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TECHNICAL MEMORANDUM

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Subject: South Fork Nooksack River Skookum-Edfro Reach Phase 3 Basis of Preliminary Design

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Introduction and Background

This memorandum presents the basis for the preliminary design of Phase 3 of the South Fork Skookum-Edfro Reach Habitat Restoration Project (Project). In 2021 the Lummi Nation Natural Resources Department (LNRD) began moving forward with Phase 3 of the Project to develop and implement restoration actions to address the habitat limiting factors (summarized below) in the Phase 3 reach of the South Fork Nooksack River (South Fork), which is between River Mile (RM) 12.70 and RM 13.95 (Figure 1). This memorandum summarizes various technical analyses, design development work, and rationale for the configuration of preliminary design of the Project including the following:

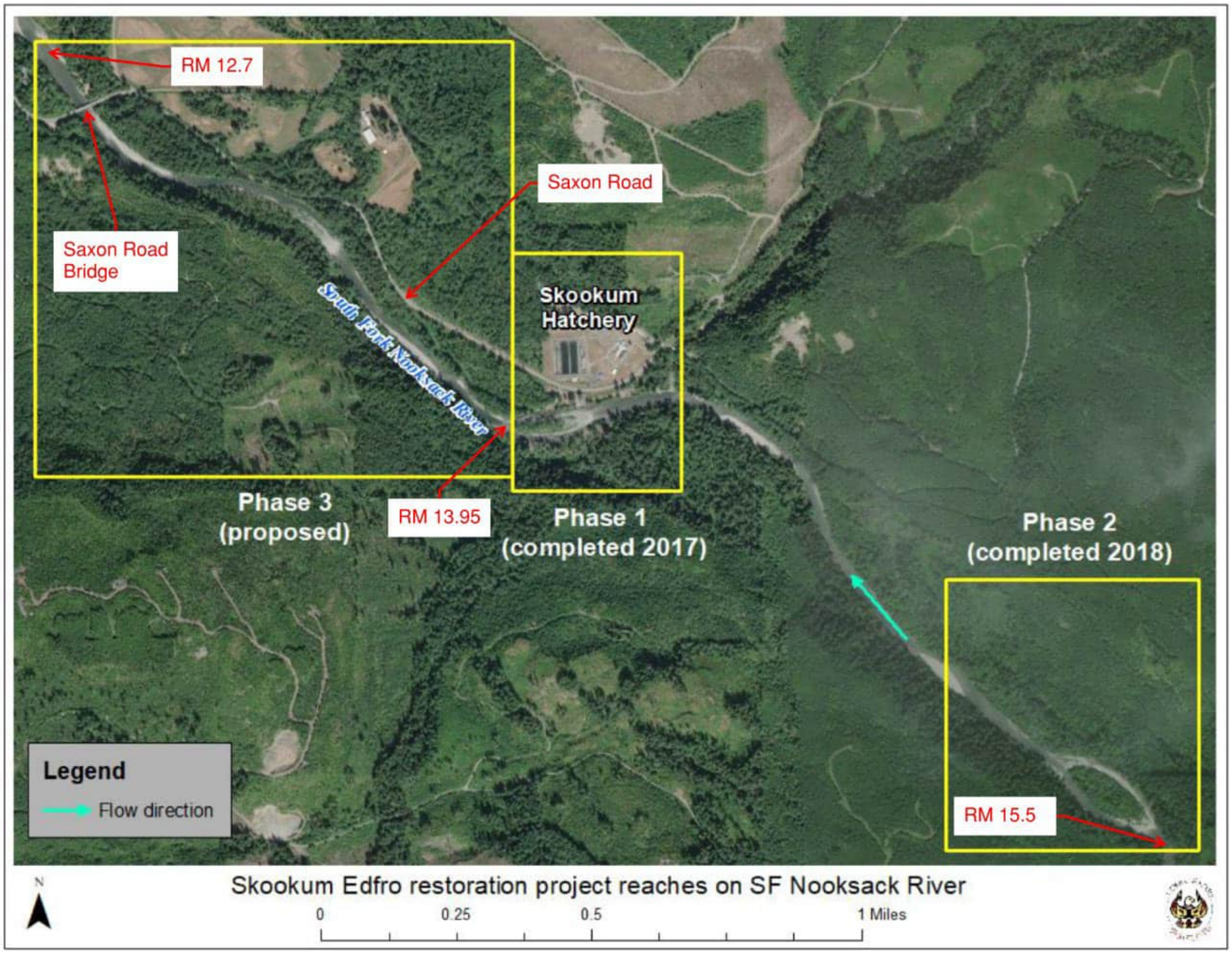
- Information obtained in multiple site visits to the Phase 3 reach to observe and document existing (pre-project) instream and floodplain geomorphic and hydraulic conditions.
- Restoration opportunities and recommended restoration measures that address the habitat limiting factors.
- Development and evaluation of a suite of conceptual restoration design alternatives.
- Development of hydraulic models for existing conditions and for the conceptual restoration design alternatives to help inform selection of a preferred alternative for preliminary design advancement and to ensure the project meets the Federal Emergency Management Agency's (FEMA's) zero-rise requirements at insurable structures since the Project is located within a FEMA-designated floodway.
- Feedback obtained in several outreach meetings with project stakeholders and nearby landowners regarding the alternatives and the preferred alternative, and how that feedback has been incorporated into the preliminary design.
- Proposed restoration measures including instream engineered log structures (ELSs) and channel modifications.

Since 2007 habitat restoration in the South Fork has been a high priority for restoring and improving impaired habitat conditions for salmonid species listed as Threatened under the federal Endangered Species Act (ESA) including Puget Sound Chinook salmon, Puget Sound steelhead, and bull trout. Specifically, recovery of the South Fork early Chinook population is essential to recovering the threatened Puget Sound Evolutionarily Significant Unit (ESU) of this species and for restoring runs to sustainable and harvestable levels for local tribal communities. The LNRD has implemented habitat restoration projects in the Skookum-Edfro Reach of the South Fork, located between RM 12.70 and RM 15.50, since 2010. The Skookum-Edfro Reach Restoration Project was implemented in 2010 and included constructing three ELSs along the right bank (when looking downstream) of the South Fork adjacent to LNRD's Skookum Creek Fish Hatchery between RM 14.00 and RM 14.30, and realigning Saxon Road approximately 100 feet landward to its current location adjacent to the hatchery.

Phase 1 of the Project, also located adjacent to LNRD's Skookum Creek Fish Hatchery, was completed in 2017. That work included constructing four ELSs and four small habitat structures and enhancing the three ELSs constructed in 2010. Phase 2, located upstream of the Phase 1 project between RM 14.90 and RM 15.50, was completed in 2018 and included constructing 15 ELSs. Phases 1 and 2 focused on addressing key habitat-limiting factors that continue to hinder Chinook salmon recovery goals in the Nooksack River basin (WRIA 1 Salmon Recovery Board 2005), including:

- Reduced habitat diversity including insufficient complex edge and floodplain habitats (e.g., undercut banks, backwater areas, side channels, sloughs and braids).
- Loss of stable instream large wood material (LWM) that creates thermal and velocity refugia, creates pools and cover adjacent to spawning areas, and promotes formation of complex channel and bed forms favorable for salmonid spawning, holding and rearing.
- Insufficient size, abundance and complexity of pool habitat (with and without cool water influences) for adult salmon holding.
- Seasonally elevated water temperatures.

Figure 1. Locations of Phased Habitat Restoration Projects in the Skookum-Edfro Reach of the South Fork Nooksack River.



Phase 3 Reach Conditions

Herrera completed multiple site visits with LNRD in 2022, 2023, and 2024 to the Phase 3 reach. The intent of these site visits was to observe and document existing instream and floodplain geomorphic and hydraulic conditions; to identify habitat restoration opportunities and constraints; to begin generating ideas for conceptual design alternatives; and to collect data necessary to develop and run the two-dimensional (2D) hydraulic model as described later in this memorandum. Herrera and LNRD project team members also walked the Phase 3 reach with nearby landowners and project stakeholders to describe the proposed restoration measures, discuss construction challenges and potential channel responses, and to solicit feedback that could be incorporated into the alternatives. Herrera prepared a detailed summary of the existing geomorphic and hydraulic conditions in the Phase 3 reach following a site visit on September 15, 2022, that helped to inform identification of restoration opportunities (Appendix A) and the conceptual restoration design alternatives described later in this memorandum.

In summary, the poor habitat conditions observed in the past 2 years in the Phase 3 reach match those previously documented by others as described in Appendix A. The Phase 3 reach has been substantially modified from its historical conditions as the natural geomorphic functions that create and maintain high quality instream and floodplain habitats have been significantly compromised due to past development in the floodplain and river channel management actions, and thus fish habitat conditions are severely degraded. The loss of the anastomosing channel morphology and resultant reduction of floodplain connectivity was likely the most significant historical impact to habitat functions. Poor instream habitat conditions are due to the following:

- No stable instream LWM accumulations
- Very few pools
- Simplified channel planform
- Armored banks
- Few areas suitable for spawning, rearing and refugia
- No off-channel habitats
- Seasonally elevated water temperatures

These habitat problems are further compounded by the incised channel conditions and a disconnected floodplain that is not engaged except during very large and thus infrequent flow events, resulting in increased flow velocity and scour potential. Consequently, there is an acute lack of low velocity and cool water refugia for juvenile and adult salmonids and to support rearing habitat for juvenile salmonids, and extremely limited adult salmonid holding and spawning opportunities. With the lack of stable LWM and the subsequent transition into a single thread channel form most of the high-functioning salmonid habitat that historically existed in this reach has been lost.

Project Alternatives Development

Target Habitat Conditions and Restoration Strategy

The general approach to improving habitat conditions in the Phase 3 reach is to implement restoration measures that will promote natural geomorphic processes that create and maintain diverse and complex habitat conditions, to ultimately promote recovery of ESA listed salmonid species while also benefiting non-listed species. Therefore, the restoration strategy is to achieve increased habitat function through restoring lost channel processes and conditions by emulating, to the extent possible, the probable historical channel conditions with immediate and/or near-term benefits under a range flow conditions, for as long a duration as possible. To accomplish this the Project design addresses the following target habitat conditions established by the WRIA 1 co-managers for various restoration project elements and associated performance monitoring for the South Fork (WRIA 1 Salmon Recovery Board 2005):

- Eighteen (18) deep pools with greater than 1-meter residual depth per mile. A pool quantity of less than 1.4 channel widths per pool is considered a "good" condition, and a pool quantity of less than 1 channel width per pool is considered a "very good" condition.
- Two-thirds of all pools formed by naturally occurring wood or by LWM placed for restoration purposes.
- Thirty (30) stable logjams per mile in unconfined channel reaches (from approximately RM 12.70 to RM 14.00) and 10 per mile in confined channel reaches (RM 13.60 to RM 14.00). This equates to one logjam (i.e., ELS) approximately every 180 feet of channel length (equivalent to spacing between ELSs of approximately one channel width for the Phase 3 reach). Logjams forming deep, complex pools within cool water influence areas and within other areas is a Tier 1 restoration strategy identified by the WRIA 1 co-managers.
- Removal of "hardened" armored (riprap) banks.

Herrera identified opportunities in the Phase 3 reach where specific restoration measures can be implemented, striving to:

1. Achieve the target habitat conditions noted above
2. Improve habitat resiliency
3. Improve habitat diversity (habitat units that span the majority of the channel), complexity, and accessibility
4. Not increase existing flooding and geomorphic risks to nearby private property and infrastructure including meeting FEMA's "zero-rise" requirements for insurable structures in the floodplain

A summary of these restoration opportunities, which informed development of the conceptual restoration design alternatives described below, is included in Appendix A.

The entire Phase 3 reach is considered a high-energy area based on the 2D hydraulic model results and current geomorphic conditions. Therefore, ELSs of various sizes and function are the primary restoration measures that can reduce flow velocities, encourage retention of finer spawning sized sediments and channel aggradation in incised sub-reaches, and create deep, cool and complex pools while significantly increasing the overall hydraulic and geomorphic complexity within the Phase 3 reach. In combination with the ELSs, side channel reestablishment, riprap removal from a bank no longer needing armoring, gravel bar regrading, and placement of surplus material derived from gravel bar regrading and ELS excavations along riprap armored banks that must remain in place (e.g., along the right bank where the river flows adjacent to Saxon Road) for adjacent land protection purposes can also be implemented to achieve the target habitat conditions. To help meet FEMA's zero-rise requirements channel widening in strategic locations along the Phase 3 reach is a necessary project element to increase hydraulic conveyance capacity within the main stem channel, offsetting the loss of conveyance that will result due to ELS placements in the channel.

Conceptual Restoration Design Alternatives and FEMA Zero-Rise Compliance Strategy

Herrera developed, and evaluated via 2D hydraulic modeling, three conceptual restoration design alternatives. Modeling results for the alternatives were compared to the existing conditions model results to assess potential changes in water surface elevations, flow depths and velocities, hydraulic and geomorphic complexity, and flood and erosion/channel migration risks associated with each alternative. A detailed summary of the 2D model development and results of the existing conditions modeling including graphics of the model results are included in Appendix A. Appendix B includes plan view graphics of the three alternatives and the conceptual design plans for the preferred alternative (Alternative 3).

To meet the habitat targets described above, and to evaluate each alternative's ability to meet FEMA's zero-rise requirement, Alternatives 1, 2, and 3 include a range of ELS types/sizes (large, medium and small) and quantities. This was done to test the sensitivity of the number and sizes of ELSs when comparing the 2D hydraulic model results of each alternative to each other and when evaluating each alternative's ability to meet the zero-rise requirement. Satisfying the targets for "18 deep pools per mile" and "30 stable logjams per mile" in the 1.25-mile-long Phase 3 reach translates into each alternative including a minimum of 38 stable ELSs and 23 deep pools assuming a certain percentage (varying from as low as 20 percent to as high as 100 percent) of ELSs are stable and a certain percentage of ELSs would form deep pools. This was done under the conservative assumption that most, but not all, ELSs will remain stable, form deep pools, and provide desired habitat benefits during low flow periods after construction as the Phase 3 reach geomorphically responds to high flows.

Alternative 1 (low density of ELSs) assumes a higher percentage of ELSs provide direct habitat benefits during low flow periods so fewer ELSs are needed to meet target habitat conditions, whereas Alternative 2 (medium density of ELSs) assumes a lower percentage of ELSs will provide direct habitat benefits during low flow periods so more ELSs are needed to meet the target habitat conditions. Alternative 3 (medium density of planform complexity ELSs) includes slightly fewer ELSs than

Alternative 2; however, because more of the Alternative 3 ELSs are assumed to provide direct habitat benefits during low flow periods compared to Alternative 2 (because they would be placed further into the channel and away from the banks than ELSs in Alternative 2), slightly fewer ELSs were included. This redundancy is important in light of anticipated climate change as summer-time base flows are predicted to slowly decrease in the future. Resiliency in the form of more ELSs spread throughout the Phase 3 reach where the low flow channel is likely to develop is important to build into the alternatives. Thus, an alternative that has a higher redundancy and thus more resiliency to climate change is preferred over an alternative with less redundancy while also balancing the ability to satisfy FEMA's zero rise requirements.

An early restoration design concept developed by Herrera and LNRD (before landing on Alternatives 1, 2, and 3 summarized in this document) included relocating Saxon Road further landward into private property and a buried setback revetment structure to protect the road and property if the channel were to migrate towards the relocated road. During meetings with potentially affected landowners, they expressed that this concept was not acceptable and would not relinquish property for it. Another concept that was not included in the alternatives evaluated in detail included a very high density of ELSs in the channel (more than in Alternatives 1, 2, and 3) and excavation for side channel creation into a privately owned heavily forested floodplain area containing large mature trees. The affected landowners were not agreeable with this option because of extensive flood risks that would be created on their property in the floodplain and unacceptable construction alterations to property such as potential removal of large mature coniferous trees.

Tables 1, 2, and 3 summarize the quantities of ELS types, pools, and stable ELSs that are included in Alternatives 1, 2, and 3, respectively.

Table 1. Assumed Number of Engineered Log Structures and Pools Under Alternative 1 – Low Density of ELSs.

ELS Type	Total Number of ELSs	Number of Pools	Number of Stable ELSs
Large	10	8	10
Medium	16	13	16
Small	12	5	12
Total	**38**	**26**	**38**

Table 2. Assumed Number of Engineered Log Structures and Pools Under Alternative 2 – Medium Density of ELSs.

ELS Type	Total Number of ELSs	Number of Pools	Number of Stable ELSs
Large	13	13	13
Medium	23	12	21
Small	15	2	4
Total	**51**	**27**	**38**

Table 3. Assumed Number of Engineered Log Structures and Pools Under Alternative 3 – Medium Density of Planform Complexity ELSs.

ELS Type	Total Number of ELSs	Number of Pools	Number of Stable ELSs
Large	9	7	9
Medium	15	8	15
Small	25	13	15
Total	**49**	**28**	**39**

Other design measures common to Alternatives 1, 2, and 3 between RM 13.17 and RM 13.50 include:

1. Approximately 2,275 linear feet (lf) of new side channel along the toe of the left/east valley slope within the left bank (when looking downstream) floodplain
2. Regrading of the large left bank gravel bar
3. Placement of salvaged alluvium from gravel bar regrading and side channel construction along approximately 1,350 lf of riprap armoring on the right bank of the main stem channel, part of which is adjacent to Saxon Road

Each alternative also includes removal of approximately 250 lf of relic riprap from the left bank toe near RM 13.10.

For Alternatives 1 and 2, placement of ELSs is focused primarily along the left and right banks of the main stem river channel whereas for Alternative 3, some of the large and medium ELSs and many of the small ELSs would be placed further into the main stem channel and away from the banks to increase channel planform complexity and create pools within the low flow channel area as the channel responds to high flows following construction. Alternative 3 also differs from Alternatives 1 and 2 in that it includes:

1. A significant amount of channel widening along the left and right banks between RM 13.50 and RM 13.80
2. More aggressive gravel bar regrading (more volume of gravel removal) between RM 13.13 and RM 13.50
3. Two small right bank floodplain berms—one at RM 13.60 and one at RM 13.85
4. Removal of a relic timber-pile based railway bridge abutment
5. Minor floodplain regrading
6. A large ELS near the former abutment on the upstream right bank side of the current Saxon Road Bridge over the river at RM 12.90

The purpose of these additional design measures for Alternative 3 is to increase the hydraulic conveyance area within the main stem channel thereby offsetting the loss of conveyance area that would occur due to ELS placement in the channel if no other measures are taken to increase hydraulic conveyance capacity in the main stem channel. If done correctly, this approach will likely mitigate any increases in the FEMA 100-year regulatory Base Flood Elevations (BFEs) at insurable structures within the floodplain, achieving FEMA's zero-rise requirements to enable the project to be permitted for construction.

Preferred Conceptual Restoration Design Alternative and Hydraulic Modeling Results

Herrera completed 2D hydraulic modeling of the 2-year, 10-year, and 100-year floods for Alternatives 1, 2, and 3 to help evaluate each alternative's ability to:

1. Increase hydraulic (and thereby geomorphic) complexity while reducing flow velocities needed for improving habitat conditions as flows interacts with the ELSs and other design measures
2. Avoid increases in the 100-year regulatory BFEs at insurable structures in the floodplain to meet FEMA's zero-rise requirements in the floodplain

If this condition can be met, then the project can be permitted for implementation by Whatcom County despite any increases in BFEs within the main stem channel and the regulatory floodway. However, such increases in BFEs in the floodway would trigger submittal of an application to FEMA for a Conditional Letter of Map Revision (CLOMR) by the project sponsor, and subsequent approval of the CLOMR by FEMA. The application would have to document anticipated changes in BFEs and map new BFEs expected after the project has been constructed and the project sponsor has submitted the post-construction Letter of Map Revision (LOMR).

The 2D hydraulic model results for Alternatives 1, 2, and 3 showed significant improvements in instream hydraulic complexity and floodplain activation for all flood flows evaluated with Alternative 3 showing the greatest increase in instream hydraulic complexity but having slightly less floodplain activation than Alternatives 1 and 2. This is because the additional hydraulic conveyance within the main stem channel would be significantly greater for Alternative 3 compared to Alternatives 1 and 2; channel widening and gravel bar regrading would reduce the extent of floodplain inundation compared to Alternatives 1 and 2 during flood events. For Alternatives 1 and 2, the significant additional roughness resulting from the ELSs combined with no channel widening would cause water to overflow onto the floodplain sooner than it would under Alternative 3 for a given flood flow. Because of this condition, increased water surface elevations relative to the mapped BFEs would occur at insurable structures in the floodplain, thereby violating FEMA's zero-rise requirements. The 2D model results for Alternative 3 demonstrated no increases in 100-year flood water surface elevations at insurable structures in the floodplain; increases relative to mapped BFEs would only occur within the main stem channel and associated floodway, which can be acceptable pending FEMA's approval of a CLOMR and thereafter a LOMR. This result was also produced with FEMA's 1D "effective model" of the South Fork, which was used to produce the currently published flood insurance rate maps. Herrera's subconsultant, Watershed Science & Engineering (WSE), is completing the 1D modeling and submittal requirements for the CLOMR and LOMR for the Phase 3 project using the FEMA 1D effective model. Therefore, based on the ability of Alternative 3 to meet FEMA's zero-rise requirements at insurable structures while achieving the habitat target conditions, LNRD's preferred alternative is Alternative 3. Graphics of the 2D hydraulic model results for Alternative 3 are included in Appendix C. The following sections describe the preferred alternative in more detail and analyses completed to date in support of its design.

Basis of Preliminary Design

This section documents the basis of the preliminary engineering design for the preferred alternative (Alternative 3). The preliminary design plans showing the design measures described below are included in Appendix D. Herrera's estimate of construction costs for the preliminary design is included in Appendix E. ELS stability calculations will be completed during the final design phase, and a summary of those calculations will be included in a subsequent version of this document as the preliminary design is advanced to final design.

Project Summary

The Phase 3 preliminary design includes the following design measures, which are described in more detail in the following section:

- 18 small Type 1 ELSs, 4 small Type 2 ELSs, and 13 medium Type 3 ELSs.
- 11 large ELSs including: two Type 4 mid-channel apex type ELSs, five Type 5 right bank deflector type ELSs, one Type 5 left bank deflector type ELS, and three Type 6 right bank deflector type ELSs.
- Removal of a relic timber-pile based railway bridge abutment, associated minor floodplain regrading and one large Type 5 right bank deflector type ELS near the former abutment on the upstream right bank side of the current Saxon Road Bridge over the river at RM 12.90.
- Channel widening along the left and right banks between RM 13.50 and RM 13.80, construction of two small right bank floodplain berms (one at RM 13.60 and one at RM 13.85), and channel widening and regrading of the large left bank gravel bar and main stem channel between RM 13.13 and RM 13.50.
- Approximately 2,275 lf of new side channel along the toe of the left/east valley slope within the left bank floodplain between RM 13.13 and RM 13.50.
- Removal of approximately 250 lf of relic riprap from the left bank toe near RM 13.10.
- Placement of salvaged alluvium excavation spoils from gravel bar regrading and side channel construction along approximately 1,350 lf of riprap armoring on the right bank of the main stem channel, part of which is adjacent to Saxon Road between RM 13.23 and RM 13.48. This work will also include placement of multiple simple log structures along the toe of the alluvium fill to provide a moderate degree of toe protection between the large ELSs placed along this bank.

The preliminary design has three fewer ELSs than were included in the original Alternative 3 concept (46 in the design being advanced compared to 49 in the original concept). These minor changes were necessary as the Phase 3 design was refined to the preliminary design level and will not impact the Project's ability to meet the target habitat conditions.

Restoration Design Measures Summary

The following summaries describe in detail the proposed preliminary design measures listed above.

Type 1 and Type 2 (Small) ELSs

Type 1 ELSs are small and simple habitat structures that will create a small (5- to 8-foot wide), low profile flow obstruction within the channel. Type 2 ELSs are small habitat structures that are slightly larger (15- to 20-feet wide) and slightly more complex than the Type 1 ELSs, to create more of a flow obstruction in the existing river channel. Both structure types are semiporous (i.e., will allow some flow through them), will form scour pools, accumulate some flood-borne large wood material, and create complex localized instream habitat. These structures are not intended to deflect flows or accumulate large amounts of LWM. The spacing of Type 1 ELSs along the river banks and mid-channel throughout the Phase 3 reach is intended to work in concert with the larger Type 3, Type 4, and Type 5 ELSs and to significantly increase the quantity of LWM-based, instream habitat. Following regrading of the large left bank gravel bar between RM 13.15 and RM 13.50, the Type 2 ELSs will be located mid-channel opposite of the existing riprap armored right bank between the large Type 5 and Type 6 ELSs. Small ELSs are important features that can provide smaller-scale complexity and bed material variability between the larger ELSs, which is ideal for low flow habitat (small pools and cover), and also more gravel sorting spatial variability, which is ideal for spawning. Type 1 and Type 2 ELSs will be anchored to withstand buoyancy and hydraulic drag forces during high flows by deeply burying the downstream ends of the logs into the channel substrate as shown in the structure details included with the preliminary design plans in Appendix D; no artificial anchoring methods (e.g., tethered rock anchors used in the large ELSs) are needed for these structures.

Type 3 (Medium) ELS

Type 3 ELSs are medium-sized habitat structures with a triangular footprint dimension of approximately 25 to 30 feet per side. They are designed to be engaged by flow from multiple upstream directions. They are economical, easily constructed, and designed to be self-settling as scour develops around them. The Type 3 ELSs are located along river channel banks in the design plans, rather than in the middle of the existing channel, so they are not subjected to higher flow velocities that occur in the middle of the channel during flood events. The Type 3 ELSs will also provide opportunities to economically meet LNRD's target habitat conditions using a hydraulic obstruction footprint that is smaller than the larger Type 4, Type 5, and Type 6 ELSs, thereby reducing the overall backwatering effect they induce as compared to the greater backwatering effect from the larger the larger Type 4, 5, and 6 ELSs. Lesser backwater effects help to avoid increases in BFEs in the floodplain while supporting target habitat conditions.

The spacing of Type 3 ELSs in the design plans along the existing river channel banks is intended to work in concert with the larger mid-channel Type 4 and bank deflector Type 5 ELSs and the smaller Type 1 ELSs. Their primary function is to provide additional flow and geomorphic complexity to areas along the Phase 3 reach banks that are lacking smaller stable accumulations of LWM during low flow conditions, to form and maintain pools and disrupt generally homogenous flow patterns (e.g., long runs/glides). Their secondary function is to provide opportunities to retain and stabilize flood-borne LWM. These ELSs will provide large-scale hydraulic roughness along the channel banks to reduce flow velocities thereby significantly increasing the area of functional habitat along the banks while also encouraging sediment deposition and diversification of deposited sediment sizes. The Type 3 ELSs will also enhance aquatic habitat by providing much needed woody substrate for benthic communities.

Construction of the Type 3 ELSs will include excavation and embedment of vertical logs and some of the lower horizontal log layers. The bottom of the vertical logs (piles) will be about 15 feet below the channel bed. The Type 3 ELSs are designed to extend approximately 6 to 8 feet above the channel bed elevation such that they will accommodate a small variation in channel bed elevations and scour expected to occur while also being stable when overtopped during high flows. The multiple upstream-facing root wads are at varying angles in their design relative to the river channel alignment to encourage scour pool formation and activation with flow coming from multiple directions. Each Type 3 ELS incorporates five 4-ton rock anchors (20 tons/10 rocks total per ELS) placed over various horizontal logs within the interior core of the structure to counter buoyancy and lateral movement of the logs. Each anchor consists of two 2-ton rocks tethered together with heavy duty steel chain. Racking logs and slash material will also be placed amidst the anchors and backfill material to ensure structure stability and minimize through-flow.

Type 4 and Type 5 (Large) ELSs

Type 4 and Type 5 ELSs are large, complex, and nonporous habitat structures that are approximately 45 to 60 feet wide. The Type 4 ELSs are apex type structures that will be located mid-channel so that flows split around them like natural mid-channel logjams typically found near the upstream end of mid-channel gravel bars and islands. The Type 5 ELSs are bank deflector type structures that will be located along channel banks and the outside of channel bends where natural logjams typically form when very large trees fall from the banks into the channel, eventually accumulating large amounts of flood-borne LWM. They will deflect flows away from the bank and towards the middle of the channel, thereby preventing channel migration into the bank. The Type 4 and Type 5 ELSs are designed to be stable after accumulating large quantities of flood-borne LWM and can form very large and deep scour pools.

Type 4 ELSs located mid-channel will split flow around them, promoting the development of multithreaded channels. The two Type 4 ELSs shown in the design plans mid-channel near RM 13.70, are spaced between three Type 5 ELSs located along the right bank between RM 13.60 and RM 13.80 that will be widened as part of the Project. See the Channel Widening and Floodplain Berms section below for detail about the proposed channel widening in the Phase 3 reach. The intended function of this arrangement of Type 4 and Type 5 ELSs is to deflect flows away from the right bank to hinder channel migration towards Saxon Road and encourage channel migration towards the left bank that will also be widened as part of the Project. Channel migration is a natural river process that creates complex edge habitat as it recruits floodplain gravels and trees into the channel; however, little to no channel migration has occurred within the Phase 3 reach for decades. The locations of Type 4 and Type 5 ELSs will encourage channel migration towards the left bank where there is additional forested floodplain available downstream of RM 13.75 while also encouraging a more sinuous and geomorphically complex low flow channel to develop in the vicinity of the Type 1 ELSs between the newly widened left and right banks.

Three more Type 5 ELSs are located further downstream in the design plans. One will be located near RM 13.25, which is near the downstream end of the existing riprap armored right bank that will be modified as described in the Riprap Bank Modifications section below. This Type 5 ELS will work in concert with the larger Type 6 ELSs located upstream along this bank to deflect flows away from the modified bank, which parallels Saxon Road for several hundred feet, and towards the vegetated left bank gravel bar that will be regraded as described in the Channel Widening and Floodplain Berms section below. Another Type 5 ELS is located in the design plans along the actively eroding left bank bluff at RM 13.0, which is just upstream of the upstream end of riprap placed long ago along the left bank that extends downstream to the Saxon Road Bridge. Working in concert with four Type 3 ELSs between RM 12.95 and RM 13.15 (two upstream from this Type 5 ELS along the eroding left bank bluff and two along the right bank vegetated floodplain) this ELS and the two upstream Type 3 ELSs will help to deflect flows away from the eroding left bank and towards the right bank Type 3 ELSs to encourage a more sinuous and geomorphically complex low flow channel to develop while also providing opportunities to accumulate flood-borne LWM and creating large and deep scour pools. The final Type 5 ELS is located in the design plans on the right bank immediately upstream of the Saxon Road Bridge at RM 12.90 where a relic high flow right bank floodplain channel converges with the main stem river. Here a relic timber pile type bridge abutment, which once supported a former railway bridge that collapsed, will be removed and the surrounding area regraded to increase hydraulic conveyance through the bridge. This Type 5 ELS will provide much needed habitat at this confluence area if the channel migrates towards the right bank while simultaneously deflecting flows away from the unprotected right bank abutment of the existing Saxon Road Bridge.

Construction of the Type 4 and Type 5 ELSs will include excavation and embedment of many vertical logs and some of the lower horizontal log layers. The bottom of the vertical pile logs will be embedded about 15 feet below the channel bed. These ELSs are designed to extend approximately 12 to 15 feet above the channel bed elevation such that they will accommodate variation in channel bed elevations and scour expected to occur. These ELSs are designed to not be overtopped during high flows, and they include deeply set scour aprons built around the upstream perimeters of the structures using large surplus alluvium (boulders and cobbles) and riprap to limit the depth of scour during flood events at the vertical pile logs that anchor the structure, thereby maintaining structure stability. The multiple upstream-facing root wad angles in their design function to encourage scour pool formation and complex flow activation from multiple directions. The horizontal logs in these ELSs will be ballasted using large surplus alluvium mixed with finer alluvium (cobbles, gravels and sands). Ample quantities of racking logs and slash material will prevent through-flow so the structures do not lose untethered interior logs, so they remain stable during a wide range of flow conditions.

Type 6 (Large) ELS

Three Type 6 ELSs are spaced approximately 400 feet apart in the design plans along the riprap-armored right bank between approximately RM 13.48 and RM 13.30. The riprap on this bank, which was placed to protect Saxon Road from channel migration, begins at RM 13.48 and extends downstream to RM 13.23. One Type 5 ELS will be located at RM 13.25 approximately 400 feet downstream of the downstream-most Type 6 ELS along the armored bank. As described in more detail in the Riprap Bank Modifications, Channel Widening and Floodplain Berms, and New Side Channel sections below, some of the alluvium spoils from this work will be placed over the existing riprap between these four ELSs to improve aesthetics and provide a planting substrate for riparian vegetation between the ELSs. Currently, flows are entrained along the armored bank and the channel is highly incised and geomorphically simplified due in part to channel migration being arrested and the large left bank gravel bar opposite of the armored bank that has developed and constricts flow laterally, causing the channel to incise. As a result, habitat conditions along the armored bank are very poor.

The primary function of the Type 6 ELSs is to deflect high energy flows away from the modified riprap bank, across the widened main stem channel and towards the regraded left bank gravel bar to buffer the modified riprap bank from potential erosion. This will minimize the potential for flow to become fixed along the modified bank for any significant length, thereby minimizing erosive flow conditions on the right bank. Secondary functions of the Type 6 ELSs are to provide opportunities to retain and stabilize flood-borne LWM that is transported into this area; to provide large-scale hydraulic roughness to reduce flow velocities and encourage sediment deposition in this area; and to enhance habitat by inducing and maintaining large and deep scour pools, providing substrate for benthic communities, and providing a foundation for riparian vegetation growth.

Each Type 6 ELS will extend an average of 50 feet waterward from the modified bank and is angled approximately 70 degrees out from the riprap facing, oriented in the downstream direction. The Type 6 ELSs are large, robust, pile-supported, log crib-wall type structures. Vertical piles will be embedded 10 to 11 feet below the elevation of the low flow channel thalweg (where the thalweg occurs along a transect of the channel and floodplain aligned perpendicular to the armored bank at the ELS location). Each Type 6 ELS is designed to be approximately 16 feet tall so that it will accommodate the variable channel bed elevations and water surface elevations expected to occur within this area. Each Type 6 ELS incorporates a scour apron that extends approximately 30 feet waterward along the vertical pile logs from the toe of the riprap facing on the armored bank. The scour apron is intended to limit the vertical extent of scour that can occur at the upstream face of the ELS, which allows for a much shallower pile embedment depth than would be necessary without it. It is critical to prevent failure of the piles so they provide long-term anchoring of the entire structure. The top of the scour apron is designed to be at a depth that does not hinder formation of large and deep scour pools while maintaining the necessary pile embedment to maintain structure stability. The scour apron will be 3 to 5 feet thick, consisting of a 50:50 mix of 24-inch-diameter and larger native boulders and heavy loose riprap (per WSDOT standard specification 9-13.1(1)). The structures will be backfilled using the same alluvium spoils that will be placed along the armored bank. Placing alluvium spoils along the riprap bank will bury a portion of each Type 6 ELS. Immediately following construction, approximately 50 feet of the total width of each structure will be visible, protruding from the bank.

Channel Widening and Floodplain Berms

The preliminary design includes measures necessary to increase the hydraulic conveyance within the main stem river channel to offset the loss of conveyance due to the ELSs (i.e., obstruction of the active channel and added hydraulic roughness). These measures include the following:

1. Channel widening along the left and right banks of the main stem river between RM 13.50 and RM 13.80 and construction of two low elevation right bank floodplain berms.
   a. Along the right bank, channel widening begins near RM 13.80 and extends downstream about 1,200 lf ending near RM 13.57. The base of excavation will begin near the toe of the existing bank above the low flow water level and extend landward into a heavily vegetated floodplain about 40 to 50 feet on average along most of the excavation, tapering back to the existing bank at the upstream and downstream ends. This excavation will be parallel to, and "daylight" into, an area previously occupied by the main stem river channel before the channel shifted into its current alignment and incised, creating an isolated low elevation swale between the current right bank and a higher elevation terrace. Five ELSs (two Type 3 ELSs and three Type 5 ELSs) are spaced along the widened right bank in the design plans to deflect flows towards the left bank and discourage channel migration towards Saxon Road, and to encourage highly complex habitat to develop in their vicinity if a low flow channel develops along the new bank and ELSs.
   b. Along the left bank, channel widening begins near RM 13.76 and extends downstream for a distance of about 1,350 lf ending near RM 13.50. The base of excavation will begin approximately 2 feet higher in elevation than the base of excavation along the right bank. This will lower the floodplain surface, which will increase floodplain connectivity and flood storage within the main stem channel. Between RM 13.76 and RM 13.65 (about 650 lf) the designed channel widening averages about 20 to 30 feet whereas channel widening upstream of RM 13.65 to RM 13.50 (about 700 lf) extends as much as 100 feet. Both excavation areas extend into a heavily vegetated low elevation floodplain. One Type 3 ELS is located in the design plans at the upstream end of this left bank channel widening area at RM 13.76 to work in concert with the Type 3, Type 4, and Type 5 ELSs located mid-channel and along the widened right bank across the channel from this ELS. Another Type 3 ELS is located in the design plans about 1,000 lf downstream near RM 13.57 along the toe of the original left bank. Working in concert with the three Type 3 ELSs along the right bank in this area, this ELS will encourage more frequent floodplain activation into the newly lowered floodplain while providing highly complex habitat along the bank.
   c. The two right bank floodplain berms (one at RM 13.60 and one at RM 13.85) will be built using bank excavation spoils. These berms will be constructed in areas where the hydraulic model results show flow spilling into low elevation relic channels and swales and into the floodplain; therefore, the berms are necessary to limit the amount of flow into the floodplain to avoid increased BFEs at insurable structures in the floodplain.

2. Channel widening and regrading of the main stem channel and left bank gravel bar between RM 13.13 and RM 13.50.
    a. As previously described, the existing main stem channel in this area is highly incised and confined, and the habitat is in poor condition due to the riprap armored right bank and the large left bank gravel bar. The existing active (unvegetated) channel width varies from about 60 feet near the upstream end of the armoring at RM 13.45 to about 100 to 120 feet near the downstream end of the armoring at RM 13.25, whereas upstream of the armoring the existing active channel with averages approximately 160 feet. To address this degraded condition and to facilitate the channel returning to a more geomorphically appropriate geometry, the main stem channel will be widened significantly and its slope regraded slightly between RM 13.13 and RM 13.50. This will be done by regrading the left bank gravel bar to increase the channel width to approximately 140 to 160 feet following modifications to the armored right bank that are described below. This gravel bar regrading will also include a slight regrading of the channel bed profile near the upstream and downstream section of channel in this area. This will provide a more uniform channel bed slope that is needed to help prevent increases in BFEs near insurable structures in the floodplain.

The primary purpose of this channel widening and regrading is to increase the hydraulic conveyance area within the main stem channel to offset the loss of conveyance area due to ELS placement in the channel. Riparian vegetation planting in the areas of channel widening will consist primarily of young deciduous trees. Large coniferous and deciduous trees in the floodplain amid areas where channel widening will occur will not be removed. These trees will be protected and the excavation extents modified in the field during construction to preserve them and the important shade and woody inputs they provide to the channel. Smaller coniferous and deciduous trees removed during channel widening will be salvaged for reuse in the various ELSs and/or placed in the floodplain for habitat. Some of the alluvium spoils produced from this work will be used to modify the riprap armored bank as described in the Riprap Bank Modifications section below. The remaining spoils will be hauled off site and disposed of.

New Side Channel

Between RM 13.13 and RM 13.50 within the left bank floodplain approximately 2,275 lf of new side channel will be constructed adjacent to the toe of the left bank/east valley slope. This is generally along the alignment of a relic channel that once existed before it filled in with sediment and thereafter riparian vegetation growth, which disconnected it from the main stem river as the left bank gravel bar continued expanding towards Saxon Road and the main stem channel incised. The new side channel will have three individual inlets to provide redundancy in the event one or two of the inlets become plugged with LWM or fill in with sediment. The inlets will be graded to match the elevation of the left bank gravel bar (following gravel bar and main stem channel regrading as described in the previous section) along the edge of existing vegetation to maximize side channel activation. In addition, the inlets are located across the channel from two Type 6 ELSs and two Type 3 ELSs. The backwater and flow deflection effects of these ELSs will help to route flow to the side channel inlets in a wide range of flow magnitudes, which will help to keep the channel inlets open while also enhancing side channel habitat complexity.

The side channel will have a 5-foot-wide bottom with 1H:1V bank slopes. To match the inlet and outlet elevations of the main stem channel the depth of excavation through the existing floodplain will be about 10 to 12 feet. Groundwater will likely be intercepted at this excavation depth as it is likely well within the hyporheic zone of the river. Groundwater perpetually entering the side channel will provide a source of cool water during warm low flow periods. One Type 1 ELS is located in the design plans on the downstream (right bank) side of each inlet to promote scour at the inlet, which will help keep the inlet from filling with sediment. Hydraulic modeling of the side channel shows that flow velocities downstream of the three inlets vary from approximately 3 to 7 feet per second (fps) for the 2-year, 10-year, and 100-year recurrence flood events, which should be sufficient to transport finer alluvium like sands and gravels. Sediment transport through the length of the side channel will help to maintain the desired side channel depth in the long term.

No habitat structures are proposed within the side channel. This will minimize the hydraulic roughness as much as possible to encourage as much flow into and through it, and to encourage the channel to naturally widen and adjust to flows following construction. Existing riparian vegetation growth along the side channel alignment is thick. Some of this vegetation will likely fall into the channel as it adjusts during high flow events after construction. The natural process of bank erosion where vegetation is scoured out should provide high quality off-channel habitat and flood refugia.

Riprap Removal

The preliminary design includes removing approximately 250 lf of relic riprap along the left bank toe near RM 13.10. This riprap ends where the actively eroding left bank bluff begins near RM 13.08. The riprap was likely part of a formerly continuous line of bankside riprap that extended downstream along the eroding bluff and to the Saxon Road Bridge before bank erosion along the bluff occurred and the bank armoring was lost into the channel. Removing the riprap will allow natural bank erosion into the steep left bank valley slope upstream of the eroding bluff and associated recruitment of bankside trees to resume providing a much-needed source of finer sediments and LWM to the channel. The three ELSs to be constructed along the left bank in this area (a Type 3 ELS near RM 13.17 at the confluence of the new left bank side channel and the main stem river, a Type 3 ELS near RM 13.08, and a Type 5 ELS at RM 13.0) will function to discourage unchecked erosion into the left bank but will likely allow some minor bank erosion to occur between them. If some erosion into the left bank occurs, the Type 5 ELS at RM 13.0 and the existing riprap armoring along the left bank downstream of this ELS that extends to the Saxon Road Bridge will function to prevent any further landward erosion into the left bank, thereby limiting erosion and channel migration risks to the bridge. Riprap removed from the left bank will be repurposed for ballast in some of the larger ELSs and in scour apron construction.

Riprap Bank Modifications

As previously mentioned in the Type 6 (Large) ELS section, some of the alluvium spoils generated from channel widening, gravel bar regrading, and side channel construction will be placed along approximately 1,350 lf of riprap along the right bank of the main stem channel, part of which is adjacent to Saxon Road between RM 13.23 and RM 13.48. The alluvium will be placed at a 2H:1V slope and will extend up from the bottom of the existing channel for a height of approximately 10 to 12 feet to within

4 to 6 feet of the top of the bank, then it will level off and be flat across the top until it merges with the existing bank, creating a large alluvium prism. Immediately downstream of the proposed Type 6 ELSs along this bank, the toe of the fill prism will extend as much as 40 to 50 feet from where the fill meets the existing bank at its top. The fill prism will then gently taper back towards the next downstream ELS so that the toe of the fill extends about 20 to 25 feet from where it meets the existing bank at its top. This geometry of the alluvium fill is intended to keep the upstream and waterward faces of the ELSs exposed to flow for habitat enhancement and flow deflection purposes.

Multiple small log structures, which are different from the other small Types 1 and 2 ELSs, will be installed along the toe of the alluvium fill prism between the bank ELSs that will provide a moderate degree of toe protection between them. This protection will occur via additional hydraulic roughness provided by the toe log structures that reduces flow velocities along the toe and for a height of approximately 6 feet up the bank. These toe structures will be anchored by the alluvium fill placed along the bank.

The alluvium used to construct the fill prism (and for backfilling the ELSs) will generally be coarse and consist of a mix of sand, gravels, cobbles, and some boulders, with the majority of clasts being gravels and cobbles. Biodegradable erosion control fabric will be installed along the waterward face (above the toe log structures) and top of the fill prism to provide additional short term erosion protection until riparian vegetation, which will be installed by LNRD following construction, can become established, thus providing much needed root cohesion to the erodible fill. This erosion control fabric is included in the design because the hydraulic model results indicate that 10-year recurrence and greater magnitude floods will overtop the alluvium fill prism and the tops of the ELSs on this bank, with the 100-year flood also overtopping the right bank and Saxon Road. However, the model results also show that flow velocities along this bank will decrease by more than 10 fps compared to existing conditions, which demonstrates the effectiveness of this design in deflecting high energy flows away from the bank and back into the middle of the channel.

References

WRIA 1 Salmon Recovery Board. 2005. WRIA 1 Salmon Recovery Plan. April 30, 2005; rev. October 11, 2005.

Appendix A

South Fork Nooksack River Skookum-Edfro Reach Phase 3 Existing Conditions and Habitat Restoration Opportunities Memorandum

HERRERA
Science + Planning + Design

TECHNICAL MEMORANDUM

Date: June 14, 2023

To: Alex Levell, Lummi Nation Natural Resources Department

From: Brian Scott; Ian Mostrenko, PE; Herrera Environmental Consultants, Inc.

Subject: South Fork Nooksack River Skookum-Edfro Reach Phase 3 Existing Conditions and Habitat Restoration Opportunities

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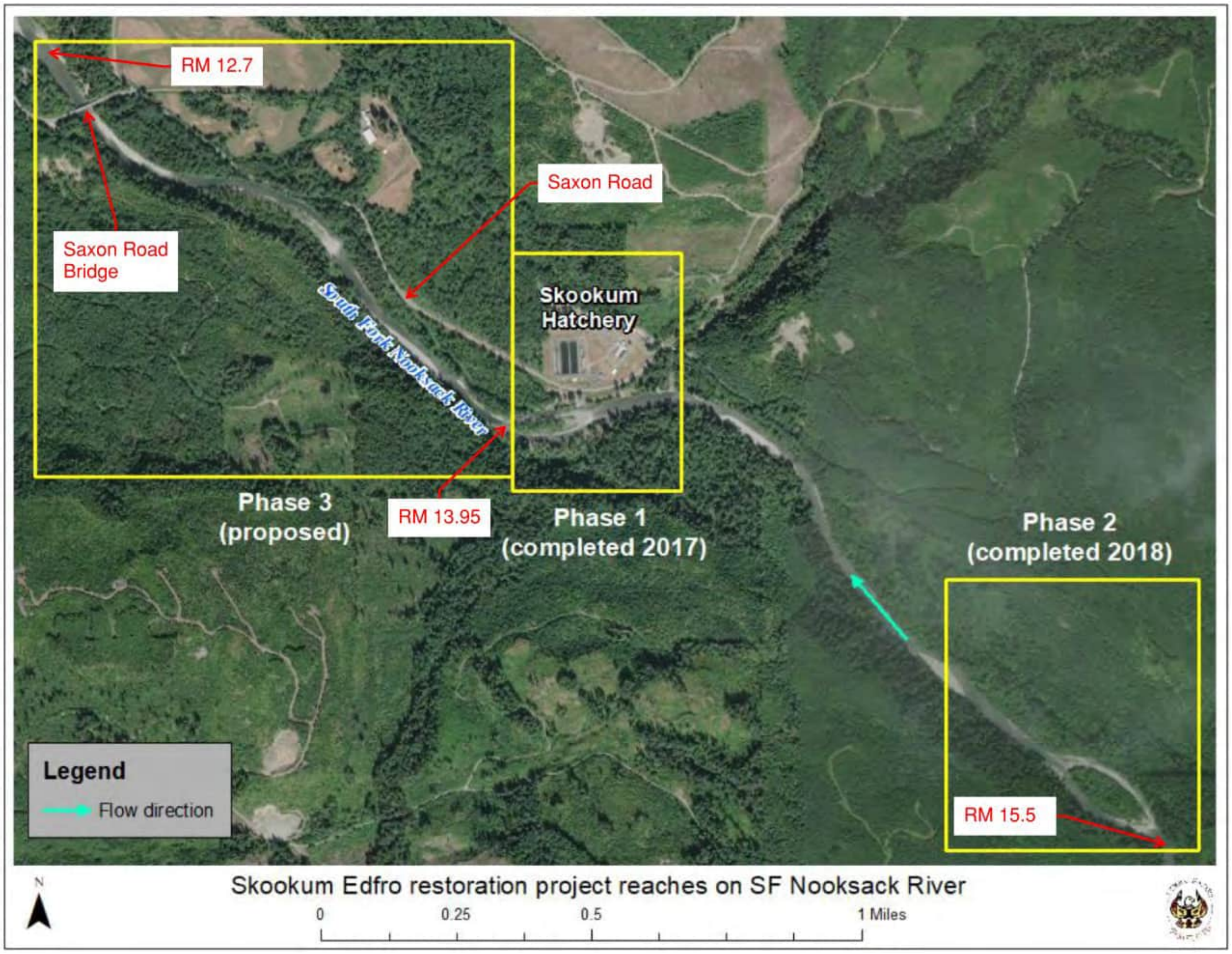
Introduction and Background

Since 2007 habitat restoration in the South Fork Nooksack River (South Fork) has been a high priority action for restoring and improving impaired habitat conditions for ESA listed salmon species including Puget Sound Chinook, Steelhead and Bull Trout. Specifically, recovery of the South Fork early Chinook is essential to recovering the threatened Puget Sound Evolutionarily Significant Unit (ESU) and for restoring runs to sustainable and harvestable levels for local tribal communities. The Lummi Nation Natural Resources Department (LNRD) has been implementing habitat restoration projects in the Skookum-Edfro Reach of the South Fork, located between river mile (RM) 12.70 and RM 15.50, since 2010 (Figure 1). The Skookum Reach Restoration Project was implemented in 2010 and included constructing three engineered logjams (ELJs) along the right bank of the South Fork adjacent to LNRD's Skookum Creek Fish Hatchery between RM 14.00 and RM 14.30 and realigning Saxon Road approximately 100 feet landward to its current location adjacent to the hatchery. Phase 1 of the South Fork Skookum-Edfro Reach Habitat Restoration Project (Project), also located adjacent to LNRD's Skookum Creek Fish Hatchery between RM 14.00 and RM 14.30, was completed in 2017 and included constructing four ELJs and four small habitat structures and enhancing the three ELJs constructed in 2010. Phase 2, located upstream of the Phase 1 project between RM 14.90 and RM 15.50, was completed in 2018 and included constructing 15 ELJs. Both phases focused on addressing key habitat limiting factors that continue to hinder WRIA 1 Chinook salmon recovery goals (WRIA 1 Salmon Recovery Board 2005), including:

- Reduced habitat diversity such as insufficient complex edge and floodplain habitats (e.g., undercut banks, backwater areas, side channels, sloughs and braids).
- Loss of stable instream large wood material (LWM) that creates thermal and velocity refugia, pools and cover adjacent to spawning areas, and promotes formation of complex channel and bed forms favorable for salmonid spawning, holding and rearing.
- Insufficient size, abundance and complexity of pool habitat (with and without cool water influences) for adult salmon holding.
- Seasonally elevated water temperatures.

In 2021 LNRD began moving forward with Phase 3 of the Project to develop and implement restoration actions to address the above listed habitat limiting factors in the Phase 3 reach, which is between RM 12.70 and RM 13.95. To support LNRD with implementing the early stages of the Phase 3 project, Herrera Environmental Consultants, Inc. (Herrera) has developed this memorandum summarizing the existing (pre-project) geomorphic and hydraulic conditions and habitat restoration opportunities within the Phase 3 reach. Herrera developed a two-dimensional (2D) hydraulic model of the Phase 3 reach following a site visit to it on September 15, 2022. Herrera used the model results and observations of the current geomorphic and habitat conditions of the reach made during the site visit to identify habitat restoration opportunities, and to identify existing flood and geomorphic related risks (i.e., bank erosion, channel migration and channel avulsion) to nearby infrastructure and private property.

Figure 1. Skookum-Edfro Reach of the South Fork Nooksack River.



Following submittal of this memorandum and receipt of feedback on the identified restoration opportunities from stakeholders, Herrera and LNRD will develop several conceptual level design alternatives for evaluation and selection of a preferred alternative that will be advanced to a preliminary design level and eventually to a final design level for future implementation. The conceptual design alternatives will be developed to achieve the targeted habitat conditions described later in this memorandum while minimizing potential flood and geomorphic related impacts based on an understanding of the hydraulic characteristics from the existing conditions hydraulic model. Once a preferred design alternative is selected Herrera will update the model to reflect proposed project conditions and use it to optimize the design to maximize improvements to habitat and geomorphic conditions. The preferred design alternative will also be refined to not increase flood or geomorphic related risks and will adhere to the Federal Emergency Management Agency (FEMA) and Whatcom County's "no-rise" regulations. Only upon modeling the preferred alternative to assess hydraulic impacts will refinement of the design occur to ensure project compliance with the regulations. Herrera will also use the proposed conditions model to support completing the project Conditional Letter of Map Revision (CLOMR) process that is required by Whatcom County and FEMA.

Phase 3 Reach Conditions

The intent of Herrera's site visit to the Phase 3 reach was to observe and document existing instream and floodplain geomorphic and hydraulic conditions; to identify restoration opportunities; to begin generating ideas for conceptual design alternatives; and to collect any data necessary to develop and run the hydraulic model as described later in this memorandum. Summaries of the existing geomorphic and hydraulic conditions is provided below. Flow in the South Fork that day (September 15, 2022), as measured by the Saxon Road USGS gage #12210000 averaged 75 cubic feet per second (cfs).

Geomorphic and Habitat Conditions

Geomorphic and habitat conditions in the Skookum-Edfro Reach are well documented in several previously completed assessments (Brown and Maudlin 2007; Maudlin et al. 2002) including the most recent assessment by Element Solutions (2015) that was specifically completed to inform Herrera's designs for the Phase 1 and Phase 2 projects in the Skookum-Edfro Reach. All previous geomorphic assessments documented significant anthropogenic hydromodifications and land use changes that have adversely impacted habitat conditions and geomorphic processes that create and sustain key habitats for salmonids at all life stages. For example, removal of existing instream logjams, installations of bank armoring (riprap), channel straightening and dredging, and loss of mature forested floodplains and riparian areas via logging and land use changes (e.g., road building, floodplain development, and agricultural) have significantly reduced the quantity, quality, diversity and accessibility of salmonid habitat in the Skookum-Edfro reach today.

Herrera's observations of geomorphic and habitat conditions during their site visit are consistent with conditions documented by Element Solutions (2015); the Phase 3 reach is highly modified, which has adversely altered geomorphic processes resulting in poor habitat conditions. Herrera reviewed said analysis before completing their site visit to refamiliarize themselves with the Phase 3 reach geomorphic conditions and to help determine if any notable changes in conditions have occurred from those described in the 2015 report.

Notable geomorphic conditions in the Phase 3 reach that have informed the restoration opportunities that are summarized later in this memorandum include the following:

- No stable instream LWM was observed. Some small transient LWM pieces were present along the left bank toe near RM 13.00 that had fallen from the top of the actively eroding bluff. A few LWM pieces were also present along the right bank in that area along the edge of the gravel bar vegetation but are likely not engaged until flows are much higher thus not providing any low flow habitat. Any LWM that is transported and deposited in the reach during a large flow event is transported out of the reach during subsequent high flows. Riparian vegetation is a mix of mostly immature coniferous and deciduous trees that if recruited into the channel will likely be transported out of the reach; however, it does provide the potential for some minor amounts of channel margin complexity and shade.

- Only four pools exist within the 1.25-mile-long reach, all of which were occupied during the site visit by many upstream migrating adult Chinook salmon. The two smallest pools were adjacent to the riprap armored left bank between RM 13.20 and RM 13.50. These secondary pools, meaning they occupy less than 50 percent of the channel area, are not well defined and have been previously mapped as runs (glides) due to the uniformly deep and slow-moving water along the armored bank. The third pool, at approximately RM 13.80, is a large and deep primary pool formed by scour around a large mid-channel boulder. A primary pool occupies more than 50 percent of the channel area. The fourth pool, at RM 13.95 is a large and deep secondary pool formed by the convergence of the two channels that flow around the north and south side of the large mid-channel island (Skookum Island) between RM 13.97 and RM 14.10. All four pools lacked woody cover as no LWM was present.

- The channel is predominantly a simplified and uniform plane-bed, single-threaded channel (i.e., no bifurcations) with very little planform and bedform complexity and low sinuosity. Channel morphology mainly consists of long and wide slowly flowing runs connected by short and steep riffle sections. There is much evidence of channel incision along the reach. Additionally, relic floodplain side channels are isolated from the main channel and are only activated during large flow events thus limiting the off-channel refugia and providing further evidence of channel incision and poor floodplain connectivity. Riprap is present along a significant length of the left and right banks between RM 12.90 at the Saxon Road Bridge and RM 13.50. This bank armoring arrests all channel migration and is a significant cause of habitat degradation and channel simplification. There is some evidence of recent bank erosion in the Phase 3 reach; however little to no channel migration has occurred since bank armoring was placed. Channel migration in the Phase 3 reach is also limited in part due to the channel incision (the channel is incising rather than laterally migrating via bank erosion) and the bedrock and steep valley wall present along the left bank.

- The average channel substrate size generally decreases slightly in the downstream direction through the reach as the channel gradient also decreases and floodplain width increases; however, channel substrate in the vicinity of the pools is much finer than the substrate downstream of them due to the general scouring of the channel bed and subsequent transport and deposition of the coarse bedload material downstream of the pools to form riffle crests. In addition, the reach has very few areas of suitable spawning substrate. Spawning survey data provided by LNRD shows limited spawning has occurred in several isolated areas along the reach with most of the spawning occurring between RM 13.10 and RM 13.20, which is consistent with Herrera's observation of channel conditions there. Gravel bar deposits are generally coarse (cobbles and small boulders) and imbricated indicating high flow velocities during large flow events. Channel bank composition was predominantly erodible alluvium, colluvium, and glacial deposits, except where riprap bank armoring is present.

In summary, the Phase 3 reach has been substantially modified from its historical conditions. The loss of the anastomosing channel morphology and resultant floodplain connectivity was likely the most significant historical impact to habitat function. The poor instream habitat conditions are further compounded by the incised channel conditions and a disconnected floodplain that is not engaged until very large flow events, resulting in increased stream velocity and scour potential. As a result, there is an acute lack of velocity and cool water refugia for juvenile and adult salmonids, rearing habitat for juvenile salmonids and poor adult holding and spawning opportunities. With the removal of woody debris and the subsequent transition into a single thread channel form, many of the habitat conditions that would have created high-functioning salmon habitat in this reach have been lost. These include channel planform and bedform complexity, velocity refugia, habitat diversity, and deep pool conditions.

Hydraulic Conditions

Herrera developed a two-dimensional (2D) hydraulic model for the existing Phase 3 reach conditions using the RiverFlow2D Plus software program (Hydronia 2016) version 7.5.1 and QGIS version 3.16 interface. Herrera used the model to characterize instream and overbank floodplain flow conditions for the 2-year (11,985 cfs), 10-year (20,200 cfs), and 100-year (29,300 cfs) recurrence interval floods and for a low flow that typically occurs during late summer and early fall during the Chinook salmon migration and spawning period (287 cfs). Model results of the 2-year flow provided insights into how much floodplain connection and inundation occurs during a relatively frequent flood. The 10-year flow results demonstrate how much flooding is expected to occur during a less frequent yet higher magnitude like the flood that occurred on November 15, 2021 (19,000 cfs approximately). The 100-year flow results are primarily used as a basis for comparing pre- and post-project construction conditions for permitting and other regulatory processes, and to complete engineering analysis of proposed design features such as ELJs for habitat improvements. The 10-year and 100-year flow rates are the same flows used in the FEMA Flood Insurance Study (FIS) one-dimensional (1D) HEC-RAS hydraulic model for the South Fork. The 2-year flow was developed as part of the Phase 1 and Phase 2 projects hydrologic and hydraulic analysis. The spawning period low flow rate was provided to Herrera by LNRD.

Herrera developed the model surface by merging the 2017 North Puget Sound bathymetric and non-bathymetric LiDAR data sets for the project reach and surrounding area, acquired from the Puget Sound LiDAR Consortium portal, with supplemental topobathymetric survey data of the project reach collected by LNRD on September 6 and 15, 2022, for the areas downstream of the Saxon Road Bridge where the non-bathymetric LIDAR data set did not include bathymetric data. Model calibration was completed by comparing modeled water surface elevations (WSEs) to WSEs either recorded or predicted to occur at the Saxon Road USGS gage #12210000 for the spawning period low flow, 2-year, 10-year, 100-year, for the November 28, 2021, flood (13,000 cfs approximately) and for the November 28, 2021, flood, and then adjusting the Manning's n values for surface roughness and editing parts of the model surface where LiDAR topography needed revising until water surface elevations were within approximately 0.1 to 0.2 foot of each other. The model was then validated by comparing modeled WSEs to WSEs established at various cross sections of the FEMA FIS 1D hydraulic model to ensure they were within acceptable differences of each other.

Notable hydraulic conditions within the Phase 3 reach for the four flow rates evaluated are summarized below. These conditions helped inform the restoration opportunities summarized in the following section. Graphics of the preliminary (not final) model results for existing conditions are in Appendix A at the end of this memorandum.

- For the spawning period flow (287 cfs): All flow is fully contained within the active channel and no relic side channels are active. There is very little hydraulic complexity (i.e., large variations in flow depths and velocities over a relatively short section of river) within the channel due to the dearth of instream structure like logjams, large logs and large boulders. Except for the four pools described in the previous section and a deep and slowly flowing run located between the two downstream most pools, flow depths are very generally quite shallow. This indicates there are few areas in the reach where upstream migrating adult salmon can hold and rest before continuing to upstream spawning areas. Froude numbers were categorized into certain biotopes (Demars et al. 2012; Entwistle et al. 2019) to identify pool, run, riffle, and rapid characteristics that corresponded well with physical habitat data collected by LNRD. This same type of analysis will be used on the preferred alternative to adjust design to achieve habitat goals.
- For the 2-year flow (11,985 cfs): All flow is fully contained within the active channel; no overbank flooding occurs and none of the relic high flow side channel are activated. This signifies the considerable extent of channel confinement and incision and the resulting floodplain disconnection that has occurred and will continue during flows that typically cause overbank flooding in less disturbed rivers where overbank flooding typically occurs between the 1-year and 2-year flow (or the effective discharge flow). There is very little hydraulic complexity within the channel due to the dearth of instream structure. In-channel flow velocities range from approximately 7 to 15 fps down the middle of the channel, which is enough to mobilize cobbles and boulders. Velocities along the banks drop to 1 to 2 fps in a few locations indicating very few areas where salmonids can seek refugia until the flow rate decreases substantially.
- For the 10-year flow (20,200 cfs): There is very little floodplain and relic side channel activation based on the low flow depths and velocities in areas where the floodplain is activated. This indicates the overall dearth of floodplain refugia in the reach. At the Saxon Road Bridge, all flow is forced under the bridge because the roadway functions like a levee with no flow overtopping it. This condition, and the resulting high flow velocities that occur under the bridge (up to 15 fps), is likely one of the causes of the general channel incision in the Phase 3 reach. This is evident by the exposed broken mid-channel wooden pilings observed just upstream of the bridge that were not visible 20 to 30 years ago based on observations made by a nearby landowner that has lived near the river since the 1970s. Like the 2-year flow, there is very little hydraulic complexity within the channel due to the dearth of instream structure. In-channel flow velocities generally range from approximately 10 to as much as 20 to 25 fps. Like the 2-year flow there is very little high flow refugia along the banks.
- For the 100-year flow (29,300 cfs): Significant floodplain inundation occurs, and many relic floodplain channels are active with flow depths and velocities likely low enough to provide refugia for salmonids; however, this floodplain connectivity is so infrequent that it provides little benefit. Yet

there is one section of the reach (Sub-reach 2; see Figure 3 in the subsequent section below) where the flow does not breach the right bank despite a lack of any feature like a steep bluff or elevated roadway that would otherwise contain the flow. At this flow rate the reach is considered a “losing reach” meaning some of the overbank flow does not return to the river until it is much farther downstream of the reach. There is still very little hydraulic complexity, and in-channel velocities range from approximately 12 to as much as 20 to 25 fps with much more of the river experiencing velocities above 15 fps than during the 10-year flow. Like the 2- and 10-year flows there is very little high flow refugia.

Phase 3 Reach Habitat Restoration Opportunities

The general approach to improving habitat conditions in the Phase 3 reach is to implement restoration measures that promote the natural physical processes that create and sustain diverse and complex habitat conditions that ultimately promote recovery of ESA listed salmon species including Puget Sound Chinook, Steelhead and Bull Trout. Specifically, recovery of the South Fork early Chinook is essential to recovering the threatened Puget Sound ESU and for restoring runs to sustainable and harvestable levels for local tribal communities. Therefore, the restoration strategy is to achieve increased habitat function through restoring lost channel processes and conditions by emulating, to the extent possible, the probable historical stream and channel conditions with immediate and/or near-term benefits under a range flows and conditions, for as long a duration as possible. To accomplish this WRIA 1 co-managers established the following target habitat conditions for the South Fork restoration project elements and performance monitoring:

- Eighteen (18) deep pools with greater than 1-meter residual depth per mile. A pool quantity of less than 1.4 channel widths per pool is considered a “good” condition, and a pool quantity of less than 1 channel width per pool is considered a “very good” condition.
- Two-thirds of all pools formed by naturally occurring wood or by LWM placed for restoration purposes.
- Thirty (30) stable logjams per mile in unconfined reaches (from approximately RM 12.70 to RM 14) and 10 per mile in confined reaches (RM 13.60 to RM 14.00). This equates to one logjam approximately every 180 feet (approximately one channel width for the Phase 3 reach). Note that logjams forming deep complex pools within cool water influence areas and within other areas is a Tier 1 restoration strategy identified by the WRIA 1 co-managers).
- Removal of “hardened” armored (riprap) banks.

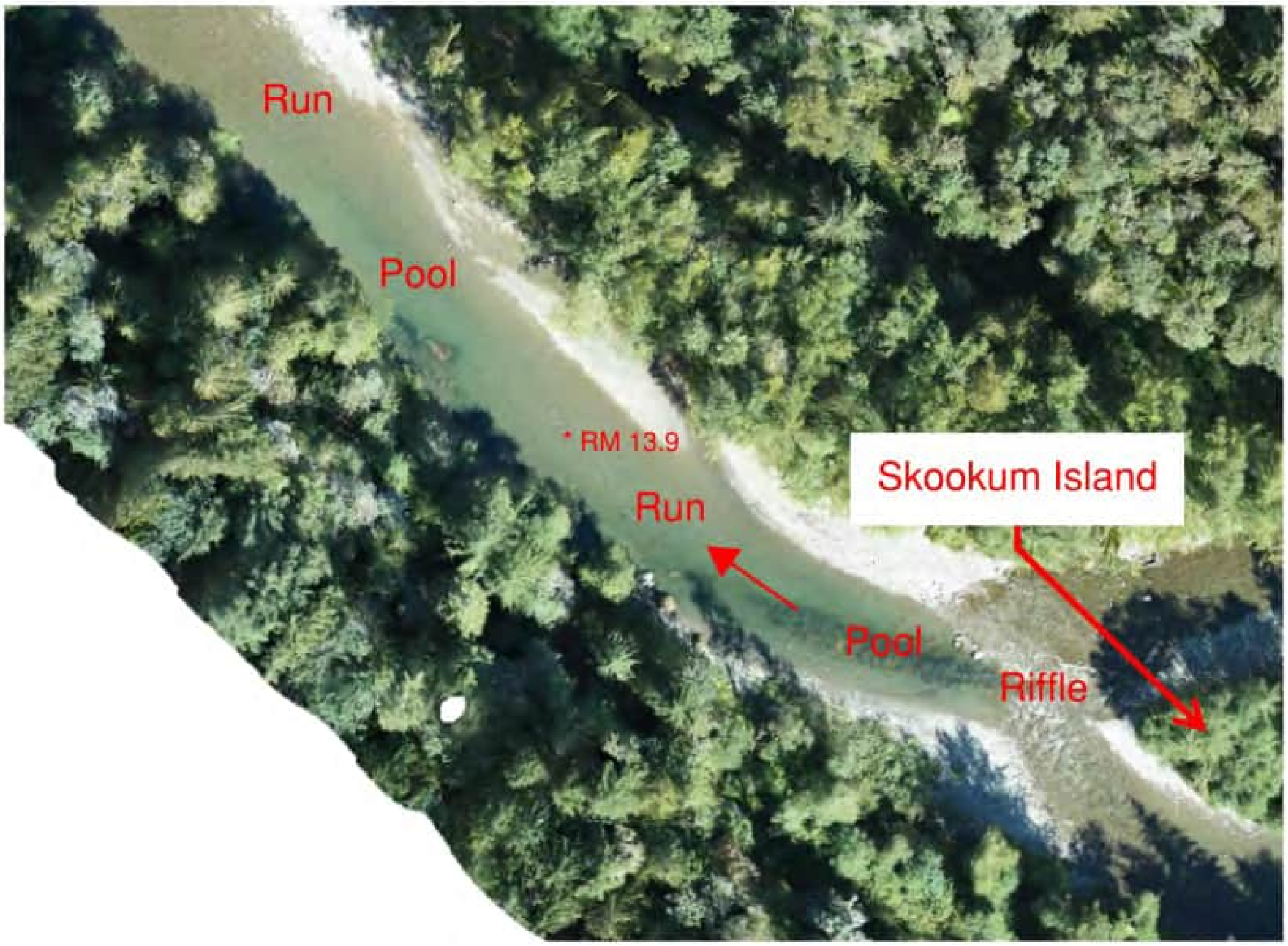
With these habitat targets in mind, Herrera identified many opportunities in the Phase 3 reach where restoration measures can be implemented to address the previously mentioned habitat limiting factors while simultaneously striving to achieve the above listed target habitat conditions and improve habitat diversity (habitat units that span the majority of the channel), complexity and accessibility while not increasing existing flood and geomorphic associated risks to nearby private property and infrastructure. The entire Phase 3 reach is considered a high-energy area based on the hydraulic model results and geomorphic conditions; therefore, ELJs of various sizes and function are the primary restoration measures that can be installed to slow flow velocities, encourage retention of finer spawning sized sediments and channel aggradation of incised sub-reaches, and create deep and complex pools while significantly increasing the overall hydraulic and geomorphic complexity within the Phase 3 reach. A combination of the ELJs with side channel regrading, riprap removal, gravel bar regrading and placement of gravel bar and surplus ELJ excavation spoils along riprap armored banks that must remain in place can also be implemented to achieve the above listed target habitat conditions.

For the purposes of summarizing restoration opportunities, the Phase 3 reach was divided into six distinct sub-reaches based on the reach geomorphology. Specific opportunities are summarized below for each sub-reach beginning at the upstream end near RM 14.00 and ending at the downstream end at RM 12.70.

Phase 3 Sub-Reach 1 (RM 13.95–RM 13.85)

Sub-reach 1 begins where the north and south channels that flow around Skookum Island converge to form a deep primary convergence pool (Figure 2). This sub-reach includes said pool and a large and deep secondary pool downstream. Deep and slowly flowing runs have developed downstream of each pool. No bank armoring (riprap) is present; however, the left bank is mostly bedrock and lateral migration rates into the left bank is extremely low. Both banks are vegetated with native trees and shrubs. Both pools are primary holding areas for upstream migrating adult salmon; therefore, restoration measures should not cause a decrease in size or depth of them but rather strive to provide woody cover in them if possible and increase channel planform and bed complexity to increase pool frequency.

Figure 2. Phase 3 Sub-Reach 1 (RM 13.95–RM 13.85).



Restoration opportunities in Sub-reach 1 include the following:

- Multiple small (5 to 10 feet wide/25 to 100 square feet (sf) in area) and medium sized (15 to 30 feet wide/225 to 900 sf) ELJs can be located near and between the pools and along the graveled banks to provide cover and significantly increase bed form and habitat complexity.
- One or two medium ELJs can be located along the left bank on the gravel bar at the downstream end of the sub-reach where the downstream most run begins to transition to the downstream riffle near RM 13.80, as shown in Figure 3 for Sub-reach 2.

Figure 3. Phase 3 Sub-Reach 2 (RM 13.85–RM 13.65).

Phase 3 Sub-Reach 2 (RM 13.85–RM 13.65)

Sub-reach 2 includes only riffles and runs; no pools are present (Figure 3). No bank armoring is present and both banks are vegetated with native trees and shrubs. A large left bank gravel bar directs lower flows towards the right bank. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity. Sub-reach 2 has a gradient of just under 0.5 percent slope and would support a more frequent pool-riffle sequence with the placement of larger LWM structures to induce more complex bedform and planform variability.

Restoration opportunities in the Sub-reach 2 include the following:

- Multiple medium and large (35 to 50 feet wide/1,225 to 2,500 sf) ELJs can be spaced along the right bank low flow channel. This configuration will encourage development of complex habitat units (pools, riffles and runs) between the ELJs.

- Multiple medium ELJs can be spaced along the left bank opposite of, and between, the right bank ELJs. Alternating the left bank and right bank ELJs in this manner will encourage flow to “zig zag” between the structures. This planform complexity and variability will help to slow flow velocities and encourage sediment to deposit locally thereby aggrading the incised channel to increase floodplain activation.
- Multiple small ELJs and individual large LWM pieces can be placed mid-channel between the bank ELJs to provide more instream LMW and encourage formation of complex mid-channel habitat features.

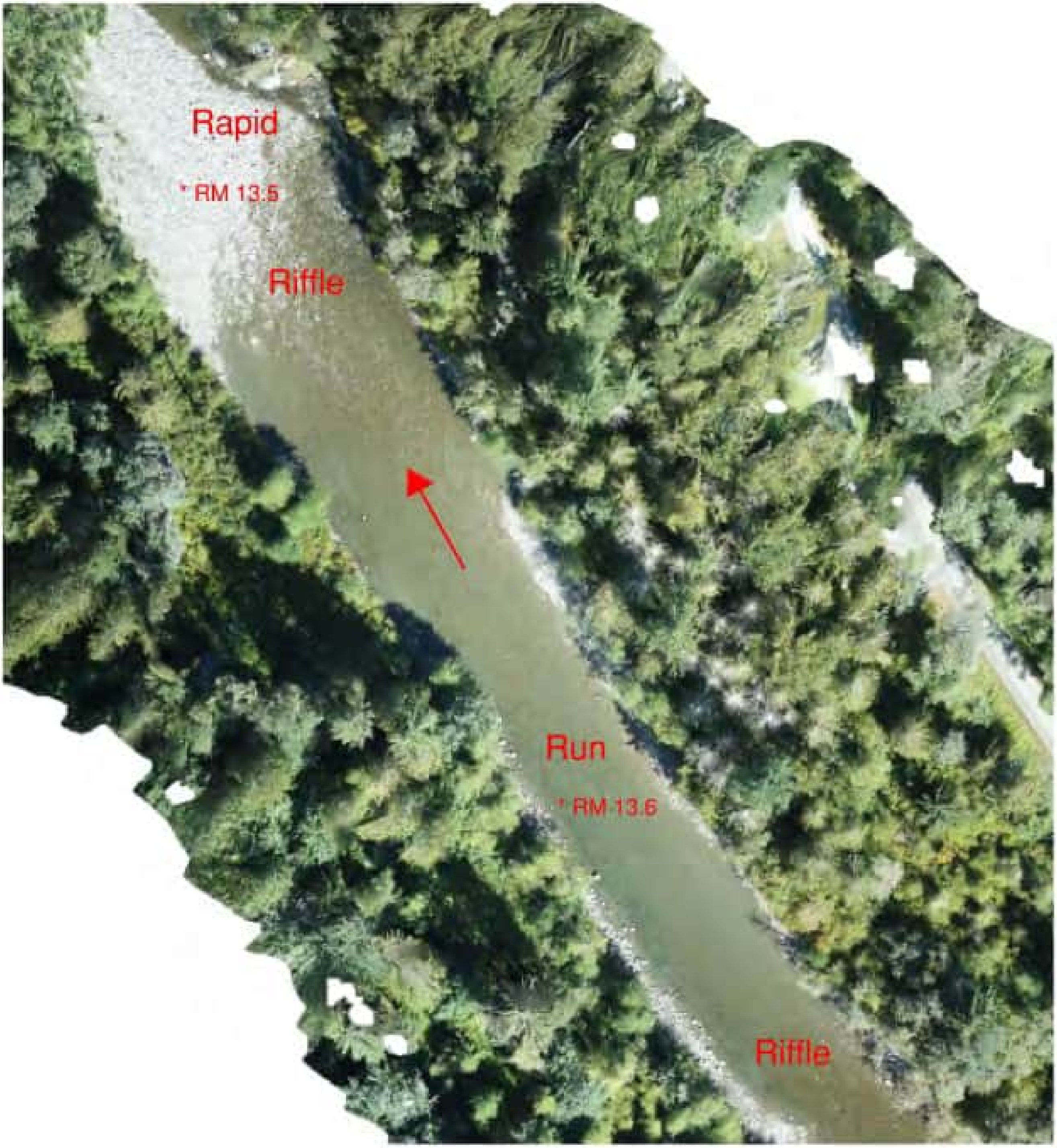
Phase 3 Sub-Reach 3 (RM 13.65–RM 13.50)

Sub-reach 3 consists primarily of a long, wide and shallow run with short riffles at the upstream and downstream side. No pools or bank armoring are present and both banks are vegetated with native trees and shrubs. The main channel has migrated away from the bedrock valley wall and there is a remnant left bank valley wall channel that is only activated at higher magnitude floods (i.e., 10-year floods and higher). Significant aggradation would be required in this reach to activate the left bank valley wall channel at meaningful flows (higher frequency) to support a frequently inundated side channel and will probably only provide high flood refugia even after restoration unless the restoration efforts are very aggressive with promoting extensive aggradation (i.e., valley-spanning structures). This sub-reach is also considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity.

Restoration opportunities in Sub-reach 3 include the following:

- Small and medium ELJs can be located along both banks in an alternating pattern to encourage flow to “zig zag” between the structures. This will help to slow flow velocities and encourage sediment to deposit locally thereby aggrading the incised channel to increase floodplain activation.
- Medium and/or large ELJs can be located along the right bank and mid-channel near the downstream end of this sub-reach to help direct flow into a relic left bank side channel that begins near RM 13.50 that can be regraded to provide off-channel habitat as described in Sub-reach 4 below and as shown in Figure 4. These ELJs will also provide functions similar to the small and medium bank ELJs described in the previous bullet.
- Multiple small ELJs and individual large LWM pieces can be placed mid-channel between the bank ELJs to provide more instream LMW and encourage formation of complex mid-channel habitat features.
- Some left bank activation may be beneficial for habitat refugia for larger events near the downstream portion of the sub-reach. This may be valuable high flow refugia because floodplain connectivity is so limited in this sub-reach and the left bank is one of the few off-channel habitat opportunities.

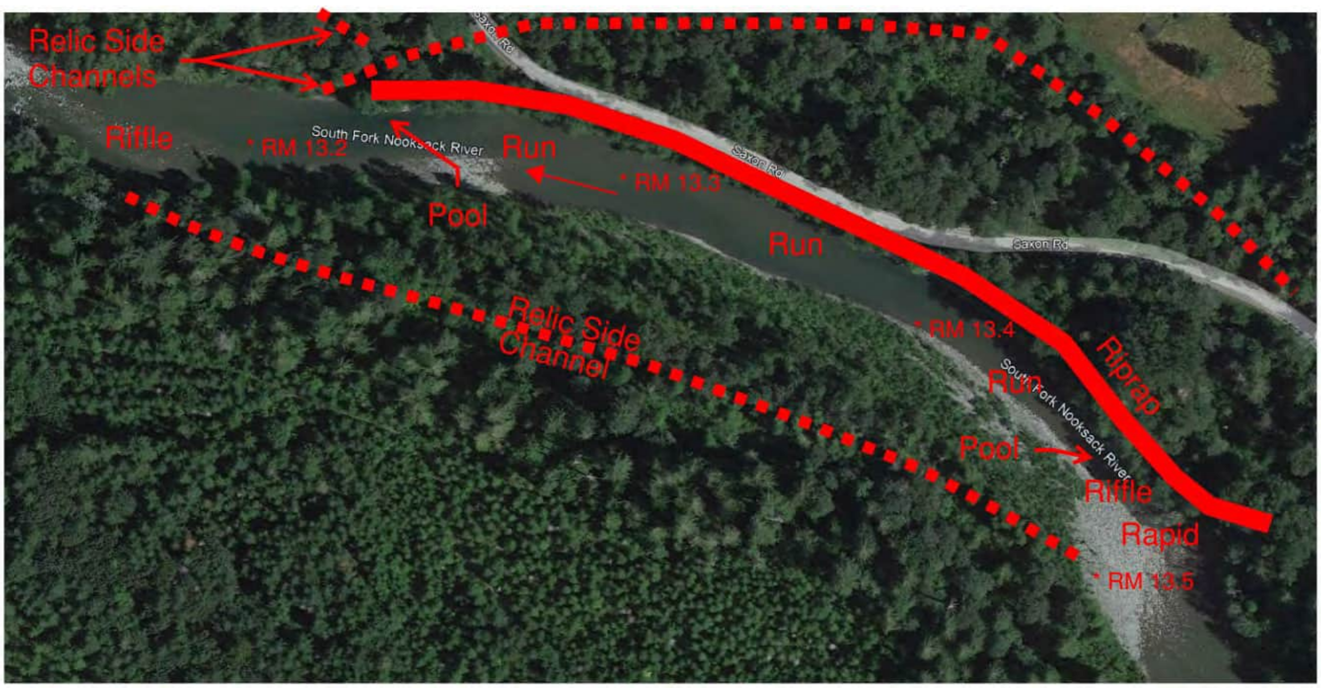
Figure 4. Phase 3 Sub-Reach 3 (RM 13.65–RM 13.50).



Phase 3 Sub-Reach 4 (RM 13.50–RM 13.20)

At the upstream end of Sub-reach 4 at RM 13.50 is a very short and steep rapid that quickly transitions to a short riffle then to a very small and shallow secondary pool. This pool quickly transitions to a very long, deep and slowly flowing run for most of the remainder of the sub-reach with a second bigger and deeper secondary pool at the downstream end of the sub-reach (Figure 5). Adult salmon migrating upstream will hold in both pools before ascending upstream. The channel is aligned parallel to Saxon Road for about half of the run. Riprap is present along most of the right bank between the top and toe of the bank to prevent further channel migration towards the roadway and the channel is entrained along it. This sub-reach is also a high energy environment; the channel is predominantly confined between the riprap and the left bank of the floodplain, and it is significantly incised downstream of the rapid. This is the result of a headcut that has propagated upstream in part because of the incision. A relic right bank high flow channel located in the vegetated right bank floodplain landward of Saxon Road crosses under the road via an 18- to 24-inch-diameter culvert and converges with the main channel at the downstream end of the riprap. Upstream migrating adult salmon will also hold in a deep section of the run at the downstream end of the riprap. Along the toe of the left/south bank valley wall is another relic, high flow floodplain side channel that has filled in with fine sediments and become overgrown with native trees and shrubs. This is due to the floodplain becoming disconnected with the main channel because of the incision. The floodplain between the valley wall and the main channel consists primarily of young native deciduous trees and shrubs.

Figure 5. Phase 3 Sub-Reach 4 (RM 13.50–RM 13.20).



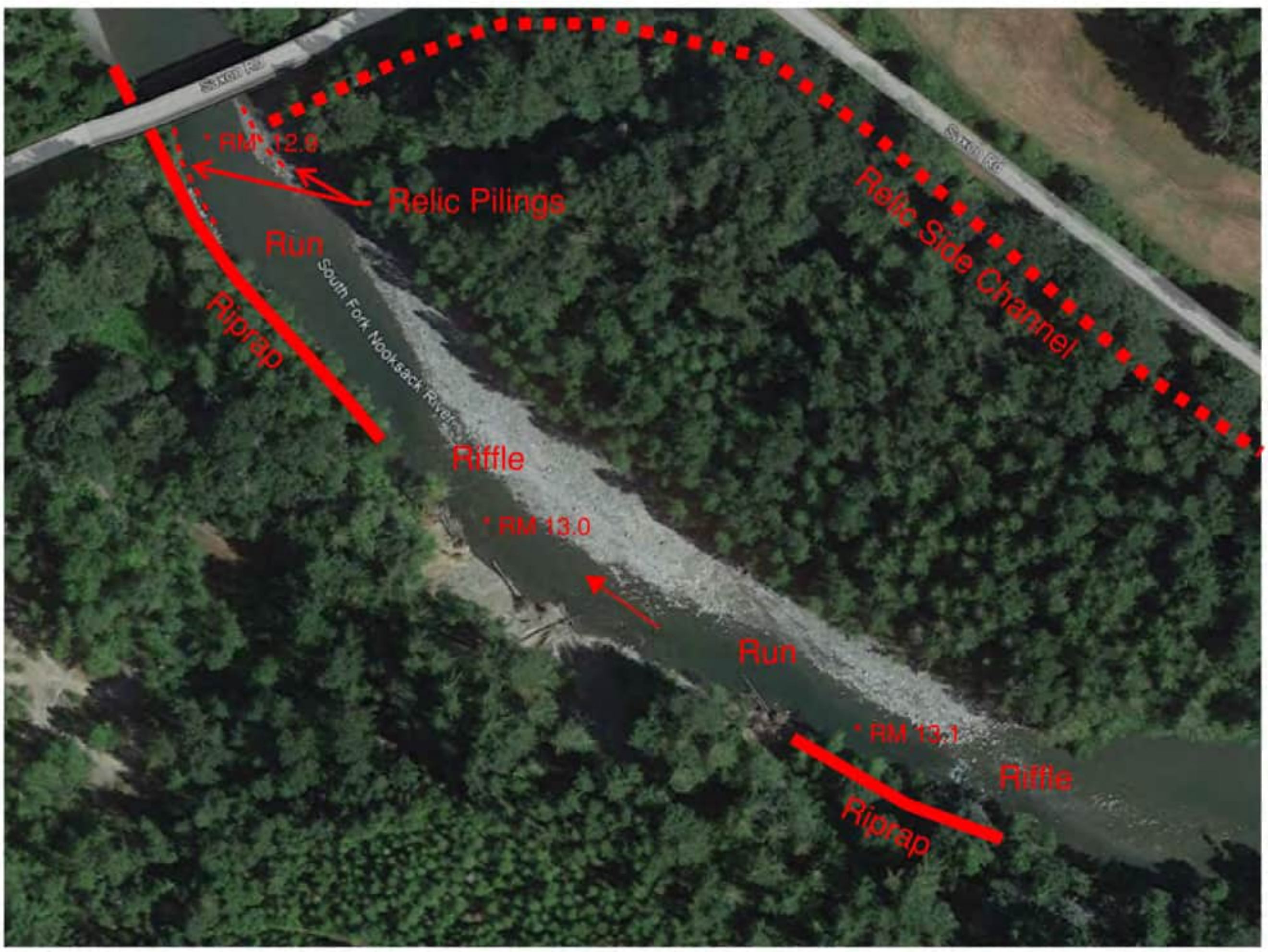
Restoration opportunities in Sub-reach 4 include the following:

- Multiple large ELJs can be spaced along the armored right bank to cover the riprap, create deep and complex pools, and dissipate flow energy to encourage sediment retention and begin reversing the effects of channel incision. A secondary benefit of these ELJs is that they can work in concert with the riprap to provide additional protection to the roadway while significantly improving habitat conditions. The ELJs can either be constructed into the bank by removing the riprap (and reusing it to ballast the structure) or the riprap can remain and the ELJs built completely landward of it. Riprap between the ELJs would not be disturbed. In lieu of multiple large ELJs, the riprap bank can be roughened by supplementing it with large logs and other smaller woody material; however, this will likely require disturbing much of the existing riprap and rebuilding the entire bank to secure the logs. Habitat improvements for this scenario would be considerably less than if ELJs were constructed.
- The main active channel along the riprap is much narrower and deeper than the main channel elsewhere in the Phase 3 reach due to the aforementioned incision; therefore, the large ELJs, by virtue of their size, will project into the channel approximately one-third to one-half of the channel width. This configuration will deflect flow towards left bank vegetated gravel bar inducing substantial, and much needed, localized bank erosion and bed scour. This will likely cause a significant rise in WSEs for a wide range of high flows (2-year flood and greater, including the FEMA regulated 100-year flood) before the bank can naturally erode, in response to the ELJs, to provide greater hydraulic conveyance and lower WSEs. Therefore, to mitigate the potential WSE rise and expedite bank erosion, the left bank of the gravel bar opposite of the ELJs and the riprap can be regraded in such a way to mimic the bank erosion that would occur there naturally to provide greater flow conveyance to help offset the potential WSE rise.
- The existing relic left bank side channel can be regraded to significantly increase activation and provide off-channel habitat. Increasing flow into this side channel will help to keep it open and result in less flow in the main channel, which will help to offset potential WSE rises and encourage sediment retention within this sub-reach to begin reversing the effects of channel incision. Small ELJs and LWM can also be placed in the side channel to provide habitat complexity.
- Alluvium removed as part of the left bank regrading and any surplus alluvium from ELJ construction and left bank side channel regrading can be regraded around the bank ELJs to keep the valuable alluvium in the system and available for downstream redistribution to address the channel incision. Finer alluvium and floodplain material can be placed over the riprap remaining between the ELJs. Topsoil and mulch can be placed over the finer alluvium and floodplain material, and over the tops of the ELJs, to provide a suitable substrate for riparian plantings to improve edge habitat conditions between the ELJs. This will also significantly improve the aesthetics of this area. Redistributing the excavated alluvium material and placement of the finer alluvium material and floodplain soils to cover the riprap will also help to reduce construction costs.

Phase 3 Sub-Reach 5 (RM 13.15–RM 12.90)

Sub-reach 5 includes two riffle-run sequences with no pools before reaching the Saxon Road Bridge with two discontinuous sections of riprap present along the left bank (Figure 6). Relic wooden pilings from previous bridges are also present near the current bridge. The channel is aligned along a steep eroding bluff in the vicinity of RM 13.00 that occasionally provides small transient woody debris to the channel. Riprap was likely present along the toe of the eroding bluff, thus making for a continuous revetment along the left bank to protect the current and past bridges, but it was likely loss due to bank erosion. The right bank floodplain is heavily vegetated primarily with second growth conifers and contains a relic high flow side channels that is aligned parallel to Saxon Road. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity.

Figure 6. Phase 3 Sub-Reach 5 (RM 13.15–RM 12.90).



Restoration opportunities in Sub-reach 5 include the following:

- Medium and large ELJs can be located along the left bank to create deep and complex pools and to catch trees recruited into the river from the eroding bluff. When combined with the small and medium ELJs along the right bank (see next bullet) they can function collectively to dissipate flow energy to encourage sediment retention and begin reversing the effects of channel incision through this sub-reach. Channel aggradation in this sub-reach and in Sub-reach 4 upstream will increase the activation frequency of the relic right bank side channel thereby improving floodplain connectivity and off-channel habitat.
- Multiple small and medium ELJs can be spaced along the right bank at the edge of the vegetation and along the large right bank gravel bar to provide woody cover and improve channel bed complexity.
- The upstream segment of riprap near RM 13.10 can be removed to allow channel migration into the steep bluff to encourage recruitment of trees into the channel and to restore natural bank conditions that will significantly improve edge habitat. The downstream segment of riprap and relic pilings along the left bank should not be removed as doing so will increase risk to the bridge, which is maintained by Whatcom County. However, ELJs can potentially be placed in the channel near the riprap to mitigate the adverse effects of it on habitat but only if they do not increase risk of failure to the riprap and pilings.

Phase 3 Sub-Reach 6 (RM 12.90–RM 12.70)

Sub-reach 6 consists of one long, wide and shallow run with no pools or other notable instream habitat features (Figure 7). Bank vegetation consists of a mix of coniferous and deciduous trees and shrubs. This sub-reach is considered a high energy area based on the hydraulic model results; therefore, there is a good potential to use ELJs to slow flow velocities, encourage channel aggradation, create deep and complex pools and improve channel planform complexity. This sub-reach terminates at the Saxon Reach Habitat Restoration project of 2012, insinuating an opportunity to link the two projects.

Figure 7. Phase 3 Sub-Reach 6 (RM 12.90–RM 12.70).

Restoration opportunities in Sub-reach 6 include the following:

- Multiple small and medium ELJs can be spaced along the left and right banks and mid-channel to create deep and complex pools, provide woody cover and improve channel bed and planform complexity. This reach is likely sensitive to WSE rise with residences on the left bank, so these ELJs should target small and localized hydraulic complexity for lower flows but not for higher flows (i.e., ELJs should have a low profile so that larger flows skip over them). Privately owned, mostly unoccupied floodplain is on the right bank, therefore landowner outreach on both banks will guide restoration opportunities.

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Appendix A

Existing Conditions Hydraulic Model Results Graphics

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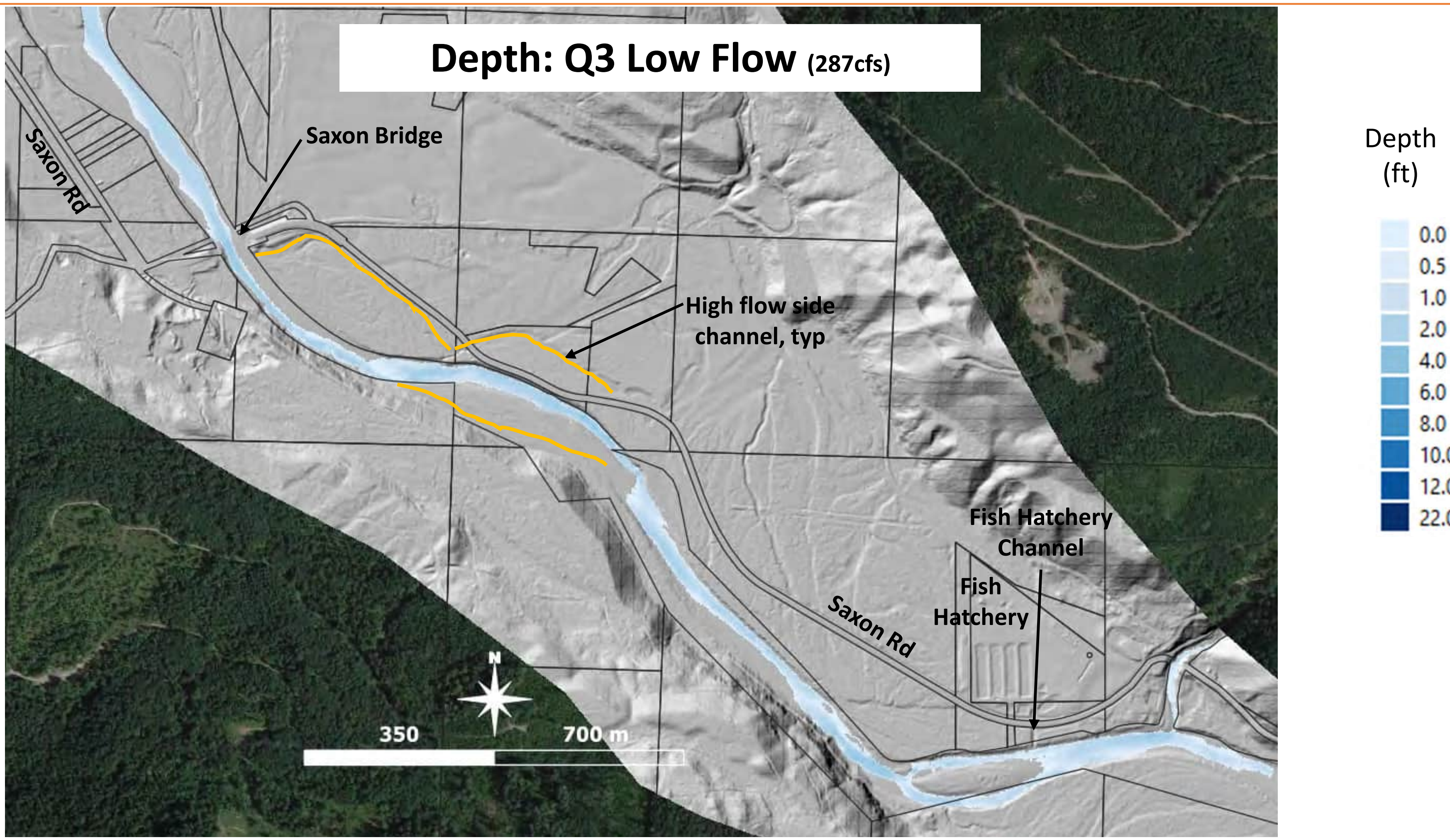
HYDRAULIC MODEL RESULTS



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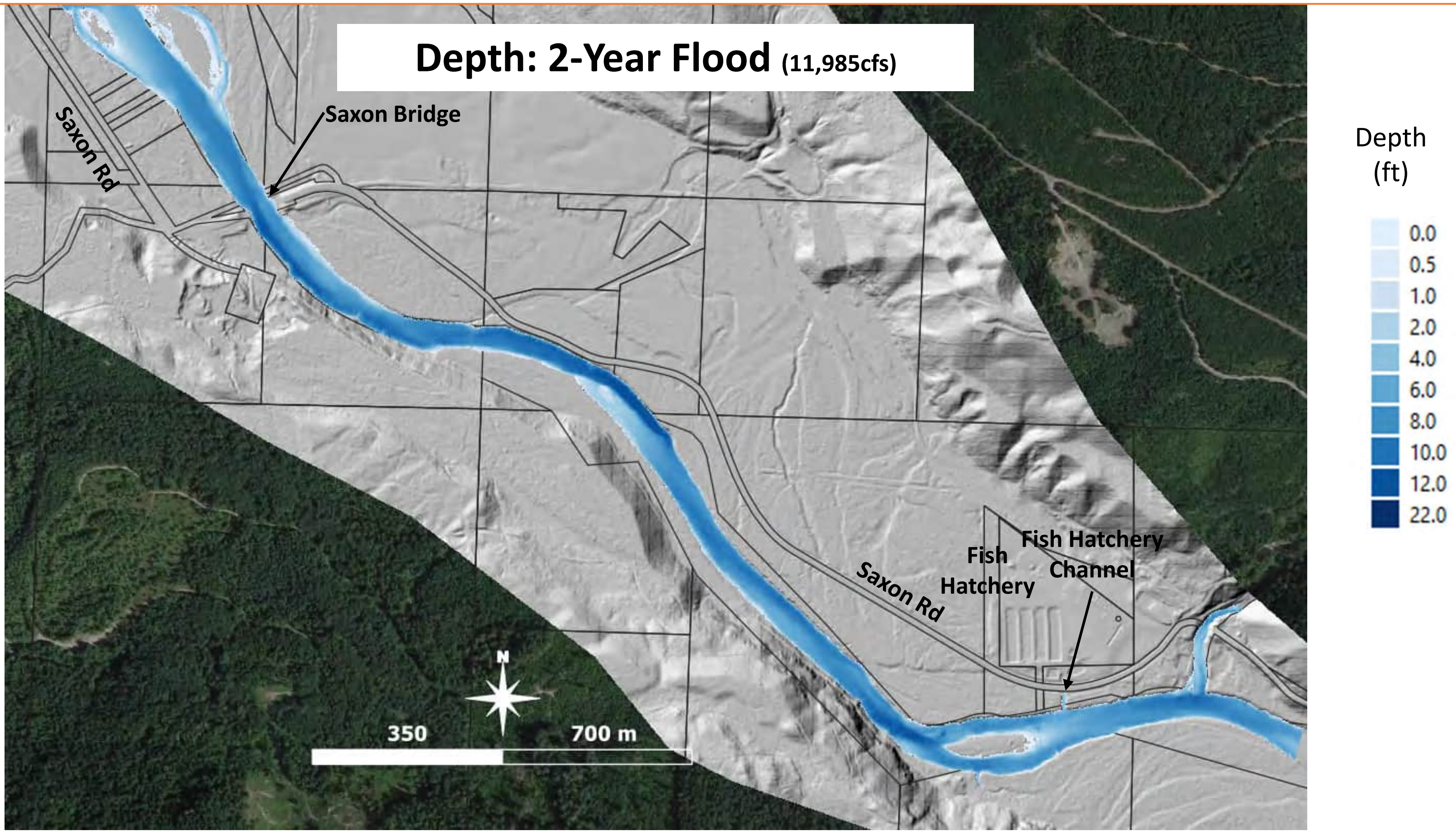

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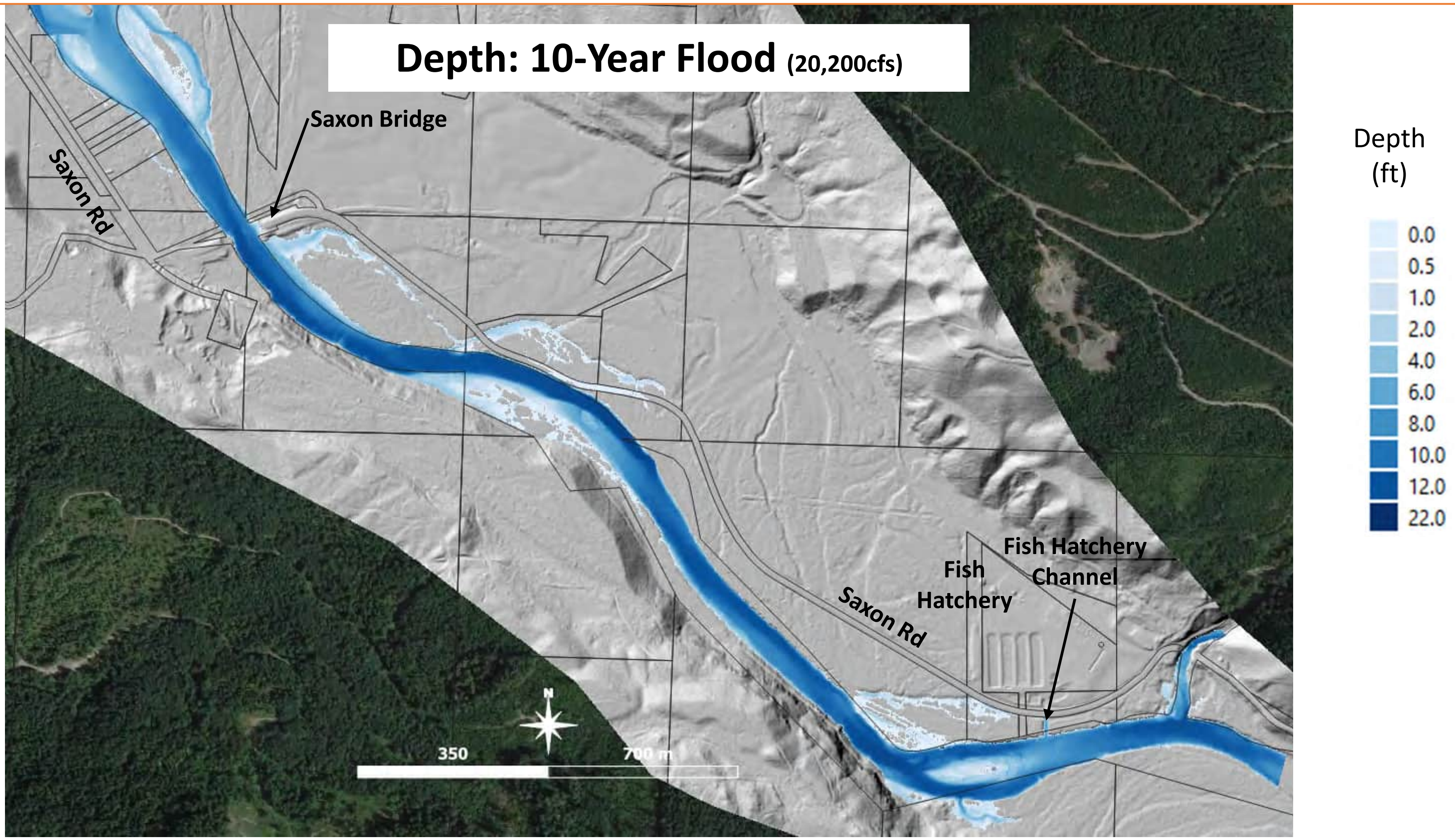

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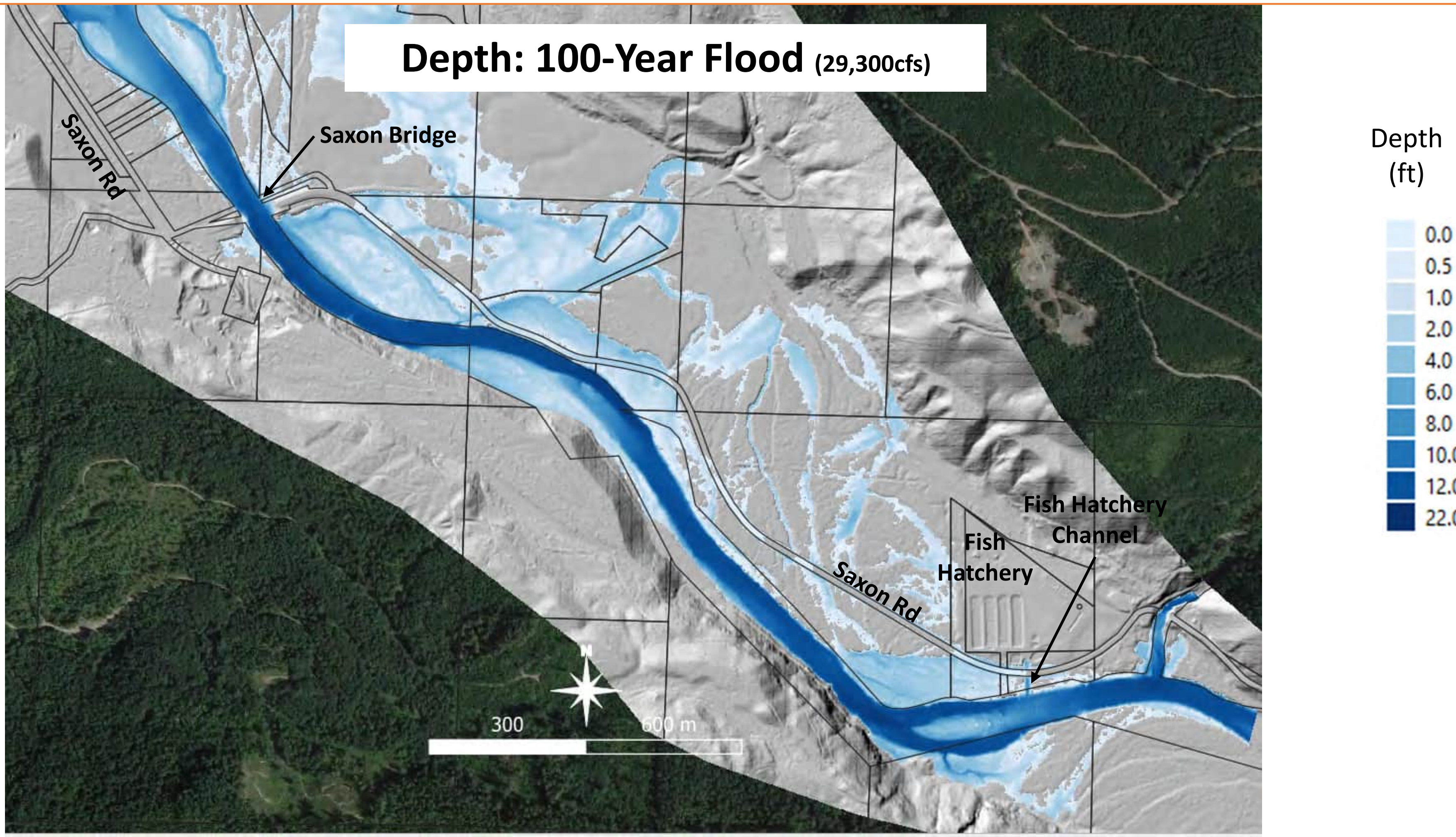

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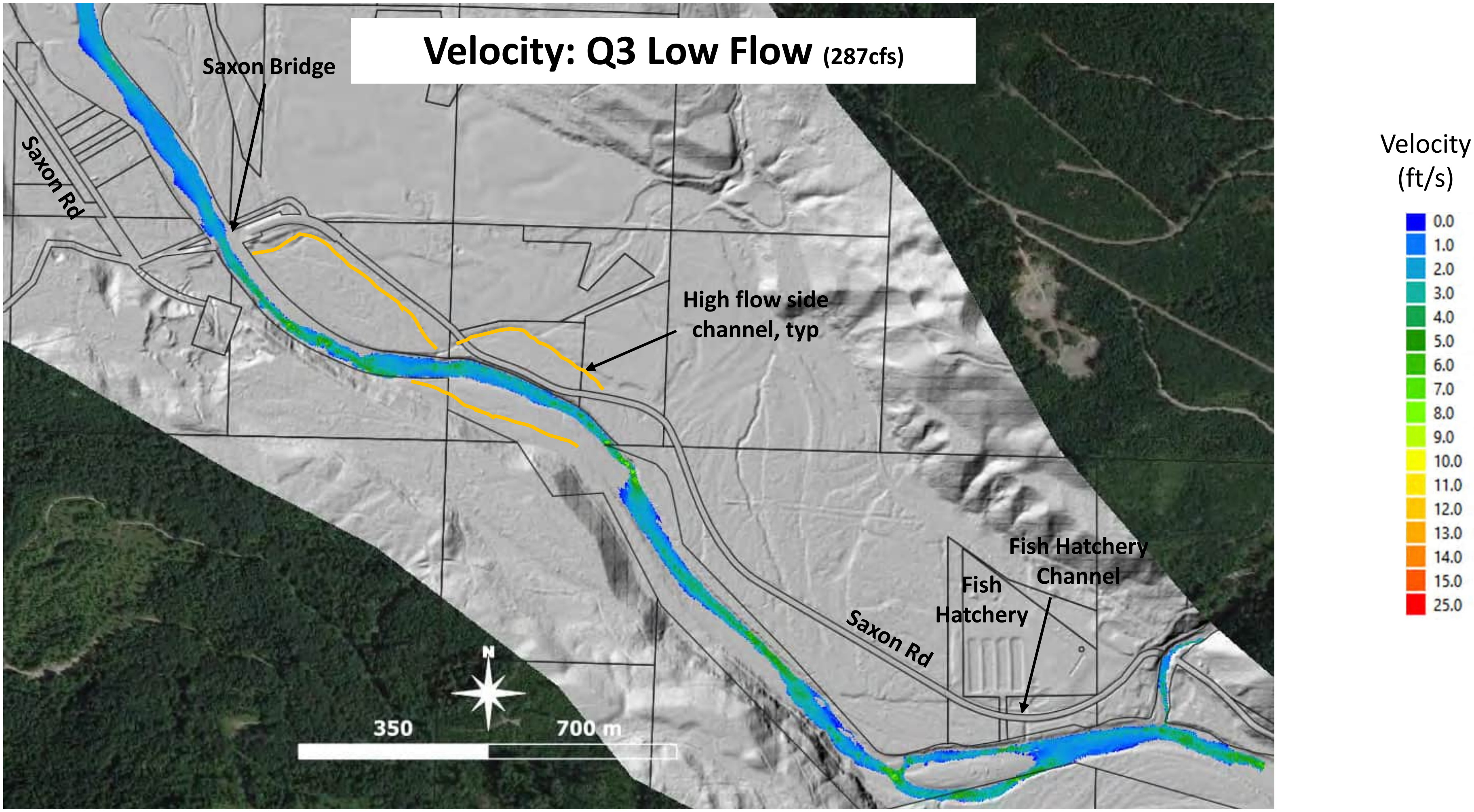

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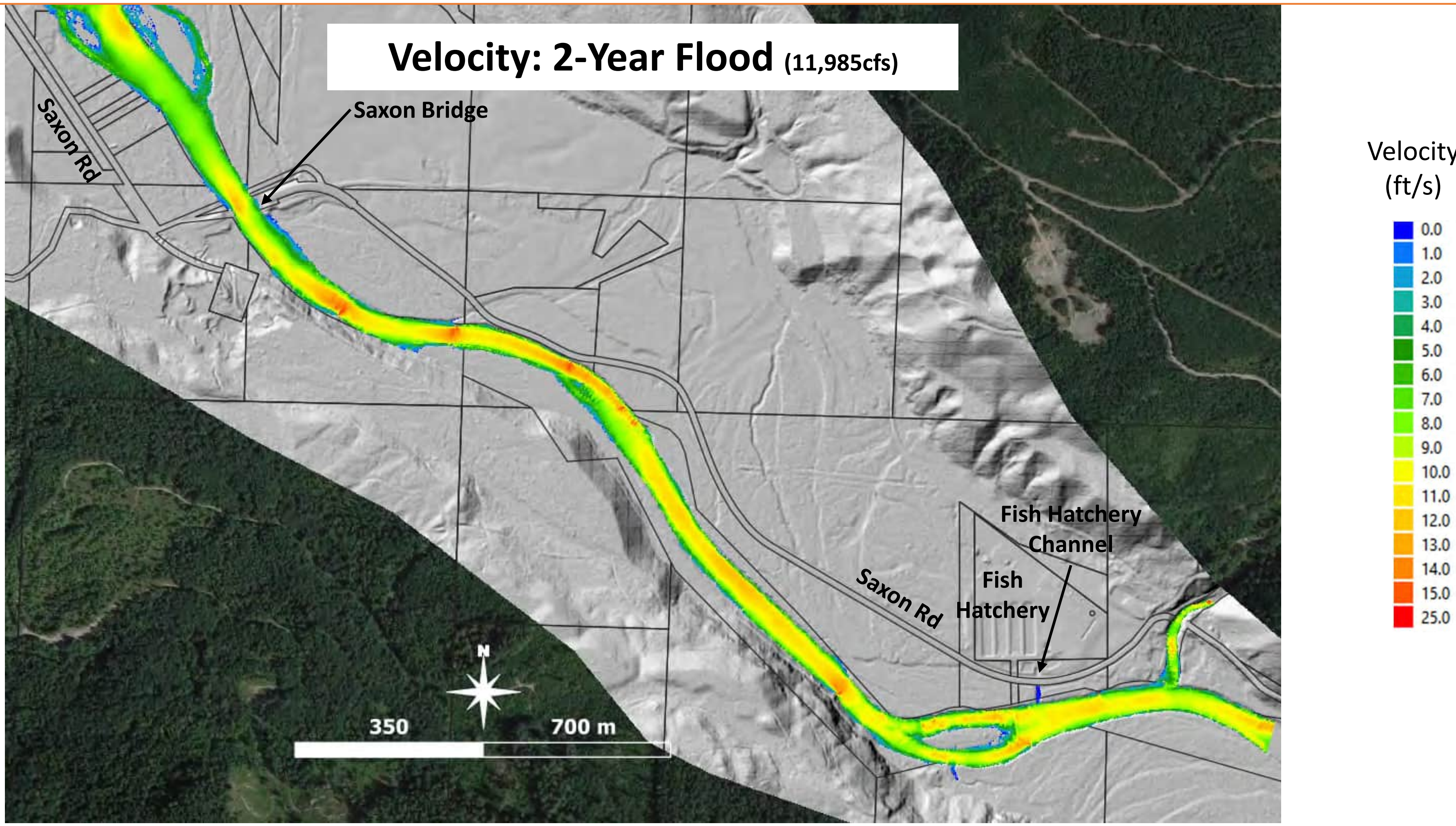

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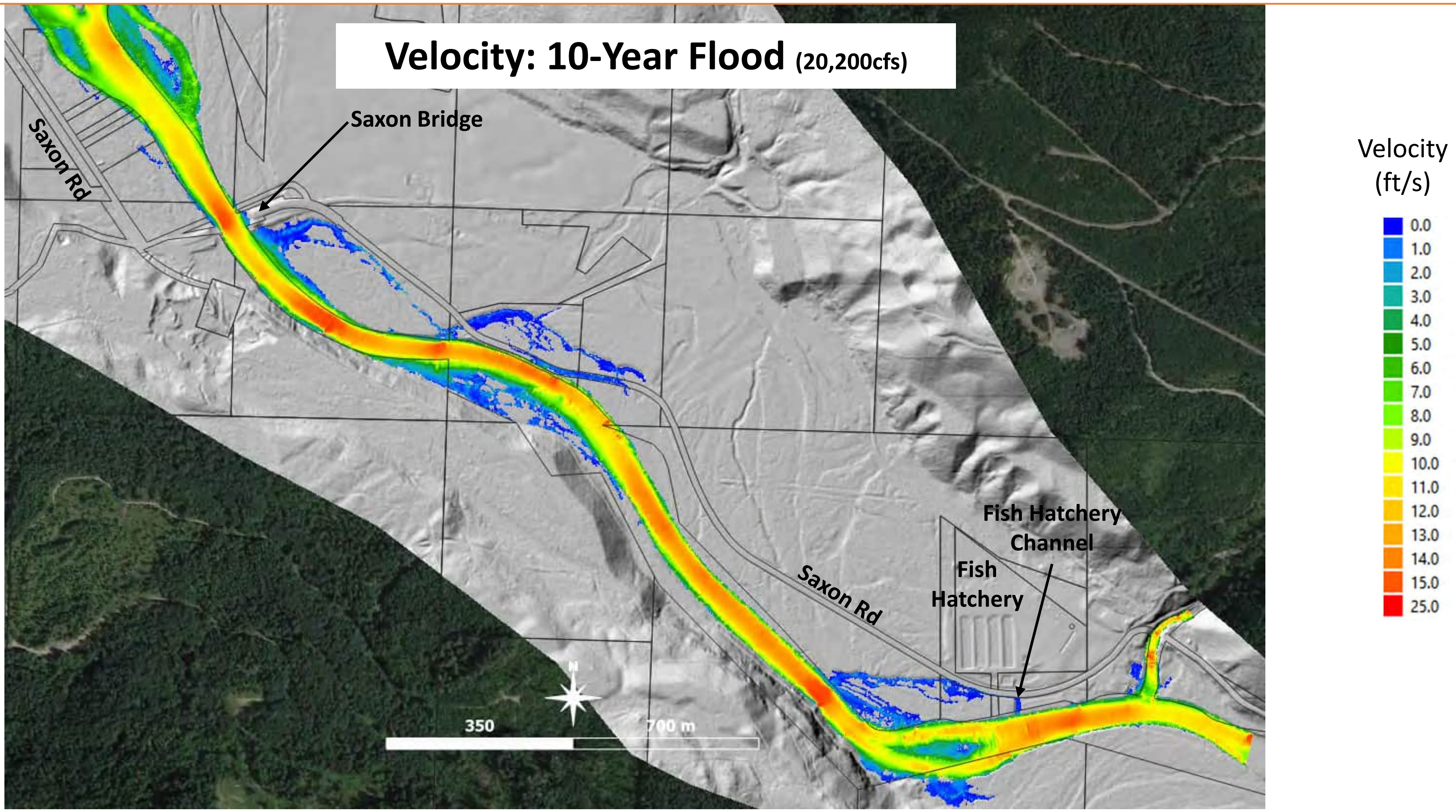

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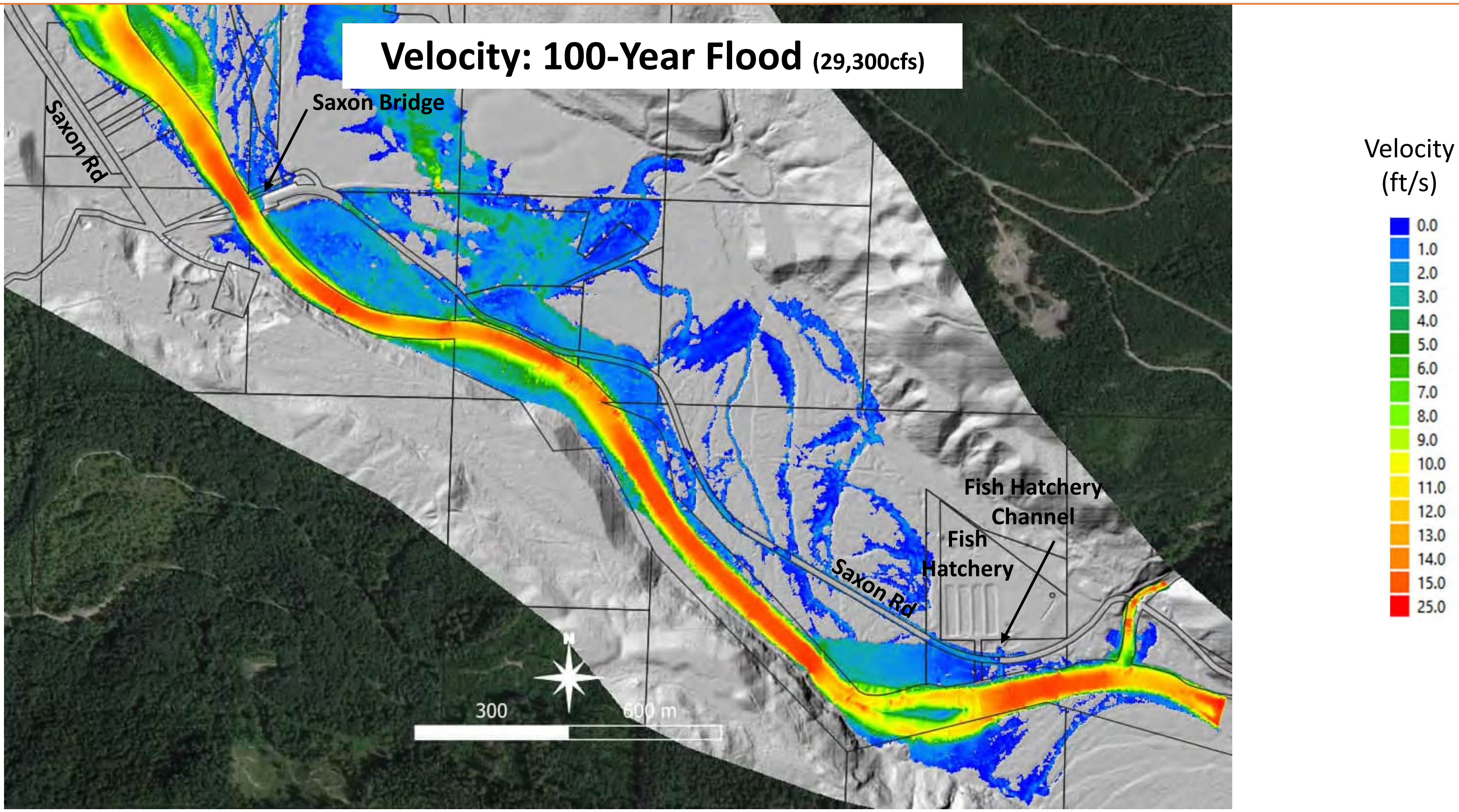

Appendix B

Phase 3 Conceptual Restoration Design Alternatives and Conceptual Design Plans for the Preferred Alternative (Alternative 3)

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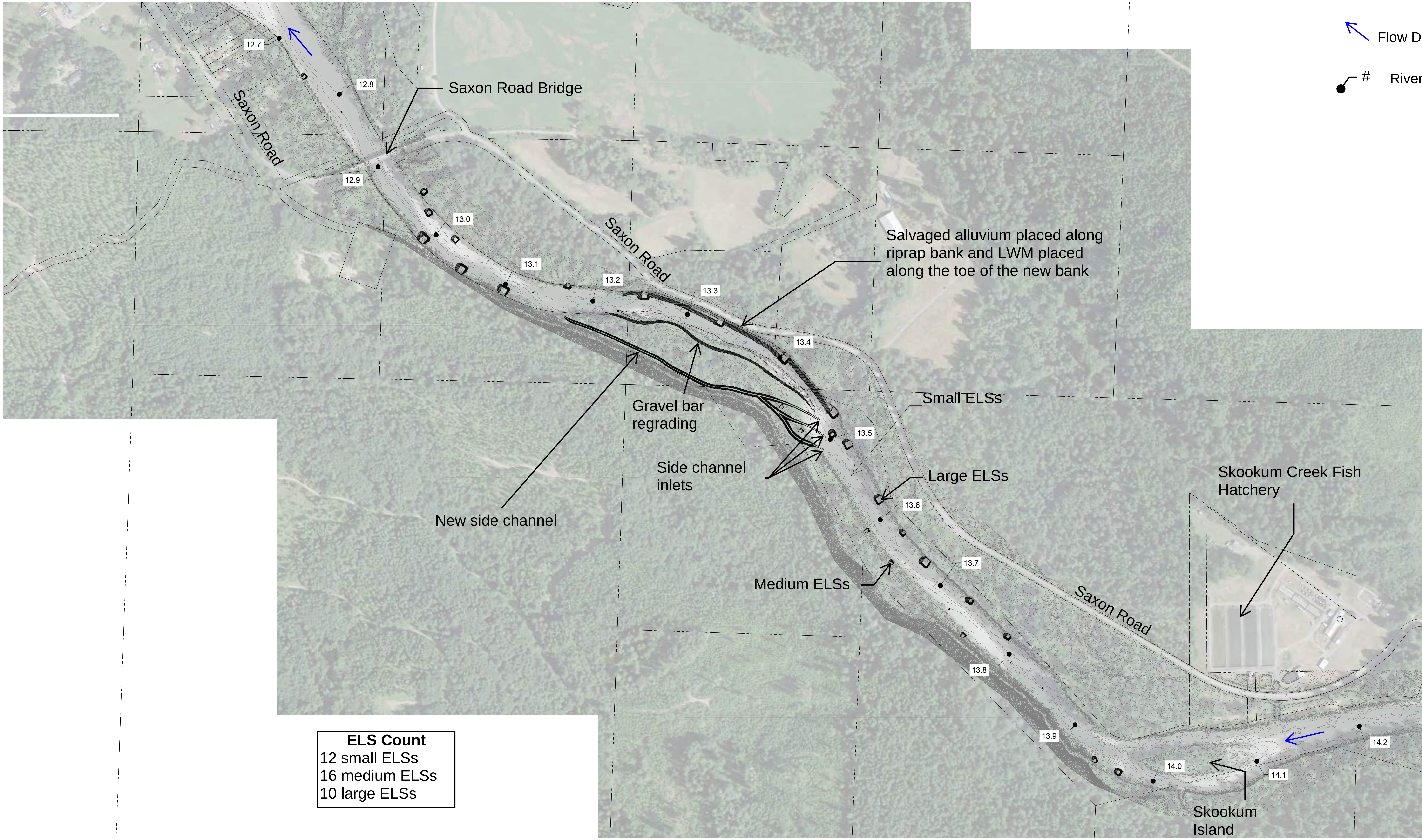
Alternative 1
South Fork Nooksack River Skookum Edfro Reach Phase 3 Restoration Project

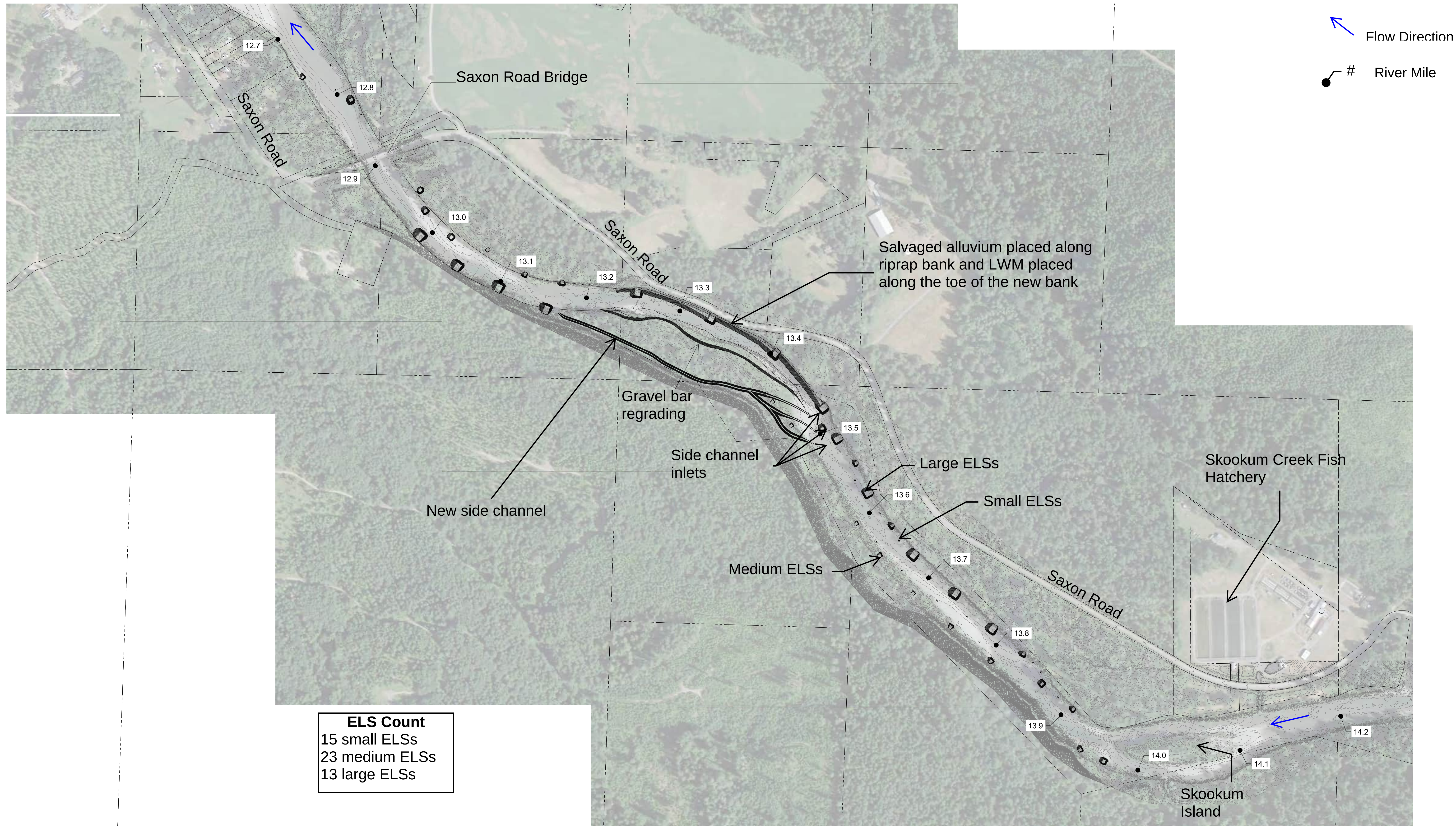


Flow Direction

River Mile

0 250 500 1000 Feet

Alternative 2
South Fork Nooksack River Skookum Edfro Reach Phase 3 Restoration Project



Alternative 3
South Fork Nooksack River Skookum Edfro Reach Phase 3 Restoration Project

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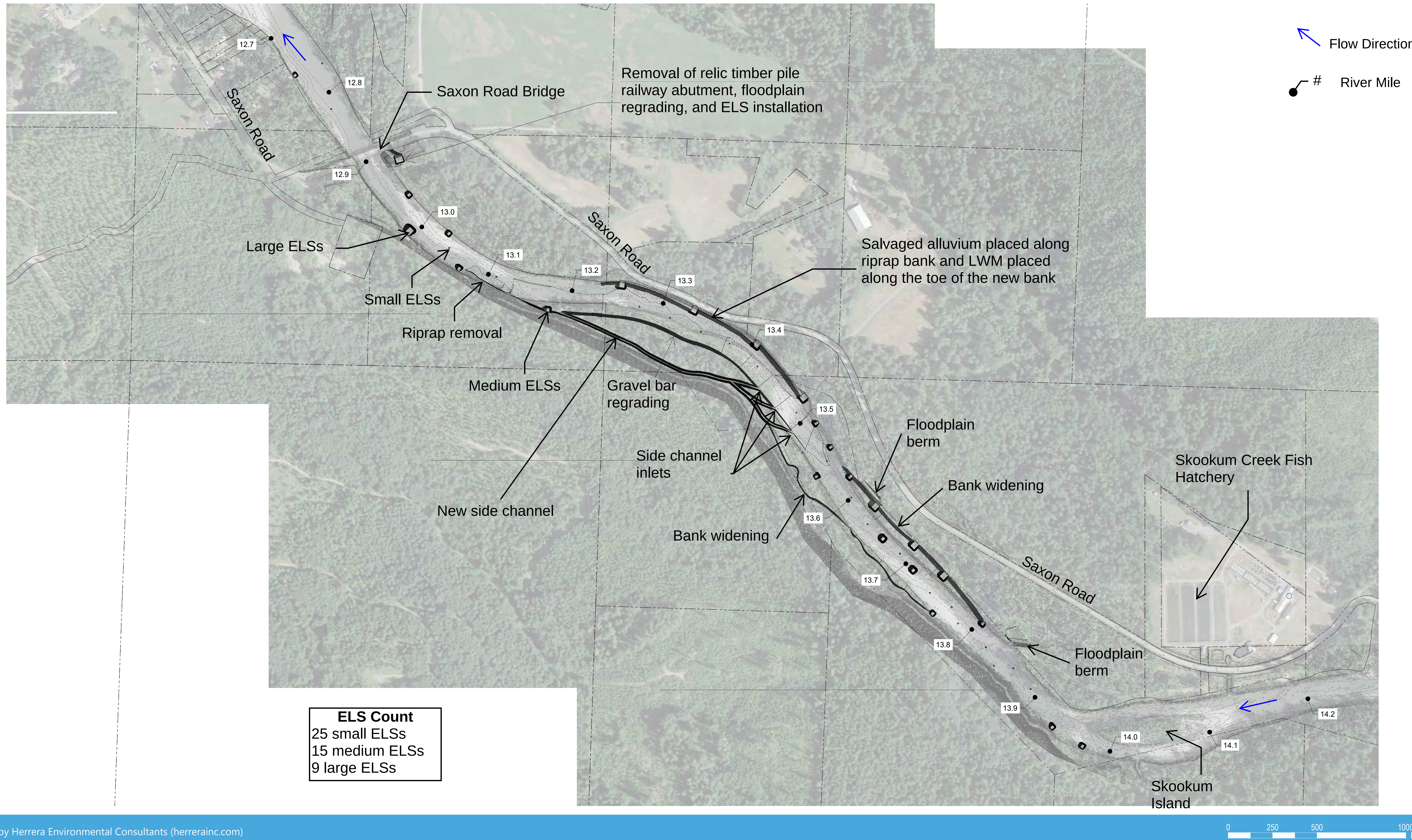
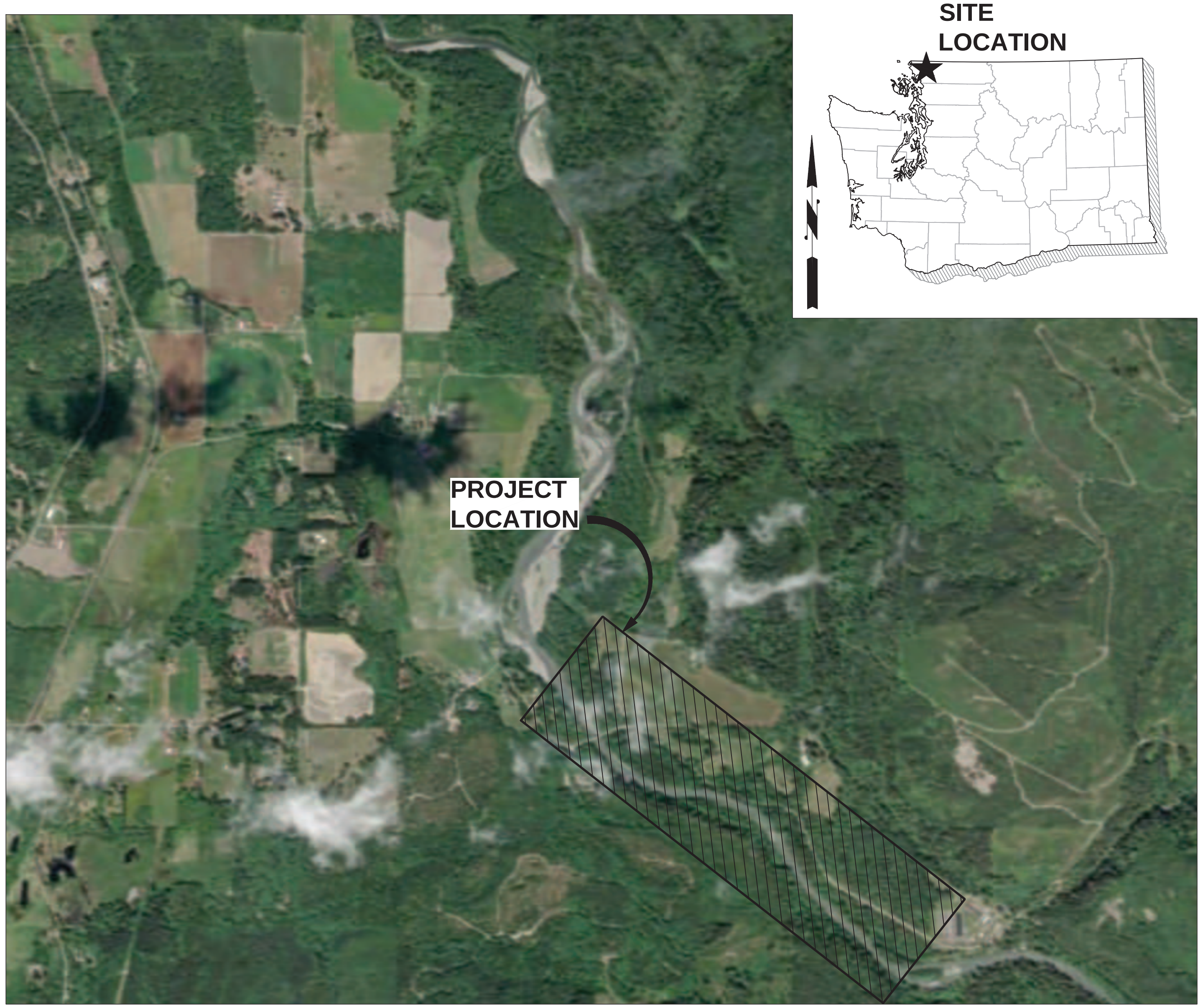


SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO HABITAT RESTORATION PROJECT - PHASE 3
WHATCOM COUNTY, WASHINGTON



VICINITY MAP
SCALE: 1"=1/4 MILE

OWNER:

LUMNI NATION
BELLINGHAM, WA 98226
PHONE: (360) 410-1988
CONTACT: ALEX LEVELL

ENGINEER:

HERRERA ENVIRONMENTAL CONSULTANTS
2200 SIXTH AVENUE, SUITE 1100
SEATTLE, WA 98121
PHONE: (206) 441-9080
CONTACT: IAN MOSTRENKO

INDEX OF DRAWINGS

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BEFORE
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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH
AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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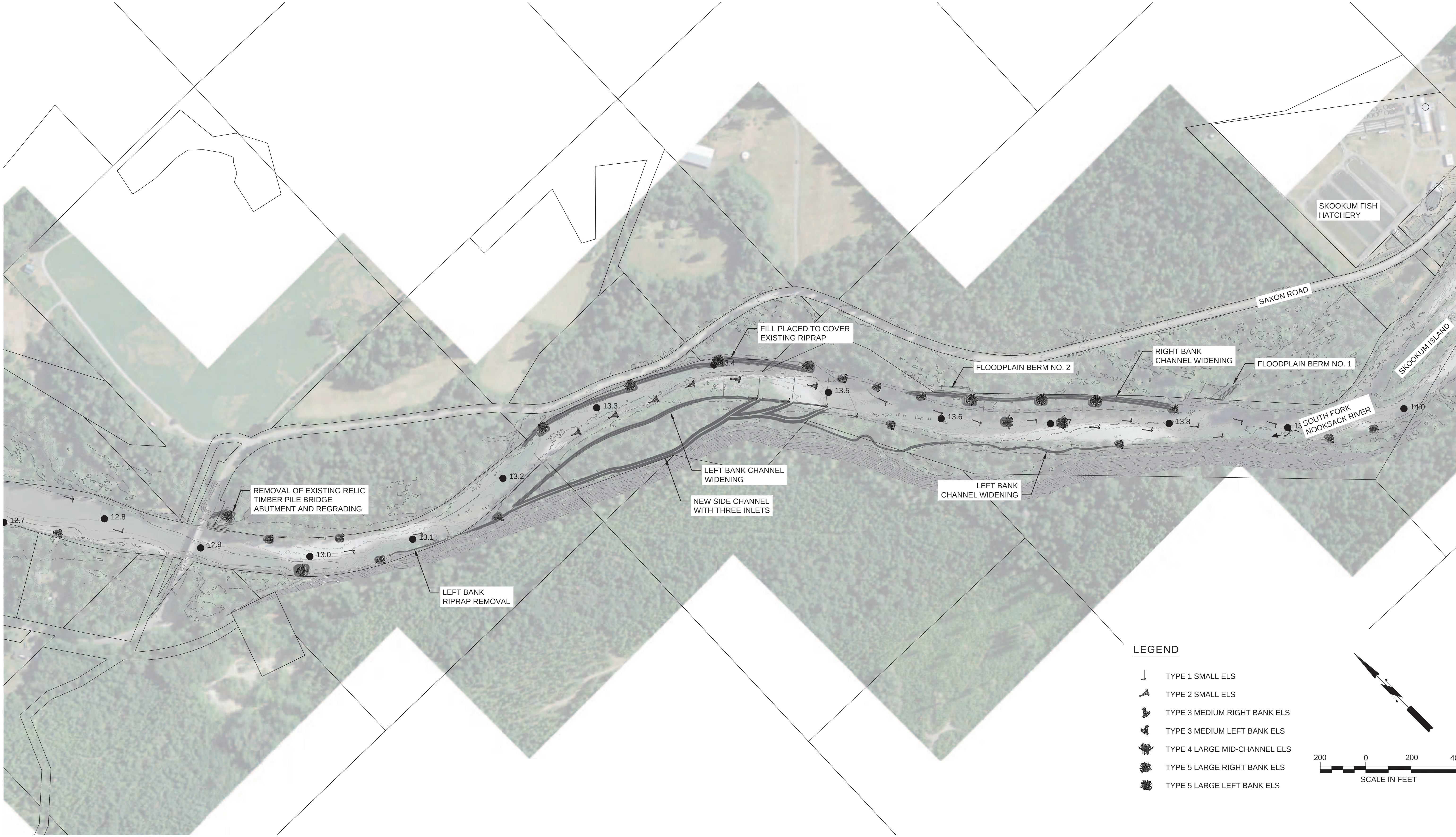
DRAFT

DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION
PROJECT - PHASE 3

COVER

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: G0.01
SHEET NO: 1 OF 12



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SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

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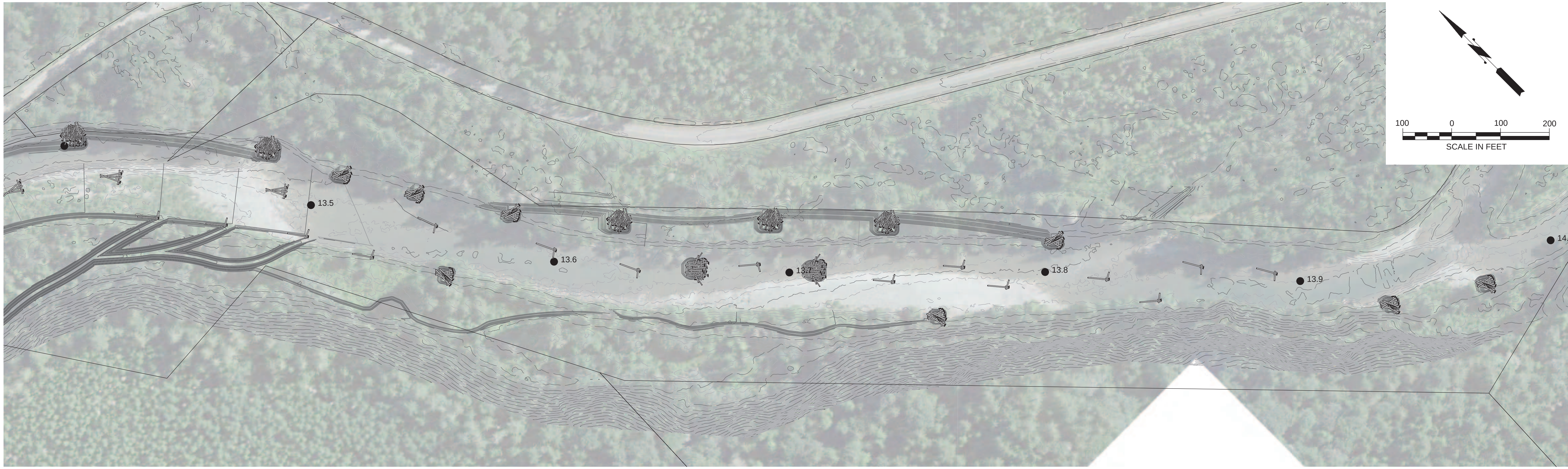
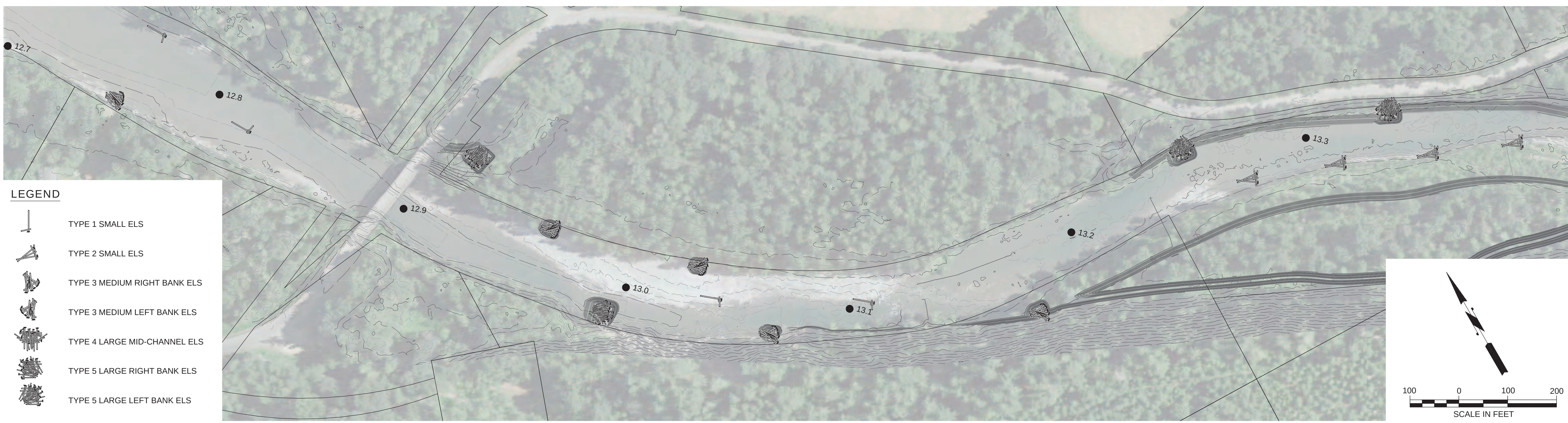
PROJECT NO: 14-05790-000
DRAWING NO: C0.01
SHEET NO: 2 OF 12





LEGEND

- TYPE 1 SMALL ELS
- TYPE 2 SMALL ELS
- TYPE 3 MEDIUM RIGHT BANK ELS
- TYPE 3 MEDIUM LEFT BANK ELS
- TYPE 4 LARGE MID-CHANNEL ELS
- TYPE 5 LARGE RIGHT BANK ELS
- TYPE 5 LARGE LEFT BANK ELS

CALL 811 BEFORE YOU DIG

CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

HERRERA
Science + Planning + Design
herrerainc.com

DRAFT

DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION
PROJECT - PHASE 3

CONCEPTUAL DESIGN SITE PLAN II

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DRAWING NO: C0.02
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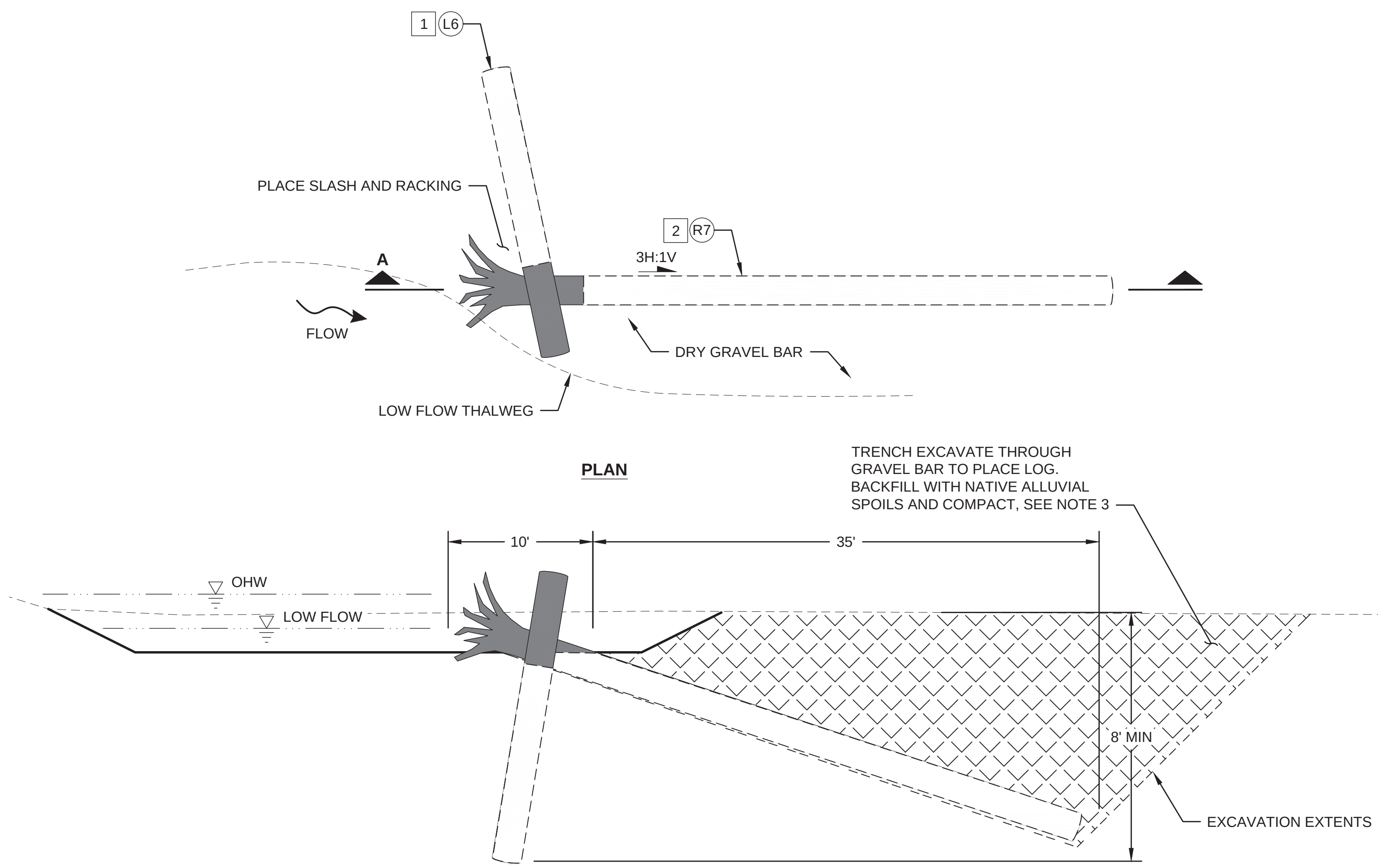

SECTION A

LOG SCHEDULE - TYPE 1 ELS:

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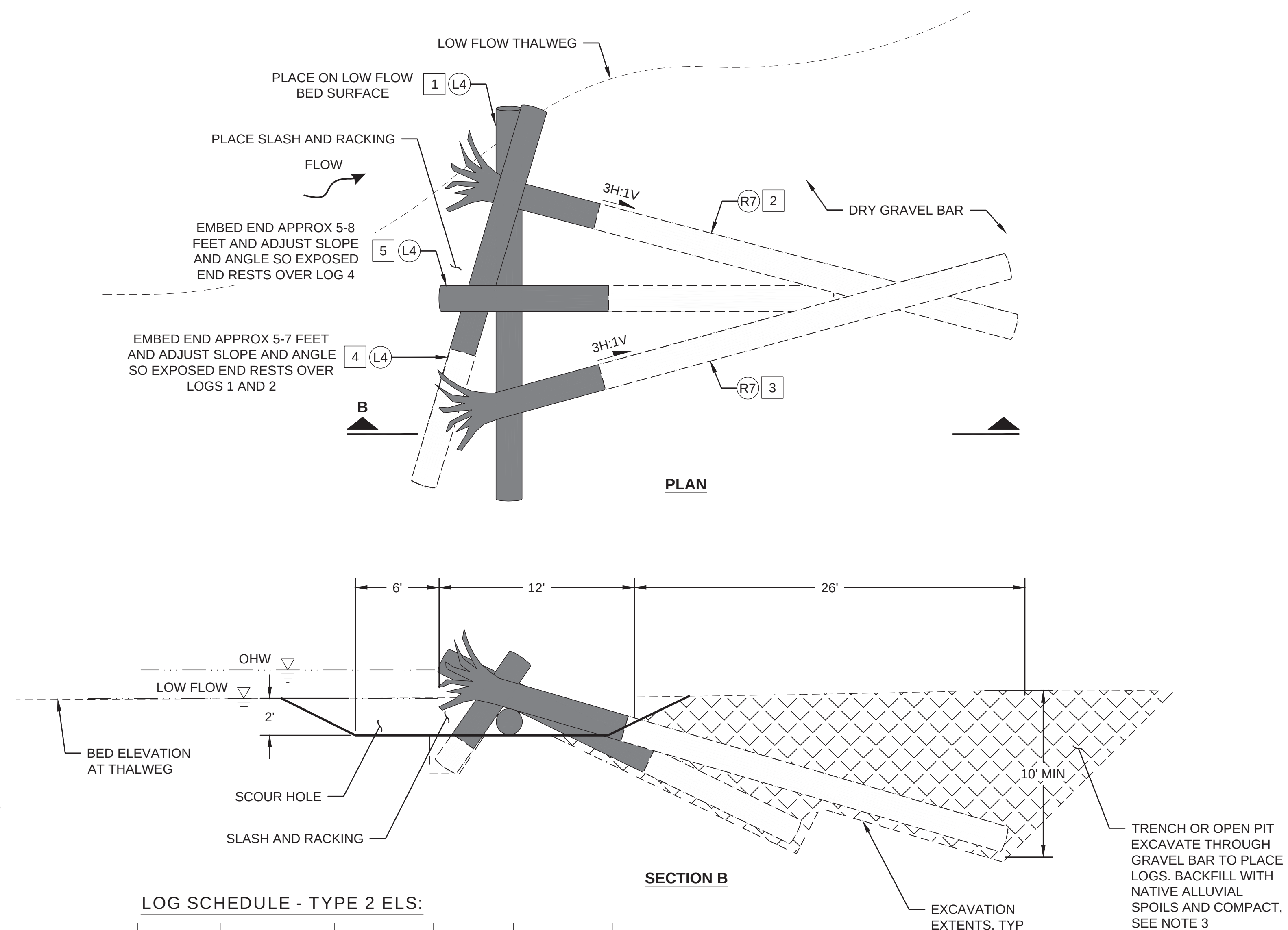
R7	24	45	YES	1
RACKING	4-16	15-30	OPTIONAL	2
SLASH	< 4	NA	NA	2 CY

DETAIL - TYPE 1 ELS

SCALE: NTS

1 VAR



SECTION B

LOG SCHEDULE - TYPE 2 ELS:

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L4	24	30	NO	3
R7	24	45	YES	2
RACKING	6-12	20	OPTIONAL	30
SLASH	< 4	NA	NA	40 CY

DETAIL - TYPE 2 ELS

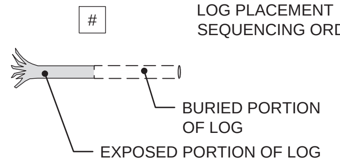
SCALE: NTS

2 VAR

LEGEND:

X# LOG TYPE ID

\# LOG PLACEMENT SEQUENCING ORDER



GENERAL NOTES:

1. STRUCTURE LOCATION AND LOG ORIENTATION SHOWN IS APPROXIMATE AND WILL VARY FOR EACH STRUCTURE BASED ON SITE SPECIFIC CONDITIONS AND LOCATION OF STEELHEAD REDDS. PRIOR TO CONSTRUCTION ENGINEER SHALL FLAG APPROXIMATE STRUCTURE CONTROL POINT LOCATION AND MAKE ANY NECESSARY FIELD ADJUSTMENTS TO LOG LOCATIONS AND ORIENTATIONS. CONTRACTOR SHALL VERIFY FINAL STRUCTURE LOCATION AND EXCAVATION EXTENTS WITH ENGINEER PRIOR TO CONSTRUCTION.
2. LOGS SHALL BE PLACED AT THE LOCATIONS, ELEVATIONS AND ORIENTATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER.
3. EXCAVATION LIMITS SHOWN ARE APPROXIMATE AND WILL VARY BASED ON CONSTRUCTION MEANS AND METHODS, SUBSURFACE CONDITIONS, AND LOCATION OF STRUCTURE. CONTRACTOR SHALL ADJUST EXCAVATION LIMITS AS NECESSARY TO COMPLETE CONSTRUCTION. CONTRACTOR SHALL BACKFILL ALL EXCAVATIONS USING ONLY DRY NATIVE ALLUVIAL EXCAVATION SPOILS IN 2 FOOT DEEP LAYERS AND COMPACT EACH LAYER WITH BACKSIDE OF EXCAVATOR BUCKET. SATURATED BACKFILL MATERIAL WILL NOT BE ALLOWED.

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH
AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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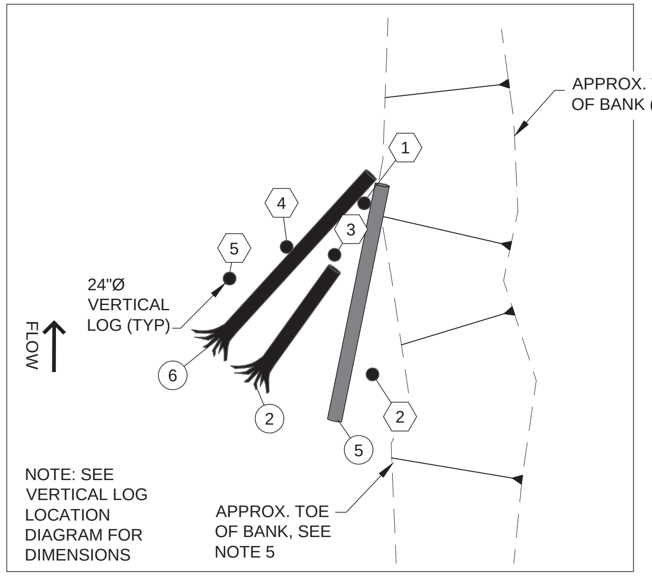
DRAFT

DESIGNED: - | DRAWN: -
DESIGNED: - | DRAWN: -
DESIGNED: - | CHECKED: -
SCALE: AS NOTED | APPROVED: -

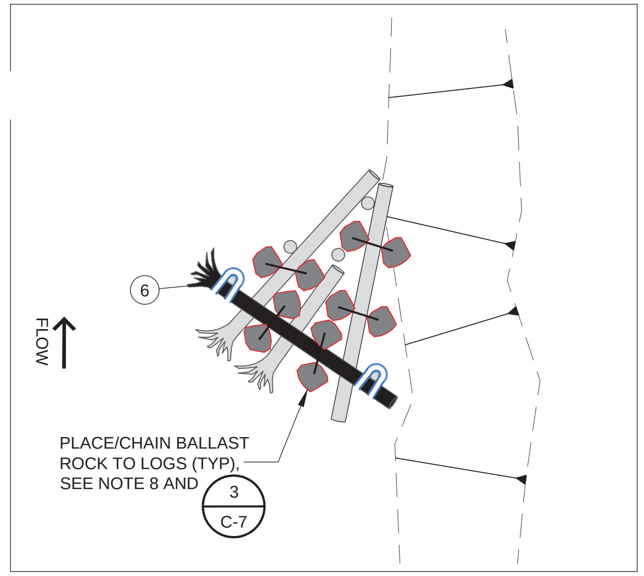
SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 1 AND 2 ELS DETAILS

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.01
SHEET NO: 4 OF 12



LAYER 1



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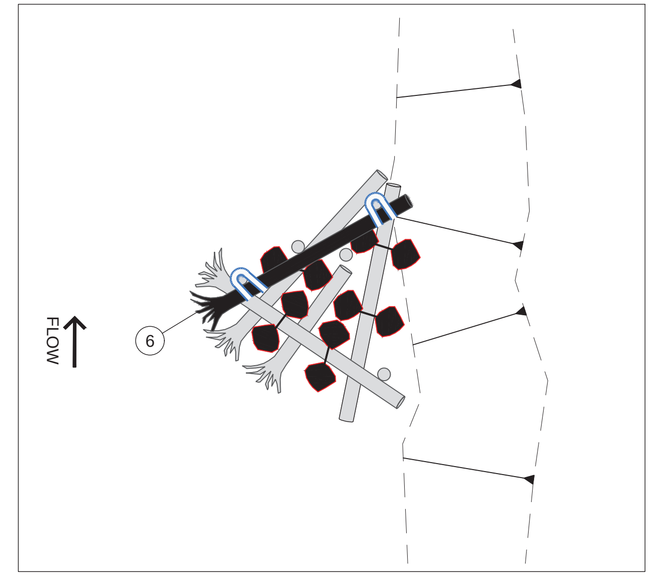

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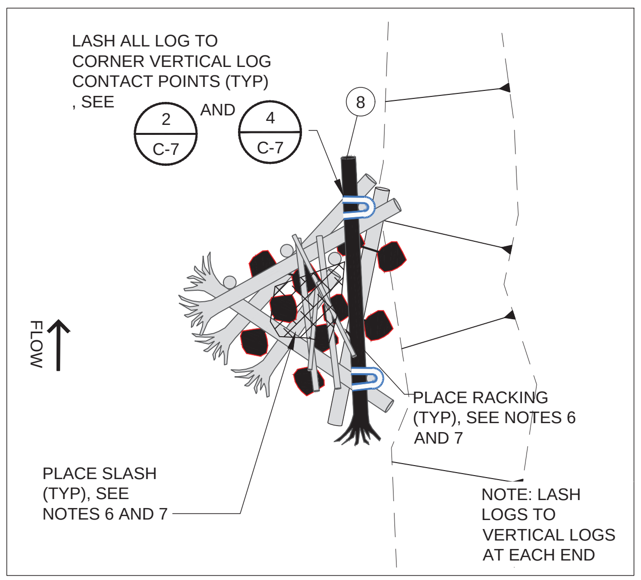

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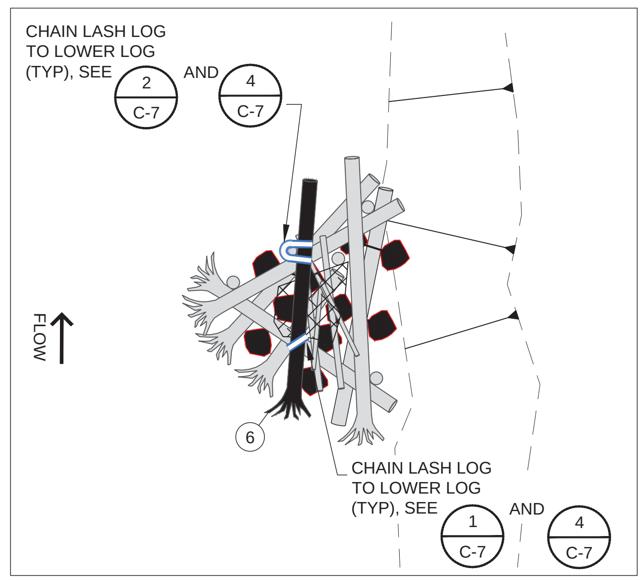

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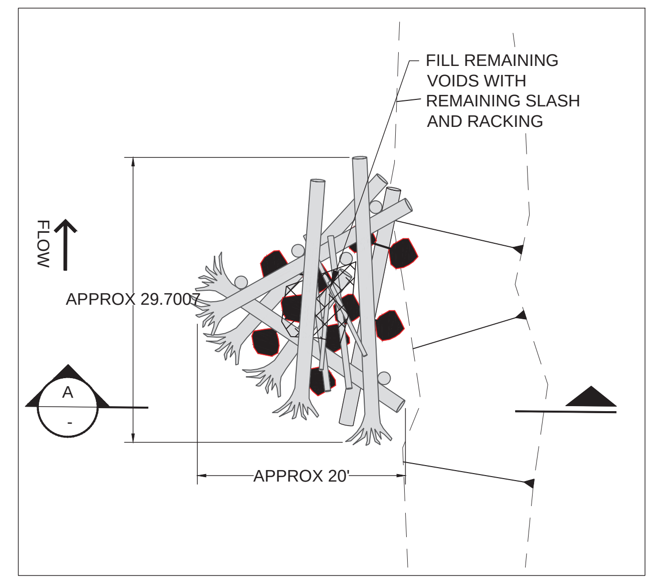

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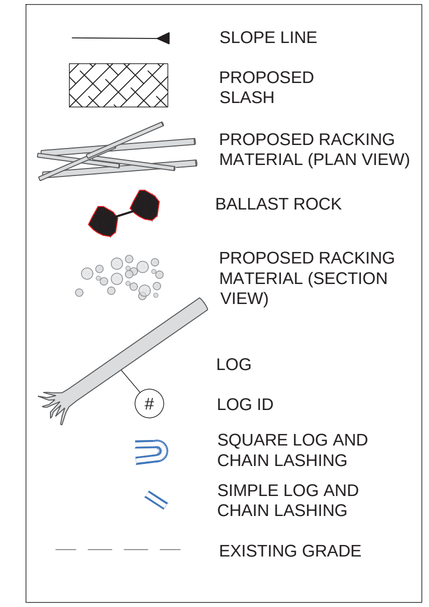


TABLE - RACKSTER SLASH SCHEDULE

	QUANTITY/ STRUCTURE (CY)
SLASH	30

TABLE - RACKSTER RACKING SCHEDULE

	QUANTITY/ STRUCTURE
RACKING LOGS	40-50

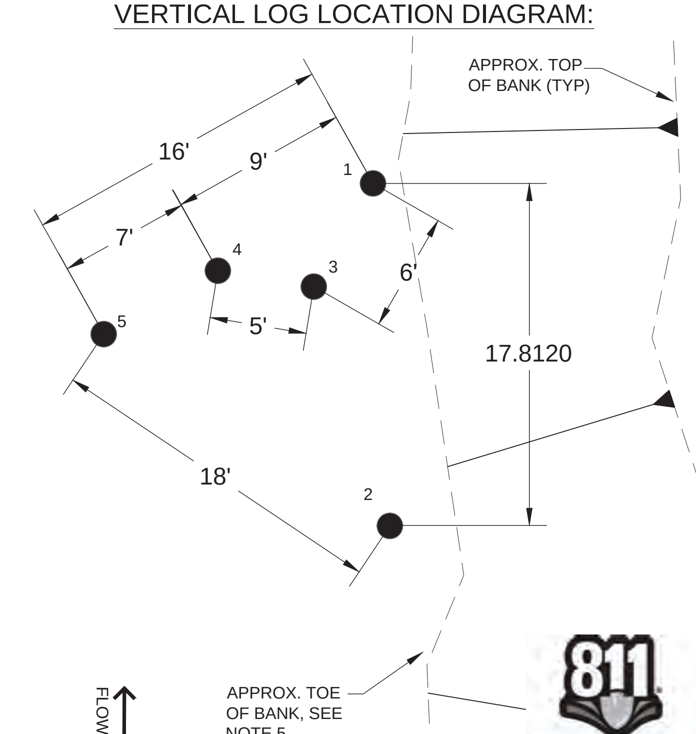
TABLE - RACKSTER ROCK SCHEDULE

	WEIGHT (TONS)	QUANTITY/ STRUCTURE
BALLAST ROCKS	2	10

TABLE - RACKSTER LOG SCHEDULE:

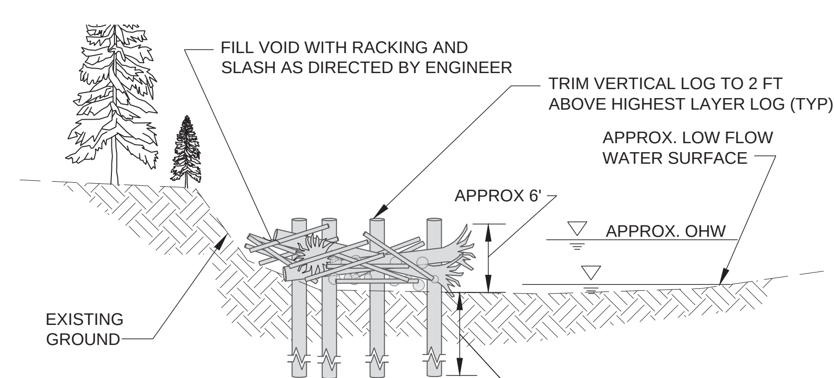
LOG TYPE ID#	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	QUANTITY/STRUCTURE
2	24	15	YES	1
5	24	25	NO	1
6	24	25	YES	4
8	18-24	30	YES	1
			TOTAL:	7 TOTAL
VERTICAL LOG #	24	20	NO	5
			TOTAL:	12 PER STRUCTURE

VERTICAL LOG LOCATION DIAGRAM:



NOTES:

1. UP TO 3 PILE LOCATIONS PER RACKSTER SHALL BE STAKED BY ENGINEER.
2. EXCAVATION SPOILS SHALL BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. LOG MATERIALS SHALL BE PLACED AT THE LOCATIONS AND ELEVATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER OR OWNER.
4. TRIM LOGS AS REQUIRED.
5. TOE OF BANK VARIES PER EACH RACKSTER.
6. SLASH AND RACKING TO FILL VOIDS BETWEEN LOG LAYERS. SEQUENCING OF SLASH PLACEMENT MAY NEED TO BE MODIFIED FOR LASHING. SUBSEQUENT LOG LAYERS SHALL COMPRESS SLASH AND RACKING PLACED IN PREVIOUS LAYERS.
7. RACKING PLACEMENT SHALL BE COORDINATED WITH LOG LAYER PLACEMENT AND SLASH PLACEMENT TO ENSURE LOG MEMBERS EXTEND THROUGH AND BIND RACKING MEMBERS AND RACKING MEMBERS EXTEND THROUGH AND BIND SLASH MATERIAL.
8. PLACE BALLAST ROCKS AS LOW WITHIN THE ELJ AS POSSIBLE AND ENSURE CHAIN BETWEEN BALLAST ROCKS HAS NO SLACK.
9. AUGMENT OR DELETE ROCK QUANTITIES AS NEEDED TO MAINTAIN AN ELJ ROCK BALLAST OF 20 TONS MINIMUM.
10. ENGINEER SHALL STAKE 2 VERTICAL LOG LOCATIONS FOR RACKSTER BASED ON APPROX 10' TO THE RELATIVE DEPTH TO THE ADJACENT CHANNEL BOTTOM, DEPTH SHALL NOT EXCEED 15' BELOW BASE FLOW WATER SURFACE. CONTRACTOR SHALL MARK DEPTH OF BURIAL LOCATION ON ALL VERTICAL LOGS PRIOR TO PLACEMENT WITH BLAZE ORANGE MARKING PAINT.
11. CONTRACTOR SHALL EXPECT FIELD FITTING
12. RACKING, SLASH, AND LASHINGS ONLY SHOWN IN LAYERS WHERE PLACEMENT OCCURS FOR CLARITY.
13. ALL LOG TO LOG LASHING SHALL BE 1/2"Ø GRADE 43 NATURAL FINISH CHAIN UNLESS OTHERWISE SPECIFIED IN LAYER PLAN. BOULDER TO LOG LASHING SHALL BE 1/2"Ø GRADE 43 NATURAL FINISH CHAIN. SEE SHEET C-7 FOR LASHING TYPES AND CONDITIONS.
14. ALL CONNECTING HARDWARE SHALL HAVE A RATED BREAKING LOAD LIMIT OF EQUAL OR GREATER STRENGTH THAN CHAIN. SHACKLES SHALL BE SAFETY SHACKLES AND THREADS SHALL BE MARRED TO PREVENT REMOVAL OF SHACKLES.



RACKSTER SECTION A -
SCALE: 1:10

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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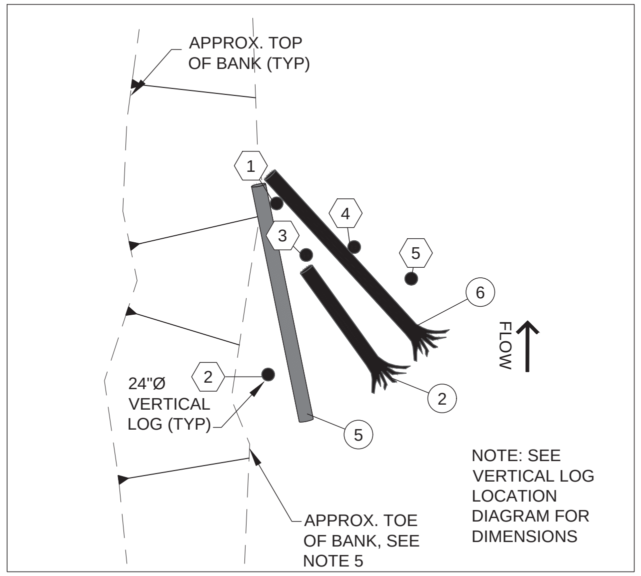
DESIGNED: - DRAWN: -
DESIGNED: - DRAWN: -
DESIGNED: - CHECKED: -
SCALE: AS NOTED APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 3 MEDIUM RIGHT BANK ELS

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.02
SHEET NO: 5 OF 12



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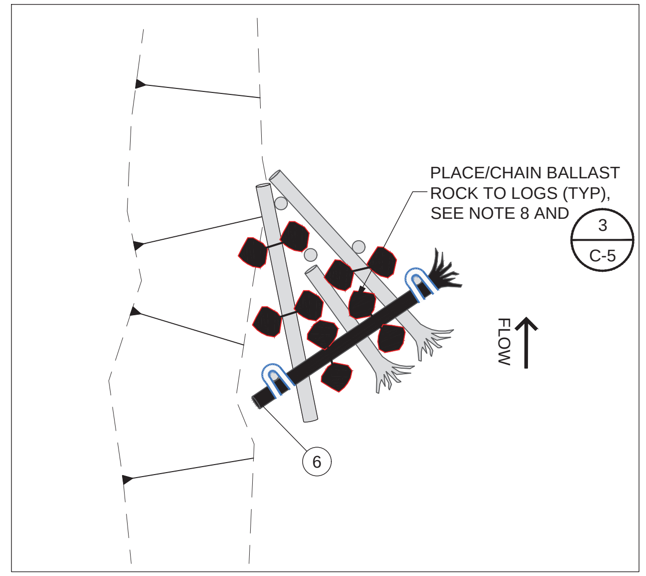

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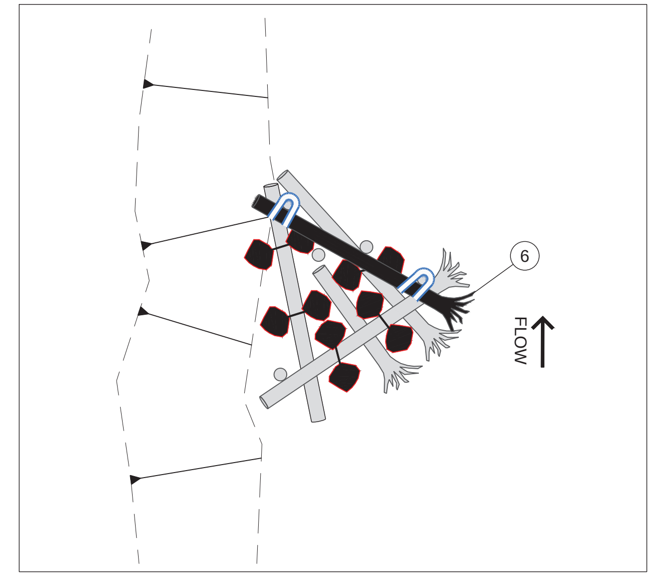

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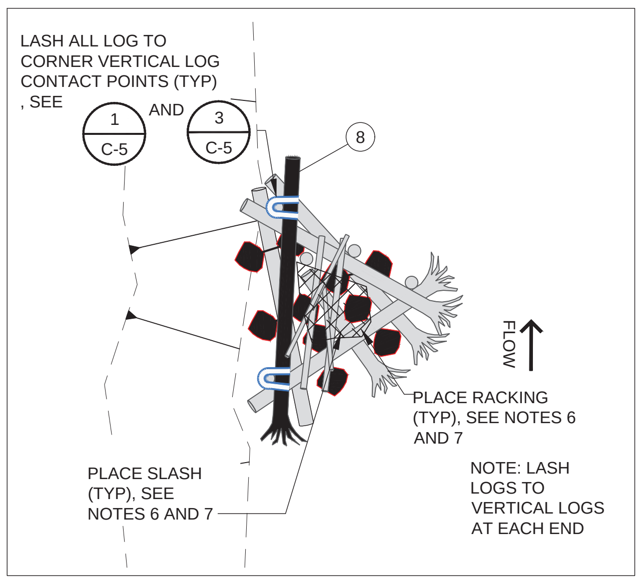

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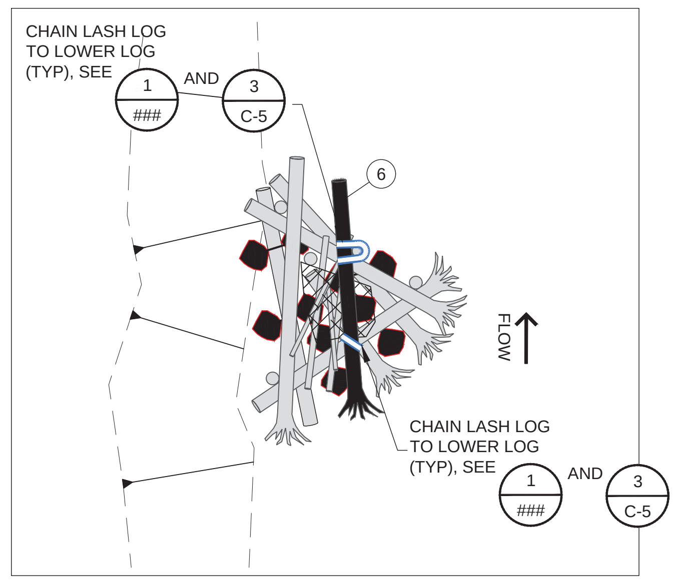

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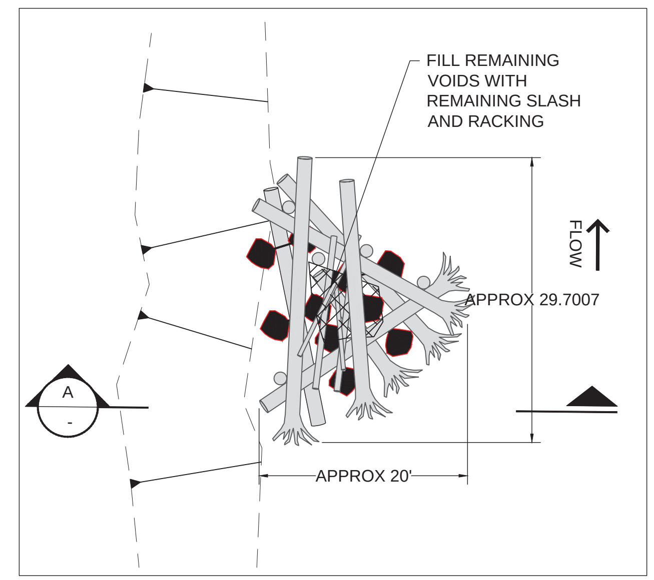


COMPLETE

LEGEND:

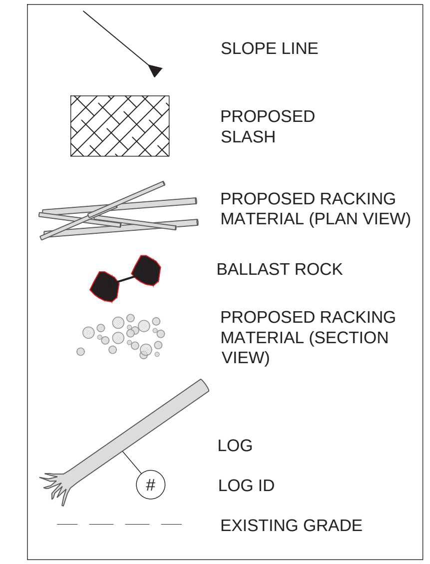


TABLE - RACKSTER SLASH SCHEDULE

	QUANTITY/ STRUCTURE (CY)
SLASH	30

TABLE - RACKSTER RACKING SCHEDULE

	QUANTITY/ STRUCTURE
RACKING LOGS	40-50

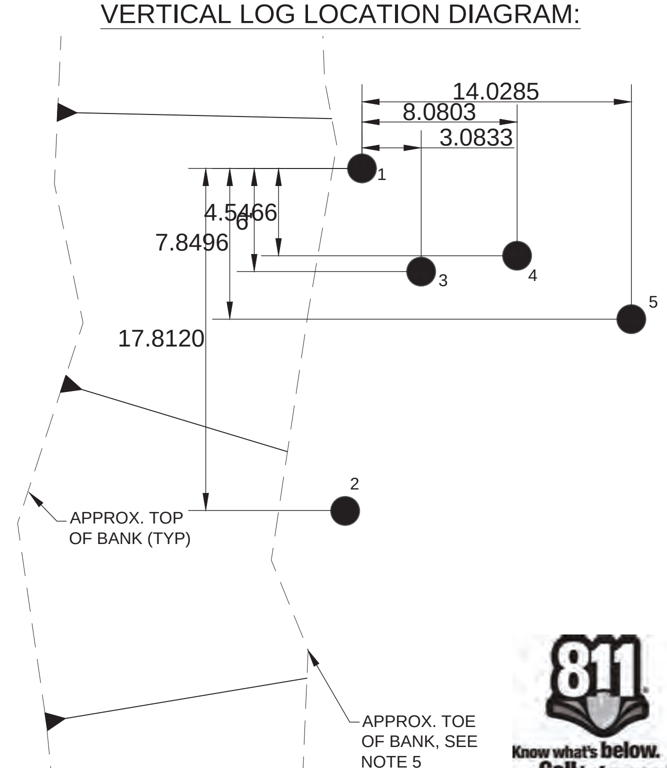
TABLE - RACKSTER ROCK SCHEDULE

	WEIGHT (TONS)	QUANTITY/ STRUCTURE
BALLAST ROCKS	2	10

TABLE - RACKSTER LOG SCHEDULE:

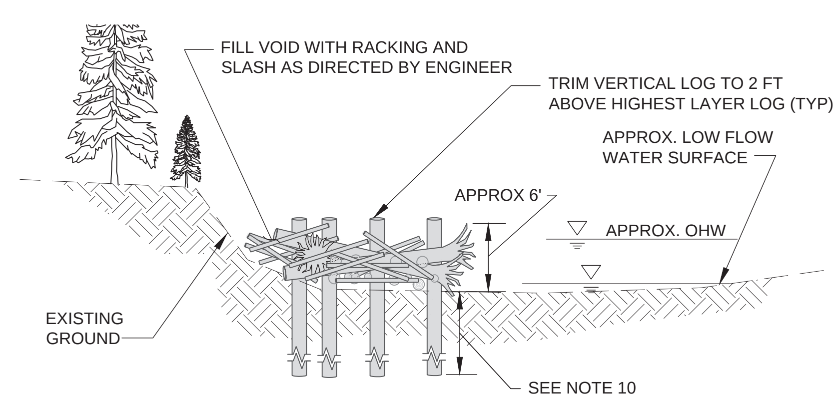
LOG ID	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	QUANTITY/STRUCTURE
2	24	15	YES	1
5	24	25	NO	1
6	24	25	YES	4
8	18-24	30	YES	1
			TOTAL:	7 TOTAL
VERTICAL LOG #	24	20	NO	5
			TOTAL:	12 PER STRUCTURE

VERTICAL LOG LOCATION DIAGRAM:



NOTES:

1. 2 PILE LOCATIONS PER RACKSTER SHALL BE STAKED BY ENGINEER.
2. EXCAVATION SPOILS SHALL BE STOCKPILED TO ALLOW LOG LAYER PLACEMENT AND CONSTRUCTION ACCESS.
3. LOG MATERIALS SHALL BE PLACED AT THE LOCATIONS AND ELEVATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER OR OWNER.
4. TRIM LOGS AS REQUIRED.
5. TOE OF BANK VARIES PER EACH RACKSTER.
6. SLASH AND RACKING TO FILL VOIDS BETWEEN LOG LAYERS. SEQUENCING OF SLASH PLACEMENT MAY NEED TO BE MODIFIED FOR LASHING. SUBSEQUENT LOG LAYERS SHALL COMPRESS SLASH AND RACKING PLACED IN PREVIOUS LAYERS.
7. RACKING PLACEMENT SHALL BE COORDINATED WITH LOG LAYER PLACEMENT AND SLASH PLACEMENT TO ENSURE LOG MEMBERS EXTEND THROUGH AND BIND RACKING MEMBERS AND RACKING MEMBERS EXTEND THROUGH AND BIND SLASH MATERIAL.
8. PLACE BALLAST ROCKS AS LOW WITHIN THE ELJ AS POSSIBLE AND ENSURE CHAIN BETWEEN BALLAST ROCKS HAS NO SLACK.
9. AUGMENT OR DELETE ROCK QUANTITIES AS NEEDED TO MAINTAIN AN ELJ ROCK BALLAST OF 20 TONS MINIMUM.
10. ENGINEER SHALL STAKE 2 VERTICAL LOG LOCATIONS FOR RACKSTER BASED ON APPROX 10' TO THE RELATIVE DEPTH TO THE ADJACENT CHANNEL BOTTOM, DEPTH SHALL NOT EXCEED 15' BELOW BASE FLOW WATER SURFACE. CONTRACTOR SHALL MARK DEPTH OF BURIAL LOCATION ON ALL VERTICAL LOGS PRIOR TO PLACEMENT WITH BLAZE ORANGE MARKING PAINT.
11. CONTRACTOR SHALL EXPECT FIELD FITTING
12. RACKING, SLASH, AND LASHINGS ONLY SHOWN IN LAYERS WHERE PLACEMENT OCCURS FOR CLARITY.
13. ALL LOG TO LOG LASHING SHALL BE 1/2"Ø GRADE 43 NATURAL FINISH CHAIN UNLESS OTHERWISE SPECIFIED IN LAYER PLAN. BOULDER TO LOG LASHING SHALL BE 1/2"Ø GRADE 43 NATURAL FINISH CHAIN. SEE SHEET ### AND C-5 FOR LASHING TYPES AND CONDITIONS.
14. ALL CONNECTING HARDWARE SHALL HAVE A RATED BREAKING LOAD LIMIT OF EQUAL OR GREATER STRENGTH THAN CHAIN. SHACKLES SHALL BE SAFETY SHACKLES AND THREADS SHALL BE MARRED TO PREVENT REMOVAL OF SHACKLES.



RACKSTER SECTION (A / -)

SCALE: 1:10

Know what's below. Call before you dig. 811

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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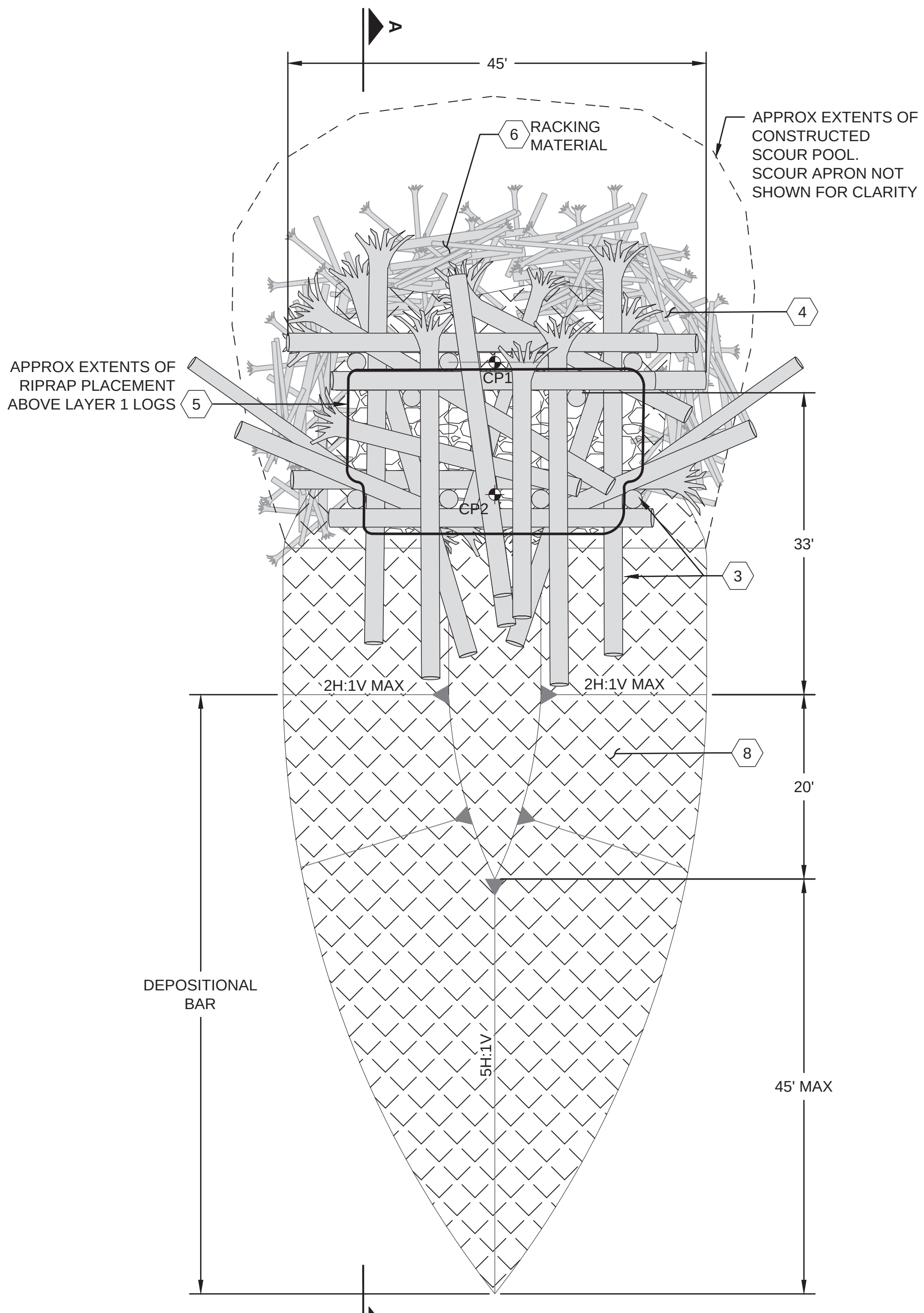
DRAFT

DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

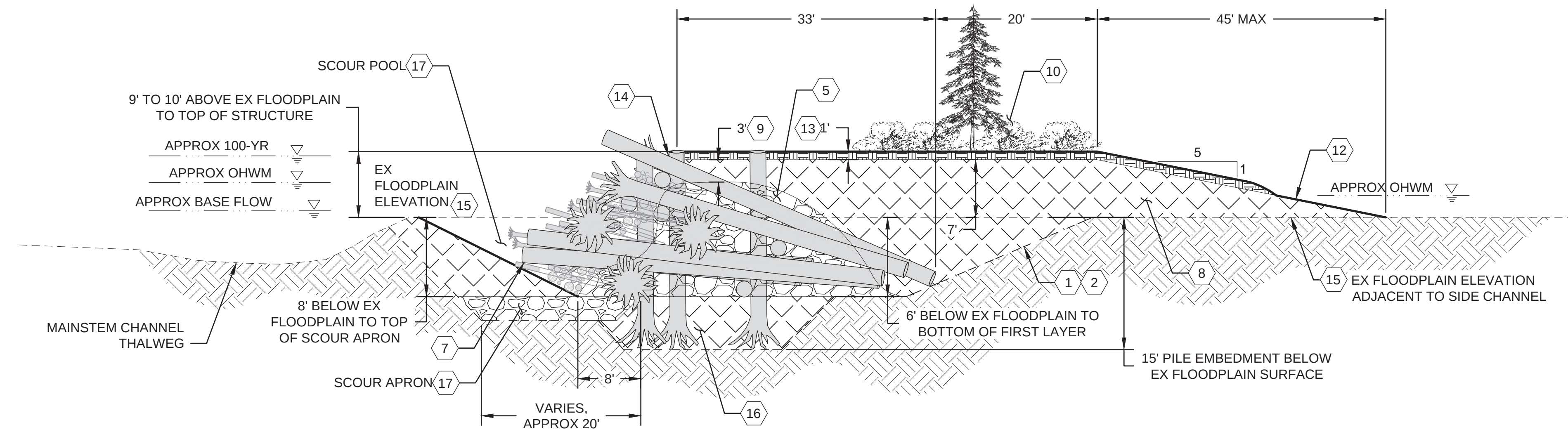
SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 3 MEDIUM LEFT BANK ELS

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.03
SHEET NO: 6 OF 12



PLAN



SECTION

KEYNOTES

1. APPROXIMATE STRUCTURE EXCAVATION LIMITS.
2. EXCAVATED SIDE SLOPE AT DOWNSTREAM END OF STRUCTURE VARIES BASED ON CONSTRUCTION ACCESS NEEDS.
3. PLACE PILES AND KEY MEMBERS ACCORDING TO STRUCTURE LAYERING PLAN.
4. SMALL WOODY DEBRIS AND SLASH EMBEDDED INTO FLANKS OF STRUCTURES IN AND AROUND INTERFACE OF KEY LOGS AND RACKING LOGS PRIOR TO BACKFILLING, EXTENDING FROM BASE OF STRUCTURE TO 3-FEET ABOVE EXISTING GRADE.
5. COORDINATE WITH ENGINEER PRIOR TO PLACING IMPORTED HEAVY LOOSE RIPRAP AND SIDE CHANNEL EXCAVATION SPOILS FOR LOG BALLAST.
6. COORDINATE WITH ENGINEER PRIOR TO PLACING RACKING LOGS.
7. LAYERS 1, 2, 3, AND 4 SHALL EXTEND THROUGH RACKING MATERIAL.
8. CONSTRUCT DEPOSITIONAL BAR WITH ON SITE EXCAVATED ALLUVIUM. DEPOSITIONAL BAR SIZE VARIES AS DIRECTED BY ENGINEER. CONSTRUCT FLANKS OF STRUCTURE AND DEPOSTIONAL BAR WITH NATIVE ALLUVIUM BACKFILL MATERIAL ACCORDING TO THE SLOPE SHOWN ON THESE DETAILS.
9. MAINTAIN A MINIMUM DEPTH OF 3-FEET OF ALLUVIUM BACKFILL MATERIAL OVER TOP OF IMPORTED BALLAST MATERIAL.
10. PLANTING TOP OF ELS TO BE COMPLETED BY OTHERS.
11. DO NOT BACKFILL UPSTREAM OF STRUCTURE. LEAVE AS A POOL.
12. ADJUST FINAL GRADE OF DEPOSITIONAL BAR ON DOWNSTREAM SIDE OF STRUCTURE AS NEEDED TO PLACE ALL EXCESS ALLUVIUM.
13. PLACE 12-INCHES OF TOPSOIL AND 2-INCHES OF MULCH ABOVE OHWM AS DIRECTED BY ENGINEER.
14. PLACE SALVAGED BRUSH ALONG EDGE OF STRUCTURE BETWEEN SOIL AND RACKING LOGS TO PREVENT BLEEDING SOIL FROM THE STRUCTURE. PLACE ADDITIONAL RACKING LOGS AND SLASH ABOVE FINAL LAYER PER DIRECTION OF ENGINEER.
15. CONTRACTOR SHALL DETERMINE EXCAVATION DEPTH AND STRUCTURE HEIGHT BASED ON EXISTING RIVER BED AND FLOODPLAIN ELEVATION.
16. LOCALLY EXCAVATE FROM BOTTOM OF STRUCTURE EXCAVATION TO ACHIEVE PILE EMBEDMENT SHOWN. PLACE PILE LOG ROOTWAD ON BOTTOM OF HOLE, BACKFILL WITH NATIVE ALLUVIUM AND COMPACT USING BACKSIDE OF EXCAVATOR BUCKET.
17. CONSTRUCT A 45-FOOT WIDE SCOUR APRON ALONG UPSTREAM FACE OF ELS TO DIMENSIONS SHOWN USING THE LARGEST EXCAVATED BOULDERS AND COBBLES AS DIRECTED BY ENGINEER. NO IMPORT MATERIALS REQUIRED.
18. CONNECT ELS SCOUR POOL TO EXCAVATION OF BOULDER AND COBBLE BAR AT INLET TO SIDE CHANNEL. EXTENTS OF BAR EXCAVATION SHOWN IS APPROXIMATE. COORDINATE WITH ENGINEER PRIOR TO EXCAVATING BAR AND ELS CONSTRUCTION. EXTENTS AND DEPTH OF BAR EXCAVATION SHALL BE VERIFIED BY THE ENGINEER. USE BAR SPOILS AS LOG BALLAST MATERIAL AND DEPOSITIONAL BAR CONSTRUCTION AS DIRECTED BY THE ENGINEER.
19. PROTECT EXISTING TREES FROM DAMAGE ALONG RIGHT BANK OF SIDE CHANNEL DURING CONSTRUCTION ACTIVITIES.

CONSTRUCTION QUANTITIES PER ELS:

HEAVY LOOSE RIPRAP, EXISTING RIPRAP, CONCRETE DEBRIS, AND CHANNEL ARMOR MATERIAL	QTY
LOG BALLAST	156 CY
SCOUR APRON	100 CY

DETAIL - TYPE 4 ELS

SCALE: NTS

1 VAR

CALL 811 BEFORE YOU DIG

CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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DRAFT

DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER

SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

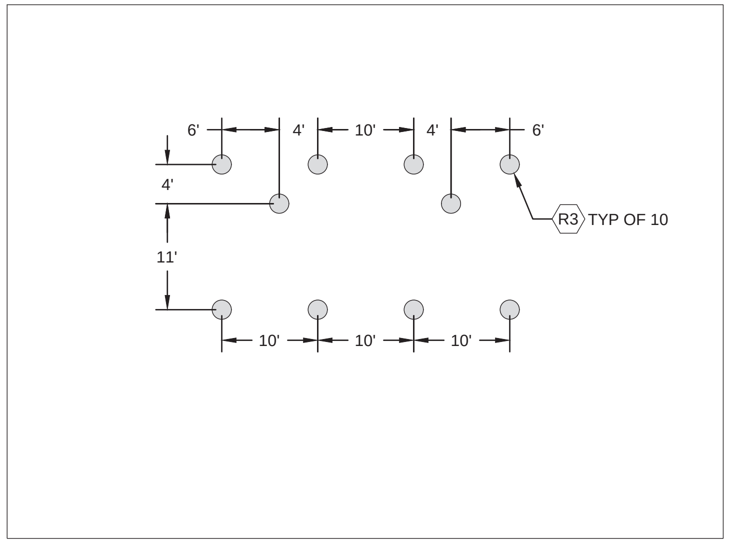
TYPE 4 LARGE MID-CHANNEL ELS

DATE: APRIL 2024

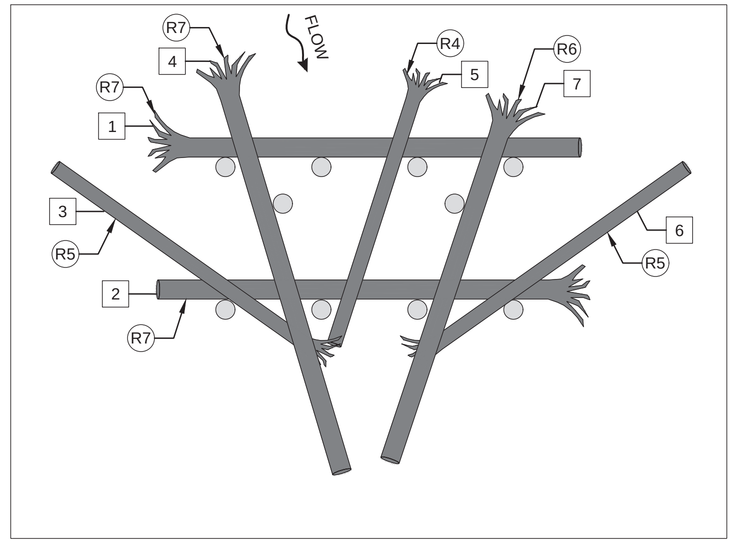
PROJECT NO: 14-05790-000

DRAWING NO: C1.04

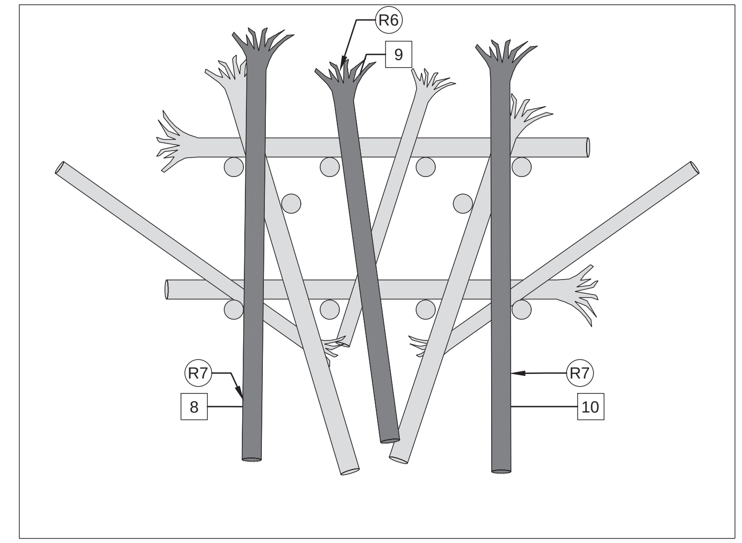
SHEET NO: 7 OF 12



PILE LAYER



LAYER 1



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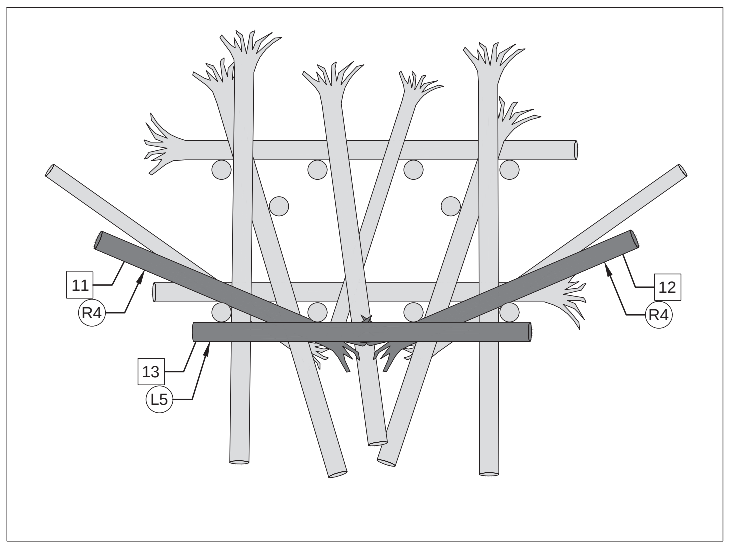

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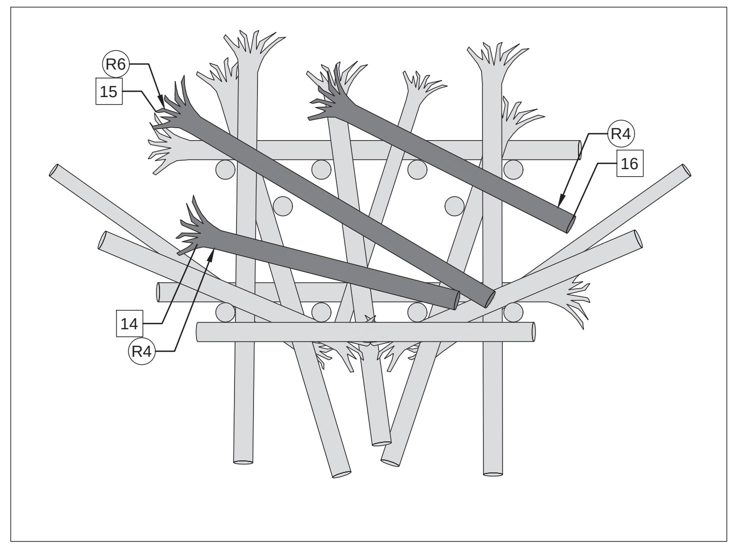

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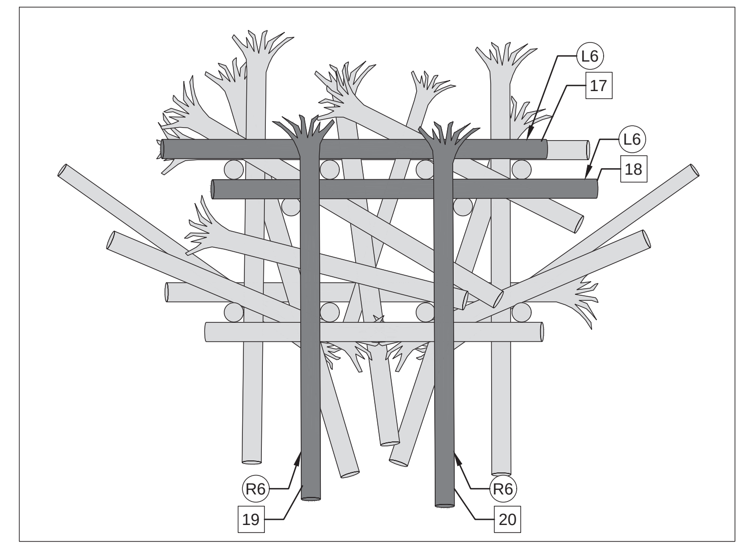

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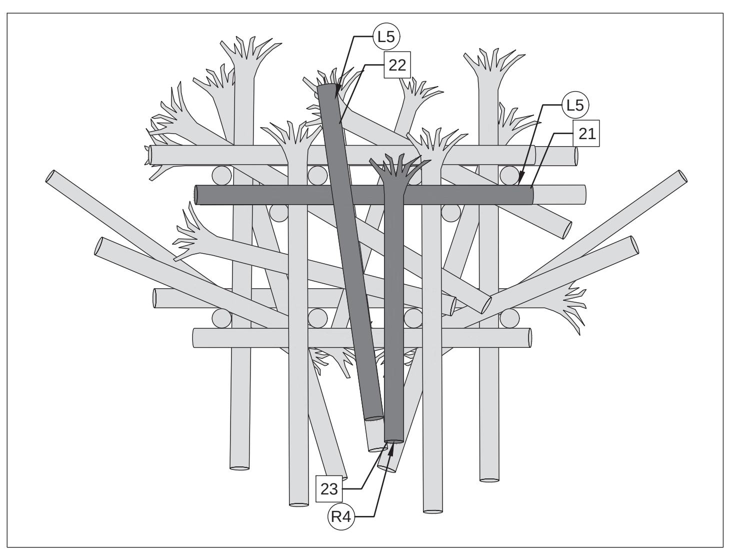

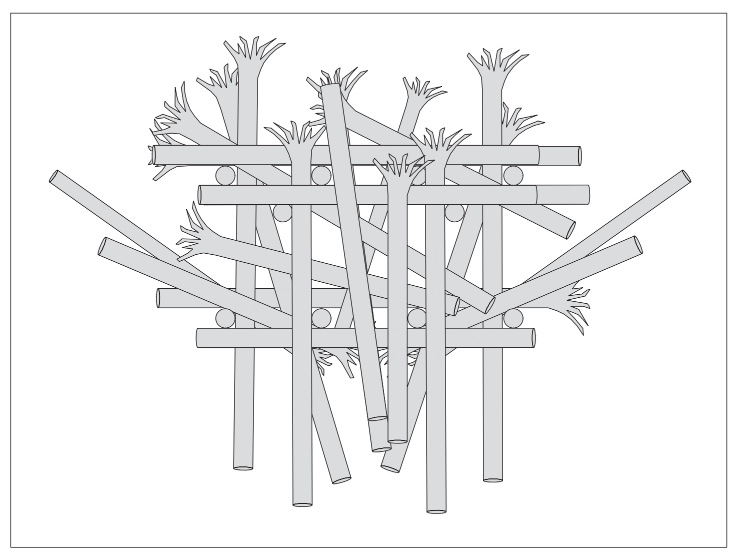

GENERAL NOTES:

1. FINAL STRUCTURE LOCATION AND ORIENTATION SHALL BE FIELD VERIFIED BY THE ENGINEER PRIOR TO THE CONTRACTOR STAKING PILE LOCATIONS.
2. PILE LOCATIONS SHALL BE STAKED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER PRIOR TO PILE INSTALLATION.
3. PILE LOCATIONS ARE SYMMETRICAL ABOUT THE STRUCTURE CONTROL POINT.
4. PILE LOCATIONS SHALL BE BASED ON THE LOCATION OF THE STRUCTURE CONTROL POINT AND SHALL BE WITHIN 6 INCHES OF THE LOCATION SHOWN ON THE DRAWINGS.
5. LOG MATERIALS SHALL BE PLACED AT THE LOCATIONS, ELEVATIONS AND ORIENTATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER.
6. TRIM LOGS TO FIT AS REQUIRED.
7. TRIM PILES A MINIMUM OF 18 INCHES AND A MAXIMUM OF 24 INCHES ABOVE FINAL GRADE.
8. EXCAVATION LIMITS VARY DEPENDING ON THE LOCAL SOIL CONDITIONS AND THE CONSTRUCTION TECHNIQUES EMPLOYED.
9. INSTALL LOGS, RACKING LOGS, SLASH, IMPORTED BALLAST MATERIAL AND NATIVE BACKFILL MATERIAL AS SHOWN ON THE PLANS AND AS DIRECTED BY THE ENGINEER.
10. SEE DRAWING C-5 FOR STRUCTURE CONTROL POINT COORDINATES.
11. RACKING NOT SHOWN FOR CLARITY. PLACE RACKING ALONG UPSTREAM FACE AND ALONG THE SIDES OF THE ELS AS SHOWN ON THE DETAIL SHEET. RACKING SHALL BE PLACED PARALLEL TO AND BETWEEN PILES EXTENDING OUT FROM THE STRUCTURE. ALL RACKING SHALL BE PLACED TO CREATE AN INTERLOCKING MATRIX OF LOGS SECURED BETWEEN PILES AND KEY LOGS. PLACE SLASH AT SAME TIME AS RACKING TO FILL VOIDS BETWEEN RACKING.

ELS CONSTRUCTION SEQUENCE NOTES:

1. INSTALL PILES TO SPECIFIED DEPTH.
2. INSTALL LAYER 1 LOGS, RACKING LOGS, SLASH AND FIRST LIFT OF IMPORTED OF BALLAST MATERIAL.
3. FILL ALL VOIDS IN BALLAST MATERIAL WITH NATIVE BACKFILL MATERIAL.
4. INSTALL LAYER 2 AND LAYER 3 LOGS, RACKING LOGS, SLASH AND SECOND LIFT OF IMPORTED BALLAST MATERIAL.
5. FILL ALL VOIDS IN BALLAST MATERIAL WITH NATIVE BACKFILL MATERIAL.
6. INSTALL LAYER 4 AND LAYER 5 LOGS, RACKING LOGS, SLASH AND THIRD LIFT OF IMPORTED BALLAST MATERIAL.
7. FILL ALL VOIDS IN BALLAST MATERIAL WITH NATIVE BACKFILL MATERIAL.
8. INSTALL LAYER 6 LOGS RACKING LOGS, SLASH AND FOURTH LIFT OF IMPORTED BALLAST MATERIAL.
9. COMPLETELY BACKFILL REMAINDER OF STRUCTURE INTERIOR AND CONSTRUCT DEPOSITIONAL BAR WITH NATIVE BACKFILL MATERIAL TO GRADE AND EXTENTS SHOWN ON STRUCTURE PLAN.
10. PLACE TOPSOIL AND MULCH OVER TOP OF STRUCTURE AS SHOWN ON STRUCTURE PLAN.

LOG SCHEDULE - TYPE 4 ELS:

LOG ID #	DIAMETER (IN)	LENGTH (FT)	ROOTWAD	QUANTITY/ STRUCTURE
R3	24	25	YES	10
R4	24	30	YES	6
L5	24	35	NO	3
R5	24	35	YES	2
L6	24	40	NO	2
R6	24	40	YES	5
R7	24	45	YES	5
RACKING	4-16	15-30		100
SLASH	-	-		100 CY

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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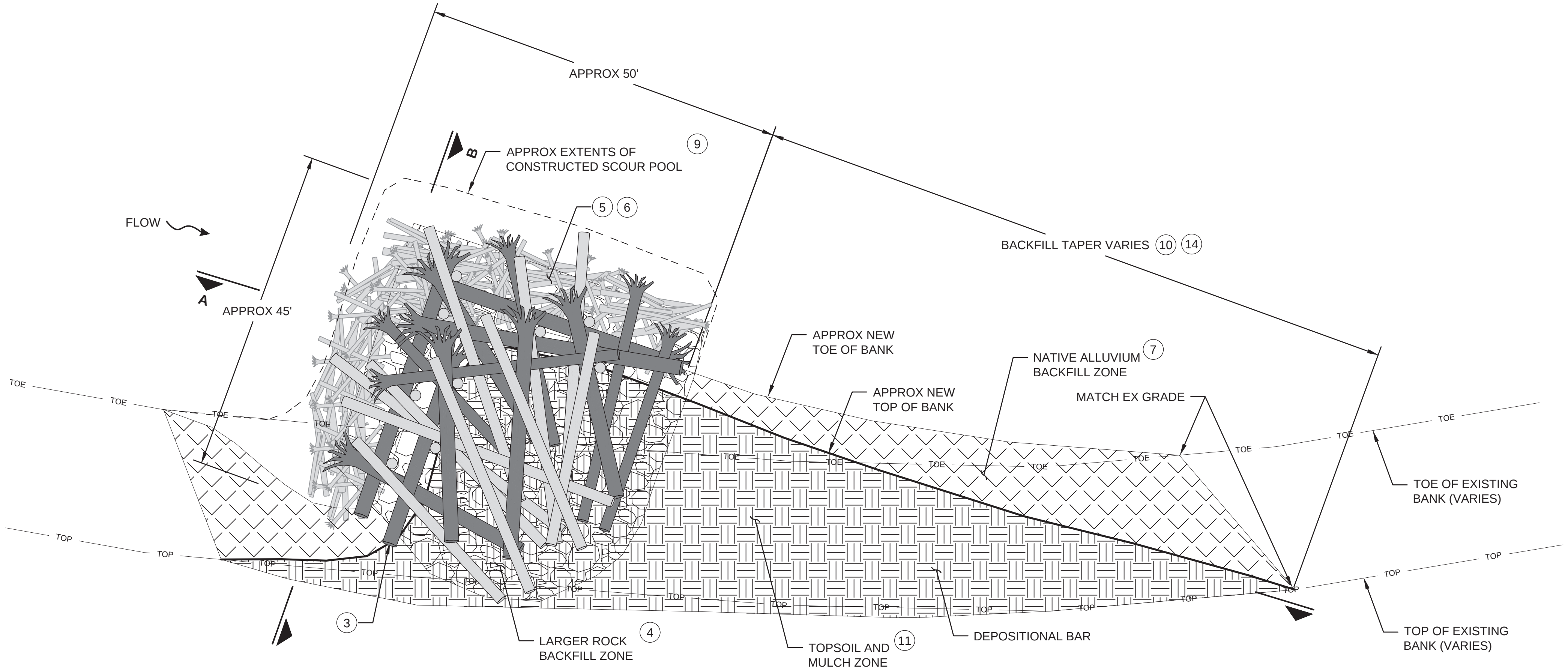
DESIGNED: - | DRAWN: -
DESIGNED: - | DRAWN: -
DESIGNED: - | CHECKED: -
SCALE: AS NOTED | APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 4 LARGE MID-CHANNEL ELS LAYERING PLAN

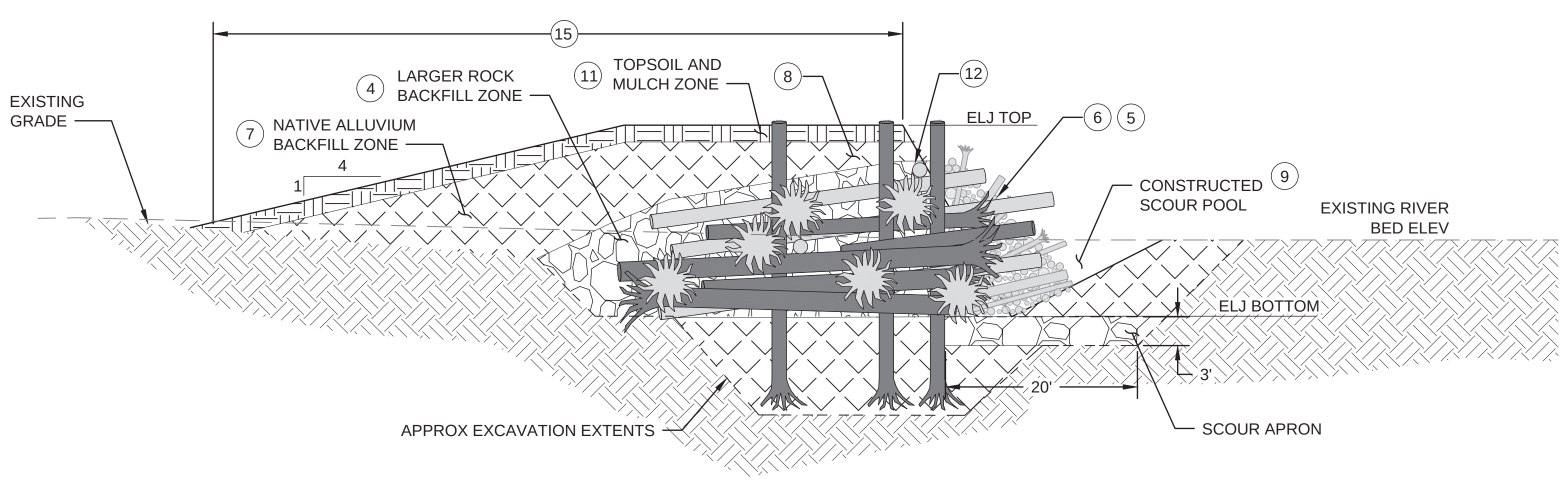
DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.05
SHEET NO: 8 OF 12



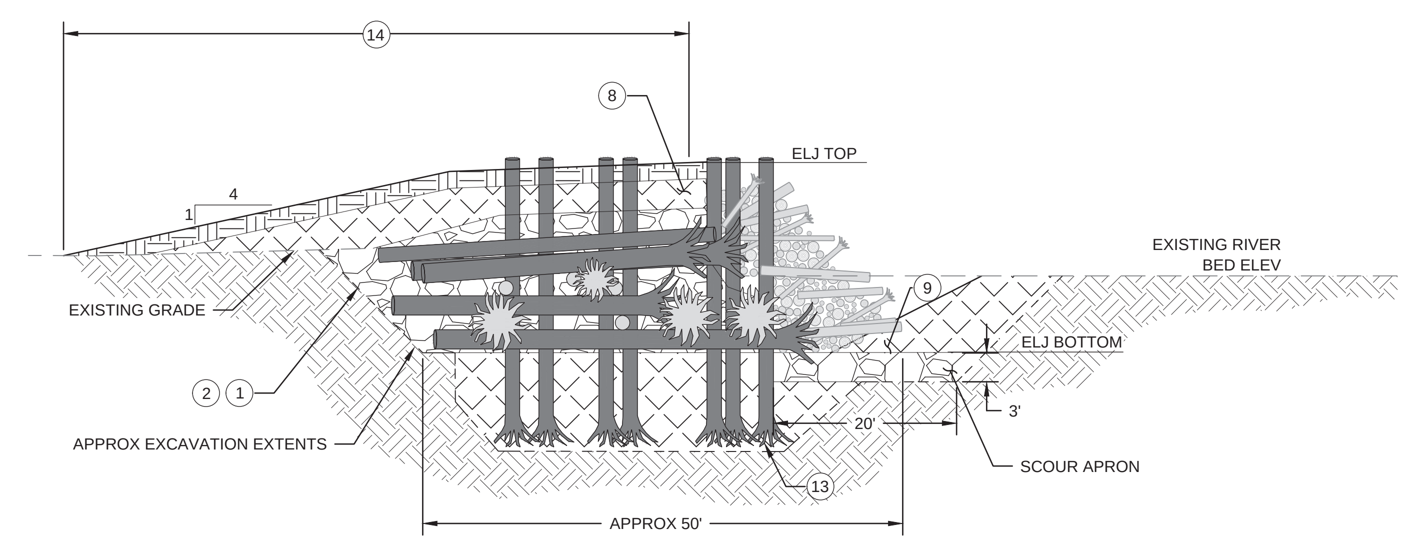
PLAN - RIGHT BANK DEFLECTOR ELS
SCALE: NTS
1
VAR

CONSTRUCTION KEY NOTES:

1. APPROXIMATE ELJ EXCAVATION LIMITS.
2. EXCAVATION SIDE SLOPES WILL VARY BASED ON CONTRACTORS MEANS AND METHODS.
3. PLACE PILES AND KEY MEMBERS ACCORDING TO ELJ LAYERING PLAN.
4. COORDINATE WITH WITH ENGINEER BEFORE PLACING LARGE ROCK AND NATIVE ALLUVIUM BACKFILL MATERIAL.
5. COORDINATE WITH ENGINEER BEFORE PLACING RACKING LOGS AND SLASH MATERIAL.
6. RACKING LOG SHALL EXTEND THROUGH LOG LAYERS 1, 2, 3, 4 AND 5.
7. CONSTRUCT DEPOSITIONAL BAR WITH NATIVE ALLUVIUM THAT IS EXCAVATED FOR SIDE CHANNEL AND ELJ CONSTRUCTION AND WITH ALLUVIUM EXACAVATED FROM SCOUR POOLS AND FROM GRAVEL BARS. CONSTRUCT FLANKS OF ELJ AND DEPOSTIONAL BAR WITH NATIVE ALLUVIUM BACKFILL MATERIAL ACCORDING TO THE SLOPE SHOWN ON THESE DETAILS.
8. MAINTAIN A MINIMUM DEPTH OF 3-FEET OF NATIVE ALLUVIUM BACKFILL MATERIAL OVER TOP OF INTERNAL LARGE ROCK BACKFILL MATERIAL.
9. DO NOT BACKFILL UPSTREAM OF ELJ. LEAVE AS A POOL.
10. ADJUST FINAL GRADE ON BANK SIDE AND DOWNSTREAM SIDE OF ELJ AS NEEDED TO PLACE ALL NATIVE ALLUVIUM BACKFILL MATERIAL.
11. 3-INCHES OF BARK OR WOOD CHIP MULCH OVER 12 TO 18-INCHES OF TOPSOIL TYPE A TO BE PLACED AS DIRECTED BY ENGINEER.
12. PLACE SLASH MATERIAL AND SALVAGED BRUSH ALONG EDGE OF ELJ BETWEEN NATIVE ALLUVIUM BACKFILL MATERIAL AND RACKING LOGS.
13. TIMBER PILES SHALL BE DRIVEN OR PLACED INTO VERTICAL DRILLED ROCK SHAFTS THROUGH SEDIMENTARY BEDROCK AND EXISTING ALLUVIUM PER SPECIFICATION SECTION 6-05.
14. DIMENSION WILL VARY ALONG ELJ TO TRANSITION TO EXISTING GRADE BASED ON TOP OF BANK ELEVATION.



SECTION - RIGHT BANK DEFLECTOR ELS
SCALE: NTS
A
-



SECTION - RIGHT BANK DEFLECTOR ELS
SCALE: NTS
B
-

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH
AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 5 LARGE RIGHT BANK ELS

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.06
SHEET NO: 9 OF 12

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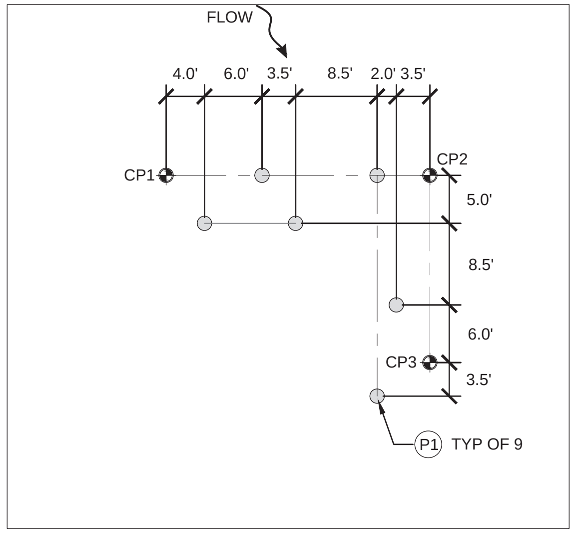
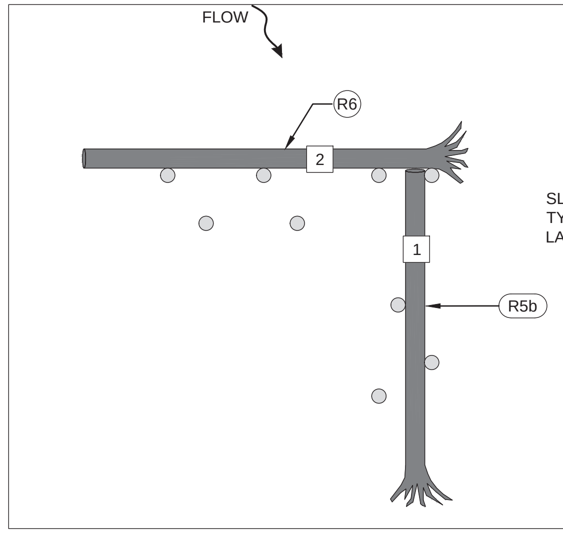


PILE LAYOUT



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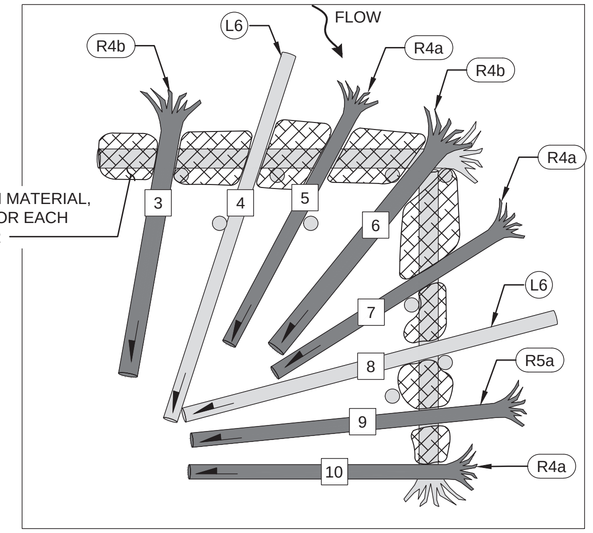

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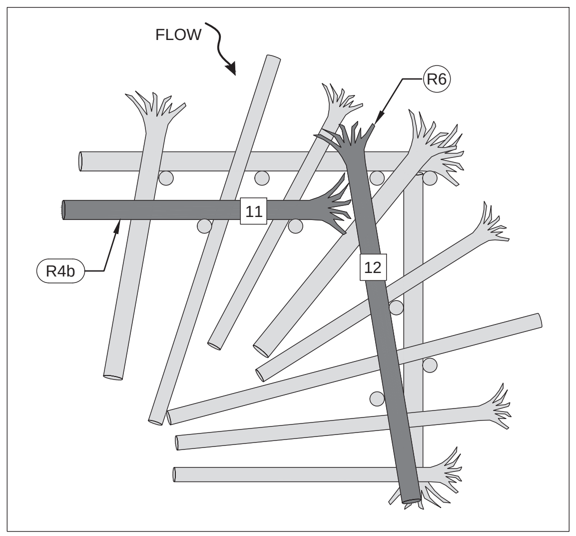

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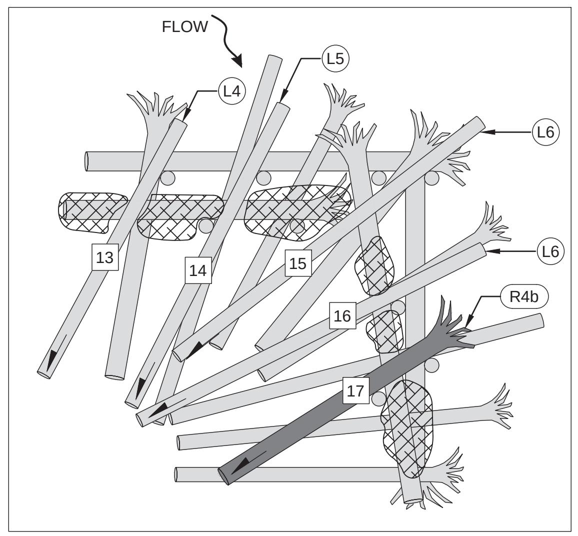

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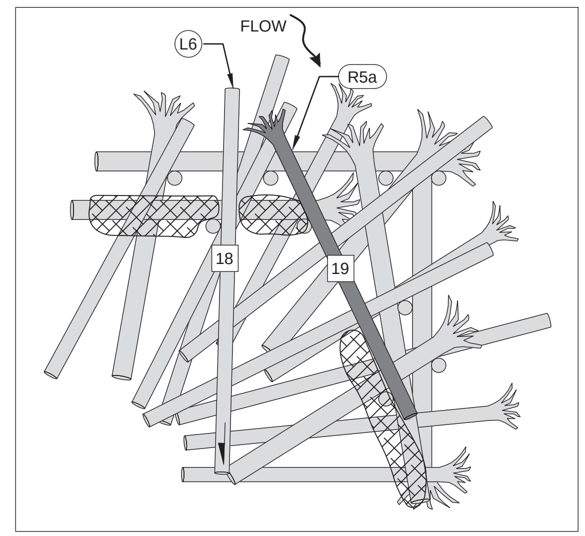

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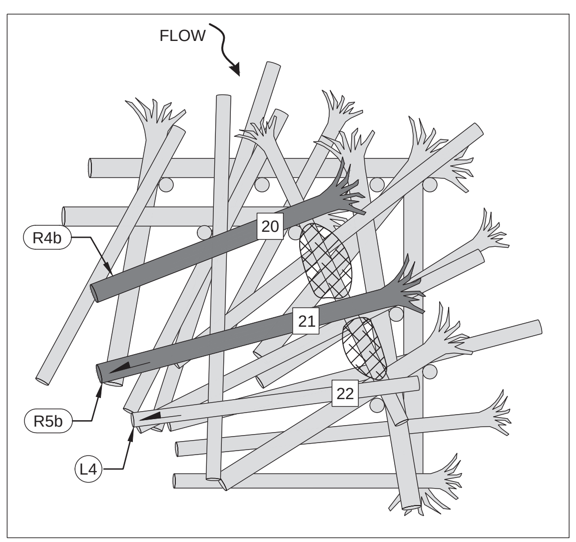

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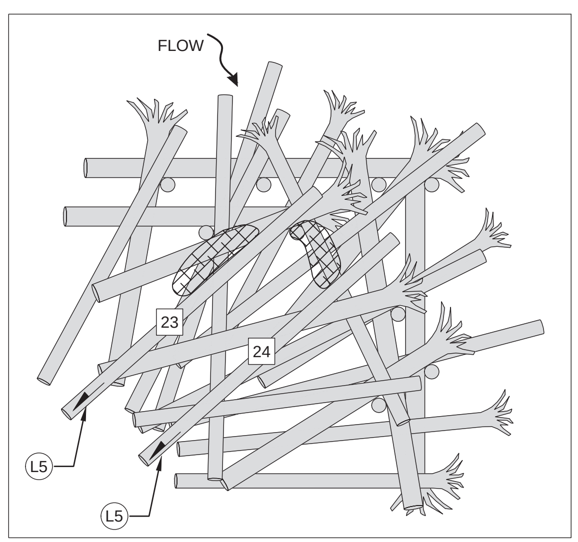

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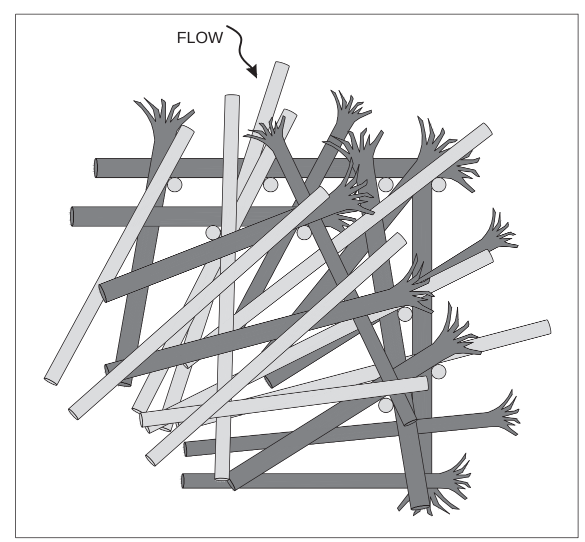

COMPLETE

GENERAL NOTES:

1. PILE LOCATIONS SHALL BE STAKED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER PRIOR TO PILE INSTALLATION.
2. FINAL ELJ LOCATION AND ORIENTATION SHALL BE FIELD VERIFIED BY THE ENGINEER AFTER THE CONTRACTOR STAKES THE PILE LOCATIONS.
3. PILE LOCATIONS ARE SYMMETRICAL ABOUT THE ELJ CONTROL POINT.
4. PILE LOCATIONS SHALL BE BASED ON THE LOCATION OF THE ELJ CONTROL POINT AND SHALL BE WITHIN 6 INCHES OF THE LOCATION SHOWN ON THE DRAWINGS.
5. LOG MATERIALS SHALL BE PLACED AT THE LOCATIONS, ELEVATIONS AND ORIENTATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER.
6. TRIM LOGS TO FIT AS REQUIRED.
7. TRIM PILES A MINIMUM OF 18 INCHES AND A MAXIMUM OF 24 INCHES ABOVE FINAL GRADE.
8. EXCAVATION LIMITS VARY DEPENDING ON THE LOCAL SOIL CONDITIONS AND THE CONSTRUCTION TECHNIQUES EMPLOYED.
9. INSTALL LOGS, RACKING LOGS, SLASH, IMPORTED BALLAST MATERIAL AND NATIVE BACKFILL MATERIAL AS SHOWN ON THE PLANS AND AS DIRECTED BY THE ENGINEER.
10. SEE DRAWING XX FOR ELJ CONTROL POINT COORDINATES.
11. RACKING LOGS NOT SHOWN FOR CLARITY. PLACE RACKING LOGS ALONG UPSTREAM FACE AND ALONG THE SIDES OF THE ELJ AS SHOWN ON DWG XX. RACKING LOGS SHALL BE PLACED PARALLEL TO AND BETWEEN PILES EXTENDING OUT FROM THE ELJ. ALL RACKING LOGS SHALL BE PLACED TO CREATE AN INTERLOCKING MATRIX OF LOGS SECURED BETWEEN PILES AND KEY LOGS. PLACE SLASH MATERIAL AT SAME TIME AS RACKING LOGS TO FILL VOIDS BETWEEN RACKING LOGS.

ELJ CONSTRUCTION SEQUENCE NOTES:

1. INSTALL PILES TO SPECIFIED DEPTH.
2. INSTALL LAYER 1 AND LAYER 2 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND FIRST LIFT OF LARGE ROCK BACKFILL MATERIAL.
4. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
5. INSTALL LAYER 3 AND LAYER 4 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND SECOND LIFT OF LARGE ROCK BACKFILL MATERIAL.
6. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
7. INSTALL LAYER 5 AND LAYER 6 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND THIRD LIFT OF LARGE ROCK BACKFILL MATERIAL.
8. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
9. INSTALL LAYER 7 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND FOURTH LIFT OF LARGE ROCK BACKFILL MATERIAL.
10. COMPLETELY BACKFILL REMAINDER OF ELJ INTERIOR AND CONSTRUCT DEPOSITIONAL BAR WITH NATIVE ALLUVIUM TO GRADE AND EXTENTS SHOWN ON ELJ PLAN.
11. PLACE TOPSOIL AND MULCH OVER TOP OF ELJ AS SHOWN ON ELJ PLAN.

LOG SCHEDULE - LEFT BANK DEFLECTOR ELS

LOG TYPE	MINIMUM DIAMETER (IN)	LENGTH (FT)	ROOTWAD	TOTAL QTY PER ELJ
P1	22-26	25	YES	9
R4a	18-22	30	YES	3
R4b	24-28	30	YES	5
R5a	18-22	35	YES	2
R5b	24-28	35	YES	2
R6	24-28	40	YES	2
L4	18-22	30	NO	2
L5	18-22	35	NO	3
L6	18-22	40	NO	5
RACKING	4-16	15-30	OPTIONAL	150
SLASH (LOOSE)	-	-	-	200 CY

LEGEND:

X# LOG IDENTIFIER

LOG PLACEMENT SEQUENCING ORDER

CONTROL POINT

CALL 811 BEFORE YOU DIG

CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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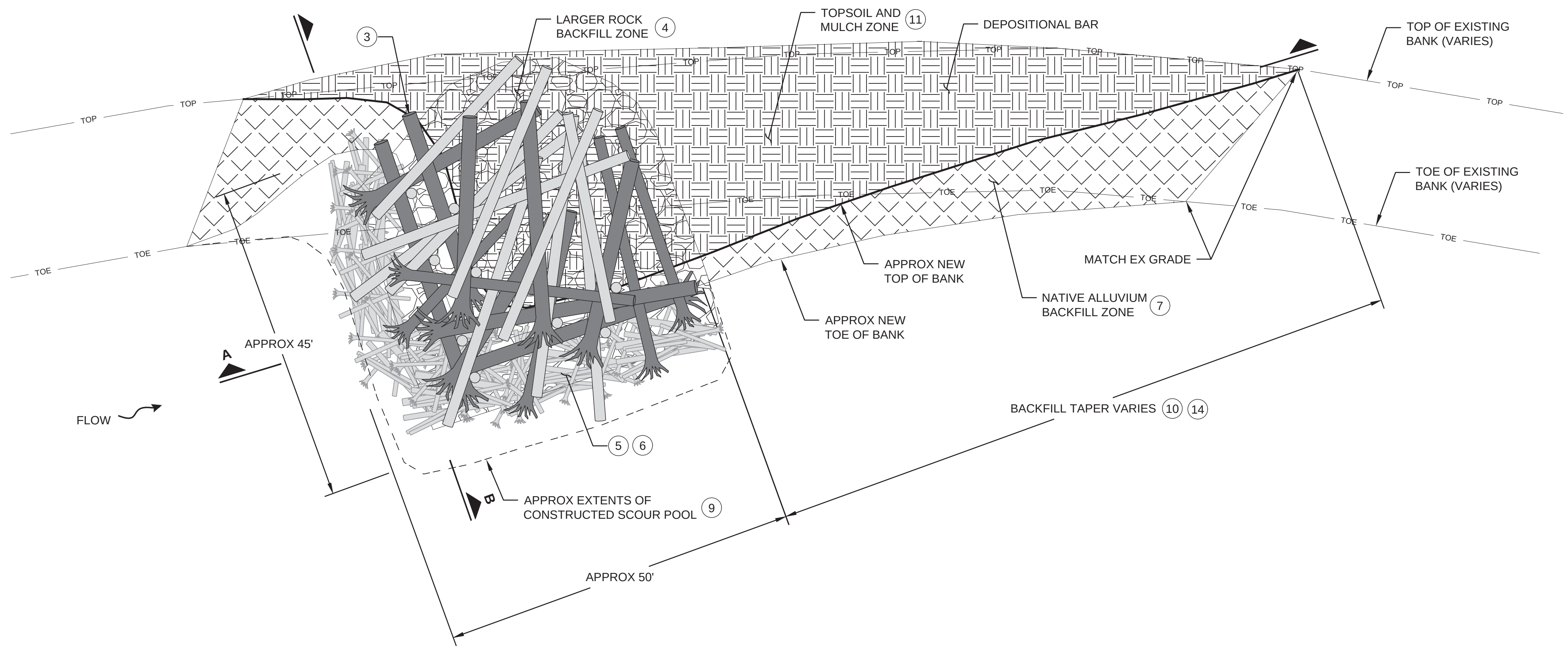
DESIGNED: -
DRAWN: -
DESIGNED: -
DRAWN: -
DESIGNED: -
CHECKED: -
SCALE: AS NOTED
APPROVED: -

SOUTH FORK NOOKSACK RIVER

SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 5 LARGE RIGHT BANK ELS LAYERING PLAN

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.07
SHEET NO: 10 OF 12



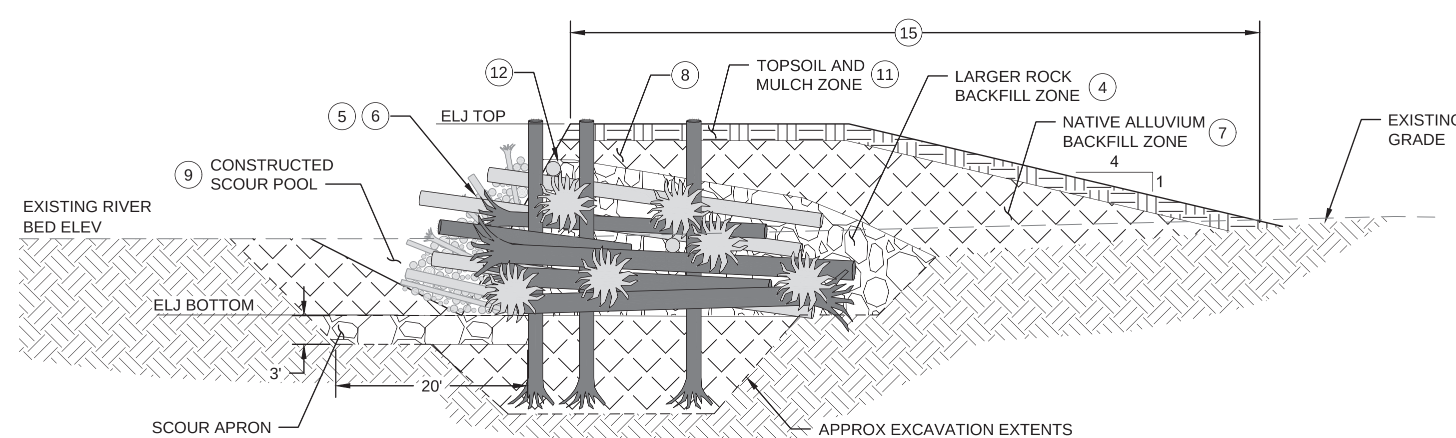
PLAN - LEFT BANK DEFLECTOR ELS

SCALE: NTS

1 / VAR

CONSTRUCTION KEY NOTES:

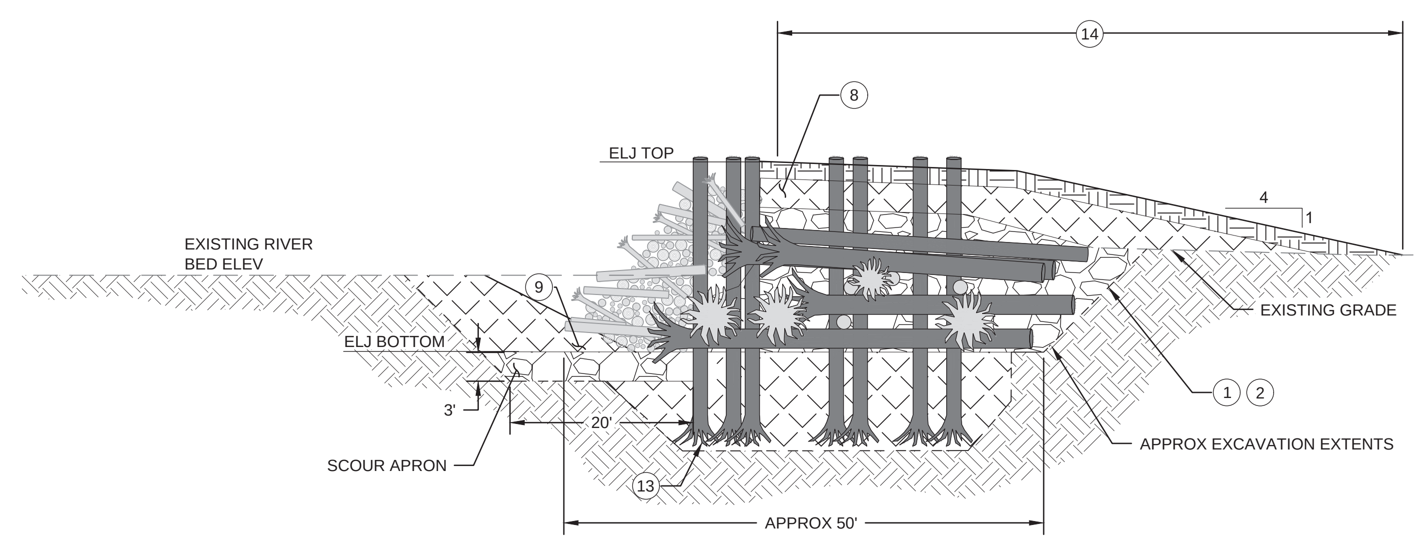
1. APPROXIMATE ELJ EXCAVATION LIMITS.
2. EXCAVATION SIDE SLOPES WILL VARY BASED ON CONTRACTORS MEANS AND METHODS.
3. PLACE PILES AND KEY MEMBERS ACCORDING TO ELJ LAYERING PLAN.
4. COORDINATE WITH WITH ENGINEER BEFORE PLACING LARGE ROCK AND NATIVE ALLUVIUM BACKFILL MATERIAL.
5. COORDINATE WITH ENGINEER BEFORE PLACING RACKING LOGS AND SLASH MATERIAL.
6. RACKING LOG SHALL EXTEND THROUGH LOG LAYERS 1, 2, 3, 4 AND 5.
7. CONSTRUCT DEPOSITIONAL BAR WITH NATIVE ALLUVIUM THAT IS EXCAVATED FOR SIDE CHANNEL AND ELJ CONSTRUCTION AND WITH ALLUVIUM EXACAVATED FROM SCOUR POOLS AND FROM GRAVEL BARS. CONSTRUCT FLANKS OF ELJ AND DEPOSTIONAL BAR WITH NATIVE ALLUVIUM BACKFILL MATERIAL ACCORDING TO THE SLOPE SHOWN ON THESE DETAILS.
8. MAINTAIN A MINIMUM DEPTH OF 3-FEET OF NATIVE ALLUVIUM BACKFILL MATERIAL OVER TOP OF INTERNAL LARGE ROCK BACKFILL MATERIAL.
9. DO NOT BACKFILL UPSTREAM OF ELJ. LEAVE AS A POOL.
10. ADJUST FINAL GRADE ON BANK SIDE AND DOWNSTREAM SIDE OF ELJ AS NEEDED TO PLACE ALL NATIVE ALLUVIUM BACKFILL MATERIAL.
11. 3-INCHES OF BARK OR WOOD CHIP MULCH OVER 12 TO 18-INCHES OF TOPSOIL TYPE A TO BE PLACED AS DIRECTED BY ENGINEER.
12. PLACE SLASH MATERIAL AND SALVAGED BRUSH ALONG EDGE OF ELJ BETWEEN NATIVE ALLUVIUM BACKFILL MATERIAL AND RACKING LOGS.
13. TIMBER PILES SHALL BE DRIVEN OR PLACED INTO VERTICAL DRILLED ROCK SHAFTS THROUGH SEDIMENTARY BEDROCK AND EXISTING ALLUVIUM PER SPECIFICATION SECTION 6-05.
14. DIMENSION WILL VARY ALONG ELJ TO TRANSITION TO EXISTING GRADE BASED ON TOP OF BANK ELEVATION.



SECTION - LEFT BANK DEFLECTOR ELS

SCALE: NTS

A / -



SECTION - LEFT BANK DEFLECTOR ELS

SCALE: NTS

B / -

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CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

HERRERA Science + Planning + Design herrerainc.com

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DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER

SKOOKUM/EDFRO RESTORATION PROJECT - PHASE 3

TYPE 5 LARGE LEFT BANK ELS

DATE: APRIL 2024

PROJECT NO: 14-05790-000

DRAWING NO: C1.08

SHEET NO: 11 OF 12

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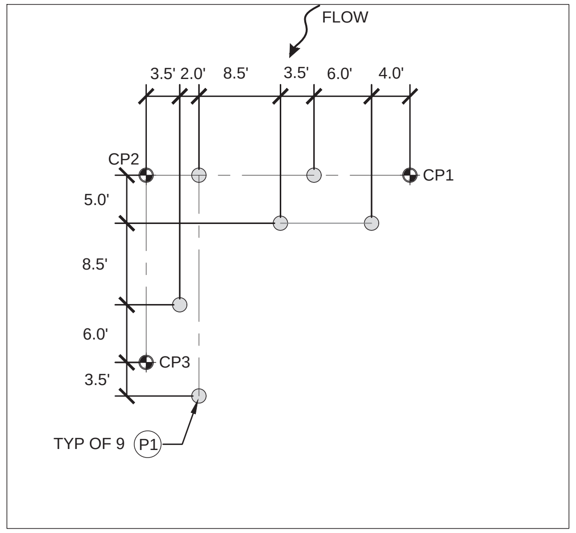
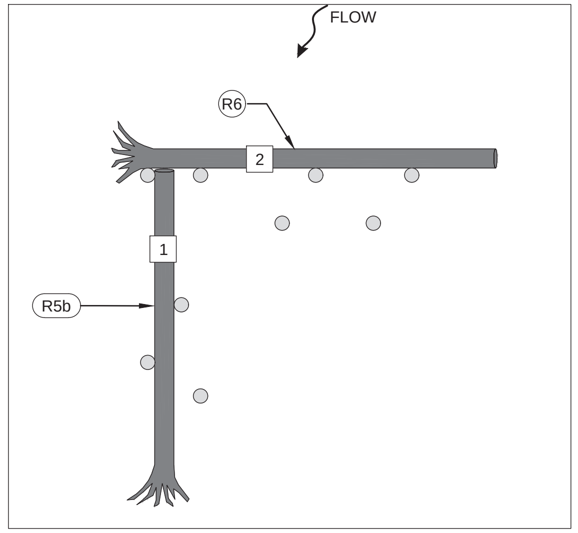


PILE LAYOUT



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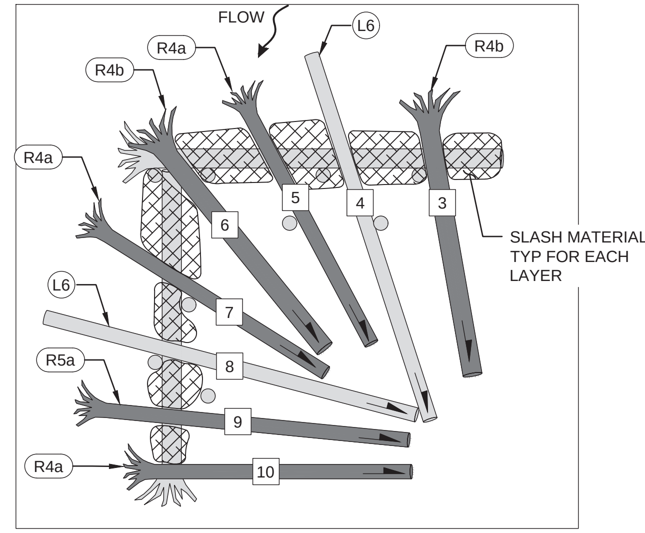

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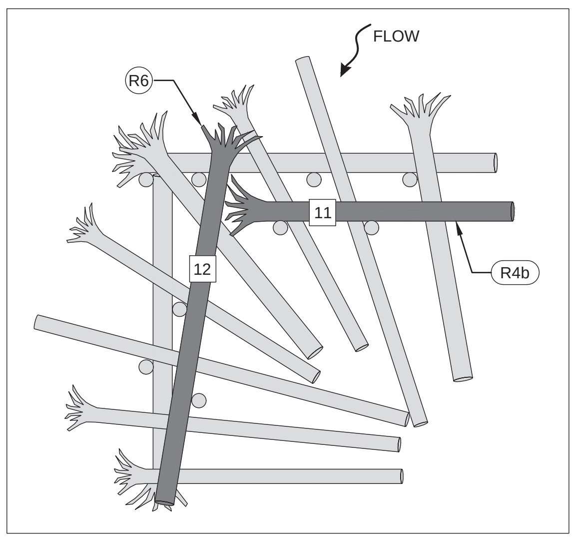

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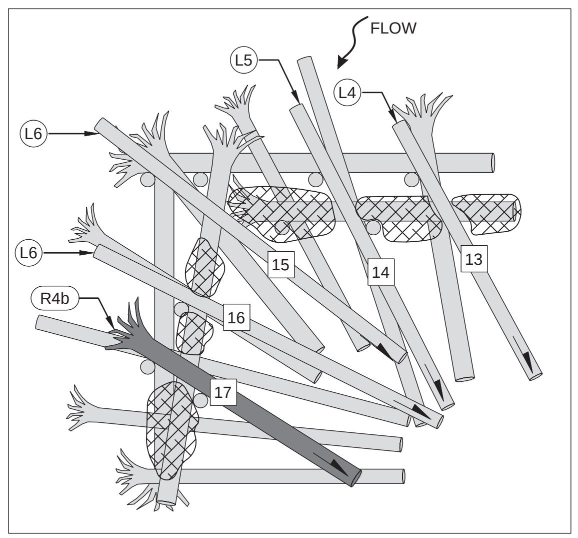

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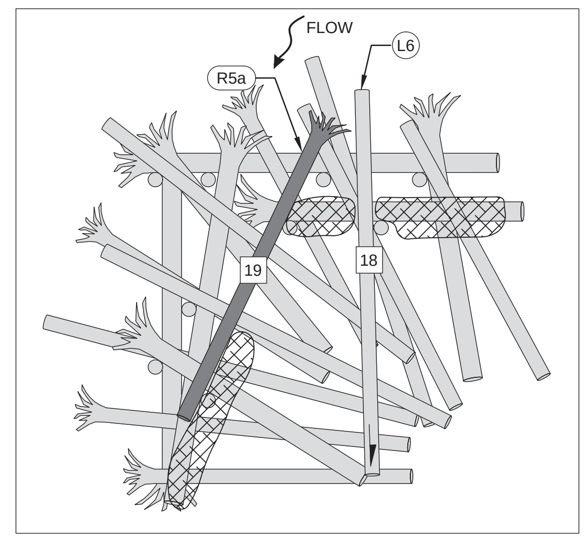

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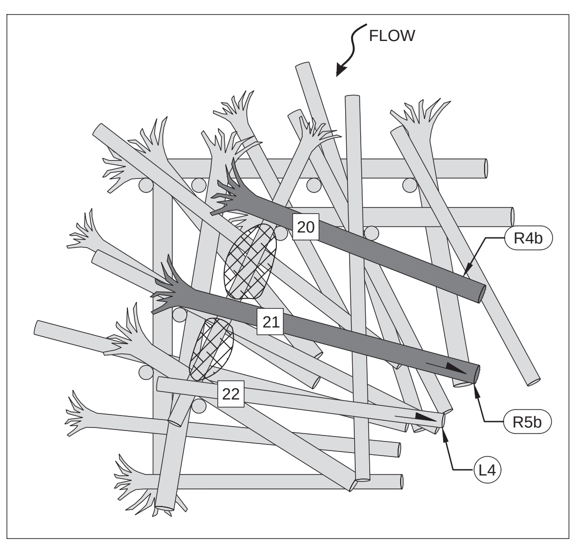

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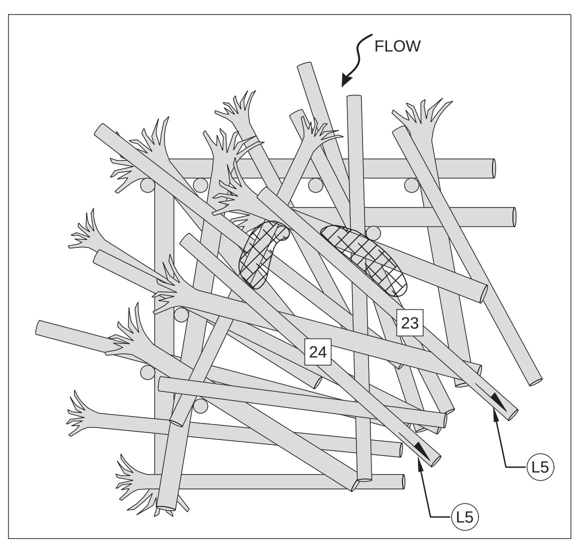

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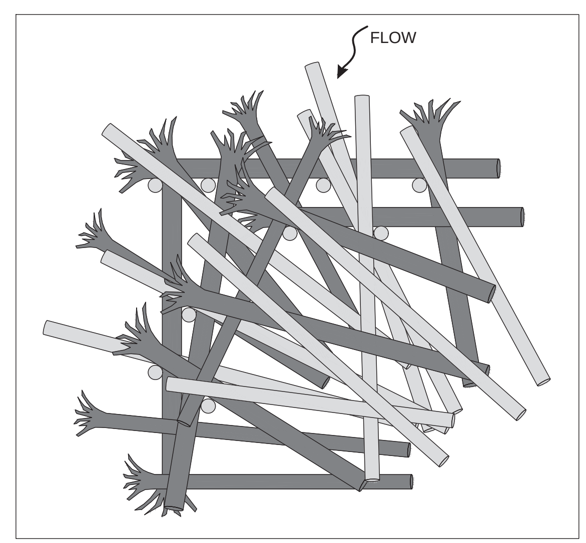

COMPLETE

GENERAL NOTES:

1. PILE LOCATIONS SHALL BE STAKED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER PRIOR TO PILE INSTALLATION.
2. FINAL ELJ LOCATION AND ORIENTATION SHALL BE FIELD VERIFIED BY THE ENGINEER AFTER THE CONTRACTOR STAKES THE PILE LOCATIONS.
3. PILE LOCATIONS ARE SYMMETRICAL ABOUT THE ELJ CONTROL POINT.
4. PILE LOCATIONS SHALL BE BASED ON THE LOCATION OF THE ELJ CONTROL POINT AND SHALL BE WITHIN 6 INCHES OF THE LOCATION SHOWN ON THE DRAWINGS.
5. LOG MATERIALS SHALL BE PLACED AT THE LOCATIONS, ELEVATIONS AND ORIENTATIONS SPECIFIED ON THE DRAWINGS OR AS DIRECTED BY THE ENGINEER.
6. TRIM LOGS TO FIT AS REQUIRED.
7. TRIM PILES A MINIMUM OF 18 INCHES AND A MAXIMUM OF 24 INCHES ABOVE FINAL GRADE.
8. EXCAVATION LIMITS VARY DEPENDING ON THE LOCAL SOIL CONDITIONS AND THE CONSTRUCTION TECHNIQUES EMPLOYED.
9. INSTALL LOGS, RACKING LOGS, SLASH, IMPORTED BALLAST MATERIAL AND NATIVE BACKFILL MATERIAL AS SHOWN ON THE PLANS AND AS DIRECTED BY THE ENGINEER.
10. SEE DRAWING XX FOR ELJ CONTROL POINT COORDINATES.
11. RACKING LOGS NOT SHOWN FOR CLARITY. PLACE RACKING LOGS ALONG UPSTREAM FACE AND ALONG THE SIDES OF THE ELJ AS SHOWN ON DWG XX. RACKING LOGS SHALL BE PLACED PARALLEL TO AND BETWEEN PILES EXTENDING OUT FROM THE ELJ. ALL RACKING LOGS SHALL BE PLACED TO CREATE AN INTERLOCKING MATRIX OF LOGS SECURED BETWEEN PILES AND KEY LOGS. PLACE SLASH MATERIAL AT SAME TIME AS RACKING LOGS TO FILL VOIDS BETWEEN RACKING LOGS.

ELJ CONSTRUCTION SEQUENCE NOTES:

1. INSTALL PILES TO SPECIFIED DEPTH.
2. INSTALL LAYER 1 AND LAYER 2 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND FIRST LIFT OF LARGE ROCK BACKFILL MATERIAL.
4. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
5. INSTALL LAYER 3 AND LAYER 4 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND SECOND LIFT OF LARGE ROCK BACKFILL MATERIAL.
6. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
7. INSTALL LAYER 5 AND LAYER 6 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND THIRD LIFT OF LARGE ROCK BACKFILL MATERIAL.
8. FILL ALL VOIDS IN LARGE ROCK BACKFILL MATERIAL WITH SMALLER NATIVE ALLUVIUM.
9. INSTALL LAYER 7 KEY LOGS, RACKING LOGS, SLASH MATERIAL AND FOURTH LIFT OF LARGE ROCK BACKFILL MATERIAL.
10. COMPLETELY BACKFILL REMAINDER OF ELJ INTERIOR AND CONSTRUCT DEPOSITIONAL BAR WITH NATIVE ALLUVIUM TO GRADE AND EXTENTS SHOWN ON ELJ PLAN.
11. PLACE TOPSOIL AND MULCH OVER TOP OF ELJ AS SHOWN ON ELJ PLAN.

LOG SCHEDULE - LEFT BANK DEFLECTOR ELS

LOG TYPE	MINIMUM DIAMETER (IN)	LENGTH (FT)	ROOTWAD	TOTAL QTY PER ELJ
P1	22-26	25	YES	9
R4a	18-22	30	YES	3
R4b	24-28	30	YES	5
R5a	18-22	35	YES	2
R5b	24-28	35	YES	2
R6	24-28	40	YES	2
L4	18-22	30	NO	2
L5	18-22	35	NO	3
L6	18-22	40	NO	5
RACKING	4-16	15-30	OPTIONAL	150
SLASH (LOOSE)	-	-	-	200 CY

LEGEND:

X# LOG IDENTIFIER

LOG PLACEMENT SEQUENCING ORDER

CONTROL POINT

CALL 811 BEFORE YOU DIG

CONCEPTUAL DESIGN

No.	REVISION	BY	APP'D	DATE

ONE INCH

AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

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DESIGNED: -	DRAWN: -
DESIGNED: -	DRAWN: -
DESIGNED: -	CHECKED: -
SCALE: AS NOTED	APPROVED: -

SOUTH FORK NOOKSACK RIVER
SKOOKUM/EDFRO RESTORATION
PROJECT - PHASE 3

TYPE 5 LARGE LEFT BANK ELS LAYERING PLAN

DATE: APRIL 2024
PROJECT NO: 14-05790-000
DRAWING NO: C1.09
SHEET NO: 12 OF 12

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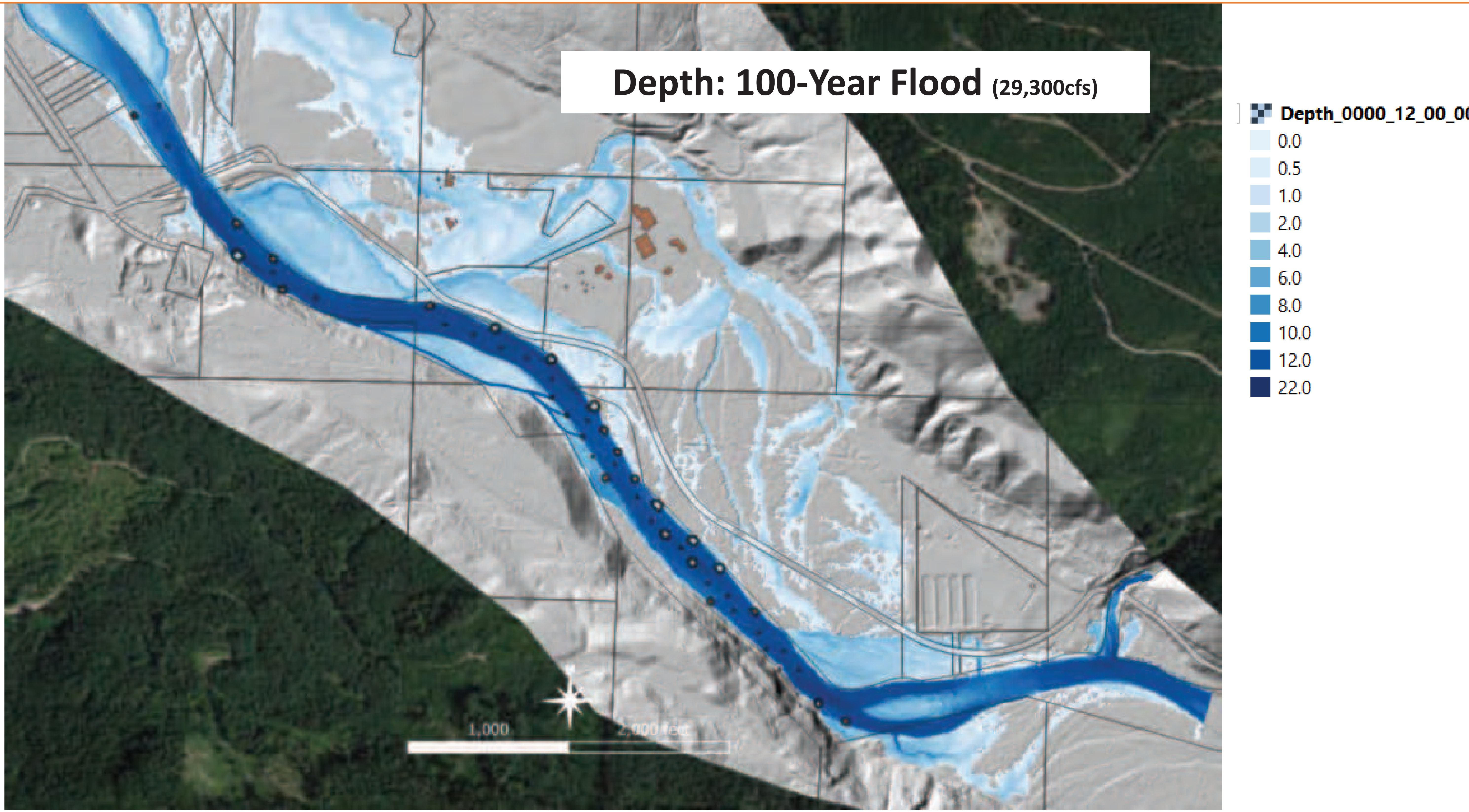
Appendix C

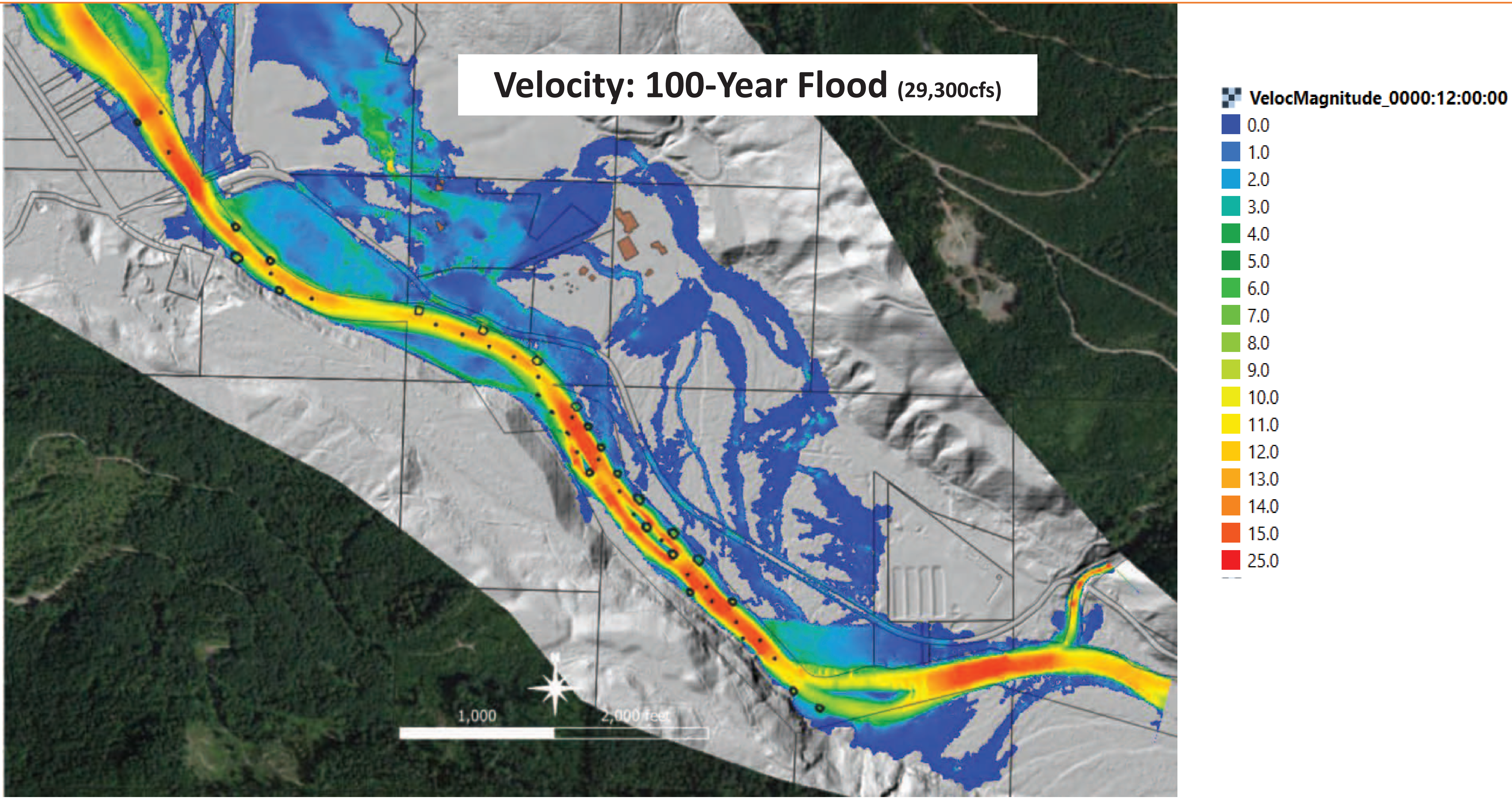
Proposed Conditions Hydraulic Model Results for the Preferred Alternative (Alternative 3)

Herrera
Science + Planning + Design

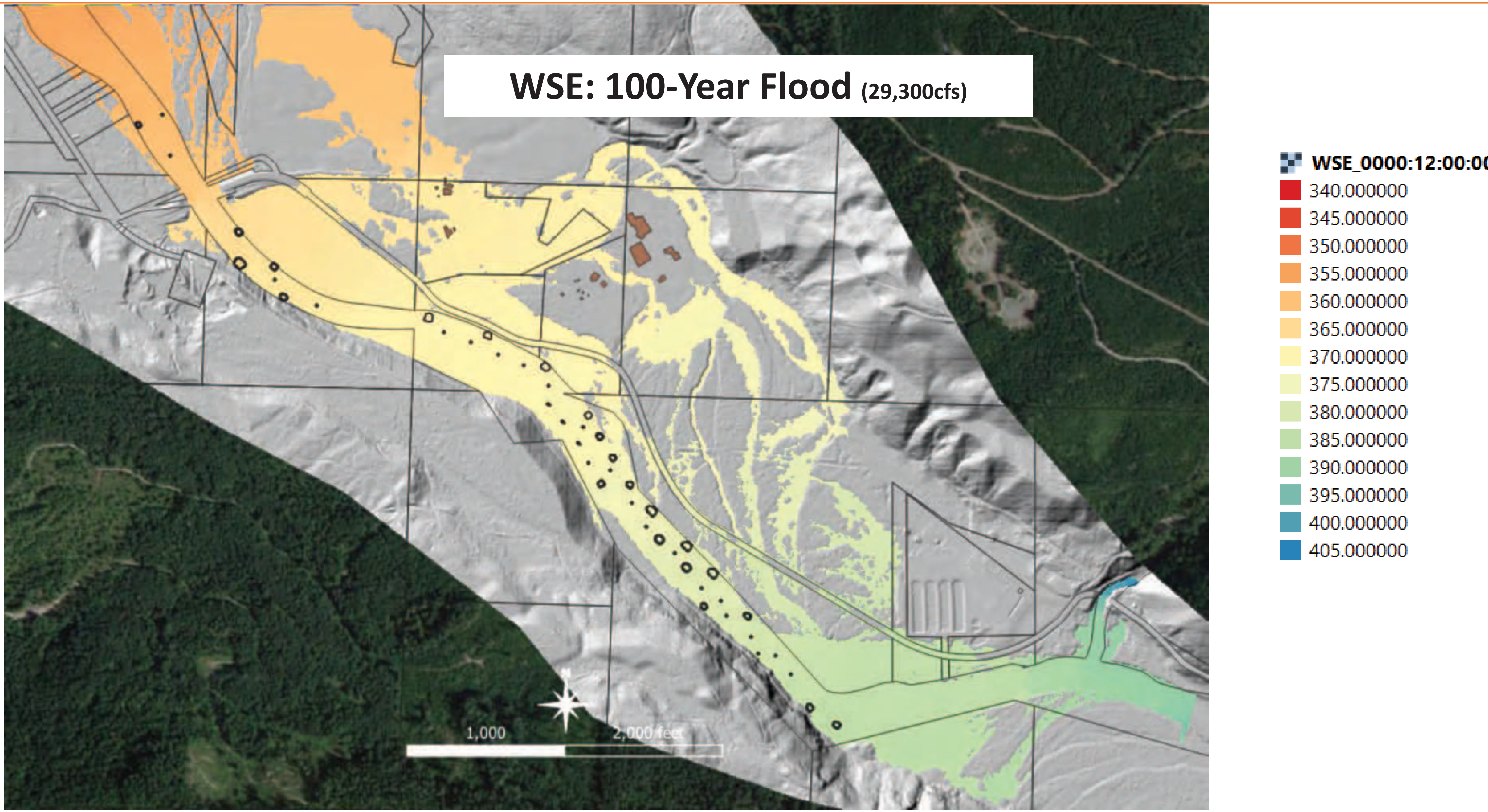
HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



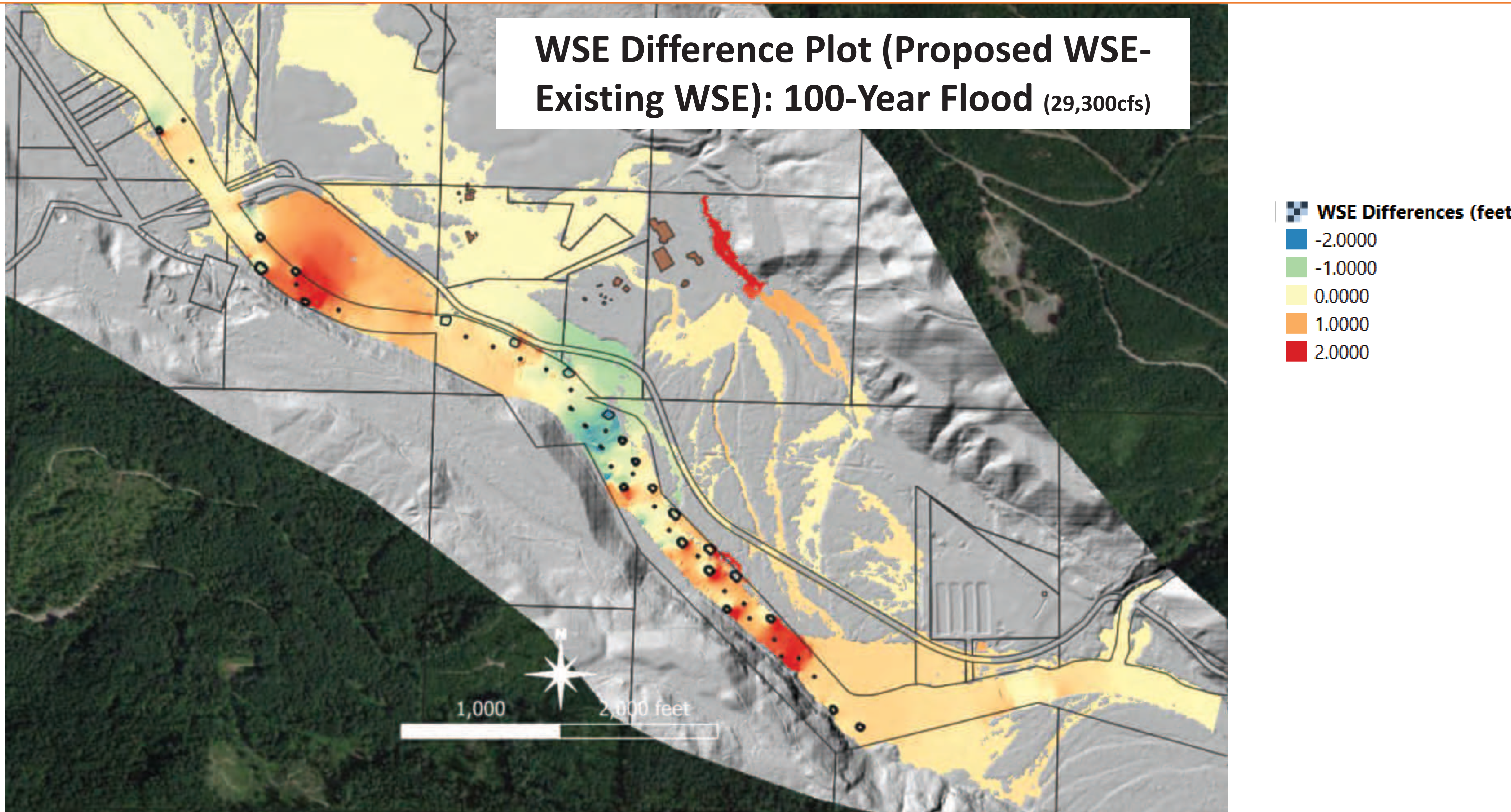
HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



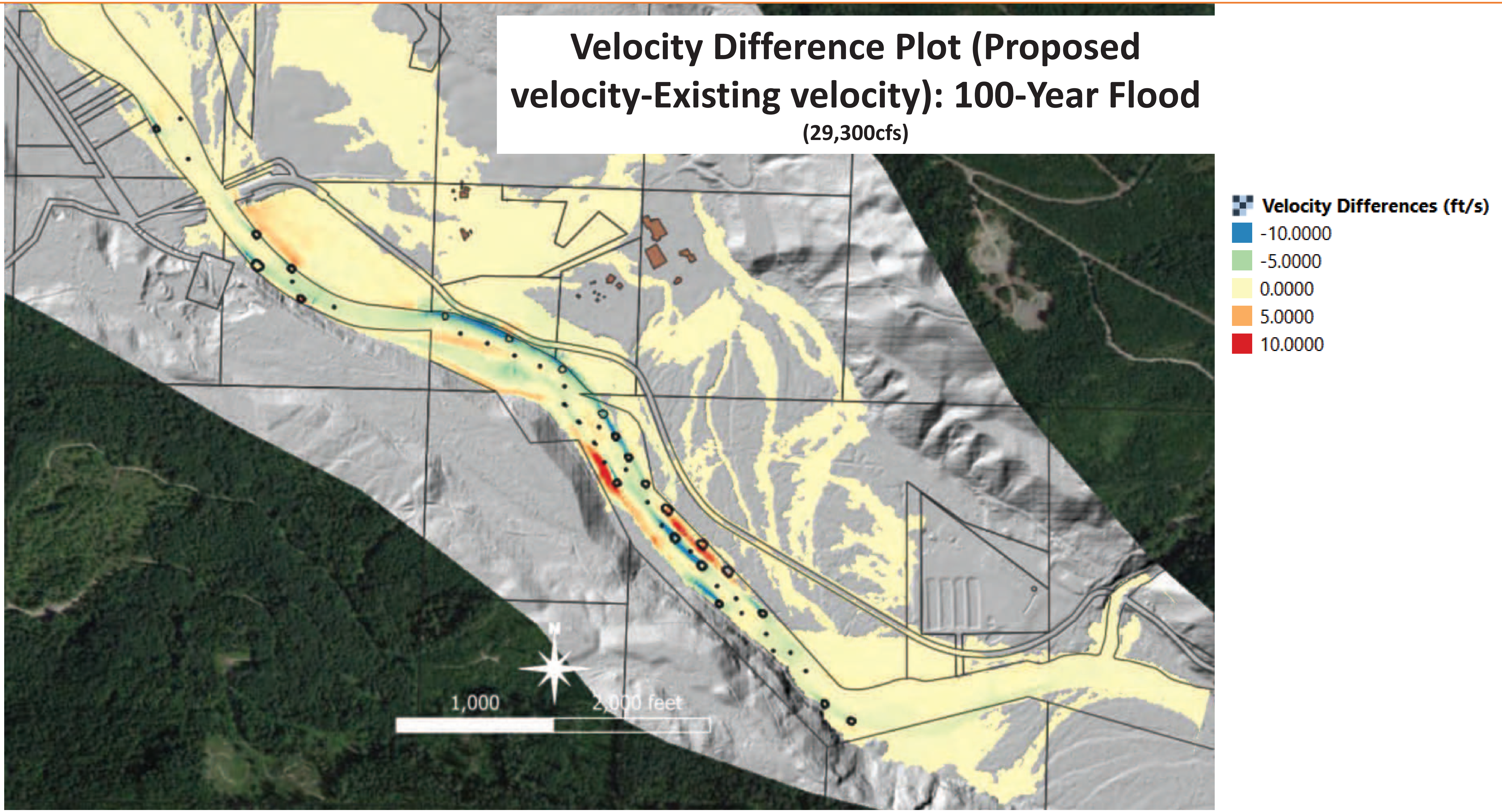
HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



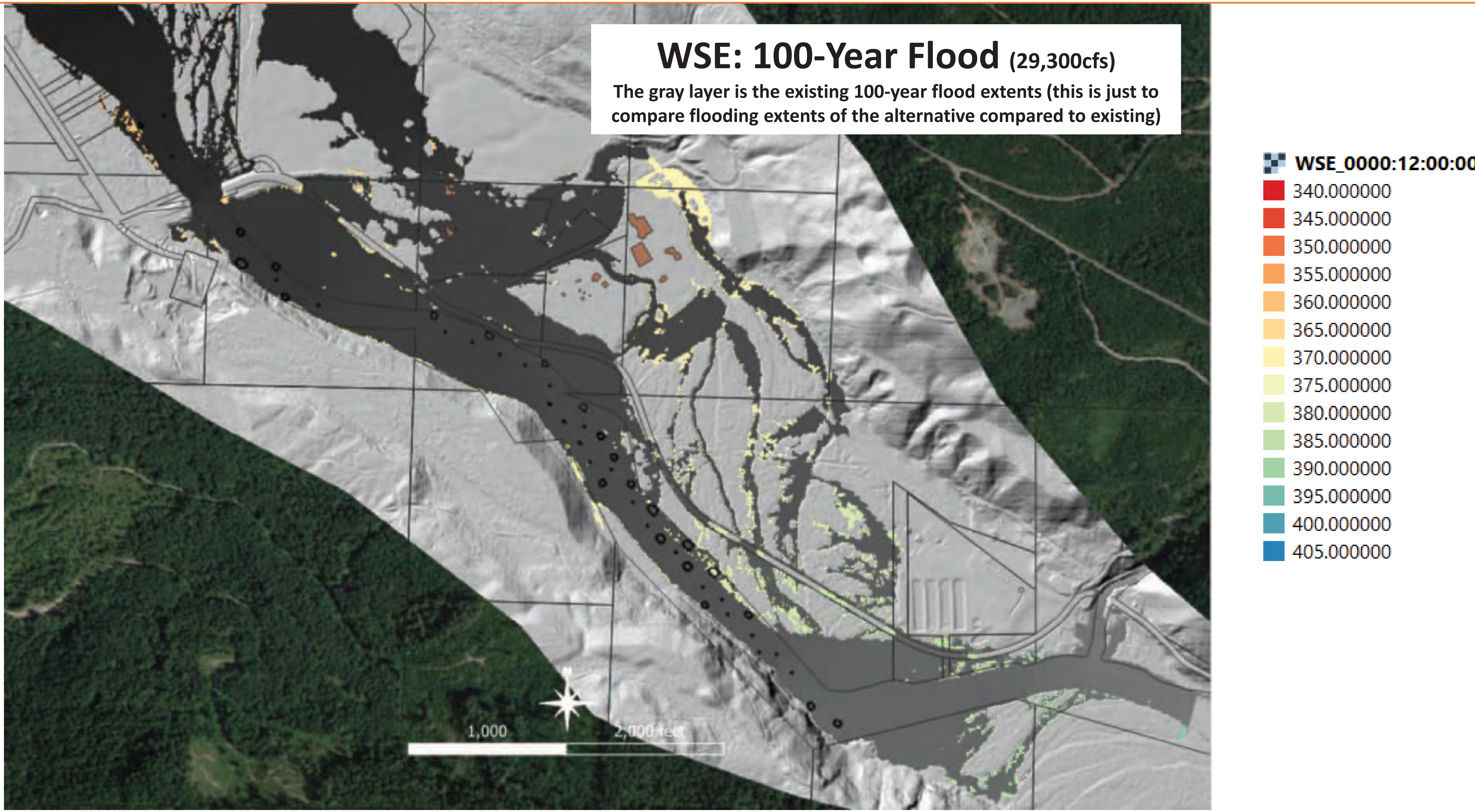
HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



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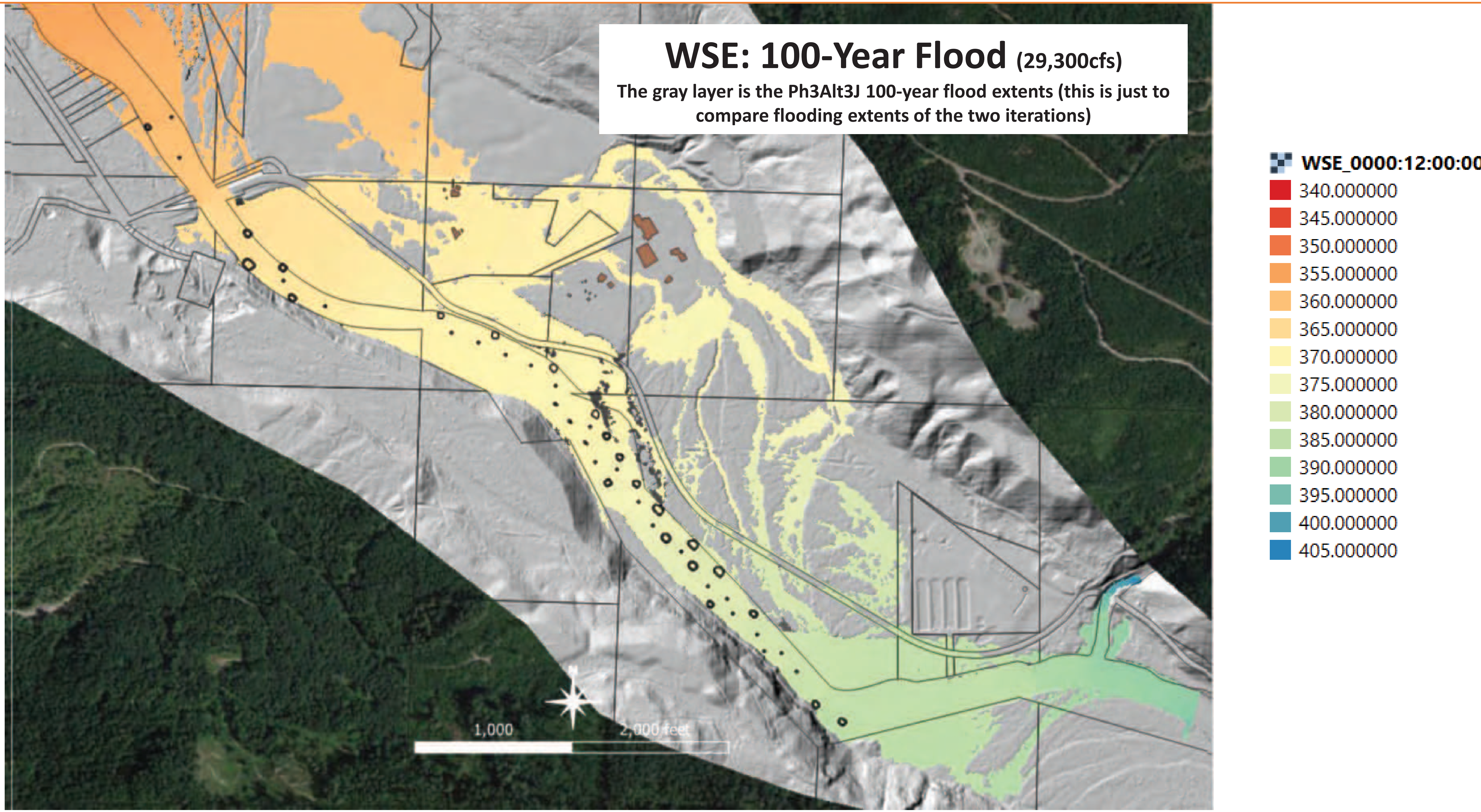

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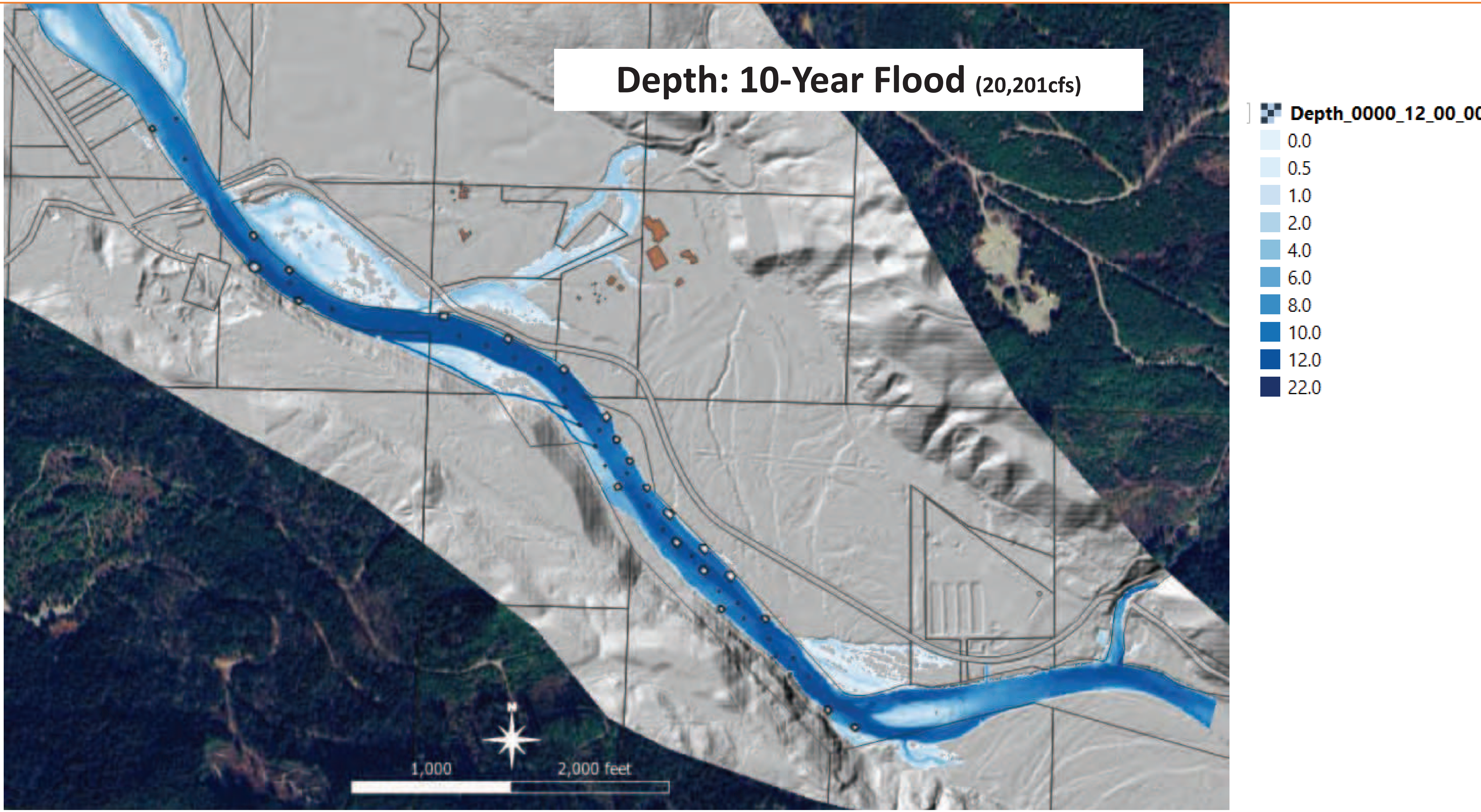

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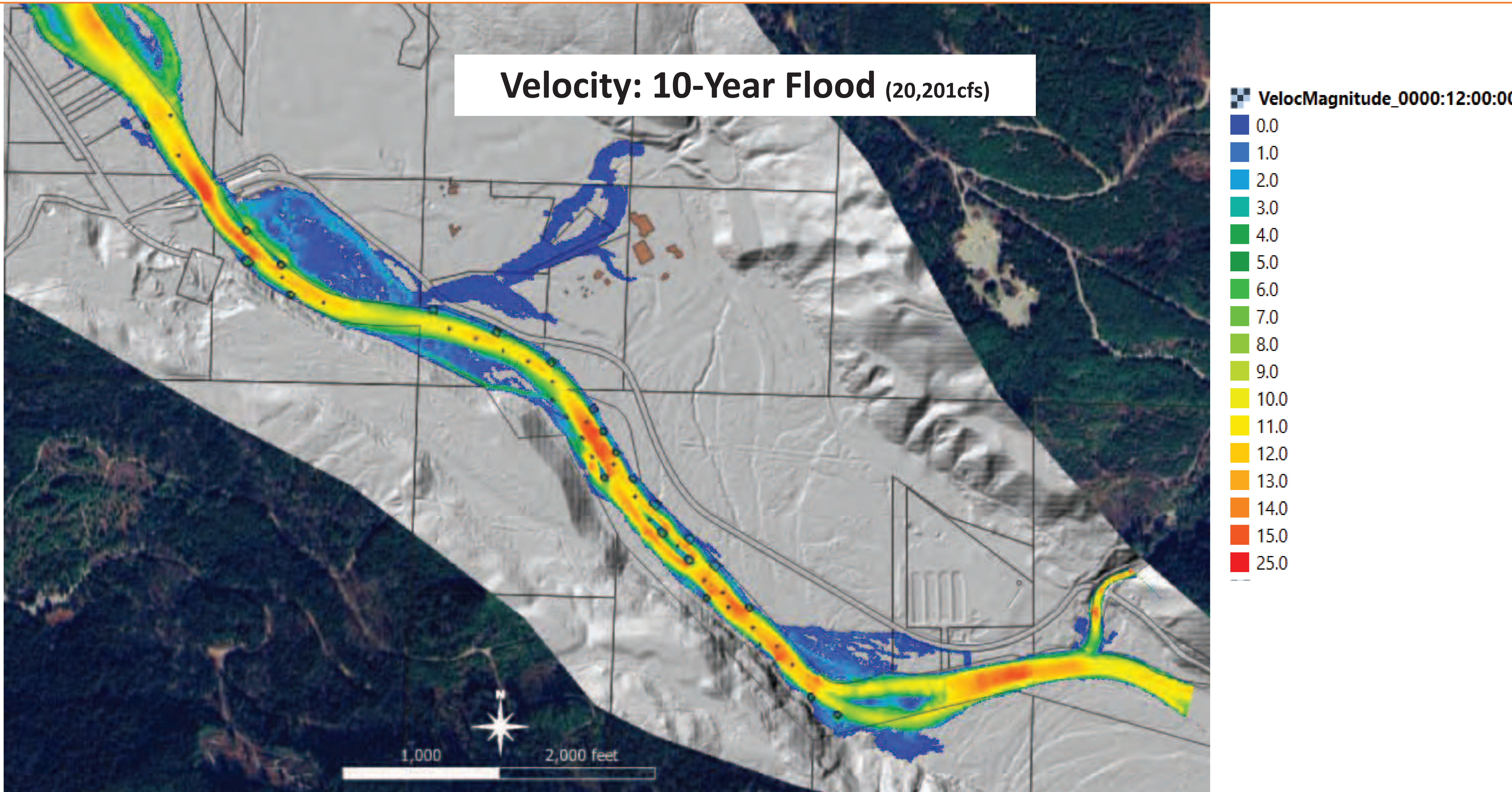

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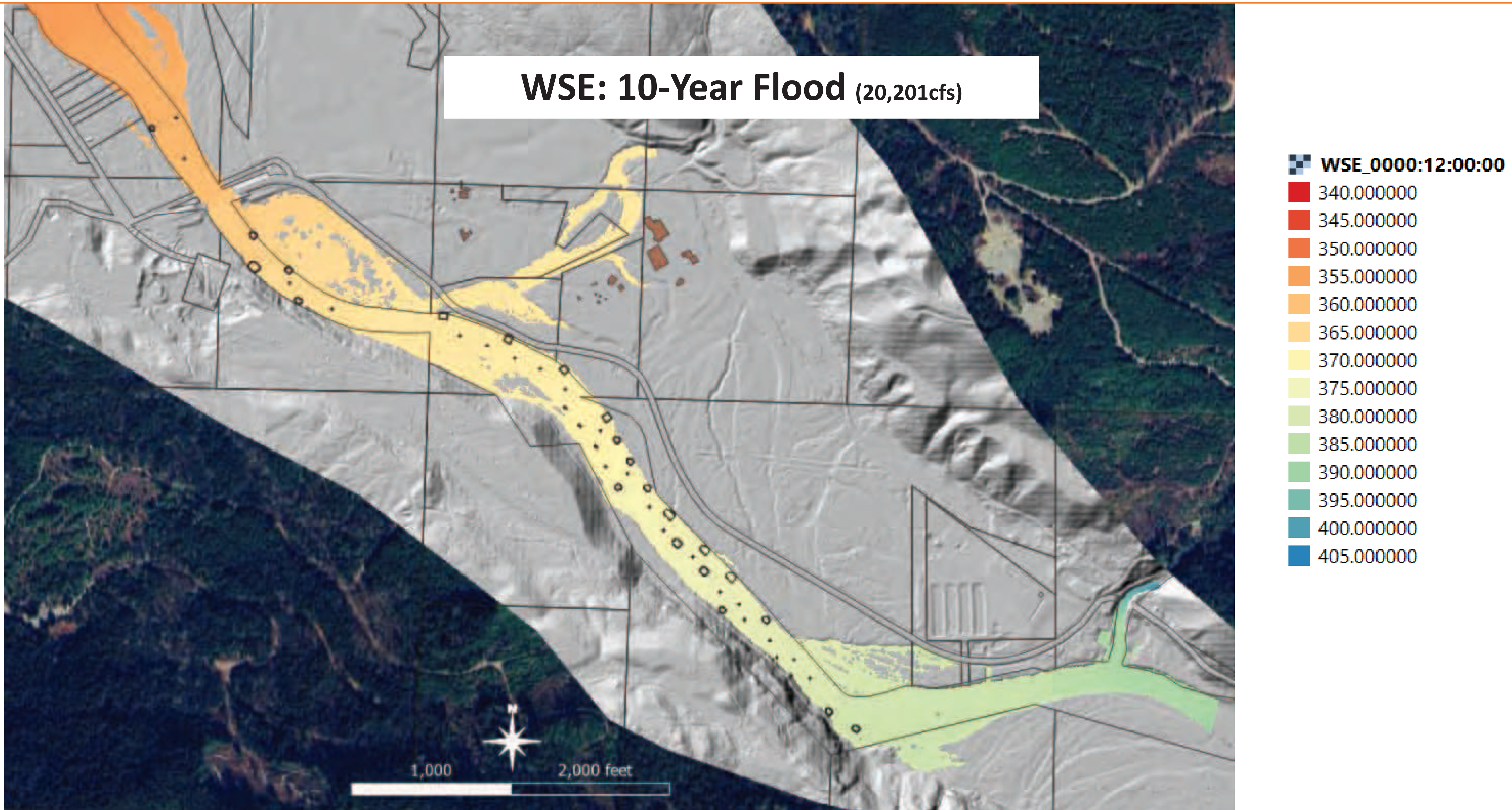

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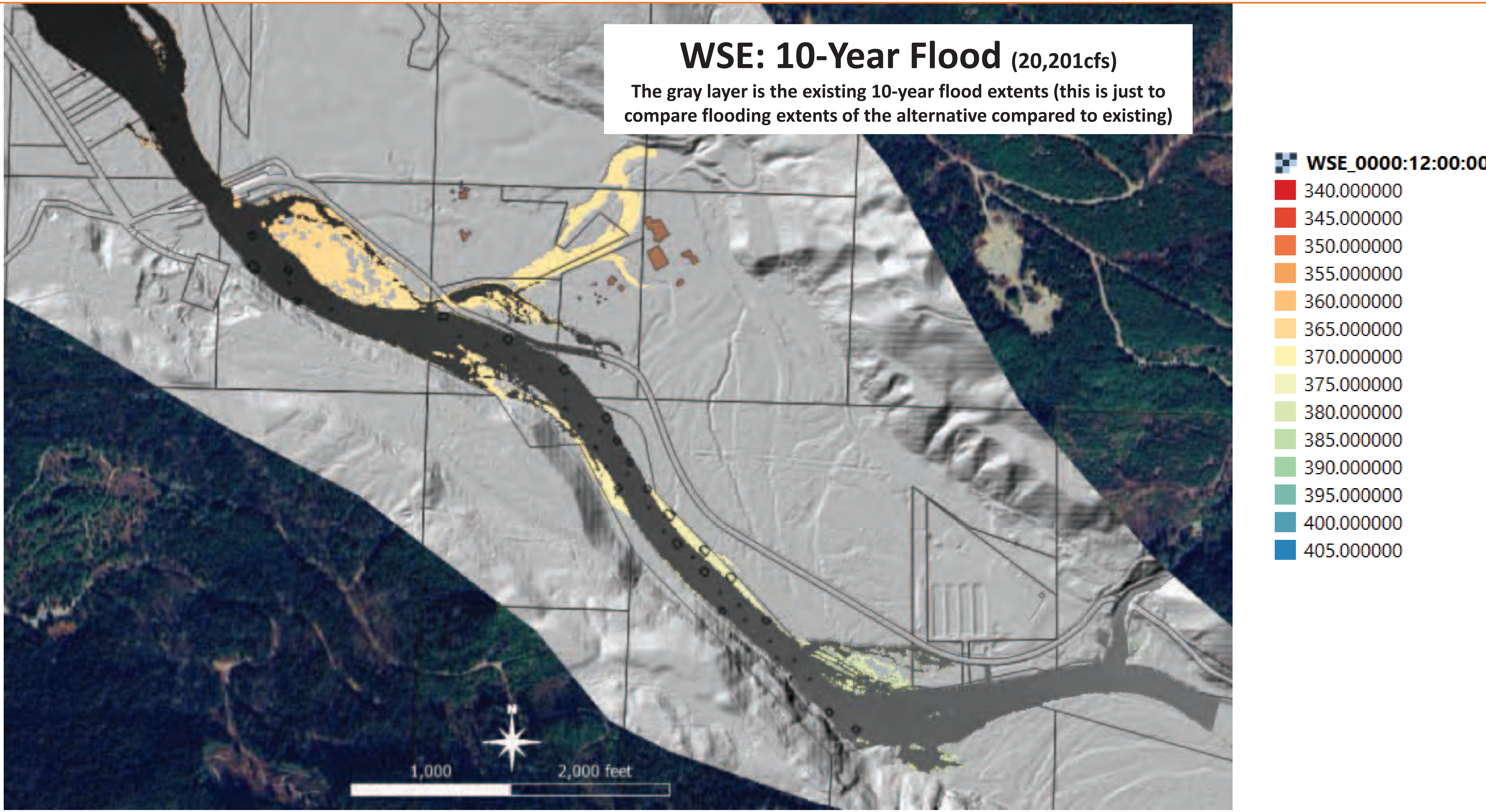

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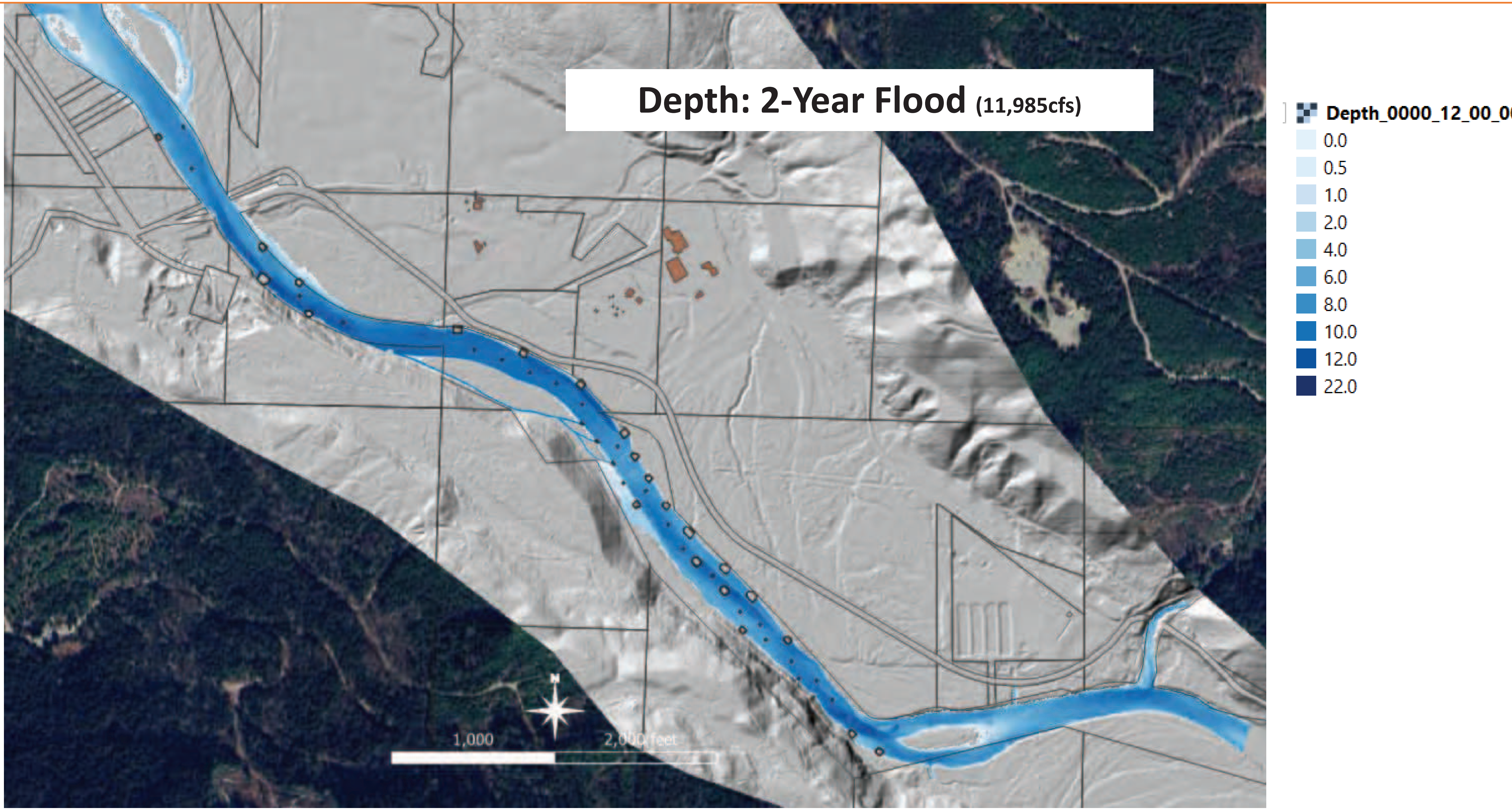

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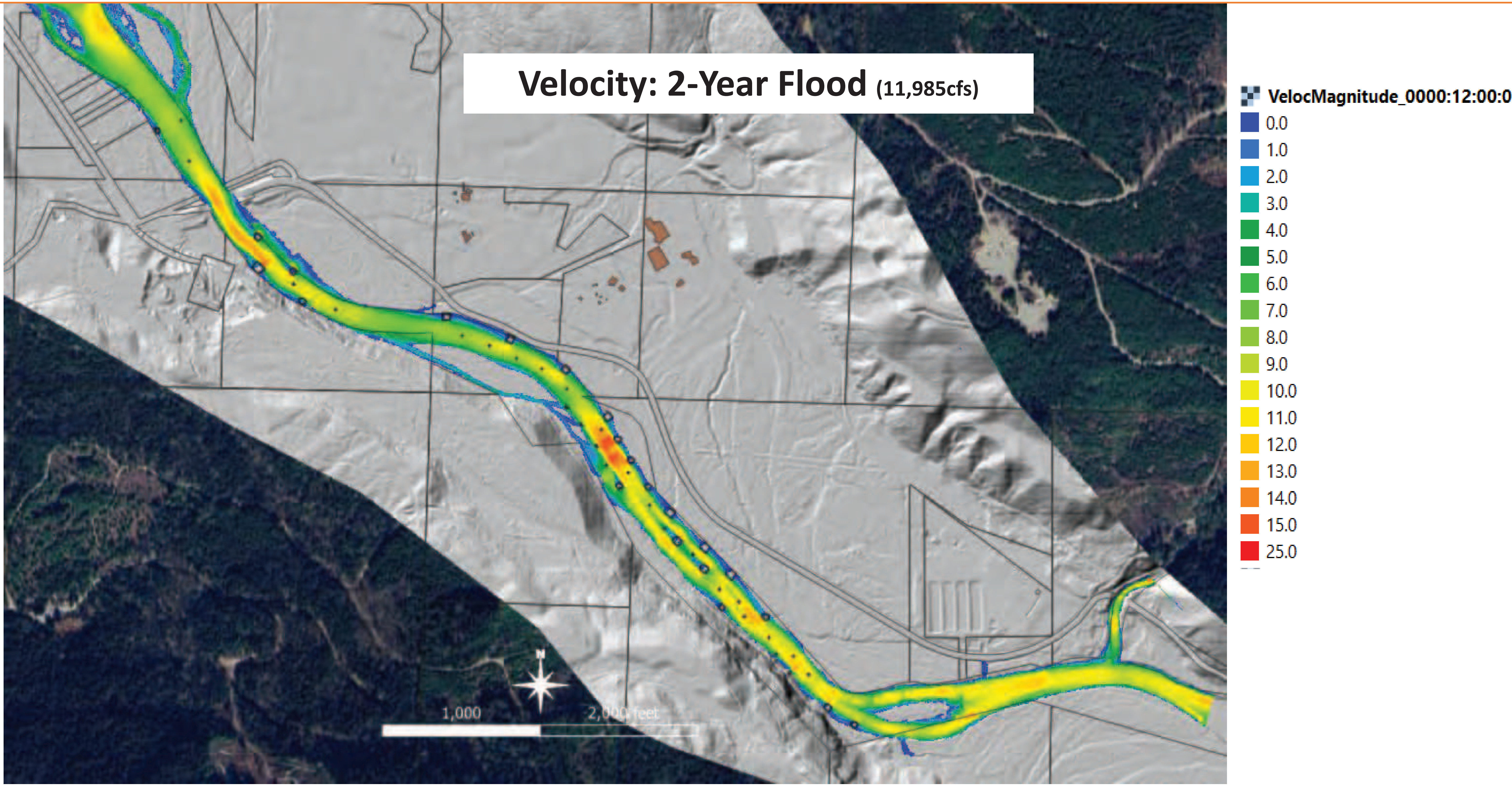

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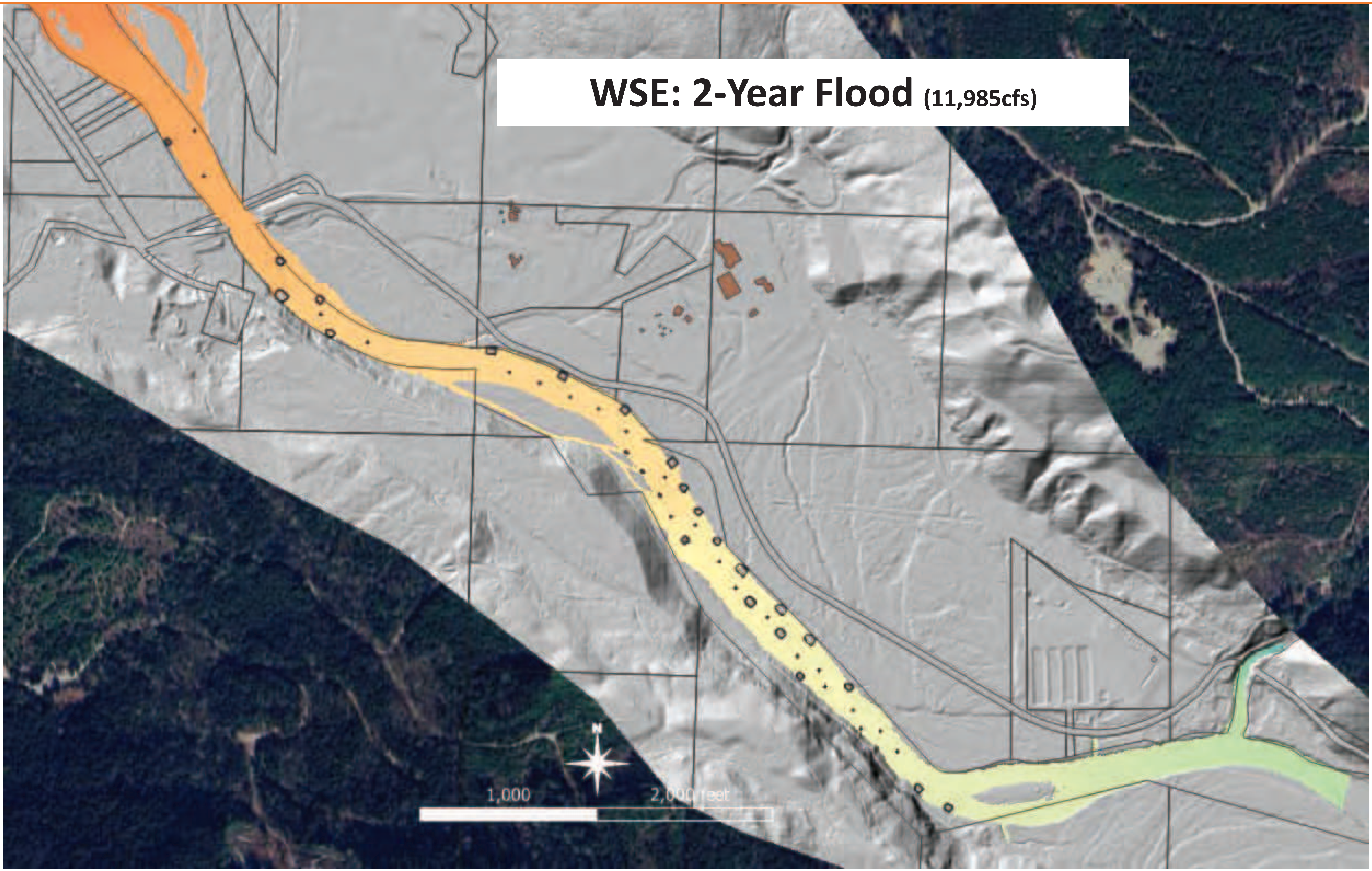

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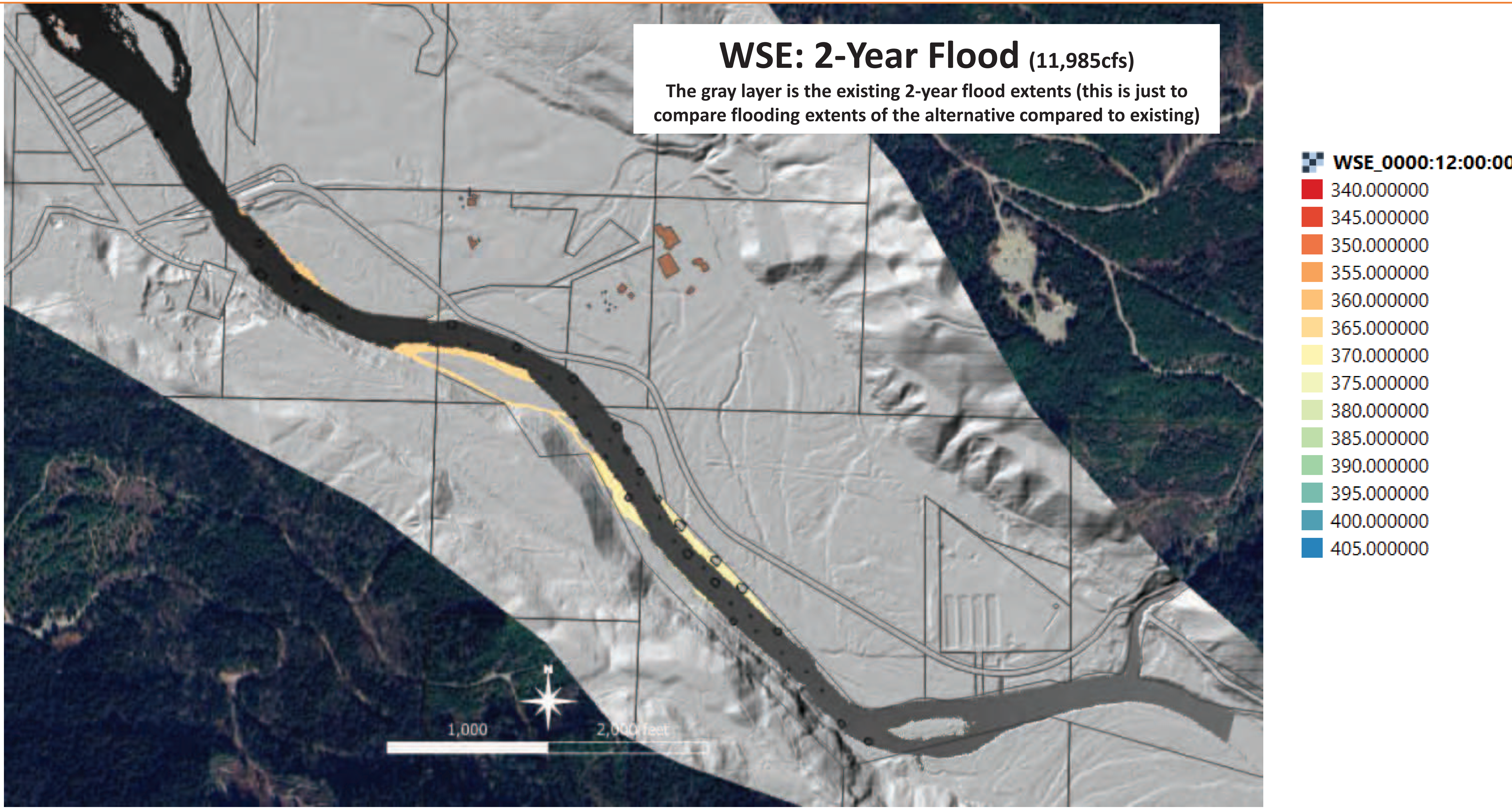
HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



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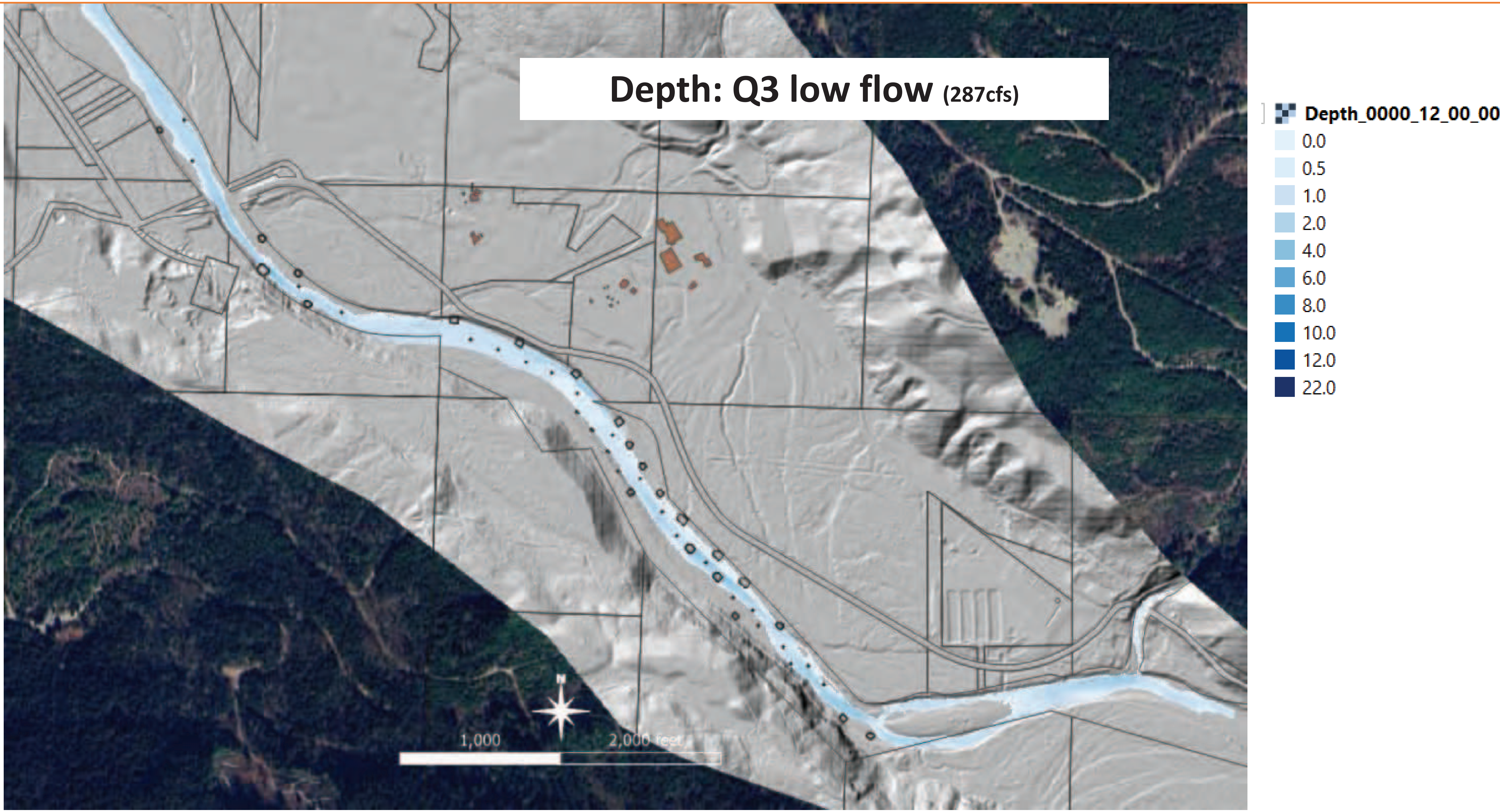

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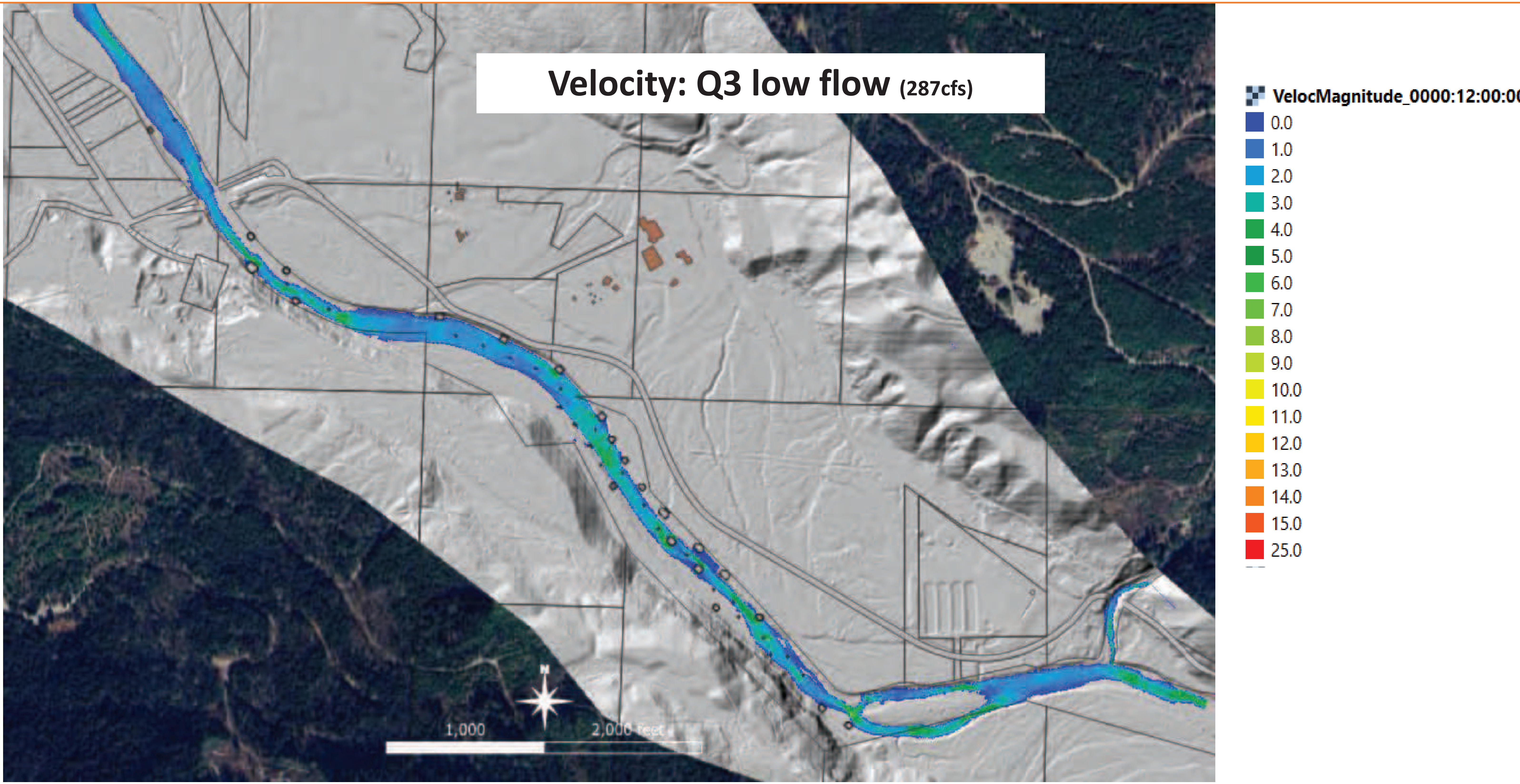
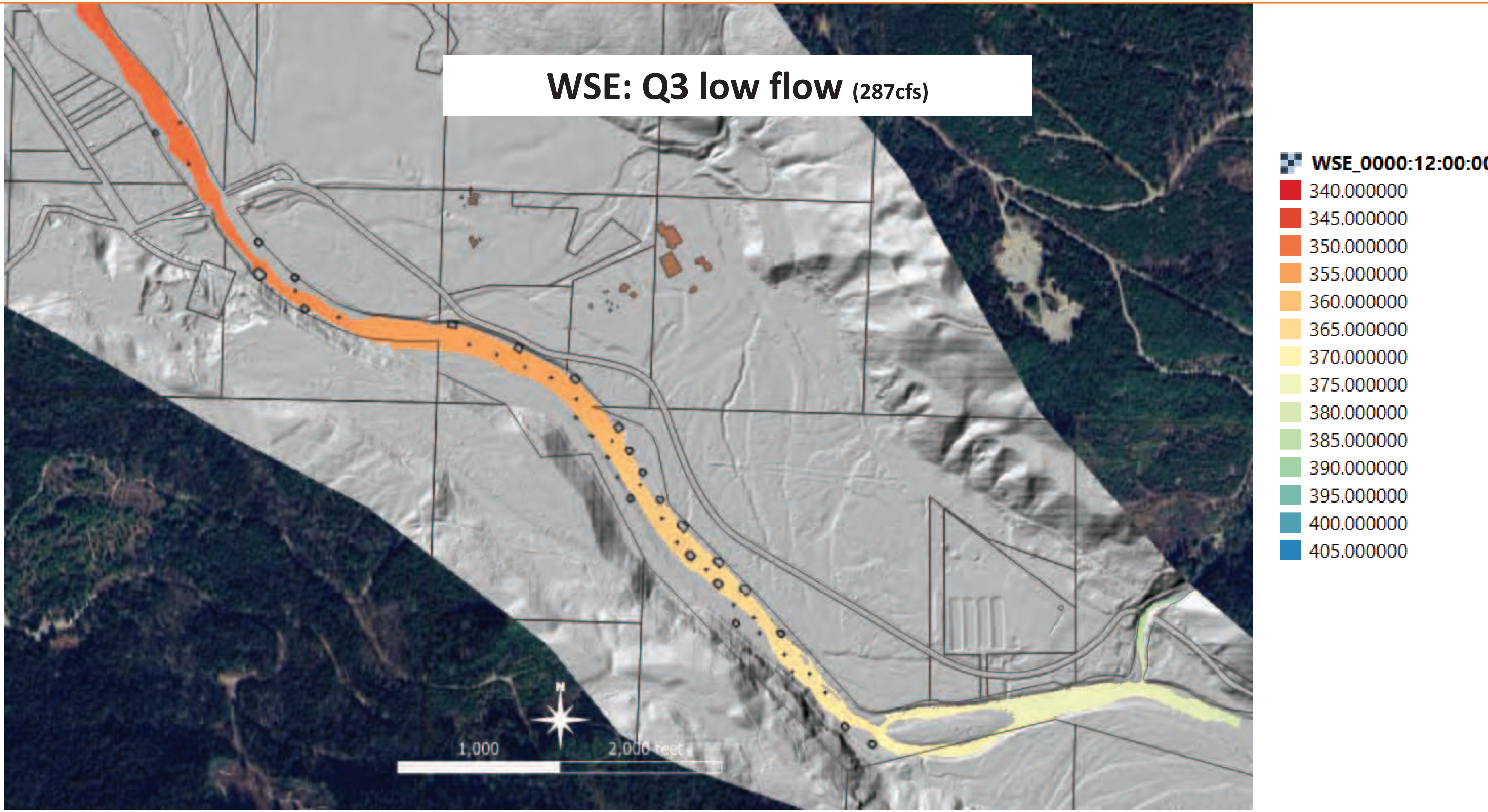


HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3



HYDRAULIC MODEL RESULTS: PHASE 3 ALTERNATIVE 3