FINAL REPORT ◦ DECEMBER 2016

# Sultan River
# Riverine Habitat Monitoring





PREPARED FOR

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Cover photos: Clockwise from top left: Pool feature formed by installed wood at the head of Side Channel 4; gravel accumulation at outlet of Side Channel 2; riffle near the head of Side Channel 1; outlet of a newly formed pool in Side Channel 3.

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# EXECUTIVE SUMMARY

Stillwater Sciences conducted a field habitat survey of the lower 2.7 miles of the Sultan River in July 2016, including four side channels (all of which had been previously surveyed). The study was undertaken to determine if any habitat changes have occurred due to a significant high-flow event that occurred in November 2015. The 2016 survey was the second such resurvey conducted since issuance of the new license for the Henry M. Jackson Hydroelectric Project (Project) in 2011. The project is operated by the Public Utility District No. 1 of Snohomish County (the District) and these habitat surveys are required by the Fisheries and Habitat Monitoring Plan under Article 410 of the license.

Surveys conducted in 2007 and 2010, as part of the relicensing of the Project, provided the baseline data that have allowed post-2011 resurveys to determine the effects of subsequent high-flow events, of which the first occurred in March 2014 (Stillwater Sciences 2015). Table ES-1 lists each reach and the year they were each surveyed.

Riverine habitat attributes recorded for this study included instream unit subtype (e.g., pools, riffles, glides, islands), measurements of wetted unit surface area dimensions (length and width), unit margin features (lengths of undercut banks and bar edges), and the distribution and characterization of large woody debris (LWD). Subsequent to the 2007 and 2010 surveys, engineered LWD structures were installed in 2012 along the margins of the mainstem and side channels, along with other channel enhancements in all four side channels.

**Table ES-1.** Reaches surveyed and the year the survey was conducted.

| Reach | Surveyed in 2007 | Surveyed in 2010 | Resurveyed in 2014 | Resurveyed in 2016 |
|---|---|---|---|---|
| Mainstem | Yes | No | Yes | Yes |
| Side Channel 1 | No | Yes (partially) | Yes | Yes |
| Side Channel 2 | No | Yes | Yes | Yes |
| Side Channel 3 | Yes | No | Yes | Yes |
| Side Channel 4 | No | No | Yes | Yes |
| | | LWD INSTALLATIONS ↑ 2012 | ↑ HIGH FLOW MARCH 2014 | ↑ HIGH FLOW NOVEMBER 2015 |

As in 2014, the results of the 2016 study indicate that natural processes of wood recruitment and channel evolution have thus far resulted in modest changes to habitat attributes in the mainstem of the Sultan River since the baseline surveys were conducted. Although the mainstem is largely unchanged, the side channels have been transformed into more variable reaches with frequent pools and pool-riffle-glide complexes. This represents a marked improvement over their previous composition of primarily glide habitat dotted with some low-gradient riffles and a few small pools. Since 2012, high flows have reworked and modified the channels. This has led to a system that overall expresses a somewhat more dynamic, "natural" trajectory. For this survey, the largest positive changes observed since the 2014 survey occurred in Side Channels 2 and 4 (SC2 and SC4).

While the presence of engineered LWD structures and LWD in the mainstem river and along the side channels has successfully stabilized the inlet to side channels, one small area in the mainstem and a longer section of Side Channel 1 (SC1) that had flowing water in 2014 at the 320 cubic feet per second (cfs) mainstem discharge were dry at a similar discharge in 2016. This change was most evident in SC1 and comprised 594 feet (ft) of dry channel with marsh and isolated interspersed pools.

In summary, little measurable change can be documented in the mainstem as a result of this survey. However, the study results indicate that installations have initiated changes in habitat features and improved channel complexity, in terms of variability of depths and flow, in the side channels following high flows. Pool habitat has significantly increased, both in terms of the amount of surface area pools encompass and the overall number of pools observed in the study area. Based on relatively consistent results to date, future high flows are expected to interact with the installations and result in even greater side-channel habitat complexity in the future.

# 1 STUDY OBJECTIVES AND DESCRIPTION

The objective of this habitat survey was to delineate in-river habitat units and to conduct an in-river large woody debris (LWD) inventory in the Sultan River's lower 2.7 miles, including four previously identified side channels (Figure 1). The mainstem and Side Channel (SC) 3 were surveyed as part of Jackson Hydroelectric Project (Project) relicensing in 2007 and reported in *Revised Study Plan 18: Riverine, Riparian, and Wetland Habitat Assessment* (hereafter referenced as RSP 18) by Public Utility District No. 1 of Snohomish County (the District). In 2010, habitat was surveyed in SC1 and SC2 and a geomorphic assessment was conducted to inform wood placement and channel enhancement feasibility. Construction occurred in 2012, with inlet and outlet enhancements and boulder placement associated with the four side channels (SC1, SC2, SC3, and SC4). Enhancements included multiple log structures and individual logs in the side channels and eight large engineered LWD structures in the mainstem.

Follow-up habitat surveys, triggered by high-flow events (termed "process flows"), are required by the Fisheries and Habitat Monitoring Plan under Article 410 for the continued operation of the Project. Resurveys were conducted following two high-flow events that have since occurred:

- March 2014 (with a peak discharge of 4,940 cubic feet per second [cfs] at U.S. Geological Survey [USGS] Gage No. 12138160, corresponding to a 3- to 4-year event);
- November 2015 (with a peak discharge of 7,320 cfs at USGS Gage No. 12138160, corresponding to about a 7-year event).

The primary purpose for resurveying is to identify any significant changes that have occurred following the November 2015 high-flow event that could affect fish habitat in the lower Sultan River. This study thus evaluates habitat changes that have occurred as a result of the constructed habitat enhancements and their interaction with two high-flow events. This study also provides analysis of current conditions compared with baseline information previously compiled for the mainstem and side channels of this reach of the Sultan River. Per License Article 410, the frequency of these surveys is greatest between Year 1 and 10 of the new license and is reduced over the remainder of the license term.

# 2 BACKGROUND INFORMATION

As part of the formal relicensing process for Culmback Dam in 2007, RSP 18 was conducted to address Federal Energy Regulation Commission (FERC) requirements for a detailed description of aquatic and terrestrial resources of the Project-related environment between Culmback Dam and the mouth of the Sultan River.

The Sultan River below Culmback Dam is a highly confined, steep channel over 13 miles of its 16-mile length to its confluence with the Skykomish River The canyon that confines the river creates a high-energy environment that significantly affects the nature of instream habitats found within it. At approximately river mile (RM) 3.3, however, the river transforms into an alluvial valley where the channel widens and gravels from upstream sources deposit and accumulate. This survey was conducted on the lowermost, low-gradient alluvial portion of the watershed (Figure 1) from the power line crossing at RM 2.7 to the confluence of the Sultan and Skykomish rivers.

The Sultan River below Culmback Dam currently provides spawning and rearing habitat for numerous species of resident and anadromous salmonids.[1] The reach between the Culmback Dam and the Diversion Dam (RM 9.7) historically has supported self-sustaining stocks of resident rainbow trout (*O. mykiss*) and mountain whitefish (*Prosopium williamsoni*). Anadromous species, including Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), pink salmon (*O. gorbuscha*), chum salmon (*O. keta*), coastal cutthroat trout *(O. clarki)* and steelhead trout (*O. mykiss*), are utilizing spawning and rearing habitats within the river downstream of the Diversion Dam, which until recently was a barrier to upstream passage. Bull trout (*Salvelinus confluentus*) have not been observed spawning in the Sultan River but are known to use the lower river as rearing/foraging habitat.. Each of these fish species depend on aquatic habitats that are affected by Project operations, and it is thus important to collect information on habitats within the affected reach on an ongoing basis.

[1] Volitional fish passage through the sluiceway gate at the Diversion Dam at RM 9.7 was completed in October 2016, allowing unimpeded fish access to habitats upstream of the Diversion Dam for the first time since 1929.


**Figure 1**. Overview map of Study Area, spanning the lowermost 2.7 miles of the Sultan River upstream of its confluence with the Skykomish River (bottom right portion of the image). The four side channels covered by this survey are labeled.

# 3 METHODS

## 3.1 Study Area Description and River Reach Delineation

RSP 18 broke the river into three "operational reaches" and four "survey reaches," each of which contained multiple habitat units identified by Natural Sequence Order (NSO) or "unit" numbers. The present Study Area for the 2016 survey covers the lower mainstem Sultan River from the Bonneville Power Administration (BPA) power lines at RM 2.7, including four side channels within the reach, to its confluence with the Skykomish River. The 2016 survey took place wholly within Operational and Survey Reach 1, as defined in RSP 18. Habitat unit numbers previously assigned to the mainstem and side channels have not been altered except in the case where a habitat unit has changed. Maps illustrating habitat units are included in Appendix A for 2014 and in Appendix B for 2016.

## 3.2 Riverine Habitat Mapping and Large Woody Debris Survey

Methods used to quantify in-river habitat units and associated LWD for the 2016 survey were identical to those utilized in 2014, 2010, and 2007. These methods were selected to provide repeatable identification of habitat types, dimensions, and locations, as well as documentation of associated LWD.

The classification schemes used to identify specific habitat unit types, substrate sizes, and LWD attributes are given in Tables 1 and 2. Because some of the side channels had habitat types not included in the pre-existing classification scheme, some additional habitat types (i.e., isolated pools and marshy areas) were added in the field at the time of the survey.

**Table 1**. Riverine (instream) habitat types.

| | |
|---|---|
| **Habitat types** | Pool |
| | Riffle |
| | Cascade |
| | Rapid |
| | Glide |
| | Island |
| | Side Channel |
| | Undercut Banks |
| | Backwater Areas |
| | Bar Edges |

**Table 2.** Large woody debris (LWD) attributes.

| | |
|---|---|
| **LWD jam** | Number of Pieces |
| | Dimension (length, width, height) |
| | Channel Position (bank, mid-channel, bar) |
| | Percent of Channel Width |
| | Largest Piece Size |
| **LWD piece** | Length |
| | Diameter |
| | Decay Class |
| | Species Class (conifer, deciduous) |
| | Rootwad (yes, no) |
| | Anchoring (bed bank) |
| | Channel Position (bank, mid-channel, bar) |

### 3.2.1 Delineation of in-river habitat units

The in-river habitat unit classification system and field methods from RSP 18 were used for this survey. The classification system and field methods were adapted from those commonly used in Washington State (Pleus et al. 1999, Schuett-Hames et al. 1999). They provide consistency for unit type identification and for recording unit dimensions. Habitat attributes recorded include unit type (e.g., pools, riffles), measurements of wetted unit surface area dimensions (length and width), unit margin features (lengths of undercut banks and bar edges), and LWD characteristics. Example habitat unit field data collection forms and respective criteria for identification are provided in Appendix C.

The habitat and LWD assessments were conducted in July 2016 within the Study Area. The assessment involved a field survey (or census) by a two-person crew and was conducted moving upstream from the mouth of the Sultan River to RM 2.7. Flows during the survey (317–357 cfs) were maintained by dam releases to match the discharge experienced during the initial surveys in 2014 (313–320 cfs) and 2007 (319 cfs). Prior to enhancements, SC1 and SC2 were only activated at higher flows; therefore, the 2010 survey of these two side channels was conducted at a higher discharge (Table 3).

**Table 3.** Discharge at time of each survey as measured by USGS Gage No. 12138160, "Sultan River below Powerplant near Sultan, WA."

| Year of survey | Flow (cfs) |
|---|---|
| 2007 | 319 |
| 2010 | 561 to 802 |
| 2014 | 313 to 320 |
| 2016 | 317 to 357 |

Habitat unit delineation and measurement of habitat features are best conducted at similar flows in order to improve the reliability of direct comparisons between measurements on different dates. At different flows, bank edges can be inundated or revealed (changing the measurement of bar edges and undercut banks), and wetted widths and depths will obviously be altered.

The field crew surveyed each unit semi-sequentially to identify habitat unit boundaries and associated attributes. For the mainstem, data were collected in a hierarchical manner to first identify or confirm previous habitat unit boundaries, to verify or assign a habitat subtype, and to define the unit's position within the lateral channel (Table 4). These first-order, reach-scale data were recorded using the same alphanumeric coding system as in RSP 18 that assigned: (1) a unique numeric data identifier (NSO unit number); (2) a primary habitat unit type (pool, riffle, or other); (3) a habitat subtype (riffle, pool, subsurface flow, obscured, or other [Pleus et al. 1999]); and (4) a ranking that defined the degree to which the unit occupied the wetted channel. The latter included primary main channel units (Category 1), secondary main channel habitat units (i.e., units that did not span the entire river channel) (Category 2), and side channel habitat units separated from the main channel by an island (Category 3). Islands (Category 3) were identified according to Schuett-Hames et al. (1999), who defined the minimum length of an island unit being at least two times the bankfull channel width with the terrestrial area vegetated by perennial plants two meters or greater in height.

Subsequent data, including unit subtype and dimension measurements, were recorded for each habitat unit. Length, average depth (except in pool habitat units), and three wetted width measurements were either verified from the previous study or recorded for each habitat unit that were either newly delineated (as in the side channels) or re-delineated where habitat units had changed since the last survey. Habitat unit subtypes were designated for the "pool" and "riffle" primary units according to the criteria given in Table 4. Additional information was recorded for pools, including maximum depth, residual pool depth, and the dominant factor forming the pool according to the criteria given in Table 5 (Pleus et al. 1999).

**Table 4**. Criteria used to identify primary and subtypes and associated field code acronyms. (Subtype designations and definitions are adapted from Flosi et al. 1998 and Edelen 2005.)

| Primary habitat unit type | Habitat unit subtype | Criteria for identification |
|---|---|---|
| Riffle (R) | Low-gradient Riffle (LGR) | Shallow reaches with swiftly flowing, turbulent water with some partially exposed substrate. Gradient <4% is usually cobble-dominated. |
| | High Gradient Riffle (HGR)* | Relatively higher-gradient than low-gradient riffles and dominant bed material is cobble instead of gravel. |
| | Rapid (RPD) | Steep sections of moderately deep, swift, and very turbulent water. Amount of exposed substrate is relatively high. Gradient is >4%, and substrate is boulder dominated. In Flosi et al. (1998) these are termed "high gradient riffles." |
| | Glide (GLD) | Wide uniform channel bottom. Flow with low to moderate velocities, lacking pronounced turbulence. Substrate usually consists of cobble, gravel, and sand. |
| | Cascade (CAS) | The steepest riffle habitat, consisting of alternating small waterfalls and small shallow pools. Substrate is usually bedrock and boulders. |

| Primary habitat unit type | Habitat unit subtype | Criteria for identification |
|---|---|---|
| Pool (P) | Main Channel Pool (MCP) | Large pools formed by mid-channel scour. Water velocity is slow, and the substrate is highly variable. |
| | Lateral Scour Pool (SCP) | Formed by flow impinging against a partial channel-bank obstruction. |
| | Pool Complex (CPX)** | Series of pools separated by other habitat units (typically very short riffles) not as long as the wetted width (and thus not delineated as separate habitat units). |
| | Backwater | A pool off the channel (either main channel or side channel) with no obvious flow-through. |
| | Intermittent Pool** | Series of pools separated by dry areas. |
| | Isolated Pool** | A pool surrounded by dry channel. |
| Other (OT) | Island (ISL) | Bars or land segments within the stream channel that are relatively stable, usually vegetated, and normally surrounded by water. |
| | Subsurface flow (SUB)* | That portion (part or all) of the water that infiltrates the stream bed and moves horizontally through and below it. It may or may not return to the stream channel at some point downstream. |
| | Alcove** (ALC) | An off-channel area with no obvious flow-through. Differs from a backwater pool in being more uniform depth (no obvious concavity). |
| | Dry Channel** | Stream channel dry at the flows experienced during the survey. |
| | Marsh** | Portions of the stream channel that are wet, muddy and heavily vegetated, with no discernible flow. |

* These habitat subtypes were not observed in the 2016 survey.
** These habitat subtypes were added in the 2016 survey.

**Table 5**. List of pool-forming factors and associated field codes (Pleus et al. 1999). Definitions for individual LWD pieces versus debris jams are according to Schuett-Hames et al. (1999).

| Field code | Pool-forming factor |
|---|---|
| 1 | LWD log(s) |
| 2 | LWD rootwad(s) |
| 3 | LWD jam |
| 4 | Roots of standing tree(s) or stump(s) |
| 5 | Boulder(s) |
| 6 | Bedrock |
| 7 | Channel bedform |
| 8 | Resistant bank |
| 9 | Artificial bank |
| 10 | Beaver dam |
| 11 | Other/Unknown |

### 3.2.2 In-river LWD inventory

Survey methods to characterize and enumerate LWD within the Study Area followed methods refined for the Timber Fish and Wildlife Monitoring Program (Schuett-Hames et al. 1999). Deviations from survey methods included consolidating LWD into size categories and characterizing LWD in debris jams by tallying individual pieces and rootwads, as was done in 2007 and 2014. Example field data collection forms and criteria are provided in Appendix C.

For the field survey, LWD was defined as dead logs, limbs, or rootwads partially or entirely located within the bankfull channel. LWD was enumerated according to a minimum size and length criteria. Individual downed logs and rootwads tallied had a minimum length of two meters and a mid-point diameter of twenty centimeters or greater. Total length for each piece was recorded, and a diameter class was assigned. Diameter classes were defined as (1) ≥20 centimeters (cm) to <40 cm, (2) ≥40 cm to <60 cm, and (3) ≥60 cm. The location of LWD, either primarily (greater than 50%) within the wetted channel (zone 1) or within the bankfull channel width (zone 2), was also recorded based on the wetted channel conditions present. Additional LWD data attributes recorded were:

- anchor feature (root system, boulder, pinned, or unstable [Schuett-Hames et al. 1999]);
- species class (conifer, deciduous, or unknown);
- decay class (1-5, [Robison and Beschta 1990 cited in Schuett-Hames et al.1999]); and
- the presence or absence of an intact rootwad.

In addition to individual pieces of LWD, debris jams were recorded on base maps and their dimensions estimated. The criteria for identifying debris jams was the accumulation of ten or more pieces of interlocked LWD (including rootwads) where at least ten pieces were ≥20 cm (8 inches [in]) in diameter and >1.8 meters (m) (6 ft) in length, and the majority of the debris jam was located within the bankfull channel (Schuett-Hames et al. 1999). Attribute data recorded for debris jams included a tally of all pieces and rootwads meeting the criteria described above, and approximate length, width, and height dimensions. Specific diameter and length measurements were recorded for the most prominent individual piece within each jam. All LWD locations were identified by recording the associated habitat unit NSO in addition to other data described above. The location and characteristics of engineered log structures and single-placed logs were noted separately from the naturally occurring LWD.

### 3.2.3 Characterization of river channel substrate

Wolman pebble counts (Wolman 1954) were conducted using the standard methodology in the same mainstem habitat unit as in 2007 and 2014 (habitat unit 89), and one count was conducted in each of the side channels in the same units as in 2014. No pebble counts were conducted in SC3 during the 2014 survey and therefore no comparative SC3 pebble counts were conducted in 2016. Pebble count results are typically summarized by the intermediate diameter of the median particle size, $D_{50}$ (Wolman 1954). $D_{50}$ values lying between 20 and 60 millimeters (mm), and having less than 10% of particles smaller than 0.85 mm in diameter (i.e., $D_{10} > 0.85$ mm), are considered suitable substrate size for spawning of anadromous fish (Kondolf and Wolman 1993, Kondolf 2000). In addition to the value of $D_{50}$, we also calculated $D_{16}$ (the particle size that 16% of all particles are smaller than) and $D_{84}$ (the particle size that 84% of all particles are smaller than).

## 3.3 Deviations from RSP 18/Monitoring Plan

There were no significant deviations from the RSP 18 measurement methods, although the same enhancements employed in 2014 to facilitate current and future uses were also employed for the 2016 survey. These include a Google Earth .kmz file, with all habitat units delineated and field photographs from the 2010, 2014, and 2016 surveys embedded. Global positioning system (GPS) coordinates for the wetted width measurements of the side channels are provided with the geographic information system (GIS) data to ensure repeatability with future efforts.

# 4 RESULTS

## 4.1 Survey Results: Riverine Habitat and Large Woody Debris

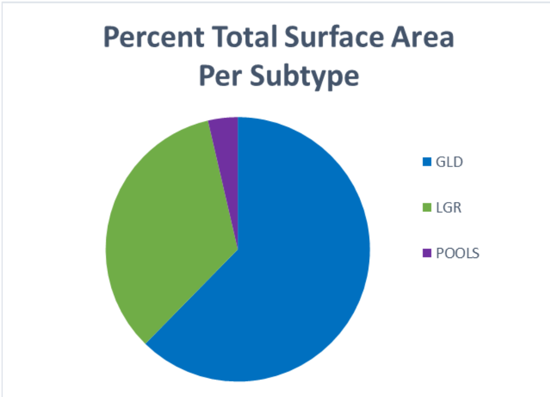
### 4.1.1 Habitat unit composition

A total of 230 in-river habitat units were surveyed within the Study Area (Table 6). This is an increase of 119 units, essentially twice the number of units identified in 2014, indicating that the study reach comprises complexly changing channels. Habitat subtypes not previously observed were identified in the study reach. The newly identified subtypes include isolated pools, intermittent pools, pool complexes, alcoves, marshes, and dry channels. Isolated and intermittent pools are recorded within using the subtype category of "Pool (other)". Maps illustrating 2016 habitat units are included in Appendix B, although the spatial distribution of these habitats is best viewed using the maps and interactive .kmz file provided with this report.

Though the mainstem units remained largely unchanged in the last two years, with only limited boundary shifts and unit additions, the side channels have undergone significant changes. Since 2014, SC1 has evolved from a channel containing 18 distinct units (primarily main channel pools, low-gradient riffles, and glides) to one that is now made up of 93 units including 35 main channel pools, stretches of dry channels and isolated pools and pool complexes, as well as a marsh, islands, and riffles (glides and low gradient). Similarly, since 2014, SC4 has been transformed from essentially one long glide (with a small pool and riffle) to a variable pool-riffle-glide reach providing a mixture of flows and depth.

Tables 6 and 7 provide summary statistics for habitat unit types and subtypes by reach. In 2016, low-gradient riffles, glides, and channel-spanning pools were the most abundant habitat unit subtypes; in total they accounted for 81% of all habitat units surveyed (Table 6). In terms of combined average percent surface area per subtype, glides and low-gradient riffles accounted for the majority of the surface area, mostly due to the presence of long and wide glides and riffles along the mainstem's length and the prevalence of these subtypes in each of the side channels. Pools (including main channel, lateral scour, isolated, intermittent, backwater, and complexes) accounted for a combined average 21.5% (Table 7), which is a significant increase from 2014 when pools accounted for <5%.

Figure 2 provides two alternative representation of the relative proportion of the primary habitat types and subtypes. The first graph (left) displays the total surface area per type/subtype across all reaches (i.e., mainstem and side channels) as a percent of the study reach total surface area (from Table 6). The second graph (right) displays the sum of each type/subtype's average percent surface area as calculated for each side channel and the mainstem individually (from Table 7).



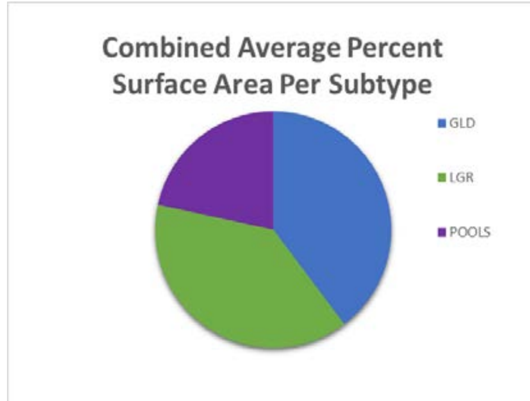




**Figure 2.** 2016 survey percent total surface area and combined average percent surface area per subtype. Habitat subtypes are as listed in Table 5: glide (GLD), low-gradient riffle (LGR), POOLS (including pool complexes and main channel, lateral scour, backwater, intermittent, and isolated pools).

**Table 6.** Composition of surveyed riverine habitat units by river reach and side channels of the lowermost 2.7 miles of the Sultan River.

| Habitat | | Process reach ID and side channel | | | | | | Total number of habitat units | Percent of total habitat units |
|---|---|---|---|---|---|---|---|---|---|
| **Primary unit type** | **Subtype** | **Mainstem (unit category 1)*** | **Mainstem (unit category 2 & 3)*** | **SC1** | **SC2** | **SC3** | **SC4** | | |
| Pool | Main channel pool | 2 | 4 | 35 | 8 | 3 | 10 | 62 | 27.0% |
| | Lateral scour pool | - | - | 1 | 2 | - | - | 3 | 1.3% |
| | Pool complex | - | - | 3 | - | - | - | 3 | 1.3% |
| | Backwater | 1 | - | - | - | - | - | 1 | 0.4% |
| | Pool (other) | - | - | 12 | - | - | - | 12 | 5.2% |
| Riffle | Low-gradient riffle | 14 | 17 | 12 | 8 | 9 | 5 | 65 | 28.3% |
| | Rapid | 1 | - | - | - | - | - | 1 | 0.4% |
| | Glide | 13 | 4 | 23 | 7 | 7 | 7 | 61 | 26.5% |
| Other | Island | 5 | 7 | 3 | - | 1 | - | 16 | 7.0% |
| | Alcove | - | 1 | - | - | - | - | 1 | 0.4% |
| | Marsh | - | - | 1 | - | - | - | 1 | 0.4% |
| | Dry channel | 1 | - | 3 | - | - | - | 4 | 1.7% |
| **Total** | | **37** | **33** | **93** | **25** | **20** | **22** | **230** | **100%** |

* Mainstem (unit category 1) includes primary mainstem channel units. Mainstem (unit categories 2 and 3) include secondary habitat units that did not span the entire mainstem river channel and side channel habitat units separated from the main channel by an island.

**Table 7**. Percent total surface area by riverine habitat unit, by river reach and side channels in the Study Area.

| Habitat | | Process reach ID and side channel | | | | | | Combined average % surface area |
|---|---|---|---|---|---|---|---|---|
| **Primary unit type** | **Sub-type** | **Mainstem (unit category 1)*** | **Mainstem (unit categories 2 & 3)*** | **SC1** | **SC2** | **SC3** | **SC4** | |
| Pool | Main channel | <1 | 9 | 36.3 | 15.3 | 11.5 | 44.3 | 19.4 |
| | Lateral scour | | | <1 | 2.3 | | | <1 |
| | Backwater | <1 | | | | | | <1 |
| | Pool complex | | | 5.1 | | | | <1 |
| | Pool (other) | | | 4.8 | | | | <1 |
| Riffle | Low gradient | 31 | 70.1 | 17.2 | 43.9 | 40.3 | 27.7 | 38.4 |
| | Rapid | 1.8 | | | | | | <1 |
| | Glide | 67.1 | 20 | 35.5 | 38.4 | 48.2 | 28.1 | 39.6 |
| Other | Alcove | | | | | | | <1 |
| | Marsh | | | <1 | | | | <1 |

* Mainstem (unit category 1) includes primary main channel units. Mainstem (unit categories 2 and 3) includes secondary main channel habitat units (units that did not span the entire river channel) and side channel habitat units separated from the main channel by an island.

For this study, wetted width data for units surveyed previously were visually compared to current conditions and re-measured with a laser rangefinder. The average wetted width for pools in the side channels ranged from 5.6 to 31.2 ft. Wetted widths in 2014 ranged from 11.2 to 31.9 ft, not because wetted widths decreased for previously surveyed pools but rather because new, smaller pools have formed since 2014. For riffles and glides in the mainstem and the four side channels, the average wetted width ranged from 10.3 ft for low-gradient riffles in SC1 to 109.5 ft for glides in the main channel (Table 8). These widths are largely unchanged from 2014.

The lengths of individual habitat units within the total Study Area range between 9 ft and 1,695 ft, with rapid and glide habitat units being the longest and intermittent and isolated pools measuring the shortest (Table 9). Glides were longest in the main channel with a median length of 616 ft. The sole rapid in the Study Area within the mainstem was 485 ft long. In SC2, average unit lengths are generally smaller than the other reaches, contributing to the side channel's complexity as measured by the spatial variability of habitat.

**Table 8**. Average wetted width (ft) by surveyed riverine habitat unit within the Study Area.

| Habitat | | Process reach ID and side channel | | | | | |
|---|---|---|---|---|---|---|---|
| **Primary unit type** | **Subtype** | **Mainstem (unit category 1)** | **Mainstem (unit categories 2 & 3)** | **SC1** | **SC2** | **SC3** | **SC4** |
| Pool | Main channel pool | 14.7 | 31.1 | 12.5 | 21.0 | 31.2 | 19.2 |
| | Lateral scour pool | - | - | 14.0 | 13.3 | - | - |
| | Pool complex | | | 16.0 | | | |
| | Backwater | - | - | 5.6 | - | - | - |
| | Pool (other) | - | - | 14.3 | - | - | - |
| Riffle | Low-gradient riffle | 95.7 | 26.3 | 10.3 | 27.0 | 41.7 | 22.2 |
| | High gradient riffle | - | - | - | - | - | - |
| | Glide | 109.5 | 32.2 | 10.7 | 28.1 | 46.8 | 20.2 |

**Table 9.** Average unit length (ft) by surveyed subtype within the Study Area.

| Habitat | | Process reach ID and side channel | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Primary unit type** | **Subtype** | **Mainstem (unit category 1)*** | **Mainstem (unit categories 2 & 3)*** | **SC1** | **SC2** | **SC3** | **SC4** | **Total average unit length (ft)** |
| Pool | Main channel | 56 | 101 | 50 | 62 | 103 | 65 | 57 |
| | Lateral scour | - | - | 29 [1] | 40 | - | | 36 |
| | Pool complex | - | - | 66 | - | - | | 66 |
| | Backwater | 129 [1] | - | - | - | - | | 129 [1] |
| | Pool (other) | - | - | 32 | - | - | | 32 |
| Riffle | Low gradient | 386 | 159 | 70 | 92 | 132 | 70 | 176 |
| | Rapid | 485 [1] | - | - | - | - | | 485 [1] |
| | Glide | 755 | 195 | 76 | 94 | 145 | 55 | 236 |

| **Habitat** | | **Process reach ID and side channel** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Primary unit type** | **Subtype** | **Mainstem (unit category 1)*** | **Mainstem (unit categories 2 & 3)*** | **SC1** | **SC2** | **SC3** | **SC4** | **Total average unit length (ft)** |
| Other | Island | 490 | 239 | 55 | - | 230[1] | | 282 |
| | Alcove | | 48 [1] | | | | | 48 [1] |
| | Marsh | | | 43 [1] | | | | 43 [1] |
| | Dry channel | 58 [1] | | 275 | | | | 221 |
| **Total average unit length (ft)** | | 339 | 169 | 80 | 67 | 153 | 63 | 157 |

* Mainstem (unit category 1) includes primary main channel units. Mainstem (unit categories 2 and 3) includes secondary main channel habitat units (units that did not span the entire river channel) and side channel habitat units separated from the main channel by an island.

[1] Indicates measurement of a single unit (i.e., not an average value).

#### 4.1.1.1 Additional pool habitat unit attributes

Where possible, the apparent primary factor responsible for each pool's formation was recorded during field survey efforts, as specified in the study plan. Within the Study Area, 45% of the pools were either formed or were constructed adjacent to engineered wood (Table 10). Two of the eight large engineered log structures had pools formed or created in front of them. For the remaining pools, channel bedform (18%), resistant bank (18%), or LWD (l8%) were primary factors in their formation.

**Table 10.** Primary pool-forming factors for habitat units surveyed in the Study Area.

| Pool-forming factor | Process reach ID and side channel | | | | | | Total |
|---|---|---|---|---|---|---|---|
| | Mainstem (category 1)* | Mainstem (categories 2 & 3)* | SC1 | SC2 | SC3 | SC4 | |
| Roots of standing trees or stumps (Field code 4) | - | - | - | - | - | - | 0 |
| Boulder(s) (Field code 5) | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| Bedrock (Field code 6) | - | - | - | - | - | - | 0 |
| Channel Bedform (Field code 7) | 0 | 2 | 0 | 4 | 3 | 1 | 10 |
| Resistant Bank (Field code 8) | 0 | 0 | 0 | 5 | 0 | 0 | 5 |
| Artificial Bank (Field code 9) | - | - | - | - | - | - | 0 |
| LWD (logs) (Field Code 1) | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| Engineered Log Structure Associated | 2 | 1 | 0 | 1 | 0 | 1 | 5 |
| **Total** | **2** | **4** | **0** | **10** | **3** | **3** | **22** |

* Mainstem (category 1) includes primary main channel units. Mainstem (categories 2 and 3) includes secondary main channel habitat units (units that did not span the entire river channel) and side channel habitat units separated from the main channel by an island.

Residual pool depth measurements for a given stream provide the number and spatial distribution of deep pool habitats that can support aquatic life, even through annual low-flow periods. Residual pool depth is the maximum wetted depth minus the wetted pool crest depth (Lisle 1987). In all cases, the average residual pool depth was 1.5 ft, with the first quartile measuring 0.96 ft. Median residual pool depths were comparable between reaches, ranging from 1.25 ft (SC1) to 3.4 ft (SC3). Residual depths were most variable in the mainstem (Figure 3). The smaller channels in the mainstem (categories 2 and 3) have greater residual pool depth because their downstream controls tend to be much shallower than the large mainstem pools[2]. SC3 is a natural channel and not recently constructed, which may explain its deeper residual pool depth than those measured in SC1, SC2 and SC4.

[2] Residual pool depths in the large mainstem portions of the river may be slightly less accurate. In some locations, low visibility or inability to wade to the deepest portion of the pool made it difficult to locate maximum depth accurately, in which case the field crew estimated the maximum depth.

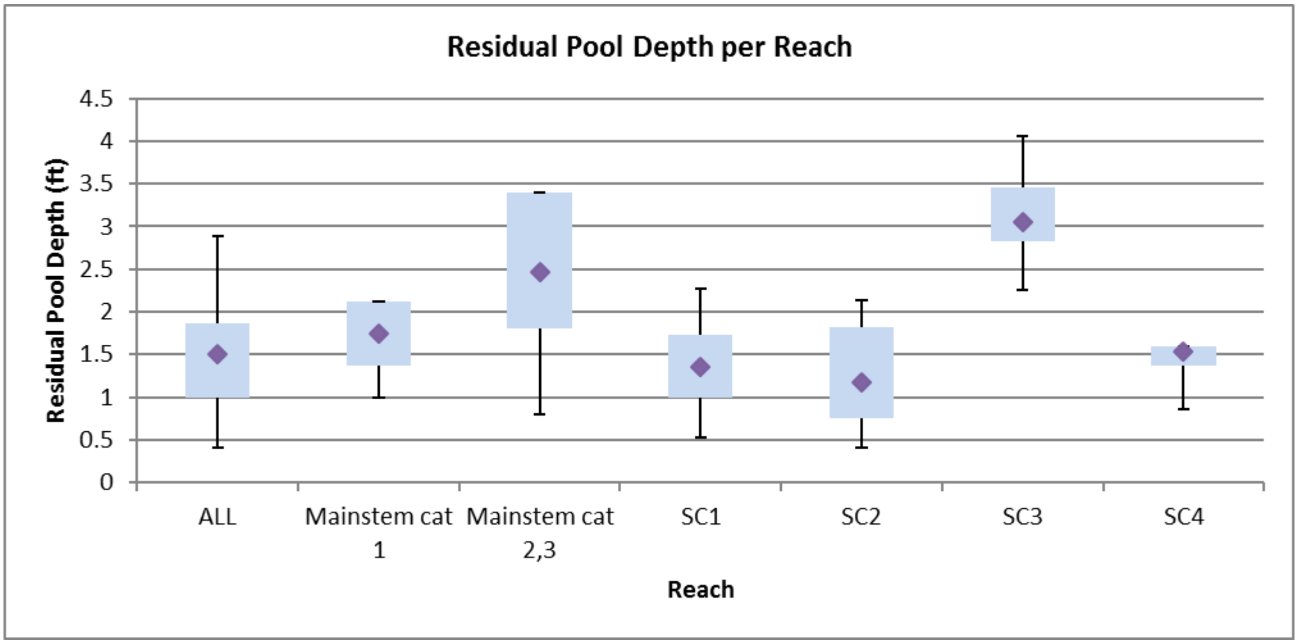



**Figure 3**. Box-and-whisker plots of surveyed residual pool depth by survey reach. The boundary of a box closest to zero indicates the 25th percentile, the diamond within a box marks the median, and the boundary of a box farthest from zero indicates the 75th percentile. Box whiskers indicate the minimum and maximum values.

#### 4.1.1.2 Bar edge and undercut habitat attributes

Bar edge habitat is used by emergent juvenile salmon during spring and early summer rearing periods because of their conditions of low velocity and shallow depth, and juvenile salmon are found primarily in low-gradient riffle and glide habitats (Figure 4). Bar edge and undercut bank habitats were estimated as the percent of the unit length on either the right or left edges of each habitat unit. Results were calculated as cumulative averages for both sides of the stream (i.e., left and right combined).

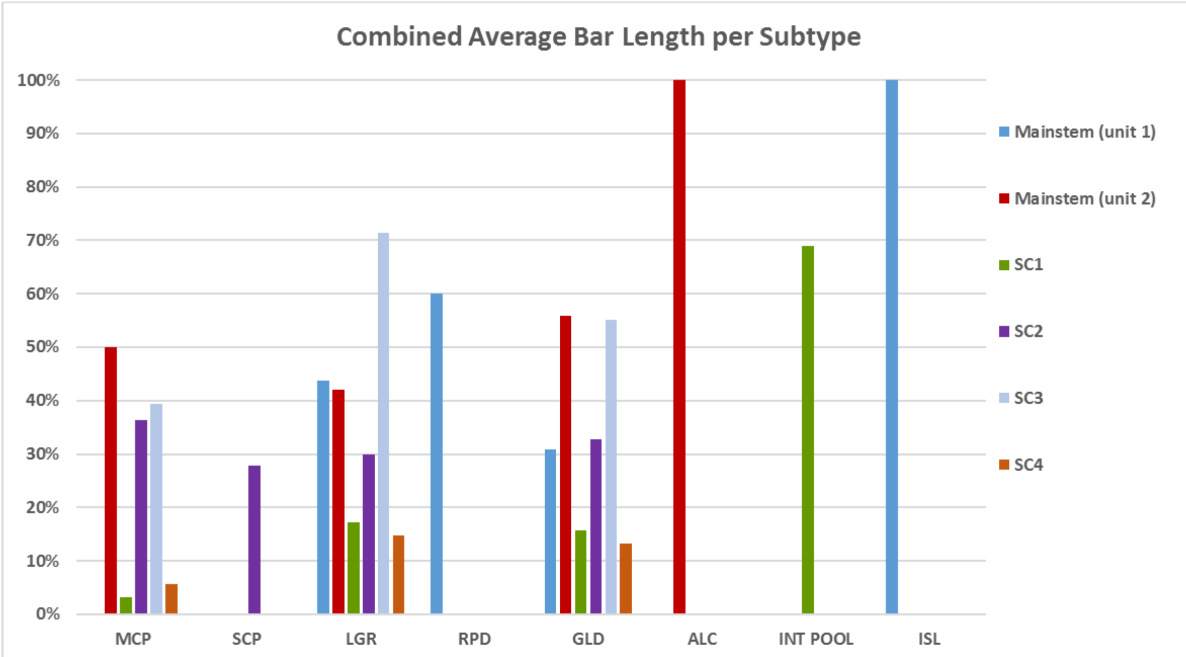



**Figure 4**. Average length (expressed as a percent) of bar edge per subtype by reach in the lowermost 2.7 miles of the Sultan River, including side channels. Habitat subtypes are as listed in Table 5: Main channel pool (MCP), lateral scour (SCP), low-gradient riffle (LGR), rapid (RPD), glide (GLD), alcove (ALC), intermittent pool (INT POOL), and island (ISL).

Within the total surveyed Study Area, measured bar edge habitat appears to constitute approximately 30% of stream length, and is most abundant in SC3 (55% of total stream length) (Table 11). Uncertainties in the accuracy and the replicability of this parameter, however, raise questions about the accuracy of these measurements in this and other surveys (see Section 5.4 for a more complete discussion).

**Table 11**. Average combined lengths of left and right bar edges for each reach per subtype (ft).

| Habitat | | Process reach ID and side channel | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Primary unit type | Subtype | Mainstem (category 1) | | Mainstem (categories 2 & 3) | | SC1 | | SC2 | | SC3 | | SC4 | |
| | | Avg length (ft) | % of total | Avg length (ft) | % of total | Avg length (ft) | % of total | Avg length (ft) | % of total | Avg length (ft) | % of total | Avg length (ft) | % of total |
| Pool | Main channel | 0 | 0% | 203 | 50% | 58 | 3% | 122 | 38% | 124 | 40% | 38 | 6% |
| | Lateral scour | 0 | 0% | 0 | 0% | 0 | 0% | 26 | 32% | 0 | 0% | 0 | 0% |
| | Intermittent | 0 | 0% | 0 | 0% | 212 | 68% | 0 | 0% | 0 | 0% | 0 | 0% |
| Riffle | Low-gradient riffle | 2,636 | 47% | 1,066 | 40% | 153 | 18% | 216 | 29% | 834 | 70% | 48 | 14% |
| | Rapid | 291 | 60% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| | Glide | 3,001 | 31% | 454 | 58% | 275 | 16% | 227 | 34% | 561 | 55% | 54 | 14% |
| Other | Alcove | 0 | 0% | 48 | 100% | 0 | 0% | 0 | 0% | 0 | 0% | 0 | 0% |
| | Marsh | 0 | 0% | 0 | 0% | 43 | 100% | 0 | 0% | 0 | 0% | 0 | 0% |

Undercut banks associated with habitat units provide refuge—cover and habitat complexity for fish and other aquatic organisms. Undercut banks are much less common than bar edges, but they were nonetheless present within all of the reaches. Across all reaches, undercut bank features were present in only 4% of total stream length, and so a detailed accounting of their locations is not provided here. They were predominantly found alongside glides (7% of total main channel pool stream length in the study area). The fraction of undercut habitat within each reach relative to twice the reach's total length (to account for the two banks) was measured as approximately 20% in SC2 and 16% in SC4, but <5% in the mainstem and the other two side channels.

### 4.1.2 Results: large woody debris (LWD) survey

The density of LWD can be presented using a variety of metrics. For this report, density of LWD is presented as pieces per mile of stream channel (Table 12). Only naturally occurring LWD was tallied (see Section 4.1.2.3 below for a discussion of the LWD in engineered wood structures). In some locations it was unclear whether the wood occurred naturally or had been placed as part of stream enhancement. Where the origin of the wood was ambiguous, it was assumed to be "natural" LWD. Maps indicating the distribution of LWD by habitat unit are included as Appendix D.

#### 4.1.2.1 LWD—individual pieces

Data collected for individual LWD pieces included categories of piece diameter, length estimates, species type, and decay class. For purposes of the survey, individual LWD pieces were tallied separate from pieces occurring within debris jams. Nearly half (46%) of all individual LWD pieces were downed trees of a small diameter class (20 to 40 cm); 41% were of medium diameter (>40–60 cm) and 13% were of large diameter (>60 cm).

**Table 12.** LWD density per mile in the Study Area[1].

| Survey reach | Length (mi) | LWD density per mile: individual pieces only | LWD density per mile: individual pieces and debris jam pieces |
|---|---|---|---|
| Mainstem | 2.7 | 42 | 70 |
| SC1 | 0.6 | 73 | 73 |
| SC2 | 0.4 | 43 | 105 |
| SC3 | 0.4 | 35 | 35 |
| SC4 | 0.3 | 30 | 30 |

[1] In addition, 16 wood pieces were rootwads and are not included in these tallies.

The position of LWD within the bankfull channel was also recorded. Wood was classified on whether it was primarily (greater than 50%) in the wetted channel (Zone 1) or within the bankfull width (Zone 2). LWD pieces in the wetted channel were also further differentiated if any part of the LWD extended to mid-channel. The position of LWD within the channel is relevant to understanding how LWD contributes to habitat complexity by affecting channel hydraulics at different river discharges (Ralph et al. 1994, Montgomery et al. 1995). Within the Study Area, most (76%) of individual LWD pieces tallied were primarily within the wetted river channel (Zone 1), with 42% of those extending into mid-channel. The remaining 24% of the individual LWD pieces were primarily in Zone 2.

Tree species type and decay class were identified for all individual LWD pieces. Throughout the total surveyed Study Area, species composition was 61% unknown species (classified as such due to a lack of bark or otherwise identifying features), 18% coniferous species, and 21% deciduous species. Using a decay class scale of 1 to 5, where 1 indicates the lowest state of decay and 5 indicates the highest state of decay, less than half (37%) of individual LWD pieces were within decay classes 1 to 3, indicating that they are of fairly recent (i.e., the last few decades) origin.

#### 4.1.2.2 LWD—jams

Within the Study Area, there were five natural debris jams within the wetted portion of the river channel at the time of the survey. This includes a jam in habitat unit 36, a jam in habitat unit 93 at the mouth of SC4 (accumulated against an engineered structure), a jam on the tip of an island in habitat unit 81, a jam at habitat unit 58, and a jam in SC2 (unit 2-16). The jams in habitat unit 36 and 93 were also present in 2014.

#### 4.1.2.3 LWD—engineered wood

A large amount of engineered LWD was installed as bank-side structures in the mainstem, and as single logs to multi-log structures in each of the side channels. The 2014 report tallied the structures present. During the 2016 survey, the focus in regard to engineered wood was to document instances of scour at, and natural wood accumulation against, the engineered wood. When scour forms at installed structures or natural LWD accumulates, the increased channel complexity can be utilized by juvenile salmonids. Table 13 illustrates those structures that have either contributed to scour or had an accumulation of additional natural wood. Other structures that have not resulted in either still provide habitat and may result in the formation of pools or larger wood accumulations in the future.

**Table 13**. Engineered structures that have caused scour or accumulated natural LWD.

| NSO # | # of logs in engineered structure* | Scour dimensions | | Natural accumulation (# of logs)** | Comments |
|---|---|---|---|---|---|
| | | Length (ft) | Max depth (ft) | | |
| 93a | 15 | 30 | 3.9 | 12 | Natural accumulation against a log structure at the head of SC4. |
| 89 | 20 | 35 | 2.5 | 0 | Scour at engineered structure. Large natural log near (but not against) the engineered structure contributed to the scour. |
| 80 | 15 | 8 | 2.5 | | At the mouth of SC1. Pool small and was not habitat typed as its own unit. |
| 79 | 15 | 10 | 2.5 | | Not certain that this scour caused by engineered structure. |
| 79a | 12 | 36 | 3.1 | | This jam formed unit 79a. |
| 69 | 10 | 20 | 2 | | Located at the head of unit 69. Did not type the scour as a separate pool unit. |
| 47 | 3 | | | 3 | Accumulated 3 large logs as well as smaller debris. |

| NSO # | # of logs in engineered structure* | Scour dimensions | | Natural accumulation (# of logs)** | Comments |
|---|---|---|---|---|---|
| | | Length (ft) | Max depth (ft) | | |
| SC2-4 | 3 | | | 5 | This is a one-log structure on the left bank and a two-log structure on the right bank, with five logs and smaller debris accumulated against them. Scour just starting to form. |
| SC2-10 | 1 | 72 | 2.3 | 1 | This forms unit SC2-10. Has one log and some smaller debris accumulation. |
| SC2-13 | 2 | 40 | 2.8 | 3 | Forms pool SC2-13A. |
| SC2-14 | 3 | | | 8 | This is a one-log structure on the right bank and a two-log structure on the left bank, with eight logs and smaller debris accumulated against them. |
| SC2-15A | 1 | 111 | 2.7 | | Caused about one-half of the scour forming unit SC2-15a. |
| SC2-15A | 2 | | | 1 | Two structures, each of one log. One on right bank, one on left. |
| SC4-1D | 3 | 52 | 2.7 | 3 | These structures form pool SC4-1D. |
| SC4-1D | 2 | | | 2 | |
| SC4-1F | 1 | 63 | 1.75 | | Forms unit SC4-1F, with some influence from a mid-channel boulder. |
| SC4-1G | 2 | 24 | 1.95 | | Forms unit SC4-1H. |
| SC4-1I | 7 | 51 | 2.7 | | A series of structures, one with one log and three with two logs form unit SC4-1J. |
| SC4-1N | 4 | 51 | 2.6 | | Forms unit SC4-1N. |
| SC4-1O | 1 | 10 | 3 | | This small scour is included in glide unit 1O. |
| SC4-1R | 5 | 201 | 3 | | Two structure, one with two logs, one with three form unit SC4-1R. |
| SC4-1T | 1 | 8 | 2.5 | | Not delineated as a separate pool. |
| SC1-2E | 1 | 36 | 1.55 | | Forms unit SC1-2E. |
| SC1-2J | 1 | 7 | .75 | | Within a larger glide unit. Both areas of scour too small to delineate individually. |
| SC1-2J | 1 | 6 | 1 | | |
| SC1-2M | 3 | 27 | 2.2 | | Three structures totaling three logs form pool SC1-2J. |
| SC1-2O | 11 | 81 | 2.32 | | Four separate structures form pool SC1-2O. |
| SC1-2Q | 4 | 6 | 1.5 | | Four log structure forming small pool at downstream end of a glide. |
| SC1-2Y | 1 | 8 | 0.5 | | Small amount of scour at one of five structures in SC1-2Y. |

| NSO # | # of logs in engineered structure* | Scour dimensions | | Natural accumulation (# of logs)** | Comments |
|---|---|---|---|---|---|
| | | Length (ft) | Max depth (ft) | | |
| SC1-2Y | 2 | | | 5 | Accumulation on a left bank structure in SC1-2Y. |
| SC1-2Y | 6 | 10 | 1.5 | | Multi-log structure forming a small scour pool. |
| SC1-2Y | 2 | 12 | 1 | | Mid-channel structure with a small amount of scour. |
| SC1-3A | 1 | 50 | 2.2 | 4 | Accumulation against a log structure forms unit SC1-3a. |
| SC1-3B | 4 | | | 2 | No noticeable scour. |
| SC1-2AA | 4 | 33 | 1.6 | | Forms unit SC1-2AA. Accumulation of small debris against a mid-channel structure. |
| SC1-6A | 3 | 27 | 1.9 | | Forms unit SC1.6A, but barely extends into wetted channel at low flow. |
| SC1-11A | 3 | 63 | 1.6 | | Forms SC1-11A. |
| SC1-11D | 2 | 24 | 1.15 | | Forms SC1-11D. |
| SC1-11G | 1 | 25 | 1.5 | | Forms SC1-11G. |
| SC1-11I | 1 | 24 | 1.4 | | Forms SC1-11I. |

* Numbers of logs in debris structures are approximate. Exact numbers are difficult to count due to overlap and burial in bank.

** Natural accumulation is the number of logs that meet the criteria for LWD. In many cases structures had also accumulated smaller debris.

In general, engineered wood is beginning to influence morphology—both forming pools and accumulating additional woody debris. Table 14 summarizes the number of pools formed and the debris accumulated in each reach.

**Table 14.** Changes in morphology due to engineered wood.

| Survey reach | # of structures influencing morphology | Pools formed | LWD pieces accumulated |
|---|---|---|---|
| Mainstem | 6 | 6 | 12 |
| SC1 | 18 | 16 | 11 |
| SC2 | 6 | 3 | 18 |
| SC3 | 1 | 0 | 3 |
| SC4 | 9 | 8 | 5 |

### 4.1.3 Characterization of river channel substrate

Sediment sizes are typically reported as percentiles of the intermediate diameter of sediment clasts on a bar or the bed of the river, notated as "D" with a subscript representing the percentage of particles smaller than that size (so, for example, $D_{50}$ is the 50th percentile, or median substrate size) (Wolman 1954). Results from Wolman pebble counts are presented in Table 15.

**Table 15.** Approximate size distribution (in mm) of river substrate material from sample sites throughout the Study Area.

| Reach* | Unit number containing sample | Stream substrate particle size (mm) | | |
|---|---|---|---|---|
| | | $D_{16}$ | $D_{50}$ | $D_{84}$ |
| Mainstem | 89 | 10 | 53 | 96 |
| SC1 | 11 | 4 | 27 | 83 |
| SC2 | 16 | 16 | 50 | 110 |
| SC4 | 1 | 10 | 31 | 70 |

* Because pebble counts have not previously been conducted in SC3, there would be no historical data to compare, and thus no pebble counts were conducted in SC3 in 2016.

The pebble counts indicated that the gravel patches assessed were all suitable for spawning (i.e., $D_{50}$ between 20 to 60 mm). Although Wolman counts cannot discriminate particles below 4 mm diameter, the reported sizes of $D_{16}$ strongly suggest that the other grain-size criterion for suitable spawning (i.e., no more than 10% finer than 0.85 mm) was also met.

# 5 DISCUSSION

## 5.1 Riverine Habitat Characteristics

The primary objective of this 2016 study was to identify any significant changes that have occurred and that could affect fish habitat since the previous studies in the lower 2.7 miles of the mainstem Sultan River and its four side channels.

When comparing the 2016 to data from 2007, 2010, and 2014, the following general observations were made:

- A total of 230 in-river habitat units were surveyed within the Study Area. This is a substantial increase of 119 units, essentially twice the number of units identified in 2014. This is not an artifact of changes in sampling methodology but rather an expression of greater spatial diversity in habitat units, indicating that the recent high-flow event, stream enhancements, and other natural processes are facilitating geomorphic and hydrologic changes that could contribute to an increase in complexity in the study area. The majority of these changes occurred in the side channels.
- Habitat subtypes not previously observed were identified and defined for inclusion in the current (and any future) survey. These "new" subtypes are intermittent and isolated pools, dry channels, alcoves, and marshes. Conversely, the previously observed habitat type of subsurface flow habitat was no longer present in 2016.
- The percent of total surface area of each subtype in the Study Area in both 2014 and 2016 was not greatly changed from what existed in in 2007, but some systematic trends have become evident. In particular, glide habitat is being converted into more complex habitat, particularly pool-riffle-glide complexes, and substantially more island habitat has been created (Table 16).

**Table 16**. Comparison of percent total surface area of habitat subtypes for 2007, 2014, and 2016.

| Year | Habitat subtype | | | |
|---|---|---|---|---|
| | Glide | Low-gradient riffle | Islands | Pools |
| 2007 | 66 | 29 | 6 | <1 |
| 2014 | 55 | 25 | 16 | 4.3 |
| 2016 | 47 | 26 | 23 | 2.9 |

- There was a substantial loss of measured bar edge habitat between 2014 and 2016. The mainstem and SC4 had the greatest apparent loss of bar edge. Compared to the bar edge measured in 2014, only 80% left bar edge and 55% right bar edge remained in 2016. This unusual result is discussed in greater detail below (Section 5.4); it is judged unlikely to reflect an actual change in riverine habitat but instead highlights an inherently noisy and unreliable parameter for repeat measurements over time. As such, it is advised to omit this parameter from future surveys.
- Compared to 2014, there is an increase in the average combined length (left and right) of undercut banks present in the side channels. In 2014 for SC2, undercut habitat accounted for 12% of the total cumulative perimeter length and in 2016 it accounted for 20% (Table 17). Mainstem undercut habitat remained largely unchanged.

**Table 17**. Comparison of combined left and right undercut banks as a percentage of total cumulative perimeter length per reach in 2014 and 2016.

| Reach | Percent total cumulative perimeter length of undercut banks (combined left and right) | |
|---|---|---|
| | 2014 | 2016 |
| Mainstem (unit 1) | 0% | 2% |
| Mainstem (units 2,3) | 1% | 3% |
| SC1 | 4% | 4% |
| SC2 | 12% | 20% |
| SC3 | 0% | 1% |
| SC4 | 0% | 12% |

### 5.1.1 Main channel

Mainstem habitat unit changes constituted ~10% of total bank length, along with localized changes in the vicinity of the engineered log structures. Specifically, the following changes were noted:

- undercut lengths decreased by 113 ft on the left bank and increased by 609 ft on the right bank; and
- average wetted widths were largely unchanged from previous studies, indicating the storm event experienced by the river system was not so extreme as to cause measurable bank erosion.

### 5.1.2 Side channels

The four side channels vary in their complexity, with SC1 having the most varied and generally smaller individual habitat units. The enhancement of the side channels has led to increased numbers of distinct habitat units, even during low flows, as outlined in the Results section. There has been a gain of 636 ft in low-flow stream channel length since 2014 (Table 18) spread amongst all side channels except SC4, adding the potential for greater habitat complexity and refugia. In SC1, however, there are now stretches of dry channel, and some glides and riffles have been transformed into a series of intermittent, isolated, and complex pools that have locally reduced aquatic habitat and connectivity.

**Table 18.** Side channel length comparisons from 2010, 2014, and 2016 data.

| Side channel | 2007 and 2010 lengths (ft) | 2014 digitized lengths (ft) | Change, 2007/ 2010–2014 | 2016 digitized lengths (ft) | Change, 2014–2016 |
|---|---|---|---|---|---|
| SC1 | 2,512 | 5,744 | +3,232 | 5,995 | +251 |
| SC2 | 1,735 | 1,722 | -13 | 1,802 | +80 |
| SC3 | 2,202 | 2,350 | +148 | 2,740 | +390 |
| SC4 | No Data | 1,467 | – | 1,382 | -85 |

**SC1**

SC1 was previously surveyed for habitat in 2010 before enhancements were made to the channel. The 2010 survey did not include the southerly extension (units SC1-1 and SC1-2 of the 2014 survey). In 2014, after enhancements were made, SC1 was substantially lengthened but still largely uniform, consisting mostly of glides with smaller amounts of pools and riffles (Figure 5). The pools mostly appear to have been constructed or have formed at installed large woody debris. There were some deeper areas beginning to form at large wood structures within the glides, and the 2014 report anticipated that habitat complexity would increase with additional high-flow events.

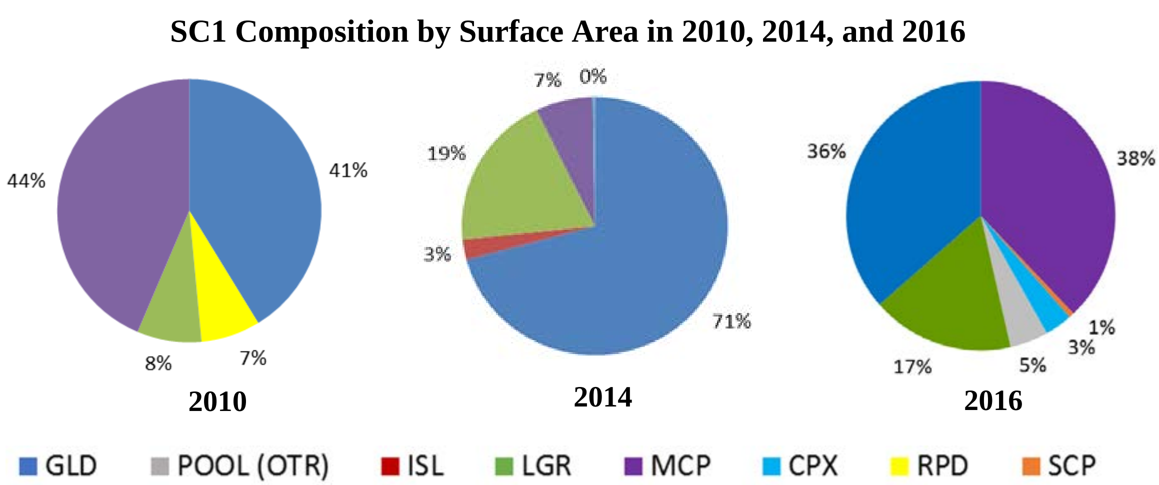



**Figure 5.** Comparison of SC1 composition by surface area in 2010, 2014, and 2016. Habitat subtypes are as listed in Table 5: Glide (GLD), Intermittent and isolated pools POOL (OTR), high gradient riffle (HGR), island (ISL), low-gradient riffle (LGR), main channel pool (MCP), pool complexes (CPX), rapid (RPD), and lateral scour (SCP).

Since 2014, SC1 has evolved from a relatively homogenous channel that comprised 18 units (primarily main channel pools, low-gradient riffles, and glides) to one that is now made up of 93 units including 35 pools, stretches of dry channels and isolated pools, as well as a marsh, islands, and glides and low-gradient riffles.

Though more complex in terms of number of distinct units that constitute the channel, the ability for SC1 to maintain cool-water refugia and channel connectivity has been compromised due to the decreasing depths and channel widths, and the stretches of dry channels and intermittent pools (which were observed to contain small fish) (Figure 6). The decreases in average wetted widths in this channel were mainly observed in glides and main channel pools, with average wetted widths for these subtypes decreasing from 2016 to 2014 by 4.4 and 4.9 ft, respectively. Average depths in SC1 were shallower (0.61 ft in 2016 compared to 0.94 ft in 2014), which could potentially affect the channel's ability to maintain cool water temperatures and support native fish. Water temperatures during these lower flow periods are unknown, but the presence of isolated pools could lead to mortality either through thermal stress or avian predation.

Discharge from the mainstem into the inlet of SC1 during the habitat assessment of 2016 was little different from 2014 and does not explain these results. What has changed between these two surveys is the split of flow at near the midpoint of the side channel (at SC1-5), where a short segment of channel returns flow to the mainstem river while the side channel itself continues for more than 1,000 ft farther before rejoining the Sultan River. Although this distributary network has increased the total length of side channels it has also allowed for the natural redistribution of water between the branches, which at present favors the shorter return segment back to the mainstem at low flows and a consequent reduction in wetted area and an increase in areas of dry channel and marsh downstream of the split along the other segment.

Over SC1 as a whole, there was a net gain of 140 ft in undercut bank length. Some collapsed banks were observed, indicating that undercutting was supplying sediment to the channel. In these still-young side channels, morphological change to the banks can be expected to continue, and the contribution of sediment from those changes is apparently exceeding the ability of flows to fully remove that introduced sediment during a single high-flow event.

**Figure 6.** SC1 downstream of the distributary split in SC1-5 was locally dry in 2016 (left); in 2014, the channel was wet in its entirety (right) from the head to its outlet.

### SC2

SC2 is more structurally complex than SC1, with generally smaller and less uniform habitat units. Since 2014, the channel has evolved from a somewhat variable channel that contained 15 distinct subtype units to an even more diverse stretch containing 25 subtype units, with changes in habitat mostly occurring in the side channel's upper reaches. LWD structures accumulated additional large wood and retained spawning gravels as predicted in 2014 and, as a result, additional pools (mainly main channel pools) have formed since the last survey.

When comparing 2014 and 2016 by surface area, results show an increase in pool and riffle habitat and a decrease in glide habitat (Figure 7). Other changes include:

- the subsurface unit at unit numbered SC1-9 is now classified as a dry channel due to the lack of visible standing water or discharge;
- stream length in the channel increased by 80 ft overall;
- average wetted widths for the lateral scour pools decreased from 31.9 ft in 2014 to 13.3 ft in 2016;
- depths in the channel in 2016 are on average half those observed in 2014, despite similar discharges during both measurements. This could be due to infilling or changes at the inlet that reduced discharge through the channel; and
- undercut lengths increased on both banks from the 2014 survey, with an additional 282 ft observed on the left and 15 additional ft observed on the right banks.

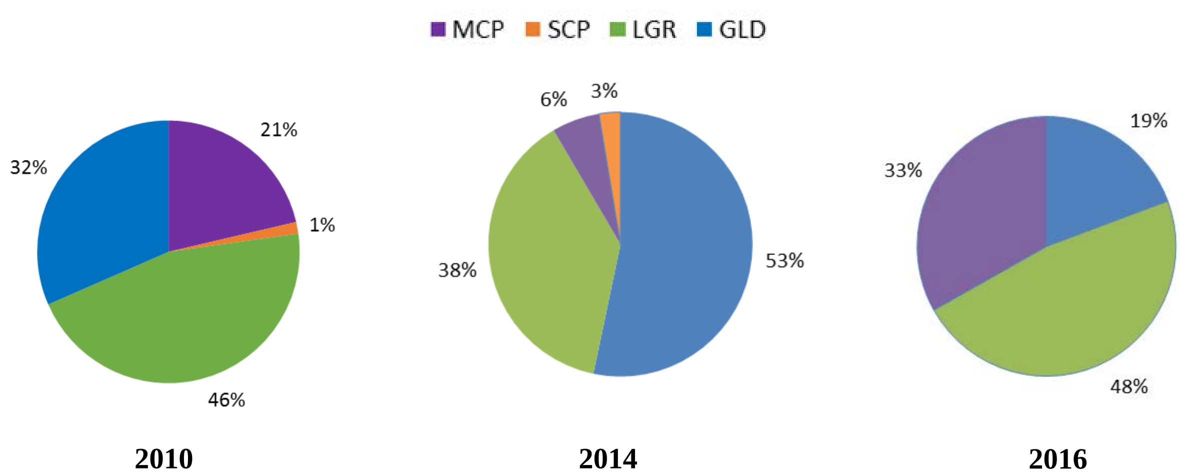



**Figure 7.** Comparison of SC2 composition by surface area in 2010, 2014, and 2016.

**Figure 8**. NSO SC2-15 was classified as a 274-ft-long glide in 2014 (left); as of the 2016 survey, it had become a shorter 45-ft glide surrounded by a large main channel pool and riffle (right).

**SC3**

The fraction of surface area per subtype in this side channel was unchanged between 2010 and 2014 (Figure 9). Between 2014 and 2016 relative areas were also similar, except for the loss of the island subtype previously measured, but with 20 distinct habitat subtypes in 2016 compared to 17 in 2014.

Additional changes in SC3 since 2014 include:

- the stream length increased by 390 ft (16%), likely due to increasing meander;
- average wetted width for main channel pools doubled, from 15.5 ft in 2014 to 31.2 ft in 2016; and
- undercut banks were not observed in any unit on the left bank and were observed to be present in only 34 ft of the right bank.

The effects of these changes on habitat and the resulting fish carrying capacity are likely inconsequential in aggregate.

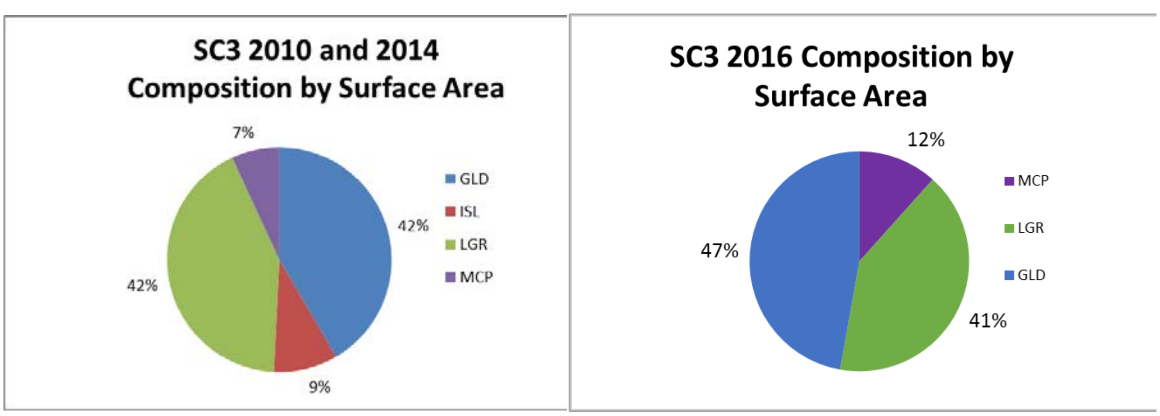



**Figure 9**. SC3 composition by surface area in 2010, 2014, and 2016.

**SC4**

The observed changes to SC4 were the most dramatic, and beneficial to fish habitat, of any side channel in the Study Area. Since 2014, SC4 has been transformed from essentially one long glide (with a small pool at its mouth and one riffle) to a variable pool-riffle-glide reach (Figure 10). Depths in SC4 now range from 0.8 to 2.7 ft, compared to 2014 when depths ranged from only 0.9 to 1.2 ft. The mixture of flows and depths derived from the more variable habitat now present is key to sustaining fish and invertebrate species. Undercut habitat also increased since 2014, by 392 ft on the left and 72 ft on the right banks.

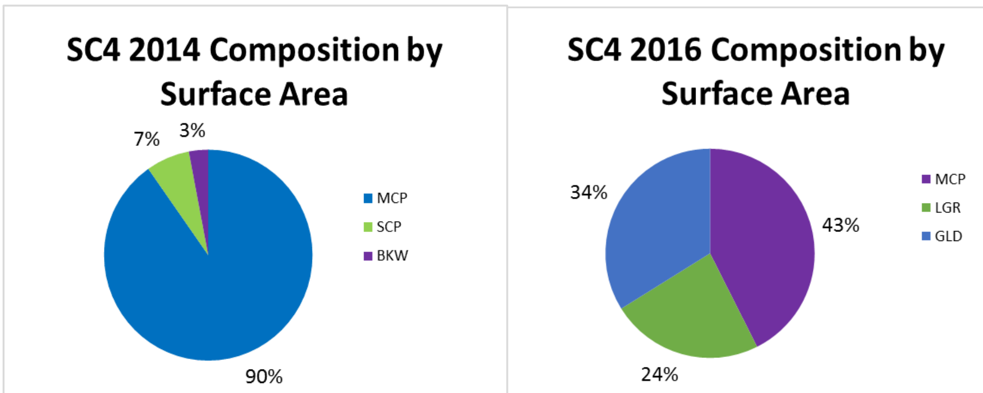



**Figure 10**. SC4 composition by surface area in 2014 and 2016.

In summary, the changes to habitat in this reach are positive, insofar as diversity of habitat supports the requirement of having variable and proximal freshwater habitats for the range of salmonid life stages, including those used for spawning, juvenile rearing, and migration of adults.

## 5.2 Large Woody Debris Characteristics

The total amount of LWD (number of logs) was remarkably similar between 2014 (216 pieces) and 2016 (214 pieces). Some obvious recruitment was observed (large trees in the channel due to bank erosion), and some wood was likely washed downstream out of the system by the high flows. There were some shifts in LWD distribution that can be best compared on the distribution maps and GIS layers from 2007, 2010, and 2014. In terms of number of pieces per mile, the amount of naturally occurring LWD was higher in the mainstem and SC2 (if debris jam pieces are included), and lower elsewhere (Table 19).

Most of the wood is individual pieces, with five jams (an increase of three jams over 2014). All jams were in the mainstem, except for one in SC2. The wood present was reported to be more decayed in 2016 than 2014, with 63% of the LWD classified in decay classes 4 or 5 in 2016, vs 43% in 2014, and 22% in 2007. It would not be expected that LWD (especially conifers) would visibly decay to that degree in two years, suggesting that this parameter may be subject to significant observer variability from year-to-year. Regardless of actual decay status, however, reaches with LWD offer more complex habitat than reaches that are completely lacking in LWD.

**Table 19.** LWD density per mile in the Study Area.

| Survey reach | Length (mi) | LWD density per mile, individual pieces only | | LWD density per mile, individual pieces plus debris jam pieces | |
|---|---|---|---|---|---|
| | | 2014 | 2016 | 2014 | 2016 |
| Mainstem | 2.7 | 36 | 42 | 53 | 70 |
| SC1 | 0.6 | 83 | 73 | 83 | 73 |
| SC2 | 0.4 | 68 | 43 | 68 | 105 |
| SC3 | 0.4 | 55 | 35 | 55 | 35 |
| SC4 | 0.3 | 17 | 30 | 17 | 30 |

The engineered log structures and LWD placed in 2012 were designed to provide habitat complexity, divert water into the side channels, retain gravel, provide bank habitat at varying flows, and roughen the flood plain. The engineered structures represent a significant increase in LWD in the mainstem over levels observed in 2007 and have begun to contribute to habitat complexity through the formation of pools and the accumulation and retention of natural LWD, which either may be limited in availability (due to the upstream dam) or flushed downstream and lost from the system, or both. The contribution to habitat complexity from the engineered LWD has increased significantly since 2014. This is especially noticeable in SC1 and SC4, as noted in the Section 4 (Results) above.

The structures and logs in the side channels are continuing to provide cover for fish over a range of flows. Structures have accumulated additional large wood and have led to the formation of additional pools and other habitat types since 2014. The structures are also well-positioned to serve as a catalyst for habitat change (e.g., accumulation of additional wood, retention of gravel, and increasing habitat complexity in the side channels) in the future.

## 5.3 Sediment Characteristics

Only one pebble count was conducted in 2007 in the Study Reach, and its location was revisited for 2014 and 2016 (Table 20). Additional pebble counts were conducted in 2014 in SC1, SC2, and SC4, which were again reproduced in 2016. The purpose of the 2016 study was to re-create previous surveys to assess habitat changes. Because there was no pre-existing particle size data for SC3, a pebble count was not conducted there in either 2014 or 2016, as there would not have been any comparisons to make.

The results of the mainstem pebble count indicate that while the $D_{50}$ particle was very similar in size in 2016 to the 2014 result, the $D_{16}$ particle was smaller and the $D_{84}$ particle was larger, indicating a wider range of particle sizes in the reach (Table 20).

**Table 20**. Comparison of approximate size distribution (in mm) of river substrate in the Study Reach for 2007, 2014 and 2016.

| Year | Unit number | Stream substrate particle size (mm) | | |
|---|---|---|---|---|
| | | $D_{16}$ | $D_{50}$ | $D_{84}$ |
| 2007* | 89 | 23 | 39 | 63 |
| 2014 | | 22 | 51 | 84 |
| 2016 | | 10 | 53 | 96 |

* The size distributions for this site were erroneously reported in RSP 22; values reported here were recalculated from the raw field data.

This result generally held true in SC1 and SC4: similar median particle size with a wider range in 2016 when compared to 2014. SC2 had results that were quite similar across the size distribution, although all representative particle classes were somewhat smaller in 2016 vs 2014, as was the overall particle size range (Table 21).

**Table 21**. Comparison of approximate size distribution (in mm) of river substrate in the side channels between 2014 and 2016.

| Year | Unit number | Stream substrate particle size (mm) | | |
|---|---|---|---|---|
| | | $D_{16}$ | $D_{50}$ | $D_{84}$ |
| ***SC1*** | | | | |
| 2014 | 11 | 3 | 23 | 50 |
| 2016 | 11-I | 4 | 27 | 83 |
| ***SC2*** | | | | |
| 2014 | 16 | 25 | 62 | 129 |
| 2016 | 16 | 16 | 50 | 110 |
| ***SC4*** | | | | |
| 2014 | 1 | 5 | 23 | 49 |
| 2016 | 1Q | 10 | 31 | 70 |

The variations seen could be the result of a number of factors and are well within the reported range of interannual variability, although none of them influence the underlying conclusion that the riffle substrates have been of a suitable size range for spawning throughout the nine years that sampling has occurred.

## 5.4 Variability and Uncertainty in Bar Edge Habitat Measurements

The reported changes in bar edge habitat over time (as noted in Section 5.1) are not readily explained by physical changes to the channel, despite the apparent magnitude of loss between 2014 and 2016. They likely represent not only actual changes in some bar edges but also the difficulty in applying a uniform criterion for their identification. Beechie et al. (2005) identified the boundary between edge units (such as bar edge habitat) and midchannel units by “a visible current shear line, the edge units having lower velocity…bars [edge habitat] had a shallow, low-gradient interface with the shore” (p. 719). This is not a very precise definition, particularly when observed at low flows when the velocity of the flow is low and so a “shear line” may be obscure or absent altogether. We also note that this habitat type is not common in most such characterizations (e.g., Frissell et al. 1986, Hawkins et al. 1993)

In this survey, the changes in the bar edges in the mainstem Sultan River recorded between 2014 and 2016 are particularly uncertain, based on comparison of the tabulated data with field photos and airphotos. This disparity is likely to have resulted in large part from the inaccuracies inherent in making long-distance observations, given that crossing the mainstem from one side to the other was typically precluded by the water depth over most habitat units. We also note that there was no spatial pattern to recorded differences between the two years, with apparent reductions spread from the top to the bottom of the study reach, and with no particular area being more or less affected. A true geomorphic basis for these differences would almost certainly have expressed some spatial variability, since bank and bar formation is not uniform through any reach of a river.

For all of these reasons, the seemingly dramatic reduction in this habitat unit is most likely a consequence of trying to measure an intrinsically ambiguous parameter, prone to observational differences from one year to another even with the same observer, and one whose defining characteristics are poorly expressed during the very flow conditions that are required for other, more critical elements of the survey. Thus, we recommend that this parameter be abandoned in future years' surveys.

# 6 REFERENCES

Beechie, T.J., Liermann, M., Beamer, E.M., Henderson, R. 2005. A classification of habitat types in a large river and their use by juvenile salmonids. Transactions of the American Fisheries Society, 134 (3), pp. 717-729.

Edelen, W. J. 2005. A Technical glossary of stream & river stabilization, restoration, and bioengineering terms. https://www.nrcs.usda.gov/Internet/FSE_PLANTMATERIALS/publications/wapmctn6333.pdf.

Flosi, G., Downie, S., Hopelain, J., Bird, M., Coey, R. and Collins, B. California salmonid stream habitat restoration manual. 1998. 3rd ed. California Department of Fish and Game.

Frissell, C.A., Liss, W.J., Warren, C.E., Hurley, M.D. 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Environmental Management, 10 (2), pp. 199-214.

Hawkins, C.P., Kershner, J.L., Bisson, P.A., Bryant, M.D., Decker, L.M., Gregory, S.V., McCullough, D.A., Overton, C.K., Reeves, G.H., Steedman, R.J., Young, M.K. 1993. A hierarchical approach to classifying stream habitat features. Fisheries, 18 (6), pp. 3-12.

Kondolf, G. M. 2000. Assessing salmonid spawning gravels. Transactions of the American Fisheries Society 129: 262–281.

Kondolf, G. M., and M. G. Wolman. 1993. The sizes of salmonid spawning gravels. Water Resources Research 29: 2,275–2,285.

Lisle, T. E. 1987. Using "residual depths" to monitor pool depths independently of discharge. Research Note PSW-394. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station, Berkeley, California.

Mongtomery, D. R., J. M. Buffington, R. D. Smith, K. M. Schmidt, and G. Pess. 1995. Pool spacing in forest channels. Water Resources Research 4: 1,097–1,105.

Olsen, D. S., B. B. Roper, J. L. Kershner, R. Henderson, and E. Archer. 2005. Sources of variability in conducting pebble counts: their potential influence on the results of stream monitoring programs. Journal of the American Water Resources Association 41:1,225–1,236.

Pleus, A. E., D. Schuett-Hames, and L. Bullchild. 1999. TFW monitoring program method manual for the habitat unit survey. Prepared for the Washington State Dept. of Natural Resources under the Timber, Fish and Wildlife Agreement. TFW-AM9-99-003; DNR#105.

Poole, G. C., Frissell, C. A., Ralph, S. C. 1997. In-stream habitat unit classification: inadequacies for monitoring and some consequences for management. Journal of the American Water Resources Association 33: 879–896.

Ralph, S. C., G. C. Poole, L. L. Conquest, and R. J. Naiman. 1994. Stream channel morphology and woody debris in logged and unlogged basins of Western Washington. Canadian Journal of Fisheries and Aquatic Sciences 51: 37–51.

Robison, E. G., and R. L. Beschta. 1990. Characteristics of coarse woody debris for several coastal streams of southeast Alaska, USA. Canadian Journal of Fisheries and Aquatic Sciences 47: 1,684–1,693.

Schuett-Hames, D., A. E. Pleus, J. Ward, M. Fox, and J. Light. 1999. TFW monitoring program method manual for the large woody debris survey. Prepared for the Washington State Department of Natural Resources under the Timber, Fish, and Wildlife Agreement. TFW-AM9-99-0004. DNR#106.

Stillwater Sciences. 2015. Sultan River riverine habitat monitoring. Prepared by Stillwater Sciences, Portland, Oregon for Snohomish County Public Utility District No.1, Portland, Oregon.

Wolman, G. M. 1954. A method of sampling coarse river-bed material. Transactions, American Geophysical Union 35, Number 6.

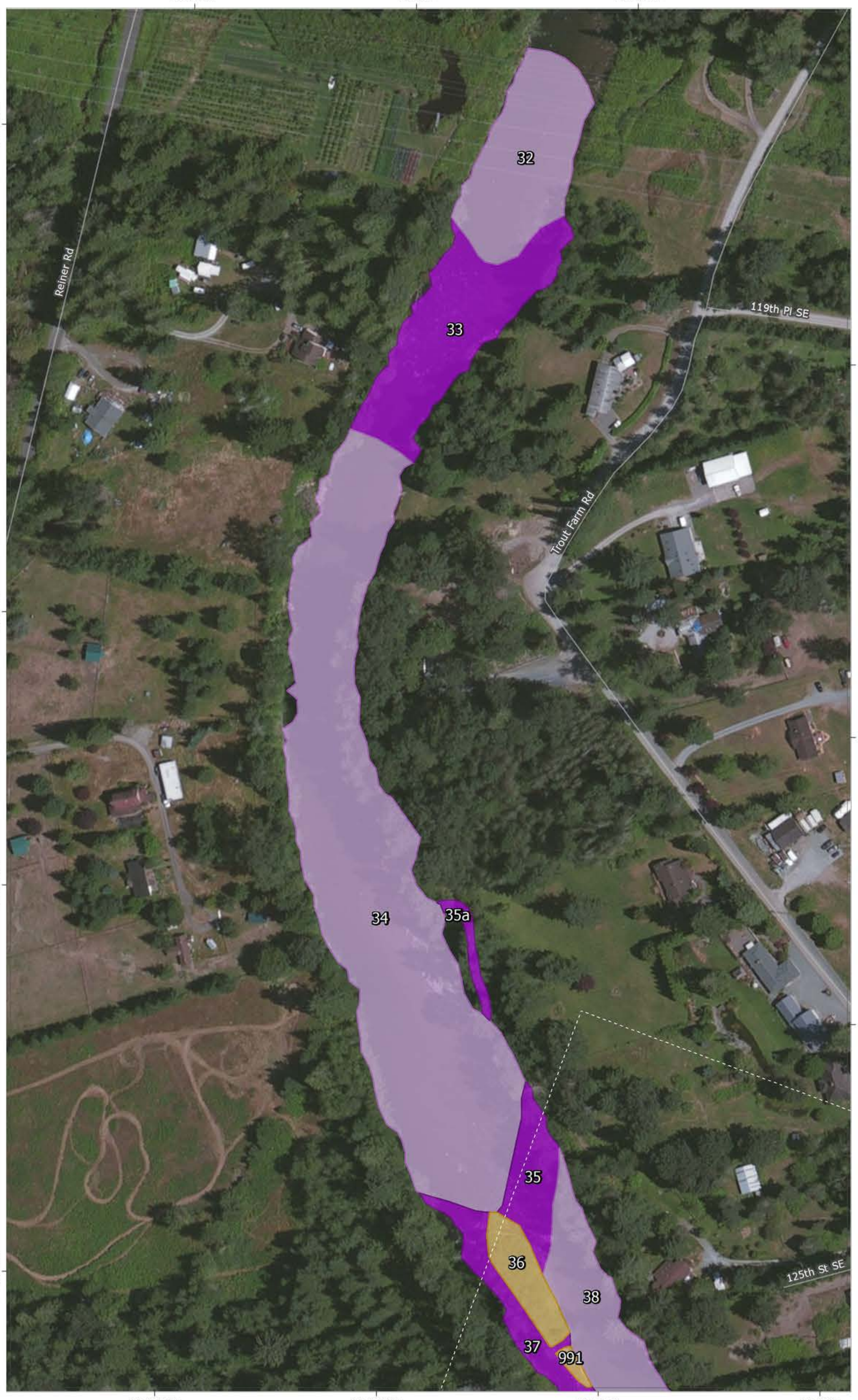
Roper, B. B., J. M. Buffington, S. Bennett, S. H. Lanigan, E. Archer, S. T. Downie, J. Faustini, T. W. Hillman, S. Hubler, K. Jones, C. Jordan, P. R. Kaufmann, G. Merritt, C. Moyer, A. Pleus. 2010. A comparison of the performance and compatibility of protocols used by seven monitoring groups to measure stream habitat in the Pacific Northwest. North American Journal of Fisheries Management. 30: 565-587.

Wolcott, J., and M. Church, 1991. Strategies for sampling spatially heterogeneous phenomena: the example of river gravels. Journal of Sediment. Petrol. 61: 534–543.

# Appendices

# Appendix A

# Maps Illustrating 2014 Habitat Units



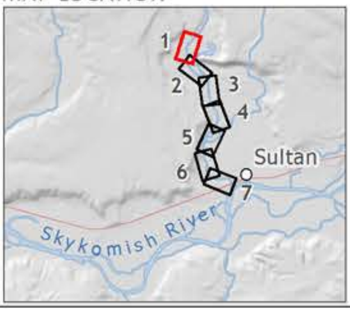

SULTAN RIVER LARGE WOODY DEBRIS

Habitat Types



- Glide
- Low-gradient riffle
- Rapid
- Island
- Main channel pool
- Subsurface flow

MAP LOCATION

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Roads: ESRI 2014

Stillwater Sciences
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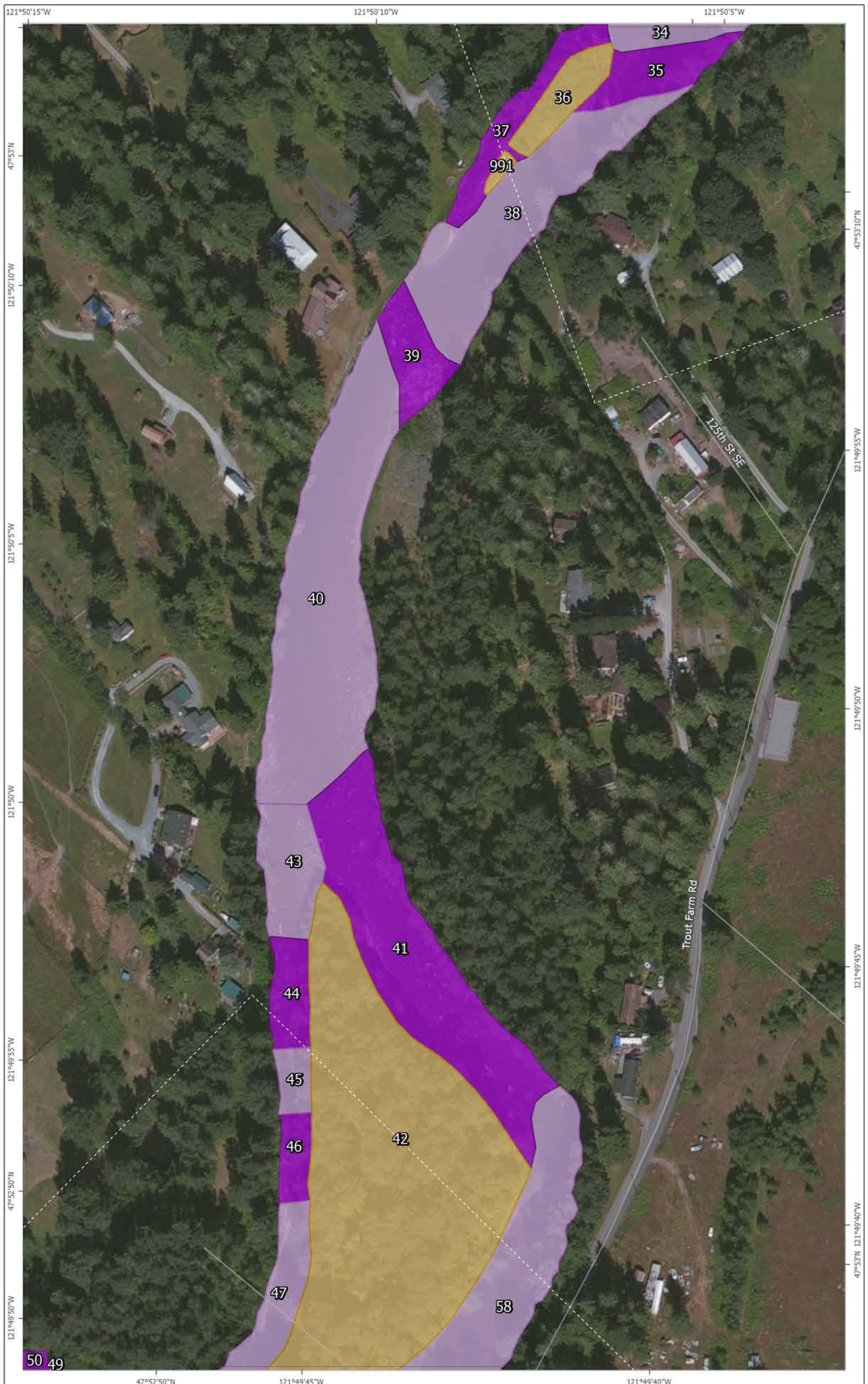


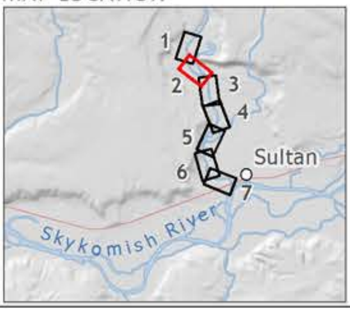

SULTAN RIVER LARGE WOODY DEBRIS

Habitat Types



Glide | Low-gradient riffle | Rapid | Island | Main channel pool | Subsurface flow

MAP LOCATION

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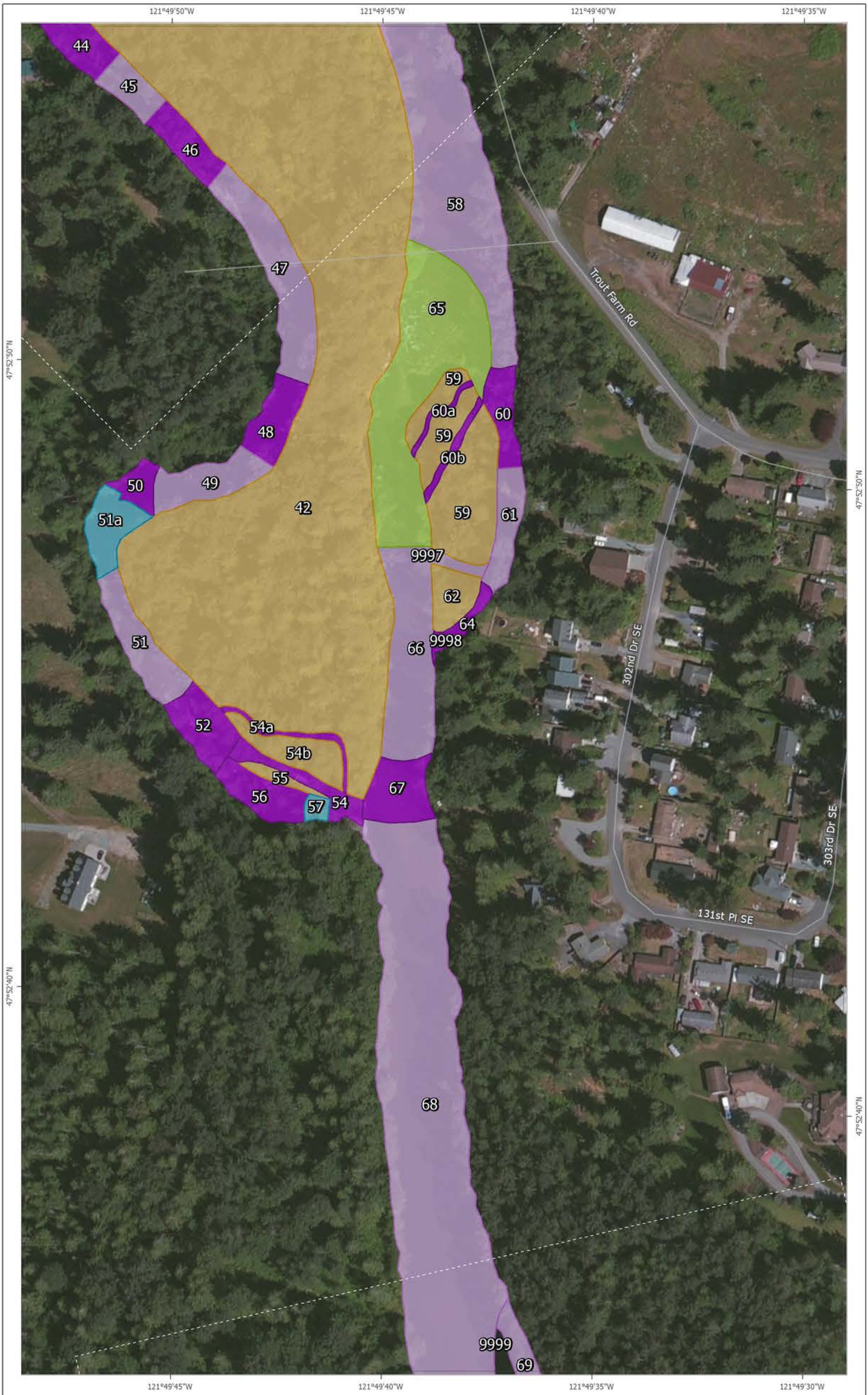
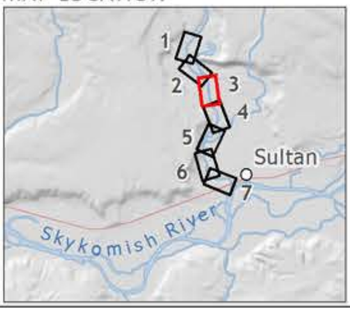



# SULTAN RIVER LARGE WOODY DEBRIS

## Habitat Types



MAP LOCATION




- Glide
- Low-gradient riffle
- Rapid
- Island
- Main channel pool
- Subsurface flow

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1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

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SULTAN RIVER LARGE WOODY DEBRIS

Habitat Types

Glide
Low-gradient riffle
Rapid
Island
Main channel pool
Subsurface flow



MAP LOCATION


0 100 200 400 Feet
0 25 50 100 Meters
1:2,100 1 in = 175 feet

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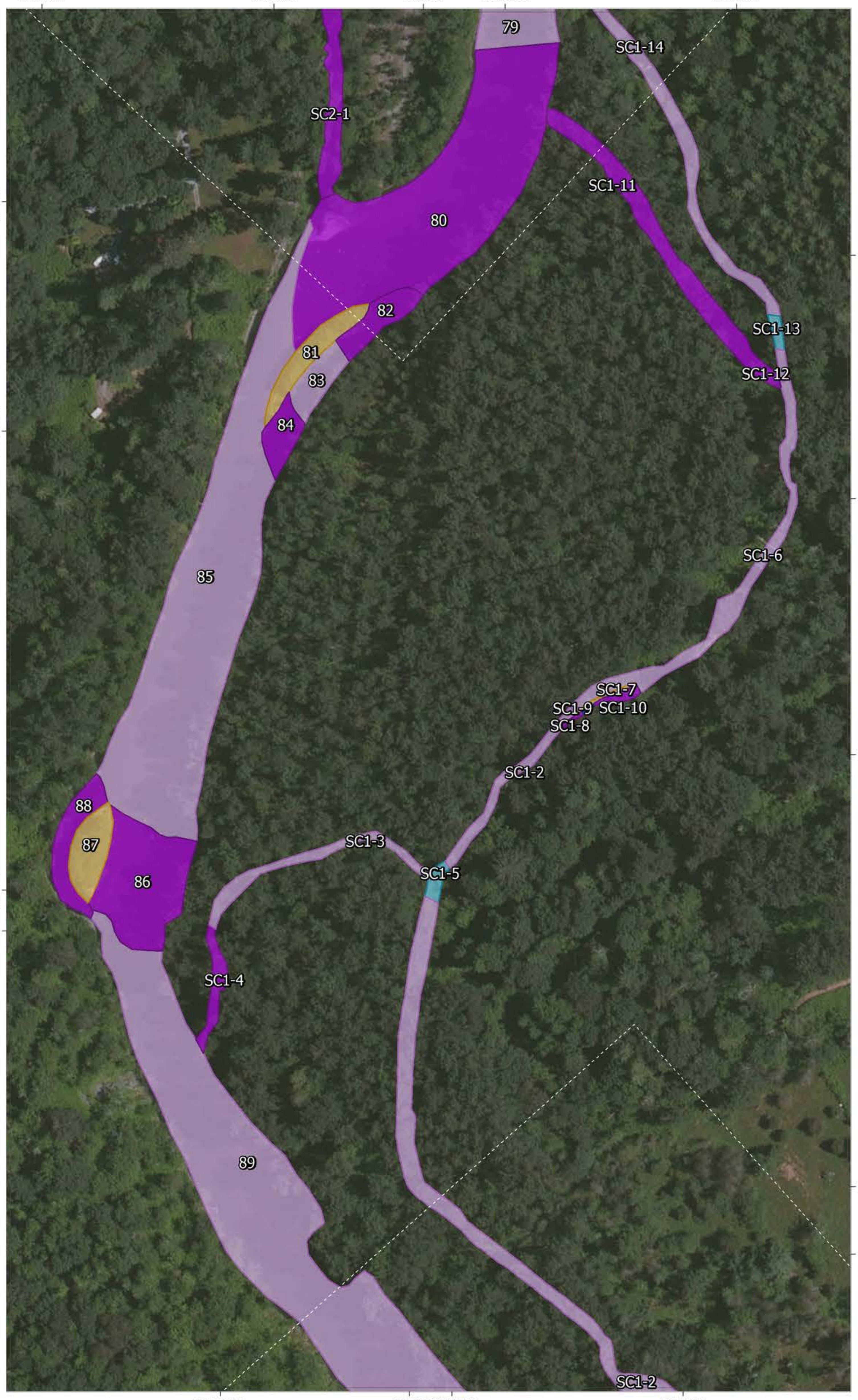
DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014



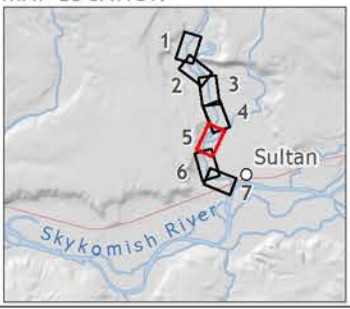

# SULTAN RIVER LARGE WOODY DEBRIS



## Habitat Types

- Glide
- Low-gradient riffle
- Rapid
- Island
- Main channel pool
- Subsurface flow

MAP LOCATION

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Roads: ESRI 2014

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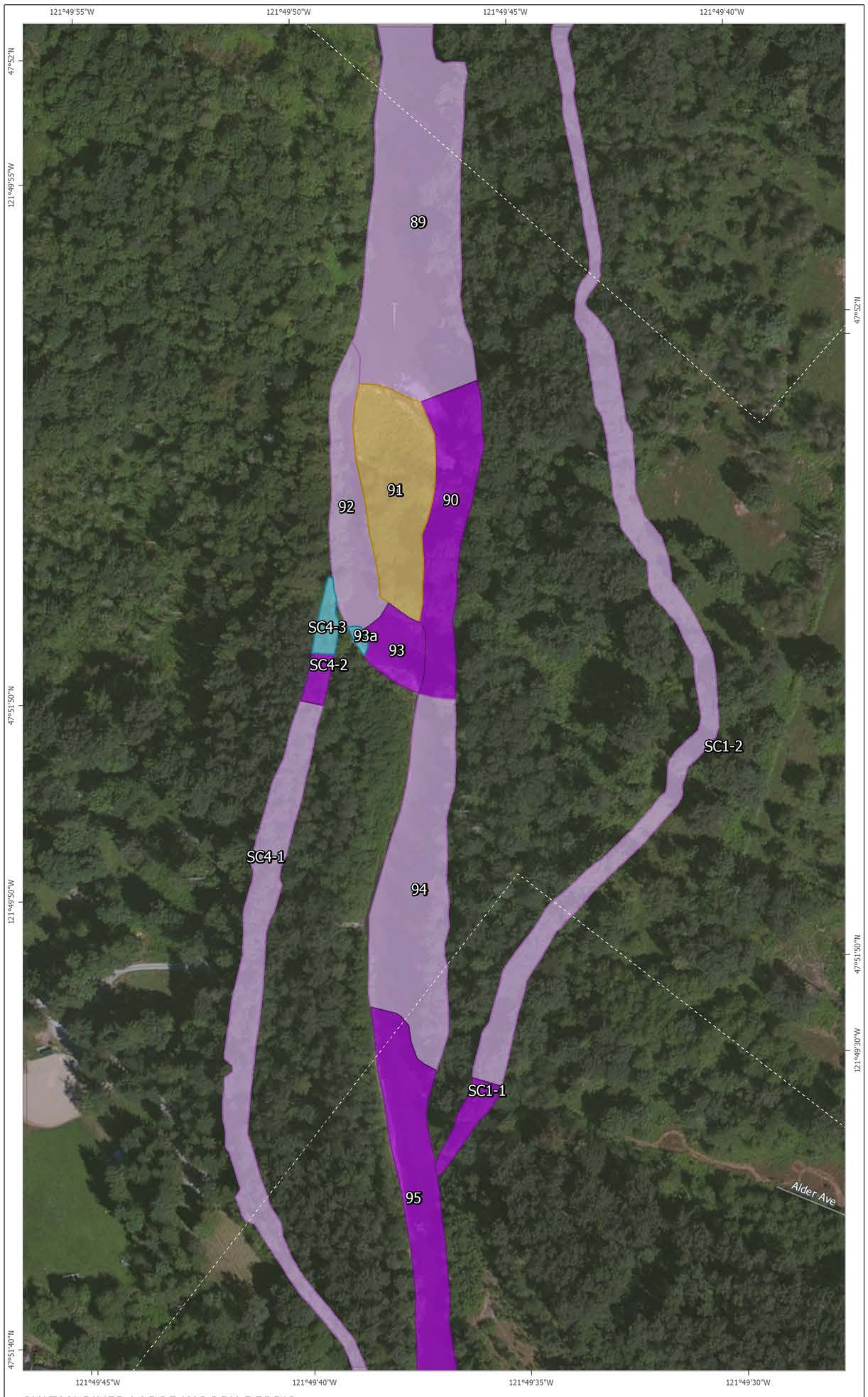


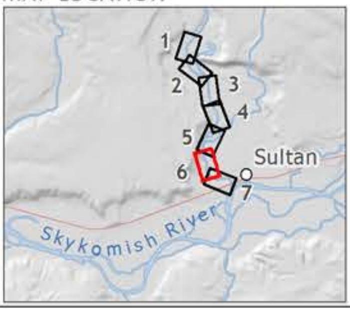

SULTAN RIVER LARGE WOODY DEBRIS

Habitat Types



- Glide
- Low-gradient riffle
- Rapid
- Island
- Main channel pool
- Subsurface flow

MAP LOCATION

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1:2,100 1 in = 175 feet

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DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

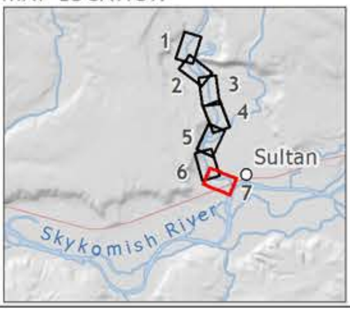

# SULTAN RIVER LARGE WOODY DEBRIS

## Habitat Types



- Glide
- Low-gradient riffle
- Rapid
- Island
- Main channel pool
- Subsurface flow

MAP LOCATION

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DATA SOURCES
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Roads: ESRI 2014

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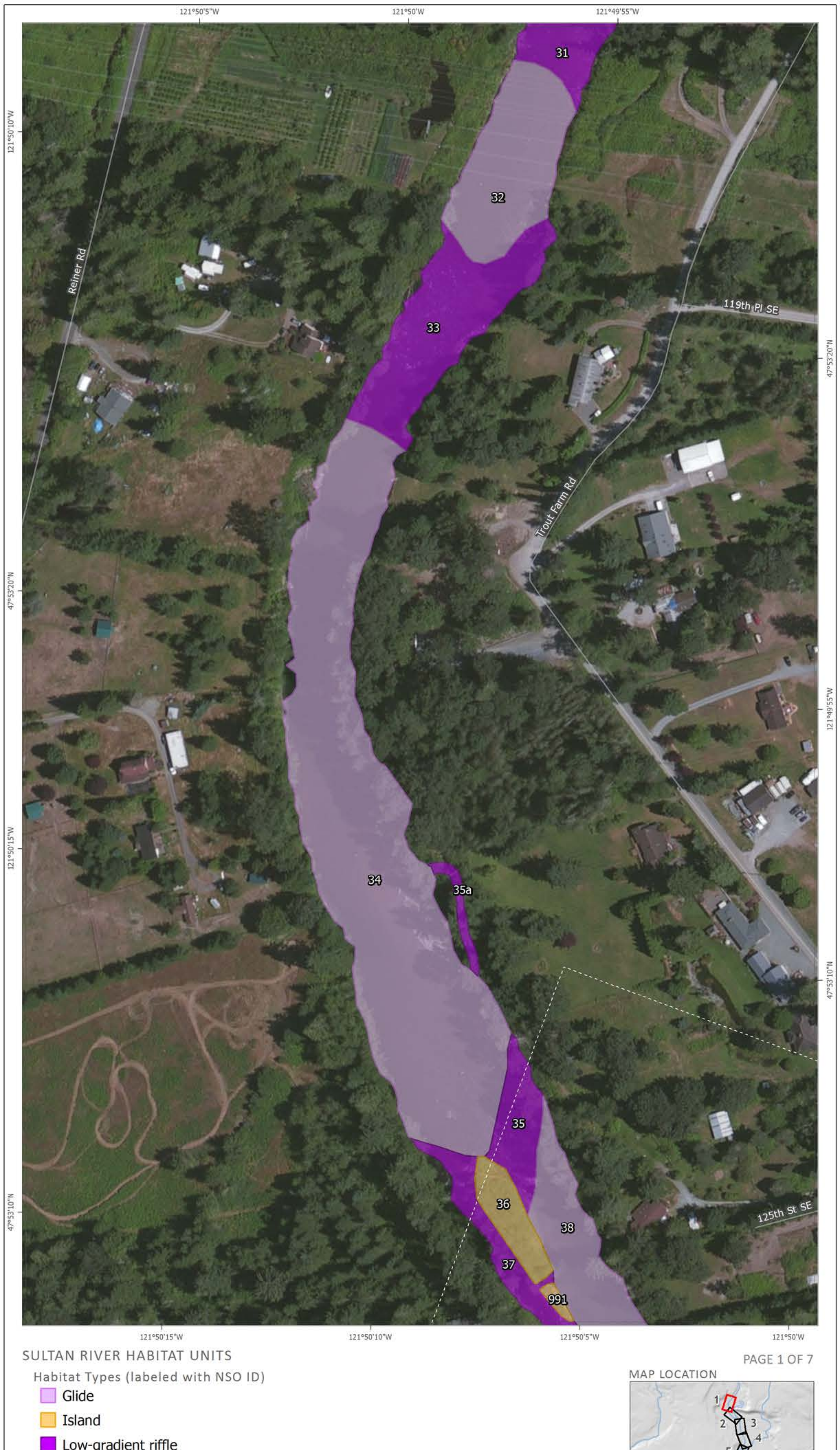
# Appendix B
# Maps Illustrating 2016 Habitat Units




SULTAN RIVER HABITAT UNITS



Habitat Types (labeled with NSO ID)

- Glide
- Island
- Low-gradient riffle

MAP LOCATION


0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

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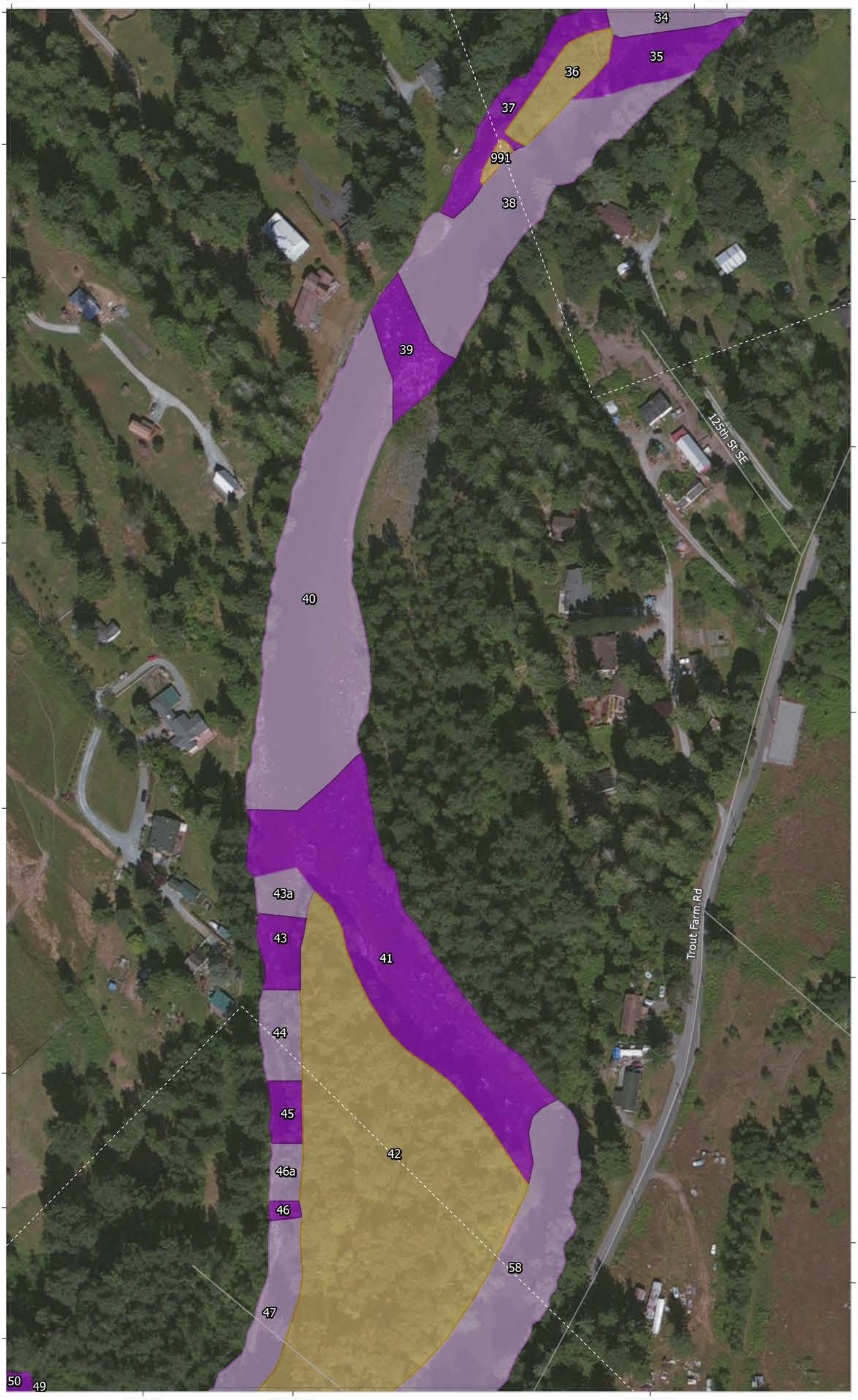


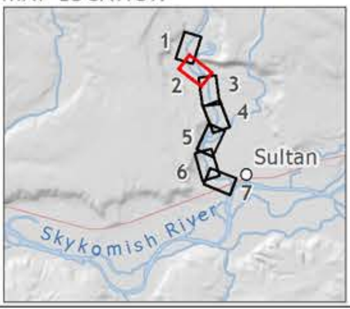

SULTAN RIVER HABITAT UNITS



Habitat Types (labeled with NSO ID)

- Glide
- Island
- Low-gradient riffle

MAP LOCATION

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1:2,100 1 in = 175 feet

DATA SOURCES
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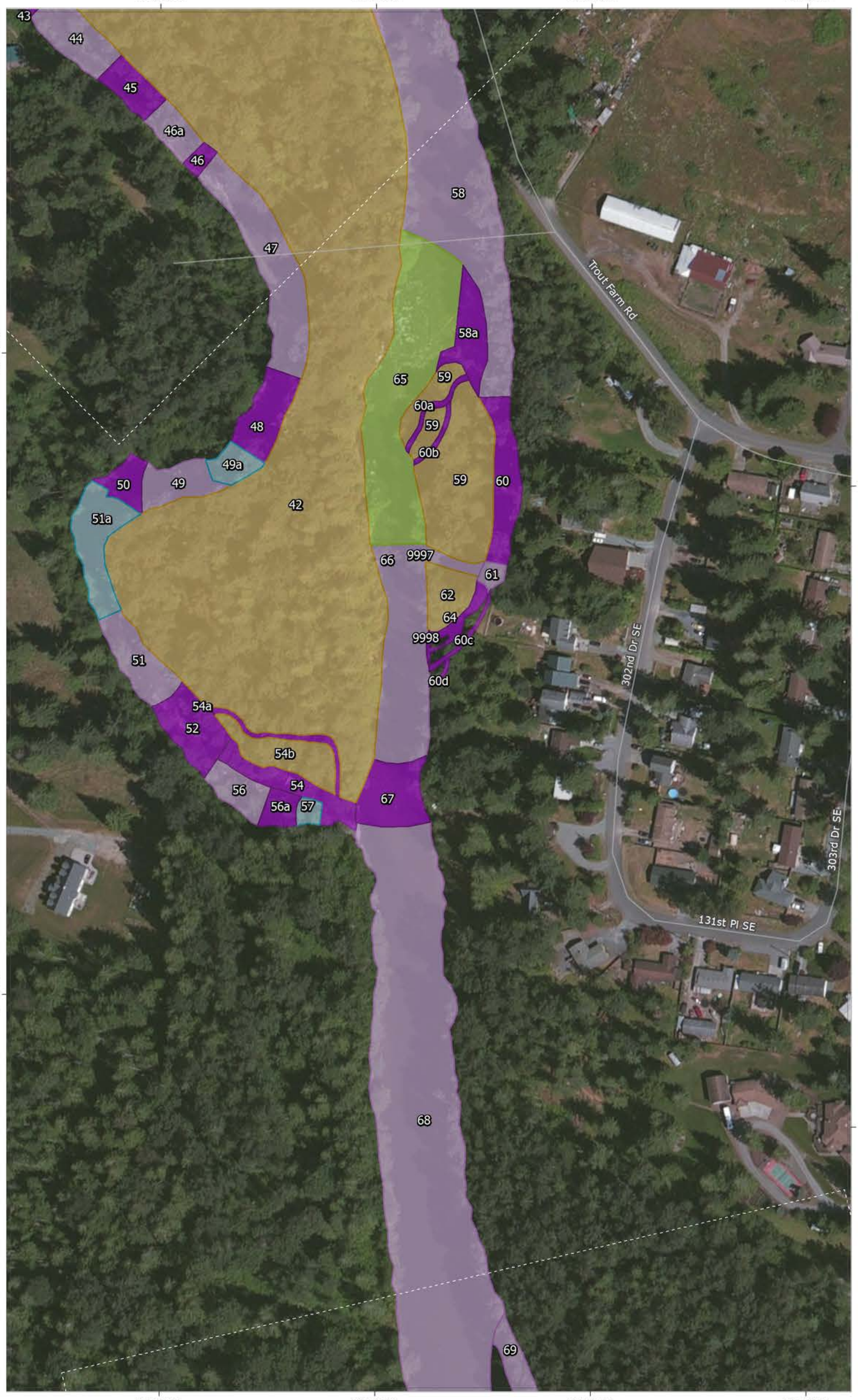


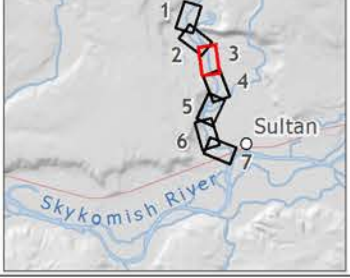

# SULTAN RIVER HABITAT UNITS



Habitat Types (labeled with NSO ID)

- Glide
- Island
- Main channel pool
- Low-gradient riffle
- Rapid

MAP LOCATION

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1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

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# SULTAN RIVER HABITAT UNITS



Habitat Types (labeled with NSO ID)

- Glide
- Island
- Main channel pool
- Low-gradient riffle

MAP LOCATION


0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

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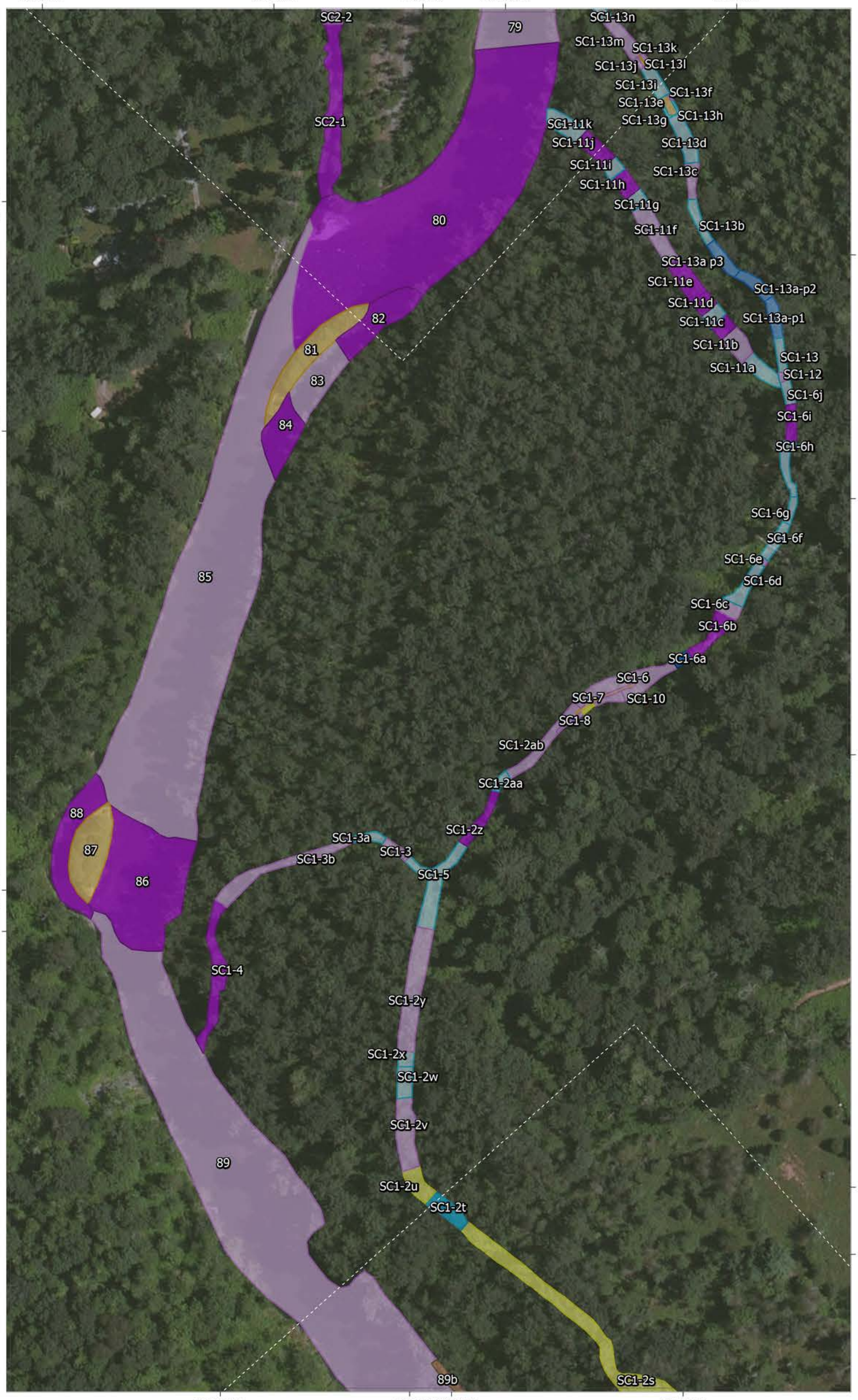



## SULTAN RIVER HABITAT UNITS

PAGE 5 OF 7

Habitat Types (labeled with NSO ID)

- Glide
- Island
- Main channel pool
- Isolated pool
- Pool complex
- Scour pool
- Low-gradient riffle
- Dry

MAP LOCATION



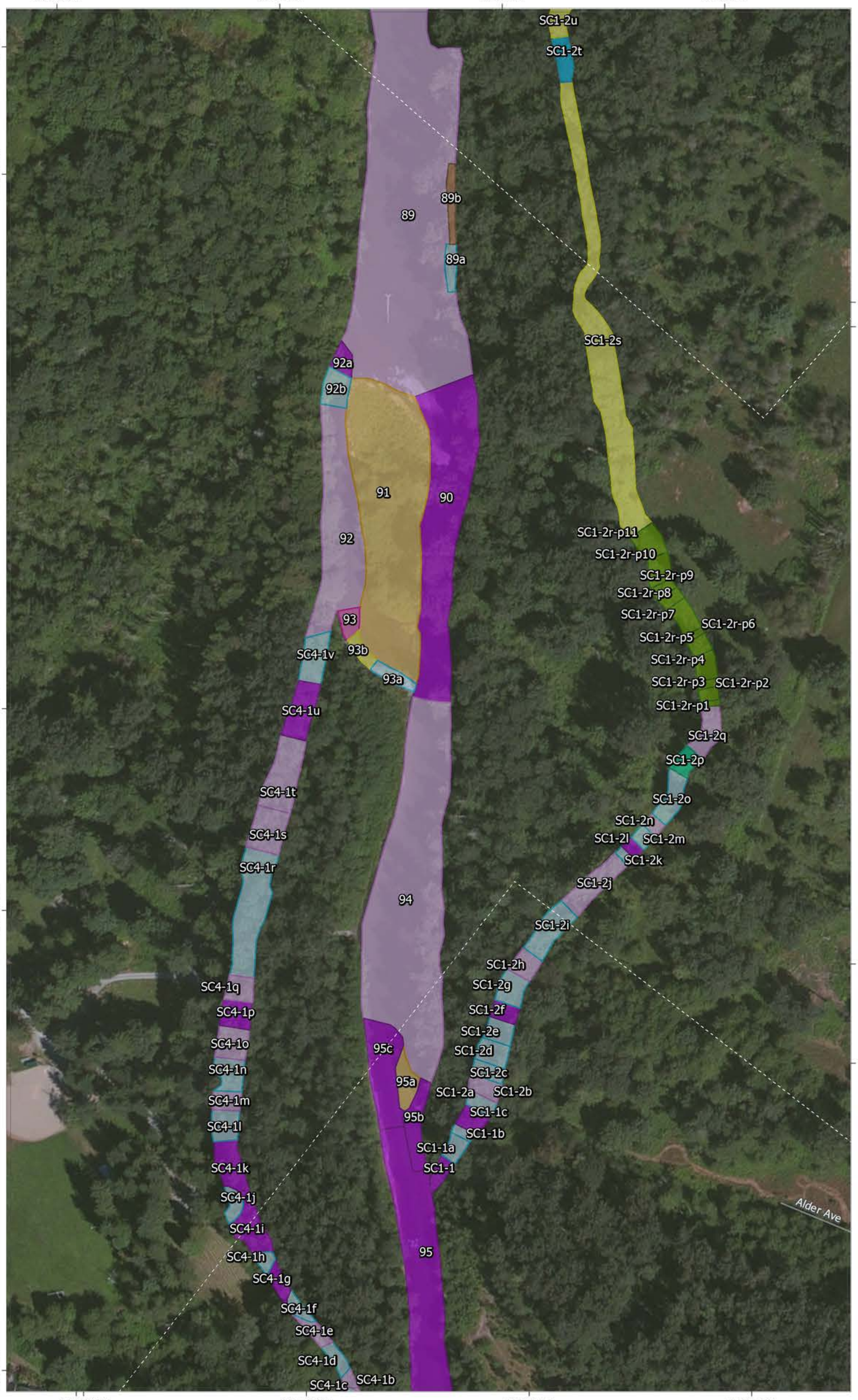
0 100 200 400 Feet

0 25 50 100 Meters

1:2,130 1 in = 178 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com



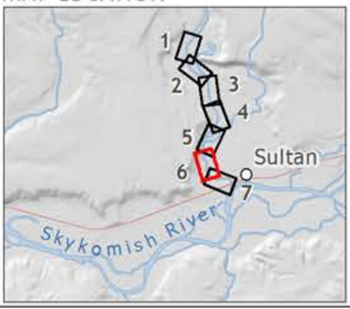

## SULTAN RIVER HABITAT UNITS

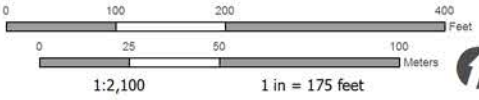


### Habitat Types (labeled with NSO ID)

- Glide
- Island
- Main channel pool
- Intermittent pool
- Isolated pool
- Low-gradient riffle
- Marsh
- Alcove
- Backwater
- Dry

MAP LOCATION




1:2,100    1 in = 175 feet

Stillwater Sciences
www.stillwatersci.com

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

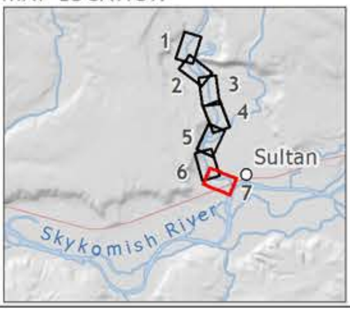

SULTAN RIVER HABITAT UNITS



Habitat Types (labeled with NSO ID)

- Glide
- Island
- Main channel pool
- Low-gradient riffle

MAP LOCATION




0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com

# Appendix C

# Field Data Sheets

## Sultan River In-River Habitat Survey

Reach ______________________

NSO (cont) ______________________

BFW Criteria ______________________

Date ______________________

Form # ________ of ________

Crew ______________________

Recorder ______________________

**QC**

Date ______________________

QC'er ______________________

| | | | | **Dimensions** | | | | | **Pool Data** | | | | **Bar Edges** | | **Undercut bank** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| nso | **core** unit type | **sub** unit type | unit **category** | length (ft) | avg. depth(ft) | wet width1 | wet width2 | wet width3 | Pool Out Depth | Pool Form Fact | Pool Max Depth | Dive (Y/N) | bar % left bank | bar % right bank | uc % left bank | uc width (ft) | uc % right bank | uc width (ft) | comments |
| | | | | | | | | | | | | | | | | | | | |
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**Reaches**

| Operational Reaches | | |
|---|---|---|
| | **A** | RM 0.0 - 2.7<br>Confluence with Skykomish River upstream to BPA transmission line crossing |
| | **B** | RM 2.7 - 4.3<br>BPA transmission line crossing upstream to Jackson Powerhouse |

| Process Reaches | | |
|---|---|---|
| | **C** | RM 4.3 - 9.7<br>Jackson Powerhouse upstream to City of Everett Diversion Dam |
| | **D** | RM 9.7 - 16.5<br>City of Everett Diversion Dam upstream to Culmback Dam |

Habitat Unit Codes

**Core Unit Types**

| | |
|---|---|
| Riffle | R |
| Pool | P |
| Sub-surface flow | SSF |
| Wetland | W |
| Obscured | OB |
| Other | OT |

**Sub - unit types (Calif. salmonid stream restoration manual)**

| | | | |
|---|---|---|---|
| Pool | MCP | main channel pool | (e.g. trench pool, mid-channel pool, channel conf. pool, step pool) |
| | SCP | scour pool | (e.g. corner pool, scour enhanced by root wad - log - boulder) |
| | BKW | backwater pool | |
| Riffle | LGR | Low gradient riffle | |
| | HGR | High gradient riffle | |
| | GLD | Glide | |
| | CAS | Cascade | |

**Pool forming features (TFW pg 24)**

| | | | |
|---|---|---|---|
| 1 | LWD log(s) | 7 | channel bedform |
| 2 | LWD rootwad(s) | 8 | resistant bank |
| 3 | LWD jam | 9 | artificial bank |
| 4 | roots of standing trees or stump(s) | 10 | beaver dam |
| 5 | Boulder(s) | 11 | other / unknown |
| 6 | Bedrock | | |

Unit Category

1. primary units: dominant units in the mainchannel
2. secondary units: sub-dominant units within the main channel that span less than 50% of the wetted channel width along less than half their channel length
3. side channel units: units in smaller clearly defined channels that are separated from main low flow channel (say by an island for example)

## LWD Single Pieces

Date ______________

Reach ______________

NSO (cont) ______________

BFW ______________

Form # ______ of ______

Crew ______________

Recorder ______________

| | Diameter | | | | | | | | | | | KEY PIECES | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NSO | Rtwd diam ≥ 20cm | Small >20 to <40cm | Med ≥40 to <60cm | Large >60cm | Length (ft) | Zone 1 or 2 | Mid-chan (Y/N) | Rtwd (Y/N) | Anchor R / P / B / U | Species Conf / Dec / Unk | Decay Class (1 - 5) | Key Piece # | Piece Diam (cm) |
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**QC'D BY** ______________ **DATE:** ______________

# Sultan River LWD SURVEY
## **Debris Jams**

Reach ______________________

NSO (cont) ______________________

BFW Criteria ______________________

Date ________________ QC

Form # ________ of ________ OC'er ________________

Recorder ________________ Date ________________

### LWD DEBRIS JAMS

| | | | | | | DJ Largest Piece | | | DJ Dimensions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NSO | Jam # | Lowest Zone (1or2) | Mid-Chan (Y/N) | Tally Rtwd diam ≥ 20cm | Tally Pieces Approx ≥20 cm | Key Piece# | Diam (cm) | Length (ft) | DJ Length (ft) | DJ Width (ft) | DJ Height (ft) |
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LWD Hab Survey Codes
Descriptions

ZONE 1 defined as the portion of the bankfull channel that is wetted at the time of the survey, regardless of whether the water is flowing or stagnant

ZONE 2 defined as the area between the bankfull channel edge on both banks, below an imaginary line that connects those points, above the wetted gravel bars channel surface, and includes areas such as dry

ZONE 3 the area vertically above Zone 2, the bankfull channel

ZONE 4 area outside of the bankfull channel and Zone 3

LWD Log Criteria
1 dead
2 the root system (if present) no longer supports the weight of the stem / bole
3 minimum diameter of 0.1 meters along 2 meters of its length, AND
4 minimum 0.1 meter of length extending into the bankfull channel

LWD Rootwad Criteria
1 dead
2 root system detached from original position
3 minimum diameter of 0.2 meters with a total length <2 meters; AND,
4 minimum 0.1 meter of length extending into the bankfull channel

LWD Jam Identification
1 minimum 10 qualifying pieces of LWD either physically touching at one or more points, or associated with jam structure
2 minimum 0.1 meter of one LWD piece's length extending into the bankfull channel

KEY PIECE CRITERIA
See pg 17 and Appendix C of TFW Large Woody Debris Survey Manual

**Sultan River Habitat Survey Wolmann Pebble Count**

Date ______________
Reach ______________
NSO ______________ BFW (m) __________
FeatureID ______________

| | size (mm) | Count | Total # |
|---|---|---|---|
| Mud Silt | <2 | | |
| Fine Sand | <2 | | |
| Sand | 2 - 4 | | |
| G | 4 - 6 | | |
| R | 6 - 8 | | |
| A | 8 - 12 | | |
| V | 12 - 16 | | |
| E | 16 - 22 | | |
| L | 22 - 32 | | |
| S | 32 - 45 | | |
| | 45 - 64 | | |
| C | 64 - 90 | | |
| O | 90 - 128 | | |
| B | 128 - 180 | | |
| B | 180 - 256 | | |
| B | 256 - 362 | | |
| L | 362 - 512 | | |
| D | 512 - 1024 | | |
| R | 1024 - 2048 | | |
| S | 2048 - 4096 | | |
| Bdrck | Bedrock | | |

**Total =**

Comments:

Date ______________
Reach ______________
NSO ______________ BFW (m) __________
Feature# ______________

| | size (mm) | Count | Total # |
|---|---|---|---|
| Mud Silt | <2 | | |
| Fine Sand | <2 | | |
| Sand | 2 - 4 | | |
| G | 4 - 6 | | |
| R | 6 - 8 | | |
| A | 8 - 12 | | |
| V | 12 - 16 | | |
| E | 16 - 22 | | |
| L | 22 - 32 | | |
| S | 32 - 45 | | |
| | 45 - 64 | | |
| C | 64 - 90 | | |
| O | 90 - 128 | | |
| B | 128 - 180 | | |
| B | 180 - 256 | | |
| B | 256 - 362 | | |
| L | 362 - 512 | | |
| D | 512 - 1024 | | |
| R | 1024 - 2048 | | |
| S | 2048 - 4096 | | |
| Bdrck | Bedrock | | |

**Total =**

Comments:

**Sultan River Hab Survey**
**Aerial Photo Mapping:  Landmark / Photo / Comments Log**

Date: ______________________________

River Reach: ______________________________

Form _____of _____

| Comments | NSO | ID / Item# | Photo# | GPS ID Info |
|---|---|---|---|---|
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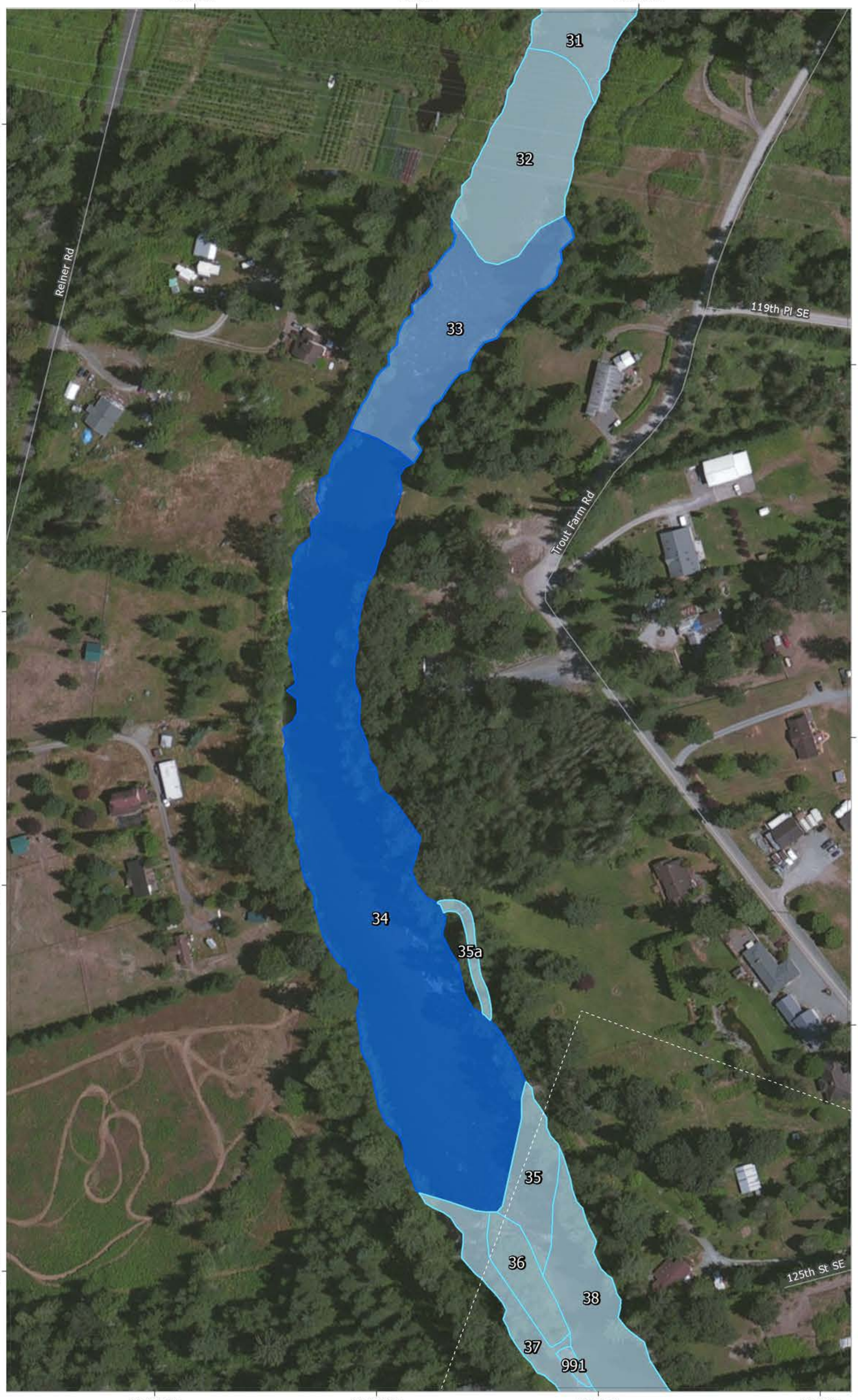
# Appendix D

# Maps Illustrating Large Woody Debris

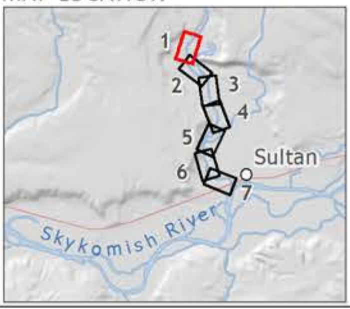



SULTAN RIVER LARGE WOODY DEBRIS

Large Woody Debris (LWD)



MAP LOCATION




LWD count by Habitat Unit

0, 1, 2 - 3, 4 - 7, 8 -10

Feet: 0, 100, 200, 400

Meters: 0, 25, 50, 100

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com


SULTAN RIVER LARGE WOODY DEBRIS

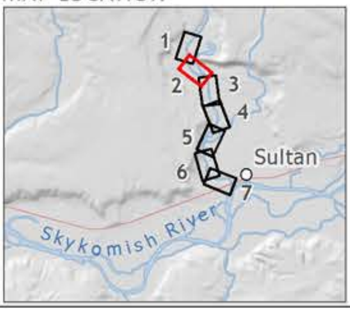
Large Woody Debris (LWD)



LWD count by Habitat Unit

- 0
- 1
- 2 - 3
- 4 - 7
- 8 -10

MAP LOCATION



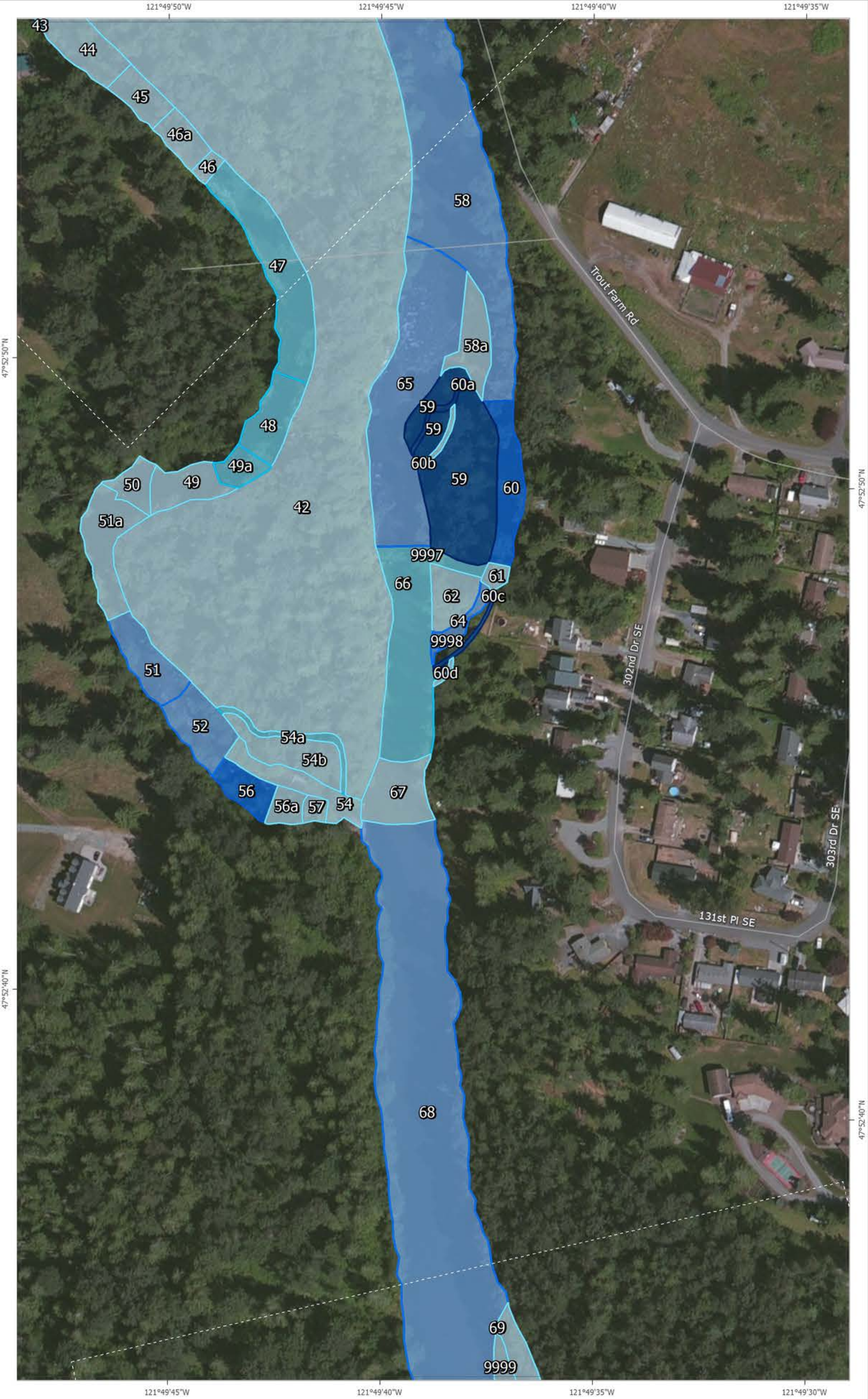

0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com




SULTAN RIVER LARGE WOODY DEBRIS

Large Woody Debris (LWD)

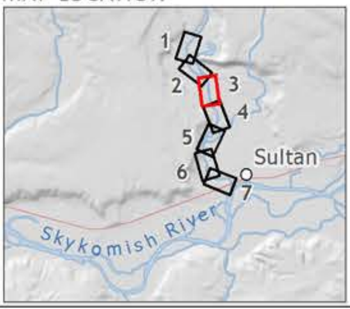


LWD count by Habitat Unit

0 | 2 - 3 | 8 -10

1 | 4 - 7

MAP LOCATION



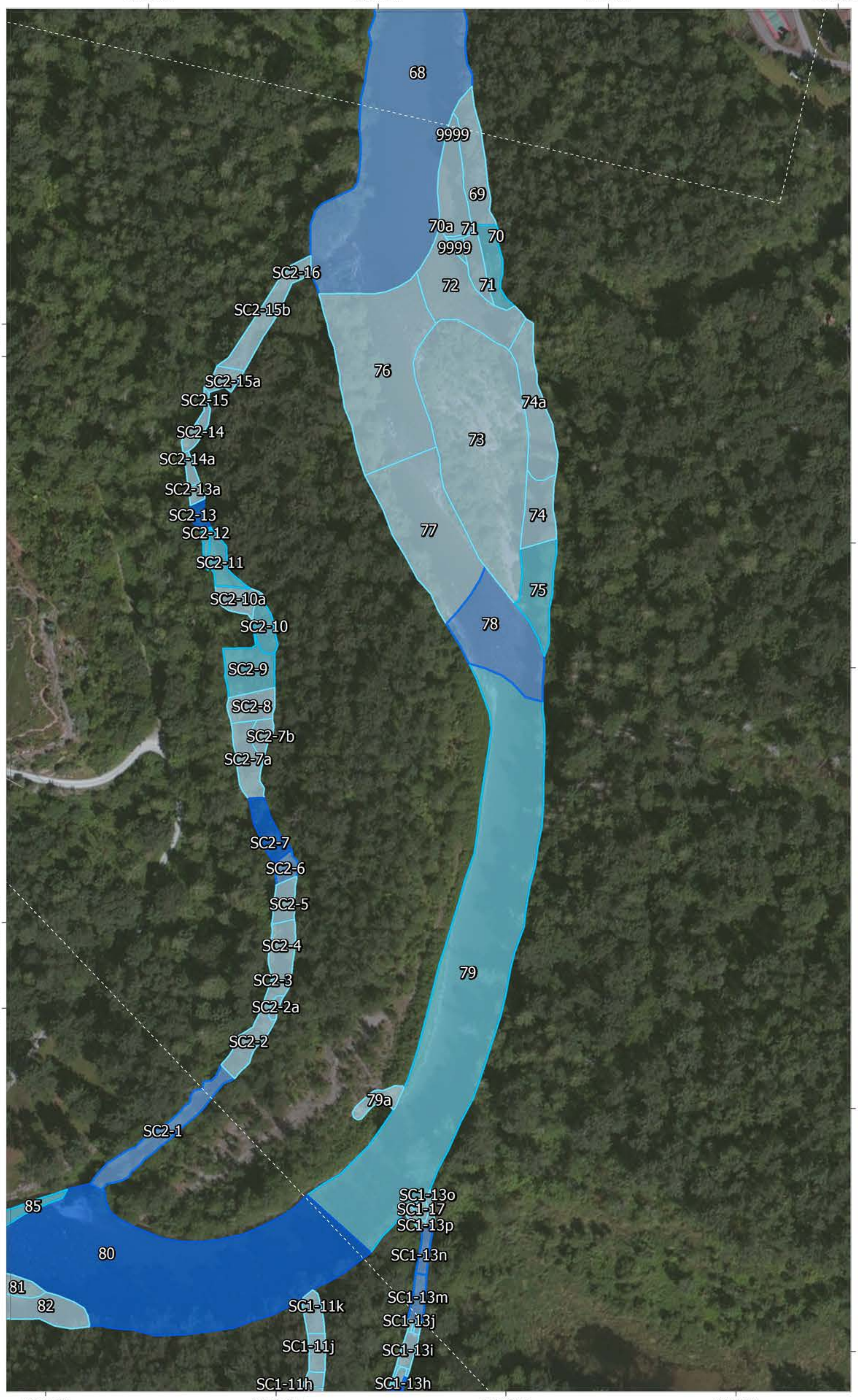

0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com




SULTAN RIVER LARGE WOODY DEBRIS

Large Woody Debris (LWD)



MAP LOCATION


LWD count by Habitat Unit

0 | 2 - 3 | 8 -10

1 | 4 - 7

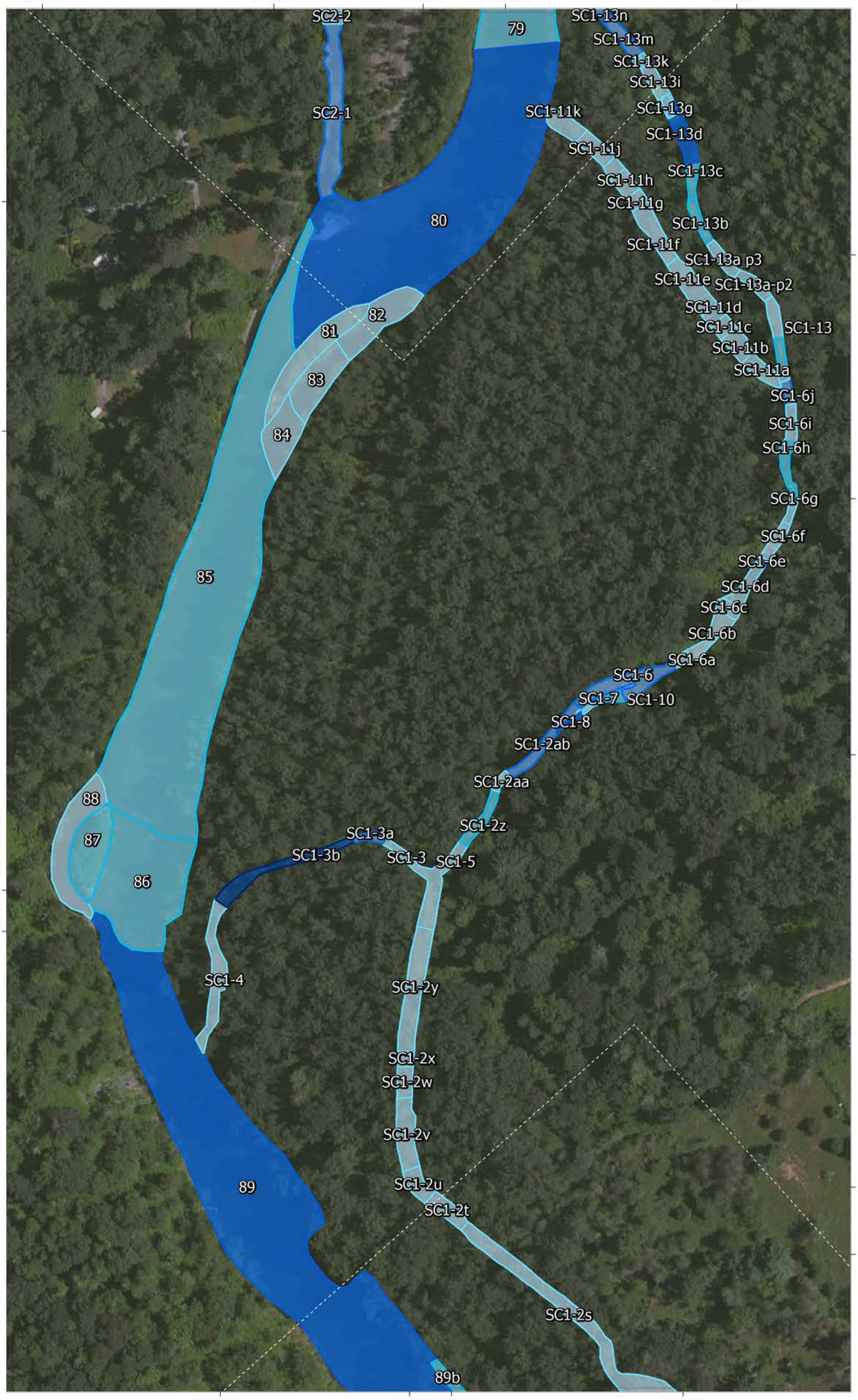
0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com

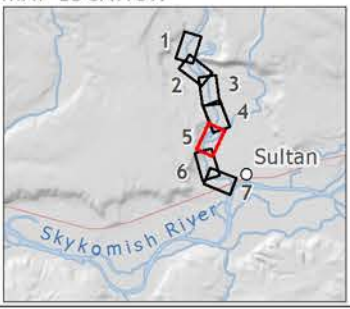



# SULTAN RIVER LARGE WOODY DEBRIS

Large Woody Debris (LWD)



MAP LOCATION




LWD count by Habitat Unit

- 0
- 1
- 2 - 3
- 4 - 7
- 8 -10

0 100 200 400 Feet

0 25 50 100 Meters

1:2,130    1 in = 178 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com


SULTAN RIVER LARGE WOODY DEBRIS

Large Woody Debris (LWD)



MAP LOCATION

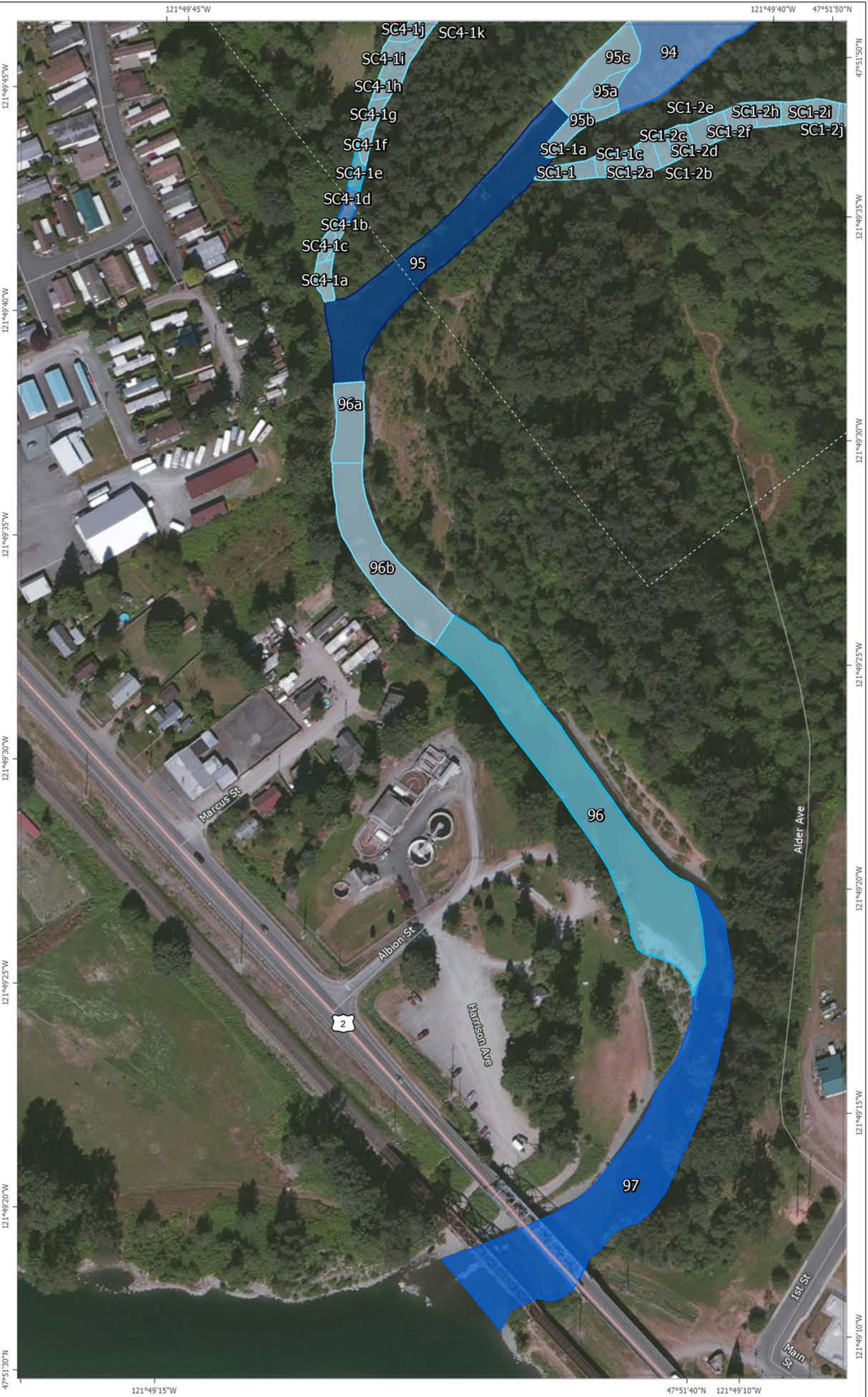

LWD count by Habitat Unit

0 | 2 - 3 | 8 -10
1 | 4 - 7

0 100 200 400 Feet
0 25 50 100 Meters
1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com




# SULTAN RIVER LARGE WOODY DEBRIS

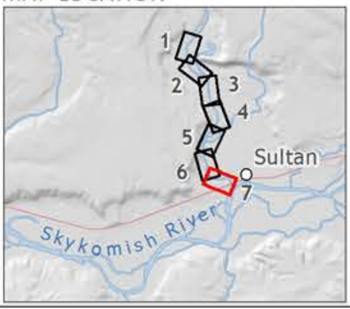
Large Woody Debris (LWD)



LWD count by Habitat Unit

- 0
- 1
- 2 - 3
- 4 - 7
- 8 -10

MAP LOCATION




0 100 200 400 Feet

0 25 50 100 Meters

1:2,100 1 in = 175 feet

DATA SOURCES
Imagery: ESRI World Mapping Service
Roads: ESRI 2014

Stillwater Sciences
www.stillwatersci.com