Wild Salmon Policy - Strategy 2: Fish Habitat Status Report for the Tahsis River Watershed

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LIST OF ACRONYMS / ABBREVIATIONS USED

AUC	**Area Under the Curve**
CU	**Conservation Unit**
CVRD	**Comox Valley Regional District**
CWAP	**Coastal Watershed Assessment Procedure**
DO	**Dissolved Oxygen**
EMNG	**Ministry of Energy, Mines, and Natural Gas**
FISS	**Fisheries Information Summary System**
FPC	**Forest Practices Code**
GIS	**Geographic Information Systems**
IT	**Impairment Temperature**
LRDW	**Land and Resources Data Warehouse**
LWD	**Large Woody Debris**
MAD	**Mean Annual Discharge**
MFLNRO	**Ministry of Forests, Lands, and Natural Resources Operations**
MOE	**Ministry of Environment**
NSWS	**Nootka Sound Watershed Society**
ppt	**Parts per Thousand**
PSCIS	**Provincial Stream Crossing Inventory System (PSCIS)**
PSF	**Pacific Salmon Foundation**
RPF	**Registered Professional Forester**
SIL	**Stream Inspection Log**
TFL	**Tree Farm Licence**
UOTR	**Upper Optimum Temperature Range**
VIHA	**Vancouver Island Health Authority**
WCA	**West Coast Aquatics**
WCVI	**West Coast Vancouver Island**
WFP	**Western Forest Products**
WSC	**Water Survey of Canada**
WSP	**Wild Salmon Policy**

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1.0 INTRODUCTION

Canada's Wild Salmon Policy (WSP) sets out a series of strategies which will serve to incorporate habitat and ecosystem considerations into salmon management, and to establish local processes for collaborative planning throughout British Columbia (Fisheries and Oceans Canada, 2005). Strategy 1 of the WSP involves the identification of salmon Conservation Units (CUs), which are defined in the WSP as "a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within an acceptable timeframe" (Holtby and Ciruna, 2007). Strategy 2 of the WSP involves the assessment of habitat status, firstly in a synoptic habitat pressure analysis to inform landscape scale pressure indicators such as total land cover alteration, road density, riparian disturbance, etc., and secondly in an analyses of species and life cycle dependent habitats in the watershed. This strategy outlines a process for the identification of factors that are limiting production, high value habitats that require protection, and data gaps that require further monitoring. The assessment of habitat status will continue with the application of a monitoring framework using a selection of indicators and benchmarks, to identify changes in habitat condition over time (Stalberg et al, 2009).

Implementation of the WSP has been initiated throughout several regions along the west coast of Vancouver Island. The selection of high priority watersheds (Tahsis River, Leiner and Perry Rivers, Sucwoa River, Canton Creek, Tsowwin River, and the Conuma River) requiring habitat status assessments by the Nootka Sound Watershed Society (NSWS) represents the initiation of Strategy 2 of the WSP within Nootka Sound. The outcomes of these assessments is intended to facilitate the planning and prioritization of prescriptive measures to improve salmon habitats and populations, as well as identify data gaps and subsequent monitoring priorities on a watershed by watershed basis.

The following report presents a Strategy 2 habitat status assessment for the Tahsis River watershed.

1.1 Objectives

This report is intended to identify the state and quantity of habitat factors that are potentially limiting fish production in the Tahsis River, as well as critical habitats (by life history stage) that require protection. Specific objectives of this report include:

- The documentation of existing habitat characteristics;
- A comparison to historical habitat characteristics, where information exists;
- Selection of habitat indicators and a comparison of assessed values to known risk benchmarks;
- Identification of data gaps requiring further monitoring; and
- Recommended enhancement activities within the study watersheds which would have both a direct and indirect effect on salmon species within the Tahsis River watershed.

In addition to the above mentioned objectives, this work is also intended to feed into a future WSP expert-based risk assessment workshop whereby identified limiting factors will be ranked in order of spatial and temporal risk to fish and fish habitat on a watershed by watershed basis. It should be noted that additional high priority watersheds (i.e. Leiner and Perry Rivers, Sucwoa River, Canton Creek, Conuma River and Tsowwin River) have also been completed under the same framework.

1.2 Tahsis River Watershed

The Tahsis River watershed is located approximately 100km west of Campbell River, B.C., on the west coast of Vancouver Island, and is comprised of both of the Tahsis River and McKelvie Creek drainages (Figure 1). The Tahsis River drains from the Haithe Range of Vancouver Island, and flows southerly into the head of Tahsis Inlet. McKelvie Creek drains the northern Tlupana Range, and flows southwesterly until its confluence with the Tahsis River (approximately 1.5km upstream from the estuary). Both the Tahsis River and McKelvie Creek watersheds encompass a drainage area of approximately 55.86km^2.

1.2.1 Climate, Topography, and Hydrology

The Tahsis River watershed is situated primarily within the coastal western hemlock (very wet maritime) biogeoclimatic zone, with small components situated in the mountain hemlock (moist maritime) and coastal mountain-heather alpine (undifferentiated and parkland) zones. This area has a mild oceanic climate with high humidity, and the majority of its annual precipitation is received as rain. Annual rainfall averages range between 990mm and 4400mm. Between the months of October and April, high water events are observed frequently (Fisheries and Oceans Canada, 2012).

The Tahsis River watershed is characterized by a north-south trending valley with a broad valley floor. Extensive steep terrain exists above the valley floor, with the highest peak in the watershed (Rugged Mountain) measuring 1,861m in elevation. The upper watershed has two headwater basins extending into the alpine with numerous avalanche tracks, natural landslides, and small headwater lakes. Below the valley walls, an unconfined to partially confined alluvial channel in a wide floodplain extends approximately 8.7km upstream from the ocean. The lower 1.4km of the floodplain is occupied by the Village of Tahsis (Horel, 2008).

The McKelvie Creek watershed is characterized by an elongate basin with a single dominant mainstem and extensive steep terrain. The upper basin extends into the alpine with numerous natural landslides and avalanche tracks present. The lower valley is V shaped with a confined to entrenched non-alluvial and semi-alluvial stream. The mid valley is slightly broader than the lower valley, with the channel transitioning to semi-alluvial and alluvial within the narrow valley floor. The upper valley is characterized by two headwater basins, steep terrain extending into the alpine, and entrenched non-alluvial streams (Horel, 2008). The highest peak in the McKelvie watershed measures 1,631m in elevation (Willis Energy Services Ltd., 2001).

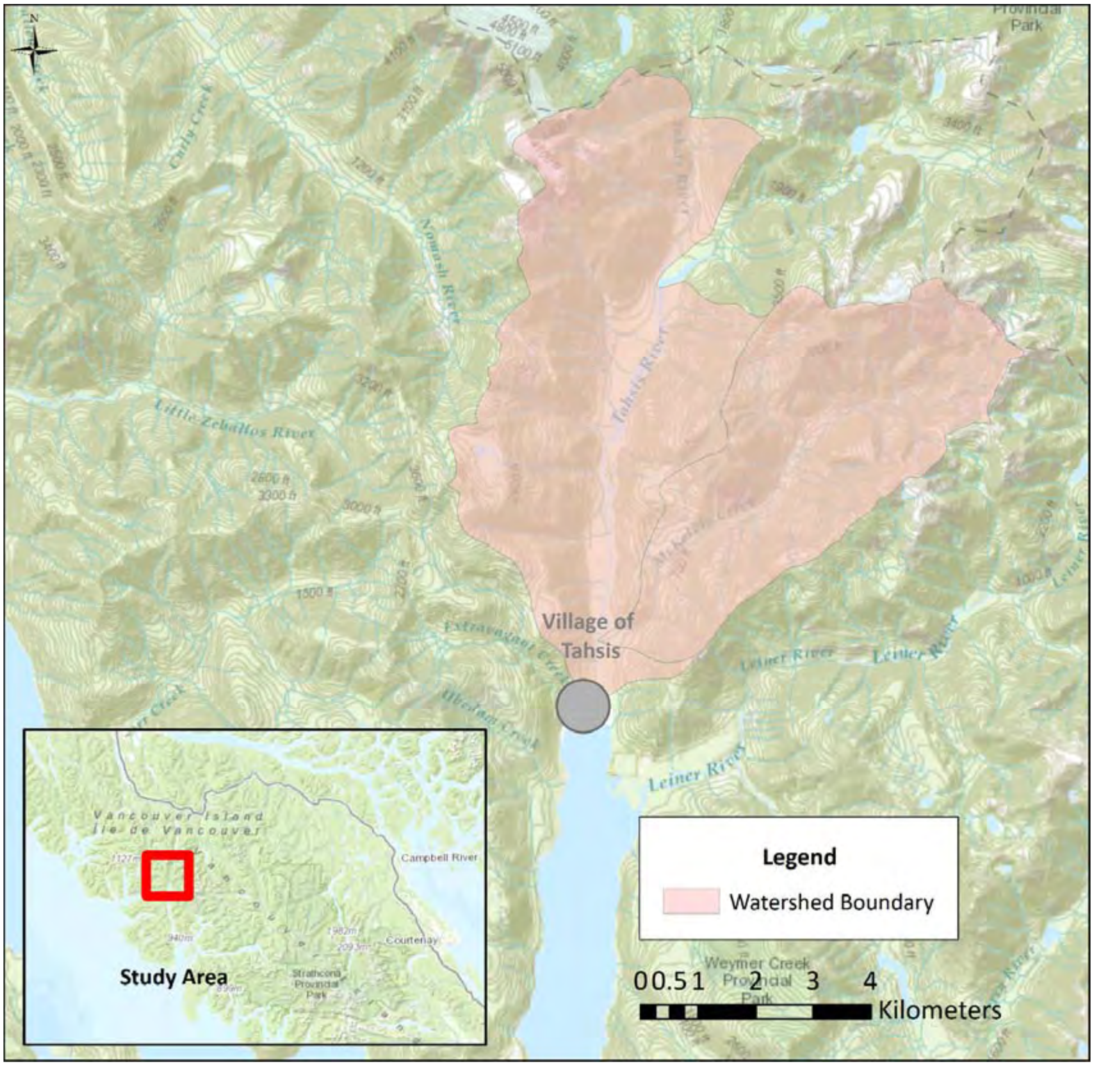


Figure 1. General location of the Tahsis River watershed.

1.2.2 Watershed Description

An analysis of watershed indicators by Horel in 2008 identified the Tahsis River watershed to be highly sensitive based on the regional landslide frequency, total area of the watershed situated in steep terrain (i.e. >60%), occurrence of natural landslides, hillslope connectivity to the mainstem, channel sensitivity, and lack of floodplains. In addition, this watershed was identified as highly disturbed based on the length of stream channel with inadequate riparian forests for LWD contribution, bank erosion control, and channel stability maintenance. The nature of the main watershed disturbance was identified as an unstable alluvial channel from riparian logging. Watershed trends (identified through the interpretation of risk ratings and changes over time as observed in air photos, satellite imagery, and helicopter reconnaissance. In the absence of riparian treatments targeted at the conversion of alders to conifers, it is estimated that limited improvements in conditions will be observed within the next 50 years (Horel, 2008).

Natural landslides in the Tahsis River are frequent. In 1998, an analysis of imagery identified that 59 of the 61 visible slides originated from either unharvested timber or old growth forests. The remaining 2 slides originated from roads near the western boundary of the watershed (Horel, 2008).

The mainstem of the Tahsis River measures approximately 12km in length and has been previously classified into 16 distinct reaches. The main tributary to the Tahsis River, McKelvie Creek, enters the mainstem approximately 1km upstream from the estuary and is comprised of two distinct reaches (Figure 2). Habitat in the Tahsis River mainstem remains fairly low gradient (between 1 and 5%) from the estuary to the bottom of reach 16, where a barrier to anadromous fish access (impassable falls) exists. Tributary habitat is characterized by abrupt changes in gradient or impassable falls present within the first 500m of channel length, limiting fish distribution to the bottom reach of these tributaries. The majority of the mainstem is alluvial, with the exception of the headwaters and the tidally influenced portion of the lower river, which have been classified as semi-alluvial (Horel, 2008).

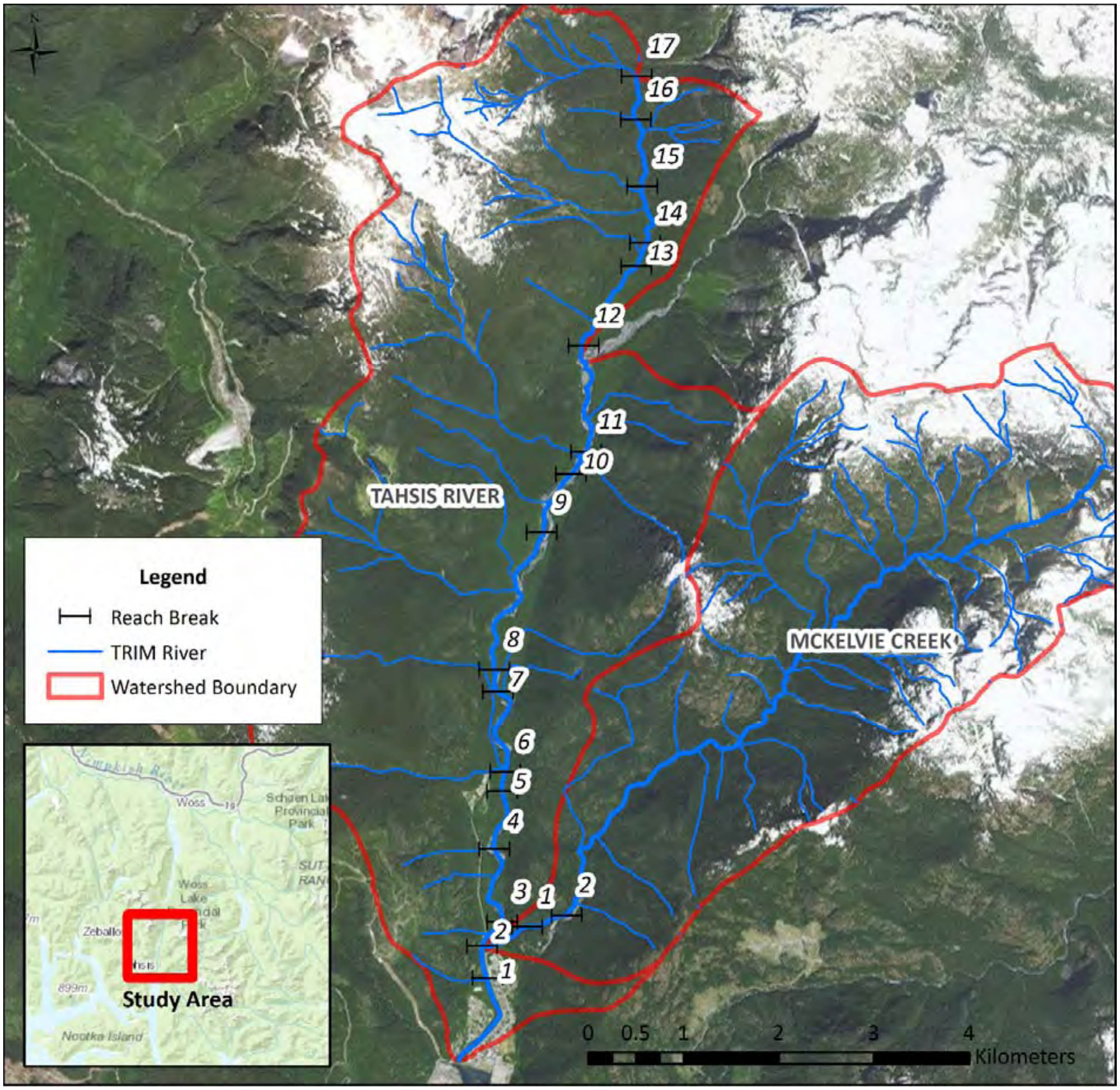


Figure 2. Tahsis River and McKelvie Creek reach breaks.

The following table describes the average bankful widths (as determined from 2013 orthophotography) for reaches 1 - 15 of the Tahsis River. Note that bankful widths could not be determined for reaches 16 and 17 based on canopy cover obscuring the stream channel in the imagery.

Table 1. Reach lengths and average bankful widths for the Tahsis River.

Reach Number	Reach Length (km)	Average Bankful Width (m)
1	1.13	39.23
2	0.35	30.06
3	0.34	25.42
4	1.04	43.49
5	0.91	52.08
6	0.22	34.57
7	1.04	62.93
8	0.25	44.48
9	1.83	50.51
10	0.81	78.56
11	0.29	68.45
12	1.17	104.11
13	1.06	21.27
14	0.26	11.32
15	0.69	14.79

An extensive zone of aggraded habitat is present approximately 250m downstream from reach break 9, and continues upstream for 2.5km to reach break 12 (Figure 3). This zone remains dewatered during low and moderate flows and limits upstream fish access during select times of the year. Previous assessments have also noted significant bank erosion in reaches 3, 8, 9, and 10 (Wright, 2002).

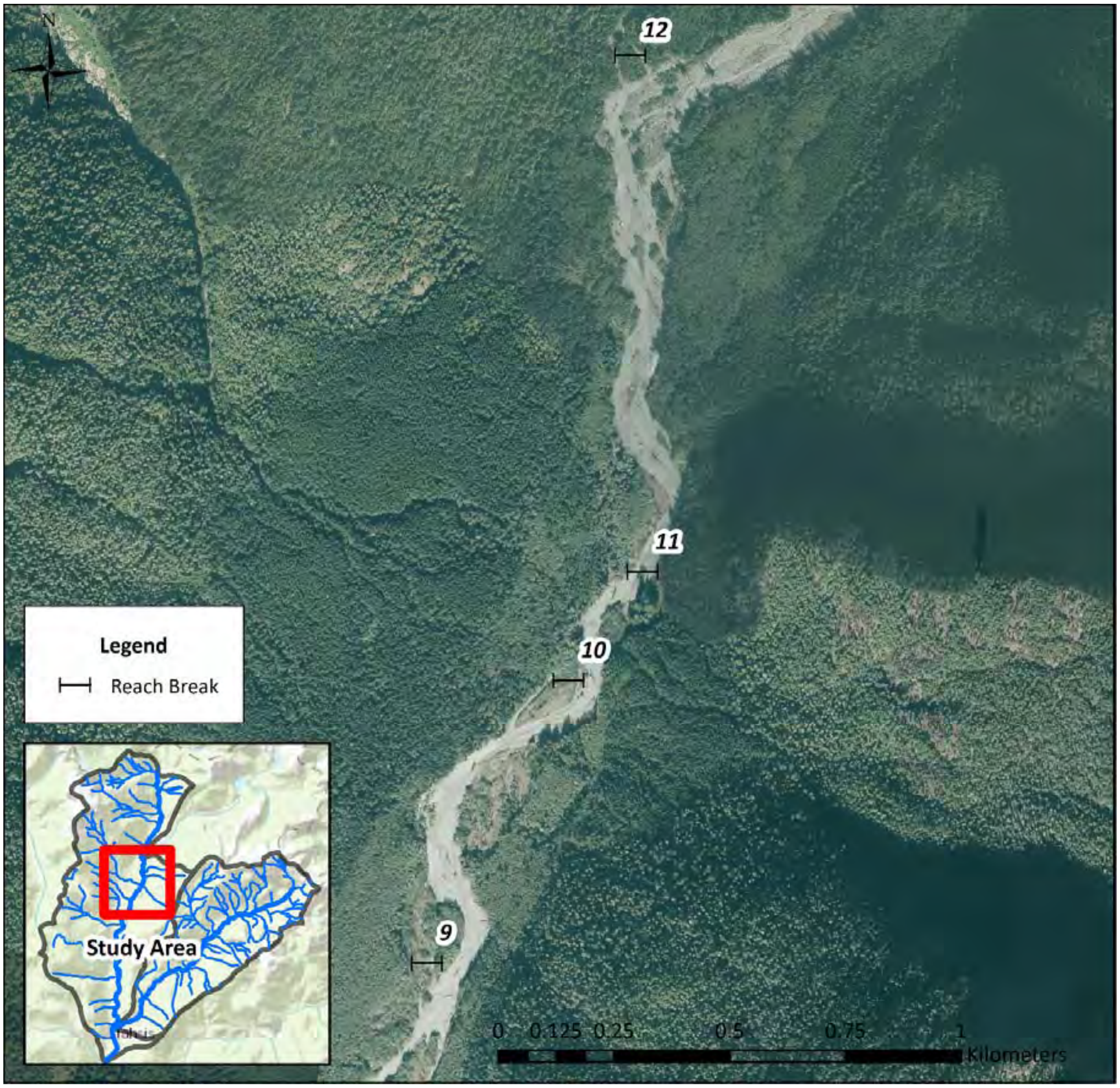


Figure 3. Aggraded habitat between reaches 9 and 12 of the Tahsis River, as observed in 2013 orthophotography.

1.2.2 Watershed History

The Tahsis River resides within the traditional territory of the Mowachaht / Muchalaht First Nation, who have remained in this area for thousands of years. The area was first visited by British and Spanish explorers in the 1770s and 1780s, with homesteaders and hand loggers settling on Tahsis Inlet as early as 1882 (Sellars, 1992).

Forest Harvesting

The Tahsis River watershed has an extensive history of forest harvesting. Logging commenced in the valley in the 1940s by the Gibson Brothers, and between the 1940s and the 1980s, the valley was extensively logged from the estuary to the treeline of Rugged Mountain. Very little riparian vegetation was preserved during logging operations with most areas harvested right to the stream bank (Photo 1). Yarding across the stream banks was common practice, and in many cases, machinery was operated directly in the river bed (J. Fiddick, pers. comm.). Following logging initiatives, no restocking / reforestation efforts were completed, resulting in natural reclamation of the valley bottom by deciduous hardwoods (red alder and broadleaf maple) (Fisheries and Oceans Canada, 2012).

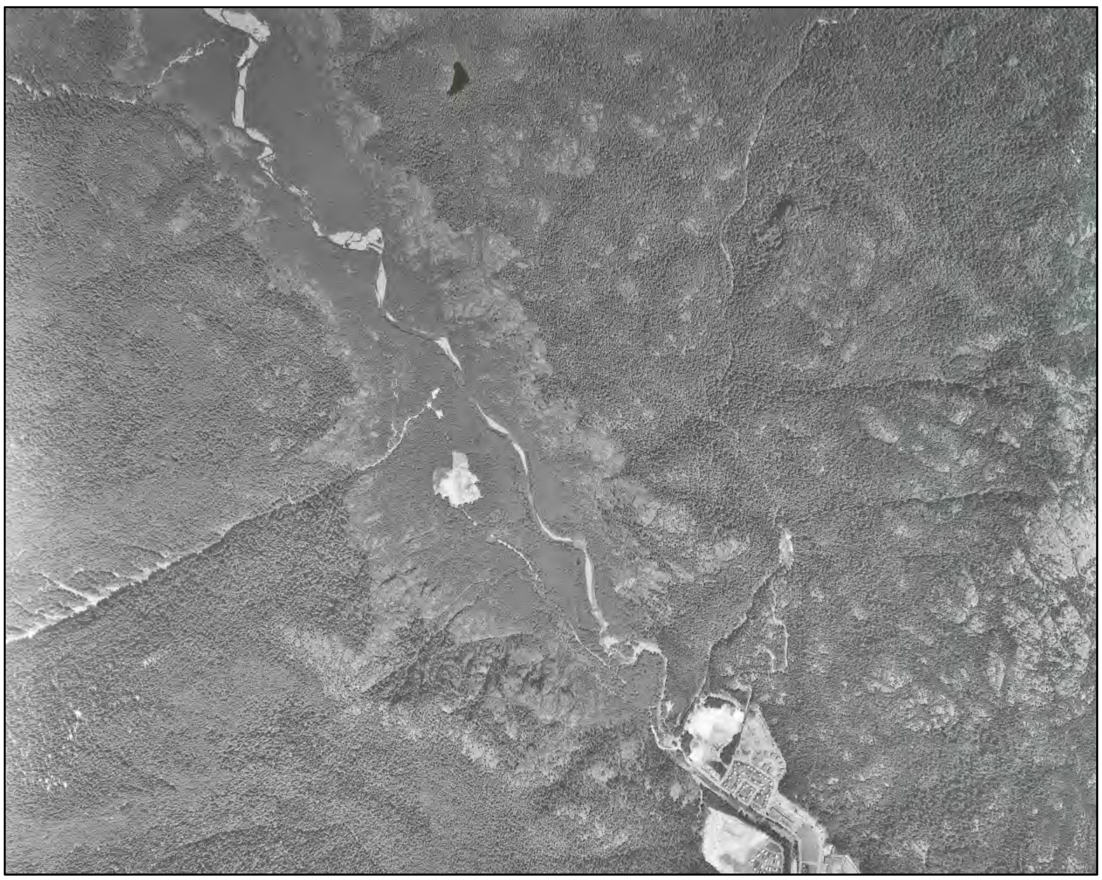


Photo 1. Logging activity in the Tahsis River watershed in 1977. Note the complete removal of vegetation along the valley bottom and reclamation by deciduous hardwoods.

Impacts resulting from forest harvesting initiatives were observed as early as 1949, where significant log jams began to form on the system. Changes to the river bed and bank erosion became obvious by the late 1950s, with the river becoming increasingly unstable as the years progressed. Significant bank erosion and bed load movement continued to occur and by 1982, aggradation 5 to 6km upstream caused the river bed to dewater. This section remains impassable to fish at low flows today (Fisheries and Oceans Canada, 1949 - 1994).

The forest land base in the Tahsis River watershed is currently licensed for harvest under Tree Farm Licence (TFL) 19. While the logging road was deactivated more than a decade ago, reactivation will likely occur as future forest harvesting plans materialize.

Townsite Development

Development at the head of Tahsis Inlet began in 1945 with the construction of a mill near the west side of the Tahsis River estuary (Photo 2). Lumber milling became a strong financial basis for Tahsis and in the 1950s, the estuary mud flats were filled in to accommodate expansion of the Tahsis sawmill and a new residential area along the east bank of the river. By 1969, a large portion of the northeast shoreline was infilled to allow for the construction of a new cedar mill (Western Canada Hydraulic Laboraties Ltd., 1981). A substantial amount of residential housing construction occurred at this time as well, with development continuing following the opening of the road between Gold River and Tahsis in 1972 (Willis Energy Services Ltd., 2001).

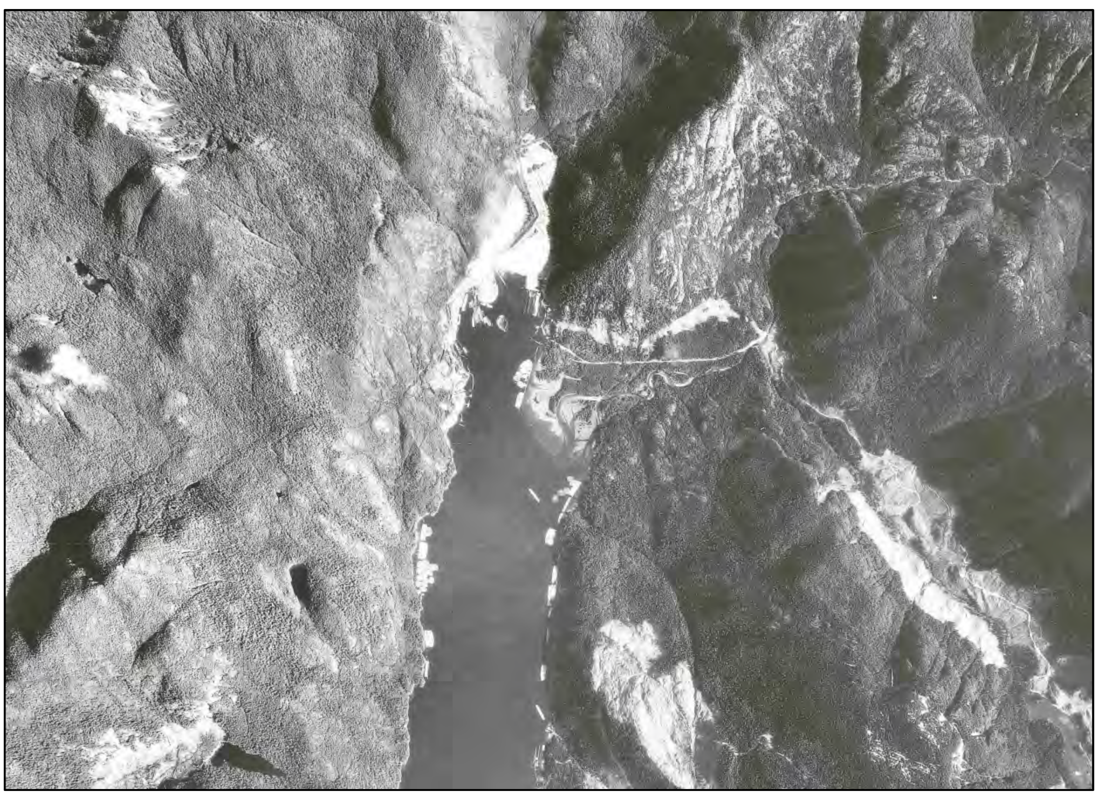


Photo 2. Historical photograph of development within the Tahsis River estuary in 1954.

By 1974, the cedar mill to the east, the Tahsis Co. bunk houses and Tahsis municipal sewage plant to the north, and the Tahsis sawmill to the west resulted in only a fraction of the original estuary remaining (Kennedy & Waters, 1974). A berm was constructed by Nootka Cedar Products along the east side of the river which resulted in the constriction of flow through the estuary (Photo 3), and two hog fuel landfills were established along the lower reach of the river, one of which the trailer court was eventually constructed on top of (Wright, 2002). The lower reach of McKelvie Creek was relocated further upstream to allow for infilling and development (Brown A. A., 1985). Dredging in the estuary by Nootka Cedar products commonly occurred to keep the area open for log handling and booming, and booming grounds were present along both sides of Tahsis Inlet (Photo 3).

Photo 3. Log booming in Tahsis Inlet in 1977. Note the lack of estuarine habitat remaining at the head of Tahsis Inlet.

By the late 1980s, declines in the forest industry resulted in mill downsizings and closures. The hemlock dimension-lumber and cedar shake mill closed in the late 1990s (Willis Energy Services Ltd., 2001). The population in Tahsis reduced from a peak of 2,500 to approximately 300 permanent residents between the early 1980s and 2012 (Village of Tahsis, 2015). The economic mainstays in Tahsis have since shifted from logging, commercial fishing, and lumber milling to ecotourism in the valley (Fisheries and Oceans Canada, 2012).

2.0 METHODS

Strategy 2 habitat status assessments require the analysis of habitats using the pressure-state indicator model identified in Stalberg et. al. (2009). Within this model, pressure indicators are considered descriptors of landscape-level (and generally man-made) stressors, which can often be evaluated through the spatial analysis of remotely sensed data. State indicators are descriptors of specific habitat conditions, and are typically representative of 'on-the-ground' data collected during field operations. The following table describes the original stream, lake, and estuary pressure and state indicators considered under WSP Strategy 2:

Table 2. Pressure and state indicators identified in Stalberg et. al. (2009).

Habitat Type	Indicator Type	Indicator
Stream	Pressure	Total land cover alterations
Stream	Pressure	Watershed road development
Stream	Pressure	Water extraction
Stream	Pressure	Riparian disturbance
Stream	Pressure	Permitted waste management discharges
Stream	State	Suspended sediment
Stream	State	Water quality
Stream	State	Water temperature: juvenile rearing – stream resident species
Stream	State	Water temperature: migration and spawning – all species
Stream	State	Stream discharge
Stream	Quantity	Accessible stream length, based on barriers
Stream	Quantity	Key spawning areas (length)
Lake	Pressure	Total land cover alteration
Lake	Pressure	Watershed road development
Lake	Pressure	Riparian disturbance
Lake	Pressure	Permitted waste management discharges
Lake	State for sockeye lakes	Coldwater refuge zones
Lake	State for sockeye lakes	Lake productive capacity
Lake	Quantity	Lake shore spawning area (length)

Estuary	Pressure	Marine vessel traffic
Estuary	Pressure	Estuary habitat disturbance
Estuary	Pressure	Permitted waste management discharges
Estuary	State	Estuary chemistry and contaminants
Estuary	State	Estuary dissolved oxygen
Estuary	Quantity	Estuarine habitat area (riparian, sedge, eelgrass, and mudflat)

The selection of applicable indicators for the Tahsis River watershed occurred following a comprehensive literature review and spatial data gathering and analyses. In addition to the indicators describe in Table 2, supplemental indicators were evaluated during the data gathering process based on data availability and their perceived importance.

2.1 Literature Review

Literature reviewed as part of the information gathering process included habitat assessments, monitoring initiatives, water use plans, watershed and estuary management plans, and various other technical documents. This information was obtained from the following sources:

- Web sources – FISS, WAVES online library, EcoCAT, J.T. Fyles Ministry of Forests online library, Google search;
- Technical reports received from local experts and stakeholders (i.e. DFO, private consultants, Western Forest Products [WFP], and others);
- Technical reports housed internally by MCW; and
- Preliminary interviews with key knowledgeable persons (i.e. the Tahsis Enhancement Society and the Nootka Sound Watershed Society)

Information from all sources was compiled and entered into a spreadsheet, and was separated by information theme (i.e. fish, habitat, impacts, water quality, etc.). Each document was comprehensively reviewed with important information extracted and synthesized on the spreadsheet. This method allowed for cross-comparison of document results, which was used to identify redundancy across sources and generate consensus on which habitat indicators apply in the system.

2.2 Spatial Data Gathering and Processing

Geographic Information Systems (GIS) data relevant to this project was obtained through the following resources:

- Land and Resources Data Warehouse (LRDW);
- West Coast Aquatics (WCA);
- Western Forest Products Ltd. (WFP);
- GeoBC;
- Ministry of Forests, Lands, and Natural Resource Operations (MFLNRO) Fish Passage Investment Program;
- University of British Columbia's Geographic Information Centre;
- Mapster;
- Shapefiles and orthophotographs courtesy of WFP; and
- Existing spatial data previously collected by MCW.

All GIS data processing and mapping was accomplished using ArcGIS Desktop 10.3 with the Spatial and 3D Analyst extensions. Once acquired, data was processed by clipping features to the BC Watershed Atlas 1:50,000 scale watershed boundaries.

2.3 Interviews

In addition to the interviews conducted in March of 2014 with the Tahsis Watershed Society, interviews with the Nootka Sound Watershed Society's and other experts in the area were also conducted to incorporate additional local knowledge of the Tahsis River. These interviews were conducted during the Nootka Sound Risk Assessment Workshop in Gold River, May 5-7, 2015.

2.4 Selected Stream Habitat Indicators

Upon review of the literature and spatial data gathered, stream habitat indicators were selected based on data availability and indicator suitability. The following sections describe methods used to analyze selected stream habitat indicators against known metrics and benchmarks.

2.4.1 Total Land Cover Alterations

Indicator Type: Pressure

Total land cover alteration captures potential changes in cumulative watershed processes such as peak hydrologic flows and sediment generation that can affect downstream spawning and rearing habitats (Poff et al., 2006 as cited in Stalberg et al., 2009). Alterations can be categorized by agriculture, urbanization, forestry, fire disturbance, mining activity, and road development.

Total land cover alterations in the Tahsis River watershed were calculated by analyzing WFP's forest age layer for each watershed. This layer categorized all forested areas within a watershed using the following classification scheme: younger than 40 years, 41 to 120 years, and older than 120 years. Forested areas classified as older than 120 years were considered un-altered. Non-forested areas were described as non-productive. For polygons classified as non-productive by WFP, data was overlaid on high resolution 2012 – 2013 orthophotographs to differentiate the type of non-productive land present. These lands were further classified as follows: non-productive (alpine), non-productive (avalanche chute), non-productive (barren surface), non-productive (fresh water), and non-productive (urban). Classification into these non-productive categories was used to determine the area of natural (i.e. unaltered) non-productive land cover versus the area of altered non-productive land cover.

Land cover compositions and distributions were summarized for the entire watershed and analyzed to determine the total land cover alteration risk.

2.4.2 Watershed Road Development

Indicator Type: Pressure

The construction of roads in a watershed has the potential to increase fine sediment deposition into adjacent streams, reduce the aquatic invertebrate diversity, and affect aquatic connectivity, channel bed disturbance, and channel morphology (Tschaplinski, The Effects of Roads on the Post-Harvest Condition of Streams, Riparian Areas, and Fish Habitats in British Columbia, 1996 - 2010., 2010). In addition, road densities are correlated with the extent of land-use within a watershed, and can be an indicator of overall watershed development (Stalberg et al, 2009).

Watershed road development was evaluated by calculating the lineal length of road per square kilometre of watershed. In order to obtain the most accurate representation of the existing road network, GIS layers obtained from the LRDW, WCA, and WFP were compared with 2013 high resolution orthophotographs. Discrepancies between layers were resolved and layers were merged to create one comprehensive road network.

Road development densities were determined by dividing the total length of roads in each watershed by the watershed area. Results were then compared with the following suggested benchmark identified in Stalberg et. al (2009):

$<$0.4km / km^2 = lower risk
$>$0.4km / km^2 = higher risk

2.4.3 Water Extraction

Indicator Type: Pressure

The consumptive use of water within a watershed has the potential to impact spawning and rearing habitats through the reduction of instream flows (ESSA Technologies Ltd., 2013). While watershed benchmarks are difficult to define in the absence of detailed climatic and hydrological data, relative risks can be assessed by comparing the total volume of licenced water extraction by watershed.

Water licence information was obtained through the LRDW. Spatial features were clipped within watershed boundaries, and permitted volumes (and licence type) were determined from the water licence attributes.

Watersheds with no licenced water extraction (for consumptive uses) were assigned low risk, while watersheds with any amount of extraction were assigned a moderate risk.

2.4.4 Riparian Disturbance

Indicator Type: Pressure

Riparian disturbance is a commonly used pressure indicator for both streams and lakes (Stalberg et al, 2009). Streamside vegetation provides many critical functions to aquatic habitats, including (but not limited to): temperature regulation, cover, large woody debris (LWD) deposition, nutrient input, and channel stability. While logging practices today are required to manage riparian vegetation adjacent to fish-bearing streams, impacts from historical logging to the stream banks have persisted. In many cases the return of riparian habitats to a proper functioning condition will require intervention through conifer release and bank stabilization practices.

Riparian disturbance in the Tahsis River was determined by classifying vegetation within 100m of the high water mark. While a 30m delineation is the commonly referenced width for managing the riparian zone during development within B.C. (e.g., *The Land Development Guidelines for the Protection of Aquatic Habitat* (Fisheries and Oceans Canada & Ministry of Environment, 1992) discussions with the NWSW identified that an understanding of vegetation beyond this 30m width was necessary in order to fully understand impacts to the riparian zone (R. Dunlop, pers. comm.).

Vegetation was classified using 2013 high resolution orthophotographs. All vegetation within a 100m buffer of the high water line was classified using the following categories:

- Mature conifer (i.e. >90% mature coniferous stand);
- Mature mixed (i.e. mixture of mature coniferous and deciduous vegetation);

- Deciduous or regenerating (i.e. >90% deciduous stand and / or a regenerating coniferous stand);
- Early regenerating; and
- Non-productive (i.e. roads and bedrock surfaces).

Once classified, the riparian composition was summarized for the fish-bearing component of the mainstem to determine the relative riparian disturbance pressure for anadromous species.

2.4.5 Permitted Waste Management Discharges

Indicator Type: Pressure

Permitted waste management discharges provide insight into potential pressures on water quality in streams, lakes, and estuaries. Information for the Nootka Sound area was obtained through the BC Ministry of Environment (MOE) permitted waste discharge authorization database (BC MOE Waste Management Website, 2015). A search was conducted for authorizations within the Tahsis, Gold River, and Zeballos. Results were mapped in ArcGIS using the coordinates provided in the database, and all authorization information was retained as fields in the attributes table.

2.4.6 Water Quality

Indicator Type: State

Suggested water quality metrics are the concentrations of contaminants, nutrients, and dissolved oxygen (DO) in stream water. This level of data is typically only available for systems with localized monitoring or research projects (Stalberg et al, 2009). For the Tahsis River, water quality data was obtained from the following sources:

- Village of Tahsis water supply monitoring dataset (VIHA, 2015);
- Ministry of Energy and Mines regional geochemical stream survey data; and
- Relevant reports pertaining to the Tahsis landfill (UMA Engineering Ltd. and Gartner Lee Limited, 1996).

2.4.7 Water Temperature: Juvenile Rearing and Migration

Indicator Type: State

Water temperature during the incubation, rearing, and migration of salmonid species has a significant impact on the timing of certain life stages (i.e. emergence), and is an important parameter to understand potential exposure to other limiting factors based on timing. No temperature data was available for the Tahsis River watershed during the juvenile rearing and migration period and has been identified as a data gap.

2.4.8 Water Temperature: Migration and Spawning

Indicator Type: State

High water temperatures during the summer and fall have the potential to delay or be stressful to migrating salmonids (Sauter et al, 2001). The Upper Optimum Temperature Range (UOTR) and Impairment Temperatures (IT) for all species of salmonids were defined in Stalberg et al (2009) as 15°C and 20°C, respectively.

Stream temperature data was obtained from 2006 to 2013 from DFO's Stream Inspection Logs (SILs). Temperatures during spawner migration in the Tahsis River were evaluated for this indicator by determining the maximum temperatures observed by snorkel survey crews each season against the UOTR and IT. Temperatures that remained below these values were considered low risk, temperatures that were at the UOTR or between the UOTR were considered moderate risk, and temperatures at or above the IT were considered high risk.

While a risk assessment of this habitat indicator was possible through SIL temperature data, it should be noted that this data represents only select point samples in time. Continuous temperature loggers during the spawning period are recommended to increase the robustness of this habitat indicator assessment.

2.4.9 Stream Discharge

Indicator Type: State

The carrying capacity of streams and their seasonal suitability for use by different salmonid species and life-stage are directly related to aspects of the annual hydrograph and "mean annual discharge" (MAD). The suggested benchmark for discharge is when the 1 in 2 year 30-day duration summer minimum flow (i.e. July – September) is less than 20% of MAD (Stalberg et al, 2009).

No discharge data was available for the Tahsis River and has therefore been identified as a data gap. However, discharge information obtained from the Water Survey of Canada (WSC) site on the McKelvie Creek was summarized and compared against the suggested benchmark.

2.4.10 Accessible Stream Length

Indicator Type: State

Determination of the accessible stream length (by species) provides an indicator on the relative productive capacity of a watershed, and allows for the analysis of how landscape pressures (i.e. disturbed riparian zones) affect different species and life stages differently. Accessible stream length was determined through the compilation of several sources of information, including the Fisheries Information Summary System (FISS), BC MOE fish passage modelling (MFLNRO Fish Passage Technical Working Group Web Page, 2013), spatial data received from WCA, various technical reports, and interviews with the Tahsis Enhancement Society (2014) and the Nootka Sound Watershed Society. Compiled data was digitized as a line feature in ArcGIS to determine the linear length of fish distribution.

2.4.12 Key Spawning Areas (Length)

Indicator Type: State

Quantification of the key spawning areas provides an indicator on the relative productive capacity of a watershed, as well as a baseline to compare future changes in spawning habitat over time. In addition, identification and documentation of these key habitats will provide guidance on critical habitats to protect from future industrial initiatives.

Key spawning areas were identified from the following sources: FISS, various technical reports, interviews with the Tahsis Enhancement Society and the Nootka Sound Watershed Society, and data extracted from recent SILs.

2.5 Additional Stream Indicators

Based on the breadth of data collected during the information gathering process and other known useful stream indicators, the following sections describe the supplemental stream indicators selected for analysis during the habitat status assessment work in Nootka Sound.

2.5.1 Stream Crossing Density

Indicator Type: Pressure

Stream crossings at roads have the potential to impede fish passage through interfering with or blocking access to upstream spawning or rearing habitats (thereby reducing the total amount of habitat salmonid habitat in a watershed (Harper and Quigley, 2000). These crossings have also been known to increase sediment delivery to streams through the provision of direct pathways to aquatic habitats (Brown et al , 2013).

Stream crossing information was obtained from the Provincial Stream Crossing Inventory System (PSCIS). Crossing density was calculated for each watershed by dividing the total number of crossings present in each watershed by the watershed area, and the distribution values across all watersheds were compared to evaluate relative risk. In addition, the number of modelled fish-bearing crossings was determined for each watershed to evaluate the number of crossings potentially affecting fish and fish habitat.

Risks were determined on a comparative basis by ranking both crossing density and the total number of fish-bearing crossings per watershed.

2.5.2 Habitat Composition

Indicator Type: State

Guidelines state that for systems greater than 15m and with gradients <2% poor salmonid habitat condition for summer and winter rearing occurs with <40% pool habitat area by reach. Systems with gradients between 2 and 5% experience poor summer and winter rearing conditions with <30% pool habitat area by reach, and systems with gradients >5% experience poor summer and winter rearing conditions with <20% pool habitat area by reach (Johnston and Slaney, 1996).

Habitat compositions for the Tahsis River were determined by digitizing macrohabitat units from 2013 orthophotographs, where visible in the imagery (note that in some cases, classification was not possible based on canopy cover and / or shadowing). In addition, historical habitat unit composition was determined through GPS data collected in the mid-1990s by M.C. Wright and Associates Ltd. (unpublished data) and digitization of geo-referenced air photos from 1995. All habitats within the bankful widths were classified based on the following categories:

- Riffle;
- Pool;
- Glide;
- Cascade;
- Braided;
- Debris jam;
- Gravel bar;
- Vegetated gravel bar;
- Side channel; and
- Secondary channel.

Habitat units by percent composition were determined by calculating and comparing the respective areas of each habitat unit type in ArcGIS. An assessment of change in habitat unit composition over time was also determined through a comparison of the 2013 and 1995 data.

2.5.3 Channel Stability

Indicator Type: State

Forest harvesting and road building in a watershed have the potential to increase peak flows, increase sediment delivery, alter riparian vegetation, and disturb channel integrity. These alterations can cause morphological changes to a channel, and may result in aggradation or degradation of the streambed. These changes will often affect the stability of stream banks and the conditions of LWD in the system and subsequently impact critical salmonid habitats (i.e. spawning and rearing zones) (Hogan and Ward, 1997).

Channel stability in the Tahsis River watershed was evaluated through the comparison of historical air photos (1980 and 1995) and recent orthophotographs (2013). Bankful widths, the location of vegetated and non-vegetated gravel bars, and eroding banks were compared between each time period, and used as an indicator of increasing or decreasing channel stability.

2.4.4 Large Woody Debris

Indicator Type: State

Large woody debris (LWD) affects channel form through the formation and stabilization of pools and gravel bars, and provides valuable habitat in the form of cover for salmonids. In many cases, a reduction in LWD amount and piece size as a result of forest harvesting has been assumed to occur gradually; however, recent studies indicate these changes occur during or shortly after harvest (Bilby and Ward, 1991). Changes in riparian stand composition (i.e. a transition from mature conifers to deciduous) are known to reduce the quality and longevity of LWD in a system as deciduous trees (i.e. alder) break down in river systems faster than mature conifers.

LWD was classified from the 2013 orthophotography where the stream channel was visible in the imagery. In many cases, canopy cover and / or shadows in the upper reaches of the systems prevented classification, and were identified as a data gap. Species differentiation of LWD (i.e. deciduous or coniferous) was not possible from the orthophotographs; however, some assumptions can be made based on classification of the adjacent riparian stand.

Visible LWD was classified using the following categories:

- Functioning (i.e. LWD situated at an angle or perpendicular to the stream bank, with the potential to create scour pools and influence channel form);
- Partially-Functioning (i.e. LWD situated at an angle or perpendicular to the stream bank, but remained only partially wetted and requires higher flows to provide full functionality, or LWD situated parallel to the stream bank);
- Non-Functioning (i.e. LWD situated parallel to the stream bank or situated on gravel bars well above the wetted width); and
- Debris Jam (i.e. a large raft of LWD, typically consisting of 10 pieces of LWD or greater).

LWD habitat condition was determined, at the reach level, using the following diagnostics described in Johnston and Slaney (1996):

- Good = >2 pieces of functional LWD per bankful width;
- Fair = 1 – 2 pieces of functional LWD per bankful width; and
- Poor = <1 piece of functional LWD per bankful width.

2.5.5 Off-Channel Habitats

Off-channel habitats provide valuable rearing and over-wintering habitat for various species of pacific salmon. Chum and coho are most strongly associated with these types of habitats, with chum often observed spawning in groundwater-fed channels or seepage areas, and coho observed spawning in groundwater channels and small surface-fed tributaries (Slaney and Zaldokas, 1997). Coho juveniles utilize refuge areas such as side channels, small tributaries, ponds, and lakes for over-wintering habitat as they provide protection from winter flood events. The productivity of coho in many coastal systems depends on the availability of of good winter refuge (i.e. off-channel) habitat (Diewert, 2007). In addition, off-channel habitats in the lower reaches of the river provide important foraging opportunities for all out-migration salmonids.

Evaluation of off-channel habitat condition in the Tahsis River watershed was restricted to interviews with local experts and information found in Wright 2002, as these habitat types were typically not visible from orthophotography due to canopy cover.

2.6 Selected Estuary Habitat Indicators

Upon review of the literature and spatial data gathered, estuary habitat indicators were selected based on data availability and indicator suitability. The following sections describe methods used to analyze selected estuary habitat indicators against known metrics and benchmarks.

2.6.1 Estuary Habitat Disturbance

Indicator Type: Pressure

Estuaries are extremely important habitats for adult salmon for staging and physiological transition, and are also important to juvenile salmon for rearing, physiological transition, and refugia. Anthropogenic impacts within an estuary and throughout a corresponding watershed can have negative effects on both adult and juvenile salmonids utilizing these habitats. These impacts are compounded considering the added physiological stresses fish experience during the transition from the freshwater to marine environments, and the importance of estuarine habitat for foraging and rearing. Common impacts within estuaries include: 1.) loss of intertidal rearing habitat due to structural development, dredging and filling, and gravel deposition from upstream sediments; 2.) decreases in dissolved oxygen due to input of sewage, agricultural practices, and dredging of anoxic sediments; 3.) creating a toxic condition due to toxic chemical spills and the discharge of chemical waste from industry and mining; and 4.) an increase in suspended solids due to logging activities upstream, agricultural practices, dredging, and input of sewage and industrial waste (Aitkin, 1998).

Relative estuarine habitat disturbances in Tahsis Inlet were evaluated through the extent of known historical activities, the presence / absence of existing initiatives in the estuary, and residual impacts identified through literature reviews and orthophoto analyses.

2.6.2 Permitted Waste Management Discharges

Indicator Type: Pressure

Permitted waste management discharges within the estuarine habitat have the potential to impact salmonid through the reduction of water quality (i.e. dissolved oxygen) and an increase in suspended solids (Aitkin, 1998). This indicator was evaluated based on the presence / absence of permitted waste management discharges within the Tahsis River estuary.

2.6.3 Estuary Chemistry and Contaminants

Indicator Type: State

An analysis of estuarine chemistry and contaminants (i.e. N, P, N:P, Metals, PAHs and PCBs) can provide an indicator of water quality suitability for aquatic life. Available water quality data was compared with the Canadian Water Quality Guidelines for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment, 1999) to determine if any parameters exceeded the thresholds of these guidelines and therefore potentially impacting salmonids utilizing the estuary.

No relevant chemistry or contaminant data for the Tahsis River estuary was available, and has therefore been identified as a data gap.

2.6.4 Estuary Dissolved Oxygen

Indicator Type: State

Dissolved oxygen levels and stratification in estuaries have been shown to be important in the freshwater-marine transitions of migrating juvenile and adult salmon (Stalberg et al, 2009). No data was available for the Tahsis River estuary; as such, this habitat indicator has been identified as a data gap.

2.6.5 Estuarine Habitat Area

Indicator Type: State

The area of riparian, sedge, eelgrass, and mudflat habitats within an estuary is considered an indicator of the productive capacity of an estuary. An analysis of estuarine habitat changes over time also provides an indicator of habitat improvement or degradation, and may identify critical habitats requiring protection and / or restoration.

Estuarine habitat area for the Tahsis River was calculated through the digitization of habitat types from the 2013 orthophotographs. While no historical habitat areas were available for comparison, this data provides a baseline of information from which future changes over time can be compared.

3.0 WILD PACIFIC SALMON OF THE TAHSIS RIVER WATERSHED

The Tahsis River watershed has been identified to have high to very high fish capacity, with large or potentially large anadromous runs (Horel, 2008). Four species of anadromous salmon - chinook (*Oncorhynchus tshawytscha), coho (O. kisutch), chum (O. keta) and sockeye (O. nerka*) are supported by the Tahsis River watershed. Assessment of these stocks occurs primarily through annual Area Under the Curve (AUC) snorkel surveys during the spawning season. The main species of interest are described in the following sections.

3.1 Chinook Salmon

3.1.1 Biology, Distribution, and Known Habitats

Chinook salmon in the Tahsis River watershed are ocean-type chinook. These chinook typically enter the river and commence spawning in late September, with peak spawning observed in early October, and the end of the run observed in mid October (Fisheries and Oceans Canada, 2012). Distribution has been observed approximately 10.1km upstream of the estuary; however, the majority of the population remains concentrated below counting station 10, or approximately 5km upstream of the estuary (Figure 4). This distribution is likely influenced by the aggraded habitat above counting station 7, which impedes fish passage during low flow periods. In recent years a significant component (approximately 50%-60%) of chinook have been observed spawning between counting station 0 and 1 (A. Eden, pers. comm.). Anecdotal information suggests that delayed entry into the river and low densities of spawner are likely influencing this distribution. Chinook have also been known to migrate into the lower reach of McKelvie Creek; however, presence in this zone is likely the influence of the hatchery using McKelvie Creek water on chinook hatchery stock (Fisheries and Oceans Canada, 2012).

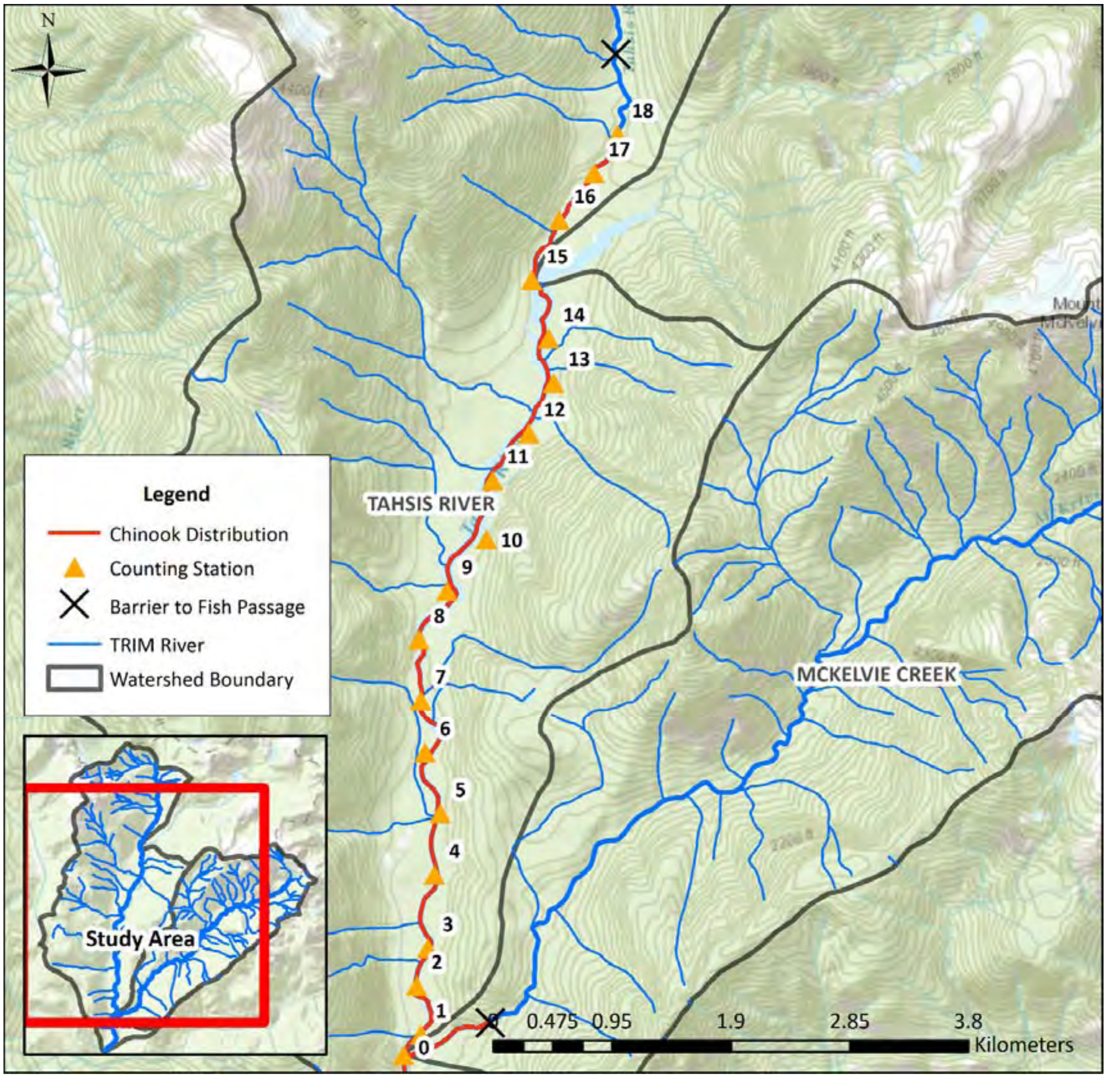


Figure 4. Known chinook distribution in the Tahsis River watershed.

During upstream migration to the spawning grounds, adult chinook take advantage of several key holding pools, notably between counting stations 1 - 2 and 7 – 9. Of particular importance is a pool beneath a large debris jam approximately 250m downstream of counting station 9 (Fisheries and Oceans Canada, 2012). In addition there are several bedrock controlled pools along the left and right banks that have been identified as critical holding habitat (Tahsis Enhancement Society, pers. comm) (Figure 5).

As chinook salmon eggs have the largest surface area to volume ratio when compared with other pacific salmon species, their eggs are most sensitive to reduced oxygen levels. As such spawning grounds with adequate subgravel flows (and typically coarser gravels) are targeted during redd selection (Diewert, 2007). In the Tahsis River, known spawning grounds have been identified in key riffles and pool tail-outs between counting sections 3-4 and 5-6 (Figure 5).

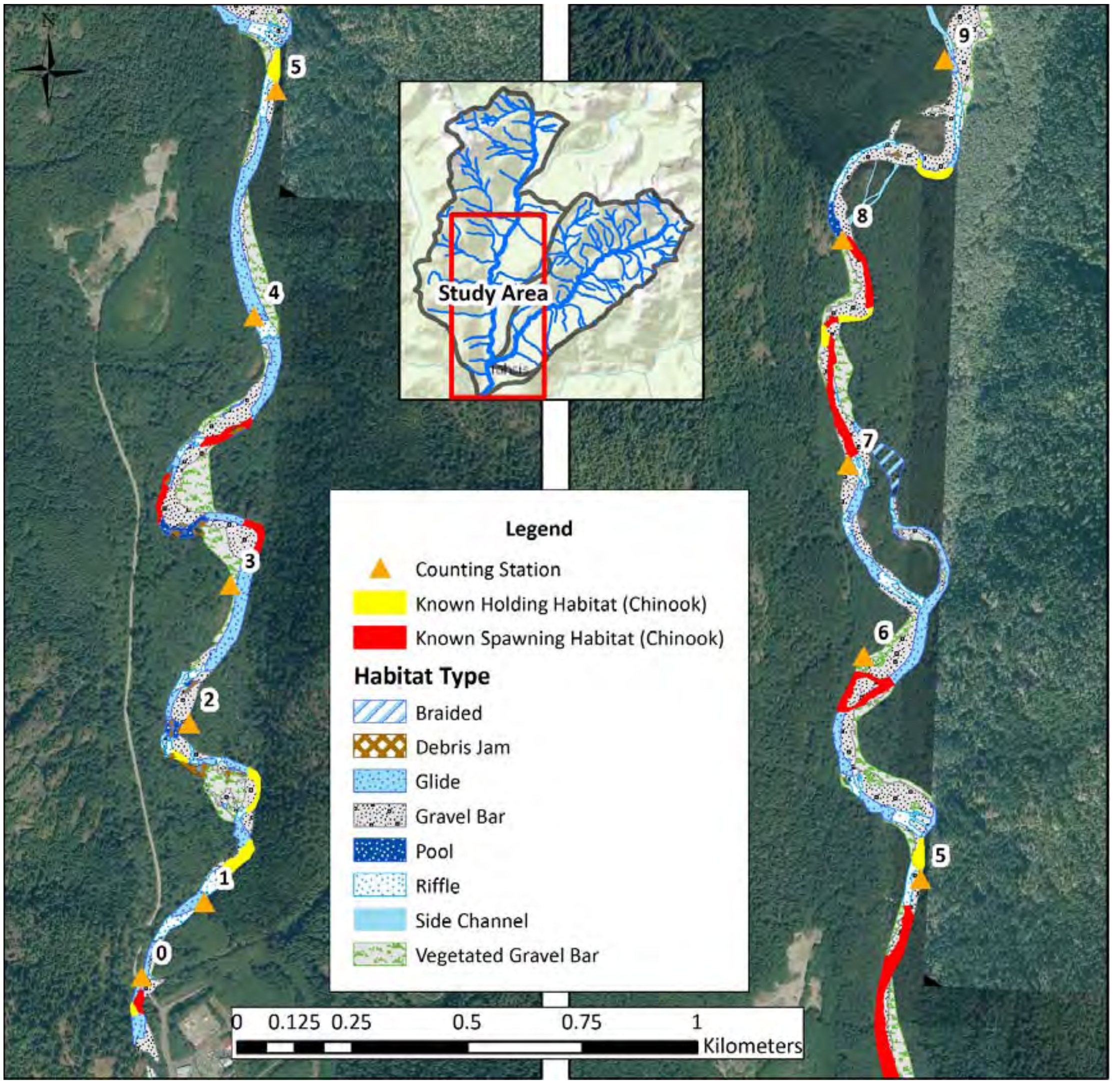


Figure 5. Known adult chinook holding and spawning habitat in the Tahsis River.

Fry emergence is partially dependent on water temperature and can vary from year to year (i.e. the lower the water temperature, the longer the incubation period required). Following emergence, fry typically migrate downstream immediately. Migration usually occurs between April and June for ocean-type chinook (note that the specific migration timing for the Tahsis River system is unknown). During downstream migration, fry typically target reduced flows at the river edges (Diewert, 2007). Given this requirement critical migration habitat for chinook fry has been inferred for the Tahsis River based on characteristics observed from the orthophotographs. In addition, chinook are known to rear and forage in the estuary and associated intertidal channels (Figure 6).

Ocean-type chinook are most dependent upon estuaries to complete their life cycle (Aitkin, 1998). They are an environmental transition zone that provides opportunities for feeding and growth and refuge from predators. Upon reaching the estuary, juveniles rear in this zone for up to several months, where rapid growth (dependant on food resources available in the estuary) typically occurs (Diewert, 2007). Previous studies in the Tahsis River estuary indicated peak outmigration to the estuary to occur in late March and early April, with juveniles remaining in the estuarine and marine foreshore zones as late as July (Western Canada Hydraulic Laboraties Ltd., 1981). While the majority of the Tahsis River estuary has been infilled over time and historical productivity levels have been greatly reduced, the remaining estuary is still classified as critical habitat as it is an integral component of this population's life cycle (Figure 6).

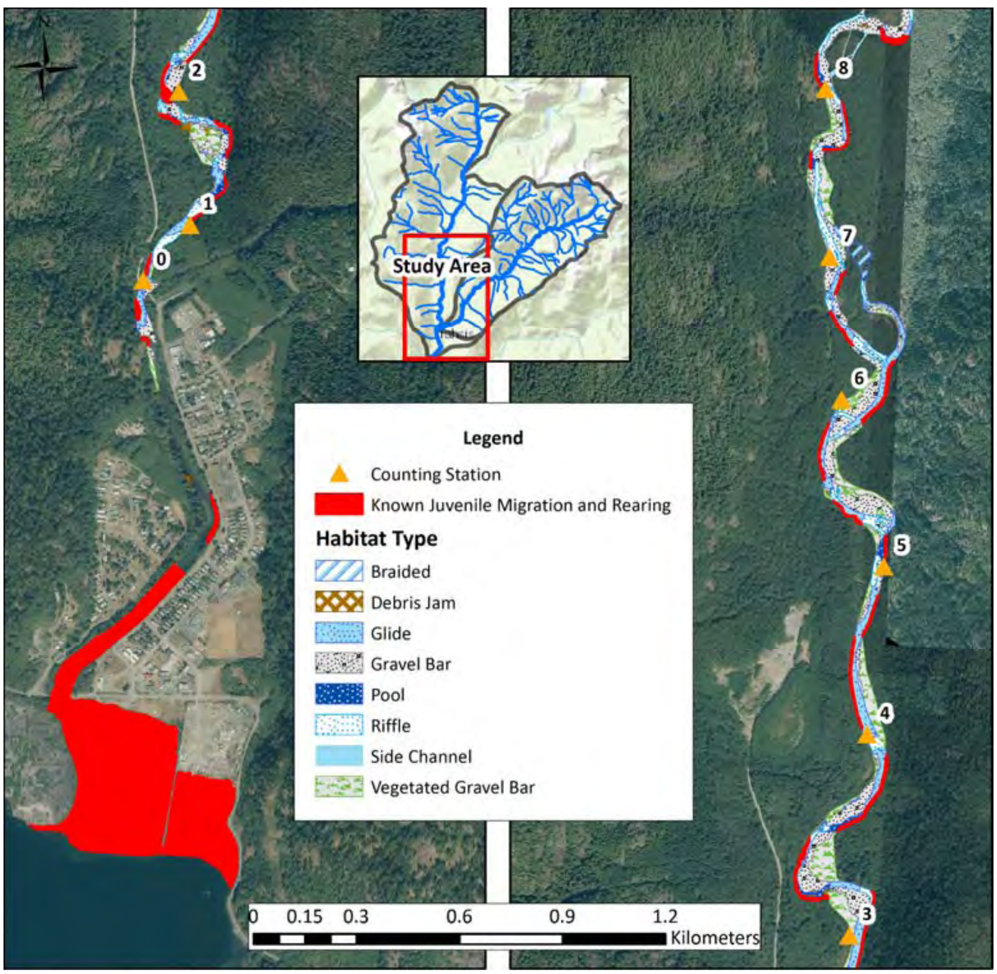


Figure 6. Known juvenile chinook migration and rearing habitat in the Tahsis River.

3.1.2 Escapement

The Tahsis Enhancement Society was established in 1984, with the objective of rebuilding vulnerable salmon stocks and to improve fish habitat to sustain these populations (Tahsis Salmon Enhancement Society, 2011). Despite efforts by this enhancement group, chinook numbers in the Tahsis River have not been stable in recent years (Fisheries and Oceans Canada, 2012). This river has been known to support escapements of up to 1,700 fish; however, recent average escapement numbers range between 150 to 600 fish.

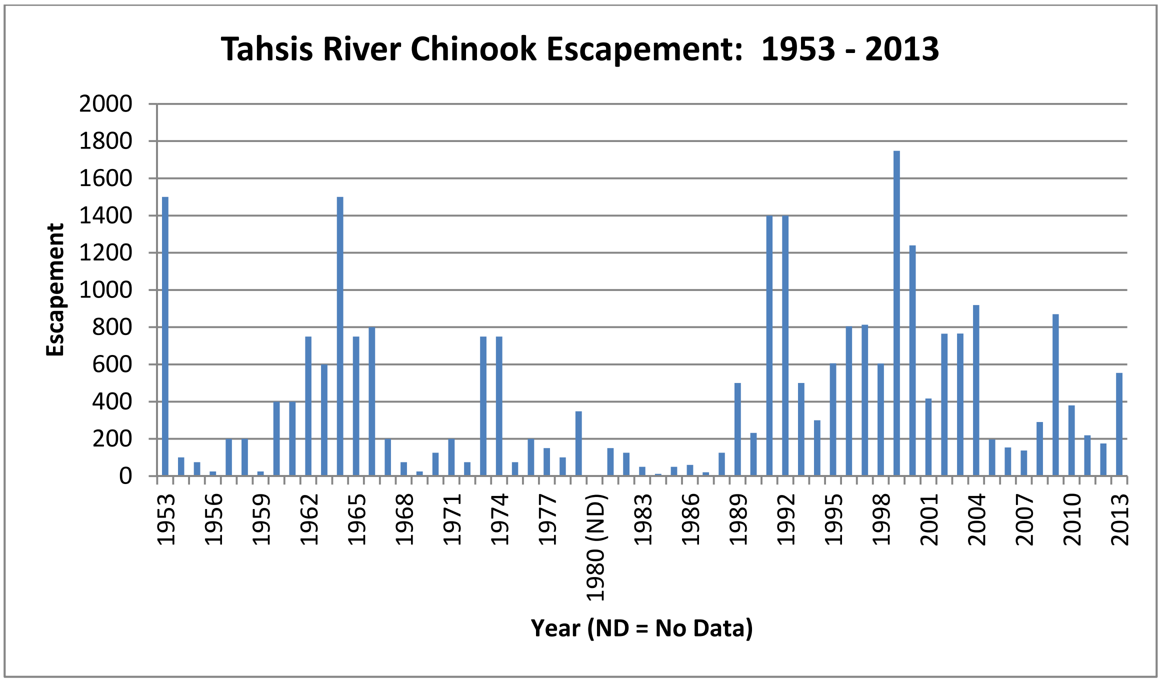


Figure 7. Chinook escapement in the Tahsis River between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.2 Coho Salmon

3.2.1 Biology, Distribution, and Known Habitats

Coho salmon typically arrive in the Tahsis River in early September and begin spawning in late October. Peak spawning typically occurs in mid-November, with the end of the run observed in late November (Fisheries and Oceans Canada, 2012). Distribution has been observed in the mainstem up to the anadromous fish passage barrier (approximately 10.8km). The most significant populations of coho utilize the lower end of the mainstem (below counting station 8), and in the tributaries also located on the lower end of the river (Figure 8) (Wright, 2002).

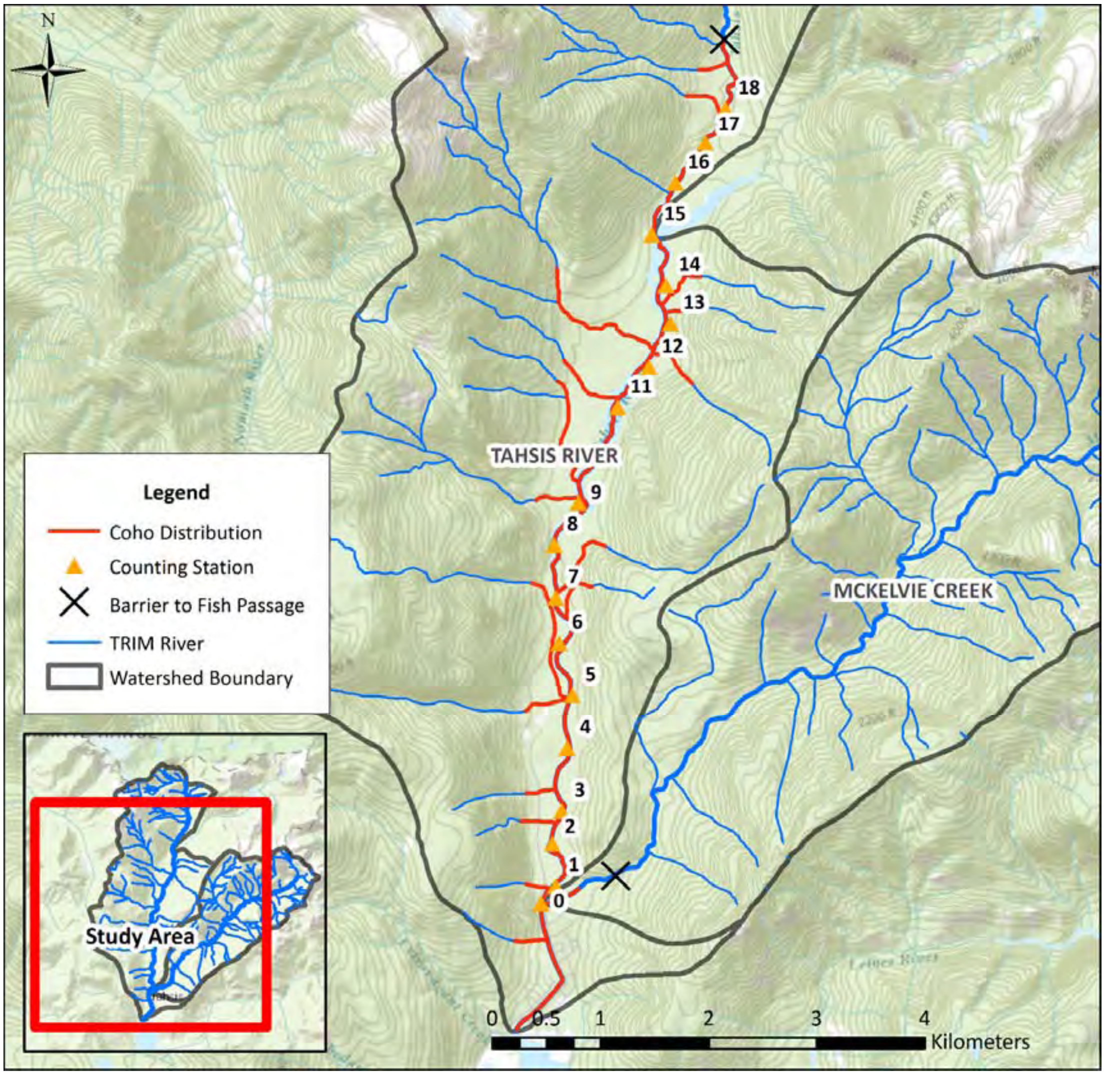


Figure 8. Known and modeled coho distribution in the Tahsis River watershed.

During upstream migration to the spawning grounds, adult coho take advantage of several key holding pools, notably between counting stations 1 - 2 and 7 – 9. Of particular importance is a pool beneath a large debris jam approximately 250m downstream of counting station 9 (Fisheries and Oceans Canada, 2012). In addition there are several bedrock controlled pools along the left and right banks that have been identified as critical holding habitat (Tahsis Enhancement Society and Nootka Sound Watershed Society, pers. comm.) (Figure 9).

Coho spawning habitat is very diverse, and can range from large river systems to small headwater streams and / or tributaries (Diewert, 2007). In the Tahsis River, key spawning areas include riffles and pool tail-outs between markers 3 and 4, 5 and 6, and 7 to 9 (Figure

9). While the tributaries to the Tahsis River are not typically assessed during snorkel surveys, spawning likely occurs in the lower reaches of these streams as well.

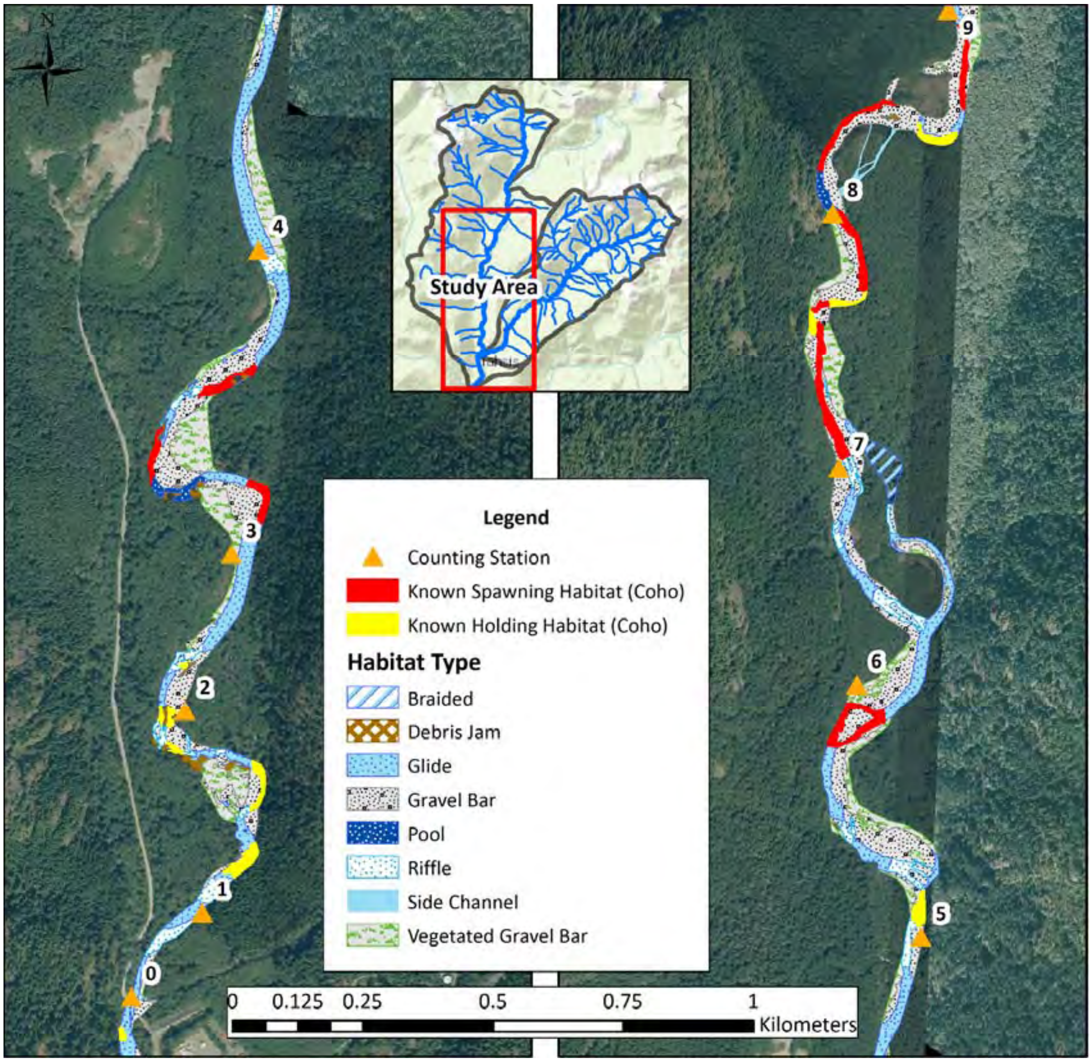


Figure 9. Known adult coho holding and spawning habitat in the Tahsis River.

Fry emergence is partially dependent on water temperature and can vary from year to year (i.e. the lower the water temperature, the longer the incubation period required), although it typically occurs between March and late June. A small percentage of coho fry in the Tahsis River migrate downstream to the estuarine environment soon after emergence, with the majority remaining in fresh water for one to two years before migrating as coho smolts (Western Canada Hydraulic Laboratories Ltd., 1981).

During early development in the river, pools, backwaters, side channels, and small tributaries are sought out as rearing habitat. By late fall / early winter, fry move into deep pools or off-channel habitats which provide shelter from winter storm events. The productivity of many coastal systems for coho largely depends on the availability of over-wintering habitat (i.e. off-channel refuge areas) (Diewert, 2007).

In the Tahsis River, important overwintering and rearing habitat is present in the lower reaches of the lower tributaries, as well as a protected side channel between counting stations 6 and 7. This side channel is known to provide adequate LWD cover for rearing coho fry and has been identified as stable habitat requiring no further remedial works (Tahsis Enhancement Society, pers. comm.). While the lower reaches of the upper tributaries have been identified as critical rearing habitat, utilization of these zones is likely low based on the known distribution densities of coho in this system. A seasonally flooded wetland along the right bank between markers 1 and 4 has also been identified as high value rearing habitat, with coho fry throughout (Wright, 2002) (Figure 10). Note that concerns with fish passage have been identified at the culvert crossings to this wetland (Tahsis Enhancement Society, pers. comm.).

A detailed habitat study at the head of Tahsis Inlet demonstrated the Tahsis River estuary to be the only area where coho fry were present in any numbers (Figure 10). Early fry arrivals were transient; however, later arrivals were resident for up to one month. Although fry numbers were low they exhibited high association with slough and sedge marsh habitat (Western Canada Hydraulic Laboraties Ltd., 1981). Previous studies on estuarine rearing fry in Carnation Creek indicated these coho prefer estuarine habitats consisting of low-velocity pools (between 45 – 225cm deep), undercut banks with overhanging vegetation, and partially submerged LWD (Tschaplinski, 1982)

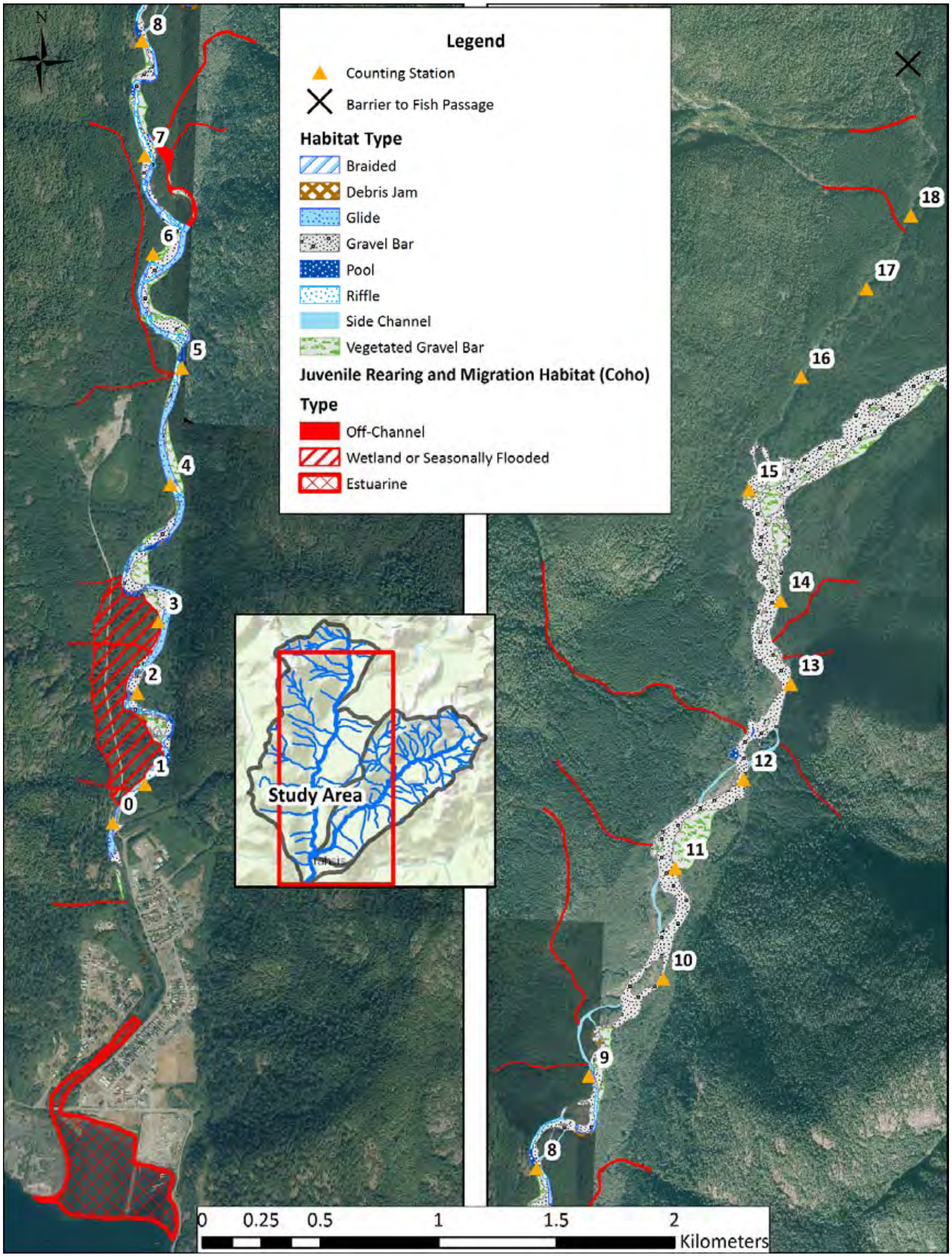


Figure 10. Known and modeled juvenile coho migration and rearing habitat in the Tahsis River.

3.2.2 *Escapement*

Coho populations in the Tahsis River have remained stable for the past 10 years at approximately 1,500 fish (Fisheries and Oceans Canada, 2012). Historical records show maximum escapements to have reached just over 3,500 fish[i]. During the early to mid 1990s, poor ocean survival resulted in a decrease in the abundance of coho on the WCVI, which was reflected in escapements to the Tahsis River within this time frame (Figure 11). Following an improvement in ocean conditions Tahsis River stocks now appear similar to historical escapement numbers.

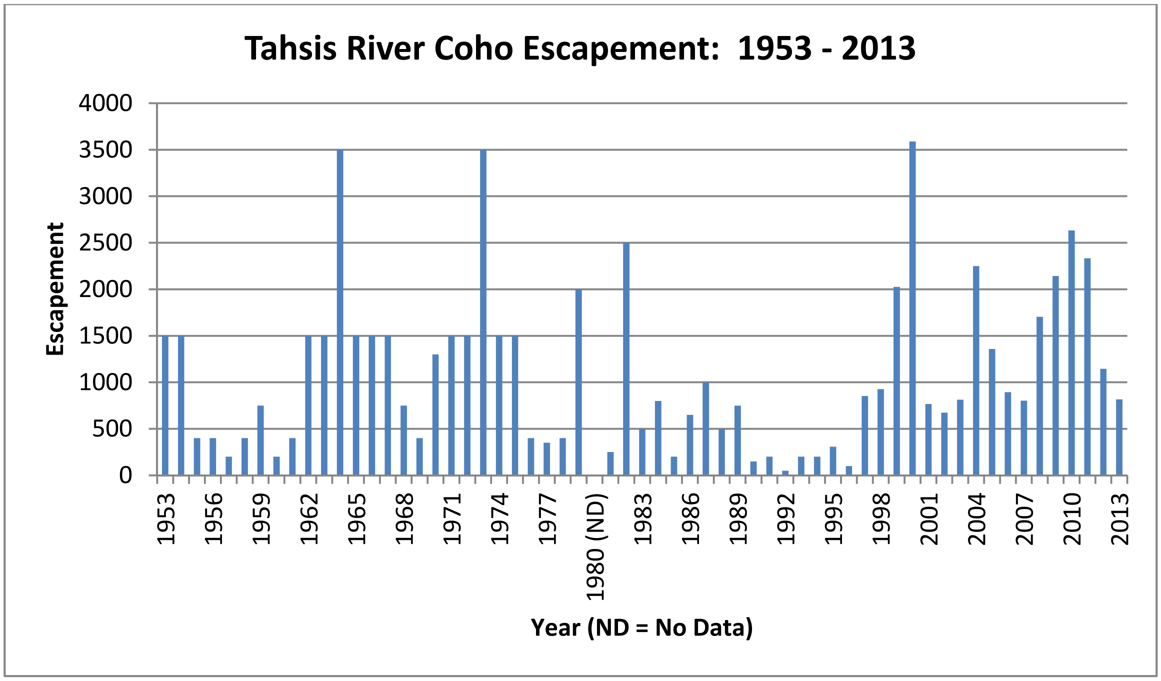


Figure 11. Coho escapement in the Tahsis River between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.3 *Sockeye Salmon*

3.3.1 *Biology, Distribution, and Known Habitats*

Sockeye arrive in the Tahsis River in early August and begin spawning in late October. Peak spawning is observed in early November, and spawning is typically over by early December (Fisheries and Oceans Canada, 2012). Distribution has been observed as high up in the mainstem as counting station 17 (Wright, 2002) (Figure 12).

[i] Note that assessment methods prior to the mid-1990s were often generalized estimates of population numbers in the whole system, as opposed to the sectionalized species count methods that were implemented in the mid-1990s and later. As such, caution should be exercised when comparing counts prior to and following this change in assessment method.

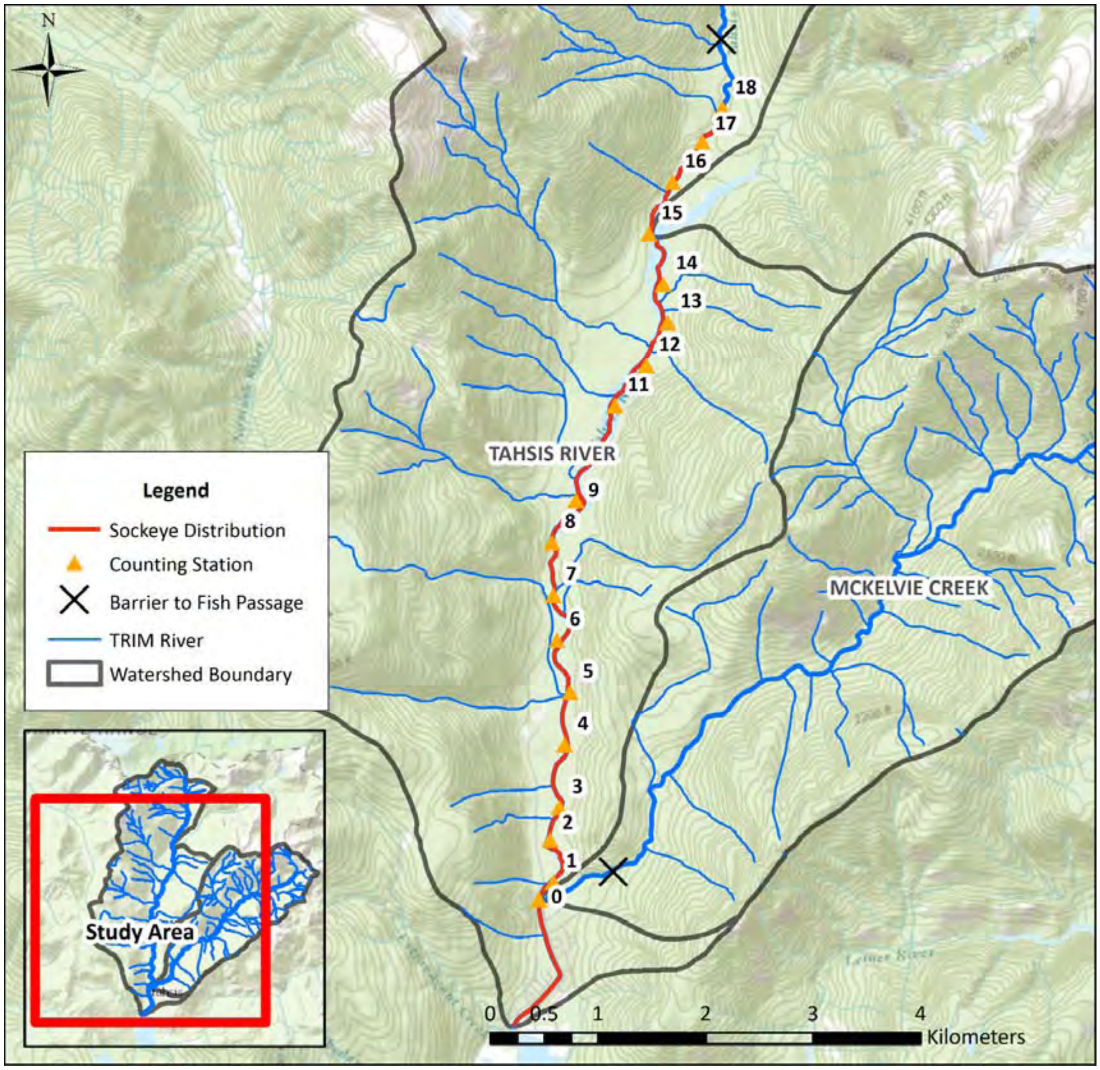


Figure 12. Known sockeye distribution in the Tahsis River watershed.

Early arriving adults move upstream quickly to a large pool located at counting station 10, and remain there until spawning occurs in the pool tail out (Figure 13). During upstream migration of both the early and later returning fish, key holding pools are utilized between counting stations 1 and 2, near counting station 5, and between counting stations 7 and 10. Other documented spawning areas include key riffles between counting stations 3 and 4 and stations 7 and 8 (Figure 13) (Fisheries and Oceans Canada, 2012) (Wright, 2002).

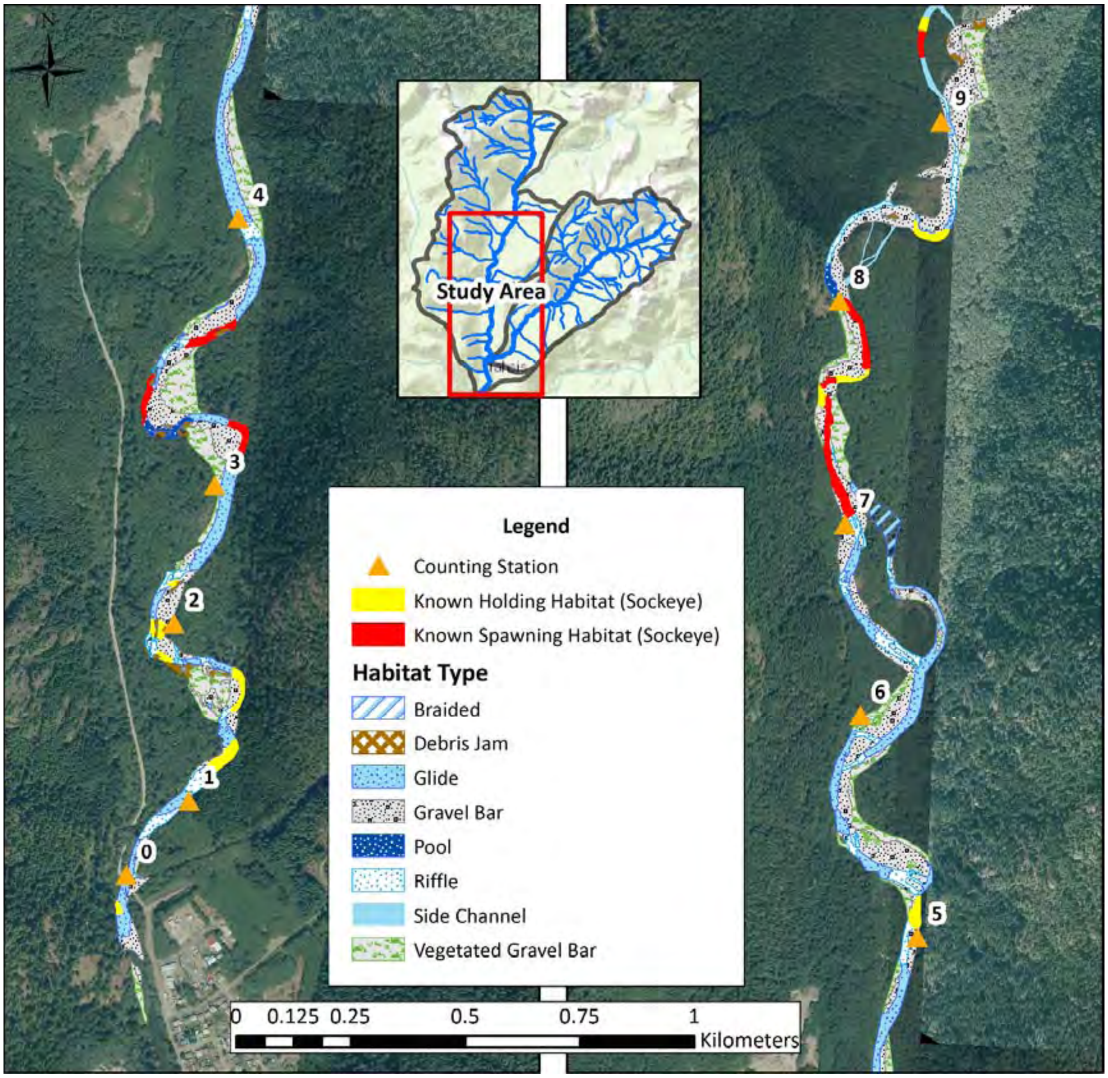


Figure 13. Known adult sockeye holding and spawning habitat in the Tahsis River.

Sockeye in the Tahsis River have a sea-type life history type, meaning that following emergence, they spend only a few months rearing in the river before migrating to the estuary (Aitkin, 1998). Little data exists on freshwater rearing habitats for the Tahsis River; however, literature suggests these fish reside in lower river reaches prior to migration into the estuary. Juveniles typically rear in the estuary for several months (Diewerts, Habitat Requirements for Stream Estuary Rearing Sockeye Salmon, 2007).

A previous study of fisheries resources in the Tahsis River estuary did not sample any sockeye fry or smolts in the estuary (Western Canada Hydraulic Laboraties Ltd., 1981). However, based on the persistence of this run, utilization of the estuary can be assumed. Specific distributions of both the freshwater and estuarine rearing and migration stages of this population have been identified as a data gap.

3.3.2 Escapement

The Tahsis River has a stable population of sockeye, with recent escapements ranging from 200 – 700 fish, and a peak escapement approximately 1,500 fish in 2011 (Figure 14). Prior to 1976 no sockeye have been observed in this river[ii] (Fisheries and Oceans Canada, 2012).

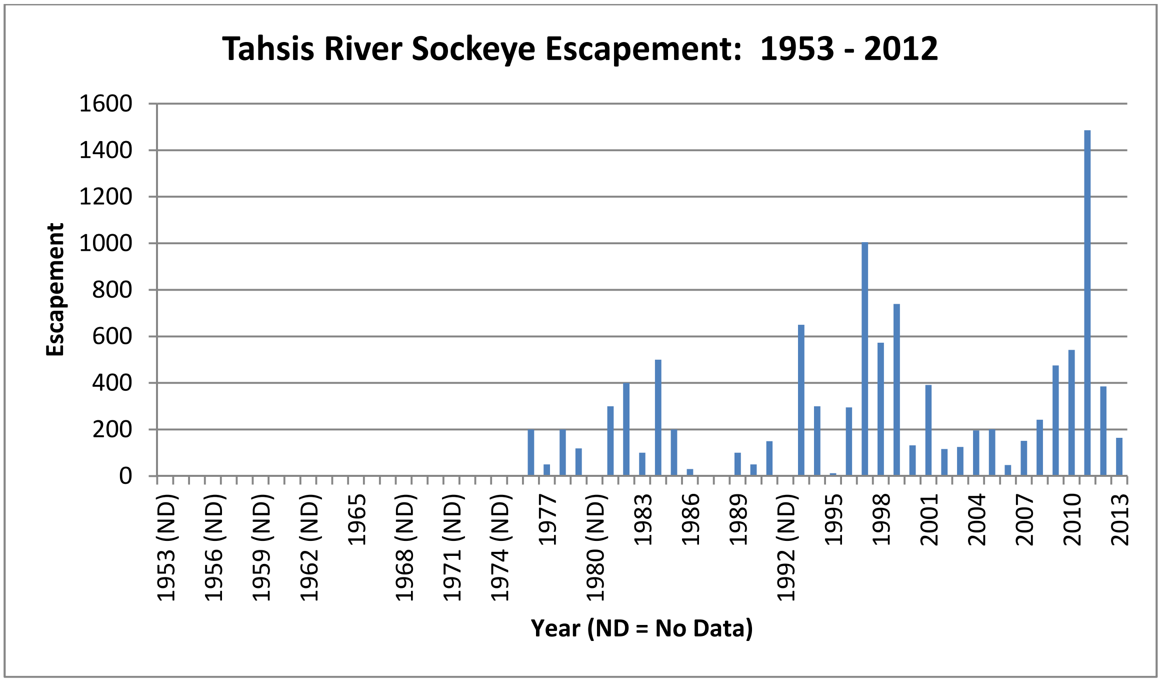


Figure 14. Sockeye escapement in the Tahsis River between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.4 Chum Salmon

3.4.1 Biology, Distribution, and Known Habitats

Chum spawning in the Tahsis River occurs over a relatively short time frame. Fish arrive and begin spawning in late October, and peak spawning is generally observed before the end of October. The run is typically over by mid-November. Chum distribution in the Tahsis River is typically limited to below counting station 9 (Figure 15).

[ii] Note that assessment methods prior to the mid-1990s were often generalized estimates of population numbers in the whole system, as opposed to the sectionalized species count methods that were implemented in the mid-1990s and later. As such, caution should be exercised when comparing counts prior to and following this change in assessment method.

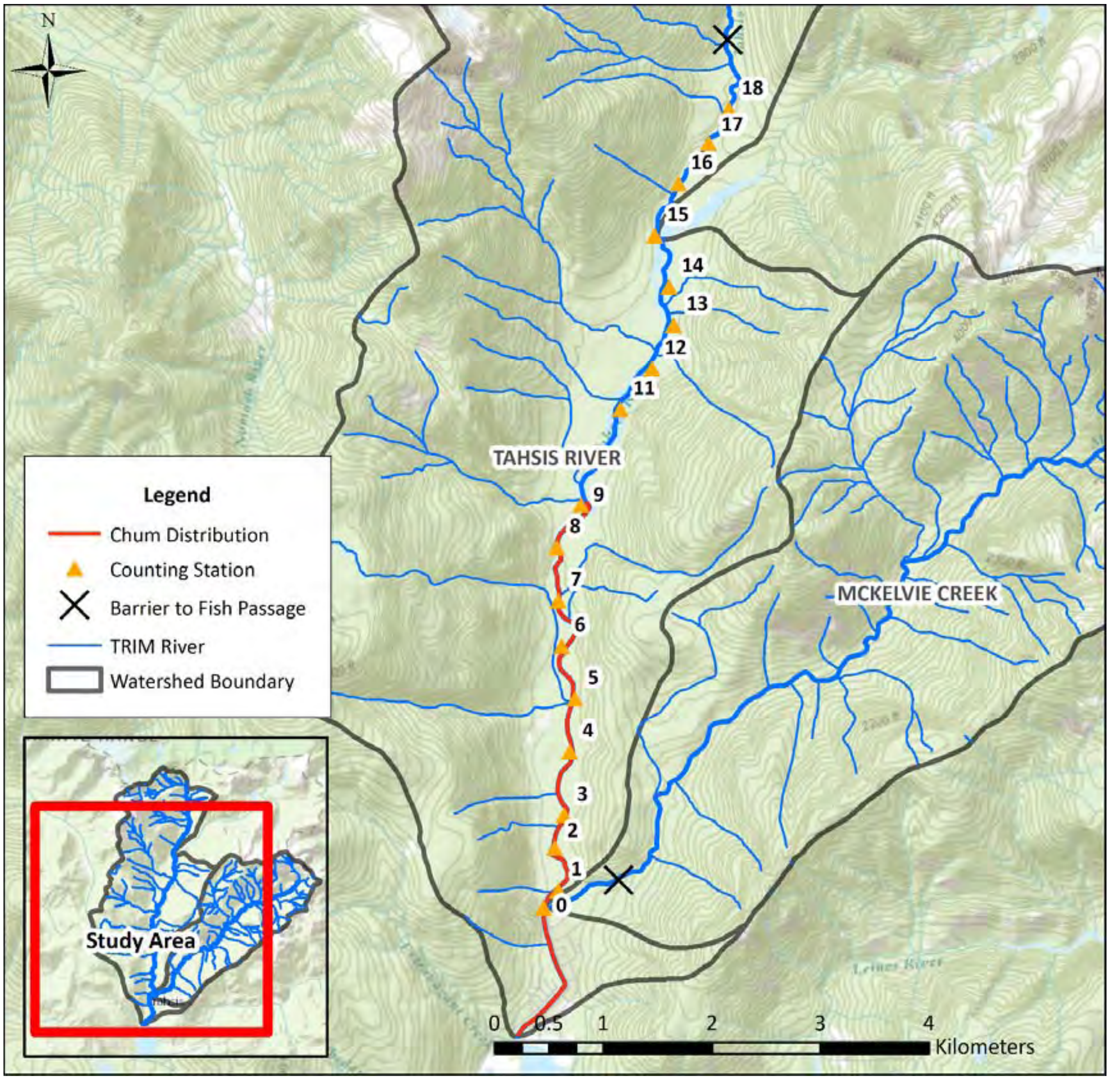


Figure 15. Known chum distribution in the Tahsis River watershed.

During upstream migration to the spawning grounds, chum salmon utilize holding key pools just downstream of counting station 0, between counting stations 1 - 2, 3 - 4, 5 - 6, and 7 – 8. Spawning occurs in key riffles and glides throughout the majority of the lower mainstem, with heaviest concentrations observed between counting stations 4 and 5 (Fisheries and Oceans Canada, 2012) (Wright, 2002) (Figure 16).

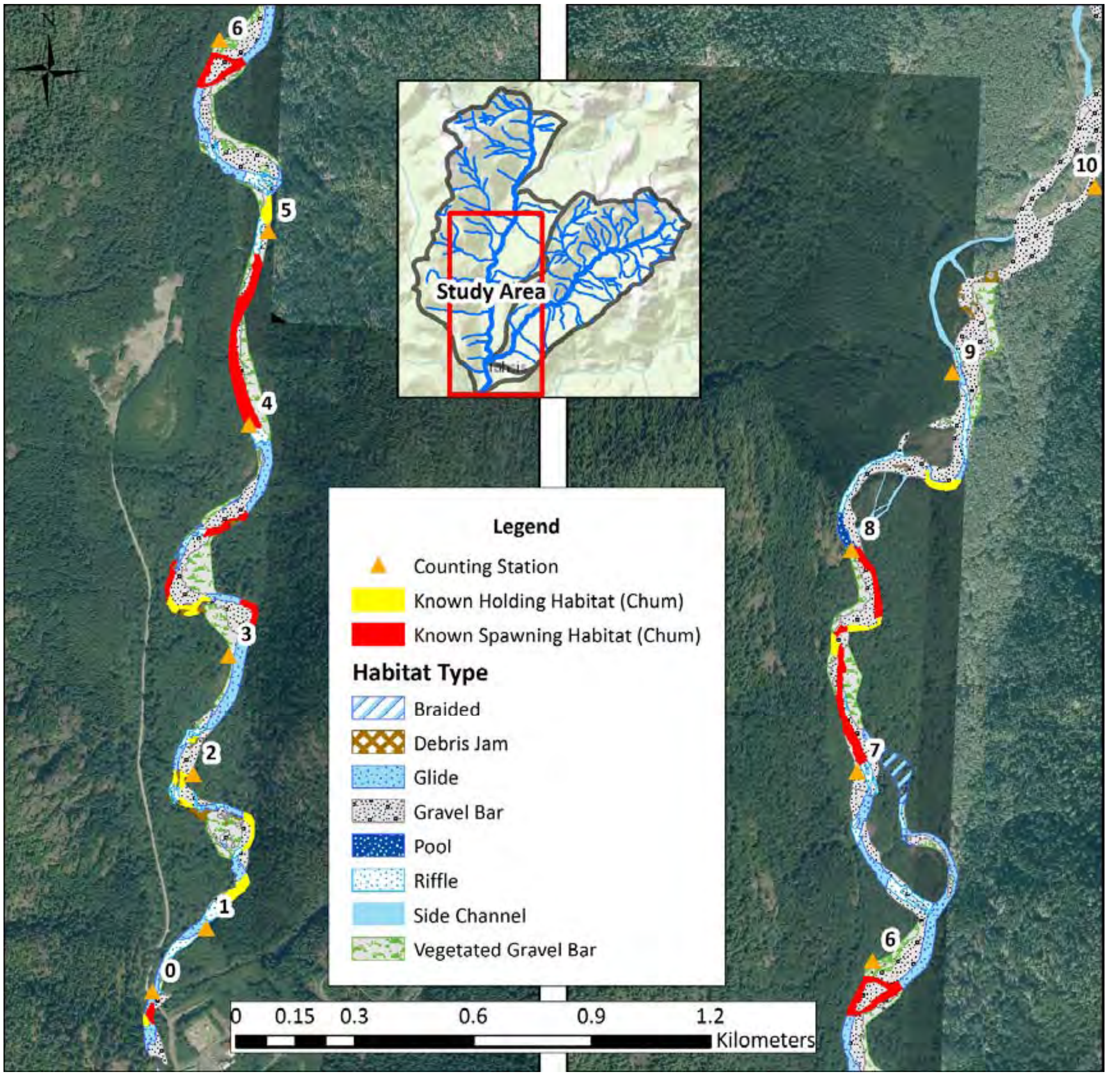


Figure 16. Known adult chum holding and spawning habitat in the Tahsis River.

Like other species in the Tahsis watershed, the length of time required for egg incubation is partially dependant on water temperature. Upon emergence fry immediately begin downstream migration to the estuary, typically between the months of March and May (Diewerts, 2007).

Chum salmon are highly dependent on estuaries for rearing and are known to spend more time in this zone than any of the other species. This period of residence in the estuarine environment appears to be the most critical phase of the life history of chum salmon, and plays a major role in determining the size of the adult return (Diewerts, 2007). Given this important life history requirement, the Tahsis River estuary has been classified as known juvenile migration and rearing habitat (Figure 17).

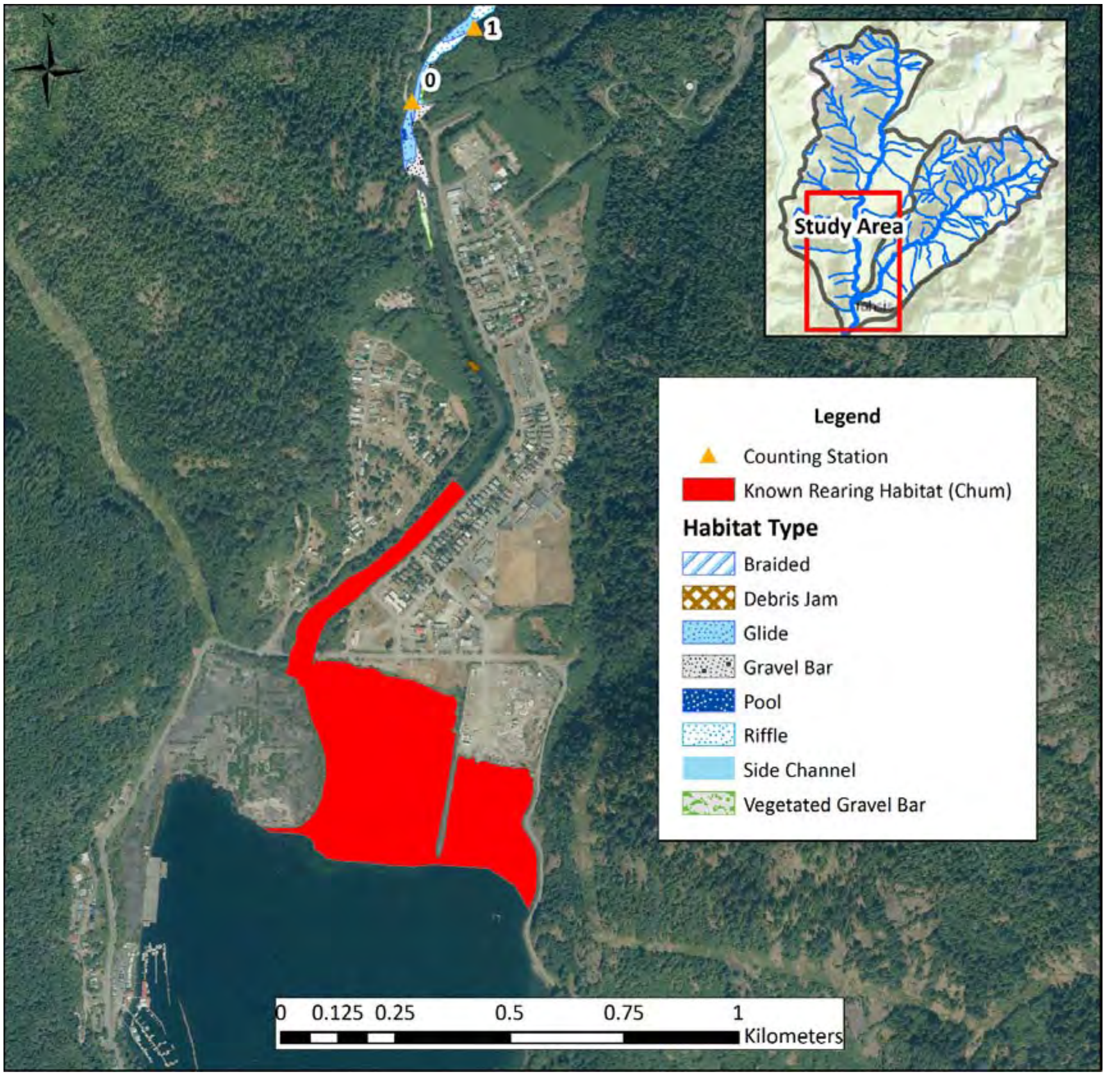


Figure 17. Known juvenile chum rearing habitat in the Tahsis River.

3.4.2 Escapement

Chum salmon have experienced falling returns in the Tahsis River over the past 5 years, a trend that has been observed in chum populations coast-wide (Fisheries and Oceans Canada, 2012)(M. Wright, pers. comm.). Peak escapements during the last decade have been upwards of 8,000 fish, whereas the escapement in 2011 was less than 1,000 fish[iii] (Fisheries and Oceans Canada, 2012) (Figure 18).

[iii] Note that assessment methods prior to the mid-1990s were often generalized estimates of population numbers in the whole system, as opposed to the sectionalized species count methods that were implemented in the mid-

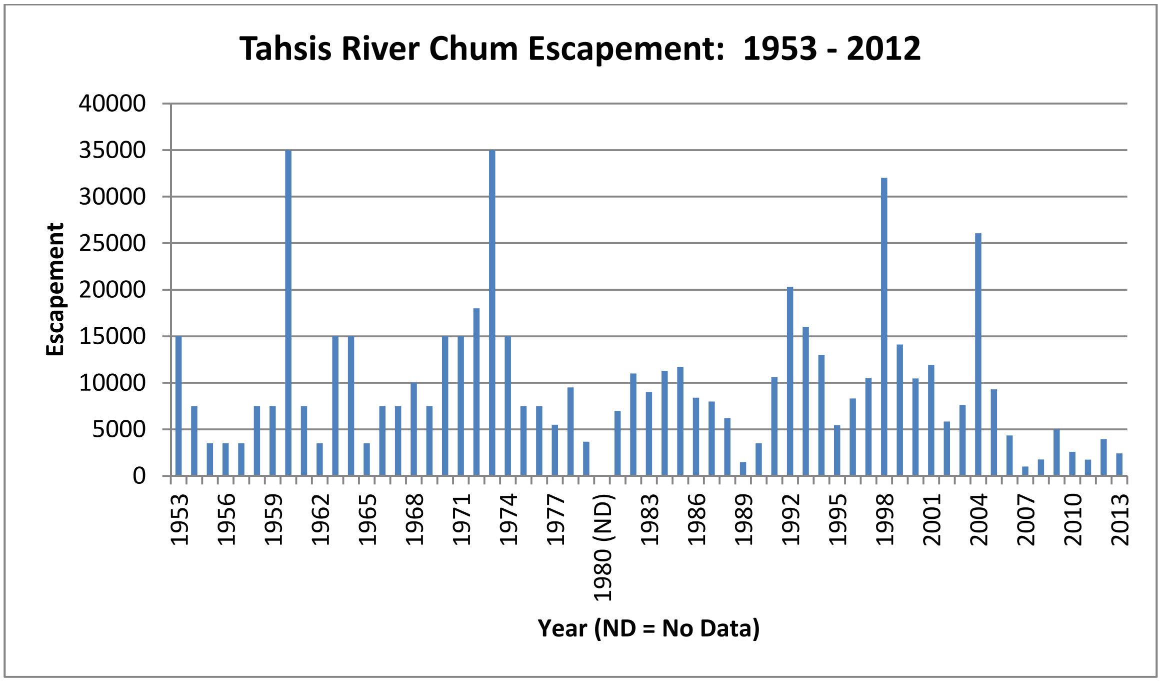


Figure 18. Chum escapement in the Tahsis River between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.5 Pink Salmon

Historical populations of pink salmon have returned to the Tahsis River in early September, with numbers averaging around 3,600 fish. However, returns have been virtually non-existent in recent years. This system is no longer considered to support pink salmon (Fisheries and Oceans Canada, 2012) (Figure 19). As such, this species is not considered in further discussions of habitat indicators and limiting factors.

1990s and later. As such, caution should be exercised when comparing counts prior to and following this change in assessment method.

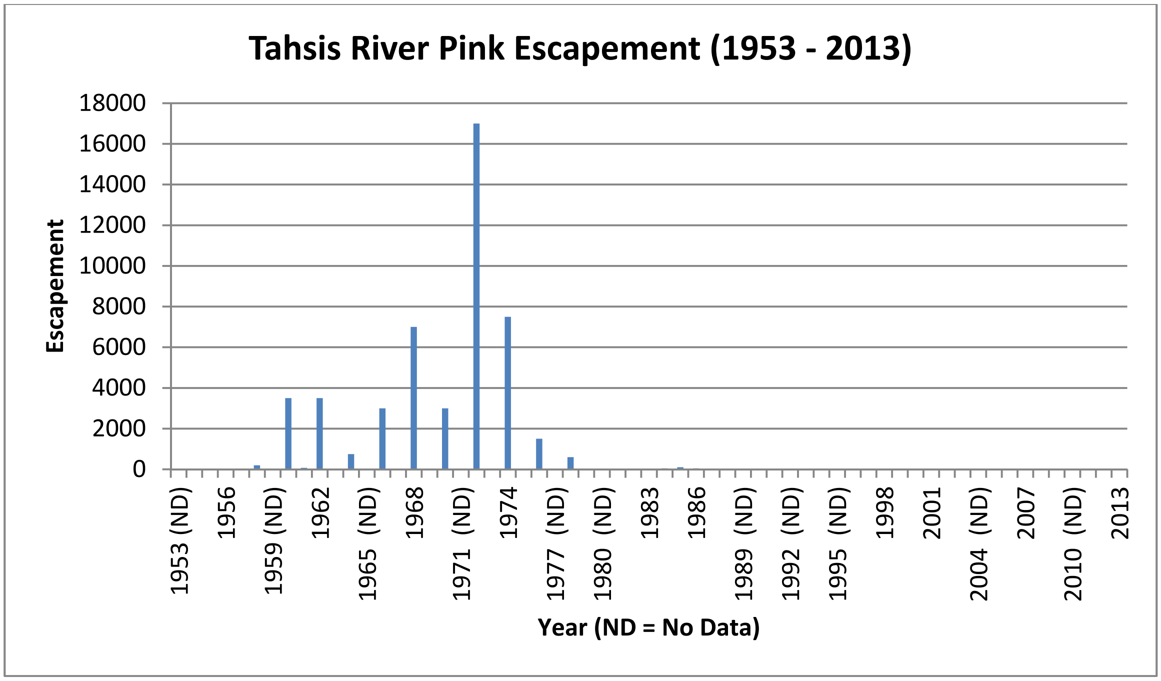


Figure 19. Pink salmon escapement in the Tahsis River between 1953 and 2013 (compiled from DFO's NuSEDs database).

4.0 HABITAT INDICATOR ASSESSMENT RESULTS

The following sections present the results of the assessed habitat status indicators in the Tahsis River watershed.

4.1 Stream Pressure Indicator: Total Land Cover Alterations

Total land cover alterations for the Tahsis River watershed are summarized in Figure 20:

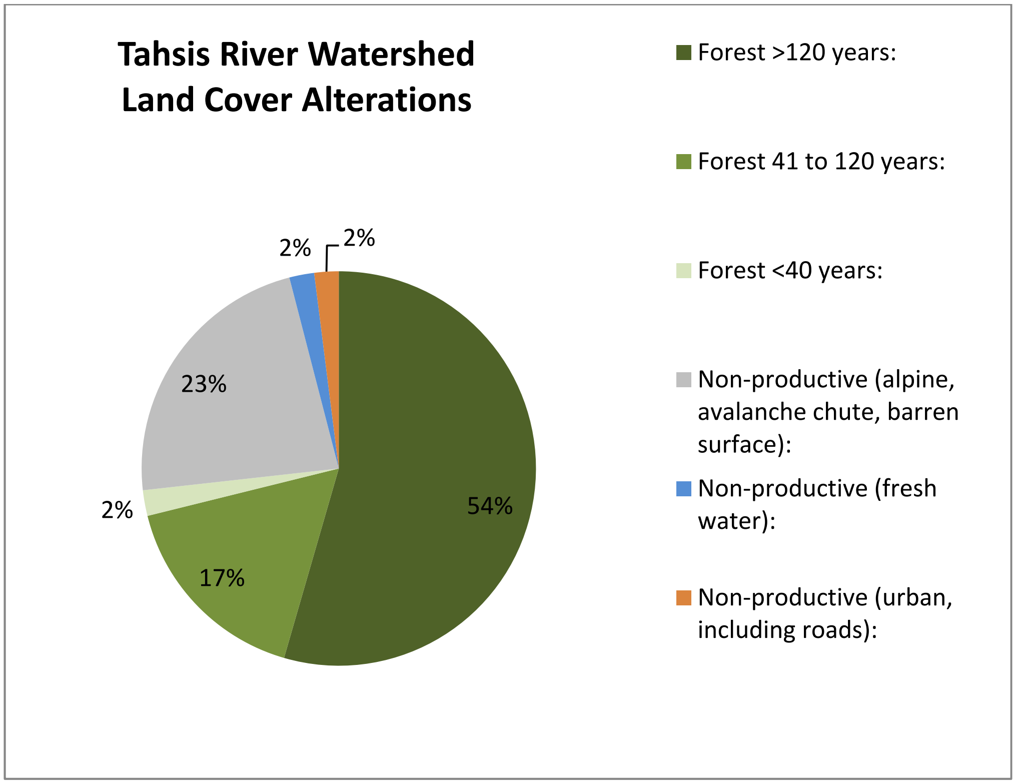


Figure 20. Total land cover alterations for the Tahsis River watershed.

Based on this figure, approximately 79% of the total area of the Tahsis River watershed remains unaltered, with mature forests (i.e. >120 years) comprising the majority of this area, and non-productive alpine, avalanche chutes, and barren surface areas constituting the remainder. Approximately 2% of the watershed has been altered as roads and urban zones as part of the Village of Tahsis, and approximately 19% of the watershed remains as altered forests (i.e. <120 years old). Note that this analysis does not include data for the McKelvie Creek watershed, as land cover data was not available for this area at the time of analysis. An additional data gap in this analysis included possible remaining alterations from the historical road network up the Tahsis River. While these areas appeared to have completely re-vegetated, the presence of old road prisms could represent potential impacts (i.e. sedimentation issues) in the watershed.

An analysis of the distribution of altered land cover areas demonstrated that while a large component of the watershed remains unaltered, altered areas are situated in areas adjacent to and / or within known salmonid habitats (i.e. riparian zone of the mainstem and the Tahsis River estuary) (Figure 21). Considering the proximity of these alterations to known salmonid habitats, the Tahsis watershed has been classified as high risk for total land cover alterations. It should be noted that the persistence of these altered zones given no harvesting has occurred in the watershed for decades indicates channel instabilities, combined with a deciduous-dominated riparian zone, are contributing to long term instabilities (and the subsequent re-establishment of old growth vegetation). Note that the re-establishment of old growth vegetation may also be attributable to dense salmonberry stands in the riparian zone suppressing seral communities (R. Dunlop, pers. comm.).

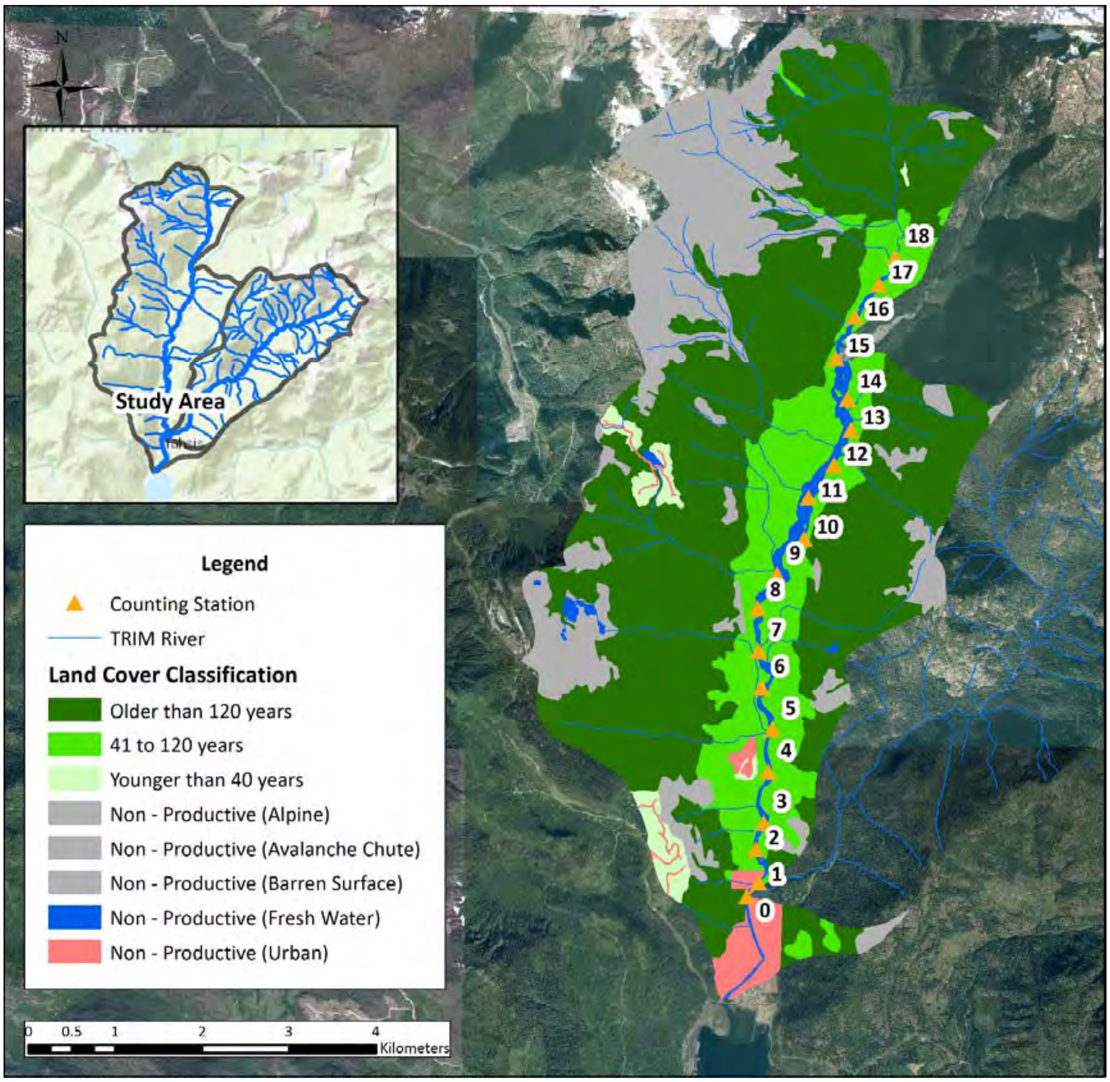


Figure 21. Total land cover alterations in the Tahsis River watershed.

4.2 Stream Pressure Indicator: Watershed Road Development

Watershed road development for the Tahsis River watershed (including McKelvie Creek) was calculated at 0.279km/km^2, which was well below the suggested benchmark of 0.4km/km^2 (Stalberg et al, 2009) (Figure 22). It should be noted that spatial data for historical roads constructed during the initial logging in the Tahsis River (i.e. prior to the 1970s) was not available and have therefore been identified as a data gap. Given the low density of roads within this watershed, the risk rating for watershed road development was determined to be low, despite the absence of this historical information.

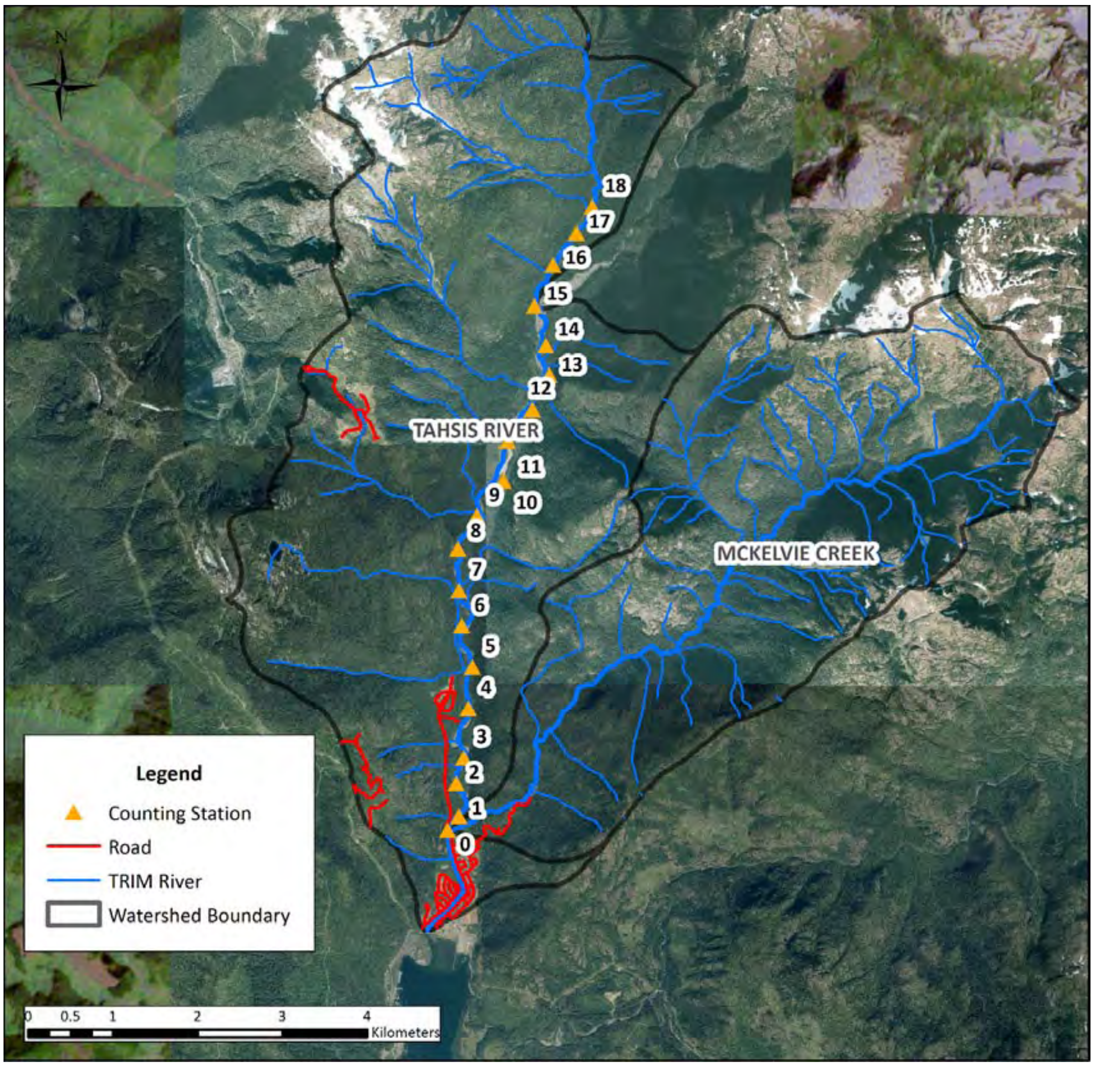


Figure 22. Tahsis River watershed road density.

4.3 Stream Pressure Indicator: Water Extraction

The Tahsis River watershed presently has two current water licences and one active water licence application within the McKelvie Creek drainage (Figure 23). Two of these licences are non-consumptive and are designated for waterpower, with a combined demand of $9m^3/s$ of water. The third licence is for consumptive purposes (i.e. drinking water source) for the village of Tahsis, with an authorized volume of $165{,}932m^3$ / year. While the presence of a consumptive licence indicates a moderate watershed risk according to the recommended metrics presented in Stalberg et al (2009), considering the downstream area of the Tahsis mainstem affected by this extraction is limited (Figure 23), this risk rating has been downgraded to low. The majority of critical spawning, rearing, and migration habitats upstream in the Tahsis River remain unaffected by this extraction.

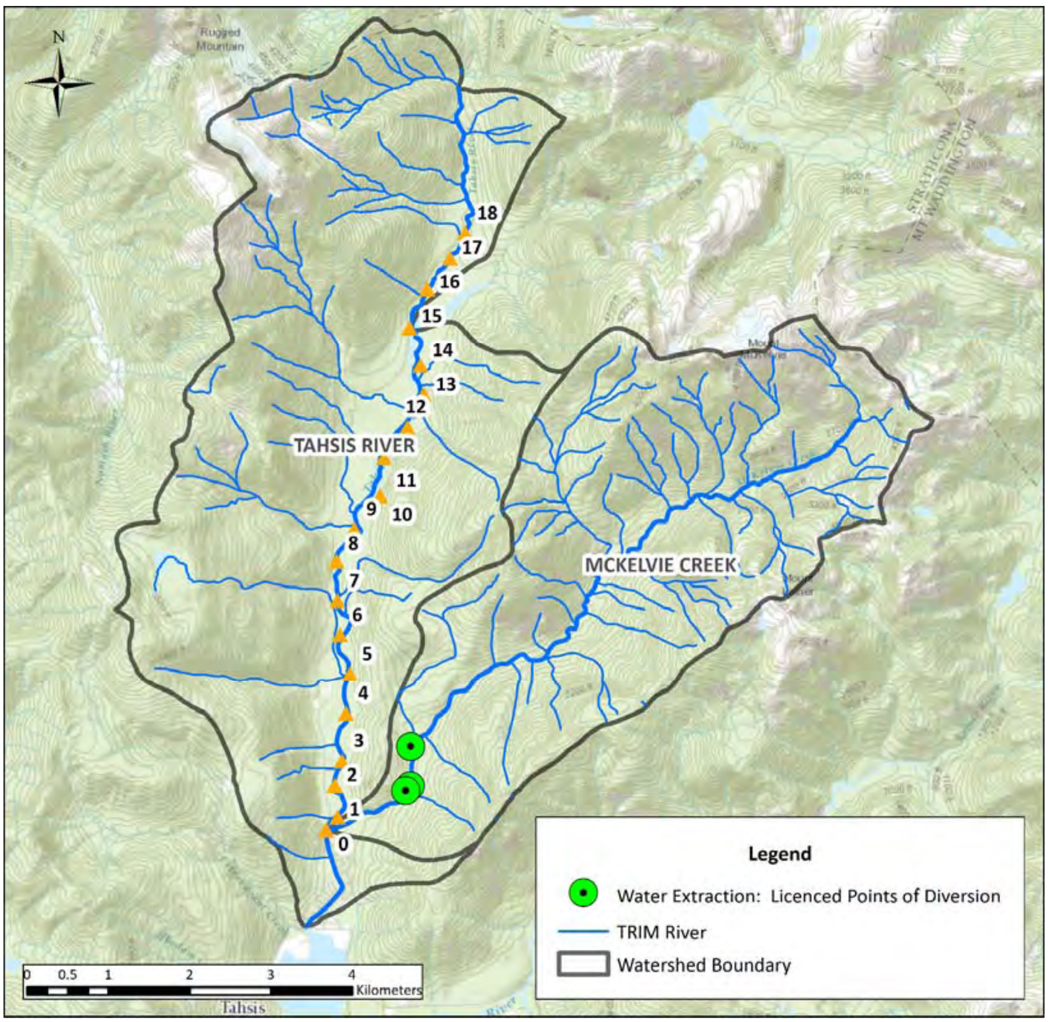


Figure 23. Licenced water points of diversion for the Tahsis River watershed.

4.4 Stream Pressure Indicator: Riparian Disturbance

The calculated riparian disturbance in the Tahsis River was significant with the mainstem of the Tahsis River dominated by a primarily deciduous and / or regenerating stand. Exceptions to this composition included the headwaters, which were predominantly mature forest, and the tidally influenced portion of the river (i.e. below counting station 0), which was comprised of a significant component of non-productive urban areas. The most significant riparian disturbances were observed in the upper half of the anadromous section of the river (i.e. between counting stations 8 and 18) (Figure 24). It should be noted that the persistence of these deciduous zones given no harvesting has occurred in the watershed for decades indicates channel instabilities are preventing the reestablishment of old growth vegetation.

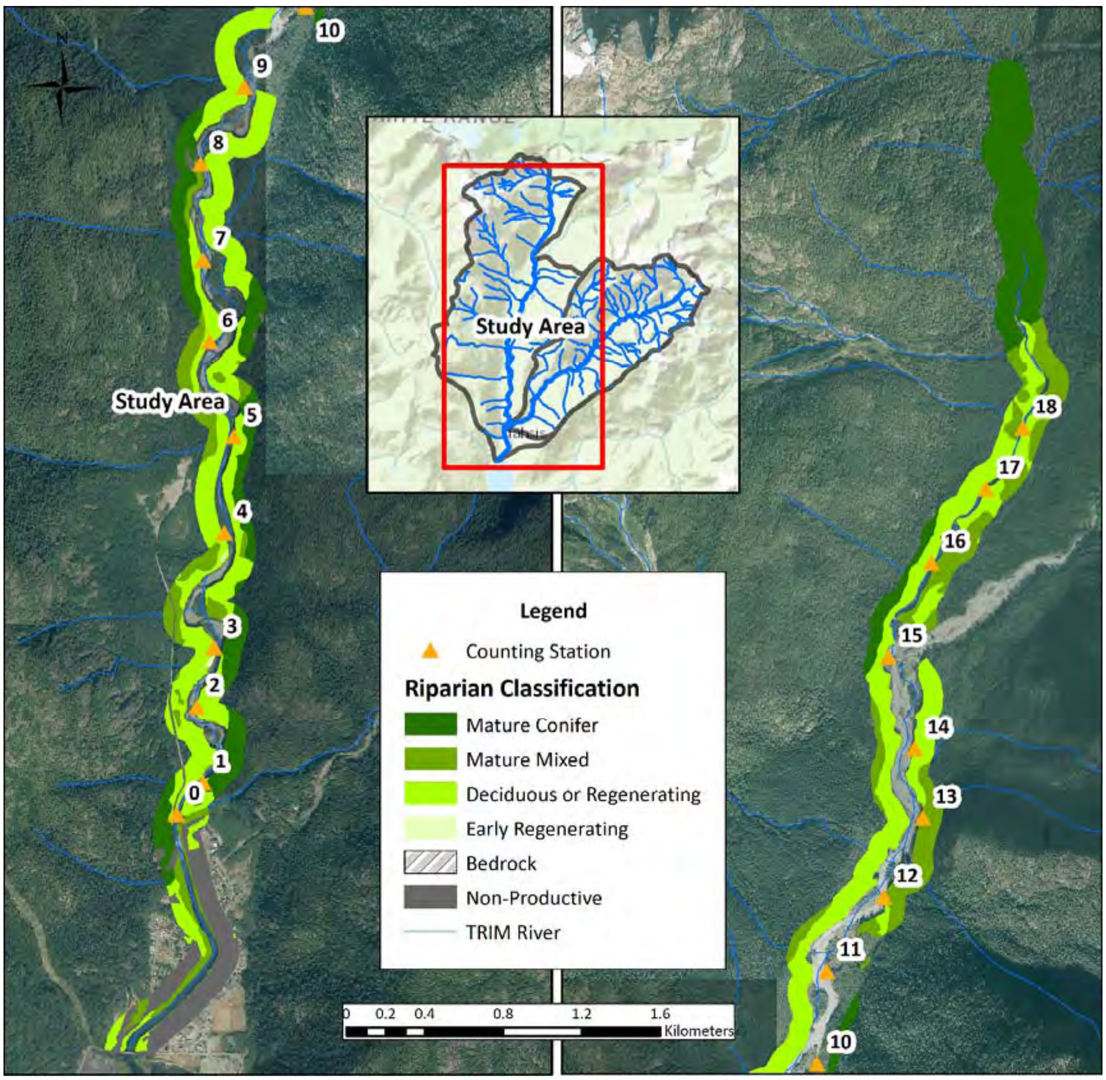


Figure 24. Riparian disturbance in the Tahsis River watershed.

The Tahsis River floodplain has experienced significant channel instability and loss of LWD as a result of degraded riparian forests. Throughout the anadromous zone, spawning and rearing habitats continue to be affected by a compromised riparian stand consisting of approximately 49% deciduous and / or regenerating forest and 8% non-productive areas (Figure 25). Habitat bordering the existing riparian zone will continue to be unstable until the riparian forest becomes a predominantly mature coniferous forest, which will require silviculture treatments. It will take decades to achieve a mature coniferous dominated riparian forest that will provide critical functions to the aquatic environment, including: temperature regulation, sufficient root structure to hold soils together, which will control sediment input and provide a source of LWD to increase channel structure and stability. Given that less than half of the riparian stand remained mature forest, the risk rating for riparian disturbance in the Tahsis River watershed was classified as high.

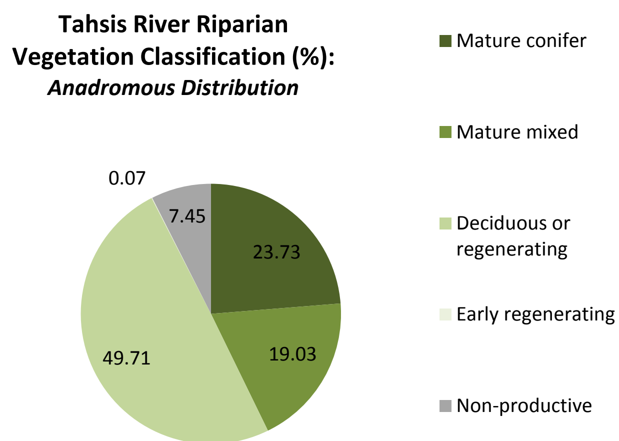


Figure 25. Riparian vegetation composition for the anadromous reaches of the Tahsis River watershed.

An analysis of riparian condition for tributaries to the Tahsis River was not possible based on uncertainty on the location of these streams. As such, this has been identified as a data gap for coho, considering this species is the heaviest utilizer of these types of habitats.

4.5 Stream Pressure Indicator: Permitted Waste Management Discharges

Within the boundaries of the Tahsis River watershed, only one active waste management discharge permit exists (Figure 26). This permit is for the discharge of refuse at the Village of Tahsis landfill and has been active since 1988. Originally, there were no restrictions on the types of materials that were permitted for disposal, and concerns over leachates into the adjacent

Tahsis River prompted upgrades and dumping restrictions in the mid-1990s (J. Fiddick, pers. comm.). Hazardous items such as paint cans, oil, and batteries are no longer accepted at the dump (Village of Tahsis, 2011). Presently, there are an estimated 300 tonnes of material disposed annually at this facility (AECOM, 2012).

In 1996, a study detailing the closure plans for the Campbell River, Gold River, Tahsis, and Zeballos landfills presented information on groundwater quality collected between November 1993 and August 1995. Results showed that relative to background levels leachate indicator parameters (specific conductance and chloride) showed that groundwater beneath the landfill had been impacted by leachate. However, with the exception of coliform bacteria where data was insufficient, water quality downstream of the landfill was within the B.C. Environment Water Quality Criteria for drinking water (UMA Engineering Ltd. and Gartner Lee Limited, 1996).

While water quality is monitored at this site by the Comox Valley Regional District (CVRD), this data was not available for review within the time frame of this review. Given the lack of a.) recent water quality information at this site and b.) suggested metrics or benchmarks for evaluating the risk of permitted waste discharges in a watershed (Stalberg et al, 2009), this habitat indicator has been identified as a data gap.

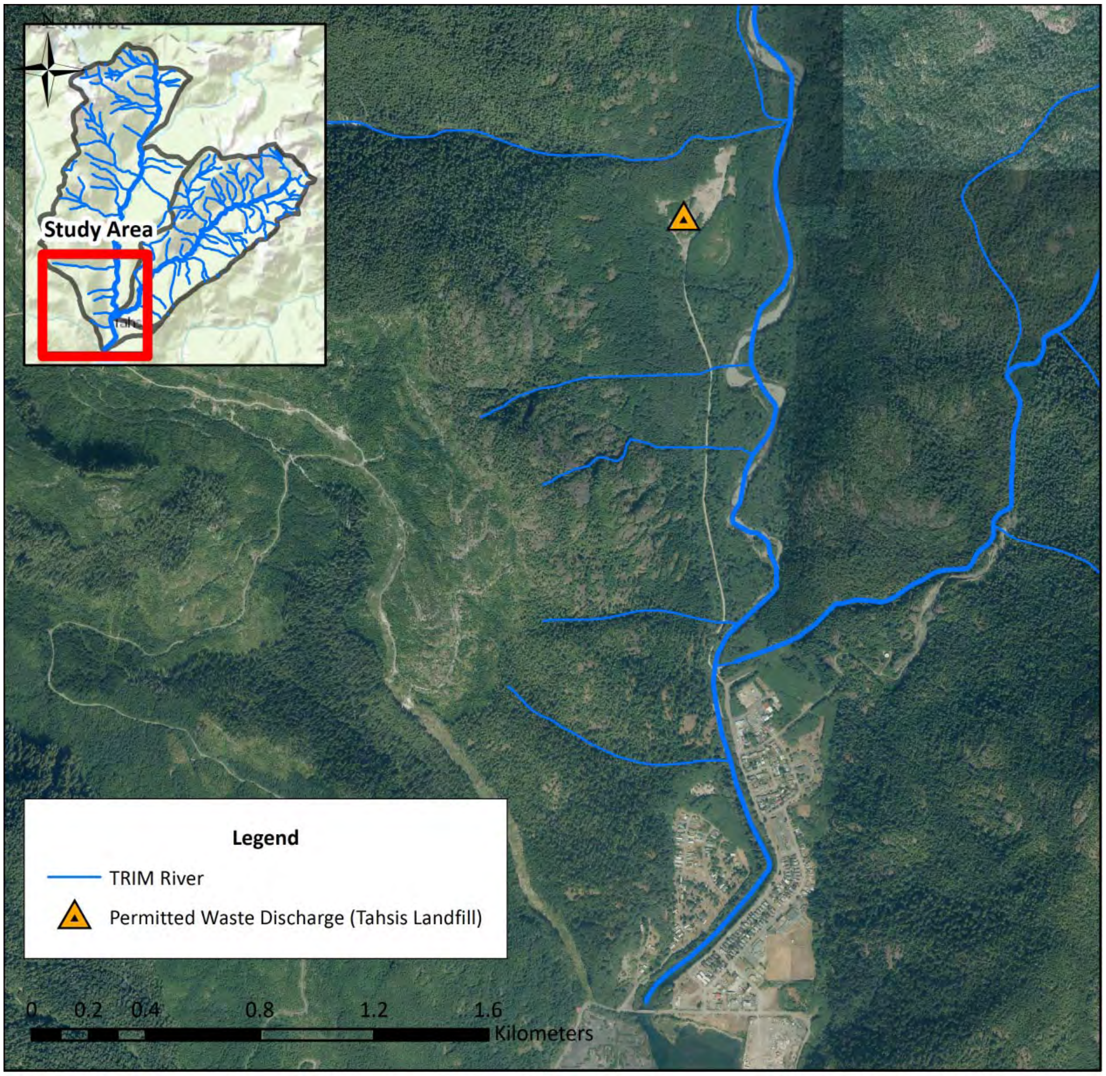


Figure 26. Permitted waste discharge location in the Tahsis River watershed (Tahsis landfill).

4.6 Stream State Indicator: Water Quality

The Village of Tahsis' drinking water is supplied through extraction from McKelvie Creek. The Vancouver Island Health Authority (VIHA) is responsible for monitoring this water supply regularly for the presence of E. coli and coliform bacteria. Recent water quality monitoring results were reviewed from January 2009 to January 2015, and of 257 sampling events, only 7 E. coli bacteria were counted in one water sample in August of 2010. The remainder of the tested samples showed no bacteria present (Vancouver Island Health Authority, 2015).

Data collected in 2007 at the four Tahsis River and four McKelvie Creek regional geochemical stream survey monitoring sites (Figure 27) showed that of the parameters detected in the samples (fluoride, uranium, and sulphate), all remained below the Canadian Water Quality Guidelines for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment, 2014). Reported pH values at these sites were between 6.4 and 7.4 (BC Ministry of Energy and Mines, 2015).

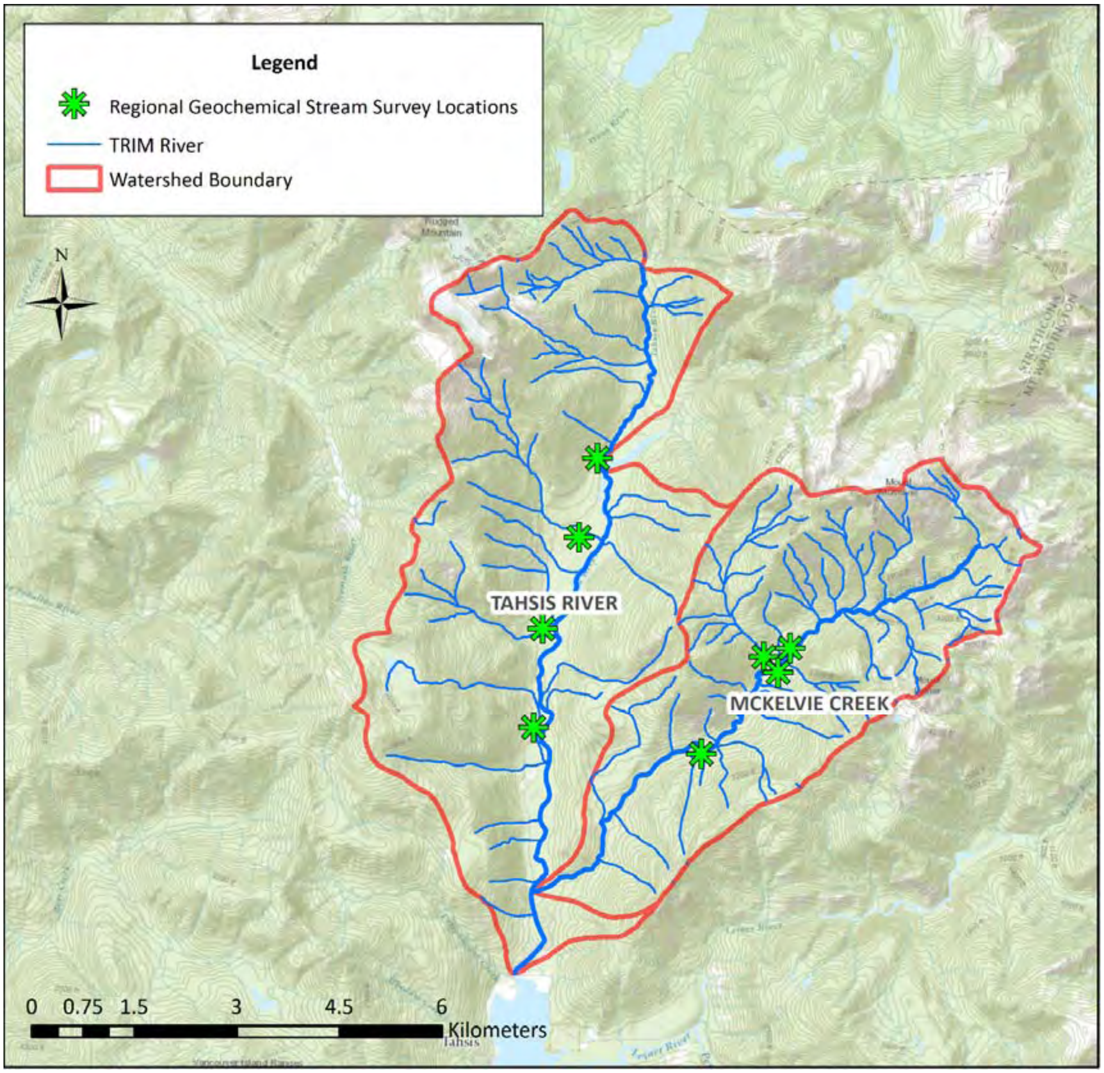


Figure 27. Regional geochemical stream survey locations in the Tahsis River watershed.

Groundwater monitoring conducted as part of the 1996 closure plan for the Tahsis landfill indicated that groundwater in the vicinity of the landfill was impacted by leachate but remained within drinking water quality guidelines. In general, groundwater was described as dilute in nature (UMA Engineering Ltd. and Gartner Lee Limited, 1996).

Note that the available water quality data for the Tahsis River watershed was both spatially and temporally limited. Much focus has been attributed towards the McKelvie Creek watershed based on its importance to the village's water supply; however, this drainage contributes considerably less in terms of fisheries values. Water quality sampling on the Tahsis River was only available for two sampling events: one in 1996 near the landfill, and one in 2007 at four of the regional geochemical stream survey locations.

No water quality data with respect to DO was available for either the Tahsis River or McKelvie Creek drainages. While the data available indicated that (of the sampled parameters) no issues were identified, the spatial and temporal distribution of this data was not robust enough to determine its influence on fish production in the watershed. As such, the water quality habitat indicator has been identified as a data gap.

4.7 Stream State Indicator: Water Temperature (Migration and Spawning)

Compilation of SIL data during the spawning period on the Tahsis River demonstrated water temperatures to have remained below the UOTR (between 15°C and 20°C) for all species between 2006 and 2013 (Appendix 2). As such, this habitat indicator was ranked as low risk.

Note that this indicator was identified as a partial data gap given the limited temporal distribution of these point samples.

Table 3. Water temperature data from 2006 to 2013 for the Tahsis River during adult migration and spawning.

TAHSIS RIVER						
Year	***Sample Date***	***Temperature (°C)***	***Species Present***			
			SK	***CO***	***CH***	***CM***
2006	Sept. 21	10	X	X	X	X
	Sept. 30	10	X	X	X	X
	Oct. 8	8	X	X	X	X
	Oct. 12	8	X	X	X	X
	Oct. 18	8		X	X	X
	Oct. 25	8	X	X	X	X
	Oct. 31	8	X	X	X	X
	Nov. 23	5	X	X		X
	Nov. 25	4	X	X		X
	Dec. 5	3	X	X		X
	Dec. 23	5		X		X
2007	Sept. 27	9	X	X	X	X
	Oct. 13	8	X	X	X	X
	Oct. 24	7	X	X	X	X
	Nov. 25	3	X	X		X
2008	Sept. 6	9	X	X	X	
	Sept. 24	9	X	X	X	
2009	Nov. 13	4.2	X	X		X
2010	Sept. 17	10	X	X	X	X
	Sept. 30	10	X	X	X	X
	Oct. 17	9	X	X	X	X
	Oct. 29	9	X	X	X	X
	Nov. 13	8	X	X		X
2011	Sept. 10	12	X	X	X	
	Sept. 19	9	X	X	X	
	Sept. 30	10	X	X	X	X
	Oct. 8	10	X	X	X	X
	Oct. 15	10	X	X	X	X
	Oct. 26	9	X	X		X
	Nov. 1	6	X	X	X	X
	Nov. 14	7	X	X		X
	Dec. 3	7	X	X	X	X
2012	Sept. 6	10	X	X		
	Sept. 15	10	X	X	X	
	Sept. 25	10	X	X	X	X
	Oct. 5	10	X	X	X	X
	Oct. 23	8	X	X	X	X
	Nov. 9	8	X	X		X
2013	Sept. 5	9	X	X	X	X
	Sept. 18	11	X	X		X
	Sept. 26	11	X	X	X	X
	Oct. 10	9	X	X	X	X
	Oct. 25	8	X	X	X	X
	Nov. 9	9	X	X		X

4.8 Stream State Indicator: Discharge

Discharge data for the Tahsis River was limited. At present, there is no WSC flow gauge or DFO hydromet station on the river. However, a 1992 flood water mapping study estimated the 20-year daily return of discharge at 363m^3/s and an instantaneous peak discharge of 639m^3/s (Fisheries and Oceans Canada, 2012). A water allocation plan for the Gold, Tahsis, and Zeballos rivers published in 1997 calculated the mean monthly and mean annual discharge for the Tahsis River as follows (Jackson & Cook, 1997):

Table 4. Mean monthly and mean annual discharge of the Tahsis River.

Tahsis River Mean Monthly and Mean Annual Discharge (m^3/s)													
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**MAD**	**20% MAD**
13.99	12.76	9.82	7.89	3.71	2.63	1.31	1.55	2.47	10.13	15.54	15.31	8.35	1.67

Environment Canada maintains an active WSC station on McKelvie Creek. Based on daily data available through Environment Canada's real-time hydrometric data website (Environment Canada, 2015), the following mean monthly and mean annual discharges were calculated for McKelvie Creek[i]:

Table 5. Mean monthly and mean annual discharge of McKelvie Creek.

McKelvie Creek Mean Monthly and Mean Annual Discharge (m^3/s)													
Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**MAD**	**20% MAD**
4.47	2.31	2.82	2.67	3.02	2.70	1.90	1.61	1.52	3.88	5.39	3.95	3.02	0.60

An assessment of discharge in the Tahsis River against the suggested benchmark of 1 in 2 year 3-day duration minimum flow of less than 20% MAD was not possible based on the absence of continuous discharge data. As such, this indicator has been identified as a data gap.

For McKelvie Creek, an analysis of data between 1998 and 2010 identified only one summer low-flow period exceeding the 30-day duration below 20% MAD. This period occurred in August and early September of 2002, and lasted for 32 days. Given only one instance exceeding this benchmark was observed over a 12 year period, the discharge indicator for McKelvie Creek was identified as low risk.

[i] Note that only data up until 2010 was used for analysis as data provided after 2010 was classified as unapproved by Environment Canada.

While an evaluation of McKelvie Creek against the discharge benchmark described in Stalberg et al (2009) was possible, fisheries values in this system are low compared with the Tahsis River. Watershed characteristics between Tahsis River and McKelvie Creek also vary considerably. As such, the discharge indicator does not necessarily relate between the two systems, and caution should be exercised when extrapolating assumptions for the Tahsis River based on discharge data from McKelive.

Note that the benchmark identified in Stalberg et al (2009) for discharge only addresses adult migration and spawning. As high discharges throughout the incubation period can scour out redds and subsequently decrease egg to fry survival, this indicator should be evaluated throughout the entire year, with some future effort dedicated towards developing a benchmark from which to evaluate this metric for incubation.

4.9 Stream State Indicator: Accessible Stream Length

Information on accessible stream length for the Tahsis River watershed was compiled from the Tahsis River stream narrative (Fisheries and Oceans Canada, 2012), the 1:20,000 fish and fish habitat inventory of the Tahsis River watershed (Wright, 2002), FISS, and interviews with the local Tahsis Enhancement Society. Based on the GIS distribution data presented in Figure 4, Figure 8, Figure 12, and Figure 15, the following table summarizes accessible stream length by species:

Table 6. Accessible stream length, by species, for the Tahsis River watershed.

	Chinook	Coho	Sockeye	Chum
Mainstem	10.07km	10.8	10.06km	5.76km
Tributary	0.76km[ii]	10.19km[iii]	0km	0km
Total	10.83km	20.99km	10.06km	5.76km

Note that for all species (except for chum) distribution is identified above the severely aggraded section of the river, between reaches 9 and 12 (Figure 3). Considering this section is known to limit fish distribution during periods of low water (Wright, 2002) it should be noted that accessible stream length for these species is significantly reduced during summer low flows.

Continual monitoring will be required to determine if accessible stream length is a limiting factor to fish production (i.e. if this length is reduced over time, it may be identified as limiting).

[ii] McKelvie Creek
[iii] McKelvie Creek and Tahsis River tributaries

4.10 Stream State Indicator: Key Spawning Areas (Length)

Key spawning area lengths, by species, were calculated based on the locations presented in Figure 5, Figure 9, Figure 13, and Figure 16. For detailed descriptions of spawning locations for each species, please refer to Section 3.0.

Table 7. Key spawning area lengths, by species, for the Tahsis River.

Chinook	Coho	Sockeye	Chum
1.56km	3.30km	2.06km	3.61km

As observed in Table 7, chinook have been identified to have the smallest spawning grounds (by length) on the river, and chum the largest. It should be noted that the spatial extent of each species' spawning grounds was not well defined (particularly in the upper reaches of accessible stream length). Accurate assessment of the upstream and downstream extents of each of these zones would improve our assessment of this habitat indicator, and would also provide a baseline from which future assessments could determine if this indicator is improving or deteriorating over time.

4.11 Stream State Indicator: Stream Crossing Density

The following table summarizes the available stream crossing data for the Tahsis River watershed (including McKelvie Creek):

Table 8. Stream crossing density (and fish-bearing status) in the Tahsis River watershed, as modelled in the PSCIS database.

Stream crossing Density: TAHSIS RIVER and McKELVIE CREEK	
# of Crossings:	5
# of Fish-Bearing:	3
# of Non-Fish Bearing:	2
Crossing Density:	0.09/km2

While the results based on the PSCIS database indicate a relatively low stream crossing density (i.e. only 5 crossings throughout the Tahsis River and McKelvie Creek watersheds), anecdotal evidence suggests this number is a large underestimation of the historical stream crossings in this system. Interviews with the Tahsis Enhancement Society indicated there were up to 10 bridge crossings over the mainstem alone of the Tahsis River (Tahsis Enhancement Society, 2014). While the bridges have since been removed, it is likely that stream crossing structures with the potential to affect fish habitat still exist along the historical road network. Considering these crossings were installed prior to implementation of the Forest Practices Code (FPC) deactivation of these structures likely did not occur. As such, this indicator has been identified as a partial data gap.

4.12 Stream State Indicator: Habitat Composition

An analysis of habitat in the Tahsis River watershed indicated this system to be dominated by gravel bars and contain very little pool habitat. Habitat between counting stations 0 and 5 demonstrated the highest frequency of pools and glides; above counting station 5, gravel bars and aggraded sections became more frequent. Habitat above counting station 9 was extremely aggraded and almost completely dewatered in the 2013 orthophotography (Figure 28).

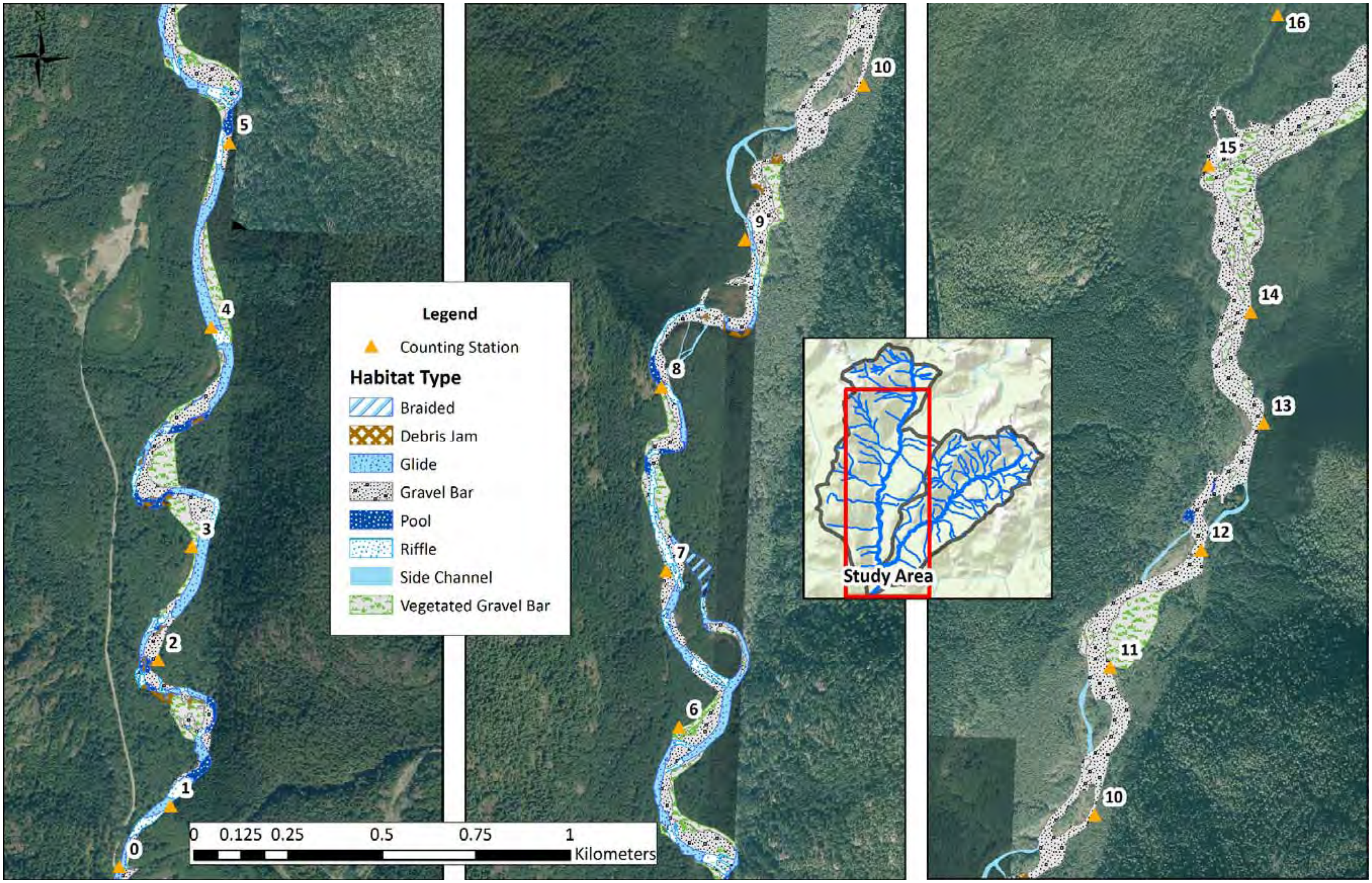


Figure 28. Habitat unit classification (2013) of the Tahsis River.

Habitat unit composition within the anadromous zone was 72.52% gravel bar. Pool frequency was extremely low at 3.28% (Figure 29). Ground truthing of the anadromous zone should be completed to provide more detail on the state of stream margin habitat (ie. Overhanging vegetation, cutbanks etc.).

The benchmarks described in Johnston and Slaney (1996) indicate that for systems less than 15m and with gradients of <2%, poor salmonid habitat condition for summer and winter rearing occurs with <40% pool habitat area by reach. Similar conditions are experienced in systems with gradients between 2% and 5% where <20% pool habitat area is observed. While the Tahsis River is greater than 15m in average width, this metric still provides a useful comparison of pool habitat composition. Considering this benchmark, the habitat composition indicator for the Tahsis River has been classified as high risk, as pool frequencies in the Tahsis remain well below the suggested benchmarks.

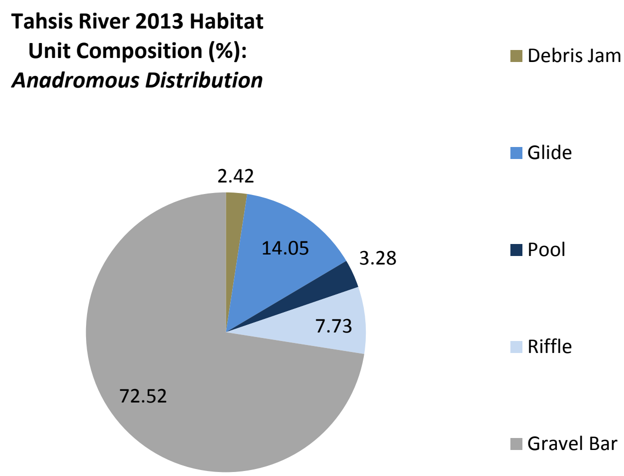


Figure 29. Habitat unit composition in 2013 for the anadromous reaches of the Tahsis River.

A comparison of habitat unit composition between 1995 and 2013 (where data overlapped between counting stations 0 and 9) has demonstrated a decrease in pool habitat from 13.1% to 9.52%, indicating continuing aggradation in this system (Figure 30). A significant loss of pool habitat was observed between counting stations 2 and 6 (Figure 31). The decrease in gravel bars between 1995 and 2013 is likely attributable to the revegetation of stable gravel bars over time.

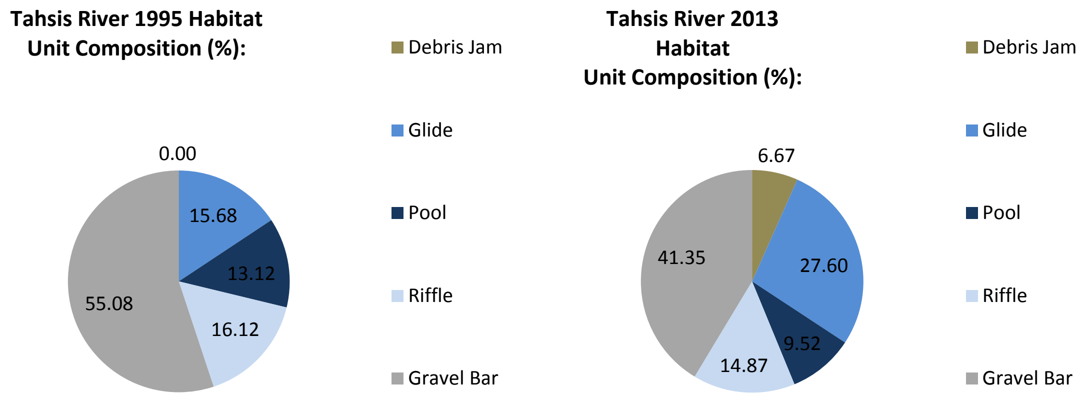


Figure 30. Change in habitat unit composition between 1995 and 2013 in the Tahsis River, between counting stations 0 and 9.

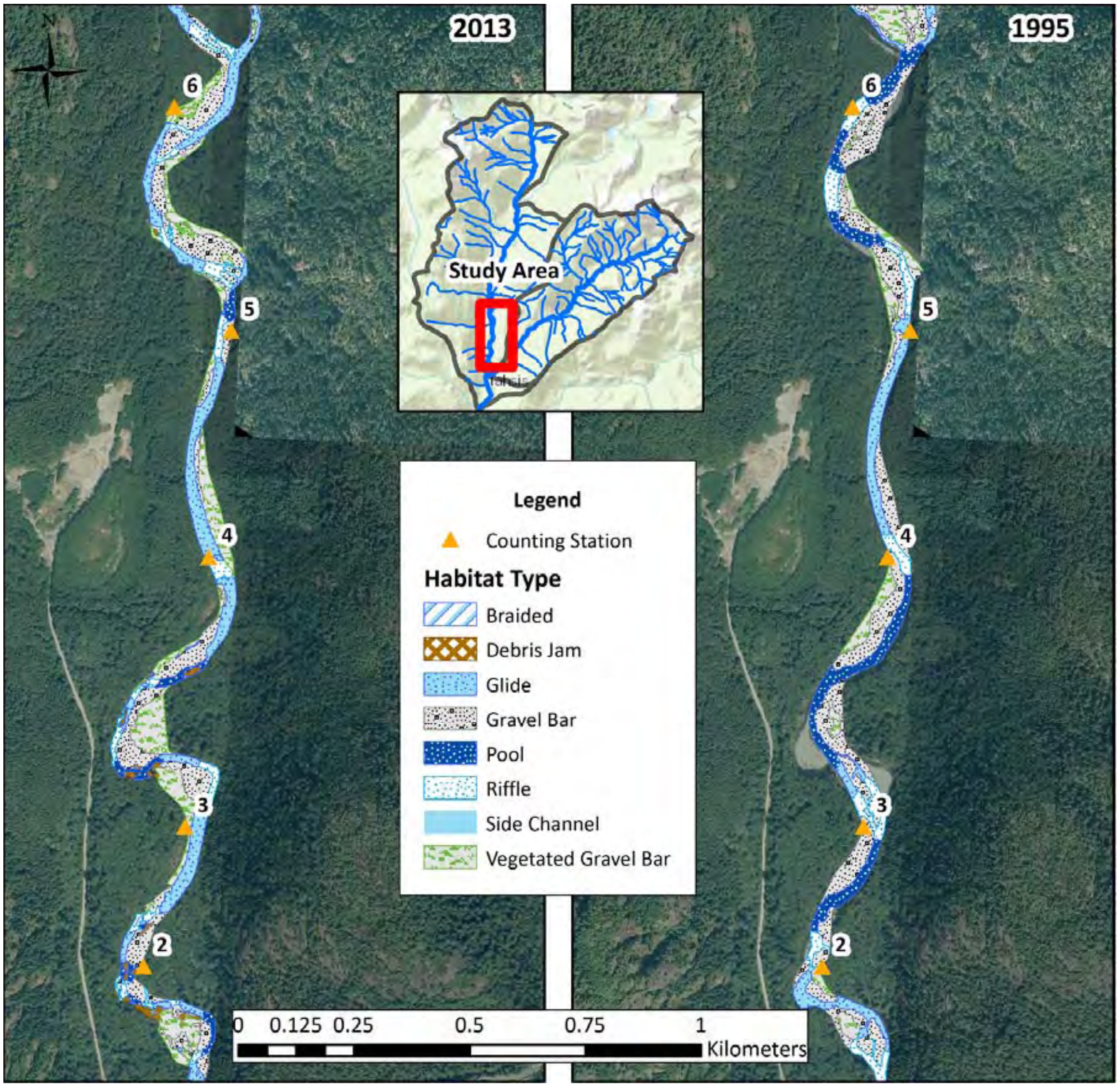


Figure 31. Habitat unit composition between 1995 and 2013 (note loss of pool habitat between counting stations 2 and 6).

4.13 Stream State Indicator: Channel Stability

A comparison of 1980, 1995, and 2013 imagery between counting stations 0 and 9 demonstrated significant migration of the channel banks in the lower river over time (Figure 32). Channel widening has continued to occur between counting stations 1 and 2, and is likely attributable to several debris jams along the right bank creating hard points and directing flow to the opposite banks. Just upstream of counting station 3, a significant bend along the right bank has developed between 1980 and 2013, with approximately 100m of channel bank lost. Erosion along the right bank between counting stations 5 and 6 has also been observed and confirmed during field reconnaissance events (M. Wright, pers. comm.).

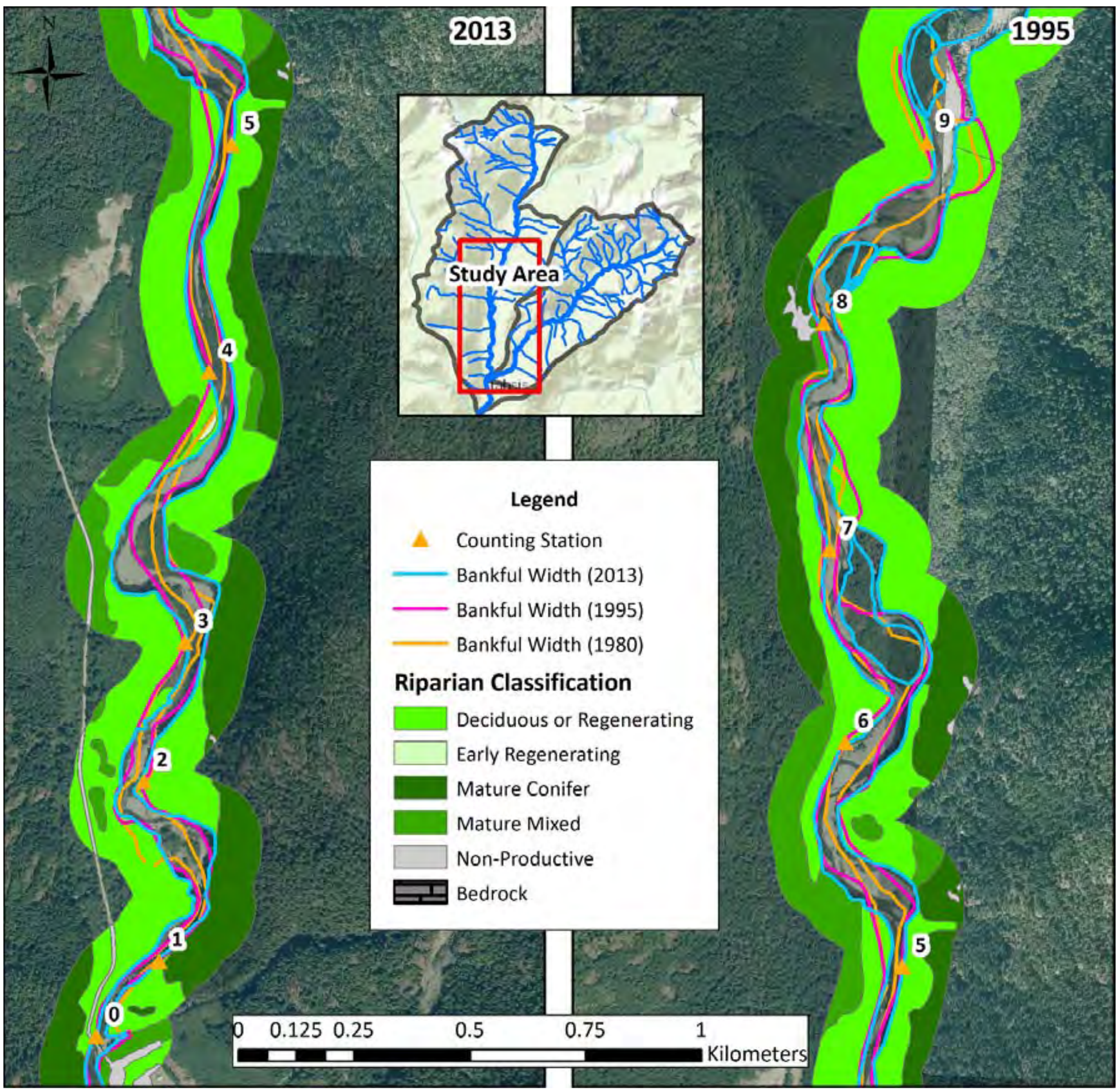


Figure 32. Bankful widths between 1980, 1995, and 2013 in the Tahsis River.

In many cases historical channel migration has eroded the banks into mature riparian zones and / or against the river valley walls. As such, channel migration in these zones is anticipated to slow based on increased channel stability from mature riparian stands. However, eroding zones just upstream of counting station 3 and between counting stations 5 and 6 remain a concern, as riparian zones consist of a significant component of deciduous and / or regenerating vegetation (Figure 32).

While some channel migration upstream of counting station 6 was observed, of most significance in this zone was the apparent stabilization (i.e. recovery) of the channel between counting stations 6 and 9. This stabilization was noted in the form of reclamation of aggraded zones with vegetation and the reduction of bankful widths in over-widened sections of the river (Figure 33).

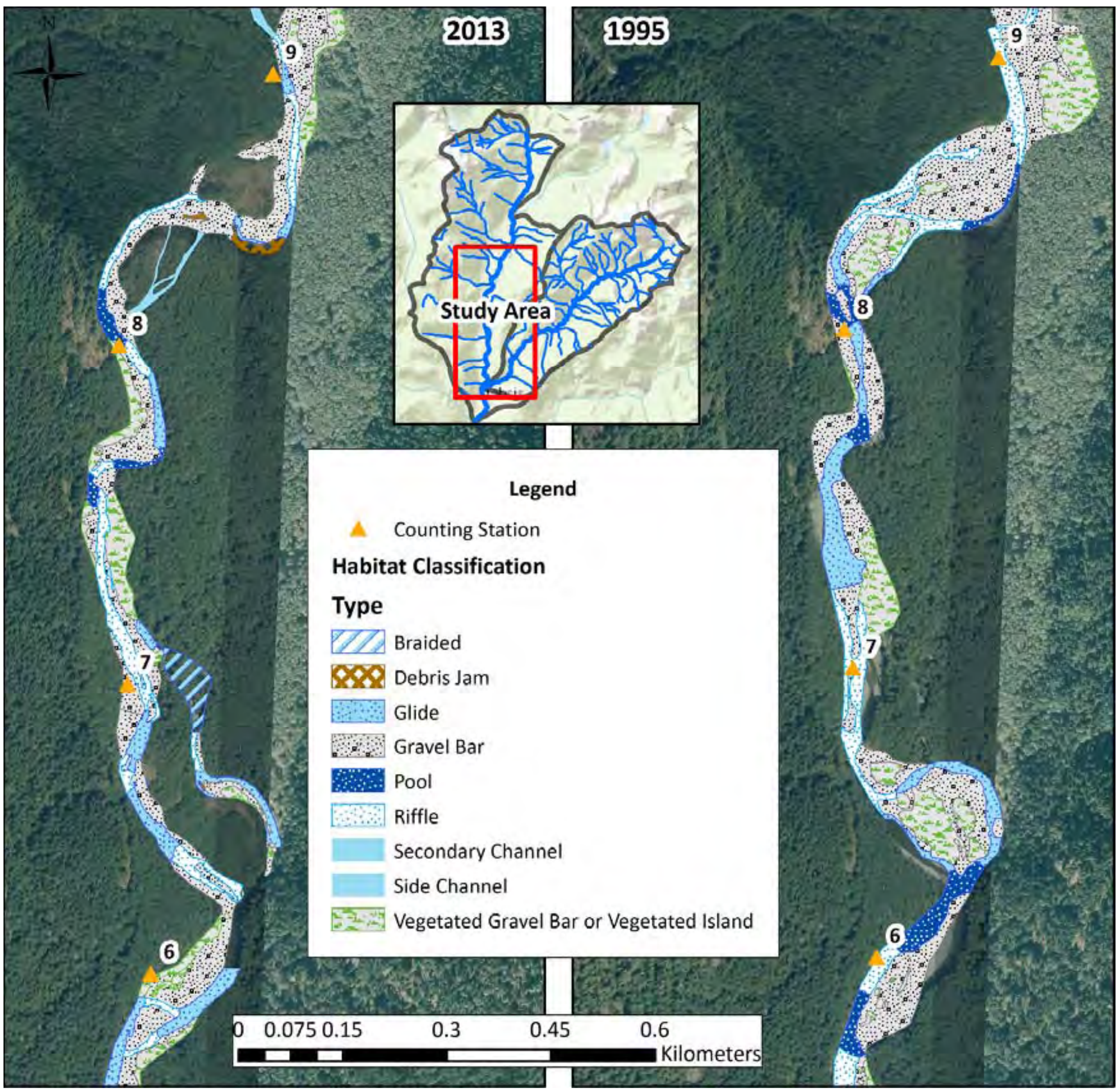


Figure 33. Channel recovery between 1995 and 2013 between counting stations 6 and 9 on the Tahsis River.

Based on the continued erosion observed below counting station 6, the channel stability indicator for this zone was ranked as high risk. Where river recovery was observed upstream of counting station 6 this indicator was ranked as moderate risk. Note that a proper study of the Tahsis River by a fluvial geomorphologist is recommended to provide a detailed assessment of this indicator.

4.14 Stream State Indicator: Large Woody Debris

LWD was evaluated in the Tahsis River to the upstream extent of Reach 12 (Figure 2). Classification beyond reach 12 was not possible due to canopy cover and / or shadowing obscuring the river in the orthophotographs. The following table summarizes the results of LWD classification by reach:

Table 9. LWD classification in the Tahsis River (reaches 1 - 12).

Reach	Pieces of Functioning LWD per Bankful Width	Pieces of Non-Functioning LWD per Bankful Width	Pieces of Partially-Functioning LWD per Bankful Width	Number of Debris Jams	LWD Classification
1	0.24	0	0	0	POOR
2	0	0	0	0	POOR
3	0.07	0	0.07	0	POOR
4	0.55	0.55	0.42	8	POOR
5	0.52	0.46	0.34	5	POOR
6	0.80	0	0	0	POOR
7	0.67	0.97	0.54	1	POOR
8	0.71	0.54	0.36	0	POOR
9	0.1	0.79	0.08	5	POOR
10	0	0.58	0	0	POOR
11	0	1.20	0	0	POOR
12	0	6.61	0	0	POOR

Based on the results presented above, there is a lack of functional LWD in the Tahsis River system. Reaches 4 – 6 demonstrated the highest concentration of functional LWD; however, the number of pieces per bankful width still remained below 1 piece per bankful width. Photo 4 presents an example of functional and non-functional LWD in reach 5. Reach 2 was virtually devoid of functional LWD, as were reaches 10 – 12.

Non-functional LWD was present throughout the system, and became progressively more abundant upstream. The majority of this LWD was present as wood accumulating on top of gravel bars (Photo 5). There was also a considerable component of this wood that was oriented parallel to the stream bank, and was therefore providing limited function to the system.

Photo 4. Example of functional LWD and non-functional LWD in the Tahsis River.

Photo 5. Example of non-functional LWD in reach 12 of the Tahsis River.

Debris jams were most common throughout reaches 4 and 5, with the largest jams observed just downstream of counting station 2 in reach 4 (Photo 6). In most cases these jams were providing functional fish habitat and in some locations preventing further bank erosion (Photo 7).

Photo 6. Debris jams located just downstream of counting station 2, in reach 5.

Photo 7. Debris jam preventing further bank erosion just downstream from counting station 9.

The overall recruitment potential for functional LWD in the Tahsis River system is low based on its riparian stand classification (i.e. predominantly deciduous). In addition, LWD present in the river is likely deciduous as well, given this stand has been dominated by alders since the system was logged in the 1970s. While smaller deciduous LWD still provides some function in the river, larger coniferous LWD is considered more stable, longer lasting, and more influential over stream flow (Poulin et al, 2000).

Based on the lack of functional LWD in the Tahsis River system and the existing LWD being predominantly deciduous, this habitat indicator was ranked as high risk.

4.15 Stream State Indicator: Off-Channel Habitats

A small wetland in Reach 1 (right bank) was identified in Wright (2002) as prime overwinter habitat for coho. The report recommended further investigation to determine if this area provides year round rearing habitat for juvenile salmonids. The investigation should be done when juveniles are migrating downstream to see if this habitat is being utilized by smolts before migrating into the estuary (ie Chinook). There is also a number of channels and wetland habitat between Reach 2 to 4 on the right bank floodplain. This habitat has been impacted by construction of the road leading the village of Tahsis dump. Much of the habitat becomes isolated during low flow periods. Observations by local experts have identified that some of the channels are infilling with material from the road during flood events. This area has historically supported spawning chum (Tahsis Enhancement Society, pers. com.).

Interviews with local experts indicated that much of the off-channel habitat has been lost though erosion and aggrading. What habitat is left has limited to no access during low flow periods. There is limited information on the extent and utilization of off channel habitat. An assessment of off-channel habitats was not possible from the orthophotographs based on heavy canopy cover. As such, the amount, condition and productivity of off-channel habitats in Tahsis River has been identified as a data gap.

4.16 Estuary State Indicator: Estuary Habitat Disturbance

The development of the village of Tahsis has resulted in the permanent loss of the majority of estuarine habitat through infilling, as described in Section 1.2.2. An assessment of the estuary in 1974 demonstrated that of the 36 hectares defined as the Tahsis River estuary, 27.5 hectares were comprised of sawmills, bunk houses, landfills, pavement, and a sewage treatment plant. In addition, approximately 109 hectares of the north end of Tahsis Inlet was being utilized for log booming and storage (Kennedy and Waters, 1974).

The Tahsis estuary today remains highly altered as no reclamation of estuarine habitat has occurred (Figure 34). In addition, there are still 21.9 hectares of aquatic foreshore that are a crown lease designated for log handling and storage.

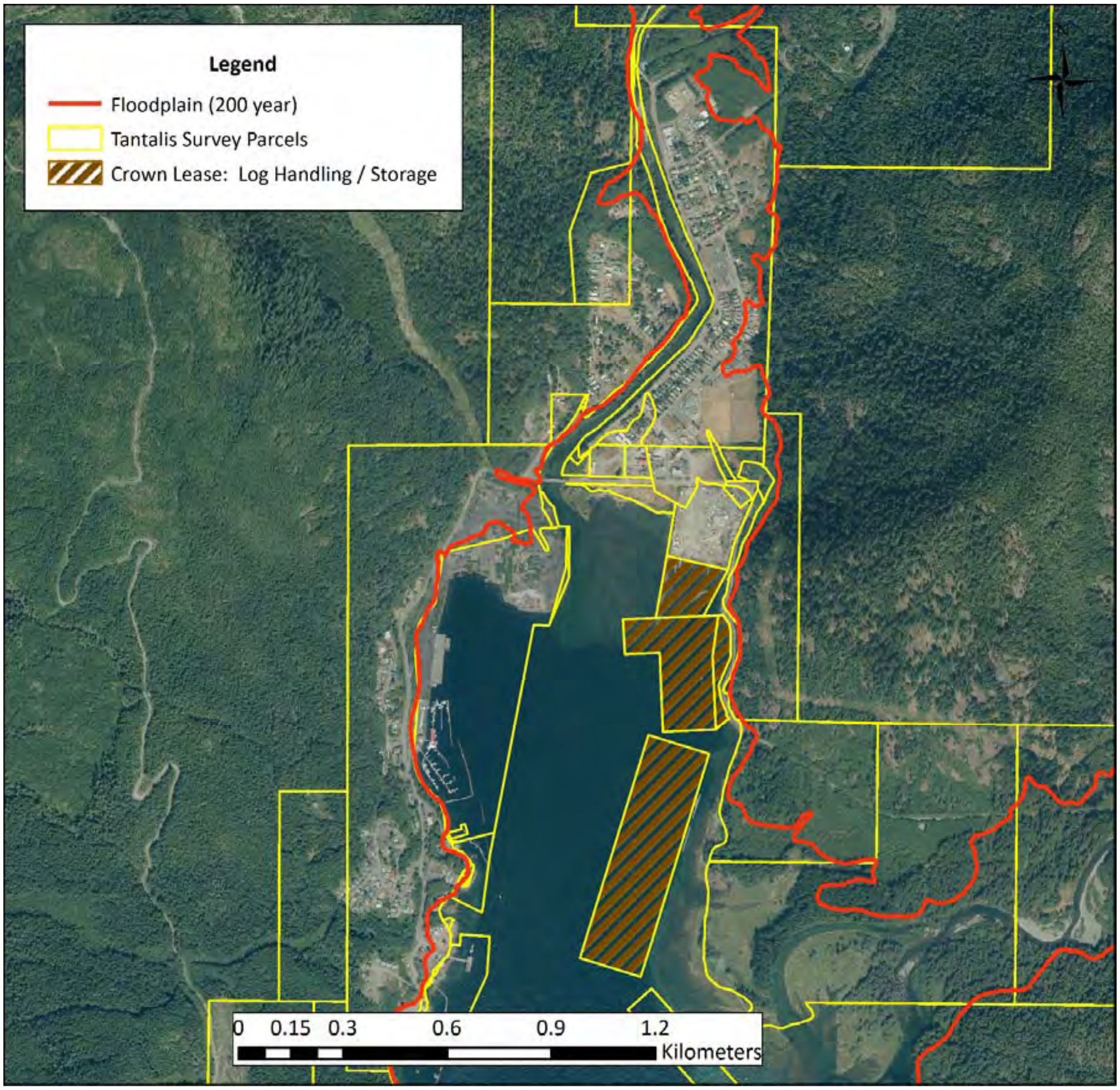


Figure 34. Present-day habitat disturbances in the Tahsis River estuary.

Based on historical disturbances and permanent alterations to the Tahsis River estuary, this habitat indicator has been ranked as high risk.

4.16 Estuary State Indicator: Permitted Waste Discharges

There are no permitted waste discharges in the Tahsis River estuary. As such, this indicator has been ranked as low risk.

4.17 Estuary State Indicator: Estuary Chemistry and Contaminants

A detailed study of habitat in Tahsis Inlet in 1981 documented salinity, temperature, tubidity, and acidity values in the estuary between March and June of 1981. Results showed that surface salinity and temperature were directly correlated with tides. Highest surface salinities were observed during high tides, and bottom salinities remained between 20 to 23 parts per thousand (ppt). Lowest salinities were observed near the mouth of the Tahsis and Leiner rivers (near 0 ppt), where temperatures typically remained below 8°C. Water samples were also analyzed for turbidity and acidity, which were found to have very low turbidity and neutral pH values (between 6.5 and 7.0) (Western Canada Hydraulic Laboraties Ltd., 1981).

Given the industrial history of the Tahsis River estuary, reduced water quality through leachate from estuary fill and potential anthropogenic debris in the subtidal zone is likely. Interviews with local residents indicated that the old Tahsis sawmill site on the west side of the estuary has undergone a Brownfield assessment (Tahsis Enhancement Society, pers. comm.); however, assessment results were not available for review within the time frame of this project.

Given that no additional data was available for water chemistry and contaminants (i.e. N, P, N:P, Metals, PAHs and PCBs), this habitat indicator has been identified as a data gap. Further efforts to acquire and evaluate the results of the Tahsis mill brownfield assessment are recommended.

4.18 Estuary State Indicator: Dissolved Oxygen

No data with regards to DO levels in the Tahsis River estuary were available. Considering the historical log handing that has occurred in the estuary and the known impacts log handling can have on DO levels through wood waste deposition (Picard et al, 2003), impacts to fish habitat can be expected from this indicator. However, based on the absence of information and / or studies, this habitat indicator has been identified as a data gap.

4.19 Estuary State Indicator: Estuarine Habitat Area

As described in Section 4.15, the Tahsis River estuary has been significantly impacted through infilling. This infill has resulted in a significant decrease in historical estuarine habitat. The following figure details habitat composition within what remains of the estuary:

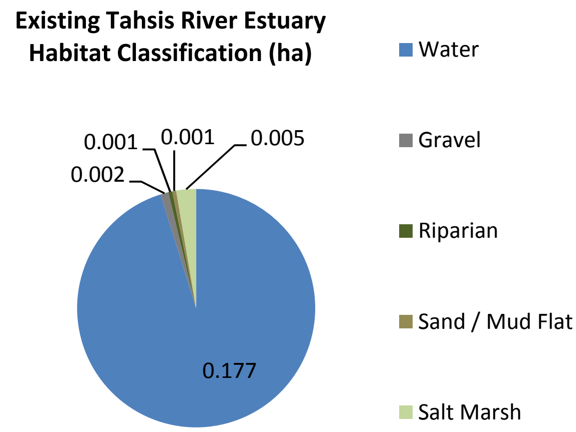


Figure 35. Habitat composition of the remaining Tahsis River estuary.

As demonstrated in Figure 35, very little valuable intertidal estuary habitat (i.e. salt marsh or mud flat) habitat remains. Figure 36 shows this habitat to be distributed within a small area near the mouth of the Tahsis River. It should be noted that no recent data was available pertaining to the subtidal component of the estuary (i.e. eelgrass presence / absence and the condition of historical impacts), and has been identified as a data gap.

Given the known importance of the estuary as a critical rearing and foraging zone for all species of outmigrating salmonids, the historical loss of this habitat represents a loss in salmonid productivity for this watershed. As such, this habitat indicator has been ranked as high risk.

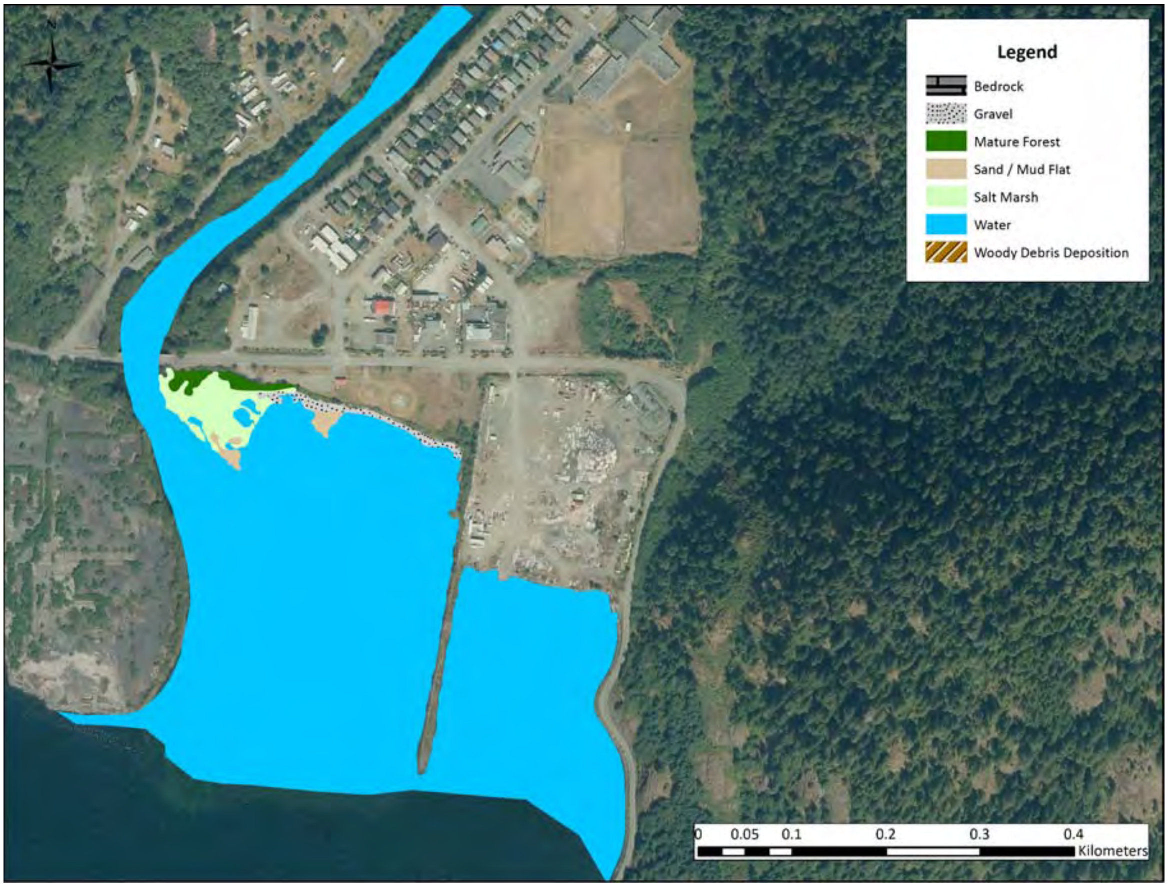


Figure 36. Estuary habitat classification and distribution of the Tahsis River estuary.

5.0 SUMMARY OF HABITAT INDICATORS AND DATA GAPS

Based on the results of the habitat status assessment of the Tahsis River watershed, it is clear that legacy impacts from forest harvesting continue to persist in this watershed. The inherent characteristics of this system (i.e. aggressive hydrology and alluvial nature) have prevented riparian reclamation from streamside logging impacts. Degraded riparian zones have promoted channel instabilities, particularly in the lower river, and subsequent sediment inputs have overwhelmed the system and resulted in overall aggradation and loss of pool habitat. Some zones are now so heavily aggraded they remain dry during the summer months, thus reducing the accessible stream length for several species of salmonids. Very little functional LWD remains in the system and recruitment potential is low considering the deciduous nature of the riparian zone.

In addition to logging impacts, development of the Tahsis River estuary has resulted in a near-complete loss of estuarine habitat. Historical infills have replaced juvenile aquatic rearing and foraging habitat with industrial areas and urban zones. At present, less than 5% of the estuary has been identified as having valuable intertidal habitats present (i.e. salt marsh and mud flats). Considering the estuary is critical to the survival of migrating juvenile salmonids (Aitkin, 1998), these developments have likely had a significant impact on the overall productivity of all salmon species in the Tahsis River.

Table 10 summarizes the results of ranked assessed habitat indicators and identifies indicator data gaps:

Table 10. Summary of assessed habitat indicators and data gaps.

Indicator	Type	Risk Rating	Data Gaps (Y/N)?	Comments
Total land cover alterations	Stream: Pressure	HIGH	N	Land cover alterations primarily in the form of deciduous-dominated riparian forests adjacent to fish and fish habitat.
Riparian disturbance	Stream: Pressure	HIGH	Y	Deciduous-dominated riparian zones. **Data gap for riparian classification of tributaries.**
Channel stability	Stream: State	HIGH (below counting station 6) MODERATE (above counting station 6)	Y - Partial	Significant channel migration observed in select locations between 1980 and 2013. In some cases, continued erosion is expected based on lack of stable channel banks and deciduous riparian vegetation in these zones. Ground truthing of these zones is recommended to complement the orthophotography assessment.
Habitat composition	Stream: State	HIGH	N	Percent pool area remains below suggested benchmarks described in Johnston and Slaney (1996). Loss of pool habitat between 1995 and 2013 observed.
Large woody debris	Stream: State	HIGH	Y - Partial	Pieces of functional LWD per bankful width remains below suggested benchmarks in Johnston and Slaney (1996) for all assessed reaches. Low functional LWD recruitment potential based on deciduous-dominated riparian zones. Ground truthing of LWD recommended to quantify additional LWD that may not be visible from orthophotographs (i.e. completely submerged LWD in deep pools).
Estuary habitat disturbance	Estuary: State	HIGH	N	Historical infilling of the Tahsis estuary has replaced majority of estuarine habitat with industrial and urban zones. Less than 5% of the estuary remains as valuable rearing and foraging habitat (i.e. salt marsh and mud flat). Historical log handling in the estuary has disturbed habitat as well, and maintenance of log handling leases in this zone present continued risk to estuary habitat.
Estuary habitat area	Estuary: State	HIGH	Y	Historical infilling of the Tahsis estuary has replaced majority of estuarine habitat with industrial and urban zones. Less than 5% of the estuary remains as valuable rearing and foraging habitat (i.e. salt marsh and mud flat). **Data gap: quantity and quality of subtidal estuarine habitat (i.e. eelgrass beds).**
Watershed road development	Stream: Pressure	LOW	Y	**Lacking spatial data for historical road network.** Indicator still ranked as low despite this data gap. Present road network in

				the watershed is extremely limited, and consideration of historical roads is still anticipated to be below the suggested metric of 0.4km/km^2.
Water extraction	Stream: Pressure	LOW	N	Only extraction presently licenced is in McKelvie Creek (drinking water source for the village). McKelvie has limited fish values and enters the Tahsis River near the downstream extent of critical migration, spawning, and rearing habitats.
Water temperature: Migration and spawning	Stream: State	LOW	N	Recorded water temperatures during spawn surveys from 2006 – 2014 showed only one occurrence of temperatures approaching the UOTR for adult salmonids. Remainder of values were consistently below this benchmark.
Permitted waste management discharges	Estuary: State	LOW	N	No permitted waste discharges identified in the Tahsis River estuary.
Stream crossing density	Stream: Pressure	LOW	Y	**Lacking spatial data for historical stream crossings.** Indicator still ranked as low despite this data gap given the extremely low number of known crossings in the watershed.
Off-channel habitats	Stream: State	Not ranked – data gap	Y	**No data available on quantity and / or quality of off-channel habitats.**
Permitted waste management discharges	Stream: State	Not ranked – data gap	Y	**No water quality data available for review at the Tahsis landfill.**
Water quality	Stream: State	Not ranked – data gap	Y	**No water quality data available for the Tahsis River.** Acquisition of landfill testing data through the CVRD would facilitate evaluation of this metric; however, additional data would need to be collected throughout the watershed to allow for a complete assessment.
Water temperature: Juvenile rearing and migration	Stream: State	Not ranked – data gap	Y	**No water temperature data available outside of the fall swim survey period.** This metric important to understand water temperature's influence on emergence timing and potential egg freezing events during winter low flows.
Stream discharge	Stream: State	Not ranked – data gap	Y	**No discharge data available for the Tahsis River.** Discharge data reviewed for McKelvie Creek not necessarily reflective of conditions in the Tahsis based on differing watershed characteristics.
Estuary chemistry and contaminants	Estuary: State	Not ranked – data gap	Y	**No water quality data (with the exception of historical pH, salinity, and temperature information) available for the Tahsis River estuary.** Given industrial history of this estuary, impacts from degraded water quality likely persist.
Estuary dissolved oxygen	Estuary: State	Not ranked – data gap	Y	**No DO data available for the Tahsis River estuary.** Given historical log handling initiatives in this zone a fiber mat likely

				exists in the subtidal zone. These fiber mats are known to result in reduced DO levels in the marine environment (Picard et al, 2003)
Accessible stream length	Stream: State	N/A	Y - partial	Requires temporal comparison of change over time to determine indicator risk. Confirmation of accessible stream length recommended through field mapping of tributary and side channel habitat.
Key spawning areas (length)	Stream: State	N/A	Y - partial	Requires temporal comparison of change over time to determine indicator risk. Ground truthing of upper and lower limits of spawning zones via GPS recommended to accurately quantify and monitor this indicator.

In addition to the data gaps presented above, an additional important habitat indicator (beyond the scope of Stalberg et al [2009]) lacking information was identified: the quantification of inter-gravel flows and DO levels in known spawning grounds. Understanding inter-gravel flows and DO levels was identified as a critical component of egg to fry survival, and must be understood to determine if the infilling of interstitial spaces reducing intergravel flows and / or lack of oxygen are reducing survival.

In many cases data gaps prevented a full assessment of state and pressure indicators. Based on the results of this habitat status assessment, recommendations can be broken down as follows: recommended restoration projects, data gaps to be addressed, and best functioning habitats requiring protection. The following sections discuss these recommendations.

5.1 Recommended Restoration Projects

Given the known impacts of a degraded riparian zone on channel stability in the Tahsis River, restoration efforts should be focused on both reclaiming these zones through riparian treatments and conducting appropriate instream works to stabilize actively eroding channel banks. In addition, reclamation of estuarine habitat and / or the creation of new habitat is highly recommended to improve juvenile rearing and foraging habitat for all species during their transition to the marine environment.

5.1.1 Riparian Treatments

Specific zones recommended for riparian treatments include the eroding right bank between counting stations 3 and 4, the deciduous-dominated right bank between counting stations 4 and 5, the eroding right bank between counting stations 5 and 6, and the deciduous-dominated left bank between counting stations 7 and 9. Note that additional riparian treatment opportunities exist upstream of counting station 9; however, restoration lower down in the watershed would target more critical habitats for all species observed in this river.

Figure 37 illustrates recommended riparian treatment zones based on stand composition, known erosion, and fisheries values (all species):

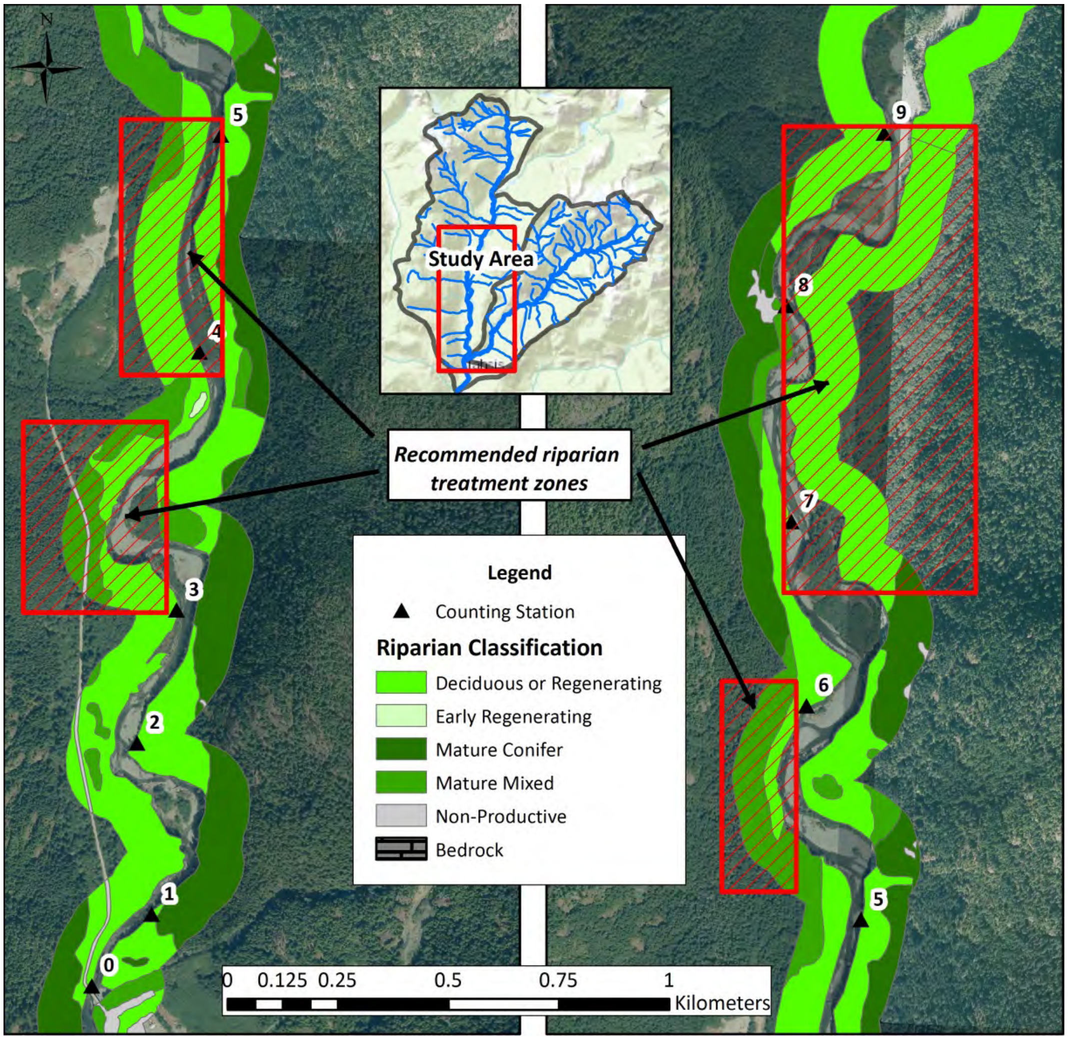


Figure 37. Recommended riparian treatment zones for the Tahsis River.

Common riparian treatments utilized in degraded riparian zones that could be applied in the Tahsis River include the following (Poulin, 2005):

- Conifer release: treatment removes competing overstory or brush by felling, girdling, or brushing.
- Uniform thin: a thinning treatment that spaces conifer generally uniformly throughout a stand. The treatment maximizes the number of large diameter conifers per unit area.
- Variable thin: allows for wide variability in conifer spacing. Mimics distribution of conifers on moist and wet sites where competition is generally most-severe.
- Planting: planting on best available microsites, implies cluster planting.

Based on the potential riparian treatment sites identified above, development of riparian prescriptions by a Registered Professional Forester (RPF) is recommended to move forward with addressing this high risk habitat indicator.

5.1.2 Channel Stabilization

Two locations have been identified along the right bank of the Tahsis River that are candidates for instream stabilization works. These locations include the eroding right bank between counting stations 3 and 4, and the eroding right bank between counting stations 5 and 6.

An analysis of channel migration through historical air photos between counting stations 3 and 4 indicated a loss of approximately 100m of channel bank between 1980 and 2013. Given the current morphology of this bend and the adjacent degraded riparian zone, continued erosion is anticipated in the absence of bank stabilization initiatives. Channel migration between counting stations 5 and 6 was also observed (though not quite as severe), and a field reconnaissance assessment in 2014 identified this zone by high risk. Figure 38 illustrates the location of these proposed bank stabilization zones:

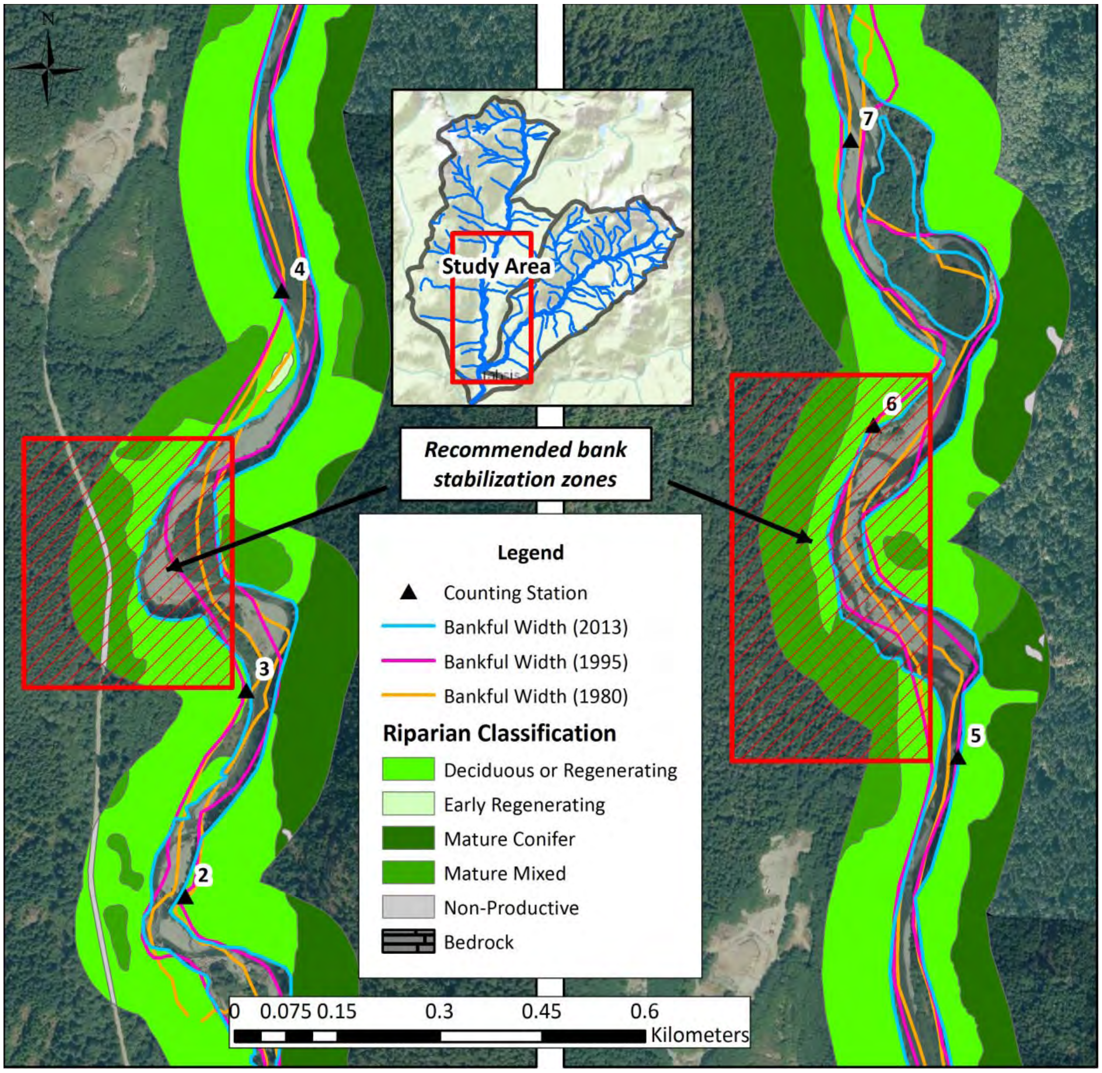


Figure 38. Proposed bank stabilization zones in the Tahsis River.

Potential instream methods that could be employed between counting stations 3 and 4 include the construction of groynes, debris catcher, and / or the installation of large woody debris revetments. Photo 8, Photo 9, and Figure 39 show examples of both groyne and woody debris revetment installations to protect existing eroding channel banks.

Photo 8. Rock groynes constructed on an eroding left bank in the Phillips River.

Photo 9. Large woody debris revetments installed on an eroding left bank of the Eve River.

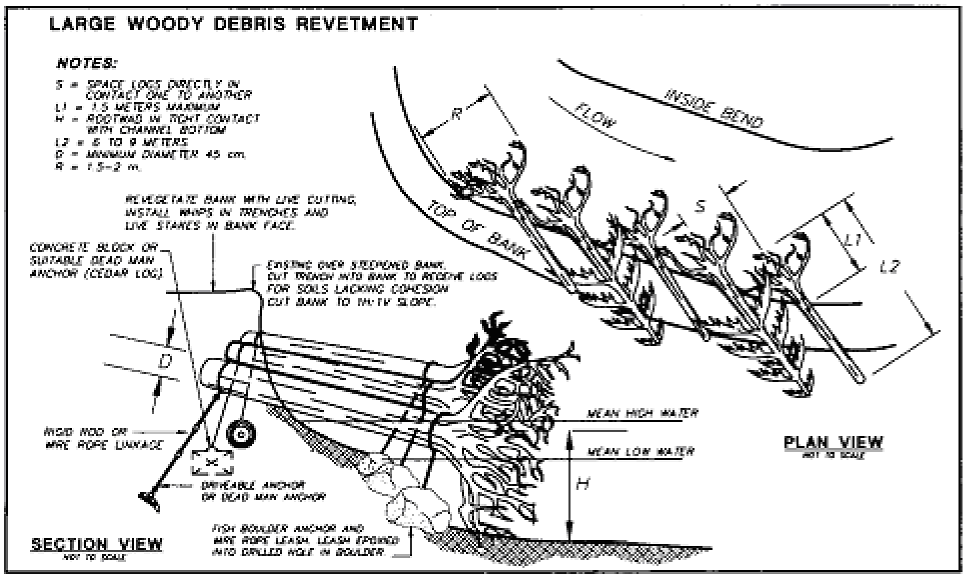


Figure 39. Typical large woody debris revement installation (Slaney & Zaldokas, 1997).

Similar methods (i.e. groynes and LWD revetments) should be considered for the eroding bank between counting stations 5 and 6; however, a flood relief channel through the left bank of this section may also be considered to relieve pressure from these eroding bends (Figure 38).

For all of the sites described above, it is recommended that a fluvial geomorphologist assess these sites and design a restoration prescription for these zones. Prescriptions should also be combined with riparian treatments to address both short and long-term solutions to these problem areas.

5.1.3 Off-channel Habitats

The wetland area on the west side of the municipal dump access road would benefit from restoration works, which would include creating year round access to habitat in this off channel area. Restoration of the channel and wetland habitat will be required. Before restoration can proceed a detailed assessment and prescription will be required.

5.1.4 Estuary Reclamation

Reclamation of the Tahsis River estuary through the removal of fill in abandoned industrial zones was identified as a high priority restoration initiative in this watershed. Works could include identifying zones where industrial lands are no longer required, removing old fill, and contouring the remaining material to intertidal elevations. A salt marsh transplant could then be conducted on the re-contoured foreshore to facilitate the re-establishment of critical salt marsh habitat. Photo 10 shows an example of transplanted salt marsh habitat on reclaimed foreshore at the East West Bay log handling facility (near Campbell River, B.C.).

Photo 10. Example of reclaimed salt marsh habitat as part of a foreshore pullback at the East West Bay log handling facility.

A detailed survey of the Tahsis River estuary is recommended to identify potential reclamation zones and / or areas where new salt marsh habitat could be constructed. Where foreshore pullbacks are recommended, detailed information on potential infill contamination issues must be collected in order to prevent the release of harmful substances into the estuarine environment.

5.2 Data Gaps and Recommended Studies

The following table presents a prioritized list of data gaps identified during this study and recommendations for future initiatives to address these gaps:

Table 11. Data gaps and recommended studies for habitat indicators in the Tahsis River.

Data Gap	Priority	Recommendation
Subtidal estuarine habitat condition	High	Conduct a detailed subtidal habitat study of the estuary, including quantifying and mapping subtidal habitat types and impacts, and analyzing water quality and sediment samples for contaminants. This study could occur in conjunction with field work required to develop prescription for potential intertidal habitat reclamation. Also, acquire and analyze results of Brownfield assessment of the old Tahsis mill.
Estuary chemistry and contaminants	High	
Estuary dissolved oxygen	High	
Water quality (Tahsis landfill)	High	Obtain and analyze water quality testing data from the CVRD.
Channel stability	High	Ground-truth key eroding sections and channel stability assessed by a geo-morphologist.
Stream discharge	Moderate	Install a hydromet station on the Tahsis River to measure continuous discharge information.
Water temperature	Moderate	
Intergravel flows and DO levels	High	Direct field efforts to collect this intergravel flow and DO data at known spawning grounds. Collect GPS coordinates of upstream and downstream extents of known spawning grounds.
Key spawning areas (length)	Low	
Status of off-channel habitats, including wetlands and tributaries, and accessible stream length of these habitats	High	Direct field efforts to map tributary locations, side channels, and wetlands (within fish-bearing reaches). Classify riparian of these locations based on 2013 orthophotographs.
Riparian classification of tributaries	Moderate	
Water quality (instream)	Moderate	Implement water quality monitoring program at several sites distributed throughout the Tahsis River.
Large woody debris	Moderate	Ground-truth LWD in the system; incorporate quantification of submerged LWD not visible in the orthophotographs.
Historical road and stream crossing network	Low	Acquire and digitize historical maps of the road and stream crossing network (if available).

5.3 Best Functioning Habitats Requiring Protection

The protection of existing known funtioning habitats is important to maintain existing fish productivity levels and prevent the loss of these important zones. Figure 40 summarizes all of the known functioning, spawning, holding, and juvenile rearing and migration habitat identified during this assessment. All of these habitats have been considered critical and therefore require consideration and protection from future industrial initiatives. Monitoring of these locations on a periodic basis is also recommended to determine if these habitats are improving or degrading over time.

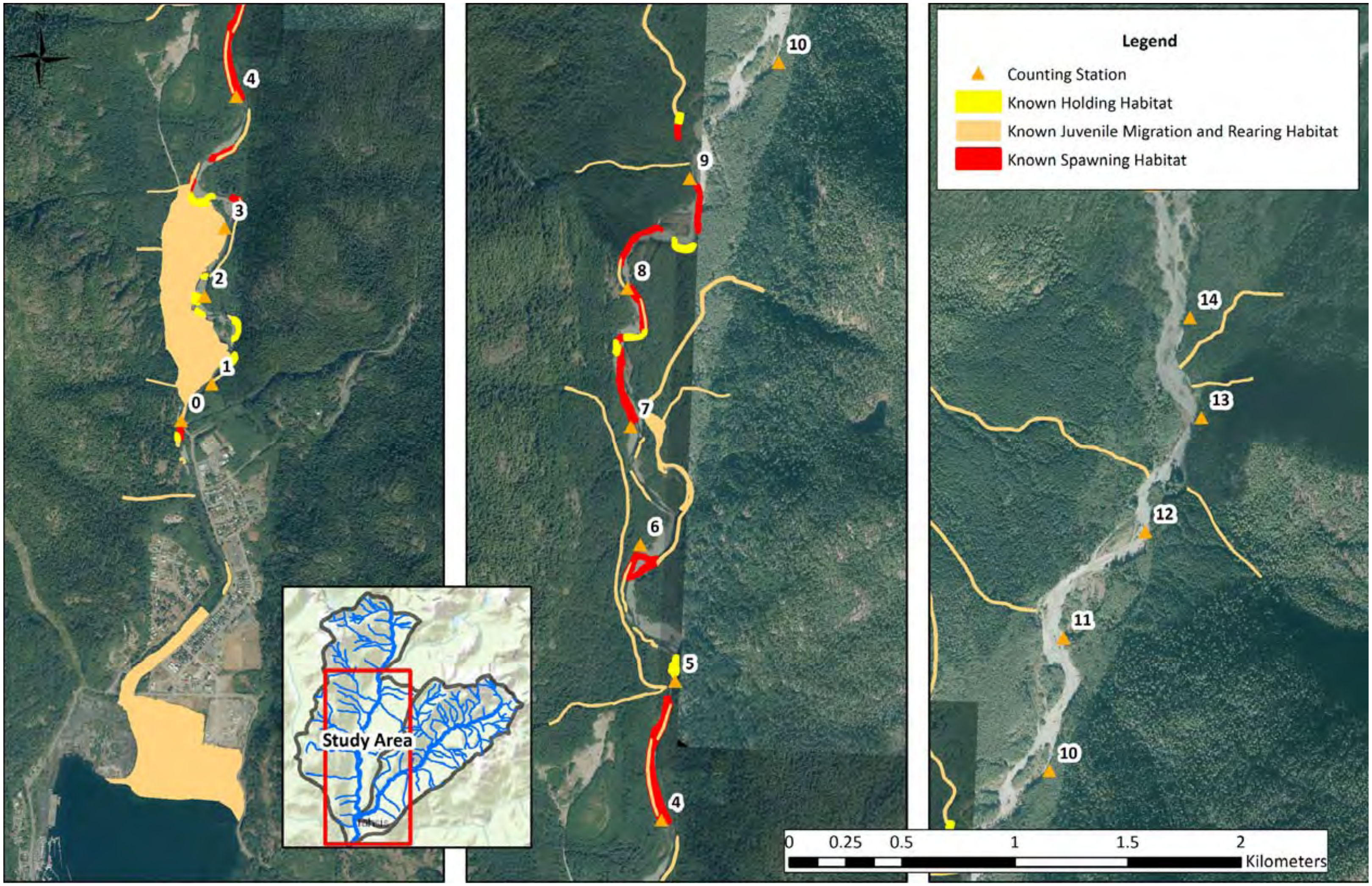


Figure 40. Best functioning (i.e. critical) habitats in the Tahsis River watershed that are recommended for protection.

6.0 CONCLUSION

The Tahsis River watershed remains highly degraded from historical logging practices removing riparian vegetation to the stream banks. Based on watershed characteristics (i.e. alluvial in nature with aggressive hydrology) and in the absence of remedial efforts, observable recovery of this watershed is not anticipated within the next 50 years (Horel, 2008).

The habitat status assessment for the Tahsis River watershed has identified high risk habitat indicators to be high total land cover alterations adjacent to fish habitat, riparian disturbances, persistence of a degraded riparian zone due to channel bank instabilities, channel bank migration and erosion, negative changes in habitat composition (i.e. loss of pool habitat) due to upstream sediment sources, lack of functional LWD, and a loss of estuarine habitat through both infilling and disturbances (i.e. log handling). Important data gaps to note include water quality (both instream and estuarine), continuous discharge and temperature data, intergravel flows and DO in key spawning grounds, and quantification of off-channel and wetland habitat condition.

Both riparian, instream and estuarine restoration opportunities have been identified as part of this assessment. Potential riparian treatment areas have been identified between counting stations 3 and 7, and several eroding banks between counting stations 3 and 6 were classified as candidates for bank stabilization through either groyne construction, debris catchers, and / or LWD revetment placement. In addition, reclamation of estuarine habitat through the pullback of old fill presented an opportunity to increase productivity levels for this high risk habitat indicator.

While high priority restoration initiatives have been identified for this watershed, important data gaps that require further understanding exist as well. More information with respect to water quality, discharge, intergravel flows, off-channel habitats, and estuarine habitat condition is necessary to obtain a more comprehensive understanding of limiting factors in the Tahsis River watershed.

7.0 REFERENCES

AECOM. (2012). *Comox Strathcona Waste Management: 2012 Solid Waste Management Plan.* Burnaby: AECOM.

Aitkin, J. K. (1998). *The importance of estuarine habitats to anadromous salmonids of the Pacific Northwest: A literature review.* Lacey: U.S. Fish and Wildlife Service, Aquatic Resources Division.

BC Ministry of Energy and Mines. (2015). *Province of British Columbia*. Retrieved January 3, 2015, from Regional Geochemistry: http://www.empr.gov.bc.ca/Mining/Geoscience/Geochemistry/RegionalGeochemistry/Pages/92e.aspx

BC MOE Waste Management Website. (2015). Retrieved January 29, 2015, from http://www2.gov.bc.ca/gov/topic.page?id=0876E90DA4744A449423D35EB4E09785

Bilby, R. E., & Ward, J. W. (1991). Characteristics and function of large woody debris in streams draining old-growth, clear-cut, and second-growth forests in Southwestern Washington. *Can. J. Fish. Aquat. Sci.*, 2499 - 2508.

Brown, A. A. (1985). *Preliminary Report on Tahsis River Flooding.* Victoria: Province of British Columbia, Ministry of Environment, Planning and Resource Management Division.

Brown, K., Aust, W. M., & McGuire, K. J. (2013). Sediment delivery from bare and graveled forest road stream crossing approaches in the Virgina Piedmont. *Forest Ecology and Management*.

Canadian Council of Ministers of the Environment. (1999). *Canadian water quality guidelines for the protection of aquatic life.* Winnipeg: Canadian Council of Ministers of the Environment.

Canadian Council of Ministers of the Environment. (2014). Retrieved March 16, 2015, from Canadian Environmental Quality Guidelines: http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/index.html

Dewhirts, J. (1990). *Mowachaht Ownership and Use of Salmon Resources of the Leiner River and Upper Tahsis Inlet, Nootka Sound, B.C.* Victoria: Archeo Tech Associates.

Diewert, R. (2007). *Habitat Requirements for Coastal Coho Salmon.* Fisheries and Oceans Canada (Unpublished).

Diewert, R. (2007). *Habitat Requirements for Ocean Type Chinook Salmon.* Fisheries and Oceans Canada (Unpublished).

Diewerts, R. (2007). *Habitat Requirements for Northern Chum Salmon.* Fisheries and Oceans Canada (Unpublished).

Diewerts, R. (2007). *Habitat Requirements for Stream Estuary Rearing Sockeye Salmon.* Fisheries and Oceans Canada (Unpublished).

Environment Canada. (2015, March 6). *Environment Canada*. Retrieved March 17, 2015, from Water Office: http://wateroffice.ec.gc.ca/report/report_e.html?mode=Graph&type=h2oArc&stn=08HE010&dataType=Daily&parameterType=Flow&year=2010&y1Max=1&y1Min=1&y1Mean=1&scale=normal

ESSA Technologies Ltd. (2013). *Southern Chinook Conservation Units: Habitat Indicators Report Cards.* Vancouver: ESSA Technologies Ltd.

Fisheries and Oceans Canada. (1949 - 1994). *B.C. 16 salmon stream spawning reports.* Fisheries and Oceans Canada.

Fisheries and Oceans Canada. (2005). *Canada's Policy for Conservation of Wild Pacific Salmon.* Vancouver: Fisheries and Oceans Canada.

Fisheries and Oceans Canada. (2012). *Assessment of West coast Vancouver Island Chinook and 2010 Forecast.* Nanaimo: Canadian Science Advisory Secretariat.

Fisheries and Oceans Canada. (2012). *BC Stream Narrative: Tahsis River.* Nanaimo: Fisheries and Oceans Canada.

Fisheries and Oceans Canada, & Ministry of Environment, L. a. (1992). *The land development guidelines for the protection of aquatic habitat.*

Harper, D., & Quigley, J. T. (2000). *No Net Loss of fish habitat: An audit of forest road crossings of fish-bearing streams in British Columbia.* Canadian Technical Report of Fisheries and Aquatic Sciences.

Hogan, D., & Ward, B. R. (1997). Watershed Geomorphology and Fish Habitat. In P. A. Slaney, & D. Zaldokas, *Fish Habitat Rehabilitation Procedures. Watershed Restoration Technical Circular No. 9.* (p. 271). Vancouver: Ministry of Environment, Lands, and Parks.

Holtby, L. B., & Ciruna, A. K. (2007). *Conservation Units for Pacific Salmon Under the Wild Salmon Policy.* Sidney: Canadian Science Advisory Secretariat.

Horel, G. (2008). *Tree Farm Licence 19 Watershed Indicators.* Nanaimo: G.M. Horel Engineering Ltd.

Jackson, C., & Cook, B. (1997). *Gold-Tahsis-Zeballos Water Allocation Plan.* Nanaimo: Province of British Columbia, Ministry of Environment, Lands and Parks, Vancouver Island Region.

Johnston, N. T., & Slaney, P. A. (1996). *Fish Habitat Assessment Procedures. Watershed Restoration Technical Circular No. 8.* Vancouver: Ministry of Environment, Lands, and Parks and Ministry of Forests.

Kennedy, K., & Waters, B. R. (1974). *Tahsis River Estuary.*

MFLNRO Fish Passage Technical Working Group Web Page. (2013, April 9). Retrieved Octoer 2014, 2015, from http://www.for.gov.bc.ca/hfp/fish/FishPassage.html

Picard, C., Bornhold, B., & Harper, J. (2003). *Impacts of wood debris accumulation on seabed ecology in British Columbia estuaries.* Victoria: University of Victoria.

Poulin, V. A. (2005). *Vancouver Island riparian restoration recommendations and prescriptions - Quinsam, Chemainus, Englishman, Little Qualicum, and Oyster rivers.* Vancouver: V.A. Poulin & Associate Ltd.

Poulin, V. A., Harris, C., & Simmons, B. (2000). *Riparian restoration in British Columbia: Waht's happening now, what's needed for the future.* Victoria: B.C. Ministry of Forests.

Sauter, S. T., McMillan, J., & Dunham, J. (2001). *Salmonid Behaviour and Water Temperature.* United States Environmental Protection Agency.

Sellars, D. (1992). *Floodplain Mapping: Tahsis, Leiner and Zeballos Rivers. Design Brief.* Richmond: Klohn Leonoff Ltd.

Slaney, P. A., & Zaldokas, D. (1997). *Fish habitat rehabilitation procedures: Watershed restoration technical circular no. 9. .* Vancouver: Ministry of Environment, Lands, and Parks.

Stalberg, H., Lauzier, R. B., MacIsaac, E. A., Porter, M., & Murray, C. (2009). *Canada's Policy for Conservation of Wild Pacific Salmon: Stream, Lake, and Estuarine Habitat Indicators.* Kamloops: Fisheries and Oceans Canada; Oceans, Habitat and Enhancement Branch.

Tahsis Salmon Enhancement Society. (2011). Retrieved March 2, 2015, from Village of Tahsis: http://www.villageoftahsis.com/salmon_enhancement.php

Tschaplinski, P. (1982). The use of estuaries as rearing habitats by juvenile coho salmon. *Proceedings of the Carnation Creek Workshop: Applying 15 Years of Carnation Creek Results.* (p. 18). Nanaimo: Fisheries and Oceans Canada.

Tschaplinski, P. (2010). *The Effects of Roads on the Post-Harvest Condition of Streams, Riparian Areas, and Fish Habitats in British Columbia, 1996 - 2010.* BC Ministry of Environment.

UMA Engineering Ltd. and Gartner Lee Limited. (1996). *Closure plans for Campbell River municipal landfill, Gold River municipal landfill, Gold River municipal landfill, Tahsis municipal landfill, and Zeballos municipal landfill.* Victoria: UMA Engineering Ltd.

Vancouver Island Health Authority. (2015). *Water Sampling Results.* Retrieved March 16, 2015, from Vancouver Island Health Authority: http://www.healthspace.ca/Clients/VIHA/VIHA_Website.nsf/Water-Samples-Frameset?OpenPage

Village of Tahsis. (2011). *Landfill Site Usage.* Retrieved March 16, 2015, from Village of Tahsis: http://www.villageoftahsis.com/pdfs/works/landfill-site-usage.pdf

Village of Tahsis. (2015). *Tahsis Economic Development Strategy Report 1 of 3: Background Report (Draft).* Tahsis: Village of Tahsis.

Western Canada Hydraulic Laboraties Ltd. (1981). *Tahsis Company Limited Report on Habitat Study in Tahsis, B.C.* Vancouver: Western Canada Hydraulic Laboratories Ltd. and Envirocon Limited.

Willis Energy Services Ltd. (2001). *Small Hydro and Wood Waste Power Development Opportunities: Preliminary Feasibility and Market Analysis.* Willis Energy Services Ltd.

Wright, M. C. (2002). *Reconnaissance (1:20,000) Fish and Fish Habitat Inventory of Tahsis River Watershed.* Nanaimo: M.C. Wright and Associates Ltd.

Personal Communications:

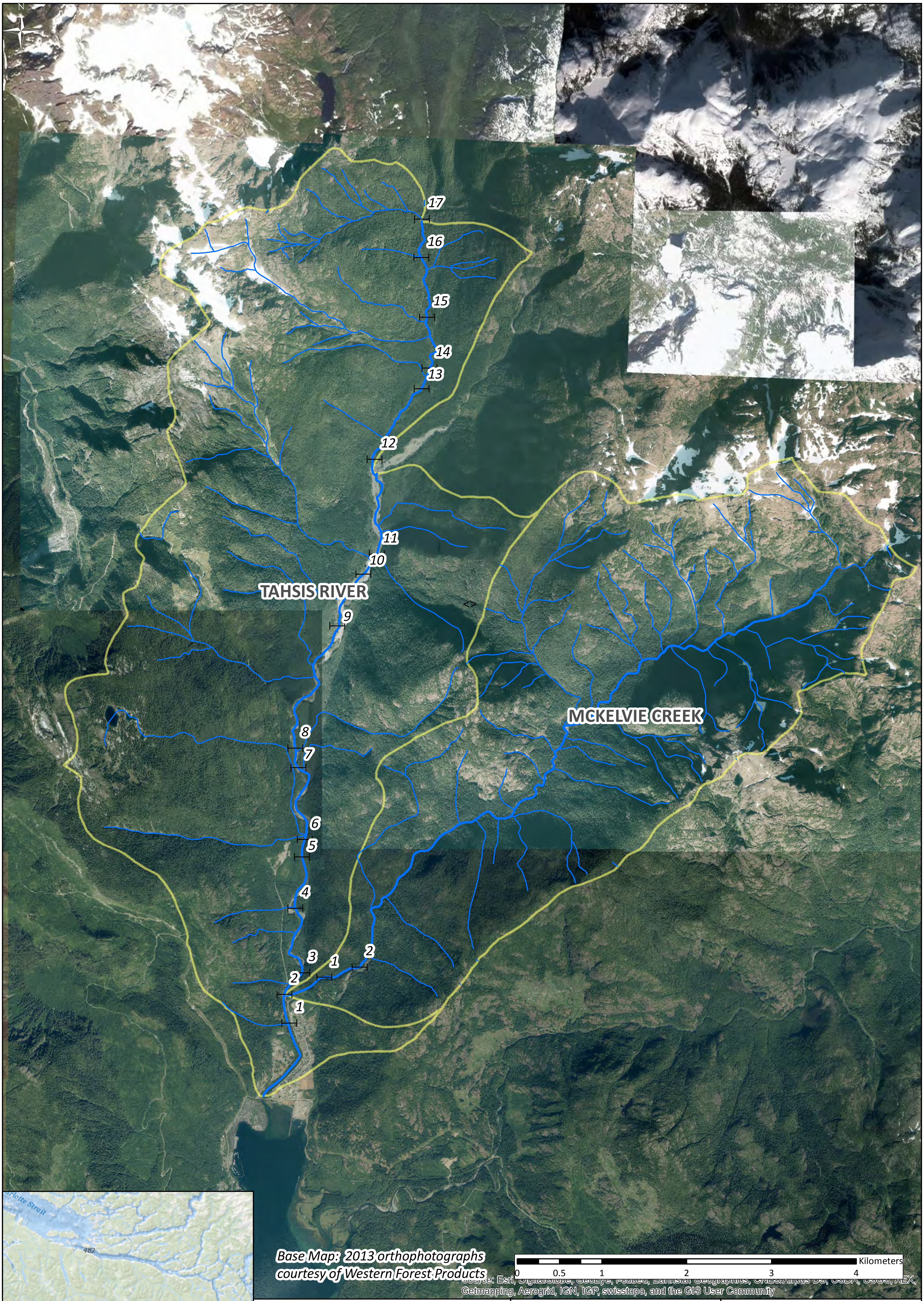
Dunlop, Roger. September 2014. Nootka Sound Watershed Society. Gold River, B.C.

Fiddick, Jim. March 2015. Western Forest Products Ltd. (Retired). Nanaimo, B.C.

Wright, Michael. March 2015. M.C. Wright and Associates Ltd. Nanaimo, B.C.

Tahsis Enhancement Society. May 2014. M.C. Wright and Associates Ltd. Tahsis, B.C.

APPENDIX 1: TAHSIS RIVER WATERSHED MAP ATLAS



Legend

- Reach Break
- TRIM River
- Watershed Boundary

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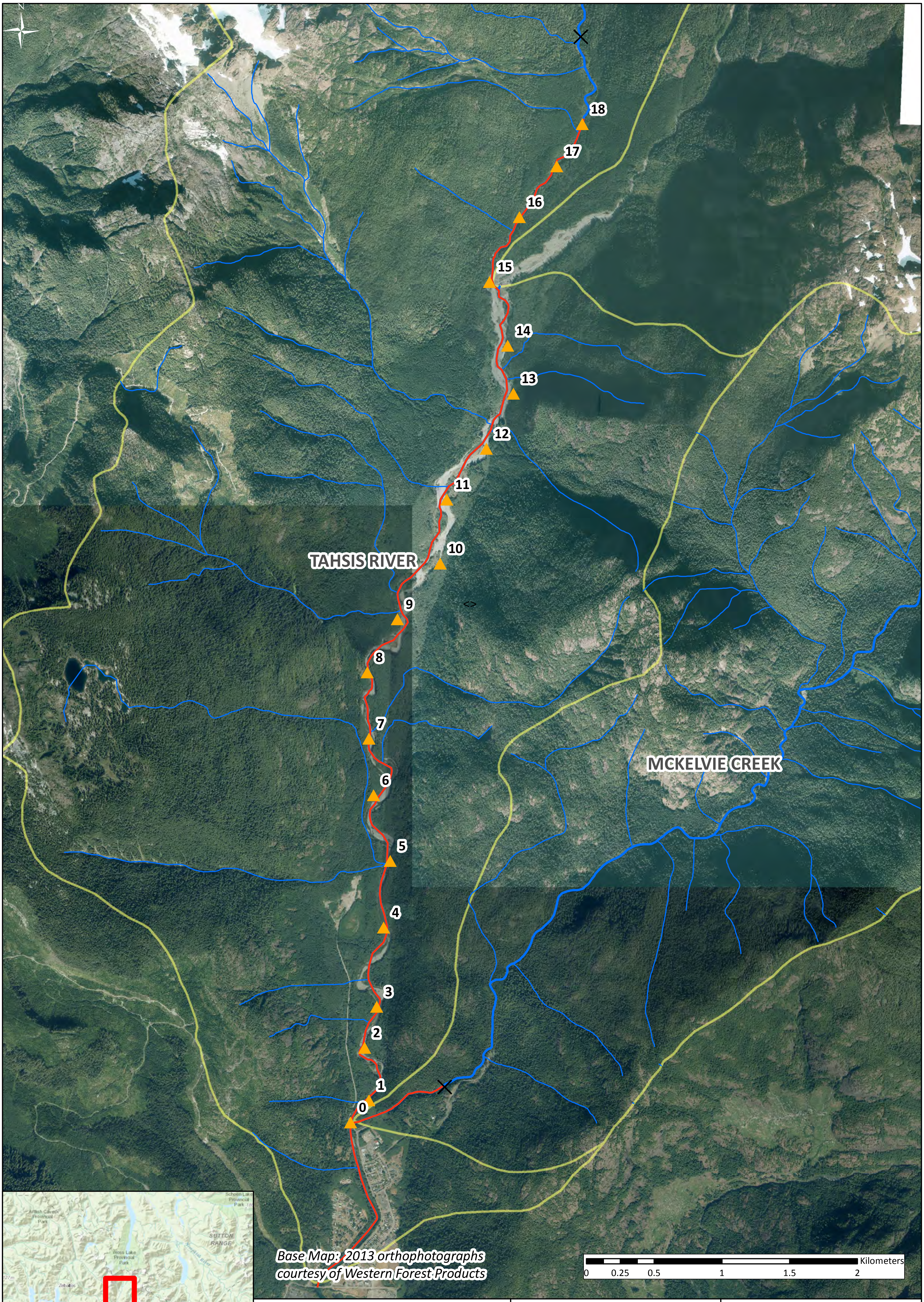
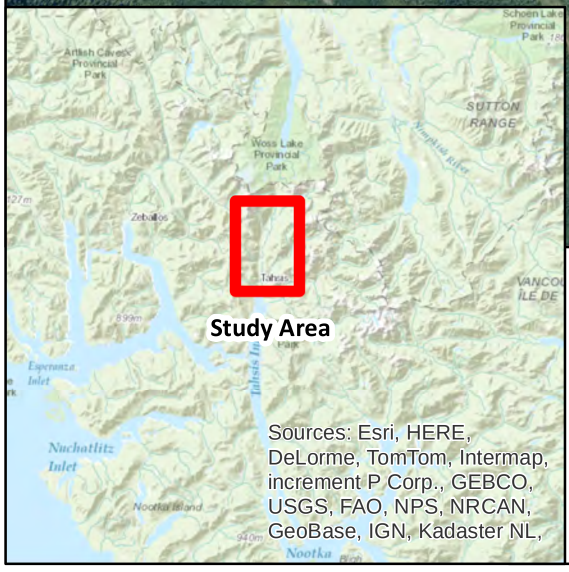
MAP 1

Tahsis River Watershed Reach Breaks





Legend

- Barrier to Fish Passage
- Counting Station
- Known Chinook Distribution
- TRIM River
- Watershed Boundary

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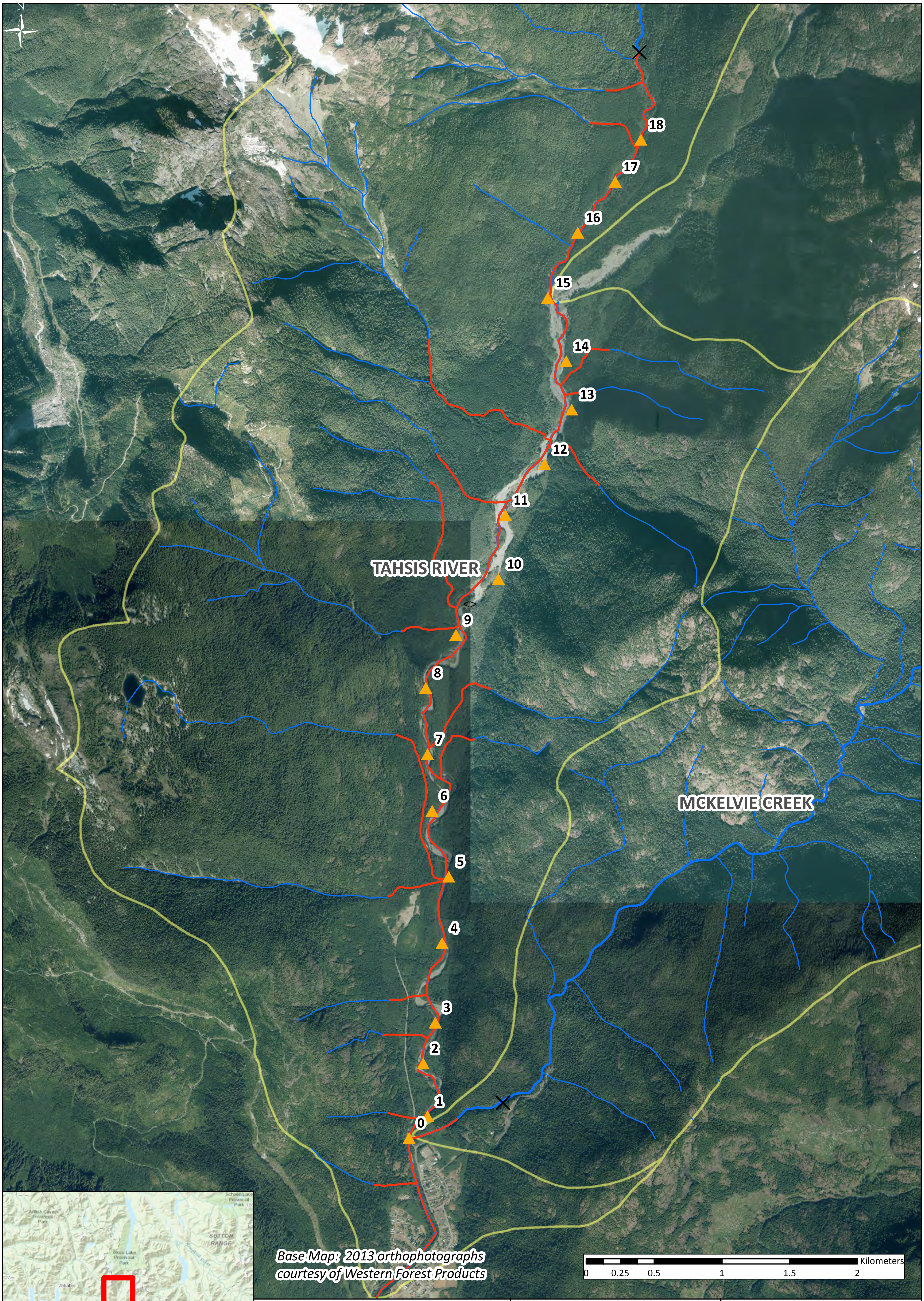
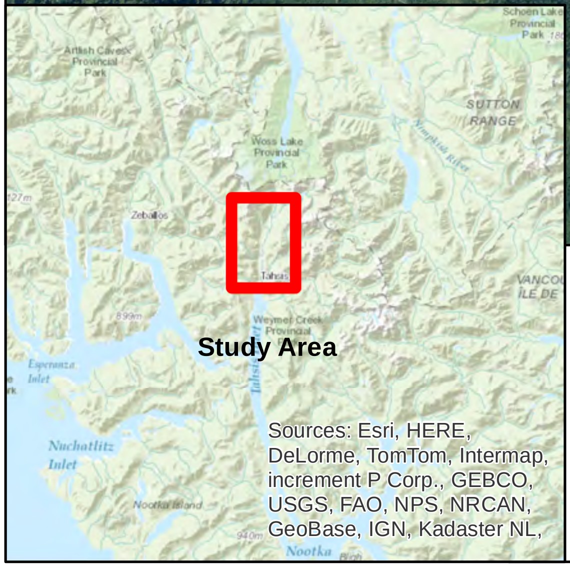
MAP 2

Tahsis River Watershed Known Chinook Distribution





Legend

- ✕ Barrier to Fish Passage
- ▲ Counting Station
- Known and Modeled Coho Distribution
- TRIM River
- Watershed Boundary

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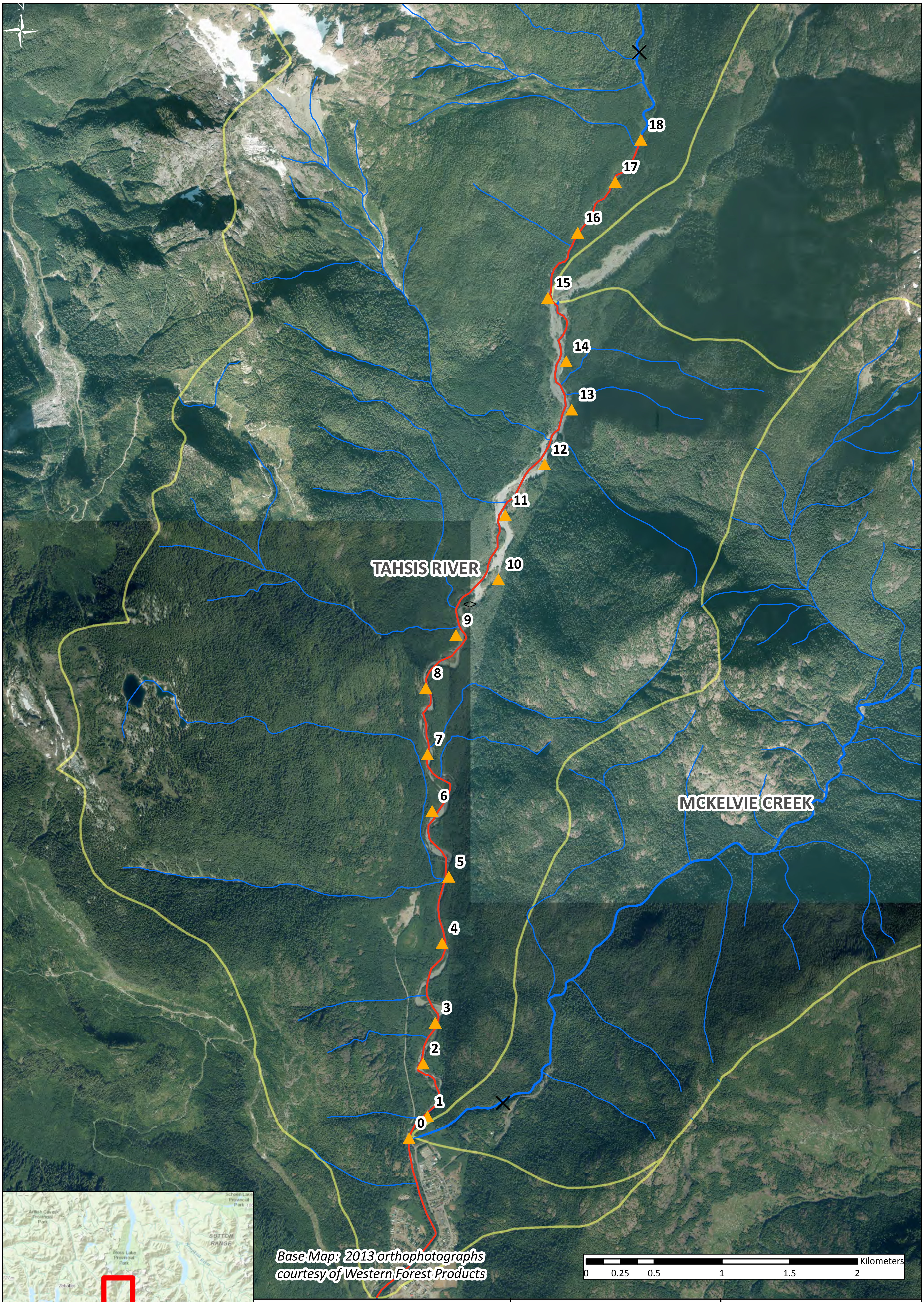
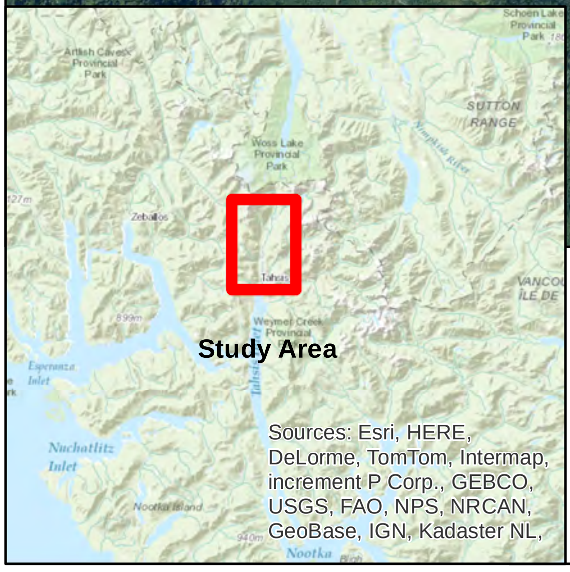
MAP 3

Tahsis River Watershed Known and Modeled Coho Distribution





Legend

- ✕ Barrier to Fish Passage
- ▲ Counting Station
- Known Sockeye Distribution
- TRIM River
- Watershed Boundary

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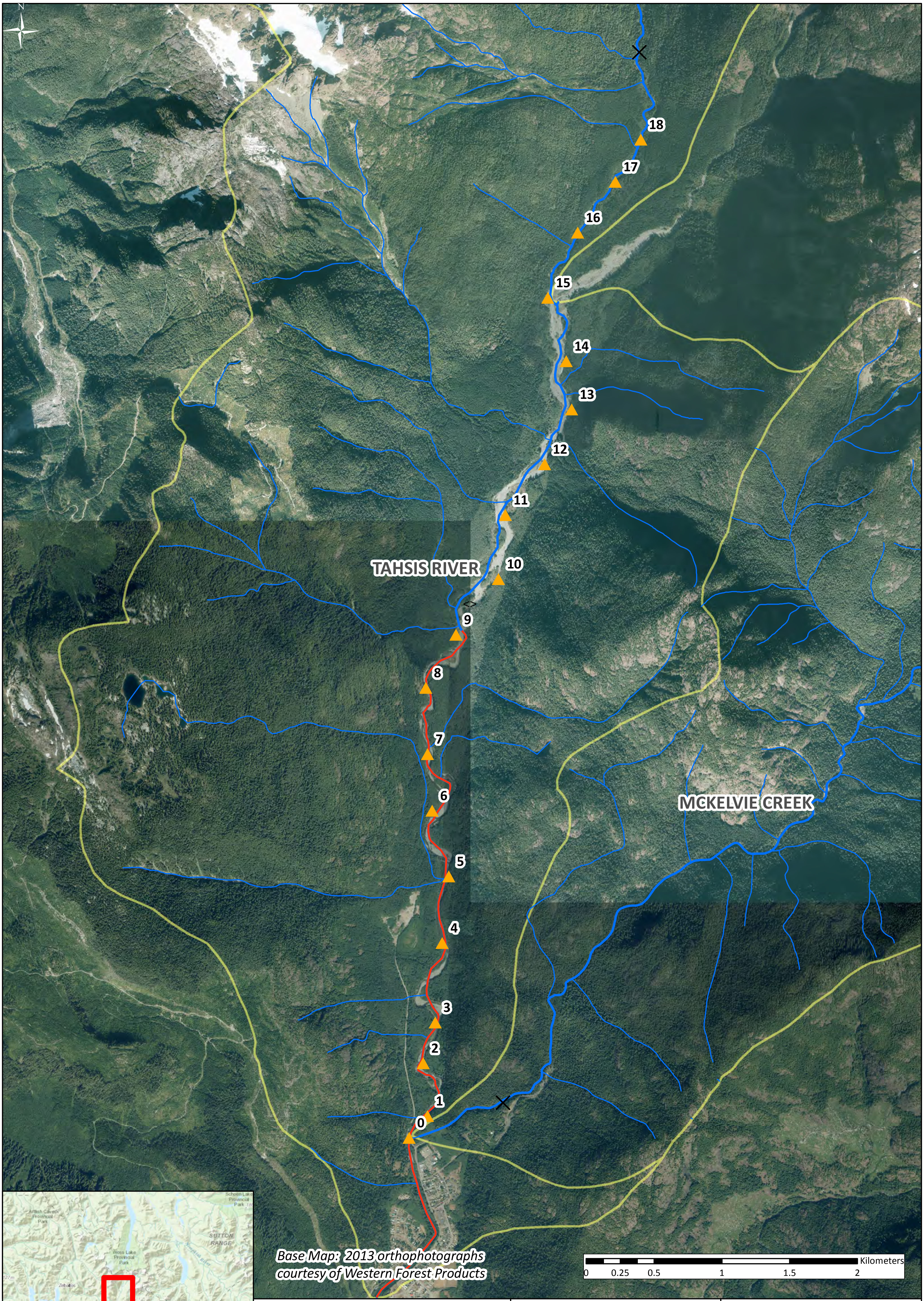
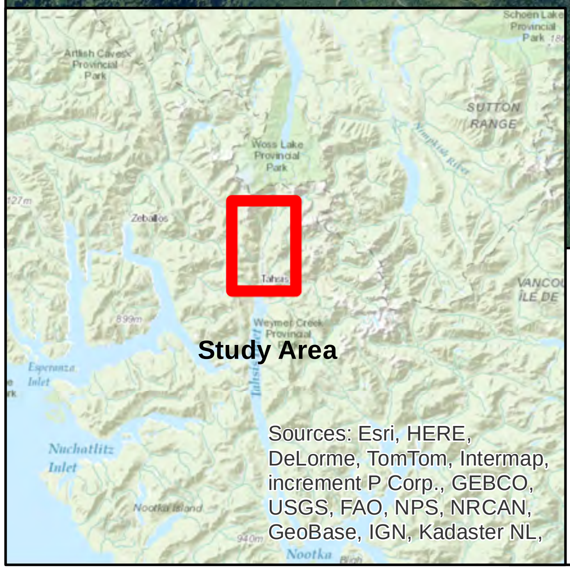
MAP 4

Tahsis River Watershed
Known Sockeye Distribution





Legend

- ✕ Barrier to Fish Passage
- ▲ Counting Station
- Known Chum Distribution
- TRIM River
- Watershed Boundary

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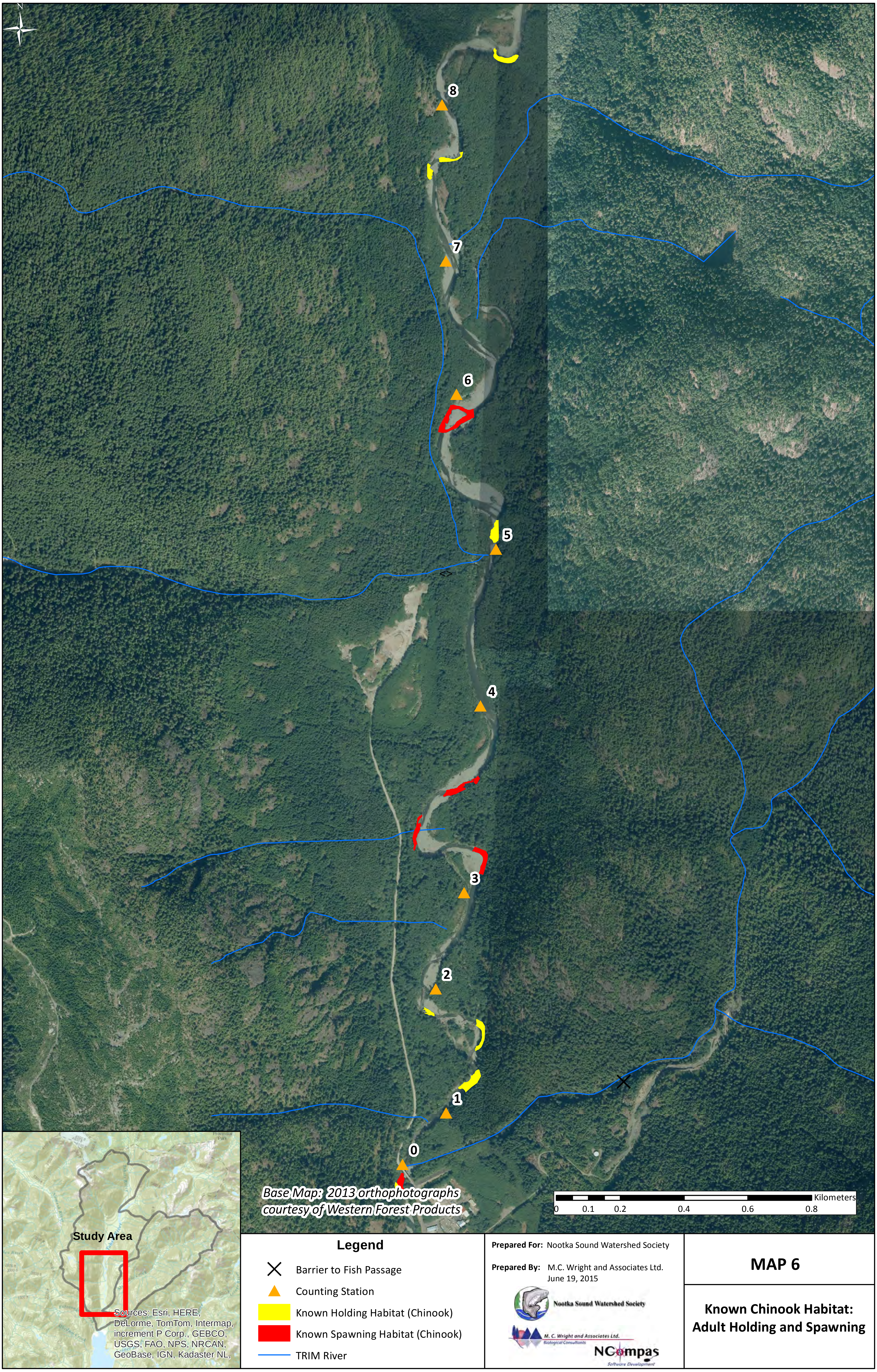
MAP 5

Tahsis River Watershed Known Chum Distribution



N
8
7
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5
4
3
2
1
0
Base Map: 2013 orthophotographs courtesy of Western Forest Products
Kilometers
0 0.1 0.2 0.4 0.6 0.8
Study Area
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL,
Legend
Barrier to Fish Passage
Counting Station
Known Holding Habitat (Chinook)
Known Spawning Habitat (Chinook)
TRIM River
Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
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M. C. Wright and Associates Ltd.
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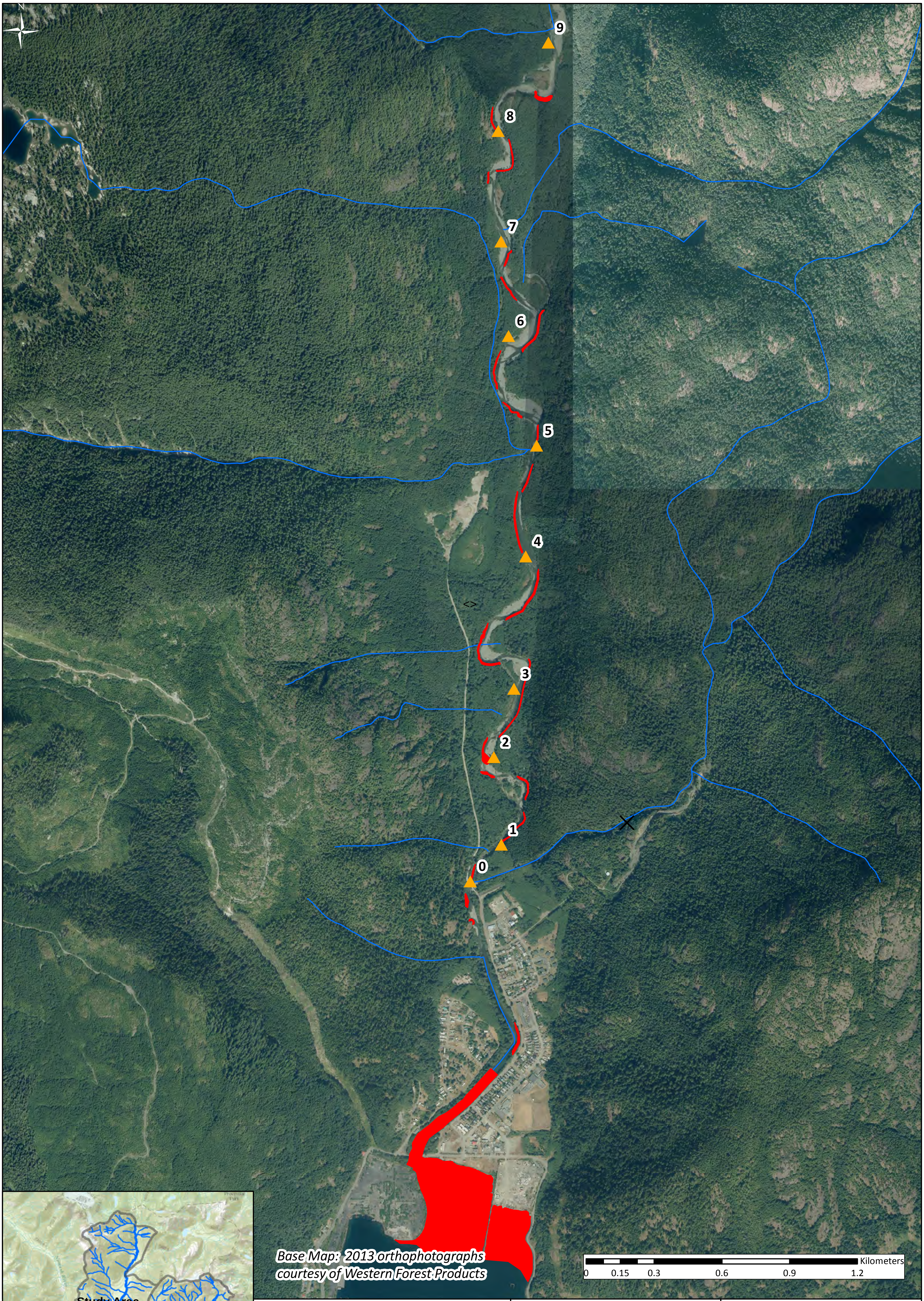
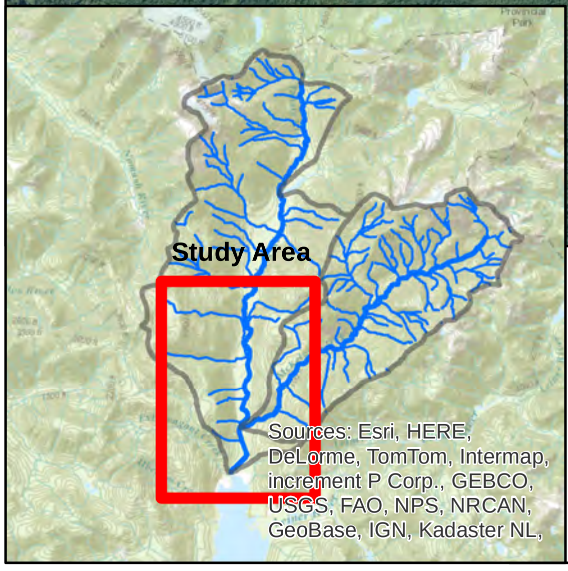
MAP 6
Known Chinook Habitat: Adult Holding and Spawning





Legend

- Barrier to Fish Passage
- Counting Station
- Known and Modeled Juvenile Rearing
- TRIM River

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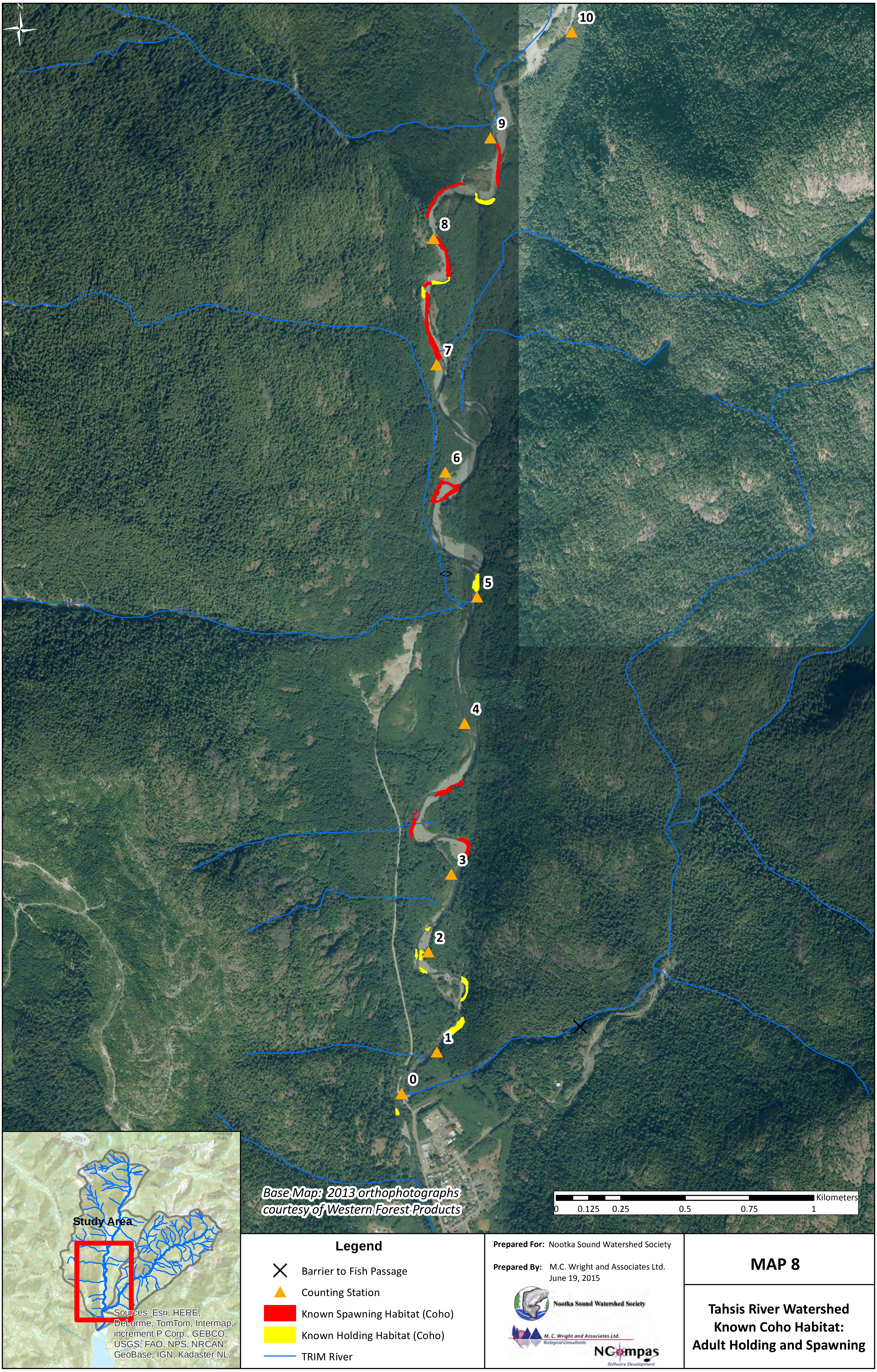
MAP 7

Tahsis River Watershed Known Chinook Habitat: Juvenile Rearing



N
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Base Map: 2013 orthophotographs courtesy of Western Forest Products
0 0.125 0.25 0.5 0.75 1 Kilometers
Study Area
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL,
Legend
Barrier to Fish Passage
Counting Station
Known Spawning Habitat (Coho)
Known Holding Habitat (Coho)
TRIM River
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Prepared By: M.C. Wright and Associates Ltd.
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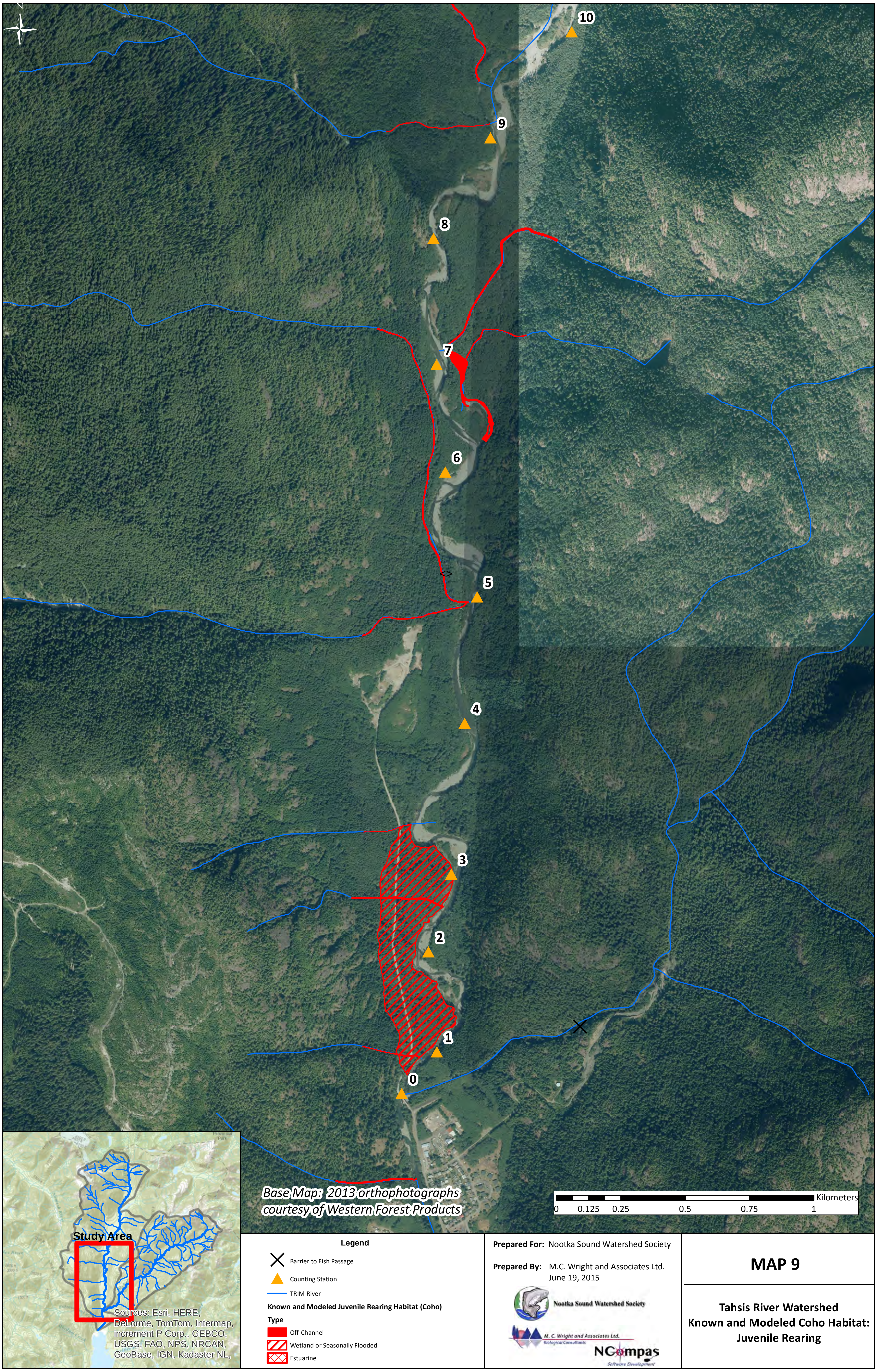
MAP 8
Tahsis River Watershed
Known Coho Habitat:
Adult Holding and Spawning



Legend

- Barrier to Fish Passage
- Counting Station
- TRIM River

Known and Modeled Juvenile Rearing Habitat (Coho)

Type

- Off-Channel
- Wetland or Seasonally Flooded
- Estuarine

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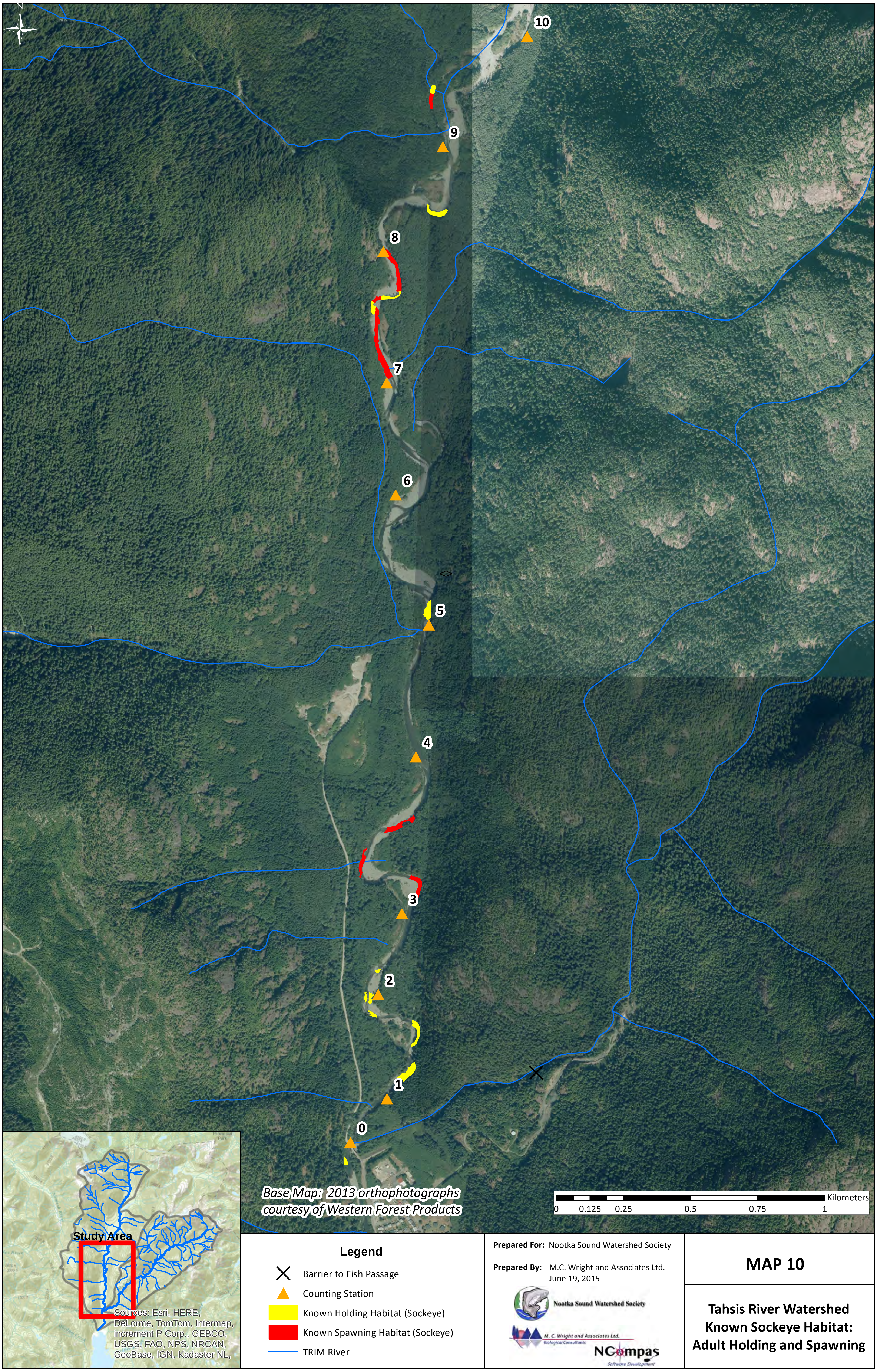
MAP 9

Tahsis River Watershed
Known and Modeled Coho Habitat: Juvenile Rearing



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Study Area
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL,
Base Map: 2013 orthophotographs courtesy of Western Forest Products
0 0.125 0.25 0.5 0.75 1 Kilometers
Legend
Barrier to Fish Passage
Counting Station
Known Holding Habitat (Sockeye)
Known Spawning Habitat (Sockeye)
TRIM River
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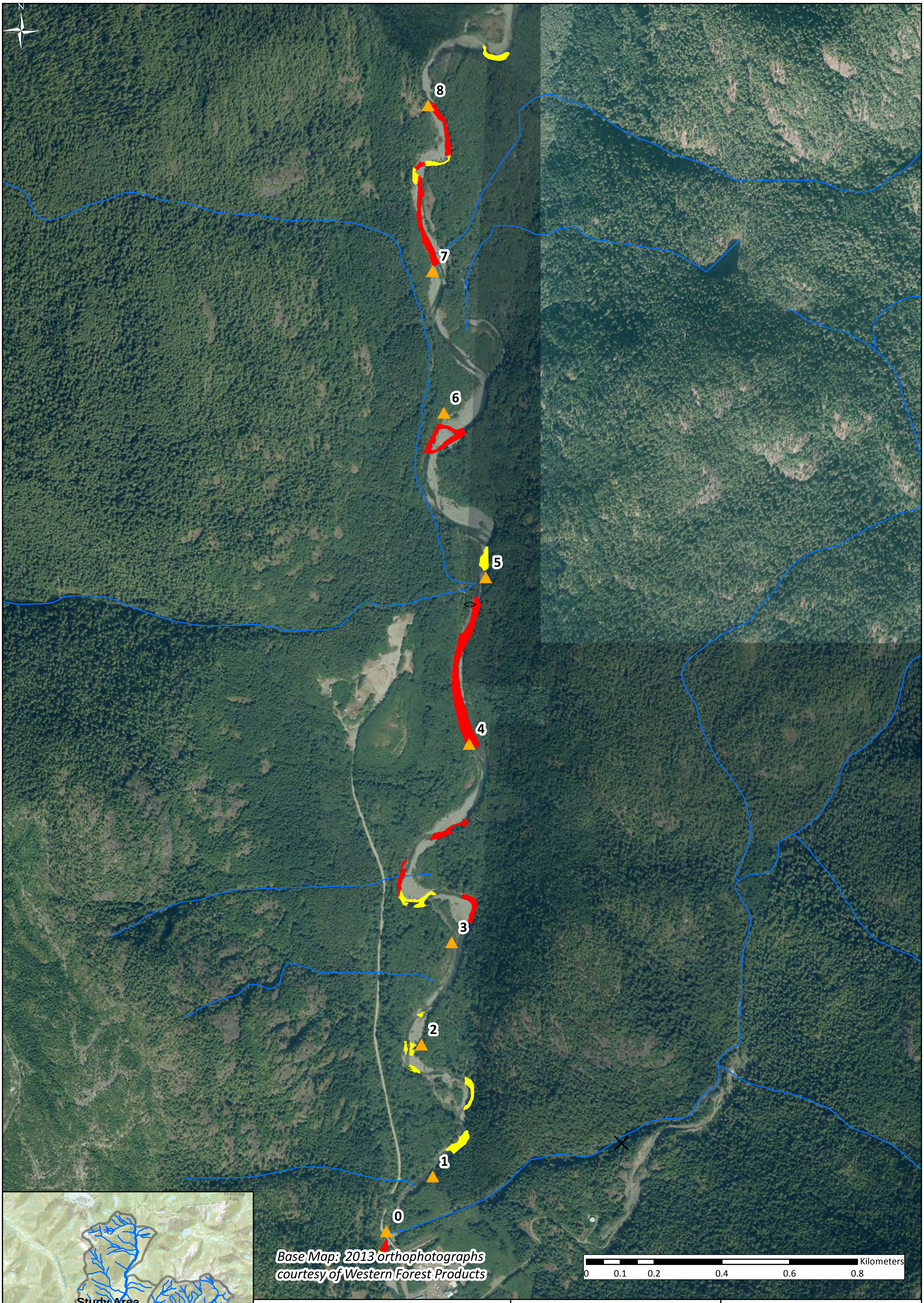
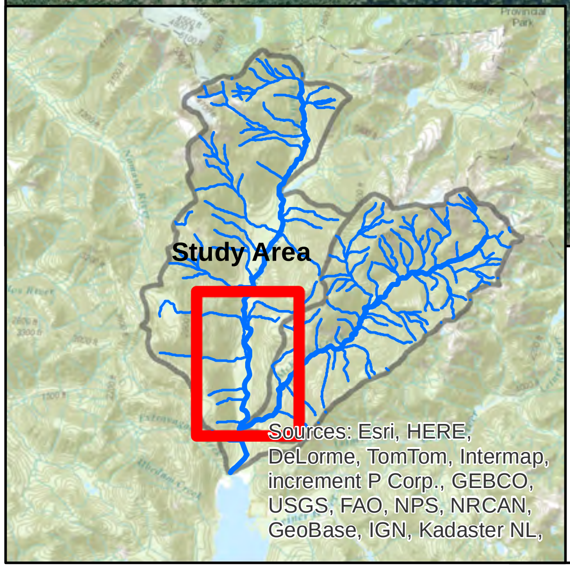
MAP 10
Tahsis River Watershed
Known Sockeye Habitat:
Adult Holding and Spawning





Legend

- Barrier to Fish Passage
- Counting Station
- Known Holding Habitat (Chum)
- Known Spawning Habitat (Chum)
- TRIM River

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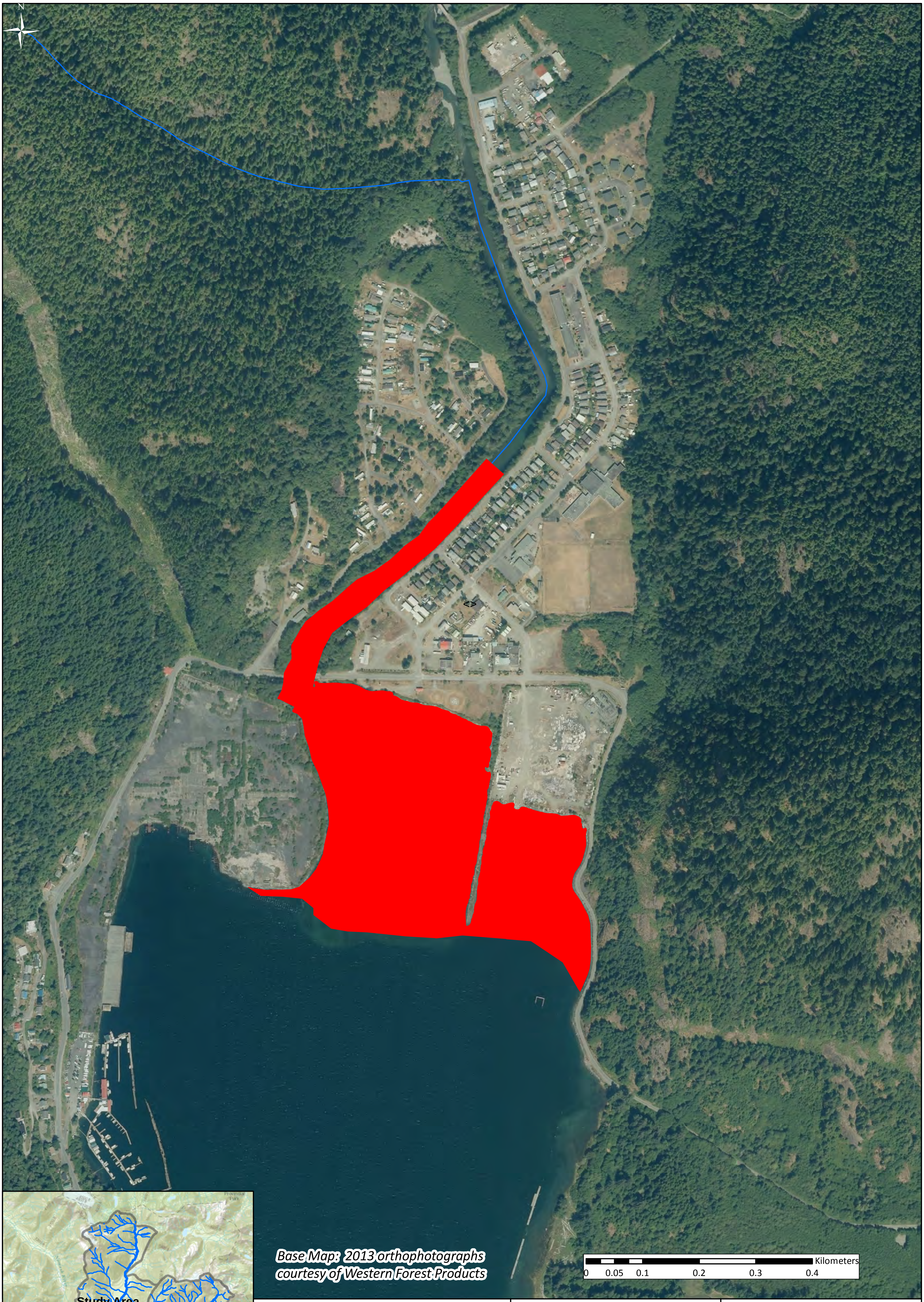
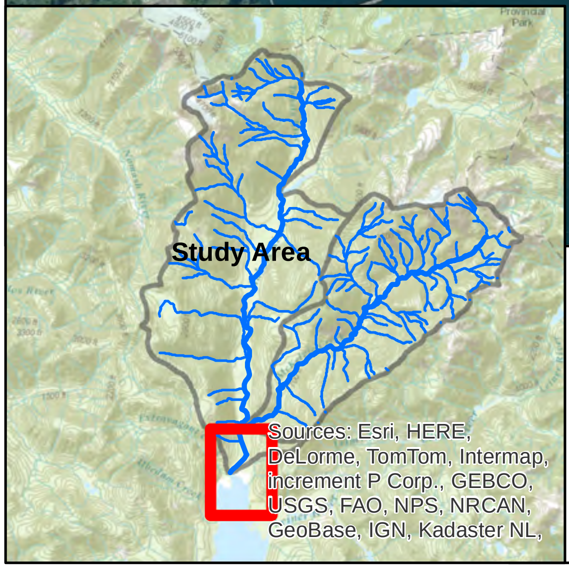
MAP 11

Tahsis River Watershed Known Chum Habitat: Adult Holding and Spawning





Legend

- Barrier to Fish Passage
- Counting Station
- Known Juvenile Rearing Habitat (Chum)
- TRIM River

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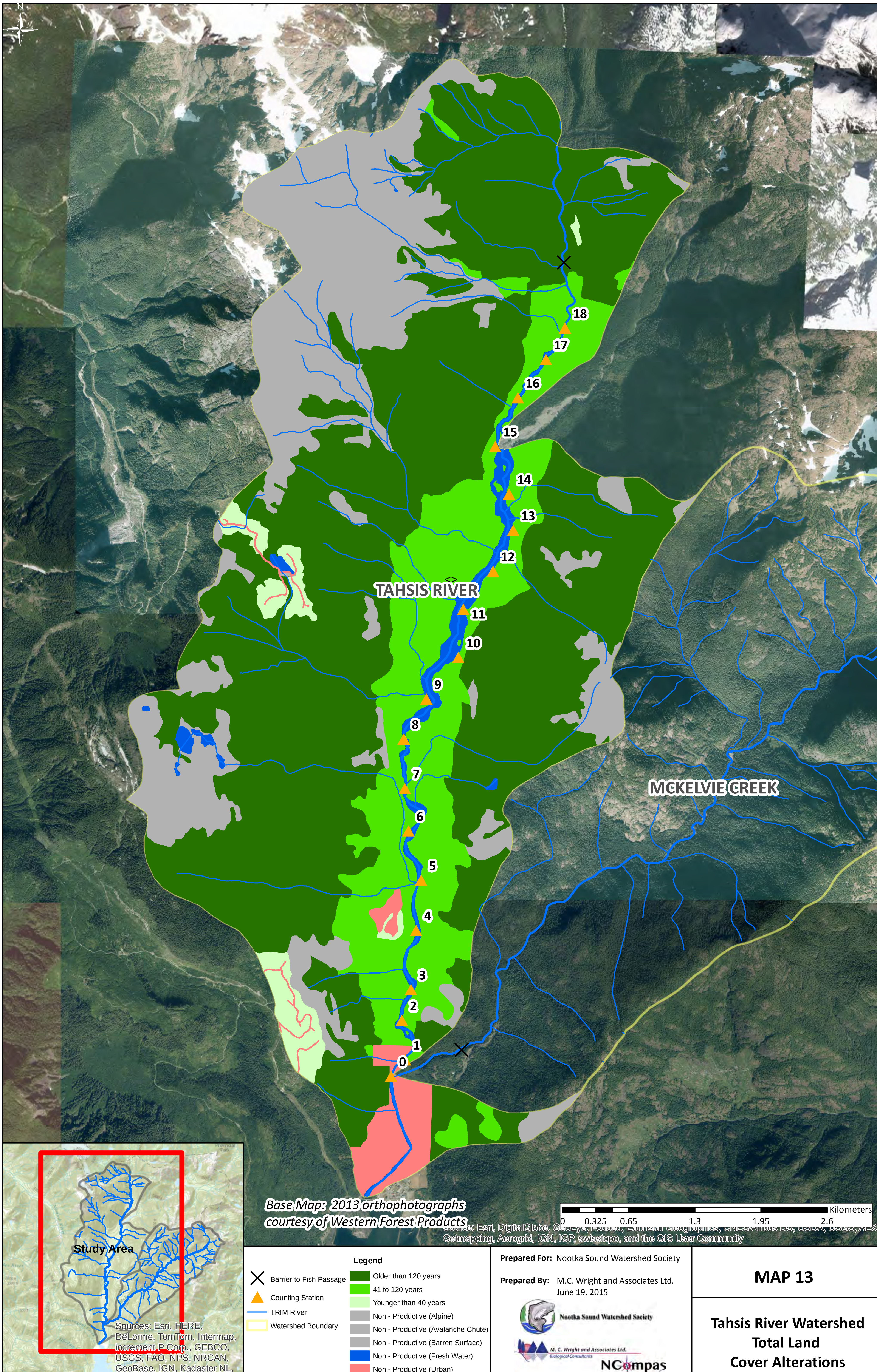
MAP 12

Tahsis River Watershed Known Chum Habitat: Juvenile Rearing



TAHSIS RIVER
MCKELVIE CREEK
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14
15
16
17
18
Study Area
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL,
Base Map: 2013 orthophotographs courtesy of Western Forest Products
0 0.325 0.65 1.3 1.95 2.6
Kilometers
Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community
Legend
Barrier to Fish Passage
Counting Station
TRIM River
Watershed Boundary
Older than 120 years
41 to 120 years
Younger than 40 years
Non - Productive (Alpine)
Non - Productive (Avalanche Chute)
Non - Productive (Barren Surface)
Non - Productive (Fresh Water)
Non - Productive (Urban)
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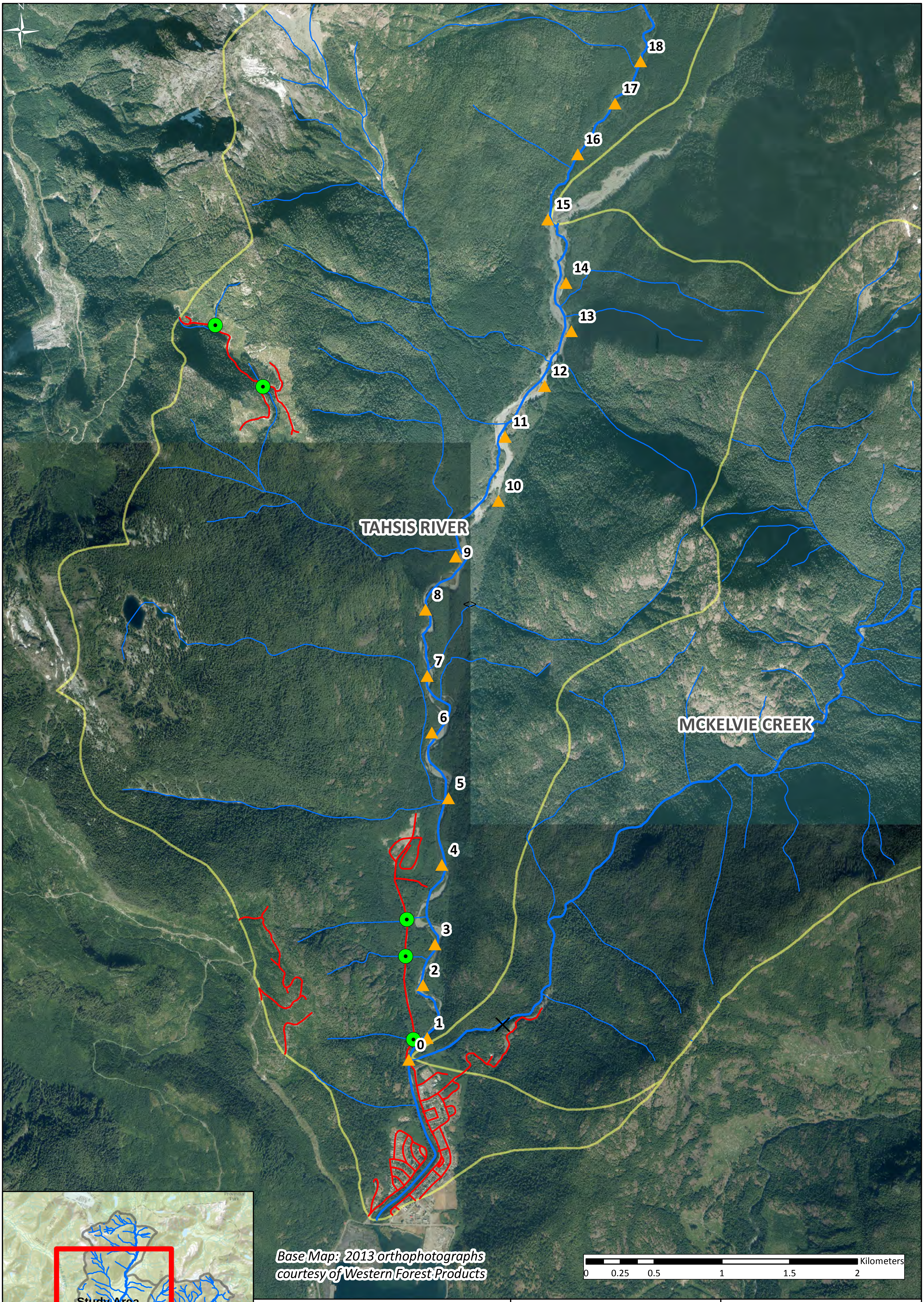
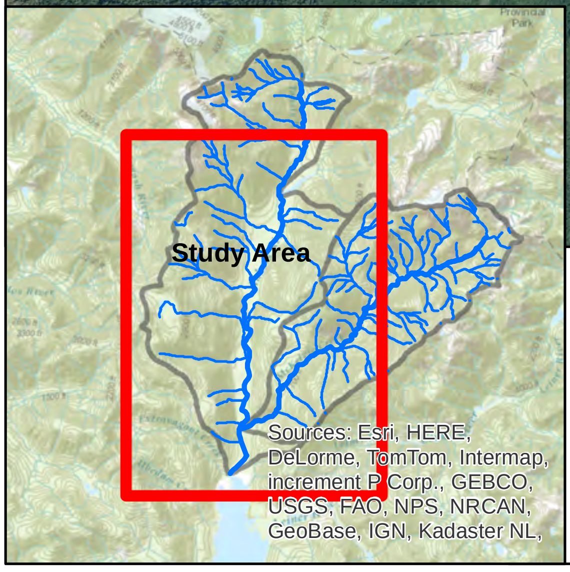
MAP 13
Tahsis River Watershed
Total Land
Cover Alterations





Legend

Barrier to Fish Passage	Road
Counting Station	TRIM River
Stream Crossing	Watershed Boundary

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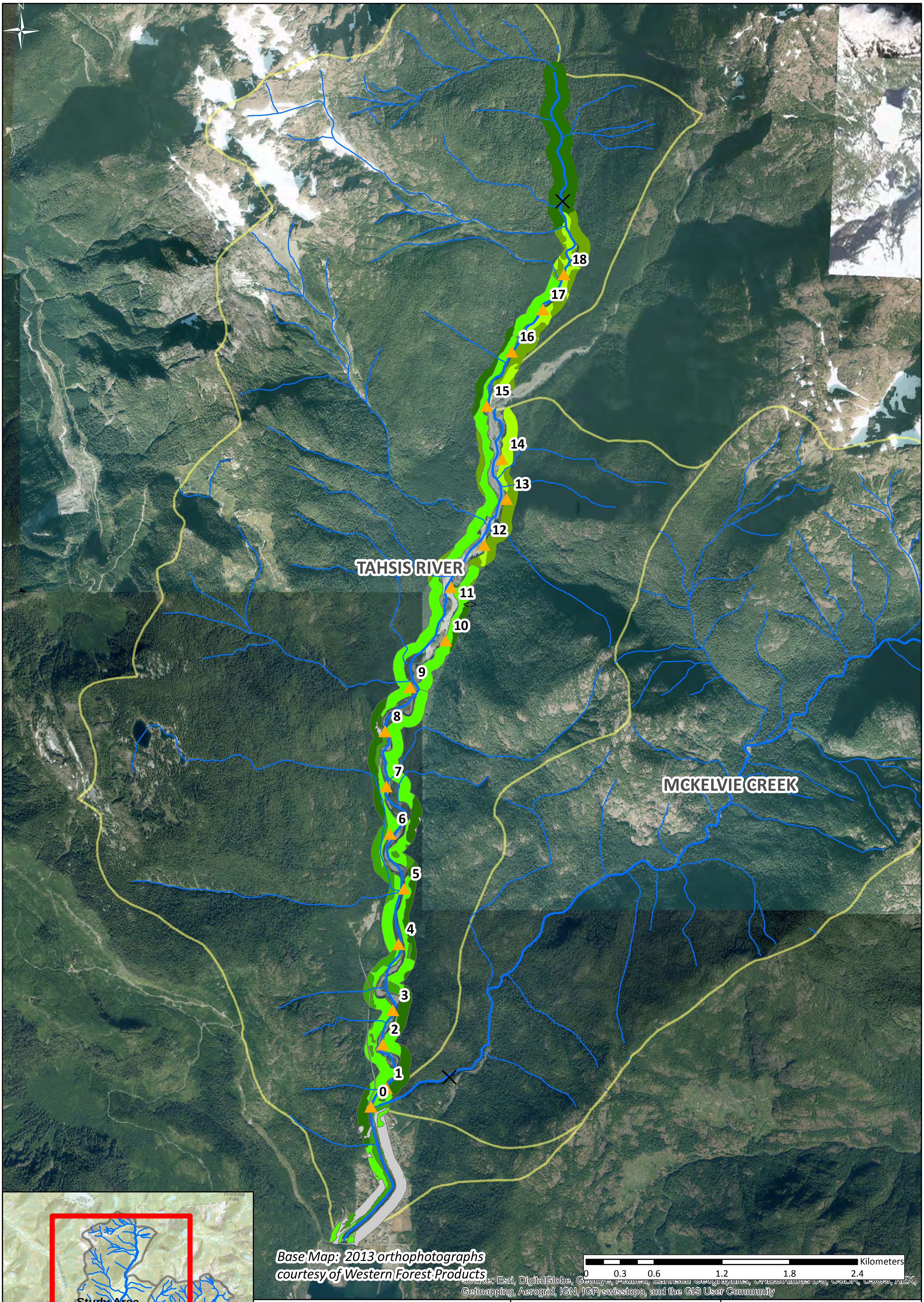
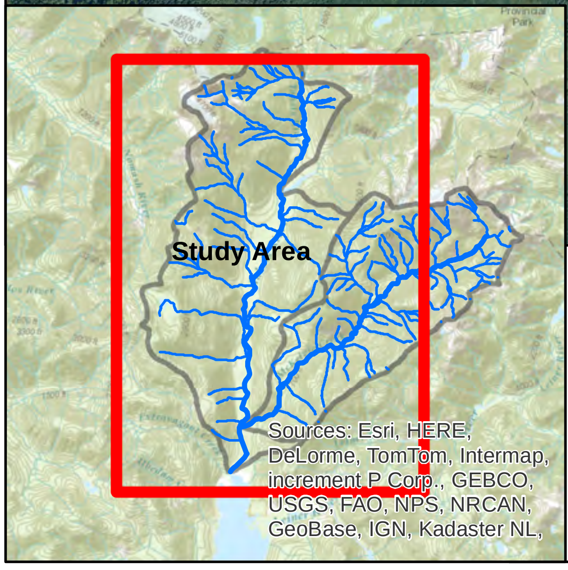
MAP 14

Tahsis River Watershed Road Density and Stream Crossings





Legend

Riparian Classification (2013)

- Mature Conifer
- Mature Mixed
- Deciduous or Regenerating
- Early Regenerating
- Bedrock
- Non-Productive
- Barrier to Fish Passage
- Counting Station
- TRIM River
- Watershed Boundary

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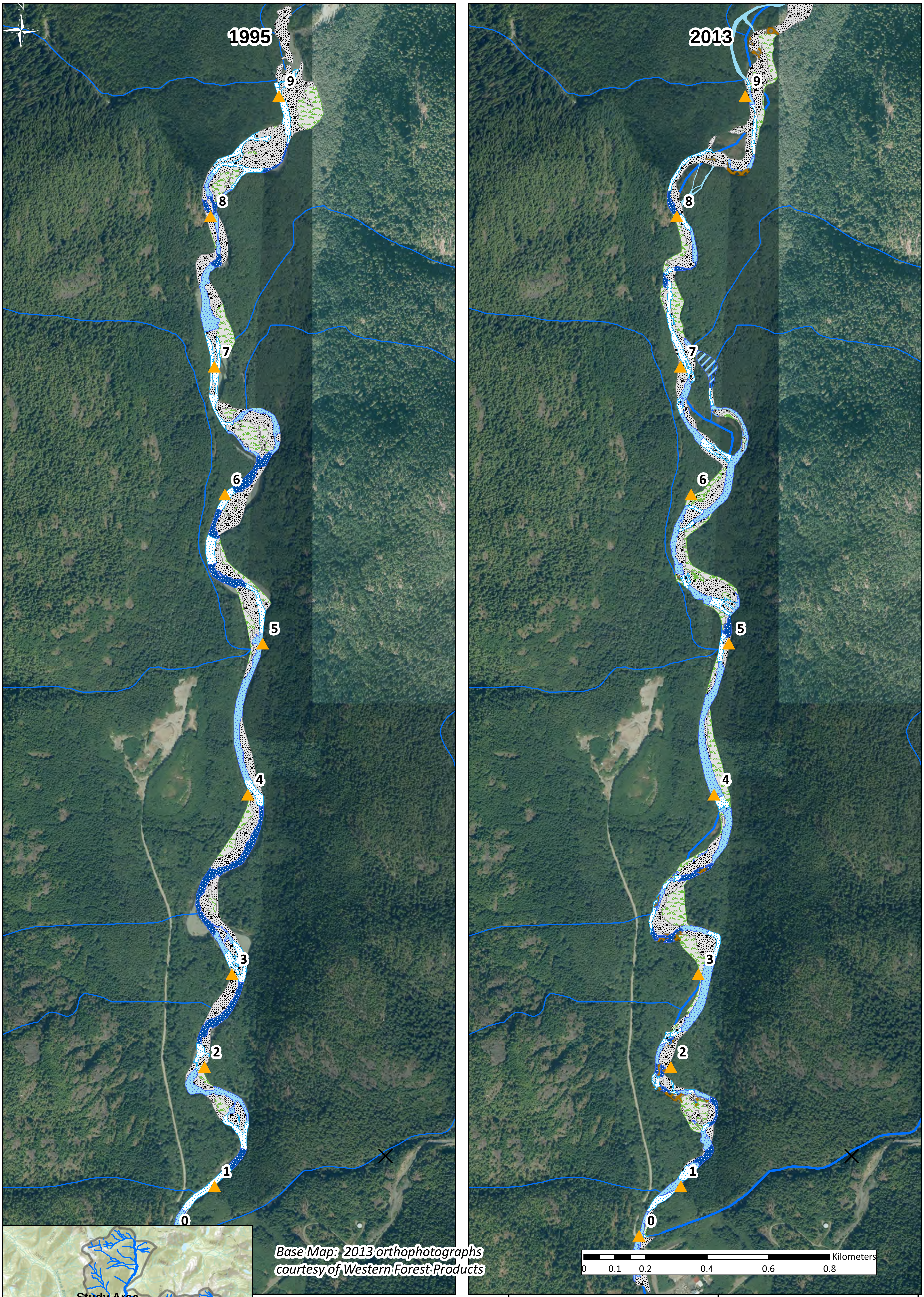
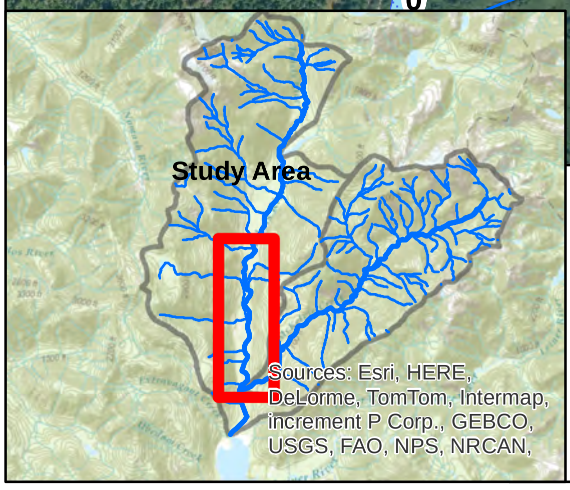
MAP 15

Tahsis River Watershed Riparian Disturbance





Legend

Habitat Type

- Braided
- Debris Jam
- Glide
- Gravel Bar
- Pool
- Riffle
- Secondary or Side Channel
- Vegetated Gravel Bar

- Barrier to Fish Passage
- Counting Station
- TRIM River

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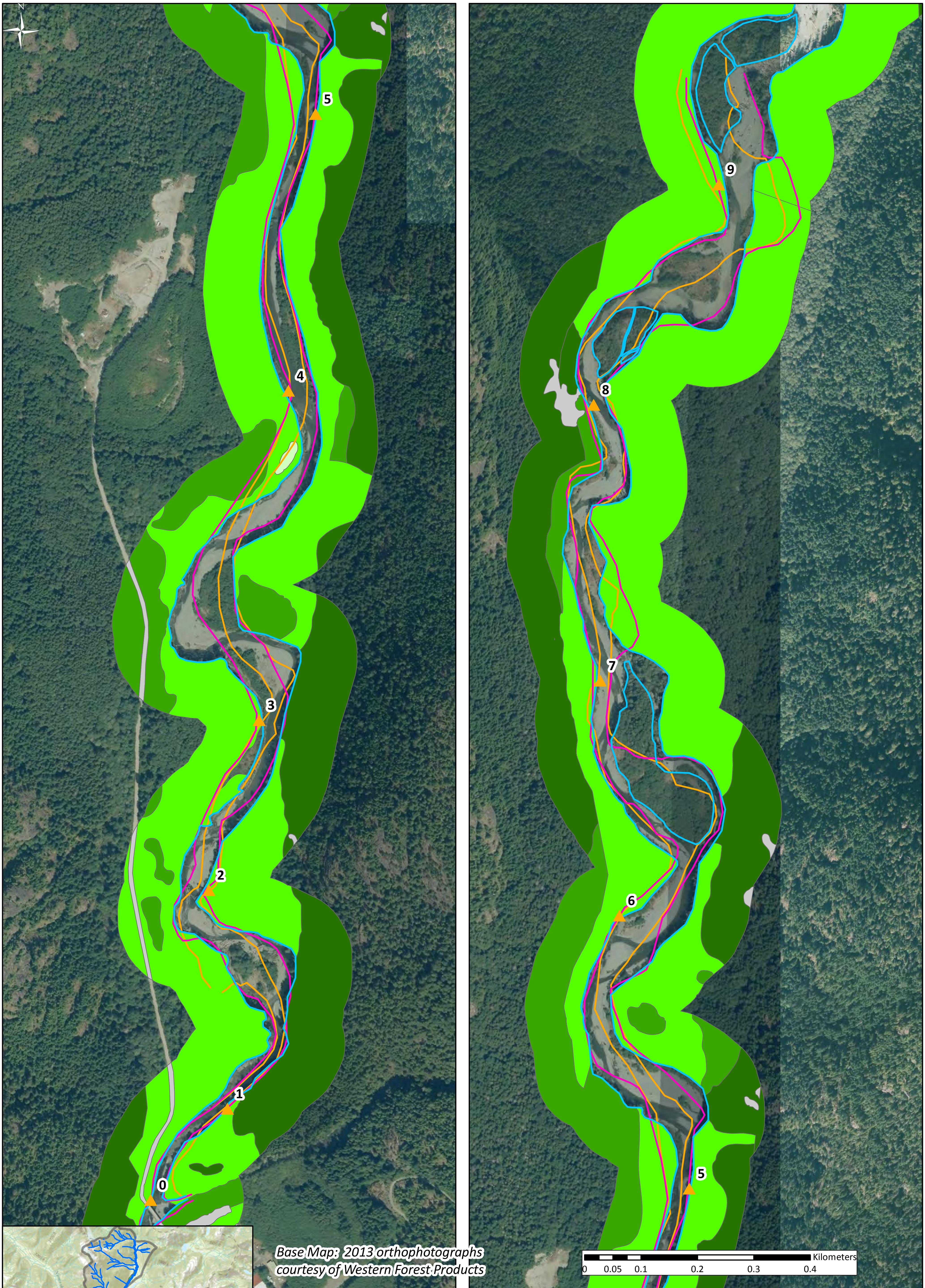
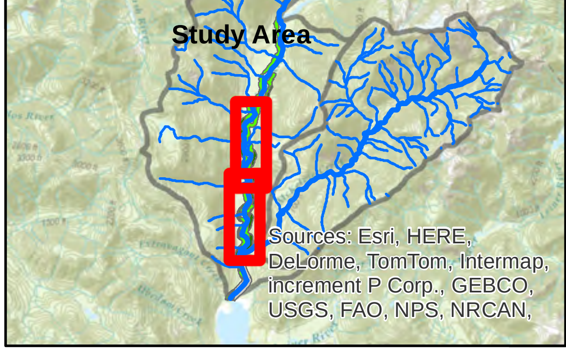
MAP 16

Tahsis River Watershed Habitat Composition 1995 vs. 2013





Legend

- Bankful Width (2013)
- Bankful Width (1995)
- Bankful Width (1980)
- Counting Station

Riparian Classification

- Deciduous or Regenerating
- Early Regenerating
- Mature Conifer
- Mature Mixed
- Non-Productive
- Bedrock

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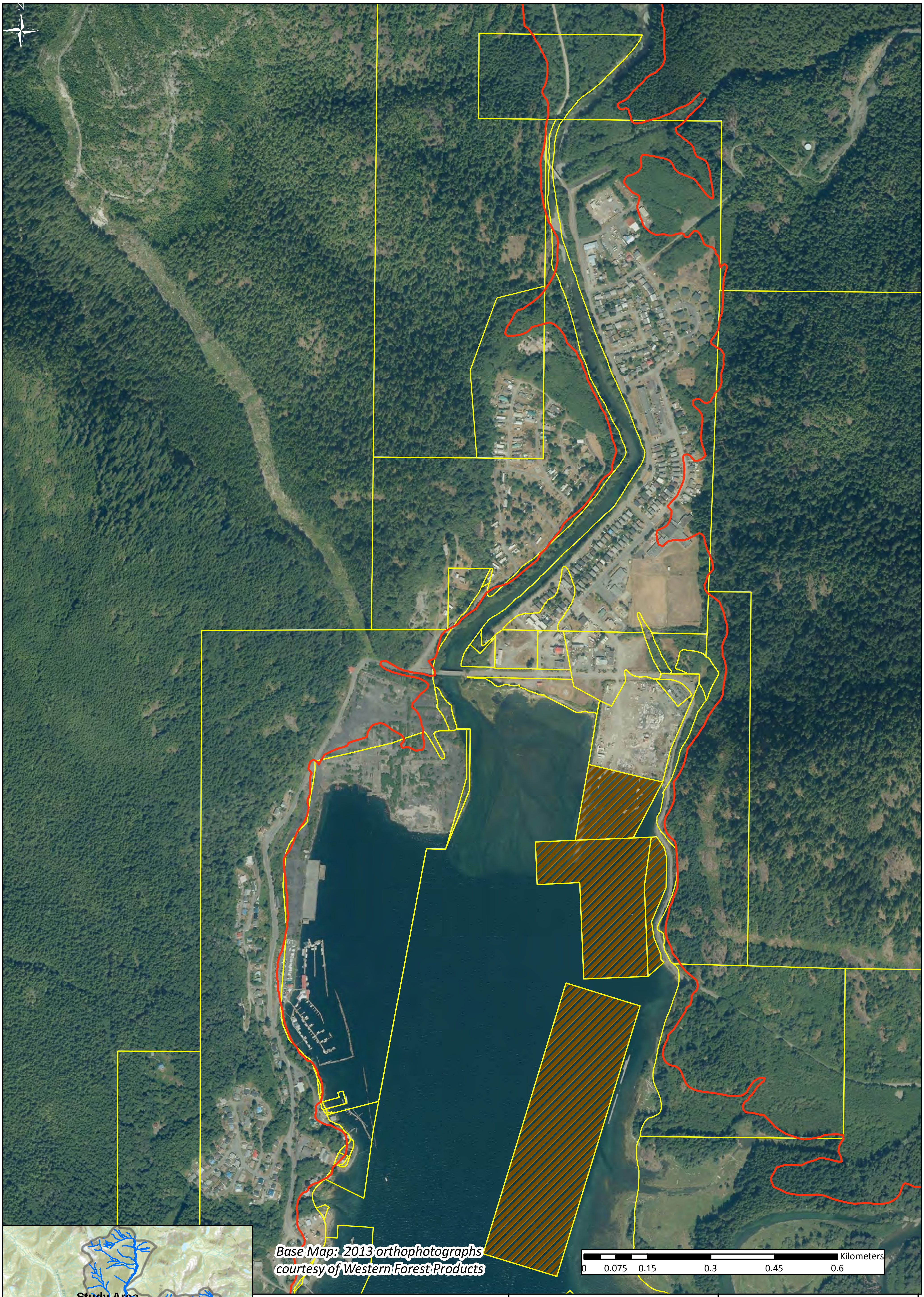
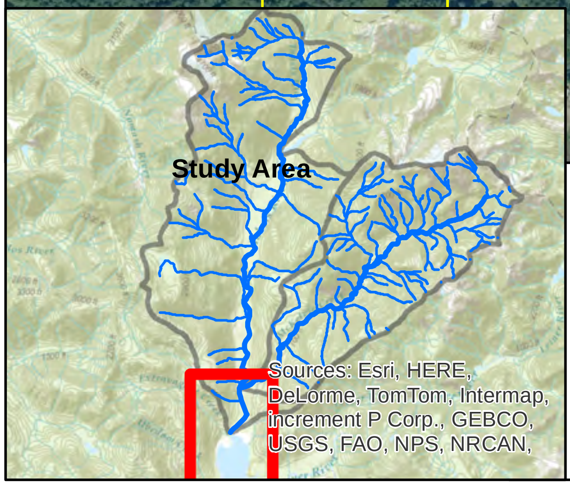
MAP 17

Tahsis River Watershed Channel Bank Stability 1980 to 2013





Legend

Floodplain (200 year)

Tantalis Survey Parcels

Crown Lease: Log Handling / Storage

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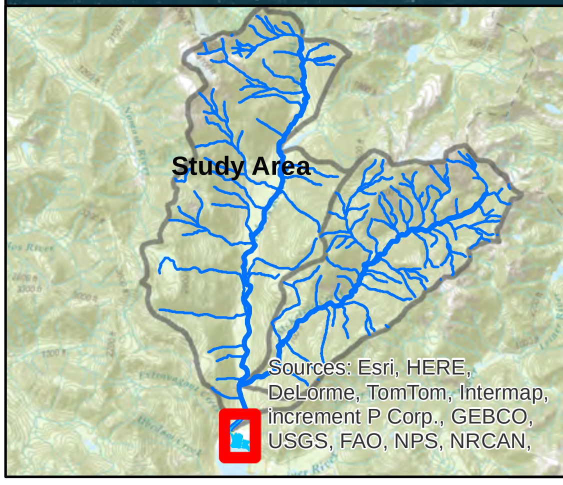
MAP 18

Tahsis River Watershed
Estuary Habitat Disturbance



Legend

- Bedrock
- Gravel
- Mature Forest
- Sand / Mud Flat
- Salt Marsh
- Water
- Woody Debris Deposition

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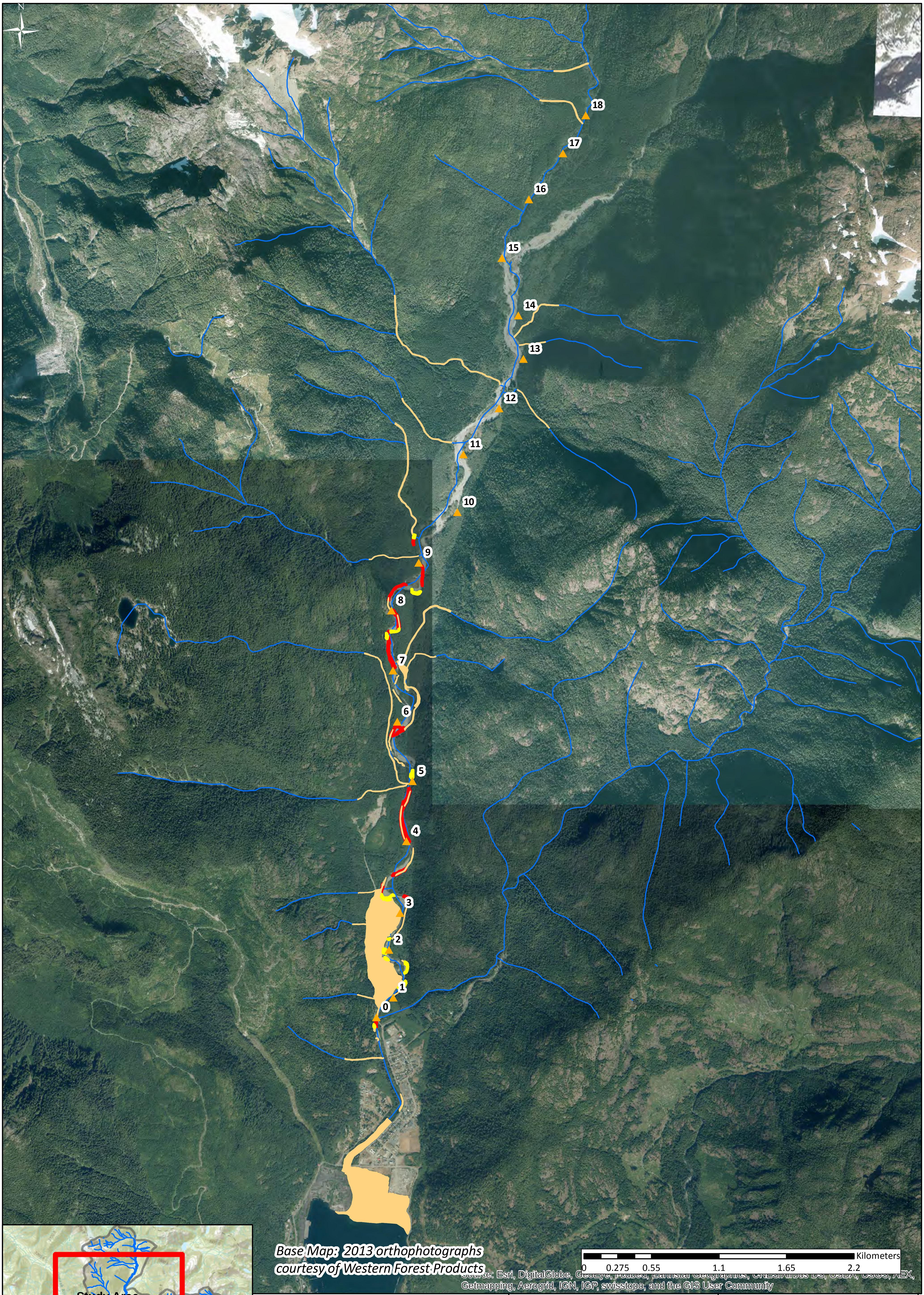
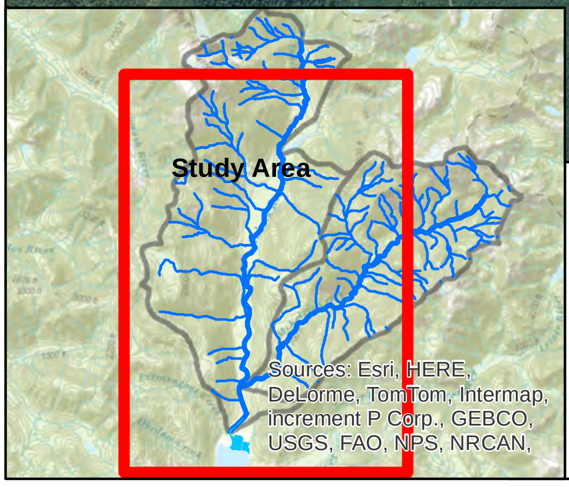
MAP 19

Tahsis River Watershed Estuary Habitat Composition





Legend

- Counting Station
- Known Holding Habitat
- Known Juvenile Migration and Rearing Habitat
- Known Spawning Habitat
- TRIM River

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MAP 20

Tahsis River Watershed Best Functioning Habitats Requiring Protection