

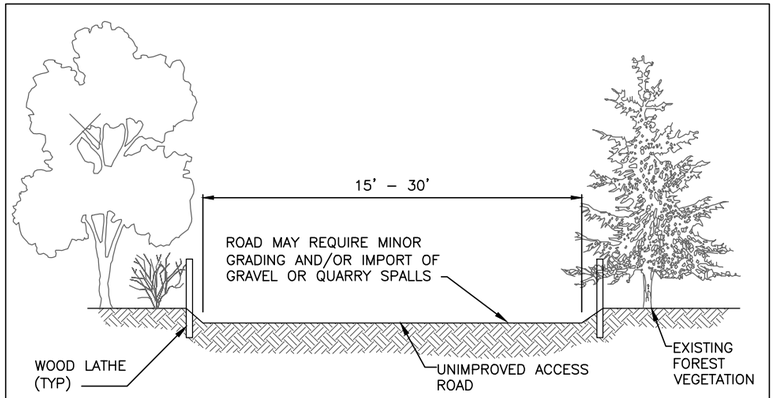
16

SHEET 16 OF 17

PRELIMINARY 60%

Jul-30-2014

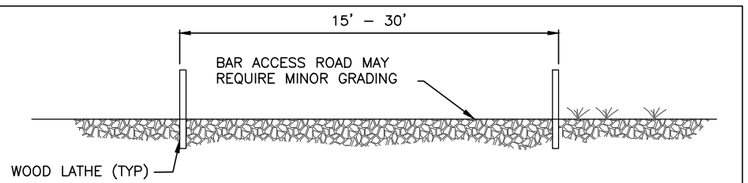
N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS - CURRENT\TESC PLAN.DWG Gonzey 5/11/2013 9:26:19 AM



NOTES FOR TEMPORARY CLEARED ACCESS

1. CLEARED ACCESS TO BE ROUTED TO MINIMIZE VEGETATION DISTURBANCE AND FOREST CLEARING.
2. CONTRACTOR SHALL MARK CLEARING LIMITS WITH FLAGGING. CLEARING LIMITS TO BE APPROVED BY ENGINEER PRIOR TO ANY CLEARING ACTIVITIES.
3. ANY TREES GREATER THAN 18" ø SHALL BE REMOVED W/ ROOTWADS INTACT AND STOCKPILED FOR USE IN LOGJAM CONSTRUCTION.
4. TREES AND SHRUBS WITH 6"–18" ø SHALL BE STOCKPILED FOR USE AS RACKING MATERIAL IN LOGJAM CONSTRUCTION.
5. REMAINDER OF VEGETATION AND ORGANIC SOIL SHALL BE GRUBBED, STOCKPILED AND BROADCASTED ON ROAD ALIGNMENT FOLLOWING TERMINATION OF WORK.
6. ACCESS SHALL BE MAINTAINED BY MINOR GRADING AND IMPORTATION OF WOOD CHIPS, GRAVEL AND/OR QUARRY SPALLS.
7. CLEARED ACCESS SHALL BE SCARIFIED AND DECONSTRUCTED TO PREVENT FUTURE ACCESS AT THE TERMINATION OF WORK.
8. REVEGETATION ROAD ALIGNMENT FOLLOWING CONSTRUCTION WILL BE PERFORMED BY CONTRACTOR.
9. ALL GRAVEL OR QUARRY SPALLS PLACED SHALL BE UNDERLAIN WITH A GEOTEXTILE AND REMOVED AT TERMINATION OF WORK IF UTILIIZED.

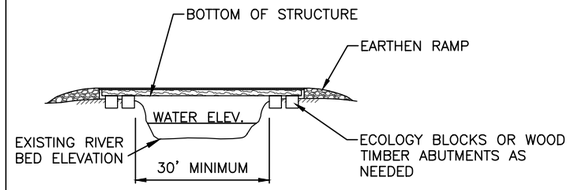
TEMPORARY CLEARED ACCESS (1/17)
SCALE: NTS



NOTES FOR TEMPORARY BAR ACCESS

1. BAR ACCESS TO BE ROUTED TO MINIMIZE VEGETATION DISTURBANCE.
2. CONTRACTOR SHALL STAKE EDGES OF PROPOSED BAR ACCESS FOR APPROVAL BY ENGINEER.
3. EQUIPMENT SHALL OPERATE ONLY WITHIN STAKED BAR ACCESS ALIGNMENT OR OTHER DEFINED PROJECT AREAS.
4. BAR ACCESS SHALL BE SCARIFIED AT TERMINATION OF WORK.

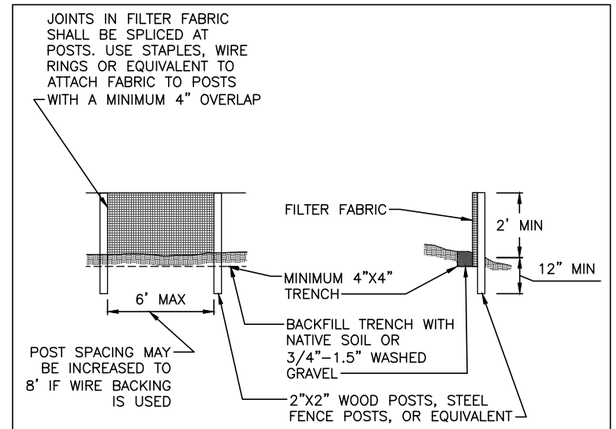
TEMPORARY BAR ACCESS (4/17)
SCALE: NTS



NOTES:

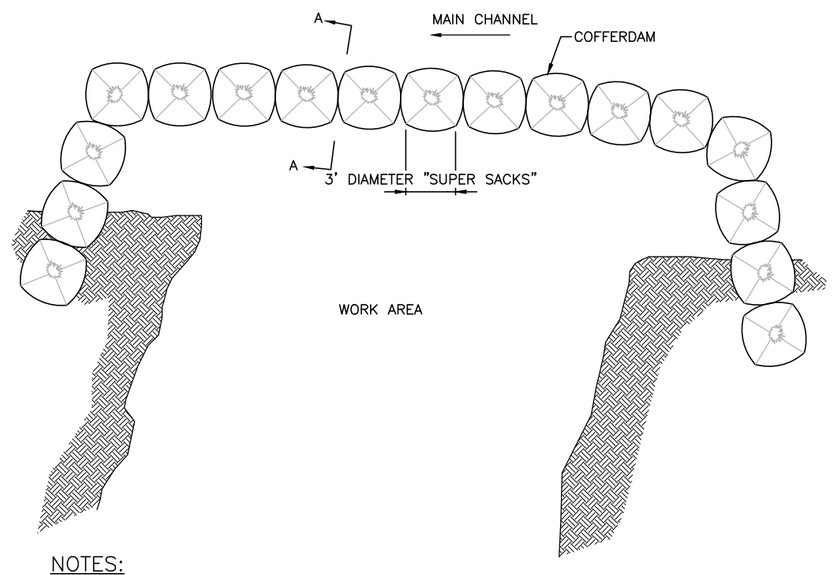
1. CONTRACTOR TO DESIGN TEMPORARY BRIDGE.
2. BRIDGE SHALL BE LOCATED SUCH THAT ONLY ONE SPAN IS USED TO ELIMINATE IMPACTS TO SUBSTRATE OF CHANNEL.
3. END OF BRIDGE SHALL BEAR ON HIGH BANKS WITH SUFFICIENT BEARING CAPACITY TO PREVENT SLOUGHING OR COLLAPSE OF SIDE CHANNEL BANKS.
4. CONCRETE ECOLOGY BLOCKS OR WOOD ABUTMENTS MAY BE USED TO SUPPORT ENDS OF TEMPORARY BRIDGE AS NEEDED.
5. BRIDGES MAY BE CONSTRUCTED FROM LOGS, RAIL CAR BEDS OR APPROVED EQUAL AND DECKED WITH STEEL SHEET, WOOD LAGGING OR APPROVED EQUAL.

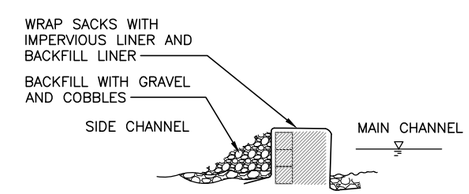
TEMPORARY BRIDGE (2/17)
SCALE: NTS



REFERENCE; WASHINGTON STATE DEPARTMENT OF ECOLOGY STORMWATER MANAGEMENT MANUAL FOR WESTERN WASHINGTON (FIGURE 4–19)

TEMPORARY SILT FENCE (3/17)
SCALE: NTS





SECTION A–A

NOTES:

1. WRAP "SUPER SACKS WITH IMPERVIOUS PLASTIC LINER TO PREVENT SEEPAGE.
2. BACKFILL THE DOWNSTREAM SIDE COFFER DAM WITH NATIVE, ADJACENT ALLUVIUM.
3. USE "SUPER SACKS" AS BUTTRESSES AS REQUIRED.

COFFERDAM (5/17)
SCALE: NTS

State of Washington Licensed Geologist 1181 Timothy B. Abbe

R. LEIF EMBERTSON STATE OF WASHINGTON 45447 REGISTERED PROFESSIONAL ENGINEER

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

NOOKSACK INDIAN TRIBE

Natural Systems Design

NAME OR INITIALS AND DATE		GEOGRAPHIC INFORMATION	
DESIGNED	RLE	LATITUDE	48°41'50"N
CHECKED	TA	LONGITUDE	122°10'02"W
DRAWN	MW	TN/SC/RG	T37N/S16/R5W
CHECKED	RLE	DATE	–

NESSET'S REACH RESTORATION

TESC DETAILS

17

SHEET 17 OF 17

PRELIMINARY 60%

Jul-30-2014

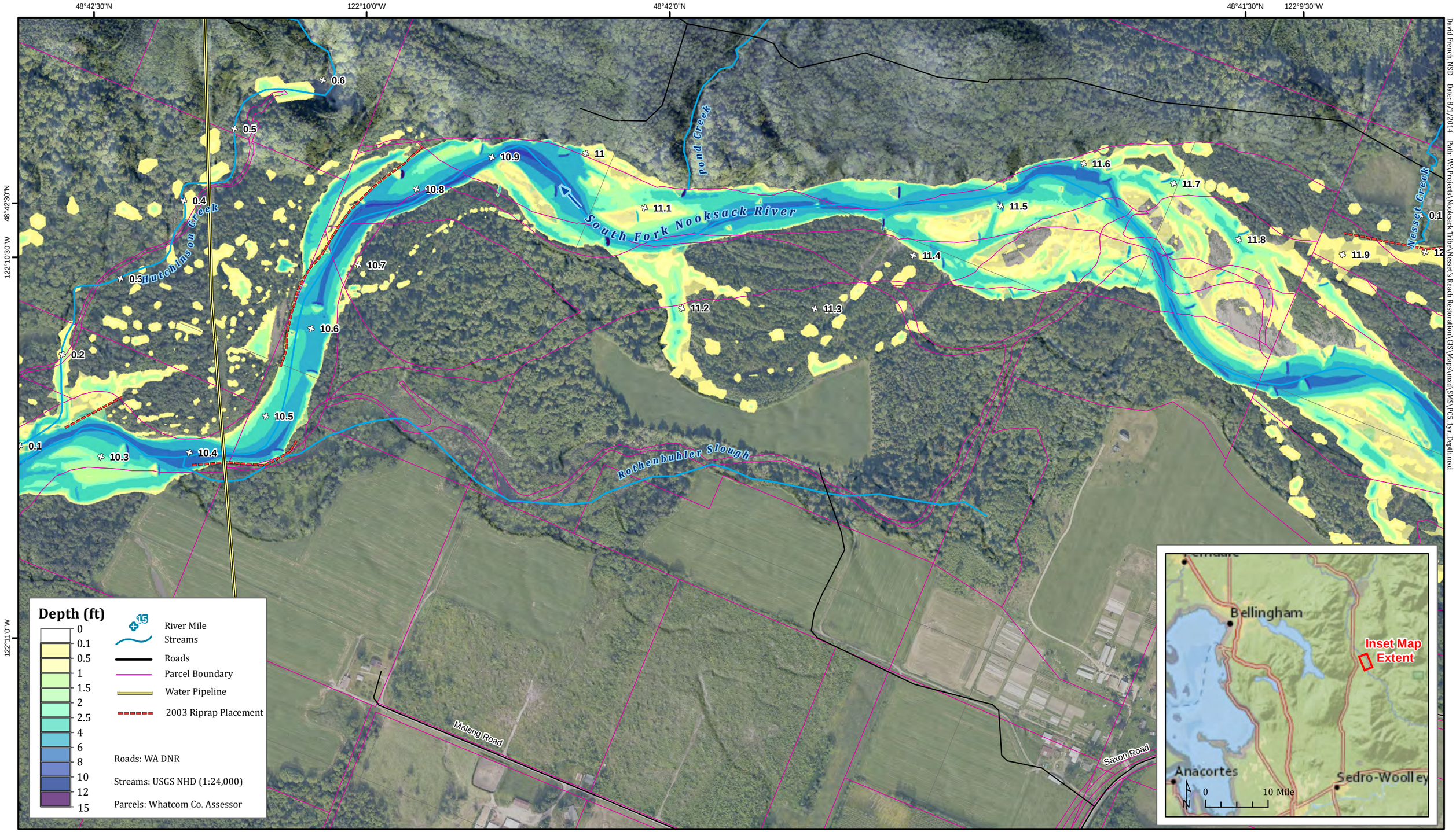
N:\PROJECTS\NOOKSACK TRIBE\NESSET'S REACH RESTORATION\DESIGN\CAD DWGS – CURRENT\TESC DETAILS.DWG Gordey 5/1/2013 9:26:19 AM

APPENDIX C

PROPOSED HYDRAULIC MODEL RESULTS

Natural Systems Design

P.O. Box 15609, Seattle, WA 98105 T: (206) 834-0175



South Fork Nooksack River - Nesset Reach Habitat Restoration

Proposed Conditions 1 year flow depth

Hydronia RiverFlo-2D Hydraulic Model outputs for 4400 cfs flow event.

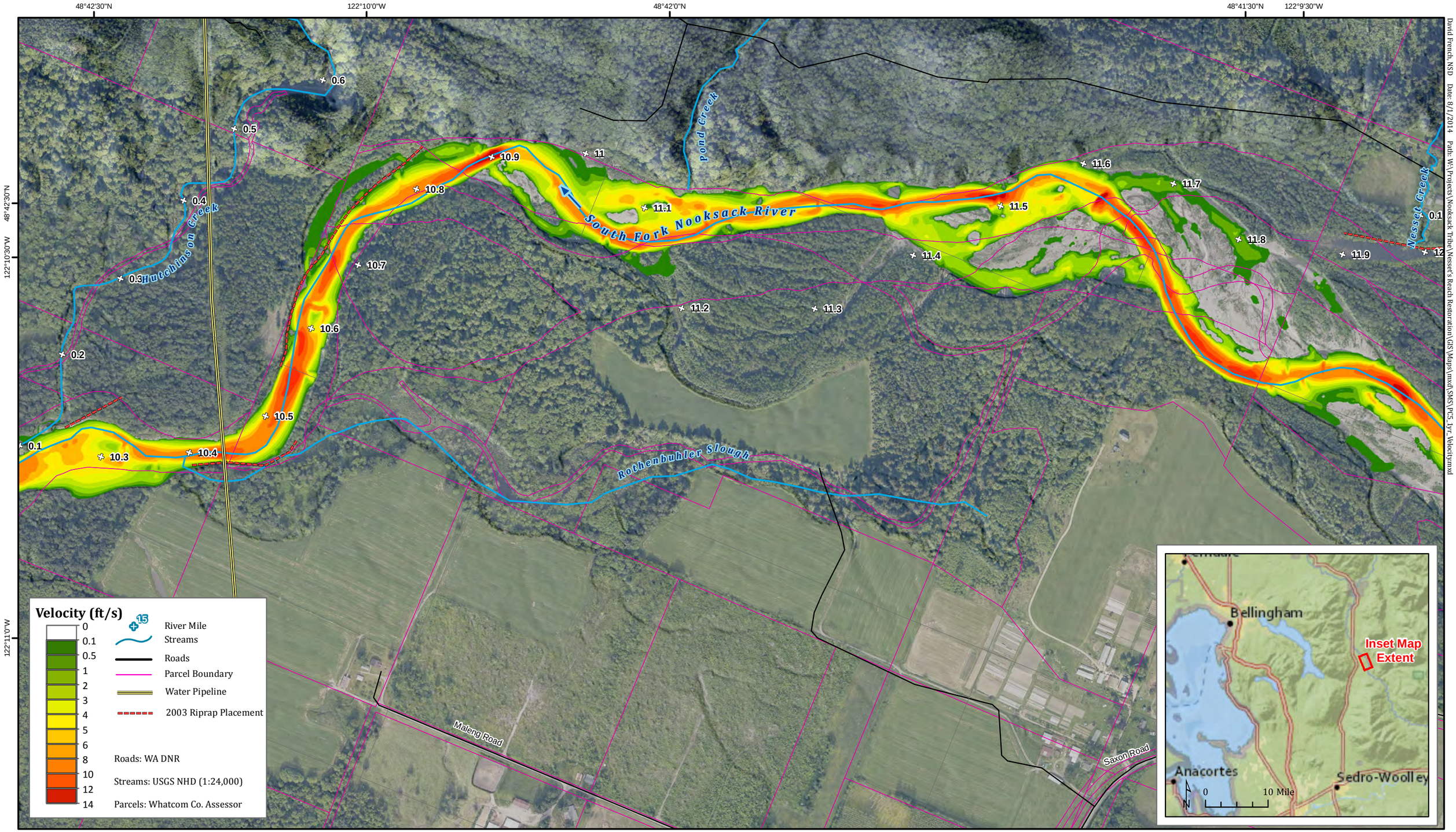
0 500 1,000 1,500 2,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 8/1/2014 Path: W:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\SMS\PC5_1yr_Depth.mxd



South Fork Nooksack River - Nesset Reach Habitat Restoration

Proposed Conditions 1 year flow velocity

Hydronia RiverFlo-2D Hydraulic Model outputs for 4400 cfs flow event.

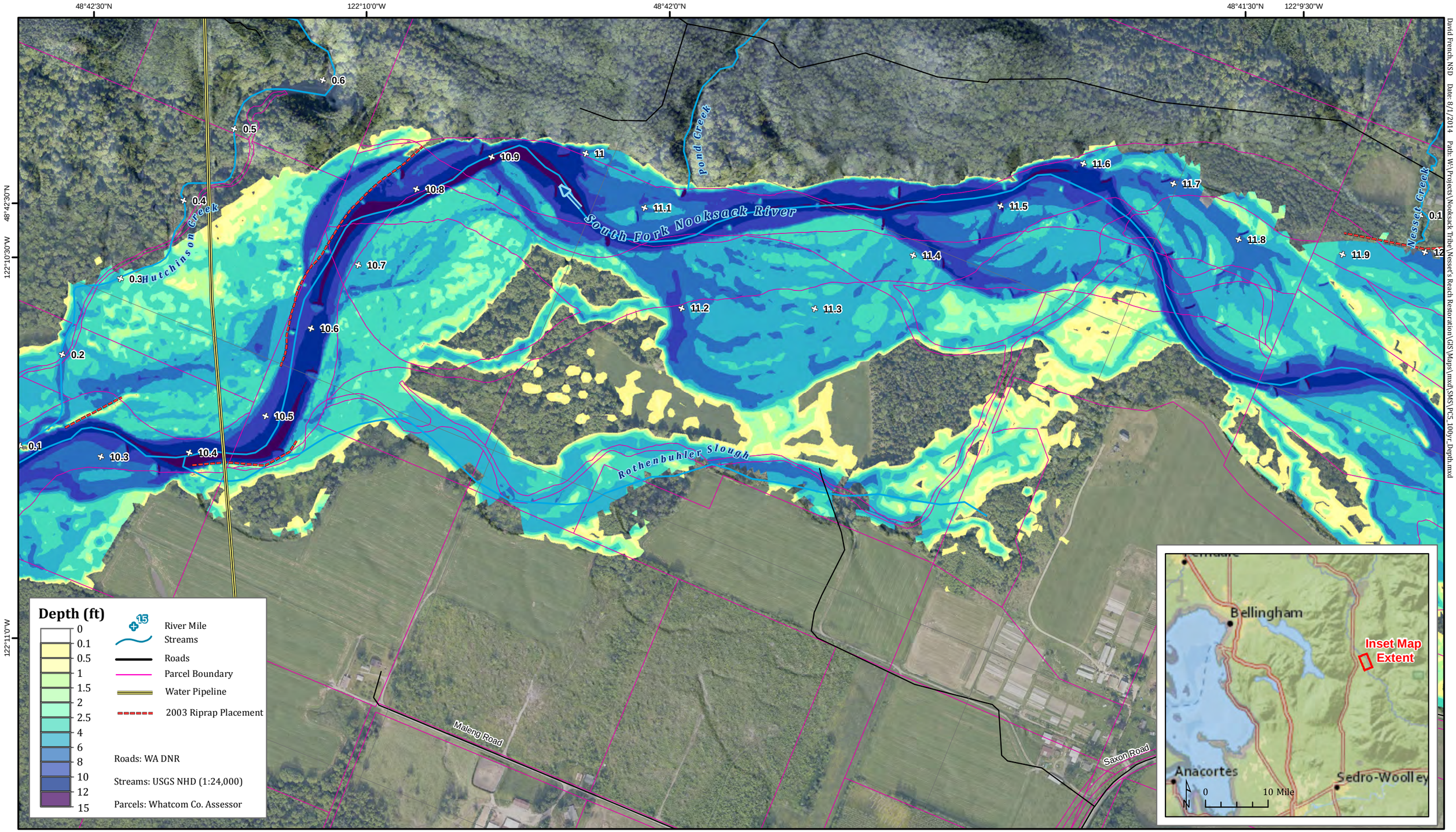
0 500 1,000 1,500 2,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 8/1/2014 Path: W:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\SMS\PC5_1yr_Velocity.mxd



South Fork Nooksack River - Nesset Reach Habitat Restoration

Proposed Conditions 100 year flow depth

Hydronia RiverFlo-2D Hydraulic Model outputs for 30,844 cfs flow event.

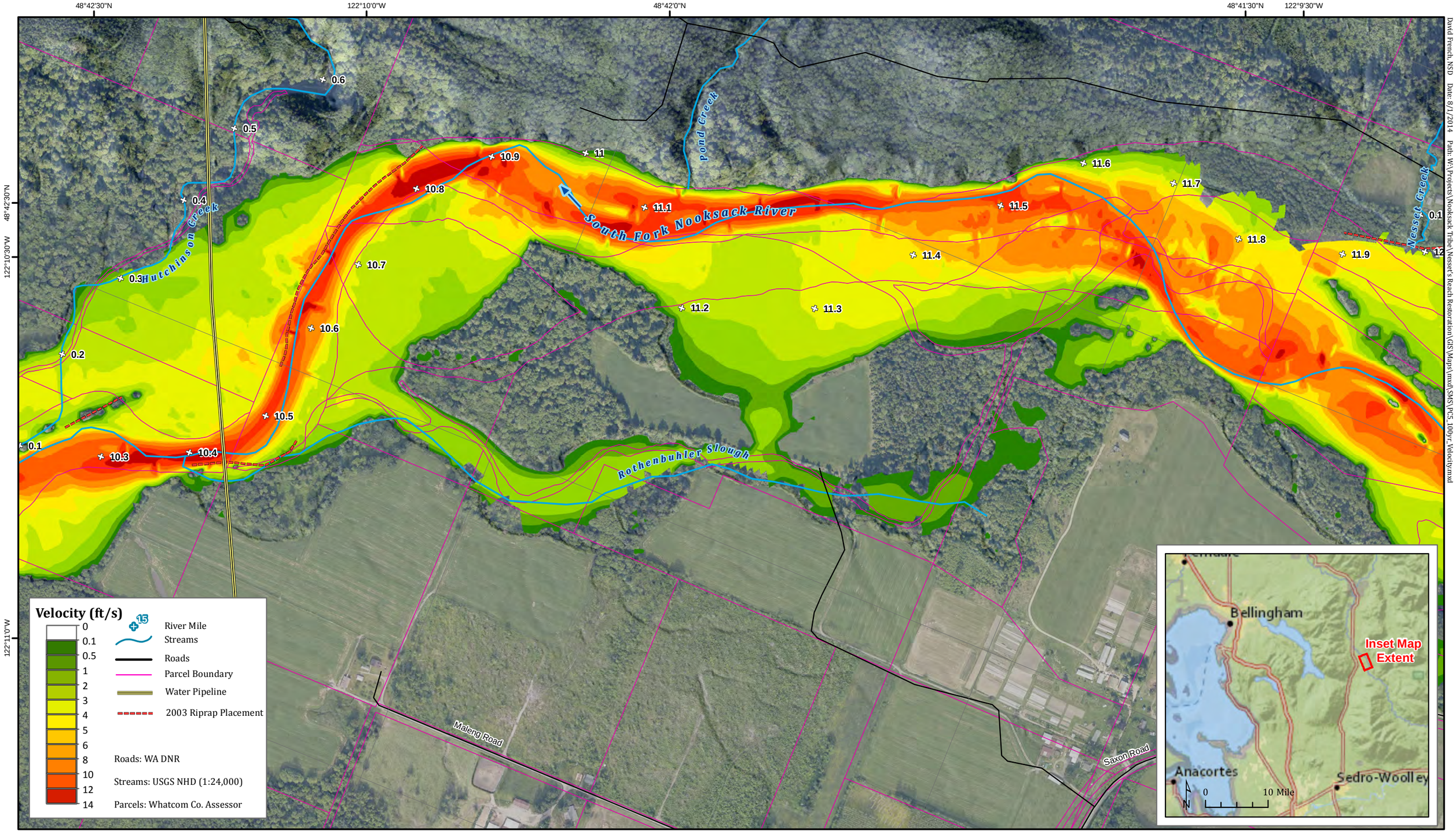
0 500 1,000 1,500 2,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 8/1/2014 Path: W:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\SMS\PC5_100yr_Depth.mxd



South Fork Nooksack River - Nesset Reach Habitat Restoration

Proposed Conditions 100 year flow velocity

Hydronia RiverFlo-2D Hydraulic Model outputs for 30,844 cfs flow event.

0 500 1,000 1,500 2,000 Feet

Lambert conformal conic projection, NAD 1983
State Plane Coordinate System (WA North Zone)

NOOKSACK INDIAN TRIBE

Natural Systems Design

David French, NSD Date: 8/1/2014 Path: W:\Projects\Nooksack Tribe\Nesset's Reach Restoration\GIS\Maps\mxd\SMS\PC5_100yr_Velocity.mxd

APPENDIX D

PRELIMINARY DESIGN

COST ESTIMATE

Natural Systems Design

P.O. Box 15609, Seattle, WA 98105 T: (206) 834-0175

Unit Costs

Project: SOUTH FORK NOOKSACK RIVER: NESSET RESTORATION DESIGN

Analyst: G. DOOLEY

Latest Revision: 8/1/14

Reviewed by: L. EMBERTSON

- This spreadsheet calculates the costs associated with site preparation. Unit costs include materials, labor, equipment, overhead and contractor profit.
- Reference used for "unit costs" include:
  (1) R.S. Means Heavy Construction Cost Data Manual, 2009 (Means)
  (2) Engineering Experience & Recent Similar Projects
  (3) Contractor or Supplier
- Inflation adjustment is a rough estimate using the Consumer Price Index average between 2009 and 2010.
- Additional adjustments are based on engineering judgment, experience and site-specific degree of difficulty.
- Blank rows are provided at the bottom for additional items. Add new items & unit costs on this sheet, if necessary. These will be used to calculate costs on subsequent sheets.
- General mark-up percentages are also provided at the bottom.

12 = Adjustment for inflation from to 2009 to 2014 (Construction) (%)

3.9 = Location Factor (Seattle, WA) (%) (Adjustment from national average)

0 = Additional Location Factor (%)

Item #	Item Description	Ref. ID	Ref. #	Page #	Units	Unit Cost ($)	Quantity per Item	Inflation & Location Adjustments (%)	Additional Adjustments (%)	Adjusted Unit Price ($)
1	MOBILIZATION	2	Cavanaugh Bids		LS	30,000				30000.0
2	TEMPORARY ACCESS ROAD	2	Cavanaugh Bids		LS	10,000				10000.0
3	TEMPORARY ACCESS BRIDGE	2	Larsons Bid		EA	8,000				8000.0
4	TESC MEASURES	2	Cavanaugh Bids		LS	15,000				15000.0
5	DEWATERING, DIVERSION	2	Cavanaugh Bids		LS	30,000				30000.0
6	SIDE CHANNEL EXCAVATION AND GRAVEL BAR NOURISHMENT	1	31-23-16.42-0200 31-23-16.46-2200 31-23-23.17-0150	219 222 226	CY	10				10.0
7	TYPE NO. 1 ELJ				EA					64600
a	Stream Excavation (short haul)	1	31-23-16.42-0200 31-23-16.46-2200	219 222	CY	7.0	1,175.00	15.9		8.1
b	Structure Backfill (short haul)	1	31-23-23.17-0150	226	CY	3.0	1,175.00	15.9		3.5
c	Log 1 - Vertical Posts - 20in DBH, 30ft long, rootwad	2	Larsons Bid		EA	578	14.00	0		578.2
d	Log 2 - 18in DBH, 30ft long	2	Larsons Bid		EA	208	2.00	0		208.1
e	Log 4 - 18in DBH, 40ft long	2	Larsons Bid		EA	266	7.00	0		266.0
f	Log 3 - 24in DBH, 50ft long	2	Larsons Bid		EA	463	2.00	0		462.5
g	Log 5 - 18in DBH, 40-feet, with rootwad	2	Larsons Bid		EA	601	6.00	0		601.3
h	Log 6 - 24in DBH, 45-feet, with rootwad	2	Larsons Bid		EA	833	4.00	0		832.6
i	RACKING MATERIAL; 8-16in DBH, 25-50- feet	2	Larsons Bid		CY	54	150.00	0		53.7
j	1/2in Steel Cabling	3	Internet supplier		LF	1.5	100.00	0		1.5
k	Crew Costs (Log Placement / ELJ Construction)	1	(see notes)		DAY	8,500.0	2.50	15.9		9851.5
8	TYPE NO. 2 ELJ				EA					44600
a	Stream Excavation (short haul)	1	31-23-16.42-0200 31-23-16.46-2200	219 222	CY	7.0	625.00	15.9		8
b	Structure Backfill (short haul)	1	31-23-23.17-0150	226	CY	3.0	625.00	15.9		3
c	Log 1 - Vertical Posts - 20in DBH, 30ft long, rootwad	2	Larsons Bid		EA	578	8.00	0		578
d	Log 2 - 18in DBH, 30ft long	2	Larsons Bid		EA	208	7.00	0		208
e	Log 7 - 18in DBH, 50ft long	2	Larsons Bid		EA	375	2.00	0		375
f	Log 8 - 18in DBH, 30-feet, with rootwad	2	Larsons Bid		EA	509	4.00	0		509
g	Log 10 - 24in DBH, 40-feet, with rootwad	2	Larsons Bid		EA	798	2.00	0		798
h	Log 9 - 24in DBH, 50-feet, with rootwad	2	Larsons Bid		EA	856	2.00	0		856
i	RACKING MATERIAL; 8-16in DBH, 25-50- feet	2	Larsons Bid		CY	54	100.00	0		54
j	1/2in Steel Cabling	3	Internet supplier		LF	1.5	75.00	0		2
k	Crew Costs (Log Placement / ELJ Construction)	1	(see notes)		DAY	8,500.0	2.00	15.9		9852
9	TYPE NO. 3 ELJ				EA					22300
a	Stream Excavation (short haul)	1	31-23-16.42-0200 31-23-16.46-2200	219 222	CY	7.0	335.00	15.9		8
b	Structure Backfill (short haul)	1	31-23-23.17-0150	226	CY	3.0	335.00	15.9		3
c	Log 12 - Vertical Posts - 18in DBH, 25ft long, rootwad	2	Larsons Bid		EA	463	9.00	0		463
d	Log 5 - 18in DBH, 40ft long, rootwad	2	Larsons Bid		EA	601	2.00	0		601
e	Log 7 - 18in DBH, 50ft long	2	Larsons Bid		EA	375	2.00	0		375
f	Log 9 - 24in DBH, 50-feet, with rootwad	2	Larsons Bid		EA	856	2.00	0		856
g	Log 4 - 18in DBH, 40ft long	2	Larsons Bid		EA	266	1.00	0		266
h	Log 11 - 18in DBH, 45ft long	2	Larsons Bid		EA	320	2.00	0		320
i	RACKING MATERIAL; 8-16in DBH, 25-50- feet	2	Larsons Bid		CY	54	70.00	0		54
j	1/2in Steel Cabling	3	Internet supplier		LF	1.5	75.00	0		2
k	Crew Costs (Log Placement / ELJ Construction)	1	(see notes)		DAY	5,000	1.00	15.9		5795
10	TYPE NO. 4 ELJ				EA					21300
a	Log 9 - 24in DBH, 50-feet, with rootwad	2	Larsons Bid		EA	856	5.00	0		856
b	Log 4 - 18in DBH, 40ft long	2	Larsons Bid		EA	266	1.00	0		266
c	Log 11 - 20in DBH, 60ft long	2	Larsons Bid		EA	370	2.00	0		370
d	RACKING MATERIAL; 8-16in DBH, 25-50- feet	2	Larsons Bid		CY	54	70.00	0		54
e	Rock collar w/ cable (7.8 tons ea)	3	Saxon Bids		EA	200.0	12.00	0		200
f	Crew Costs (Log Placement / ELJ Construction)	1	(see notes)		DAY	8,500.0	1.00	15.9		9852
11	ROADSIDE CLEANUP	3			FA	5,000		0		5000
12	LEVEE REMOVAL AND IMPROVEMENTS	1	31-23-16.42-0200 31-23-16.46-2200 31-23-23.17-0150	219 222 226	CY	10		15.9		12
13	REVEGETATION	2			LS	30,000				30000
14								0		0
101	Taxes (materials and major taxes included in line items)									8.1
102	Incidentals not included in items above (as % of Construction Sub-Total)									
103	Contingency (as % of Construction Sub-Total)									30.0
104	Permitting (as % of Construction Sub-Total)									0.0
105	Additional survey and design (as % of Construction Sub-Total)									0.0

Total Project (CIP)

Project: SOUTH FORK NOOKSACK RIVER: NESSET RESTORATION DESIGN

Analyst: G. DOOLEY

Latest Revision: 8/1/14

Reviewed by: L. EMBERTSON

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	MOBILIZATION	LS	$30,000	3.0	$90,000
2	TEMPORARY ACCESS ROAD	LS	$10,000	3.0	$30,000
3	TEMPORARY ACCESS BRIDGE	EA	$8,000	3.0	$24,000
4	TESC MEASURES	LS	$15,000	3.0	$45,000
5	DEWATERING, DIVERSION	LS	$30,000	3.0	$90,000
6	SIDE CHANNEL EXCAVATION AND GRAVEL BAR NOURISHMENT	CY	$10	10,000.0	$99,500
7	TYPE NO. 1 ELJ	EA	$64,600	2.0	$129,200
8	TYPE NO. 2 ELJ	EA	$44,600	3.0	$133,800
9	TYPE NO. 3 ELJ	EA	$22,300	31.0	$691,300
10	TYPE NO. 4 ELJ	EA	$21,300	9.0	$191,700
11	ROADSIDE CLEANUP	FA	$5,000	3.0	$15,000
12	LEVEE REMOVAL AND IMPROVEMENTS	CY	$12	3,500.0	$40,362
13	REVEGETATION	LS	$30,000	3.0	$90,000
	Constrution Sub-Total				**$1,670,000**
101	Taxes (materials and major taxes included in line items)			8.1%	$135,270
102	Incidentals not included in items above (as % of Construction Sub-Total)			0.0%	$0
103	Contingency (as % of Construction Sub-Total)			30.0%	$501,000
104	Permitting (as % of Construction Sub-Total)			0.0%	$0
105	Additional survey and design (as % of Construction Sub-Total)			0.0%	$0
	Final Construction Cost				**$2,310,000**

Phase I Total Cost

Project: SOUTH FORK NOOKSACK RIVER: NESSET RESTORATION DESIGN

Analyst: G. DOOLEY

Latest Revision: 8/1/14

Reviewed by: L. EMBERTSON

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	MOBILIZATION	LS	$30,000	1.0	$30,000
2	TEMPORARY ACCESS ROAD	LS	$10,000	1.0	$10,000
3	TEMPORARY ACCESS BRIDGE	EA	$8,000	1.0	$8,000
4	TESC MEASURES	LS	$15,000	1.0	$15,000
5	DEWATERING, DIVERSION	LS	$30,000	1.0	$30,000
6	SIDE CHANNEL EXCAVATION AND GRAVEL BAR NOURISHMENT	CY	$10	5,000.0	$49,800
7	TYPE NO. 1 ELJ	EA	$64,600	0.0	$0
8	TYPE NO. 2 ELJ	EA	$44,600	0.0	$0
9	TYPE NO. 3 ELJ	EA	$22,300	20.0	$446,000
10	TYPE NO. 4 ELJ	EA	$21,300	2.0	$42,600
11	ROADSIDE CLEANUP	FA	$5,000	1.0	$5,000
12	LEVEE REMOVAL AND IMPROVEMENTS	CY	$12	0.0	$0
13	REVEGETATION	LS	$30,000	1.0	$30,000
	Constrution Sub-Total				**$670,000**
101	Taxes (materials and major taxes included in line items)			8.1%	$54,270
102	Incidentals not included in items above (as % of Construction Sub-Total)			0.0%	$0
103	Contingency (as % of Construction Sub-Total)			30.0%	$201,000
104	Permitting (as % of Construction Sub-Total)			0.0%	$0
105	Additional survey and design (as % of Construction Sub-Total)			0.0%	$0
	Final Construction Cost				**$930,000**

Phase II Total Cost

Project: SOUTH FORK NOOKSACK RIVER: NESSET RESTORATION DESIGN

Analyst: G. DOOLEY

Latest Revision: 8/1/14

Reviewed by: L. EMBERTSON

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	MOBILIZATION	LS	$30,000	1.0	$30,000
2	TEMPORARY ACCESS ROAD	LS	$10,000	1.0	$10,000
3	TEMPORARY ACCESS BRIDGE	EA	$8,000	2.0	$16,000
4	TESC MEASURES	LS	$15,000	1.0	$15,000
5	DEWATERING, DIVERSION	LS	$30,000	1.0	$30,000
6	SIDE CHANNEL EXCAVATION AND GRAVEL BAR NOURISHMENT	CY	$10	5,000.0	$49,800
7	TYPE NO. 1 ELJ	EA	$64,600	2.0	$129,200
8	TYPE NO. 2 ELJ	EA	$44,600	2.0	$89,200
9	TYPE NO. 3 ELJ	EA	$22,300	2.0	$44,600
10	TYPE NO. 4 ELJ	EA	$21,300	3.0	$63,900
11	ROADSIDE CLEANUP	FA	$5,000	1.0	$5,000
12	LEVEE REMOVAL AND IMPROVEMENTS	CY	$12	0.0	$0
13	REVEGETATION	LS	$30,000	1.0	$30,000
	Constrution Sub-Total				**$510,000**
101	Taxes (materials and major taxes included in line items)			8.1%	$41,310
102	Incidentals not included in items above (as % of Construction Sub-Total)			0.0%	$0
103	Contingency (as % of Construction Sub-Total)			30.0%	$153,000
104	Permitting (as % of Construction Sub-Total)			0.0%	$0
105	Additional survey and design (as % of Construction Sub-Total)			0.0%	$0
	Final Construction Cost				**$700,000**

Phase III Total Cost

Project: SOUTH FORK NOOKSACK RIVER: NESSET RESTORATION DESIGN

Analyst: G. DOOLEY

Latest Revision: 8/1/14

Reviewed by: L. EMBERTSON

- This spreadsheet calculates the costs for the items noted. Item # references the Item # on the Unit Cost sheet.
- The unit costs are based upon those listed & calculated on the Unit Cost sheet.
- Blue cells represent cells that require input.

Item #	Item Description	Units	Adjusted Unit Cost ($)	No. of Units	Cost per Item ($)
1	MOBILIZATION	LS	$30,000	1.0	$30,000
2	TEMPORARY ACCESS ROAD	LS	$10,000	1.0	$10,000
3	TEMPORARY ACCESS BRIDGE	EA	$8,000	0.0	$0
4	TESC MEASURES	LS	$15,000	1.0	$15,000
5	DEWATERING, DIVERSION	LS	$30,000	1.0	$30,000
6	SIDE CHANNEL EXCAVATION AND GRAVEL BAR NOURISHMENT	CY	$10	0.0	$0
7	TYPE NO. 1 ELJ	EA	$64,600	0.0	$0
8	TYPE NO. 2 ELJ	EA	$44,600	1.0	$44,600
9	TYPE NO. 3 ELJ	EA	$22,300	9.0	$200,700
10	TYPE NO. 4 ELJ	EA	$21,300	4.0	$85,200
11	ROADSIDE CLEANUP	FA	$5,000	1.0	$5,000
12	LEVEE REMOVAL AND IMPROVEMENTS	CY	$12	3,500	$40,362
13	REVEGETATION	LS	$30,000	1.0	$30,000
	Constrution Sub-Total				**$490,000**
101	Taxes (materials and major taxes included in line items)			8.1%	$39,690
102	Incidentals not included in items above (as % of Construction Sub-Total)			0.0%	$0
103	Contingency (as % of Construction Sub-Total)			30.0%	$147,000
104	Permitting (as % of Construction Sub-Total)			0.0%	$0
105	Additional survey and design (as % of Construction Sub-Total)			0.0%	$0
	Final Construction Cost				**$680,000**

APPENDIX E

RESPONSES TO CRT AND SRFB REVIEW COMMENTS

Natural Systems Design

P.O. Box 15609, Seattle, WA 98105 T: (206) 834-0175

CRT Feedback on Nesset's Phase 1 Preliminary Design with Answers

1. I would like to see a more detailed discussion on what NSD envisions will happen at the side tributaries (Nessets and Pond Creeks), cool water seeps, and Rothenbhuler Slough.
    a. **Side tributaries within the geomorphic floodplain are anticipated to see more inundation during high flows from project elements. This will increase groundwater re-charge during the winter months and hyporheic flows during the summer months improving stream temperatures and surface water quantity in these area. Pond Creek outlets from the east valley wall and appears to be strongly influence by bedrock and is not anticipated to be strongly effected beyond from improve fish access near the outlet due to pool creation and backwater effects from adjacent ELJs.**
2. Habitat pools should not be placed near tributaries unless one accounts for the trib's sediment supply and change in habitat if the water level changes.
    a. **While we see the logic in this we don't have the time or resources to complete a sediment budget for tributaries and these are important cool water refuge areas for holding. We will use best professional judgement on elevation and location for structure location.**
3. It is unclear due to the map scale if ELJs near the cool water seeps will maintain a pool.
    a. **The intent is for these features to maintain a pool in front of their locations. The permanence of a pool feature will be dependent on the frequency of high flows to create hydraulics conditions advantageous to scour.**
4. It seems like the modeling shows that Rothenbular Slough is currently a backwater and I'm not sure the modeled design will change it.
    a. **This is likely correct in the short term. If bed aggradation results from reduced sheer stress from structure placement this could change. There are other channel scars in the floodplain near Rothenbhuler Slough that would be reactivated. Modeling only shows static bed conditions for the proposed conditions hydraulic modeling so it is more a representation of as-built conditions.**
5. Can we see a better characterization of objectives and goals, trade-offs, and expected benefits. A better visualization of future condition. What do we want the channel to look like.
    a. **See number 3 above.**
6. The presentation notes that landowner agreements are in process, have you talked to the Hibbings? They own the goat farm where the access road starts. They may be a little leery about granting access again through their property, even though we improved the road for them. I have contact information for them if you need it.
    a. **We may end up accessing from just the one main access through the Martin, Lloyd, and WLT properties even though it shows access through the Hibbings as well on the design drawings. We haven't approached them for a landowner agreement at this point. It may be cheaper and less disturbance to just bridge across but we are still evaluating that approach. I'll be in touch for the contact info if need be. Thanks!**

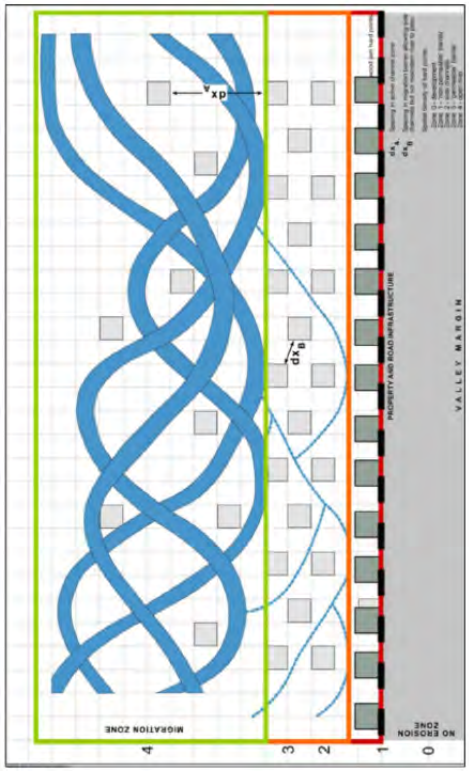
7. While County Parks are the owners for the right bank, Russell Pfeiffer Hoyt is the Trustee for the Nessets and has an interest in what happens on that side because of the deep pond known as "Nesset's pond". Alex and I took a visit over to that property before the Saxon project with Russell, and he is protective of that pond. He did note that he thought that more could be done with the creek (Nessett's creek, I assume?). We had originally sought permission from the SRFB to extend our project scope to this area (without an amendment), but they thought it was beyond the scope of the project.
    a. **We haven't discussed the project with Russell to my knowledge since he isn't the landowner. Thanks for the insight on this.**
8. Have you thought about where to pump the water from excavation? Mike Ericsson should be familiar with our problems pumping into the area on the right bank.
    a. **We haven't entered into that level of planning yet but I do recall how much pumping was required at Saxon. While pumping will still be required we are leaning towards driving piles where possible which should reduce excavation volume and time.**
9. With regards to pumps- make sure the contractor finds quiet pumps. Nick Saling and his wife could hear the pumps at Saxon when Harkness needed to keep them on during the night. He originally thought that the contractor was working, but when I told him that they were pumping the water for the ELJs, he understood the need for it. There was only 1-2 days of construction, so he was ok with us running the pump during the night. Harkness turned off the pump at night, and then arrived a few hours early to start the pump again. The next year he located pumps that were much quieter, and cheaper.
    a. **Thanks for this site specific information!**
10. Is there a time estimate on wood recruitment for the Type 3 structure? May want to think about adjusting design to get more immediate benefit rather than rely on wood accumulation.
    a. **Additional large wood pieces were added during the final design phase to improve immediate benefit. An accurate time estimate is difficult to evaluate and dependent on frequency of high flows causing bank erosion and wood recruitment, transport of recruited wood, and flow path of mobile wood through the project site. Similar constructed ELJs in the Upper Quinault show significant wood recruitment when positioned near the low flow channel. ELJs located in back bar areas have accumulated less wood and more dependent on ELJ frame logs for habitat function.**
11. Will the type 3's be limited in function if wood recruitment takes longer than expected or not at all?
    a. **Less large wood is used in these structures than most other recent ELJ designs. Cover from large wood will initially be less because of this. Racking and slash will likely accumulate within the first year as we have seen on other ELJ projects implemented in the lower South Fork Nooksack. We will discuss adding more large wood and slash to the ELJs with NSD.**
12. What are the habitat benefits of the Type 4 ballasted structures?

a. **Type 4 structures are self-settling structures that are designed to embed into the channel bottom as scour occurs around the structure. This creates a pool that could be used for holding or rearing chinook.**

13. It would be helpful if we send out informational materials ahead of time for the team to get familiar with projects before for these presentations.

a. **We apologize for not sending out materials before the meeting. We will do so for future presentations seeking feedback. Materials were sent after the meeting to aid in feedback.**

14. Make a better case for the density of structures.



The spacing of structures is intended to facilitate the encroachment of the riparian forest along the active channel margins and the development of forested islands within the active channel. Re-establishment of the floodplain forest is anticipated to have benefits to stream temperatures, edge complexity, a narrowing and deepening of the low flow channel and a reduction in channel migration rates. Within recent history the channel has migrated across this un-confined reach creating relatively shallow glide habitat devoid of significant pools (with the exception of two bedrock forced pools). Without a high density of ELJs located on bars and back channels channel migration would likely move the low flow channel away from ELJs constructed within the current channel due to the increase in roughness and flow deflection caused by ELJs reducing the immediate habitat provided by in channel ELJs

15. Is there a critical number, density of jams needed to achieve objectives? The concern is total cost.

a. **See above for explanation on density of ELJs**