Wild Salmon Policy - Strategy 2: Fish Habitat Status Report for the Tsowwin 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 Tsowwin 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 Tsowwin River, as well as known 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 Tsowwin River watershed.

In addition to the abovementioned 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. Tahsis River, Leiner and Perry Rivers, Sucwoa River, Canton Creek, and the Conuma River) have been assessed under the same framework and habitat status reports have been completed.

1.2 Tsowwin River Watershed

The Tsowwin River watershed is located approximately 100km west of Campbell River, B.C., and 40 km northwest of Gold River, B.C. (Figure 1). This system drains from its headwaters bordering the western margin of the Sucwoa River watershed, and drains southwest into the Tsowwin Narrows in Tahsis Inlet. The Tsowwin River watershed encompasses a drainage area of approximately 35.9km^2.

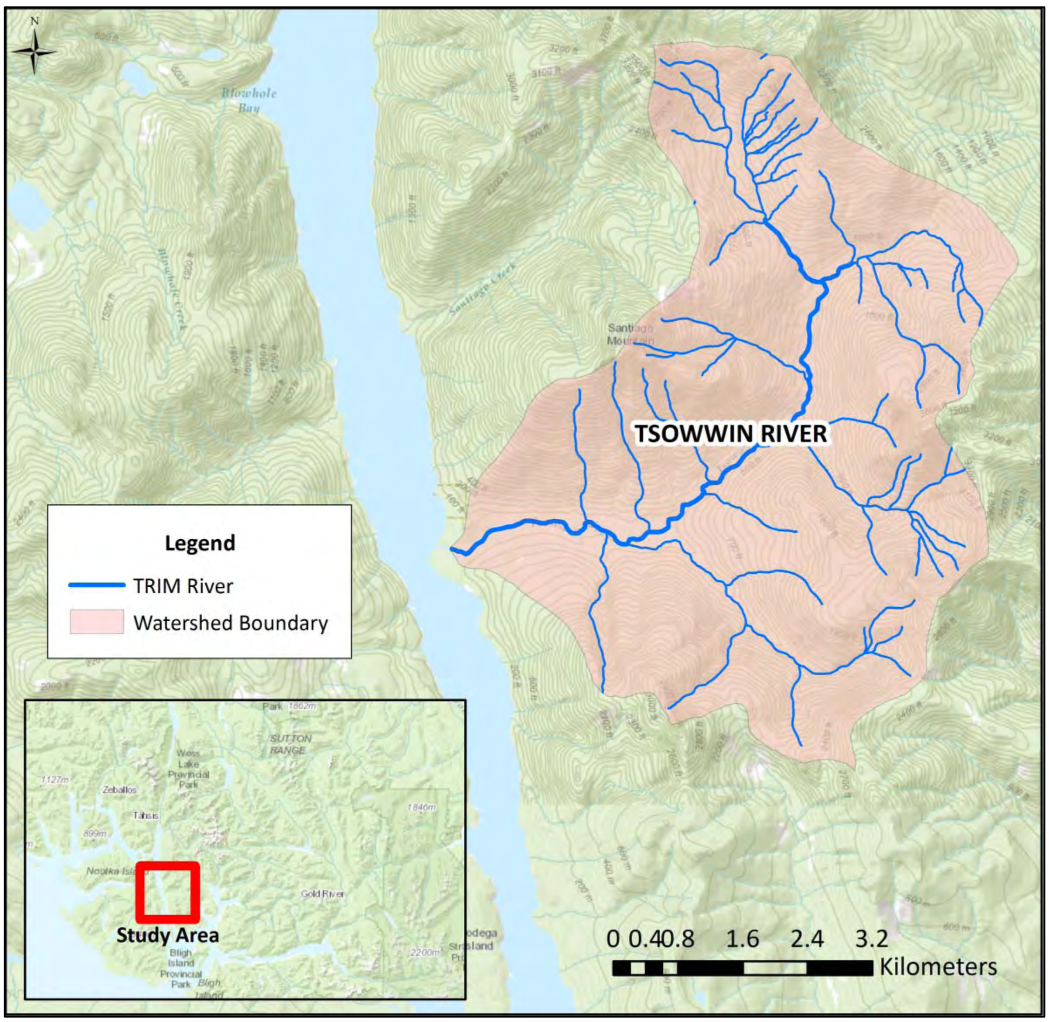

Figure 1. General location map of the Tsowwin River watershed.

1.2.1 Climate, Topography, and Hydrology

The Tsowwin River watershed is situated primarily within the coastal western hemlock (montane and submontane very wet maritime) biogeoclimatic zone, with small components situated in the mountain hemlock (moist maritime) zone (Horel, 2008). This area has a mild oceanic climate with high humidity, with the majority of its annual precipitation received as rain. The closest Environment Canada climate station located at the Conuma River hatchery identified the annual average rainfall in the area to be 3,619mm (Horel, 2008). Given this high annual precipitation, streams in this area experience large-scale, rapid fluctuations in flow (Witt and Clozza, 1980).

The Tsowwin River watershed is an ovoid-shaped watershed with variable valley alignmetnt, no lakes, and a dendritic drainage pattern. The lower 3.5km of the watershed has a narrow valley floor and floodplain that varies in width and a partially confined alluvial channel. The terrain transitions from moderate slopes lower in the watershed to steeps slopes in the upper watershed, with a significant component of terrain situated in slopes exceeding 60% in gradient. Above 3.5km the valley floor narrows and the channel becomes semi to non-alluvial with a short section of alluvial (Horel, 2008).

1.2.2 Watershed Description

An analysis of watershed indicators by Horel in 2008 identified the Tsowwin River watershed to be highly sensitive based on the regional landslide frequency, total area of the watershed 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 moderately disturbed with scoured nonalluvial channels and aggraded alluvial channels from development-related and natural landslides (Horel, 2008). Watershed trends (identified through the interpretation of risk ratings and changes over time observed in air photos, satellite imagery, and helicopter reconnaissance) indicated that noticeable improvements in conditions will take approximately 10 years (Horel, 2008).

The mainstem of the Tsowwin River measures approximately 11.5km in length, with approximately 5.9km of which are fish-bearing. The barrier to anadromous fish distribution is described as a log jam that is only passable to fish at high flows (FISS, 2014).

Over the years, the Tsowwin River has been affected by severe flooding and aggradation. Severe flooding in 1965 resulted in extensive scouring of the Tsowwin River mainstem, affecting an estimated 90% of the streambed and negatively impacting both chinook and chum spawn. Landslides resulting from significant storms in 1996 scoured nonalluvial streams and caused aggrading in alluvial reaches of the mainstem and tributaries (Horel, 2008).

1.2.3 Watershed History

The Tsowwin River resides within the traditional territory of the Mowachaht First Nation, who have resided 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 handloggers settling in Tahsis Inlet as early as 1882 (Sellars, 1992).

Resource Extraction

Harvesting began in the Tsowwin River valley in the 1940s. By the late 1940s, the majority of the valley had been logged off, and initial operations were complete by 1951. Road construction connecting the Sucowa River watershed to the Tsowwin River watershed commenced in 1975. Road construction along the river began in 1975 and by 1976, changes in the river course due to channel instabilities were noted, with changes to the mainstem observed after every flood. Logging re-commenced in 1978, with heavy harvesting continuing through to the late 1980s (Photo 1) (Fisheries and Oceans Canada, 1949 - 1994). Since this time, the channel has somewhat stabilized, with predominantly alder regeneration (Horel, 2008).

At present, the Tsowwin River watershed land base is owned by the Crown and licensed for harvest under TFL 19.

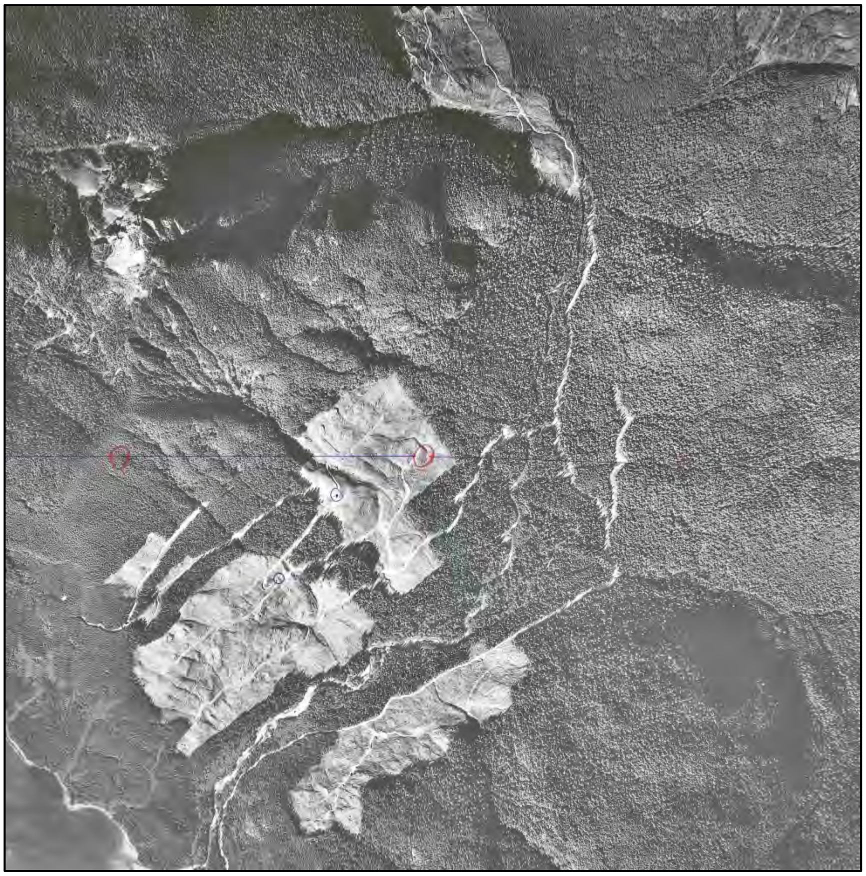

Photo 1. Forest harvesting in the Tsowwin River watershed in 1980.

No other developments, with the exception of a log dump near the Tsowwin River estuary, were identified within this watershed.

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 1. 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 Tsowwin River watershed occurred following a comprehensive literature review and spatial data gathering and analyses. In addition to the indicators describe in Table 1, 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 information compiled during the literature review and spatial data gathering, interviews with the Nootka Sound Watershed Society and other experts in the area were conducted to incorporate local knowledge of the Tsowwin River. These interviews were conducted during the Nootka Sound Risk Assessment Workshop in Gold River on 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 Tsowwin 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, 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 Tsowwin 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 municipalities. 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 Tsowwin River, select water quality data was available through the Ministry of Energy and Mines regional geochemical stream survey dataset.

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 Tsowwin 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 Tsowwin 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 Tsowwin River and has therefore been identified as a data gap.

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 and the Nootka Sound Watershed Society. Compiled data was digitized as a line feature in ArcGIS to determine the linear length of fish distribution.

2.4.11 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 known habitats to protect from future industrial initiatives.

Note that no key spawning areas were identified during the literature review, and as such, have been identified through interviews with local experts.

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 Tsowwin 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 Tsowwin 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.

2.5.4 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 Tsowwin River watershed was restricted to interviews with local experts, 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 habitat disturbances to the Tsowwin River estuary 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 Tsowwin 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 Tsowwin 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 Tsowwin 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 Tsowwin 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 TSOWWIN RIVER WATERSHED

The Tsowwin 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 (*Oncorhynchus tshawytscha, O. kisutch, O. keta, and O. nerka*) are supported by the Tsowwin 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 Tsowwin River are ocean-type chinook. These chinook typically enter the system in late September, with spawning observed through to late October (FISS, 2014). Distribution is limited to the lower 3.26km of the river (Figure 2) (Brown et al, 1979).

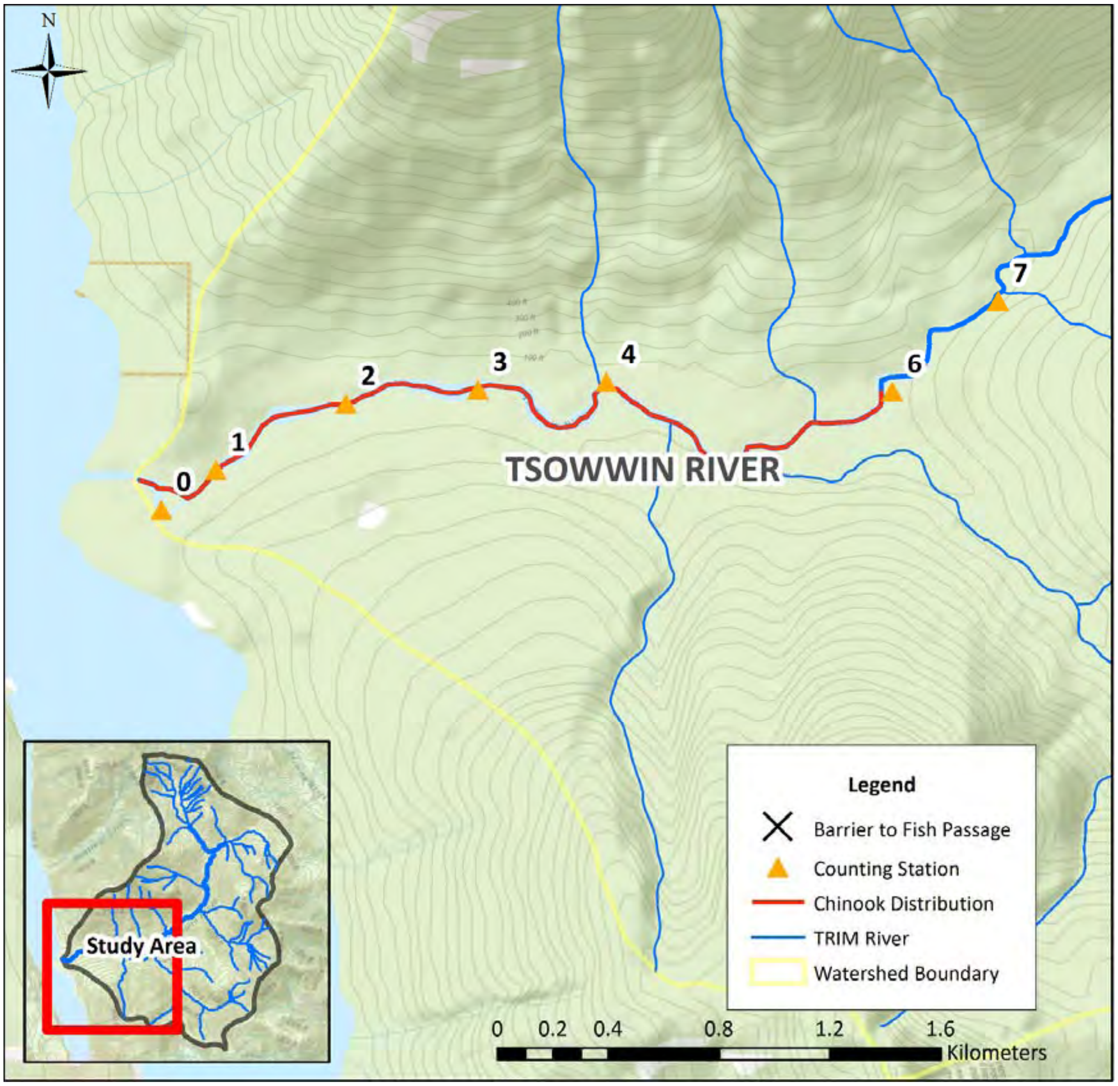

Figure 2. Known chinook distribution in the Tsowwin River watershed.

No information with regards to specific chinook adult holding and spawning habitats was available for review. Based on known life history requirements (Diewert, 2007), however, holding can be assumed to occur in all pools within the chinook-bearing reach of the system (Figure 3). Chinook spawning grounds in the Tsowwin River watershed have been identified as a data gap.

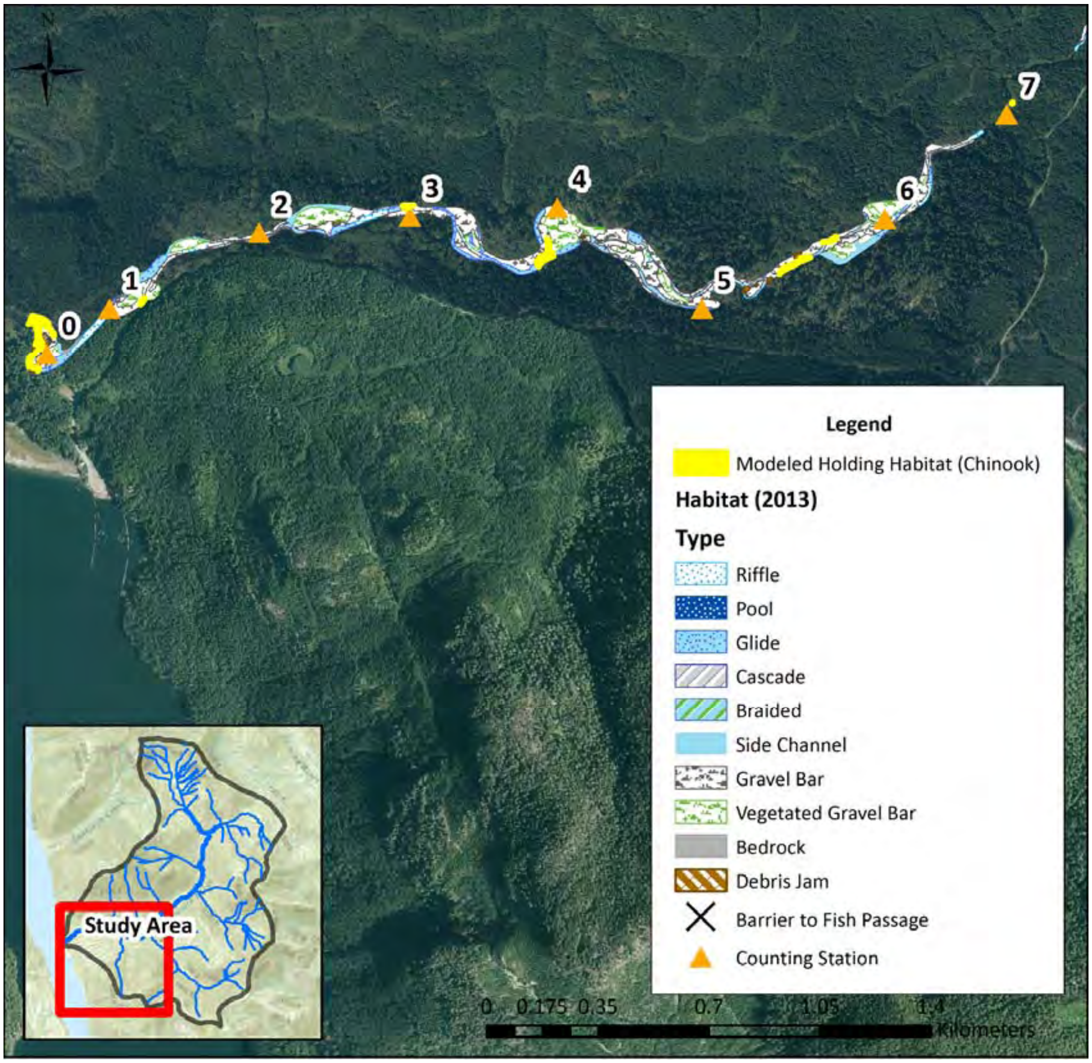

Figure 3. Modeled adult chinook holding habitat, based on known life history requirements.

Chinook 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 Tsowwin River system is unknown). During downstream migration, fry typically target reduced flows at the river edges (Diewert, 2007). Given this requirement migration habitat for chinook fry has been modeled for the Tsowwin River based on characteristics observed from the orthophotographs (Figure 4).

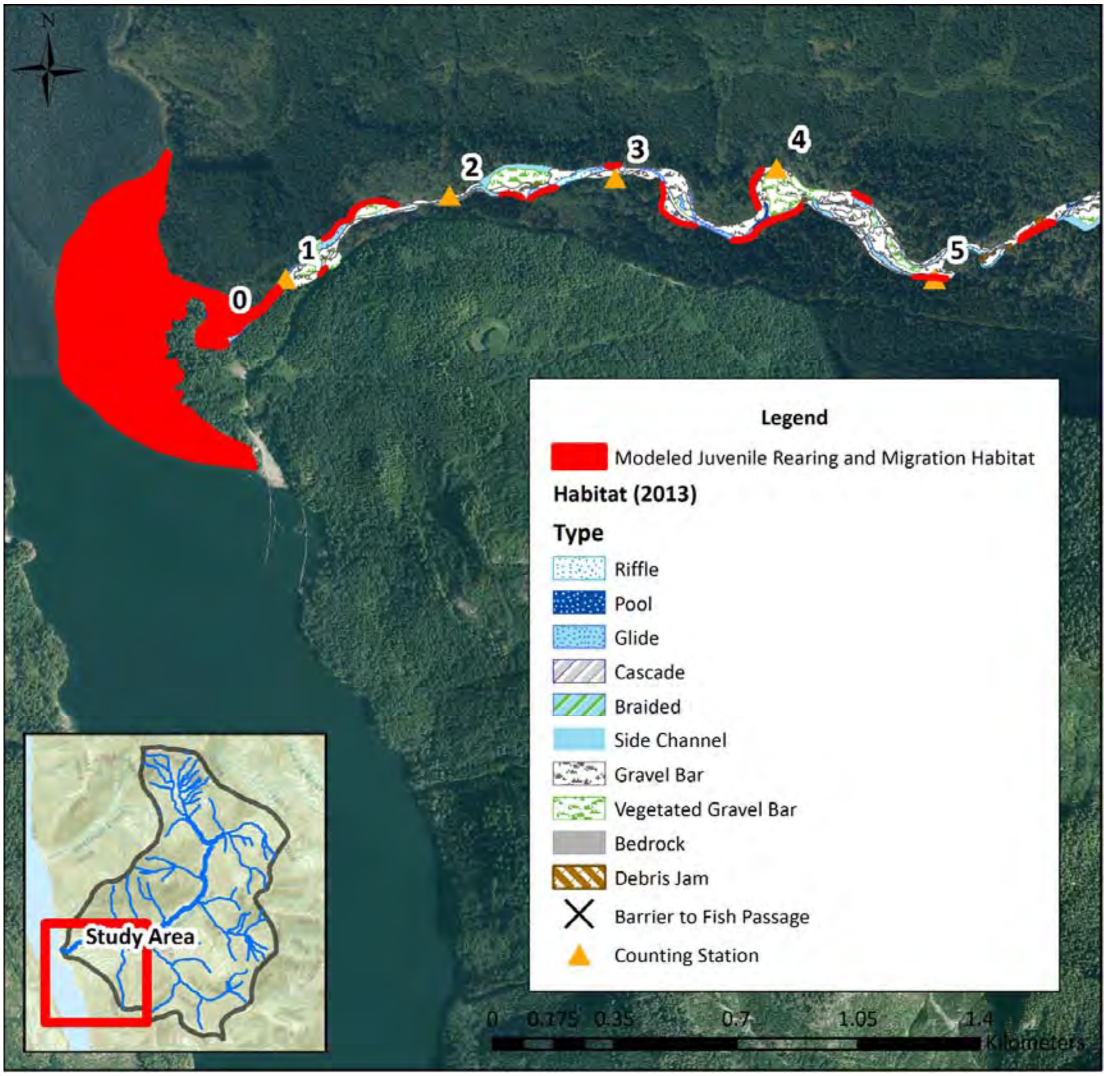

Figure 4. Modeled juvenile chinook rearing and migration habitat, inferred from known life history requirements.

3.1.2 Escapement

Historic chinook escapement numbers have been variable in the Tsowwin River. The earliest recorded escapement in 1953 was 400 fish, and numbers decreased generally to less than 200 fish between 1958 and 1963. Peak escapements of 750 fish were recorded between 1964 and 1966. Since 1966, escapement has been consistently less than 75 fish (Figure 5).

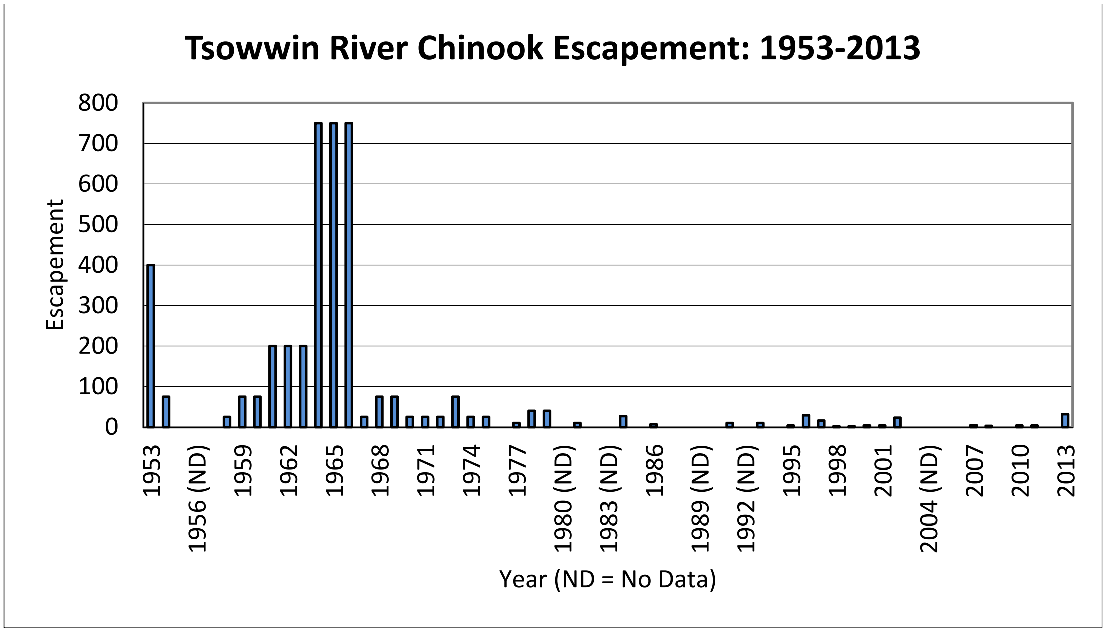

Figure 5. Chinook escapement in the Tsowwin River between 1953 and 2013 (compiled from DFO's NuSEDs database)[i].

3.2 *Coho Salmon*

3.2.1 Biology, Distribution, and Known Habitats

Coho salmon typically arrive in the Tsowwin River in late September, with spawning observed through to late December (FISS, 2014). Distribution has been observed and / or modeled in the mainstem approximately 5.89km upstream from the estuary (Brown et al, 1979) and within associated tributaries (MFLNRO Fish Passage Technical Working Group Web Page, 2013) (Figure 6).

[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.

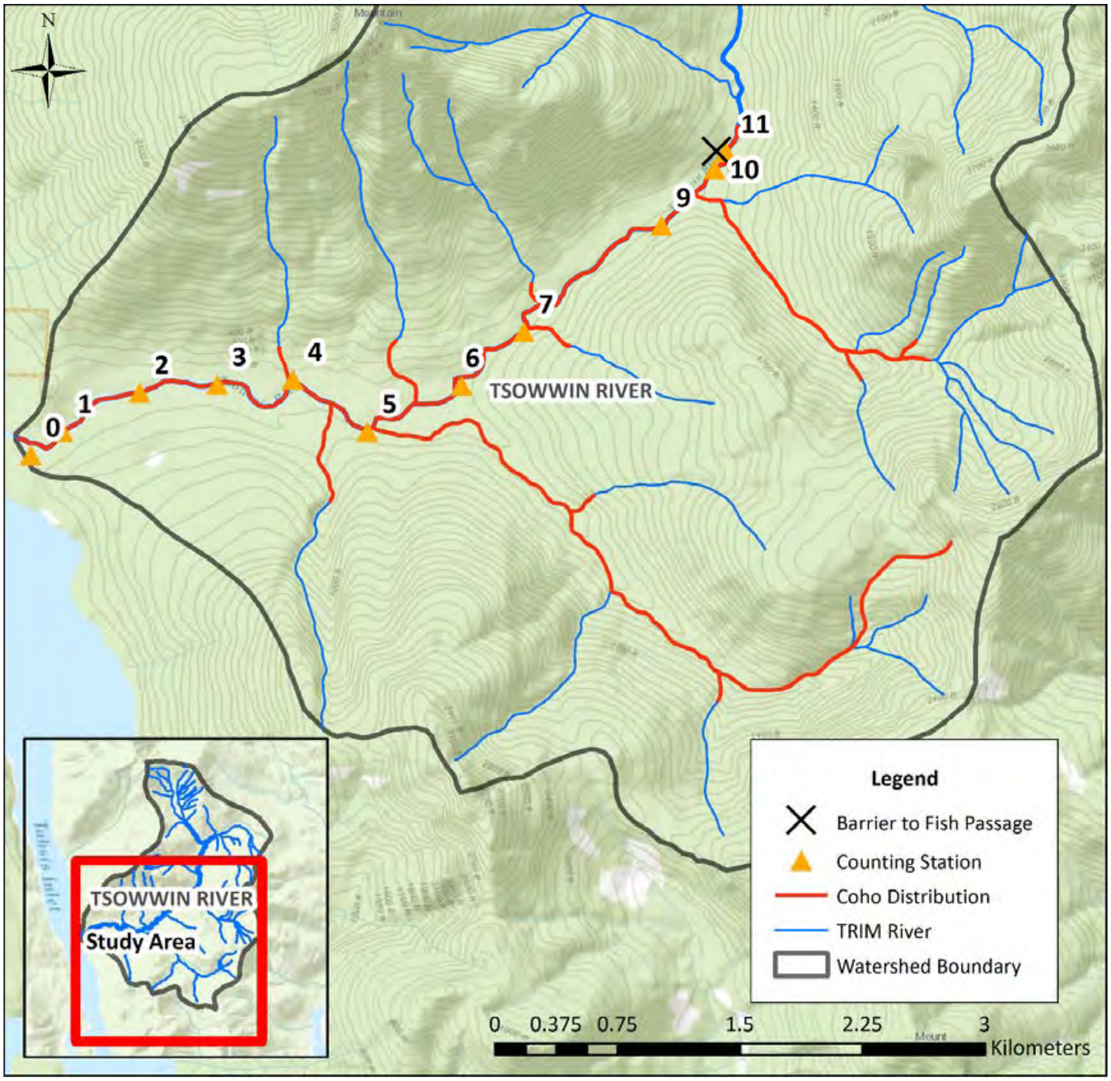

Figure 6. Known and modeled coho distribution in the Tsowwin River watershed.

No information with regards to specific coho adult holding and spawning habitats was available for review. Based on known life history requirements (Diewert, 2007), however, holding can be assumed to occur in all pools within the coho-bearing reach of the system. Visible pools between counting stations 0 and 7 were considered critical holding habitat (Figure 7); above counting station 0, river visibility became obscured, and no pools were obvious from the imagery. As such, holding habitat above counting station 7 is a data gap. Coho spawning grounds in the Tsowwin River watershed have been identified as a data gap.

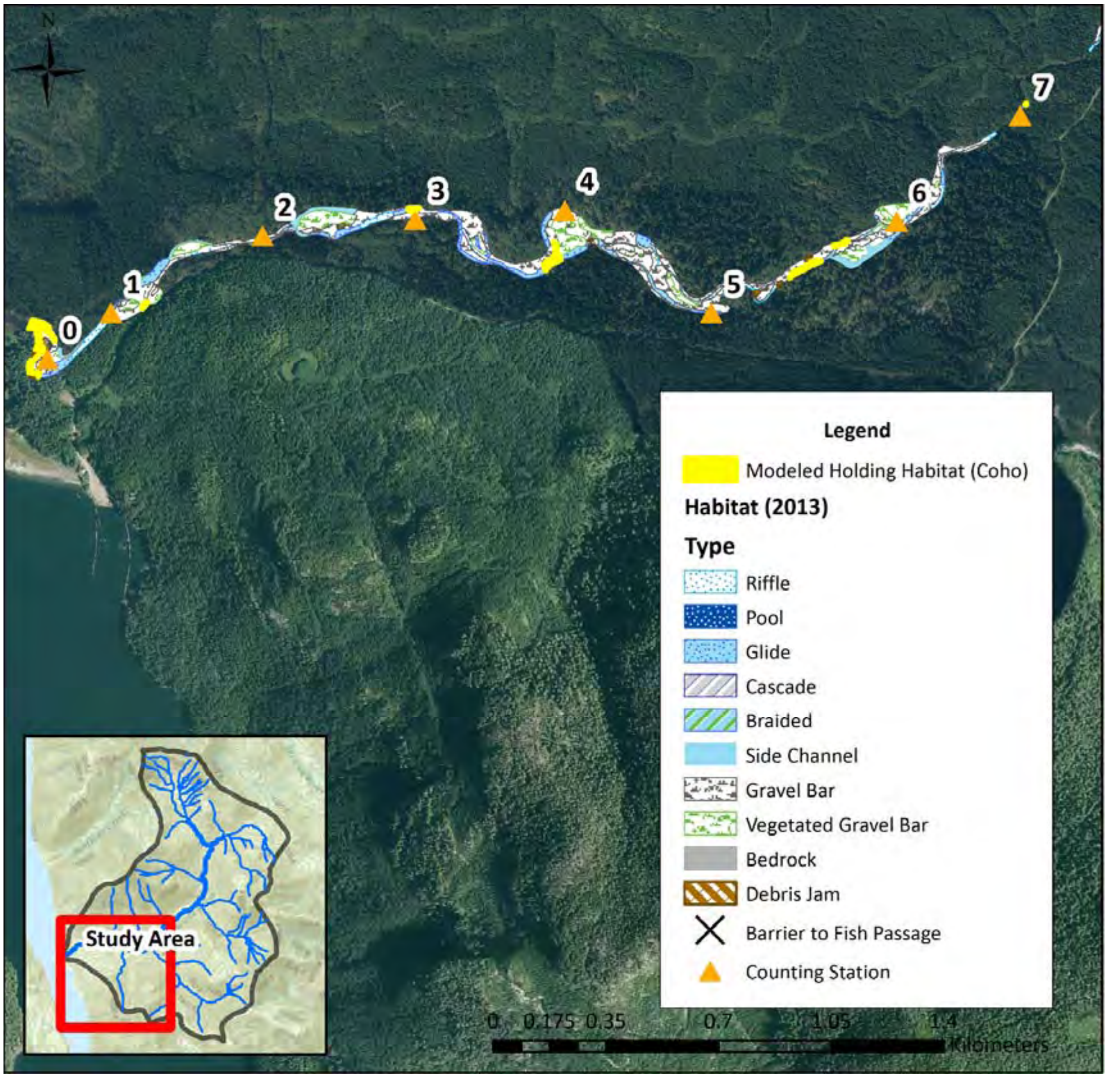

Figure 7. Modeled adult coho holding habitat in the Tsowwin River. Note that holding habitat upstream of counting station 7 has been identified as a data gap.

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 (Diewert, 2007). Fry remain in freshwater for one to two years before migrating to sea as coho smolts (Witt and Clozza, 1980).

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). No information is available on the distribution of coho fry in the Tsowwin River watershed; however, it has been noted that coho fry are particularly abundant near debris accumulations (Fisheries and Oceans Canada, 2012). Habitats depicted in Figure 8 have been modeled from both known coho life history requirements and the location of debris accumulations in the Tsowwin River.

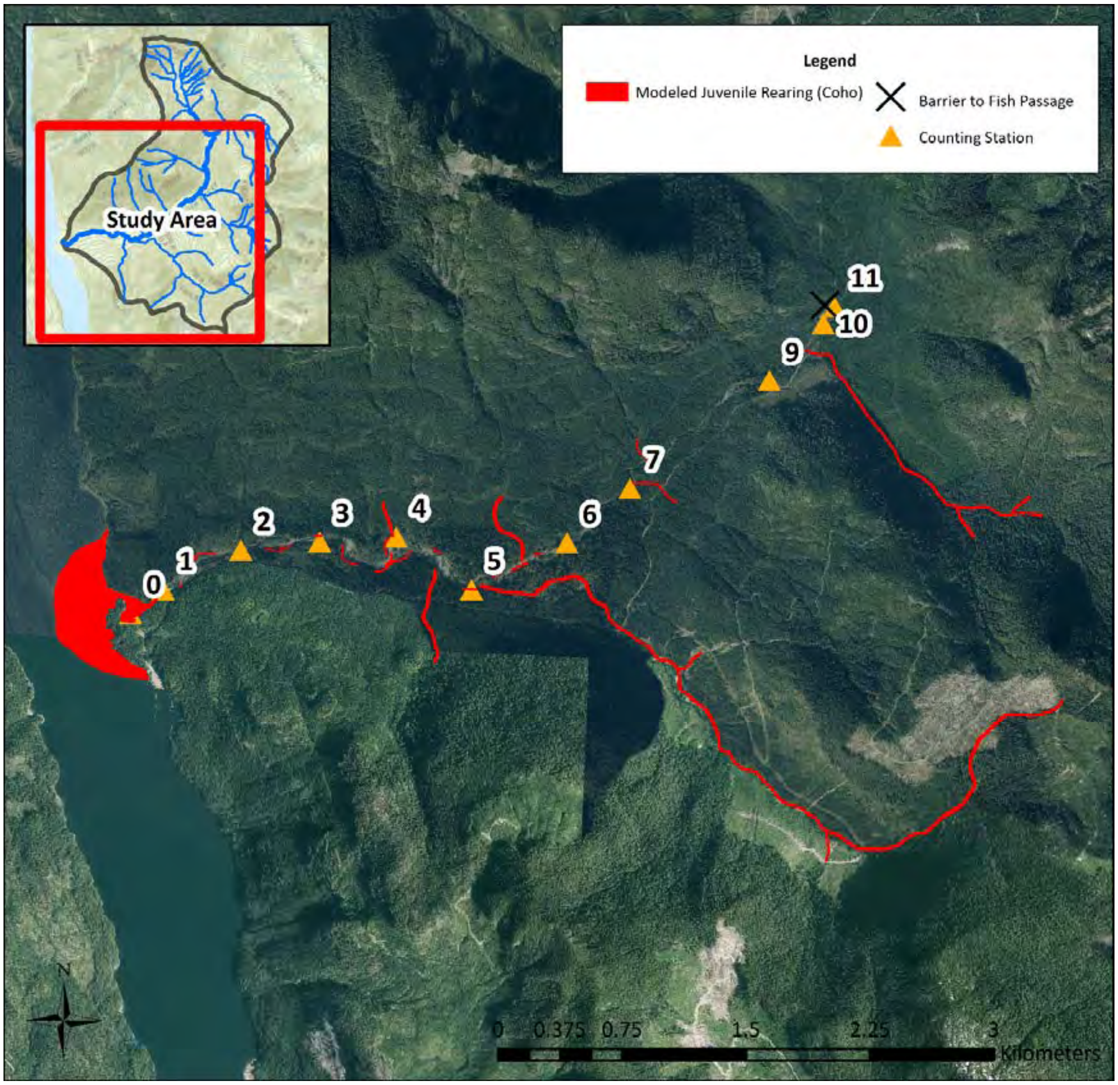

Figure 8. Modeled juvenile coho migration and rearing habitat in the Tsowwin River watershed.

3.2.2 *Escapement*

Historical records for coho populations show a peak escapement of 3,500 fish in 1964, with fluctuating numbers both prior to and following this observation. Low populations were observed between 1972 and 1989. Since the late 1990s, escapement estimates have reflected those of the 1960s, with between 250 – 500 fish estimated in the system (Figure

9). Based on the known distribution of coho beyond the survey area, escapement estimates presented in Figure 9 are likely an underestimation of the actual population size.

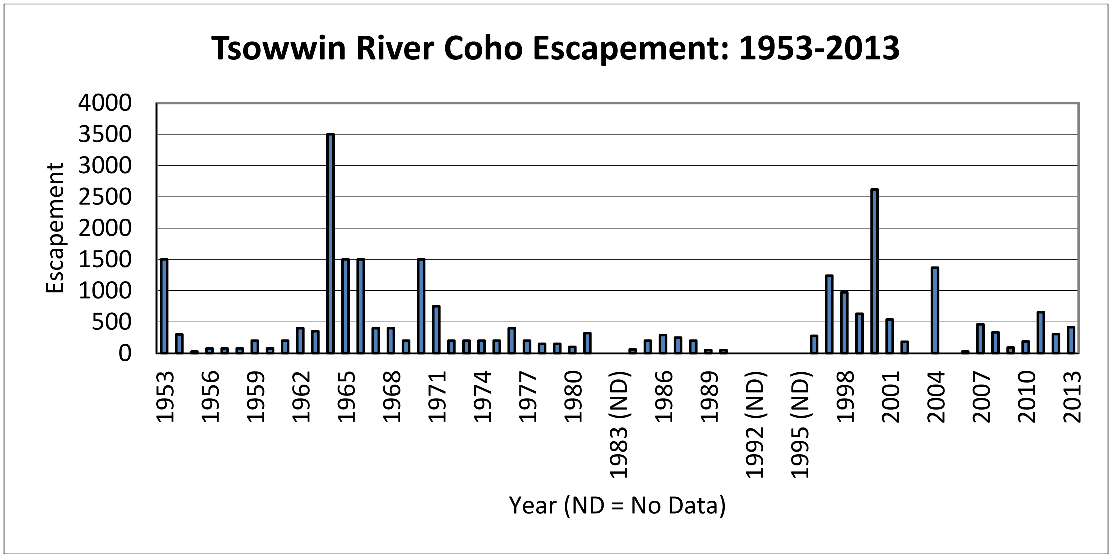

Figure 9. Coho escapement in the Tsowwin River between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.3 Sockeye Salmon

3.3.1 Biology, Distribution, and Known Habitats

Sockeye salmon arrive in the Tsowwin River in late September with spawning observed through to the end of October (FISS, 2014). Distribution is observed approximately 3.7km upstream of the estuary, just upstream of counting station 6 (Figure 10) (Brown et al, 1979).

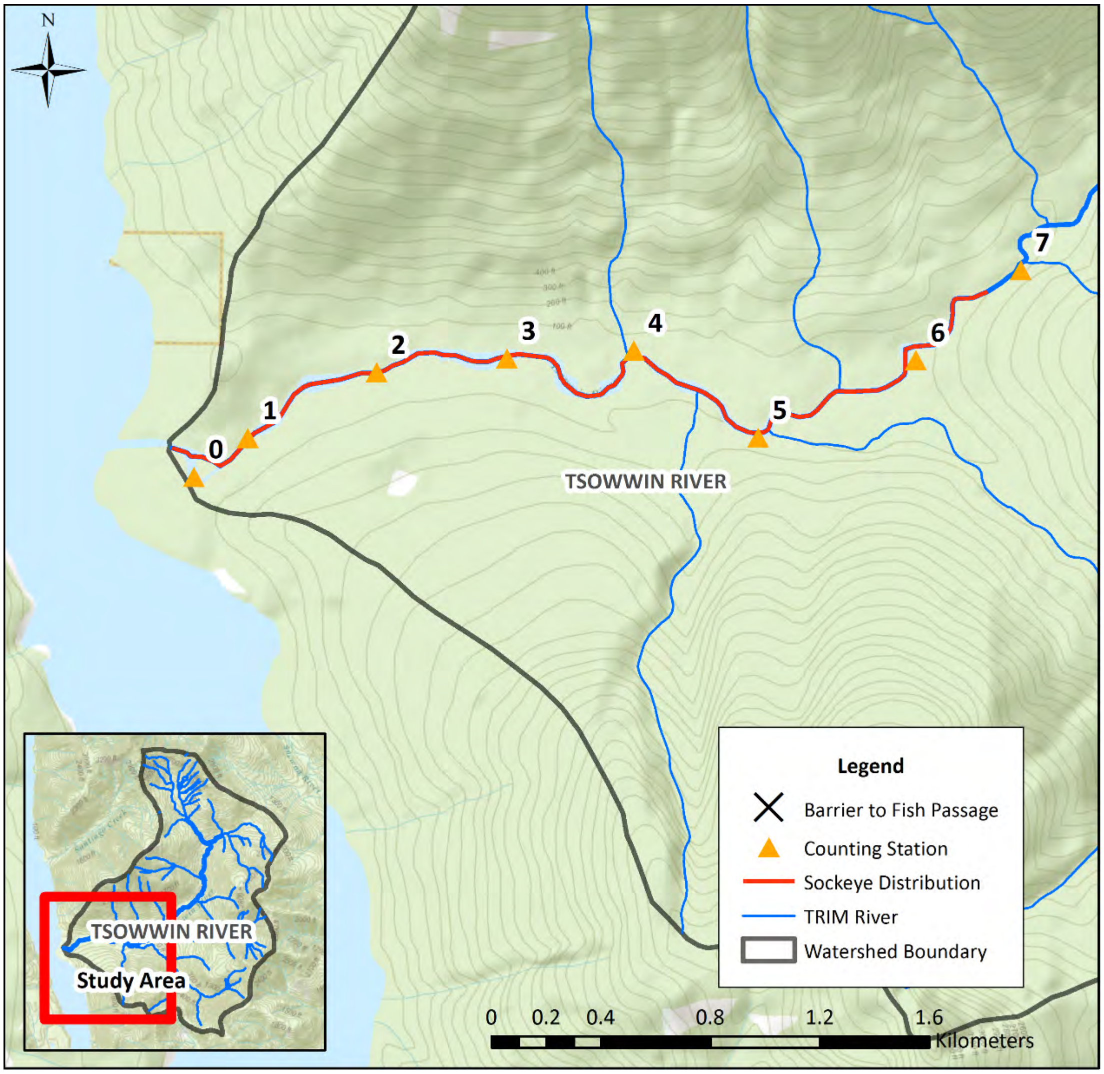

Figure 10. Known sockeye distribution in the Tsowwin River watershed.

No information with regards to specific sockeye adult holding and spawning habitats was available for review. Based on known life history requirements (Diewert, 2007), however, holding can be assumed to occur in all pools within the sockeye-bearing reach of the system. Visible pools between counting stations 0 and 7 were considered critical holding habitat (Figure 7). Sockeye spawning grounds in the Tsowwin River watershed have been identified as a data gap.

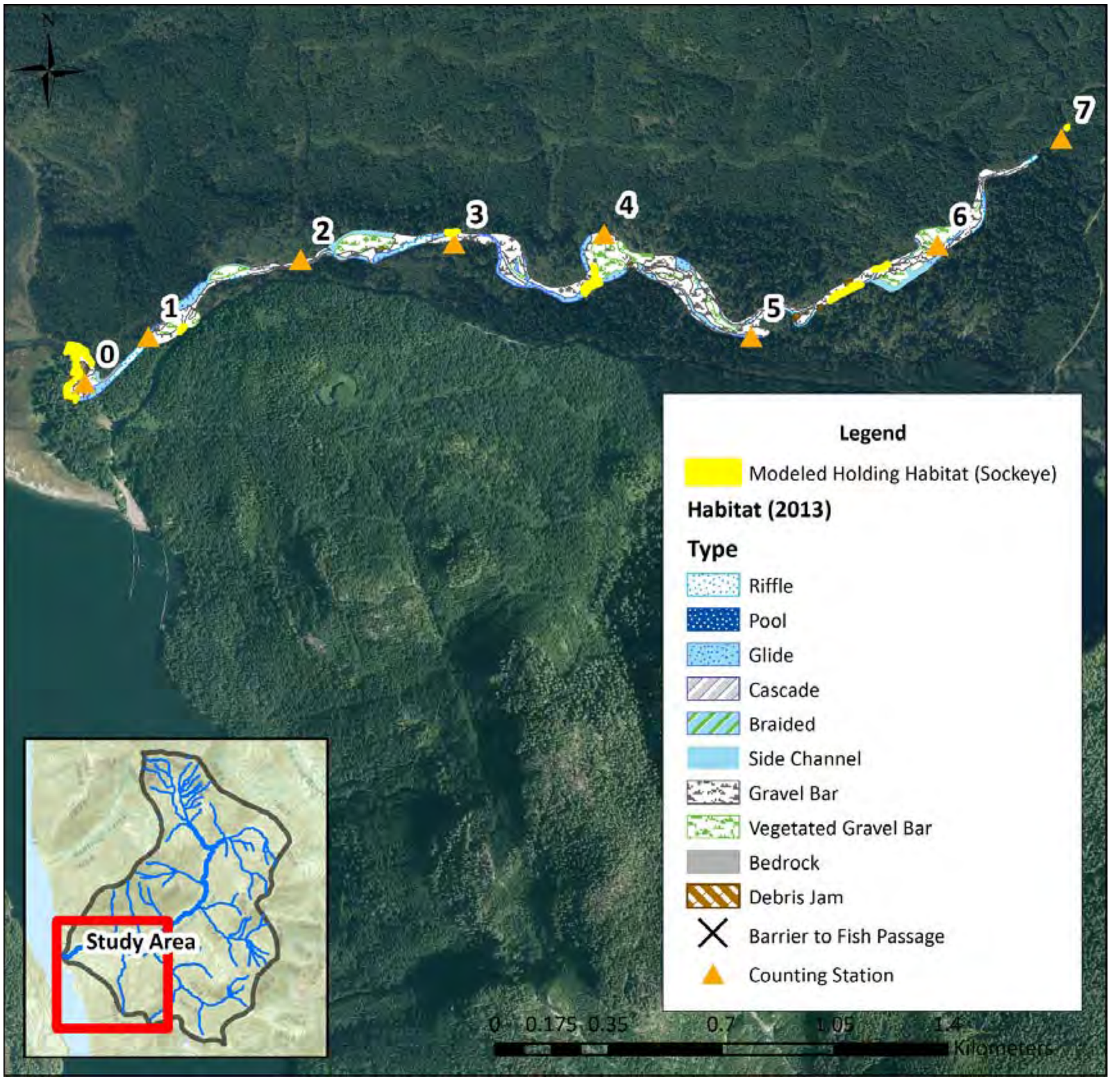

Figure 11. Modeled sockeye holding habitat in the Tsowwin River.

Due to the fact that there are no major lakes downstream of the known distribution of sockeye in the Tsowwin River, sockeye in this system are likely sea-type, and migrate downstream following emergence and rear in the estuary prior to entering the marine environment (Diewerts, 2007) (Figure 12). Little data exists on freshwater sockeye rearing habitats for the Tsowwin River, and future investigations should seek to identify the location of these habitats.

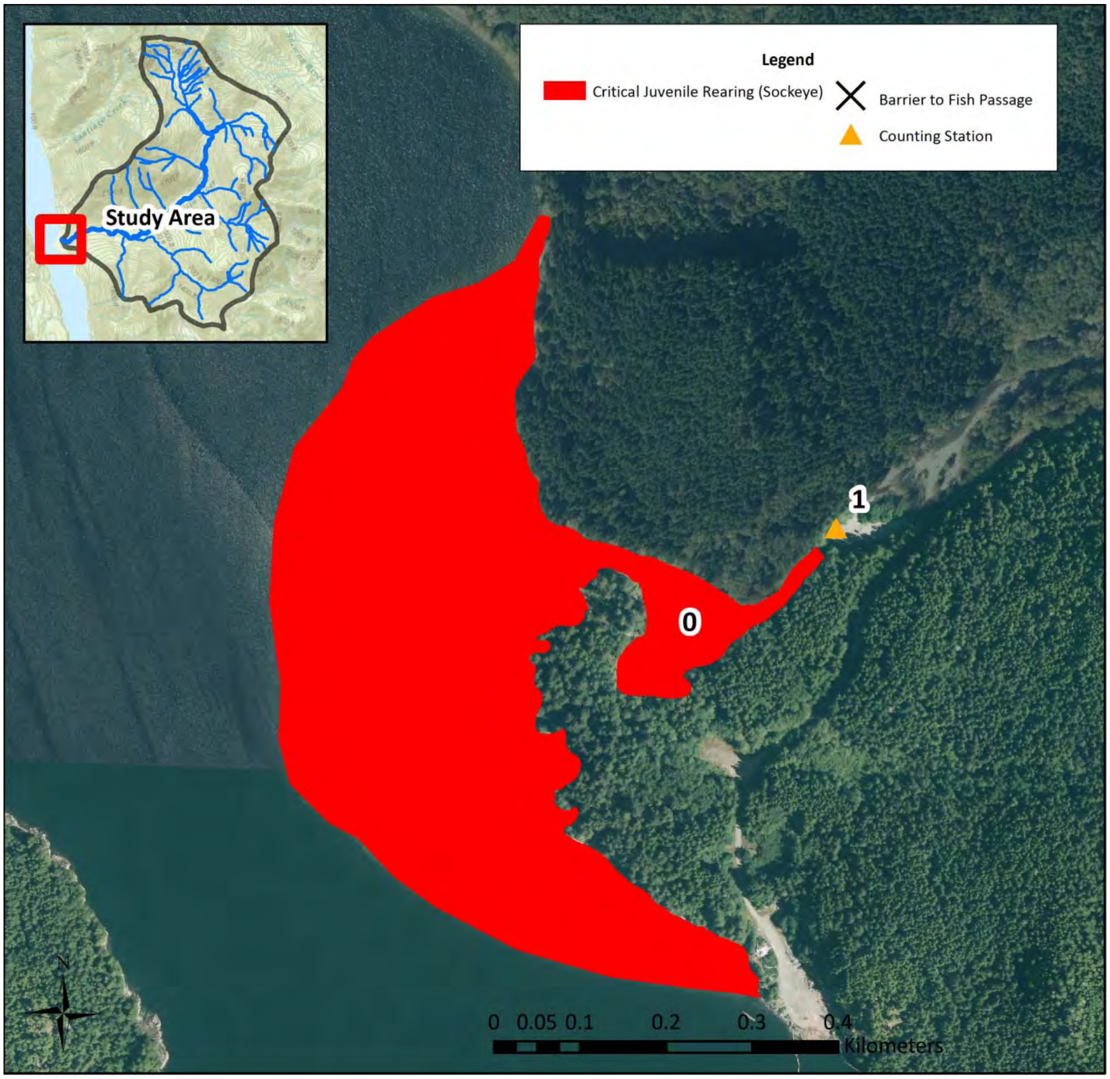

Figure 12. Modeled juvenile sockeye rearing habitat in the Tsowwin River watershed.

3.3.2 Escapement

Sockeye numbers within the Tsowwin River have remained historically low, with typically less than 250 fish estimated in the system. Recent estimates (between 2010 and 2013) have documented less than 50 fish in the system (Figure 13). Note that limited escapement estimate data exists for sockeye in this system, and no information with respect to sockeye numbers is available prior to 1974.

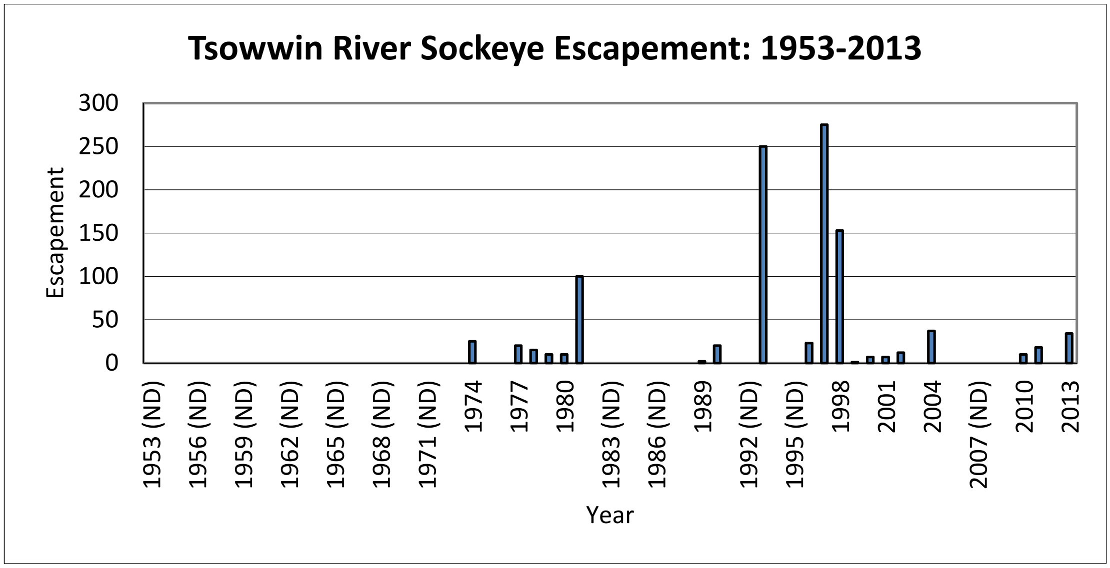

Figure 13. Sockeye escapement in the Tsowwin River watershed between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.4 Chum Salmon

3.4.1 Biology, Distribution, and Known Habitats

Chum salmon typically enter the Tsowwin River in late September, with spawning observed through to late November. Chum distribution is observed approximately 3.72km upstream of the estuary, with some fish observed in the tributary entering the left bank near counting station 5 (Figure 14).

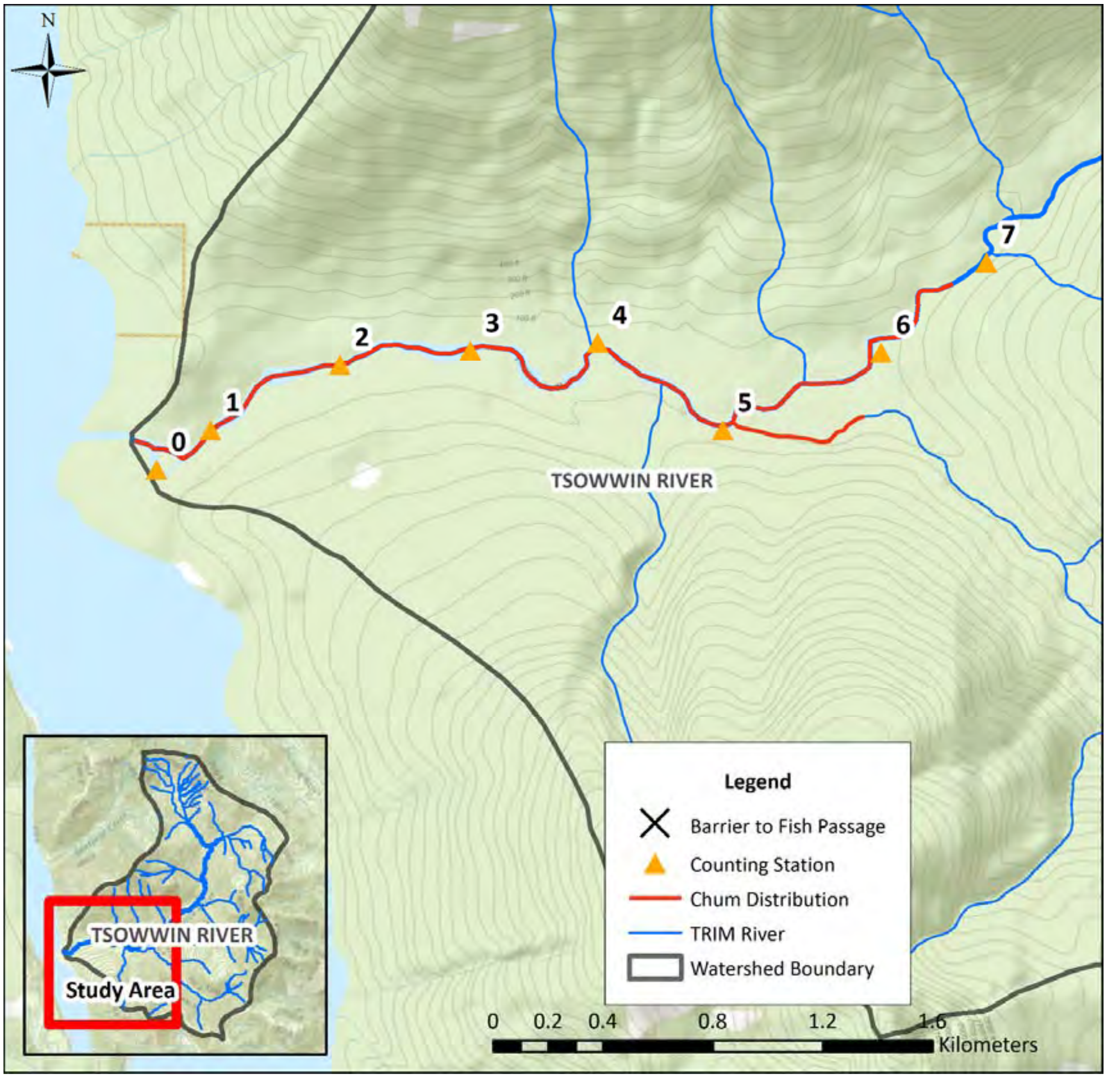

Figure 14. Known chum distribution in the Tsowwin River watershed.

No information with regards to specific chum adult holding and spawning habitats was available for review; however, SIL data indicated that the majority of holding and spawning occurs in the lower sections of the river, with periodic activity observed further upstream. These SILs also identified there are several side channels in the lower river that are heavily utilized by chum. The location of these side channels could not be discerned in the orthophotographs and have therefore been identified as a data gap.

In the absence of location data holding was assumed to occur in all pools within the chum-bearing reach of the system (Figure 15), and spawning locations were classified as a data gap.

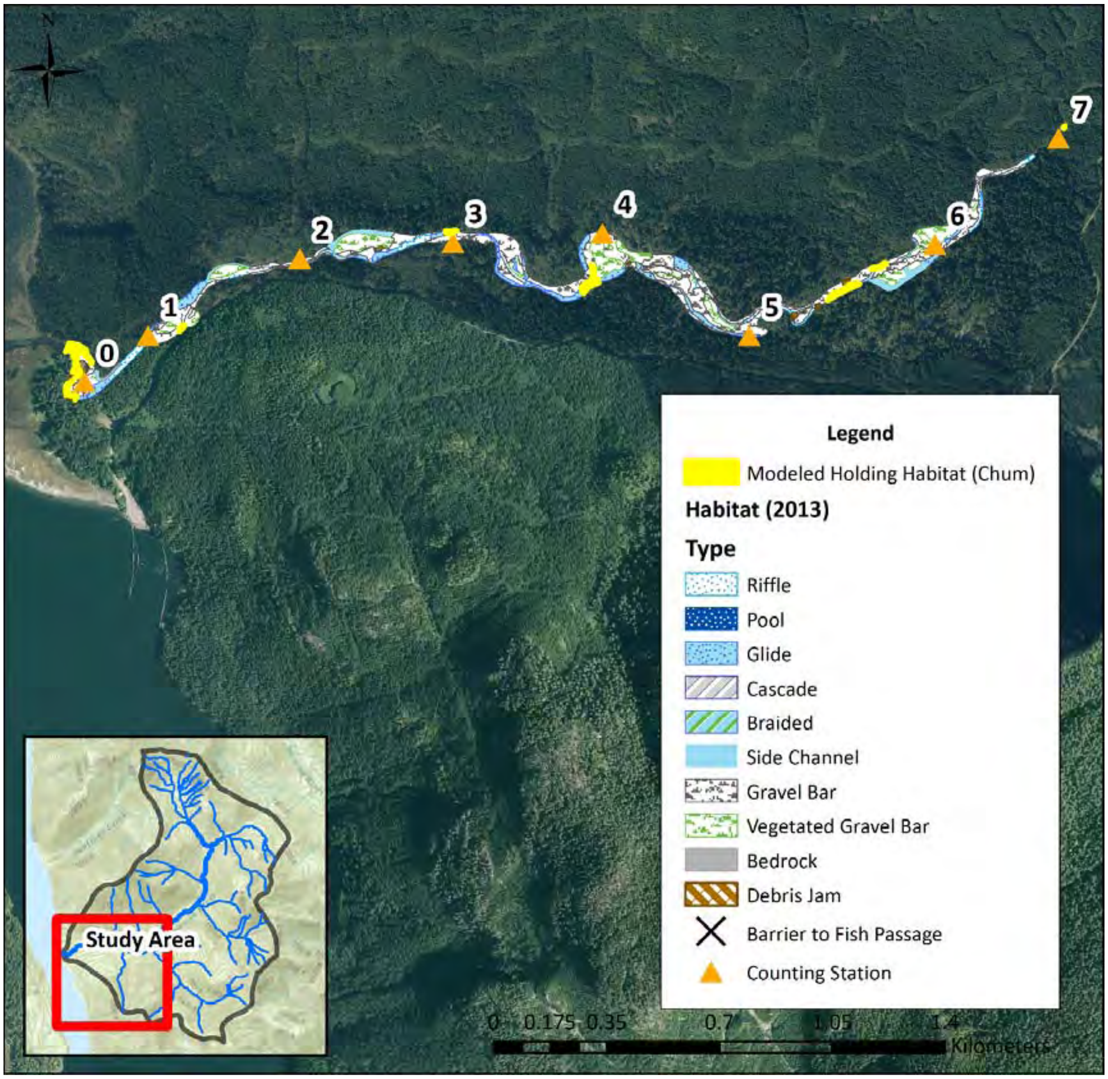

Figure 15. Modeled chum holding habitat in the Tsowwin River. Note that specific spawning locations have been identified as a data gap.

Like other species in the Tsowwin River 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 Tsowwin River estuary has been classified as critical juvenile migration and rearing habitat (Figure 16).

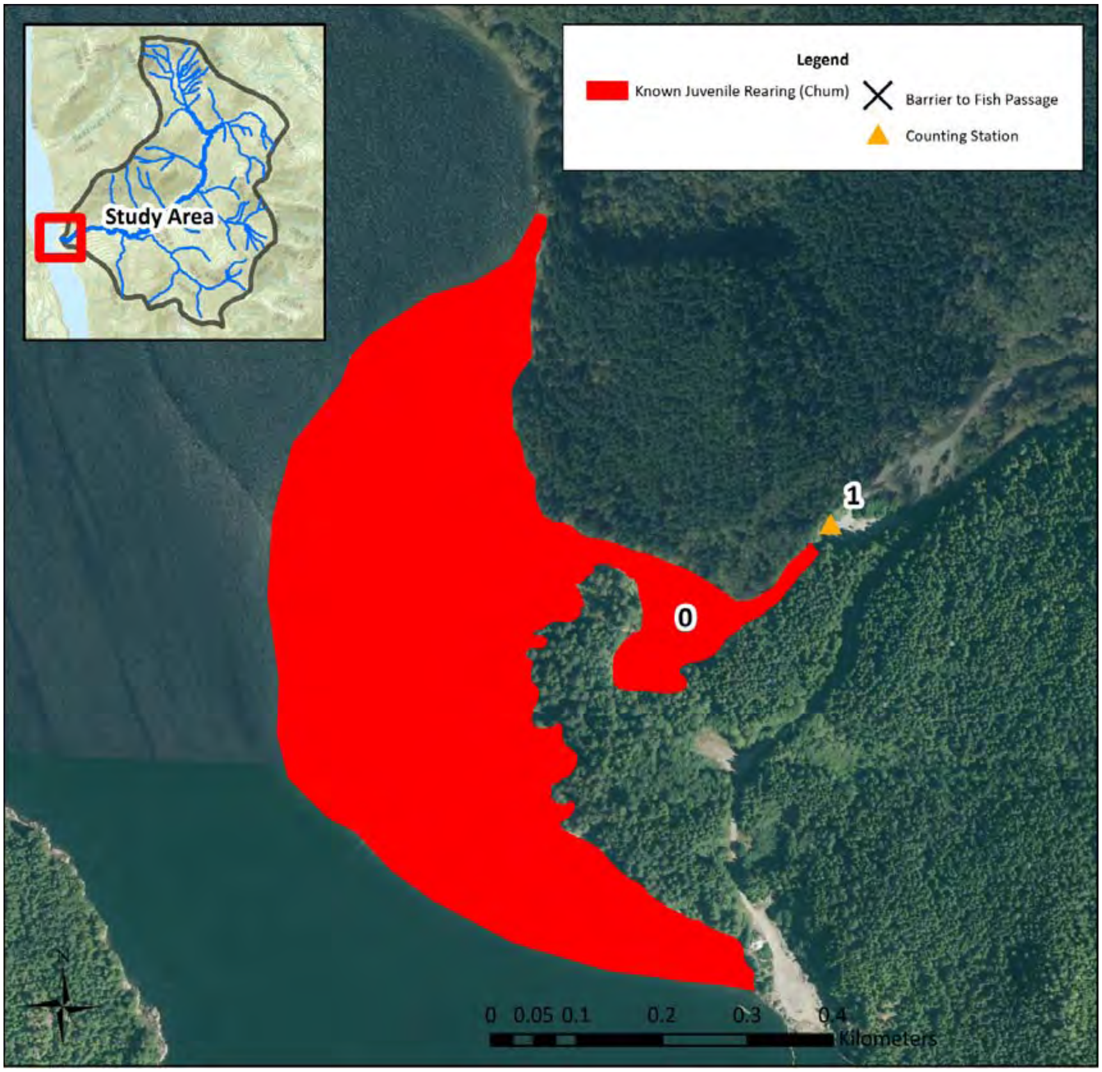

Figure 16. Known chum juvenile rearing habitat in the Tsowwin River.

3.4.2 Escapement

The Tsowwin River has historically been a consistent producer of chum salmon with average peak escapements between 1953 and 1990 of 6,906 fish (ranging from 400 – 17,000 fish). A peak escapement of approximately 45,000 fish was observed in 1992. Falling returns have been observed in the Tsowwin over the past 5 years, a trend that has been observed in chum populations coast-wide (Figure 17) (M. Wright, pers. comm.).

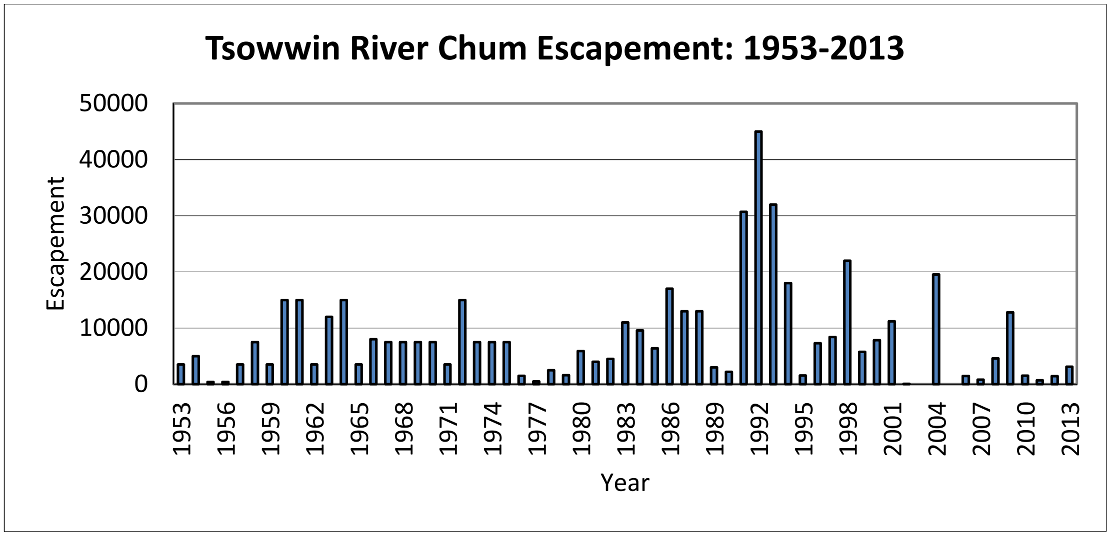

Figure 17. Chum escapement in the Tsowwin River watershed between 1953 and 2013 (compiled from DFO's NuSEDs database).

3.5 Pink Salmon

Historical records show a pink salmon return of approximately 750 fish up to 1972, and intermittent counts of approximately 50 fish after 1974. Limited escapement data is available for recent years (Figure 18). Based on the low numbers of pink salmon in the Tsowwin River and limited available data, this species is not considered in further discussions of habitat indicators and limiting factors.

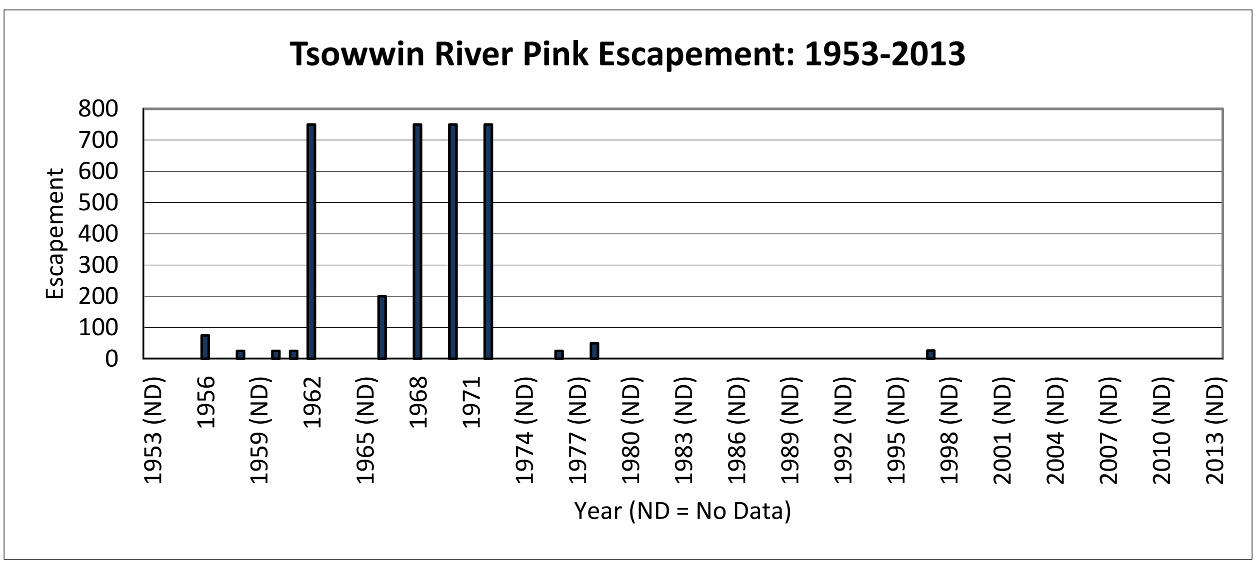

Figure 18. Pink escapement in the Tsowwin River watershed between 1953 and 2013 (compiled from DFO's NuSEDs database).

4.0 HABITAT INDICATOR ASSESSMENT RESULTS

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

4.1 Stream Pressure Indicator: Total Land Cover Alterations

Total land cover alterations for the Tsowwin River watershed are summarized in Figure 19:

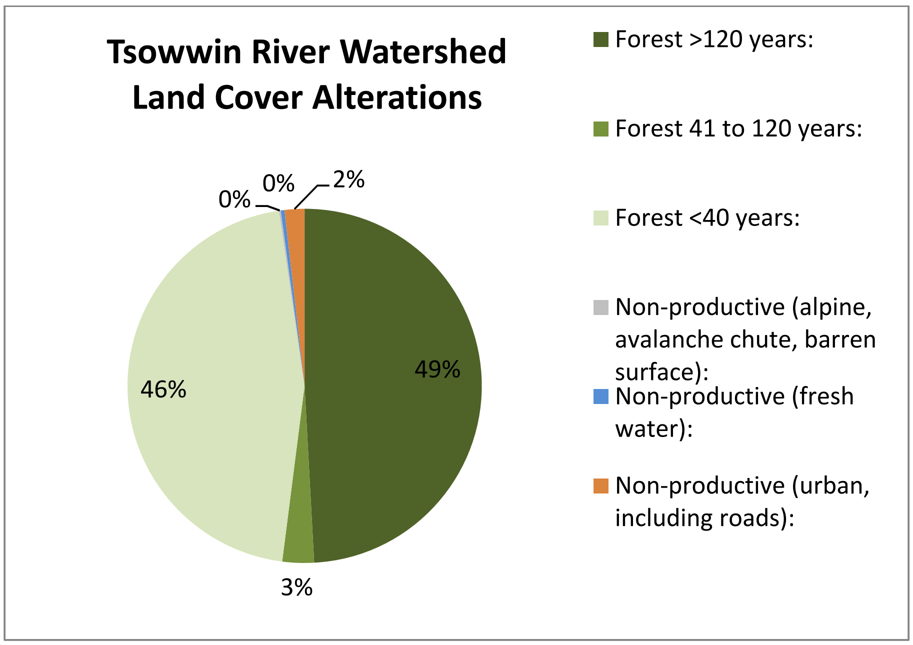

Figure 19. Total land cover alterations, by percent, for the Tsowwin River watershed.

Based on this figure, approximately 49% of the total area of the Tsowwin River watershed remains unaltered, with mature forests (i.e. >120 years) comprising the majority of this area. Approximately 2% of the watershed has been altered as roads, and approximately 46% of the watershed remains as altered forests (i.e. <120 years).

An analysis of the distribution of altered land cover areas demonstrated altered areas to be situated within areas adjacent to and / or within critical salmonid habitats (i.e. riparian zone of the mainstem and the Tsowwin River estuary) (Figure 20). Considering the proximity of land cover alterations to known salmonid habitats, the Tsowwin River watershed has been classified as high risk for total land cover alterations.

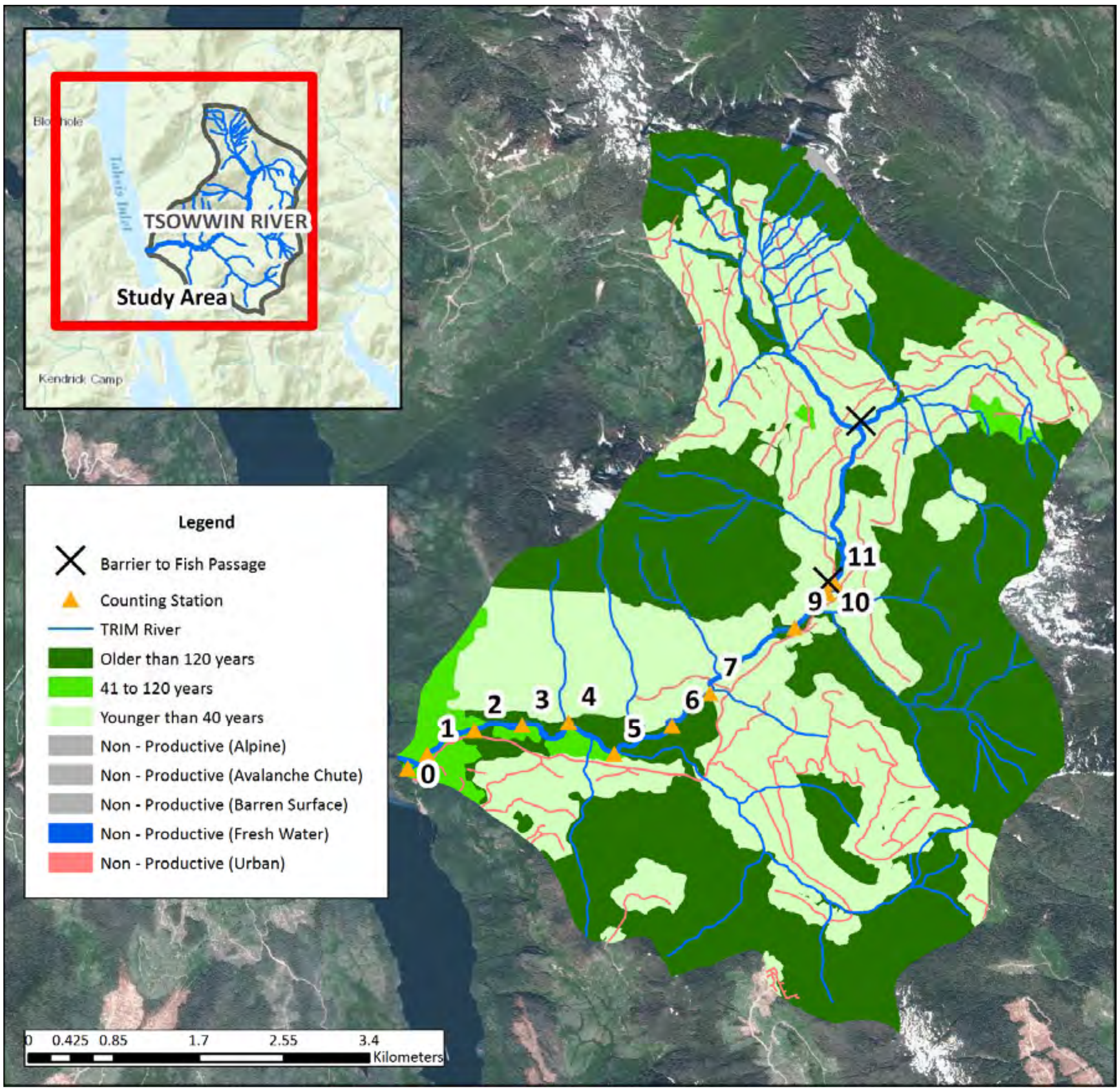

Figure 20. Total land cover alterations in the Tsowwin River watershed.

4.2 Stream Pressure Indicator: Watershed Road Development

Watershed road development in the Tsowwin River watershed was calculated at 2.18km / km ^{2}, which was well above the suggested benchmark of 0.4km / km^2 (Stalberg et al, 2009) (Figure 21). Despite the high road density calculation, it should be noted that simple road density (i.e. total length of road per area of watershed) does not distinguish between roads that are overgrown relative to those that are in active use, roads that have been deactivated or remediated from roads that have not, or roads built before the Forest Practices Code (FPC) from those built under FPC standards (Horel, 2008).

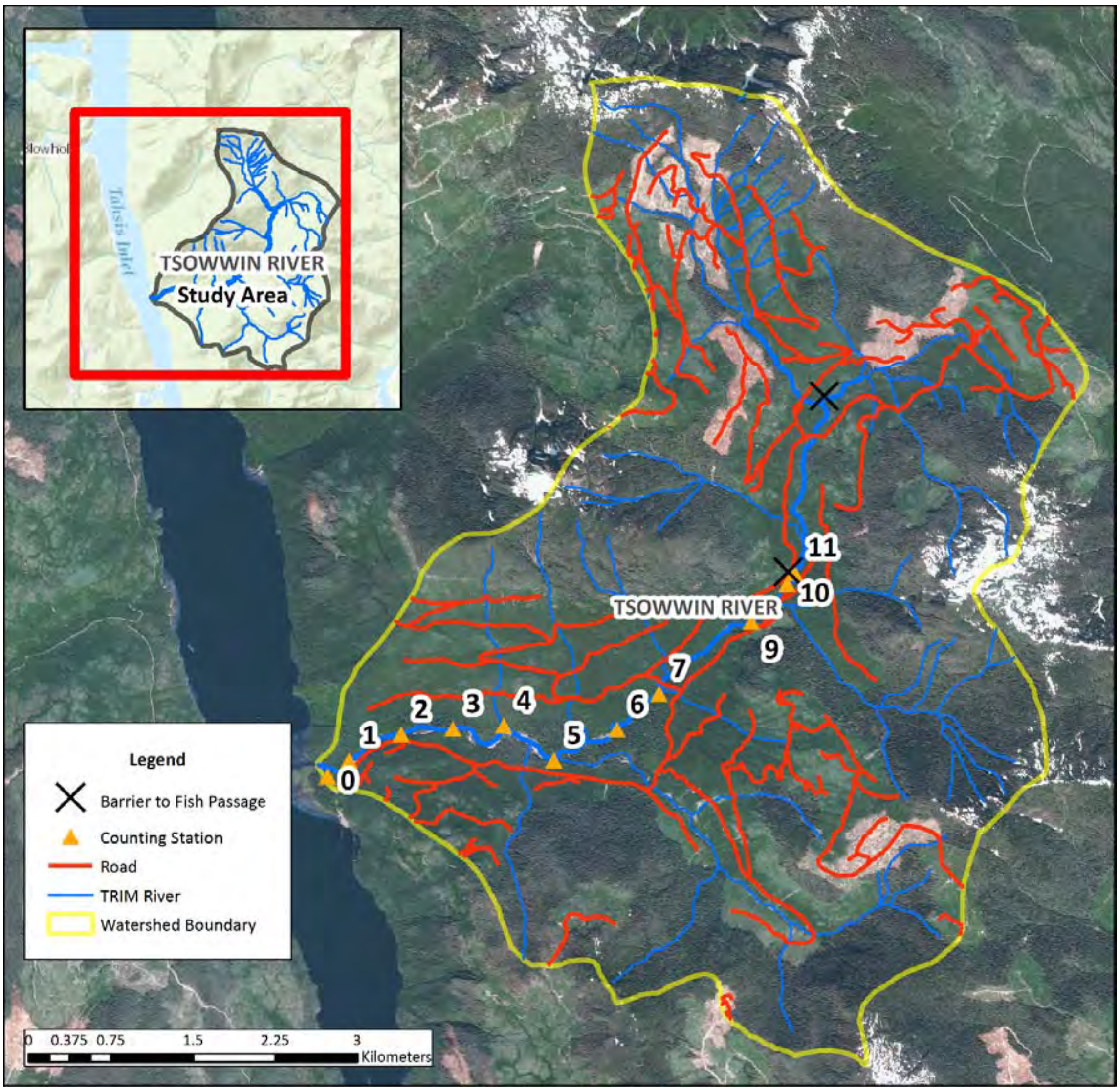

Figure 21. Watershed road density in the Tsowwin River watershed.

Based on the benchmark presented in Stalberg et al (2009) watershed road density in the Tsowwin River is identified as high risk. However, data gaps exist with respect to the condition of these roads, which has the potential to elevate or lower risk levels in the watershed. As such, road density has been classified as high risk with partial data gaps.

4.3 Stream Pressure Indicator: Water Extraction

There are currently no active water licences in the Tsowwin River watershed. As such, this indicator has been classified as low risk.

4.4 Stream Pressure Indicator: Riparian Disturbance

The calculated riparian disturbance within the anadromous component of the Tsowwin River was significant with the sections of the mainstem dominated by a primarily deciduous and / or regenerating stand. The most significantly disturbed riparian areas included the right bank between counting stations 1 and 2, 3 and 4, and 5 and 11, and the left bank between counting stations 7 and 11 (Figure 22).

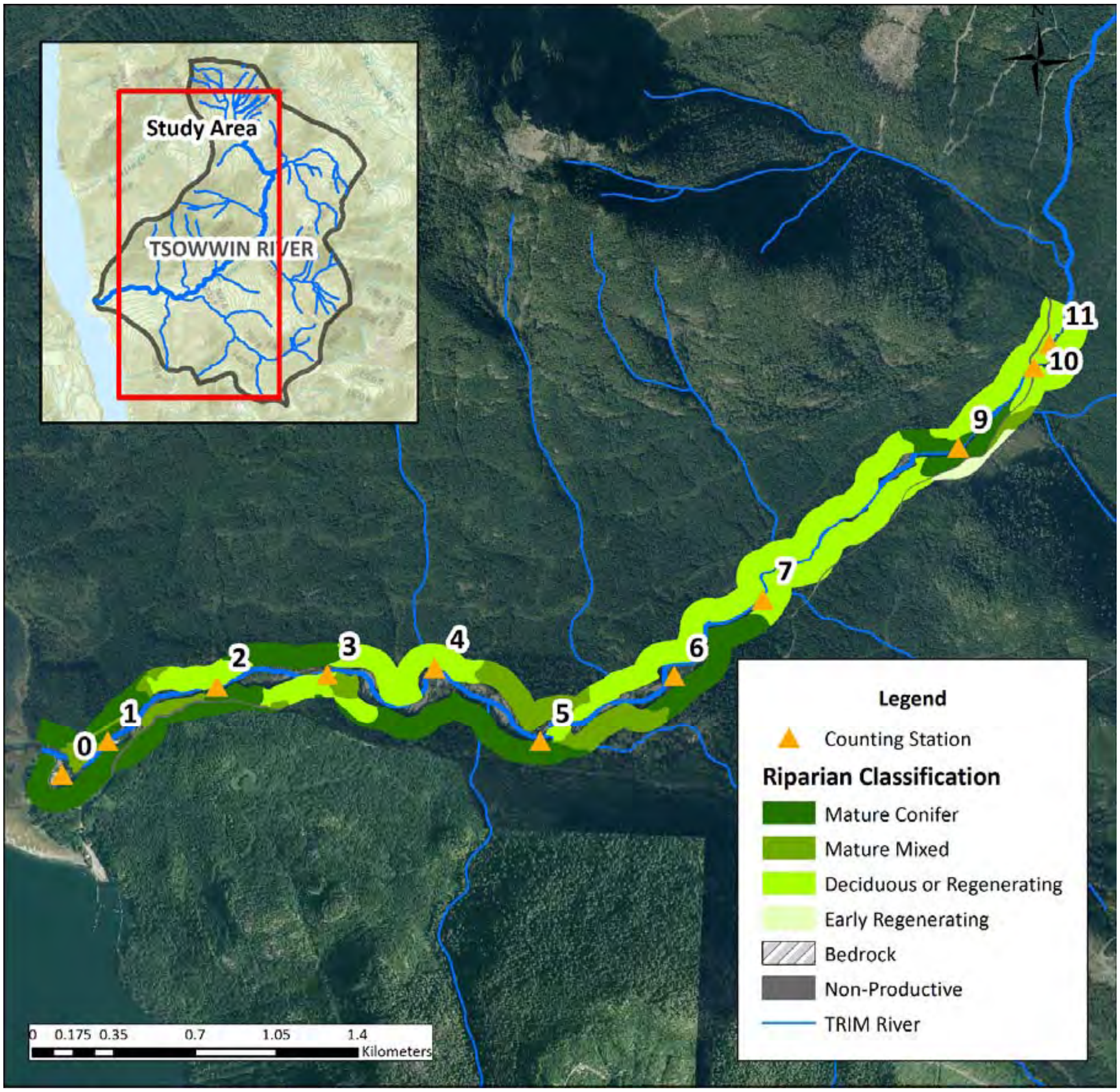

Figure 22. Riparian disturbance within the anadromous component of the Tsowwin River mainstem.

The Tsowwin 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 50% deciduous and / or regenerating forest (Figure 23). 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 a significant component of the riparian stand was classified as deciduous and / or regenerating forest throughout the anadromous reaches, the risk rating for riparian disturbance in the Tsowwin River watershed was classified as high.

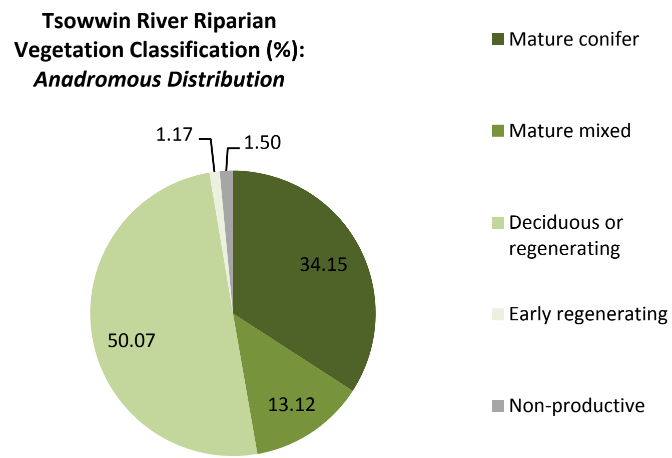

Figure 23. Riparian vegetation composition for the anadromous reaches of the Tsowwin River watershed.

An analysis of riparian condition for tributaries to the Tsowwin 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

There are currently no permitted waste management discharges in the Tsowwin River watershed. As such, this indicator has been ranked low risk.

4.6 Stream State Indicator: Water Quality

Limited water quality data was available for the Tsowwin River through EMNG regional geochemical stream survey monitoring sites. A total of four monitoring sites have been established in the watershed, all of which are situated along or adjacent to the mainstem (Figure 24).

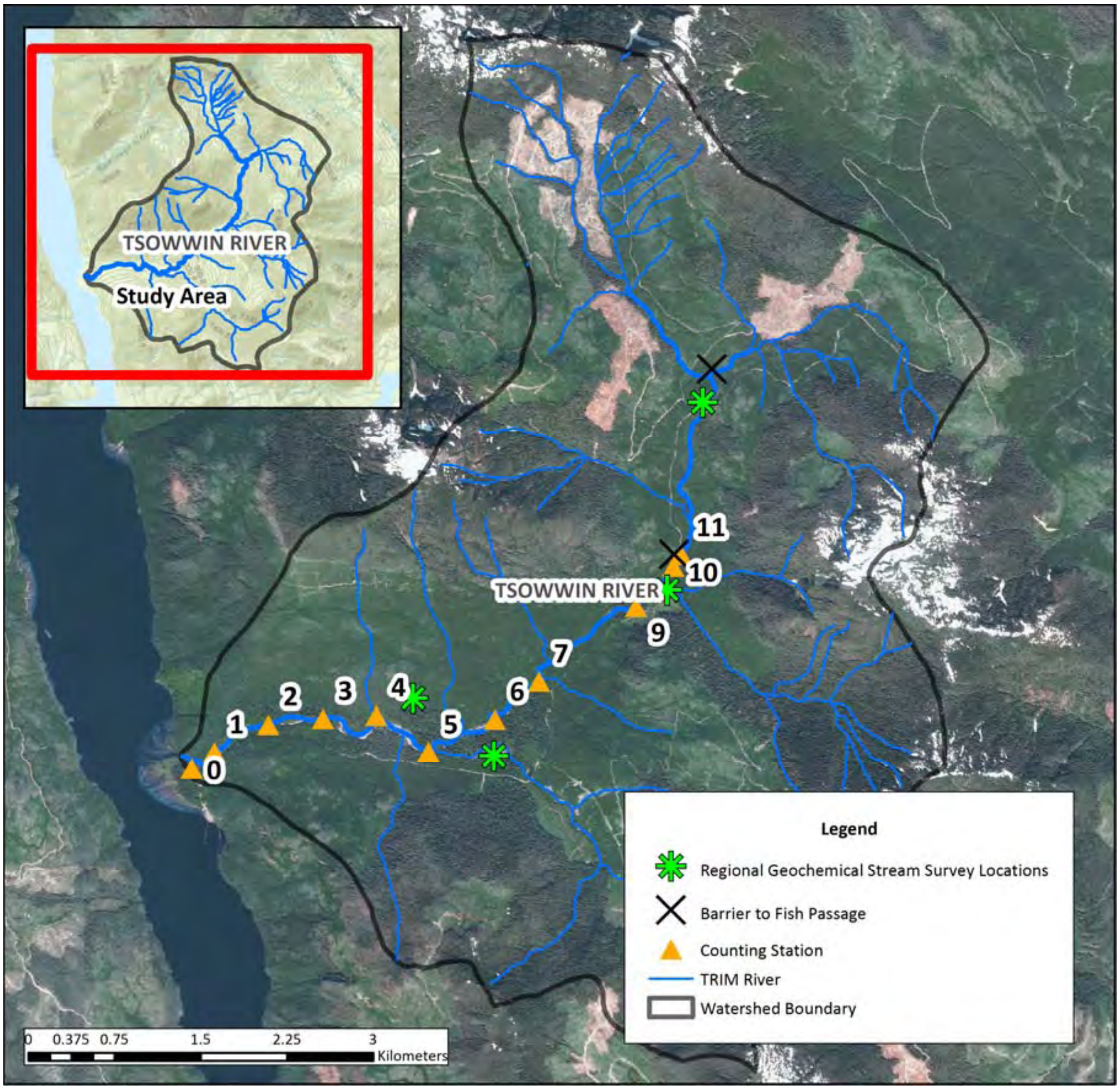

Figure 24. Regional geochemical stream survey locations in the Tsowwin River watershed.

Data collected in 2007 showed water pH levels to range between 6.4 and 7.6. All parameters detected in the samples (fluoride, uranium, and sulphate) remained below the Canadian Water Quality Guidelines for the Protection of Aquatic Life (Canadian Council of Ministers of the Environment, 1999). Note that no water quality data with respect to in-stream and intergravel DO was available for the Tsowwin River watershed. Interviews with the NSWS and local experts indicated the likelihood of water quality in this system to be impacting productivity levels was low (with the exception of intergravel flow DO levels); however, no supporting data exists (NSWS, 2015). While the data available indicated that (of the limited sampled parameters) no issues were identified, the spatial and temporal distribution of this data was not robust or diverse enough to determine the influence of water quality on fish production in this 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 in the Tsowwin River demonstrated water temperatures to have remained below the UOTR (between 15°C and 20°C) for all species between 2006 and 2013 (Table 2). Interviews with the NSWS and local experts indicated this parameter to not likely be impacting adult migration and spawning in this system (NSWS, 2015). 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 2. Water temperature data from 2007 to 2013 for the Tsowwin River during adult migration and spawning.

TSOWWIN RIVER						
Year	***Date***	***Temperature (°C)***	***Species Present***			
			SK	***CO***	***CH***	***CM***
2006	Oct. 23	8.5		X		X
2007	Oct. 1	9		X	X	X
	Oct. 14	9		X		X
	Oct. 26	8		X		X
	Nov. 5	8		X		X
2008	Sept. 23	10.5				
	Oct. 13	10		X	X	X
	Oct. 28	9		X		X
	Nov. 6	8				X
2009	Oct. 4	9		X		X
	Oct. 13	9	X	X	X	X
	Oct. 28	8	X	X		X
	Nov. 10	7		X		X
2010	Oct. 2	9	X	X	X	X
	Oct. 12	8		X		X
	Oct. 29	9	X	X		X
2011	Oct. 1	9.5	X	X	X	X
	Oct. 18	8.5	X	X	X	X
	Nov. 4	8	X	X		X
2012	Sept. 24	13				
	Oct. 12	12				X

2013	Oct. 12	8	X	X	X	X
	Oct. 27	9	X	X	X	X

4.8 Stream State Indicator: Discharge

Interviews with the NSWS and local experts indicated that higher discharges during rain events in recent years have resulted in significant bedload movement (NSWS, 2015); however, no discharge data exists for this system. As such, this parameter has been identified as a data gap.

4.9 Stream State Indicator: Accessible Stream Length

Information on accessible stream length for the Tsowwin River watershed was compiled from FISS, Brown et al's preliminary catalogue of salmon streams and spawning escapements of Statistical Area 25 (Tahsis) (1979), and provincial fish passage modeling data (MFLNRO Fish Passage Technical Working Group Web Page, 2013). Based on the GIS distribution data presented in Figure 2, Figure 6, Figure 10, and Figure 14, the following table summarizes accessible stream length by species:

Table 3. Accessible stream lengths, by species, for the Tsowwin River watershed.

	Chinook	Coho	Sockeye	Chum
Mainstem	3.26km	5.89km	3.72km	3.72km
Tributary	-	9.51km	-	0.52km
Total	3.26km	15.40km	3.72km	4.24km

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).

4.10 Stream State Indicator: Key Spawning Areas (Length)

As no information was available with respect to key spawning areas during the literature review, the key spawning areas (length) stream state indicator was identified as a data gap. Efforts should be directed towards mapping the location of these spawning grounds during future snorkey survey assessments.

4.11 Stream State Indicator: Stream Crossing Density

The following table summarizes the available stream crossing data for the Tsowwin River watershed:

Table 4. Modeled road stream crossing density in the Tsowwin River watershed.

Stream crossing Density: TSOWWIN RIVER	
# of Crossings:	61
# of Fish-Bearing:	15
# of Non-Fish Bearing:	46
Crossing Density:	1.70 / km^2

The results based on the PSCIS database indicate that the Tsowwin River watershed has a higher stream crossing density than the neighbouring Leiner River and Tahsis River watersheds (0.78 / km^2 and 0.09 / km^2 respectively) and a similar stream crossing density to the Perry River watershed (2.16 / km^2) (Abbott et al, 2015) (deVisser and Wright, 2015). The suggested benchmark for this indicator is a relative watershed comparison of crossing density and number of modeled fish-bearing crossings (Stalberg et al, 2009). In the Tsowwin River watershed, 25% of crossings are modeled as fish-bearing, whereas 75% of crossings are modeled as non-fish bearing. For comparative purposes, the percentage of fish-bearing crossings in the Leiner, Perry, and Tahsis rivers are 60%, 37%, and 42%.

Based on the higher stream crossing density when compared with other watersheds in Nootka Sound, this indicator could be considered as high risk. However, no ground-truthing of these modeled crossings exists. The risk associated with this indicator has therefore been classified as a data gap until further field assessments have been performed on crossings in the area.

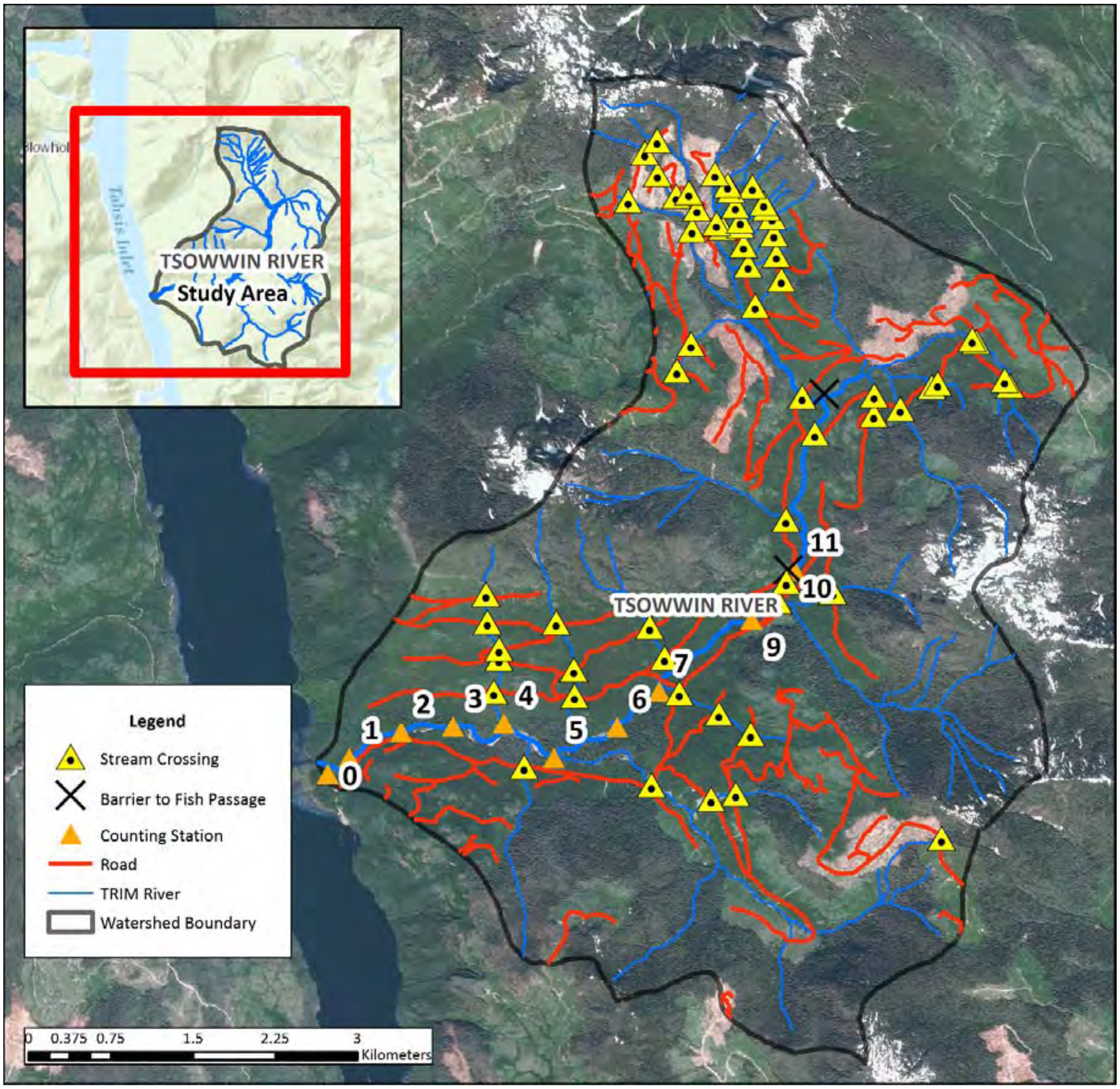

Figure 25. PSCIS modeled stream crossings in the Tsowwin River watershed.

4.12 Stream State Indicator: Habitat Composition

An analysis of habitat composition in the Tsowwin River indicated this system to be dominated by gravel bars and contain very little pool habitat. Significant braiding was evident throughout counting stations 0 and 7, and in many cases, no defined thalweg was present. Large mid-channel gravel bars were common and few pools present throughout this zone. While re-vegetation of some of the gravel bars was evident, habitat remains significantly degraded, with channel over-widening common throughout much of this section (Figure 26).

Above counting station 7, continuous habitat classification was not possible due to canopy cover and / or shadowing in incised sections. Where visible, channel widths were considerably reduced, with a smaller composition of gravel and higher composition of riffles and glides (Figure 26).

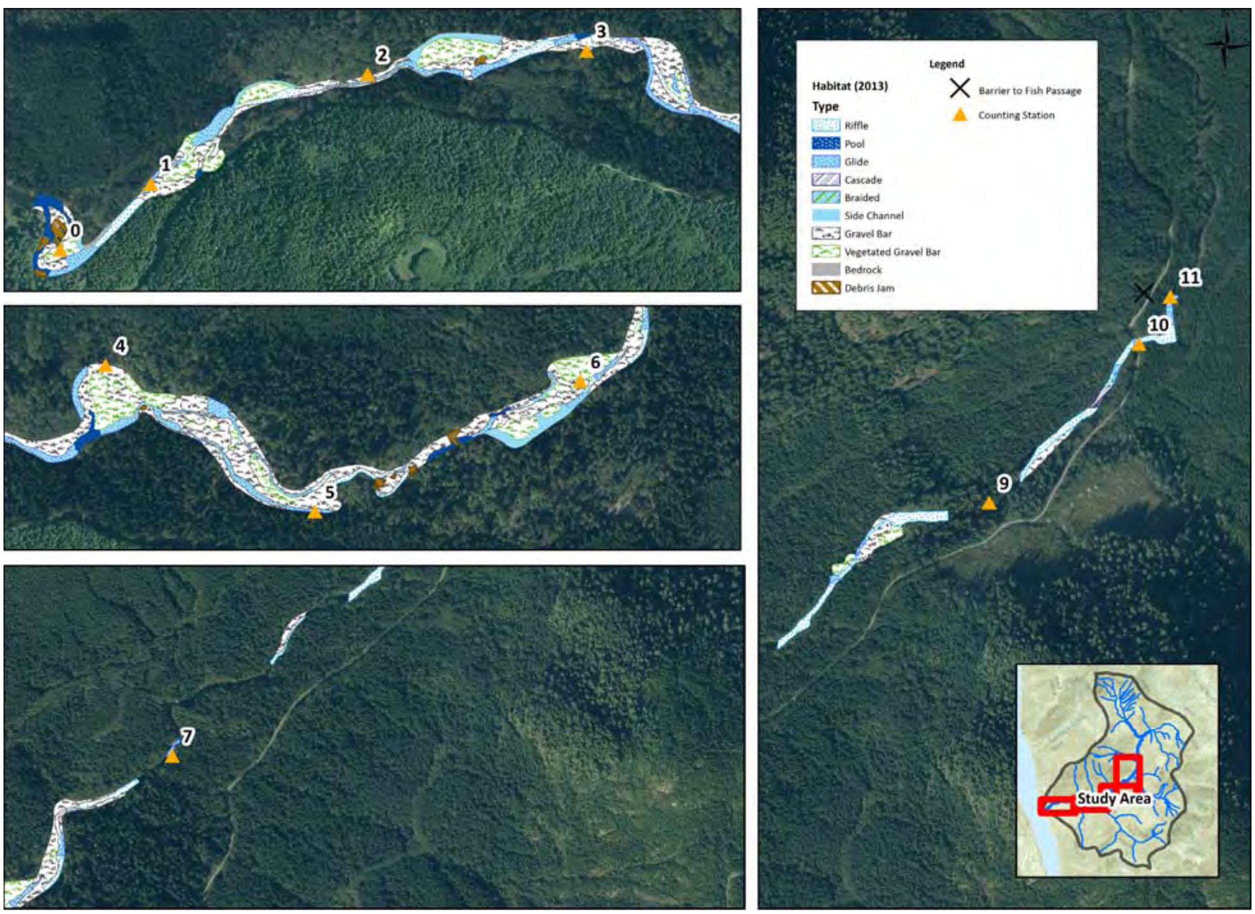

Figure 26. Habitat unit composition (2013) in the Tsowwin River watershed.

Note that because continuous habitat unit classification was not possible upstream of counting station 7, an analysis of habitat unit composition by species distribution was not considered as classification of all coho habitat was not possible. For the remainder of the species (chinook, chum, and sockeye), habitat unit compositions remained the same since distribution is similar for all species (Figure 27).

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 Tsowwin River is greater than 15m in average width, this metric still provides a useful benchmark for a comparison of habitat composition. When gravel bars, vegetated gravel bars, and debris jams are removed from the Tsowwin River composition analysis, percent pool habitat increases from 3.55% to 12.85%. Considering this value still remains below the suggested benchmark, the habitat composition indicator for the Tsowwin River has been classified as high risk, as pool frequencies in the system remain well below the suggested benchmarks.

A comparison of habitat unit composition between 1995 and 2013 (where data overlapped between counting stations 0 and 7) has demonstrated minor changes in habitat unit composition over time. A decrease in gravel bars and riffle habitat was observed, while an increase in vegetated gravel bars, glide habitat, and a minor increase in pool habitat was noted (Figure 27). The observed decrease in gravel bar and increase in vegetated gravel bars indicated some recovery to be occurring in the system. Re-vegetation was most evident between counting stations 2 and 3 and counting stations 4 and 5 (Figure 28).

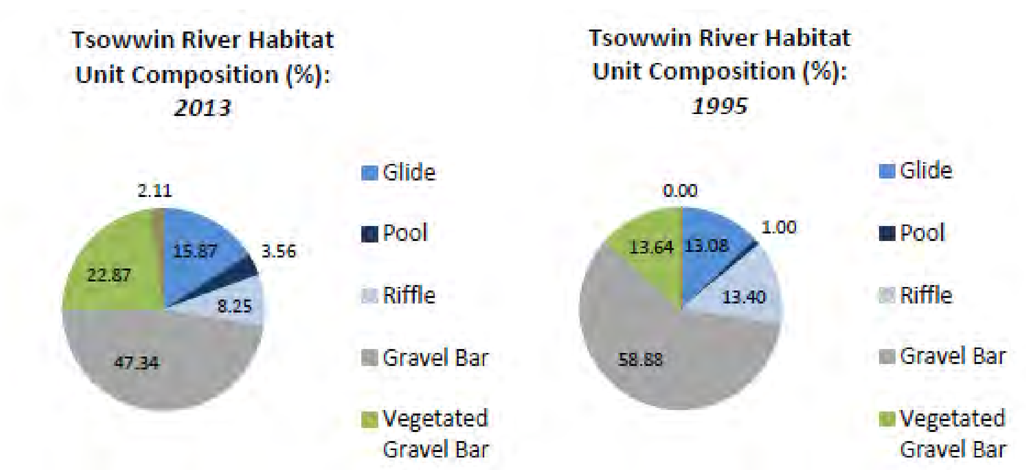

Figure 27. 2013 vs. 1995 habitat unit composition in the Tsowwin River, between counting stations 0 and 7.

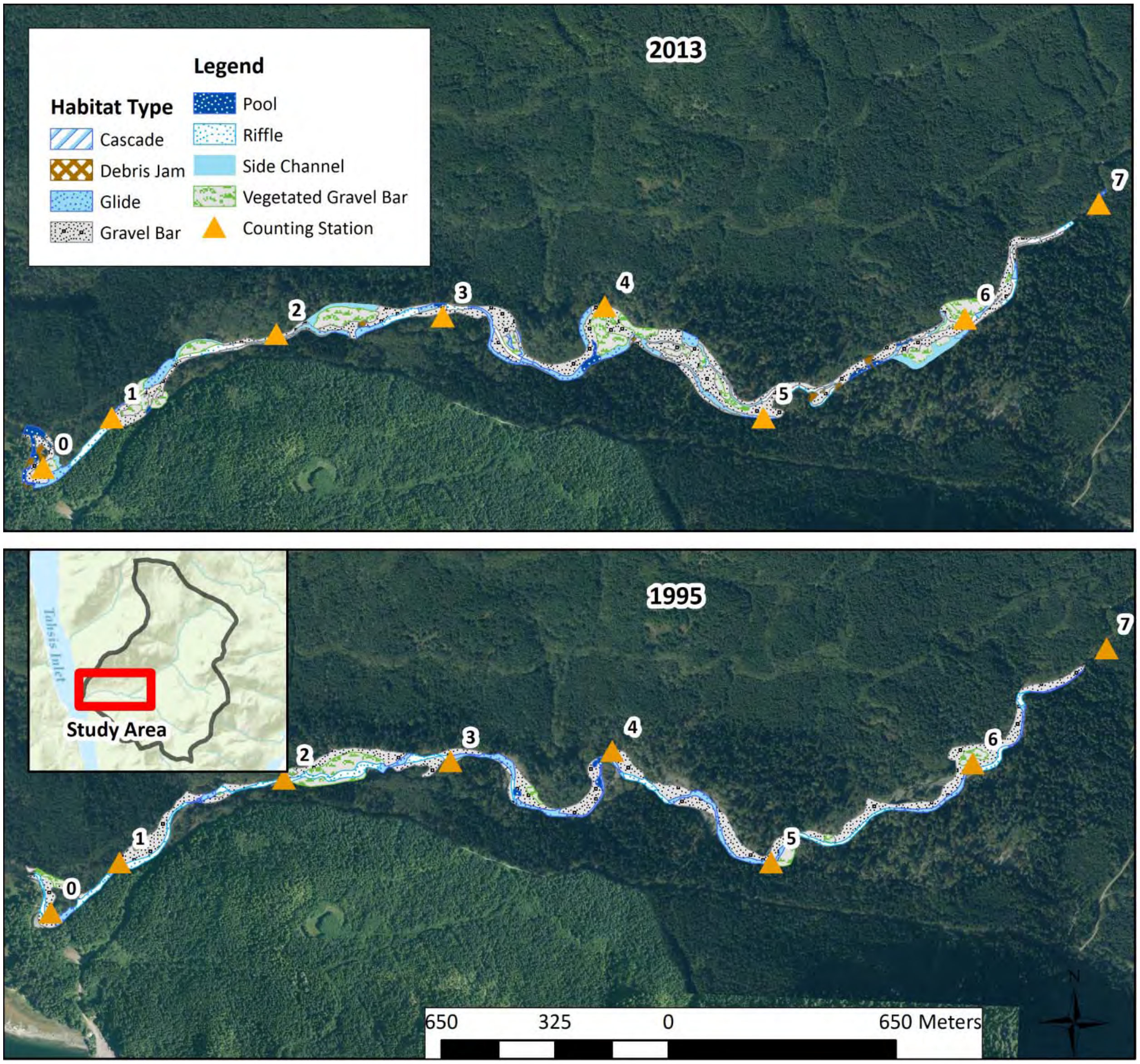

Figure 28. Changes in habitat unit composition between 2013 and 1995 in the Tsowwin River.

Interviews with the NSWS and local experts indicated that significant bedload movement from channel instabilities continues to occur in the Tsowwin River, causing a general infilling of pool habitat over time (NSWS, 2015).

4.13 Stream State Indicator: Channel Stability

While the habitat unit analysis between 1995 and 2013 demonstrated some similarities in percent composition between 1995 and 2013, a comparison of 1980, 1995, and 2013 imagery between counting stations 0 and 7 showed significant migration of the channel banks over time (Figure 29). While banks remained relatively stable between counting stations 0 and 1, channel migration was common throughout the remainder of the study area, with considerable channel widening and gravel depositions observed between counting stations 4 and 5 and just downstream of counting station 6 (Figure 29). An old channel braid near counting station 4 demonstrated the right bank channel to have historically formed an oxbow in the system; however, the current thalweg appears to have abandoned this channel and is now concentrated along the left bank. Channel bank erosion was observed near counting station 0, where continued migration of the left bank over time has been observed, and a sharp oxbow has formed (Figure 29). Considering this is an important location for adult holding and migration (and likely serves as a stopover pool used by fish during osmoregulation), future remediation works necessary to protect this habitat will need to be considered.

In general the Tsowwin River system has remained extremely dynamic over the past 35 years with persistent channel instabilities occurring from historical streamside vegetation removal. Interviews with local experts indicated this system to be highly unstable and highly braided, with its morphology changing during every flood event (R. Iles, pers. comm.).

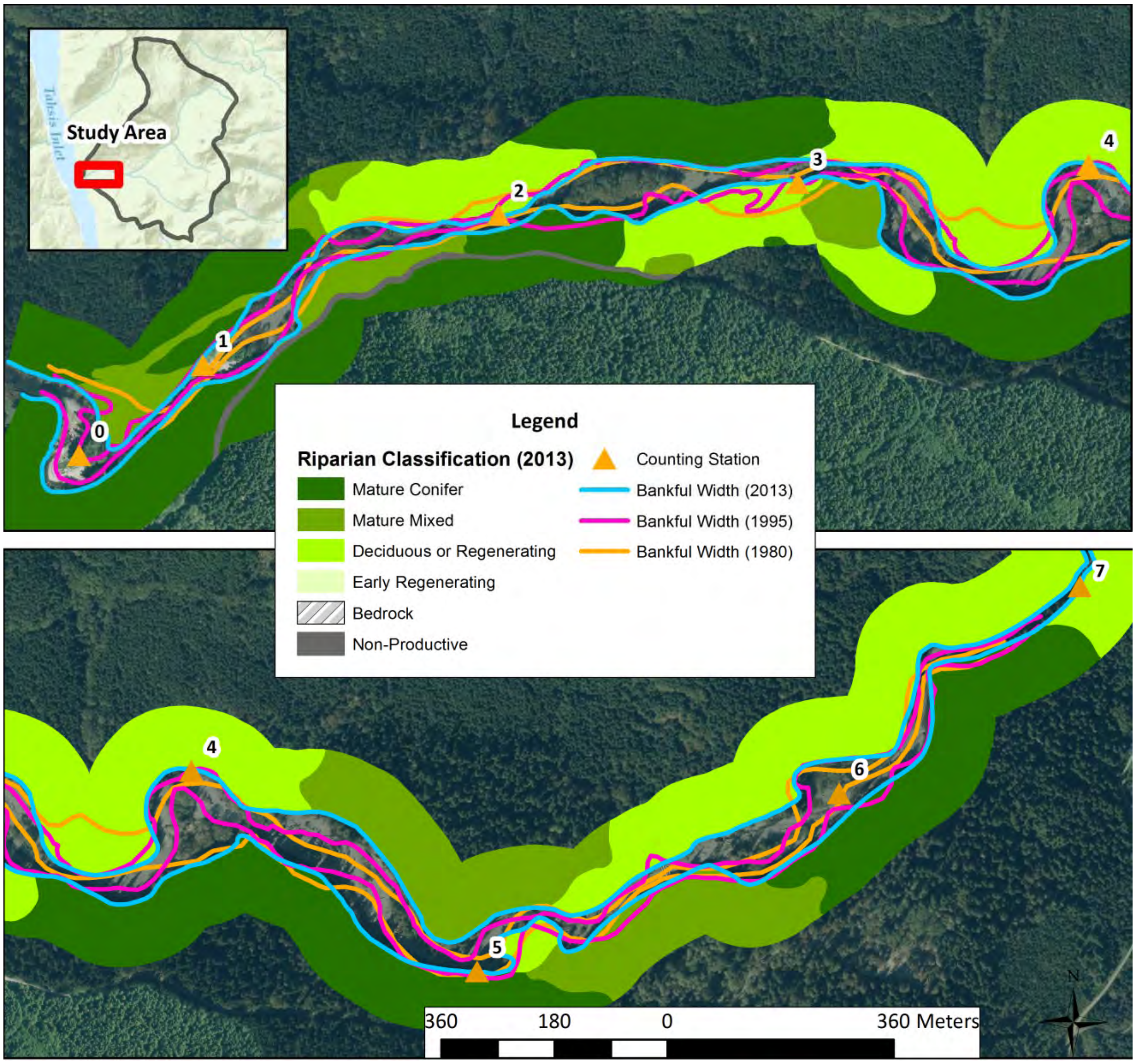

Figure 29. Observed channel migration in the Tsowwin River between 1980, 1995, and 2013.

Based on continued channel widening and instabilities observed in this analysis, the channel stability indicator has been ranked as high risk. Note that a proper study of the Tsowwin River by a fluvial geomorphologist is recommended to provide a detailed assessment of this indicator.

4.14 Stream State Indicator: Large Woody Debris

Continuous LWD classification in the Tsowwin River was not possible due to significant shading and canopy cover in the 2013 orthophotography. However, given the LWD trends observed in systems with similar characteristics in Nootka Sound (i.e. the Tahsis River, Canton Creek, and the Sucwoa River), this system is likely deficient in functional LWD. This deficiency is likely the result of low LWD recruitment potential in the adjacent riparian stand and channel instabilities (combined with aggressive hydrology) preventing the retention of LWD.

While functional LWD is likely a high risk indicator for the Tsowwin River, this habitat indicator has been classified as a data gap based on the lack of system-specific information.

4.15 Stream State Indicator: Off-Channel Habitats

The Tsowwin River was identified to have potential for off-channel habitats by local experts (NSWS, 2015); however, no data exists. As such, this indicator has been ranked as a data gap.

4.16 Estuary State Indicator: Estuary Habitat Disturbance

At present, there are two licences of occupation within and adjacent to the Tsowwin River estuary: an inactive shellfish tenure (and presumably beach culture) tenure in the northern part of the estuary (NSWS, 2015), and a log handling / storage tenure just south of the estuary (Figure 30).

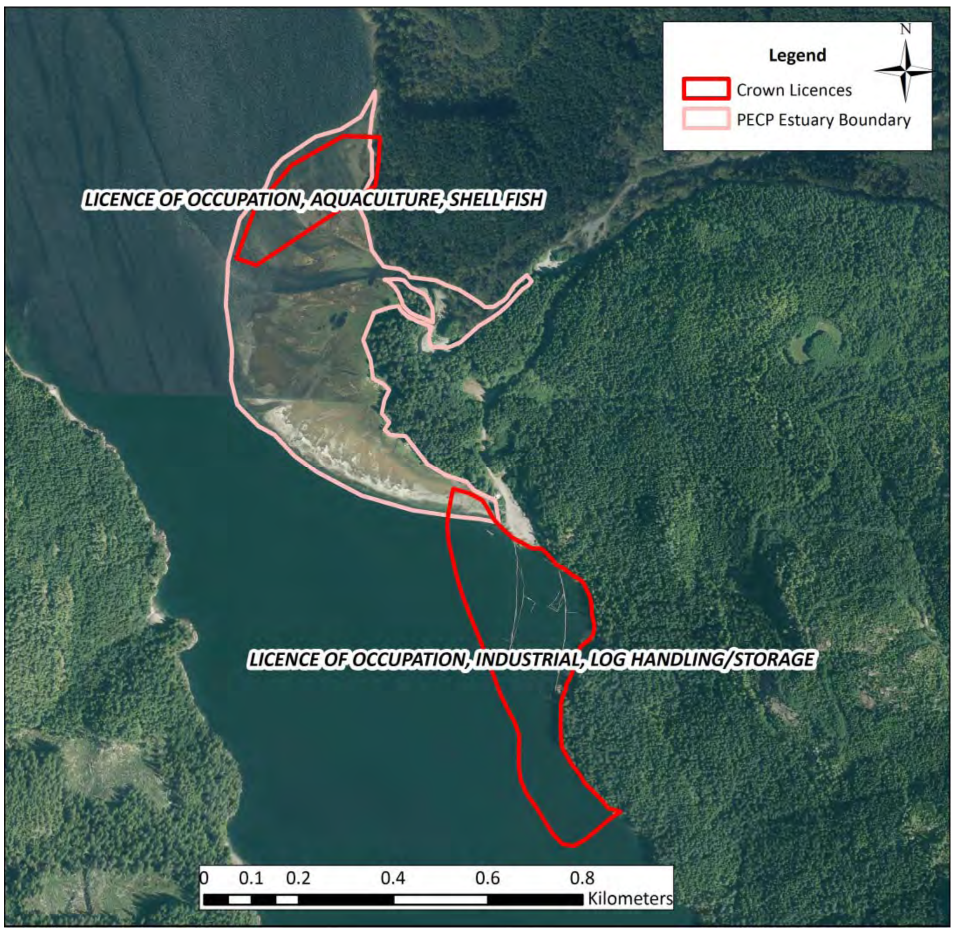

Figure 30. Known present-day habitat disturbances in the Tsowwin River estuary.

Discussions with local experts indicated minimal changes have been noted in the estuary due to anthropogenic disturbances, with the exception of the loss of a kelp bed just south of the estuary (NSWS, 2015). Note that detailed imagery of historical habitat condition was not available. As such, an evaluation of the change in estuarine habitat over time (as an indicator of disturbance) was not possible.

Given the presence of the log handling tenure near the Tsowwin River estuary and the loss of a historical kelp bed, this habitat disturbance indicator has been ranked as moderate risk. While the log handling facility is situated primarily outside of the defined estuary boundary, the strict enforcement of best management practices during operations will be necessary to ensure the protection of adjacent estuarine habitat.

4.17 Estuary State Indicator: Permitted Waste Discharges

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

4.18 Estuary State Indicator: Estuary Chemistry and Contaminants

No data with respect to estuary chemistry and contaminants was available for the Tsowwin River estuary. As such, this indicator has been identified as a data gap. Anecdotal evidence stated that there was potential for submerged commercial debris at the old camp location just south of the estuary (NSWS, 2015).

4.19 Estuary State Indicator: Dissolved Oxygen

No data with respect to estuary dissolved oxygen was available for the Tsowwin River estuary. As such, this indicator has been identified as a data gap.

4.20 Estuary State Indicator: Estuarine Habitat Area

The following figure details habitat composition within the Tsowwin River estuary:

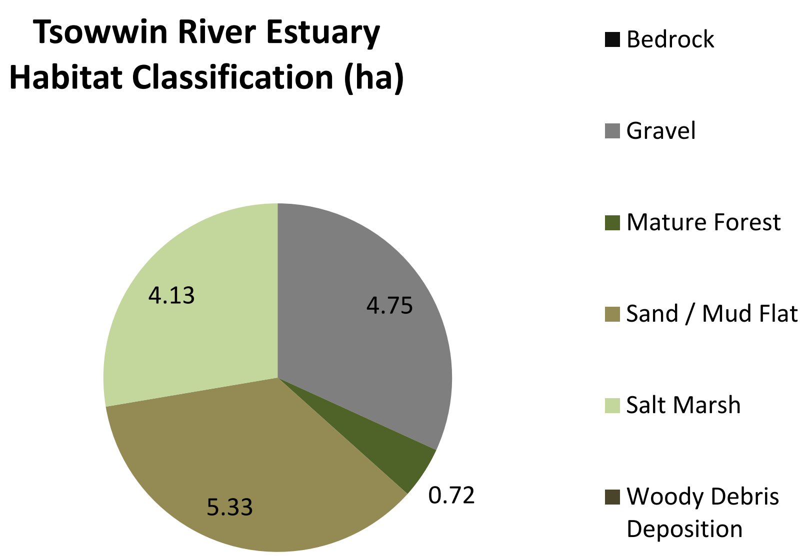

Figure 31. Estuary habitat composition in the Tsowwin River estuary.

Figure 31 demonstrates that the while the Tsowwin River estuary has retained a considerable component of salt marsh habitat (4.13 hectares, or 27.66%), a large component of the estuary is comprised of gravel deposits (4.75 hectares, or 31.82%). These gravel deposits are likely the result of upstream bed load movement and channel instabilities (Figure 29). This trend has been observed in other coastal watersheds (i.e. the Sarita River) that have a history of extensive resource extraction and habitat impacts (M.C. Wright and Associates Ltd., unpublished data). Figure 32 shows these gravel depositions to be located near the outer (and lower intertidal) margins of the estuary.

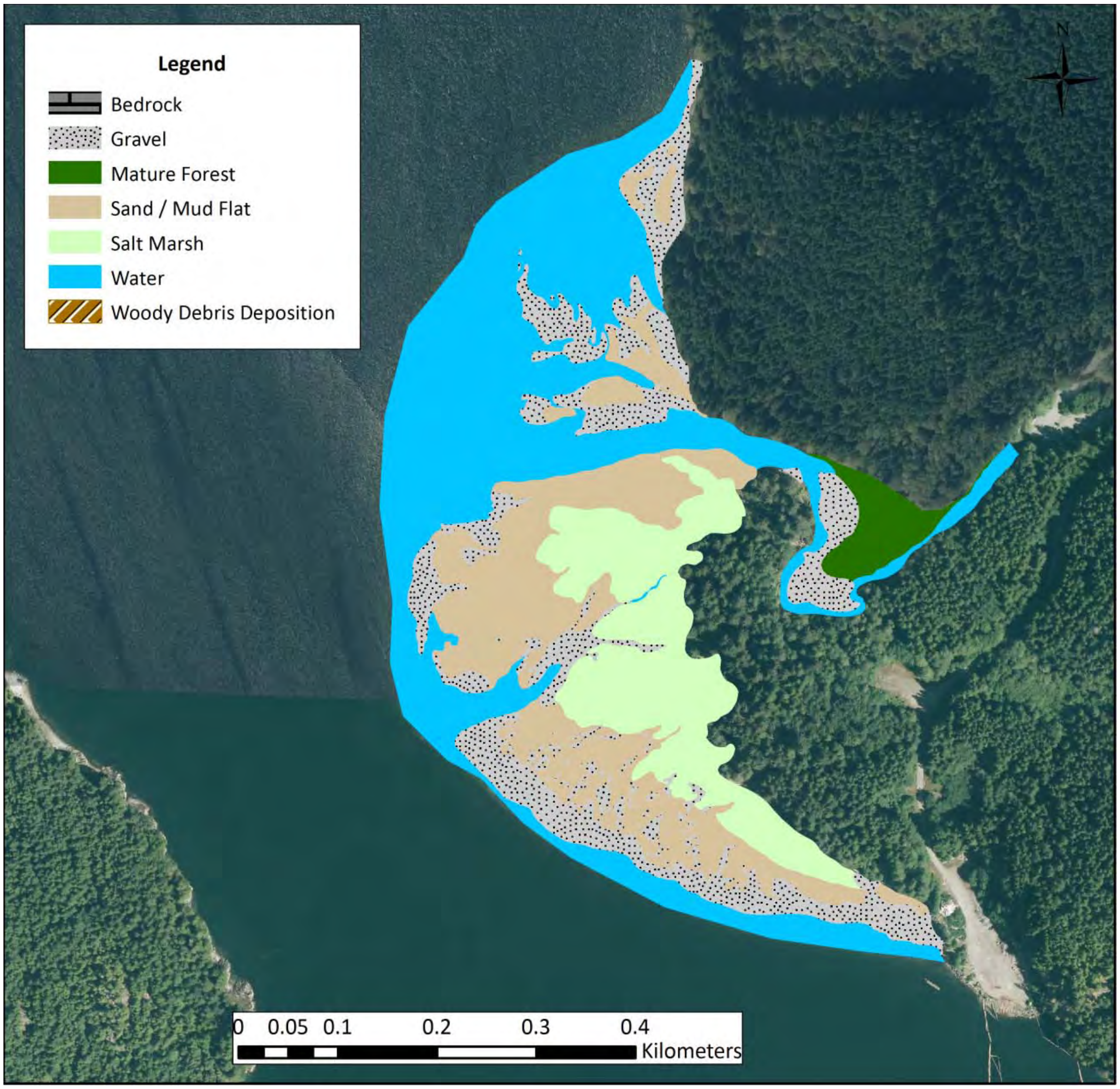

Figure 32. Habitat composition in the Tsowwin River estuary.

Given the known importance of estuaries as critical rearing and foraging zone for all species of out-migrating salmonids, and the observed impacts from upstream gravel deposition in the river, the Tsowwin River estuary has been given a moderate risk rating for estuary habitat area. Note that no subtidal habitat condition data was available for review; therefore, a partial data gap has been assigned to this indicator.

5.0 SUMMARY OF HABITAT INDICATORS AND DATA GAPS

Based on the results of the habitat status assessment of the Tsowwin River watershed, it is clear that legacy impacts from forest harvesting continue to persist in this watershed, and the system continues to exhibit instabilities and significant bed load movement. The inherent characteristics of this system (i.e. aggressive hydrology, alluvial nature, presence of steep terrain, and frequent occurrence of natural landslides), combined with ongoing forest harvesting, has resulted in significant aggradation and channel over-widening in the lower river. Gravel deposition in the estuary is indicative of upstream instabilities and gravel transport downstream. Degraded riparian zones persist along both the left and right banks of the entire mainstem, and are a result of historical forest harvesting practices and ongoing channel instabilities.

Table 5 summarizes the results of ranked assessed habitat indicators and identifies indicator data gaps:

Table 5. **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	Y - Partial	Significant channel migration observed in select locations between 1980 and 2013. Channel over-widening continuing to occur in key locations. 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.
Watershed road development	Stream: Pressure	HIGH	Y - Partial	Indicator exceeds metrics provided in Stalberg et al (2009). However, analysis does not consider condition of roads (i.e. era of construction, deactivation status, etc.); therefore, partial data gap assigned.
Estuary habitat disturbance	Estuary: State	MODERATE	Y - Partial	Active shellfish tenure located within the northern margin of the estuary; active log handling / storage tenure located just south of the estuary. Enforcement of log handling best management practices during active operations imperative to ensure protection of estuarine habitat.
Estuary habitat area	Estuary: State	MODERATE	Y - Partial	Considerable gravel depositions originating from upstream bed load movement present in the estuary. Note that no data exists on the condition of subtidal estuarine habitat.
Permitted waste management discharges	Stream: State	LOW	N	No permitted waste management discharges in the Tsowwin River.
Water extraction	Stream: Pressure	LOW	N	No licenced water extractions in the estuary.
Water temperature: Migration and spawning	Stream: State	LOW	Y - Partial	Recorded water temperatures during spawn surveys from 2006 – 2014 showed no occurrence of temperatures approaching the UOTR for adult salmonids. Note that temporal distribution of data is limited – only point samples taken during swim surveys.
Permitted waste management discharges	Estuary: State	LOW	N	No permitted waste discharges identified in the Tsowwin River estuary.

Stream crossing density	Stream: Pressure	Not ranked – data gap	Y	While high number of crossings modeled for this watershed, no confirmation data available with respect to crossing condition and potential impacts. Ground-truthing required to assess status of these crossings.
Large woody debris	Stream: State	Not ranked – data gap	Y	Canopy cover and shadowing in orthophotography prevented full LWD assessment. However, based on watersheds in Nootka Sound with similar characteristics, this system is likely deficient in LWD.
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 Tsowwin River.
Estuary chemistry and contaminants	Estuary: State	Not ranked – data gap	Y	No water quality data available for the estuary.
Estuary dissolved oxygen	Estuary: State	Not ranked – data gap	Y	No DO data available for the estuary.
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 issues of degraded riparian zones, channel instabilities, over-widening and aggradation, and erosion in known holding habitats, the following sections describe recommended restoration projects for the Tsowwin River watershed.

5.1.1 Riparian Treatments

Specific zones recommended for riparian treatments include the deciduous-dominated right bank between counting stations 1 and 2, 3 and 4, and 5 and 11, and the deciduous-dominated left bank between counting stations 7 and 11 (Figure 33). The total area of these recommended areas is approximately 61.57 hectares.

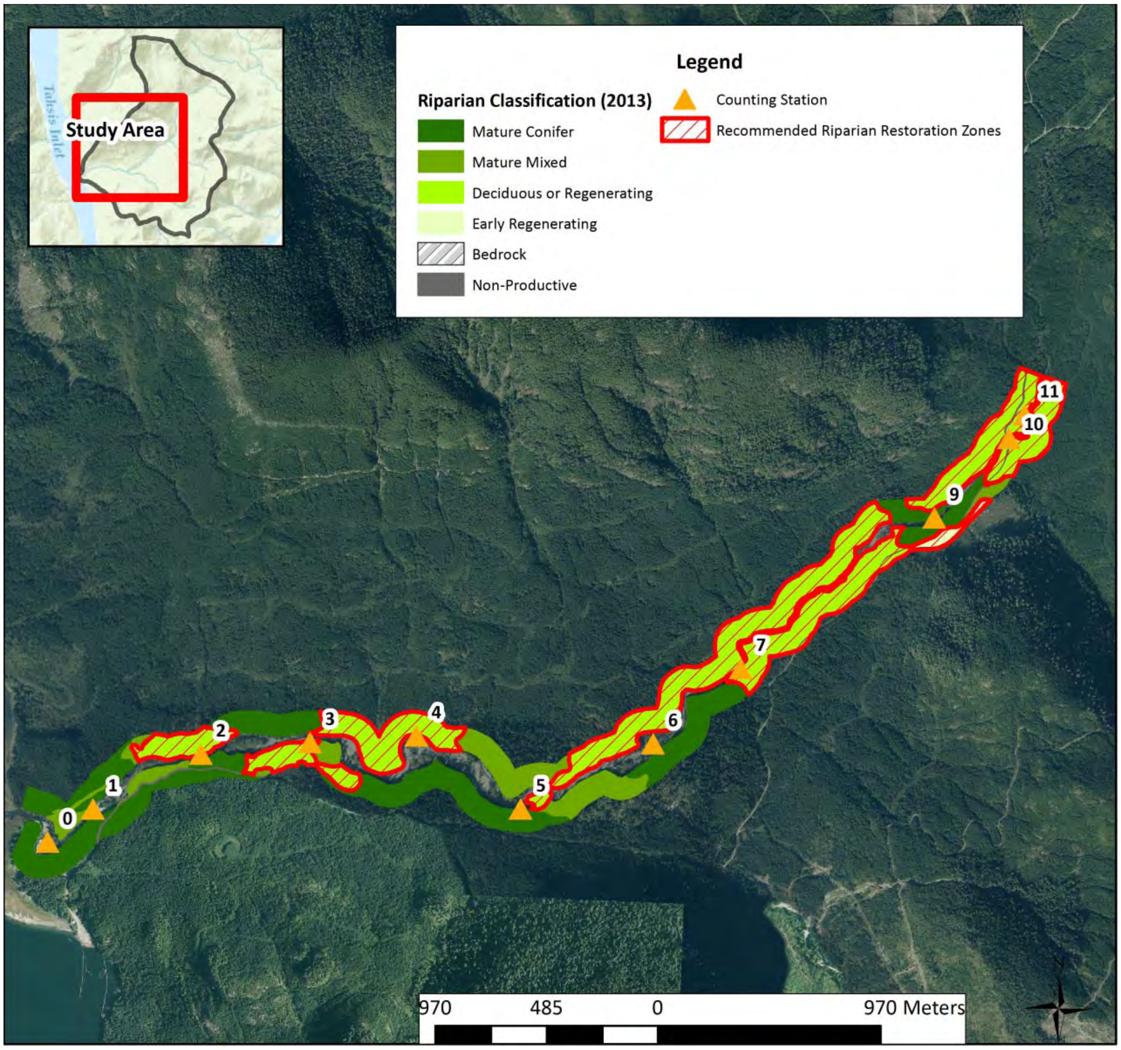

Figure 33. Recommended riparian treatment zones for the Tsowwin River.

Common riparian treatments utilized in degraded riparian zones that could be applied in the Tsowwin 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 Live Gravel Bar Staking

Live staking of gravel bars using willow (*Salix spp.*) and other plant species such as red-osier dogwood (*Osier stolonifera*) and black cottonwood (*Populus trichocarpa*) can be used to treat river channels that have become aggraded and braided. In live staking, cuttings (stakes) from the selected species are planted at high density into the gravel bars. Placing of these stakes is intended to trap woody debris and encourage local sediment deposition while live stakes continue to grow and protrude above the gravel bar. Over time, elevation of gravel bars is anticipated, while the accumulation of fines and organics will promote the establishment of additional riparian vegetation (Figure 34). Eventually streamflow will become more confined to the main channel and normal bankful widths will be achieved (Cuthbert and Redden, 2005).

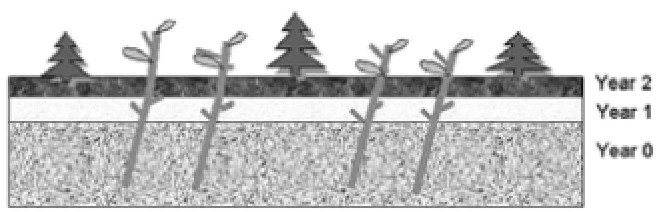

Figure 34. Live gravel bar staking resulting in eventual re-vegetation of gravel bars.

In the Tsowwin River, several gravel bars have been identified as candidates for live staking between counting stations 3 and 5. Significant channel over-widening has occurred in these zones, and opportunities exist to encourage sediment deposition (to elevations that would support coniferous trees) on either side of the natural thalweg to help reclaim this section to a natural channel width (Photo 2 and Photo 3). At counting station 4, live staking within the partially abandoned oxbow will facilitate reclamation of the riparian zone, and encourage flows to remain within the existing thalweg.

Photo 2. Live gravel bar staking opportunities between counting stations 3 and 4.

Photo 3. Live gravel bar staking opportunities between counting stations 4 and 5.

Prior to gravel bar staking, field ground-truthing of these gravel bars is required to assess if natural re-vegetation is already occurring in these zones and to evaluate channel stability. Preliminary data collection is encouraged through a community science initiative (i.e. stream keepers groups, local residents, school groups, etc.) and could include initiatives such as photo station monitoring photography, GPS data collection, and the installation and servicing of time-lapse cameras in select locations. This preliminary data can be used to facilitate future prescription development and contribute to a channel stability assessment conducted by a fluvial geo-morphologist (recommended as part of the prescription development process).

5.1.3 Bank Stabilization

Consideration of the eroding bank and oxbow identified at counting station 0 is highly recommended for a bank stabilization initiative. This bank is situated within known adult holding habitat (all species), and should erosion along this left bank continue, the channel is at risk of breaching directly into the estuary and thereby resulting in a loss of high value holding (and osmoregulation) habitat (Photo 4).

Potential stabilization methods in this location could include stabilization of existing wood in this corner, and / or the installation of LWD revetments (Figure 35).

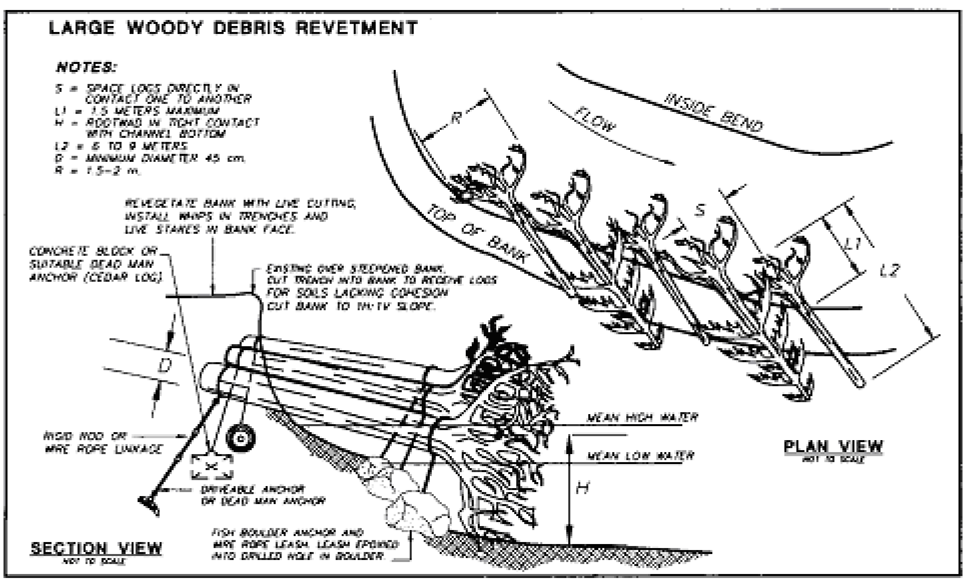

Figure 35 Typical large woody debris revement installation (Slaney & Zaldokas, 1997)

Prior to the selection of the appropriate bank stabilization method, field ground-truthing of this zone is required in order to understand how this section is affected by different flow regimes. Preliminary data collection is encouraged through a community science initiative (i.e. stream keepers groups, local residents, school groups, etc.) and could include initiatives such as photo station monitoring photography, GPS data collection, and the installation and servicing of time-lapse cameras in select locations. This preliminary data can be used to facilitate future prescription development and contribute to a channel stability assessment conducted by a fluvial geo-morphologist (recommended as part of the prescription development process).

Photo 4. Eroding bend and potential bank stabilization site near counting station 0 and the Tsowwin River estuary.

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 6. Data gaps and recommended studies for habitat indicators the Tsowwin River.

Data Gap	Priority	Recommendation
Species-specific holding and spawning habitat throughout the anadromous length of river.	Moderate	Conduct a snorkel survey throughout the anadromous reach of the river and geo-reference known holding and spawning grounds; collect local ecological knowledge on a map base for known holding and spawning locations.
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)	Moderate	
Channel stability	High	Ground-truth key eroding sections and have channel stability assessed by a fluvial geo-morphologist.
Stream discharge	Low	Install a hydromet station on the Tsowwin River to measure continuous discharge and temperature information.
Water temperature	Low	
Water quality (instream)	Low	Collect opportunistic point samples of water quality data.
Status of off-channel habitats, including wetlands, tributaries, and accessible stream length of these tributaries	High	Conduct a field mapping study of off-channel habitats. Collect water quality data simultaneously. Use field data of tributary locations to classify riparian vegetation using 2013 high resolution orthophotographs. Ground truthing of all riparian stand age required.
Riparian classification of tributaries	Moderate	
Large woody debris	High	Ground-truth LWD for functionality and assess submerged LWD not visible from orthophotographs.
Watershed road and stream crossing condition	Moderate	Conduct a detailed culvert assessment to identify potential fish passage issues with modeled crossings; in addition, note the condition of roads (i.e. de-activated, overgrown, etc.) to provide further information with respect to the road density metric.
Subtidal estuarine habitat condition	Moderate	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. Considering the close proximity of log handling to the estuary, some degradation of subtidal estuarine habitat is likely.
Estuary chemistry and contaminants	Moderate	
Estuary dissolved oxygen	Moderate	
Upper watershed tributary stability	Low	Have a fluvial geo-morphologist assess terrain stability in upper tributaries to identify future sediment sources (both location and potential relative quantities).

5.3 Best Functioning Habitats Requiring Protection

The protection of existing critical habitats is important to maintain existing fish productivity levels and prevent the loss of these important zones. Figure 36 summarizes all of the known holding and juvenile rearing and migration habitat identified during this assessment (note that spawning habitat is presently a data gap for this system). 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.

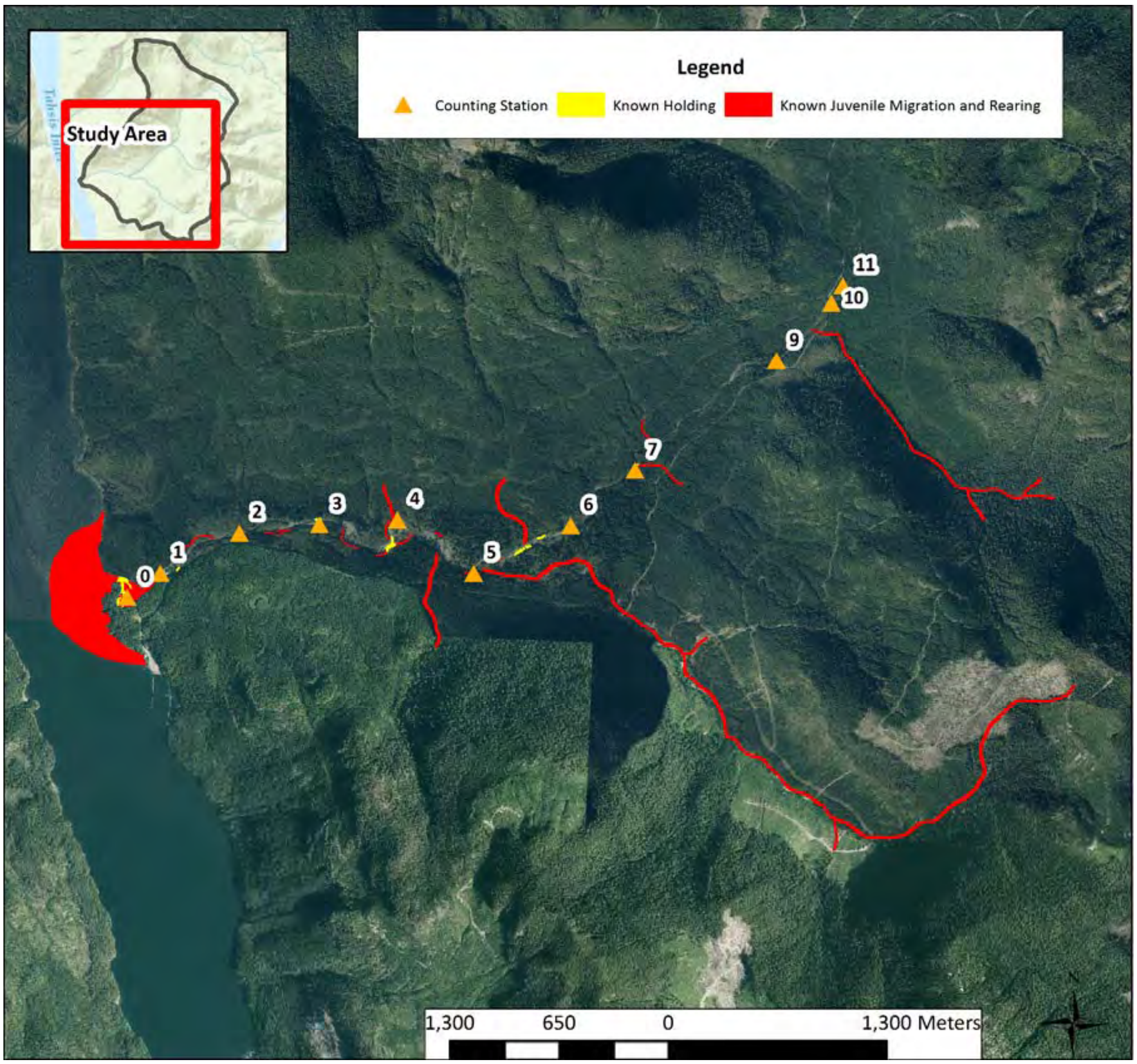

Figure 36. Critical habitats requiring protection in the Tsowwin River watershed.

6.0 CONCLUSION

The Tsowwin River watershed remains highly degraded from historical logging practices removing riparian vegetation to the stream banks. The inherent characteristics of this system (i.e. aggressive hydrology, alluvial nature, presence of steep terrain, and frequent occurrence of natural landslides), combined with ongoing forest harvesting, has resulted in significant aggradation, channel over-widening, and braiding in the lower river. Many locations in the channel are overwhelmed with sediments and the observed gravel deposition in the estuary indicates the presence of continued instability upstream.

The habitat status assessment for the Tsowwin River watershed has identified high risk habitat indicators to be high total land cover alterations adjacent to fish habitat, riparian disturbances, channel bank stability (i.e. over-widening), and habitat composition (i.e. aggradation and infilling of pools) (note that watershed road development also scored as high risk; however, data gaps exist with this metric). Important data gaps to note include instream water quality, continuous discharge and temperature data, intergravel flows and DO in key spawning grounds, and quantification of off-channel and wetland habitat condition.

Both riparian and instream restoration opportunities exist in this system. Potential riparian treatments have been identified throughout the anadromous reach along the left and right banks. Several key gravel bars between counting stations 3 and 5 would benefit from live staking to promote re-vegetation, and the assessment of the eroding left bank near counting station 0 is recommended to identify suitable bank stabilization methods required to protect known adult holding habitat in this vicinity.

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, and off-channel habitats is necessary to obtain a more comprehensive understanding of limiting factors in the Tsowwin River watershed.

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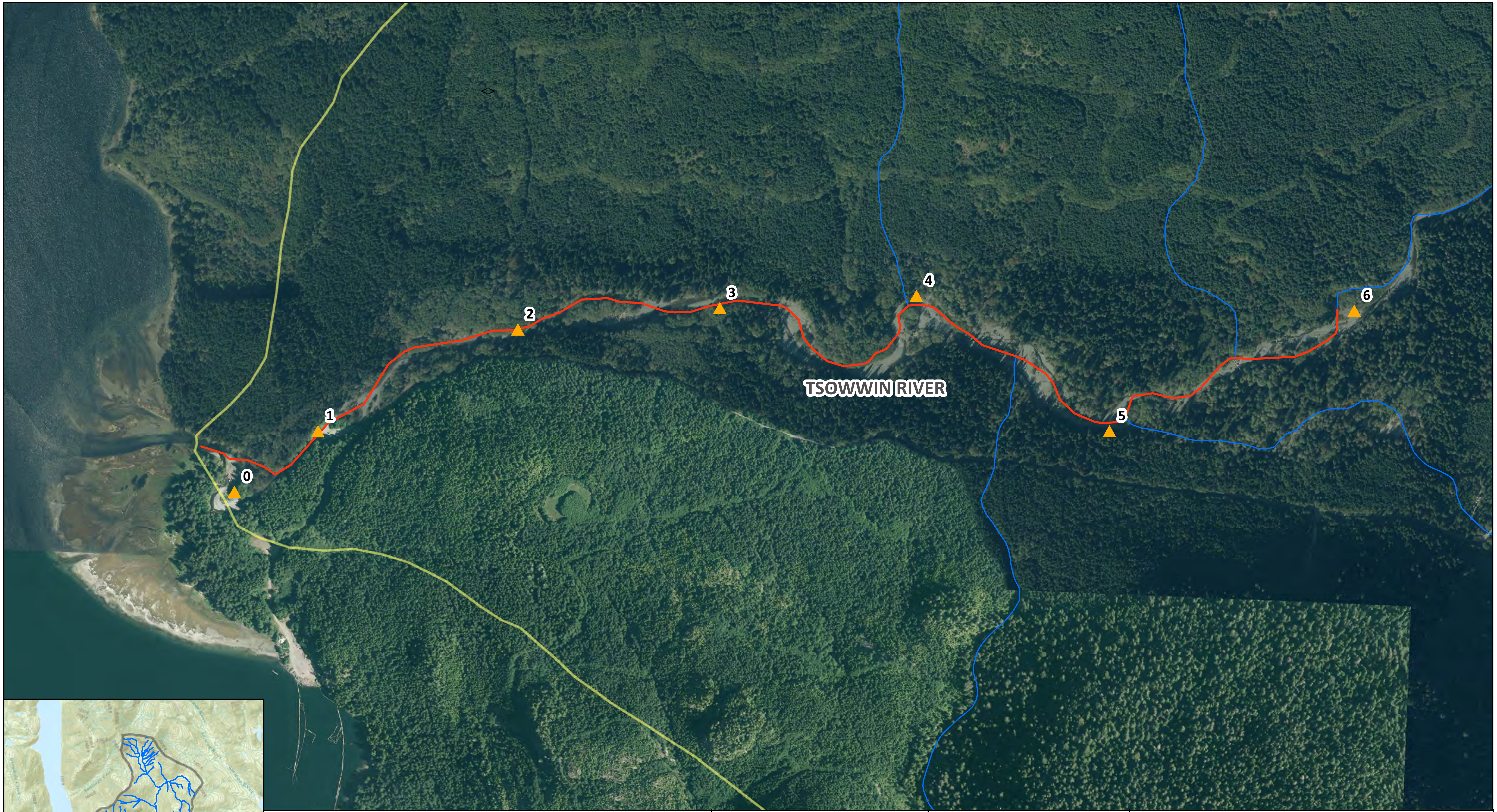
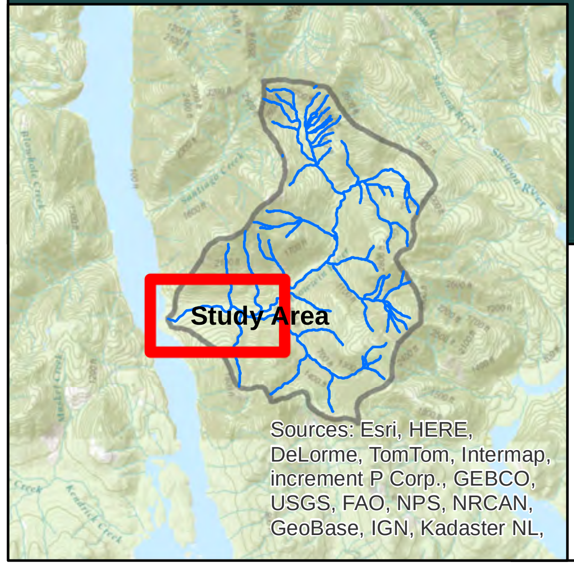
APPENDIX 1: TSOWWIN RIVER WATERSHED MAP ATLAS





Legend

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

MAP 1

Tsowwin River Watershed Known Chinook Distribution

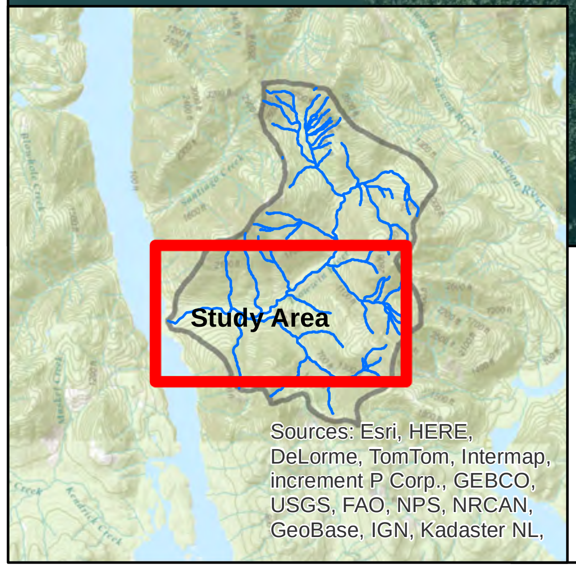
Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

Nootka Sound Watershed Society
M. C. Wright and Associates Ltd. Biological Consultants
NCompas Software Development

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N
W E
S

0 0.075 0.15 0.3 0.45 0.6 Kilometers



Legend

- Barrier to Fish Passage
- Counting Station
- Known and Modelled Coho Distribution
- TRIM River
- Watershed Boundary

MAP 2

Tsowwin River Watershed Known and Modelled Coho Distribution

Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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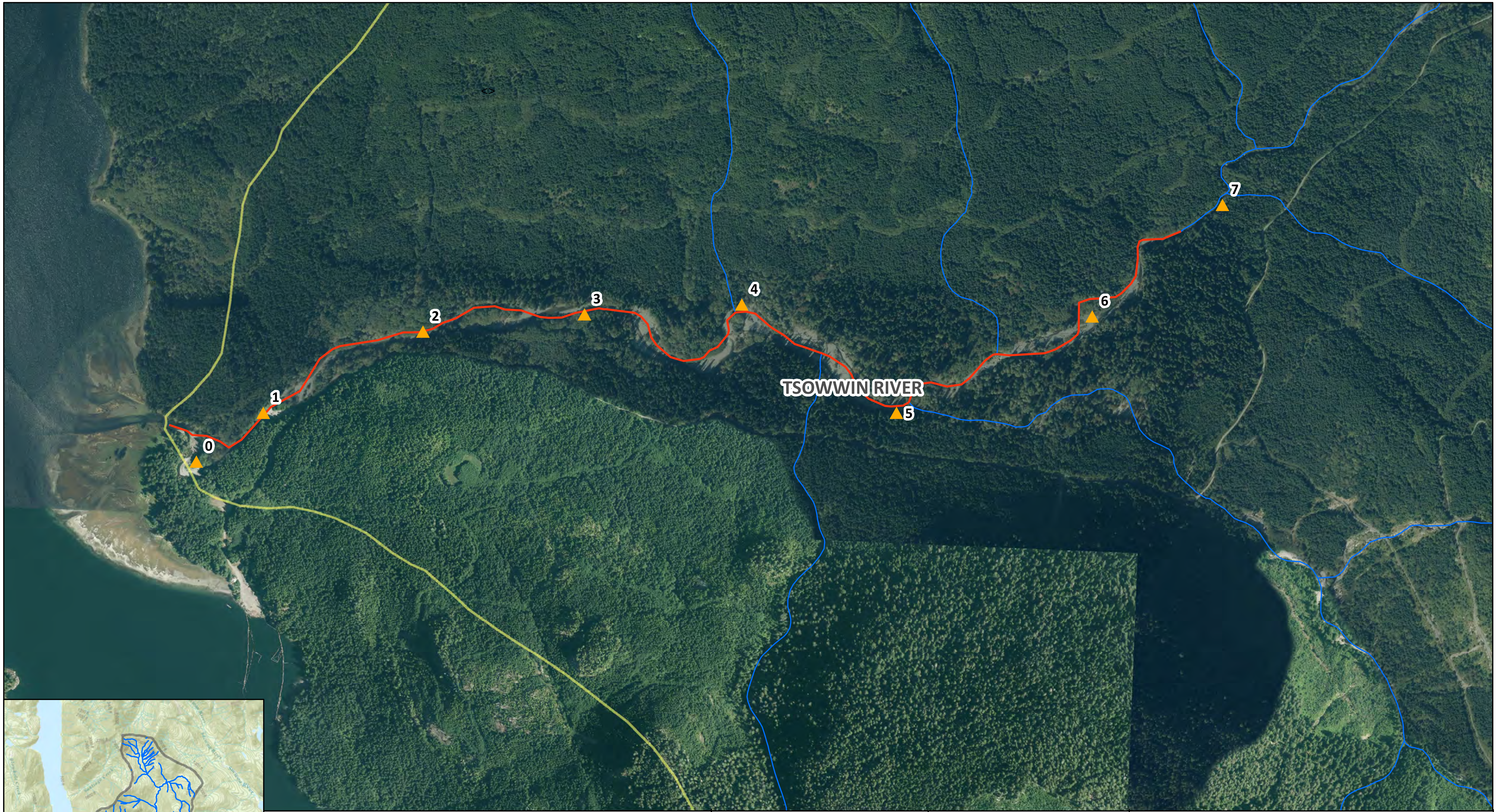
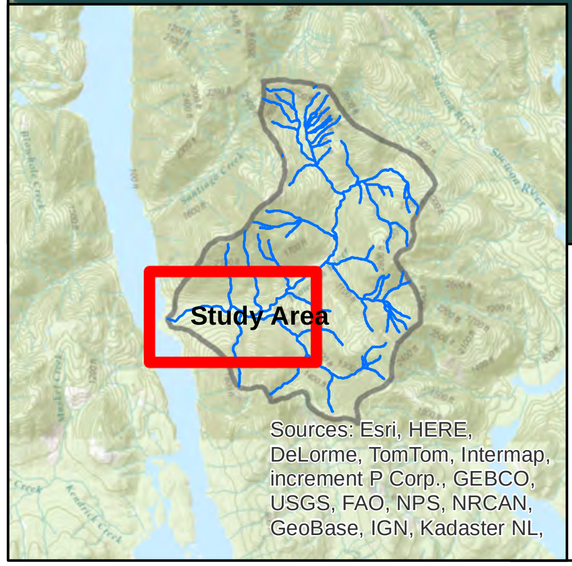
M. C. Wright and Associates Ltd.
Biological Consultants
NCompas
Software Development

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N
W E
S

0 0.125 0.25 0.5 0.75 1 Kilometers





Legend

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

MAP 3

Tsowwin River Watershed Known Sockeye Distribution

Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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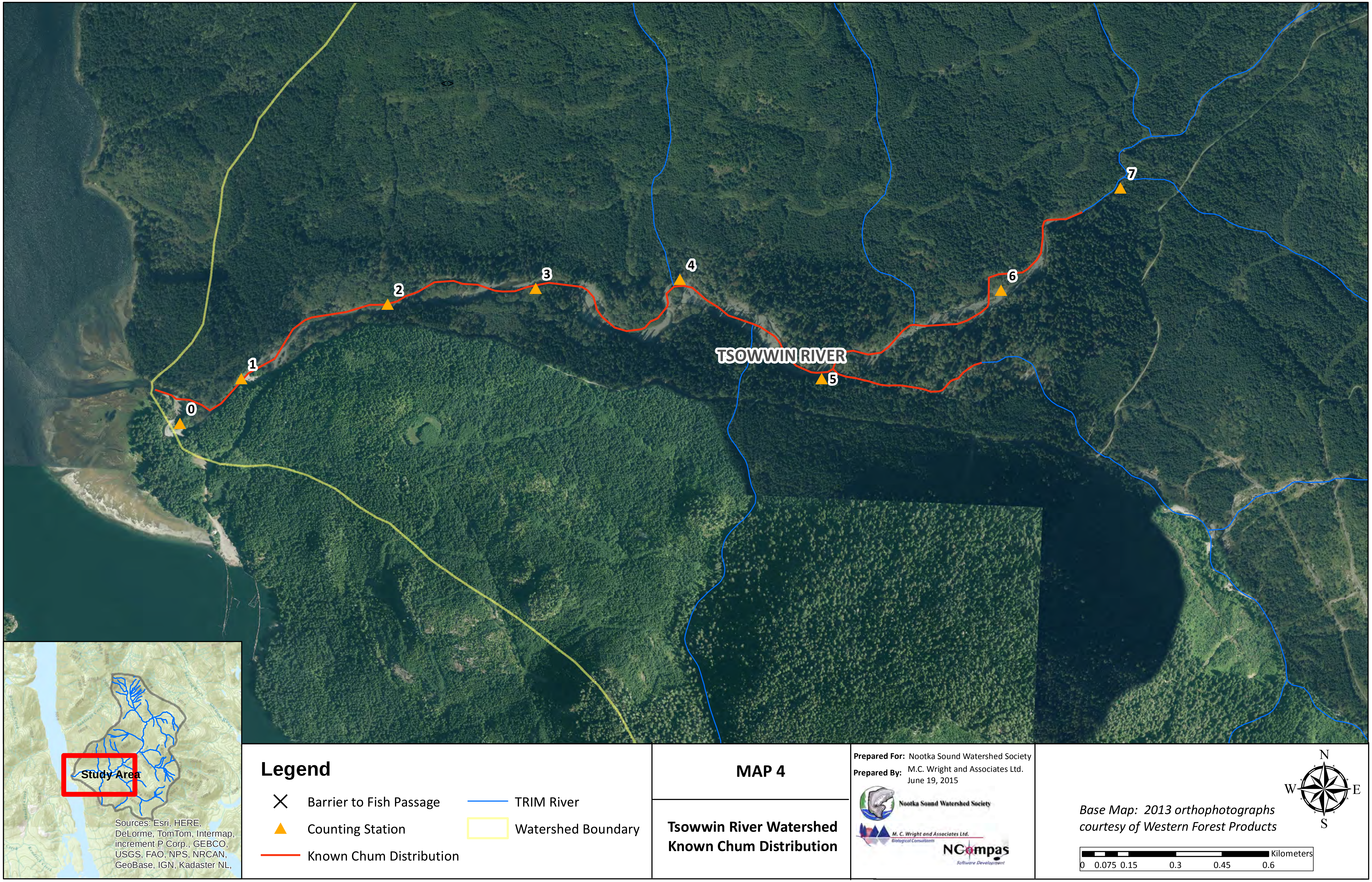
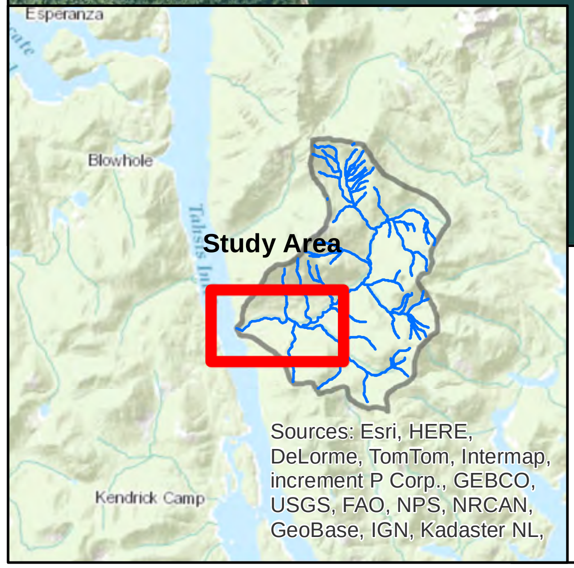
Base Map: 2013 orthophotographs courtesy of Western Forest Products

N S E W

0 0.075 0.15 0.3 0.45 0.6 Kilometers



TSOWWIN RIVER
0
1
2
3
4
5
6
7
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 Chum Distribution
TRIM River
Watershed Boundary
MAP 4
Tsowwin River Watershed
Known Chum Distribution
Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015
Nootka Sound Watershed Society
M. C. Wright and Associates Ltd.
NCompas
Base Map: 2013 orthophotographs
courtesy of Western Forest Products
N
W
E
S
Kilometers
0 0.075 0.15 0.3 0.45 0.6



Legend

- ✕ Barrier to Fish Passage
- ▲ Counting Station
- Known Holding Habitat (All Species)
- TRIM River

MAP 5

Tsowinn River Watershed
Known Habitat:
Adult Holding (All Species)

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June 19, 2015

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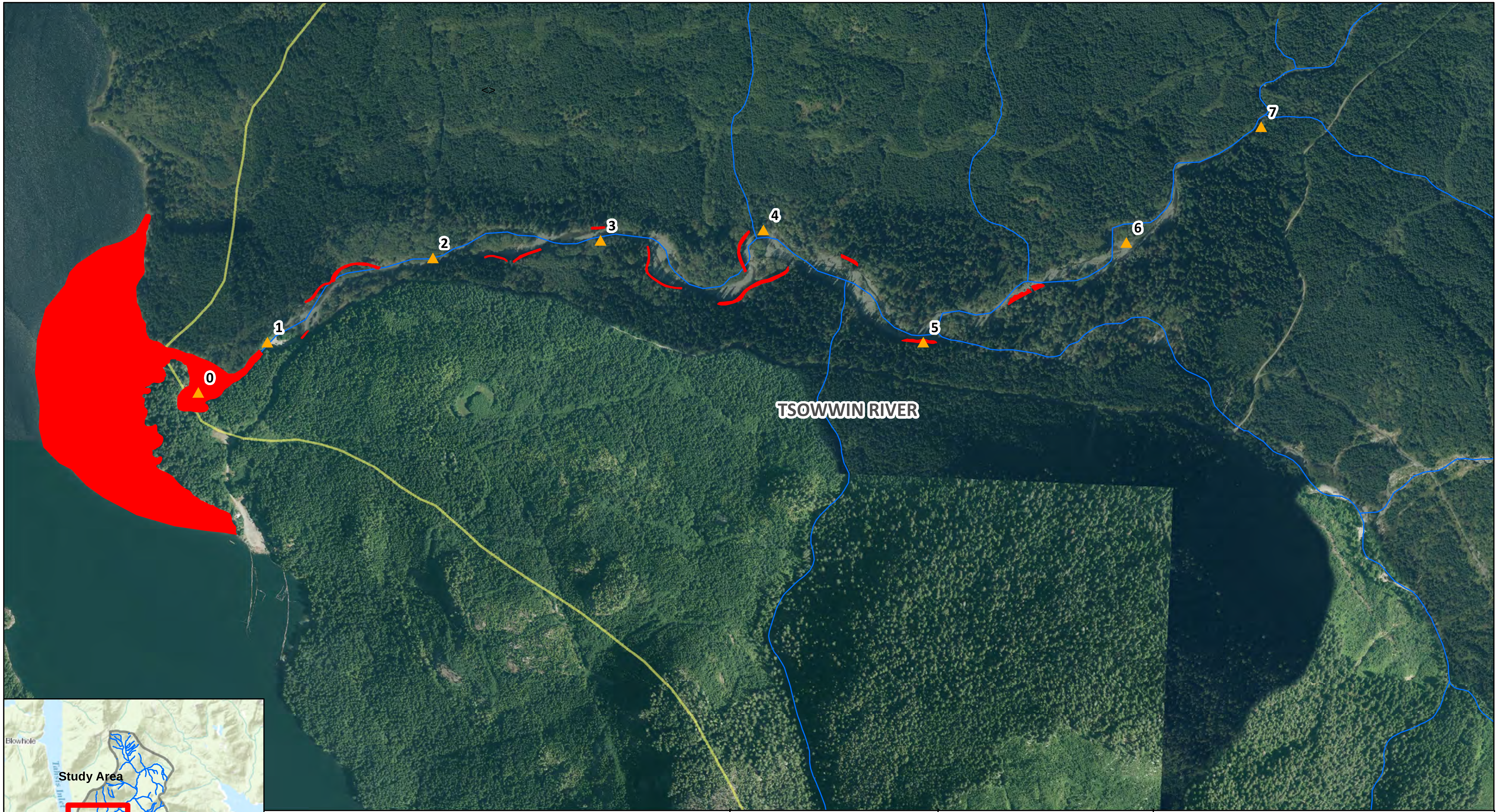
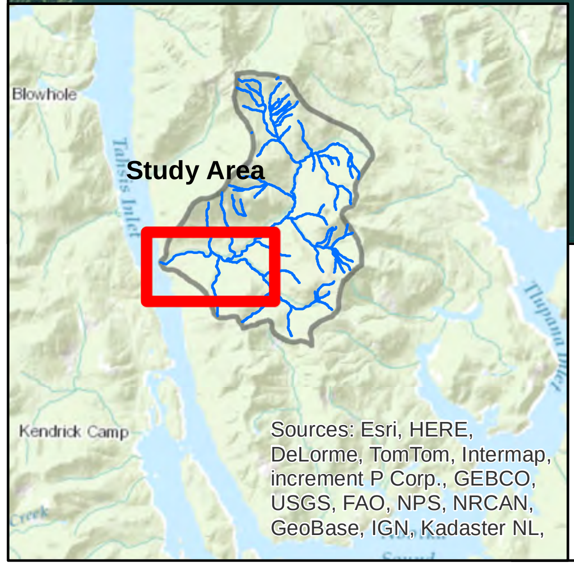
Base Map: 2013 orthophotographs courtesy of Western Forest Products

N
W E
S

0 0.075 0.15 0.3 0.45 0.6 Kilometers





Legend

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

MAP 6

Tsowinn River Watershed Known and Inferred Chinook Habitat: Juvenile Rearing

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Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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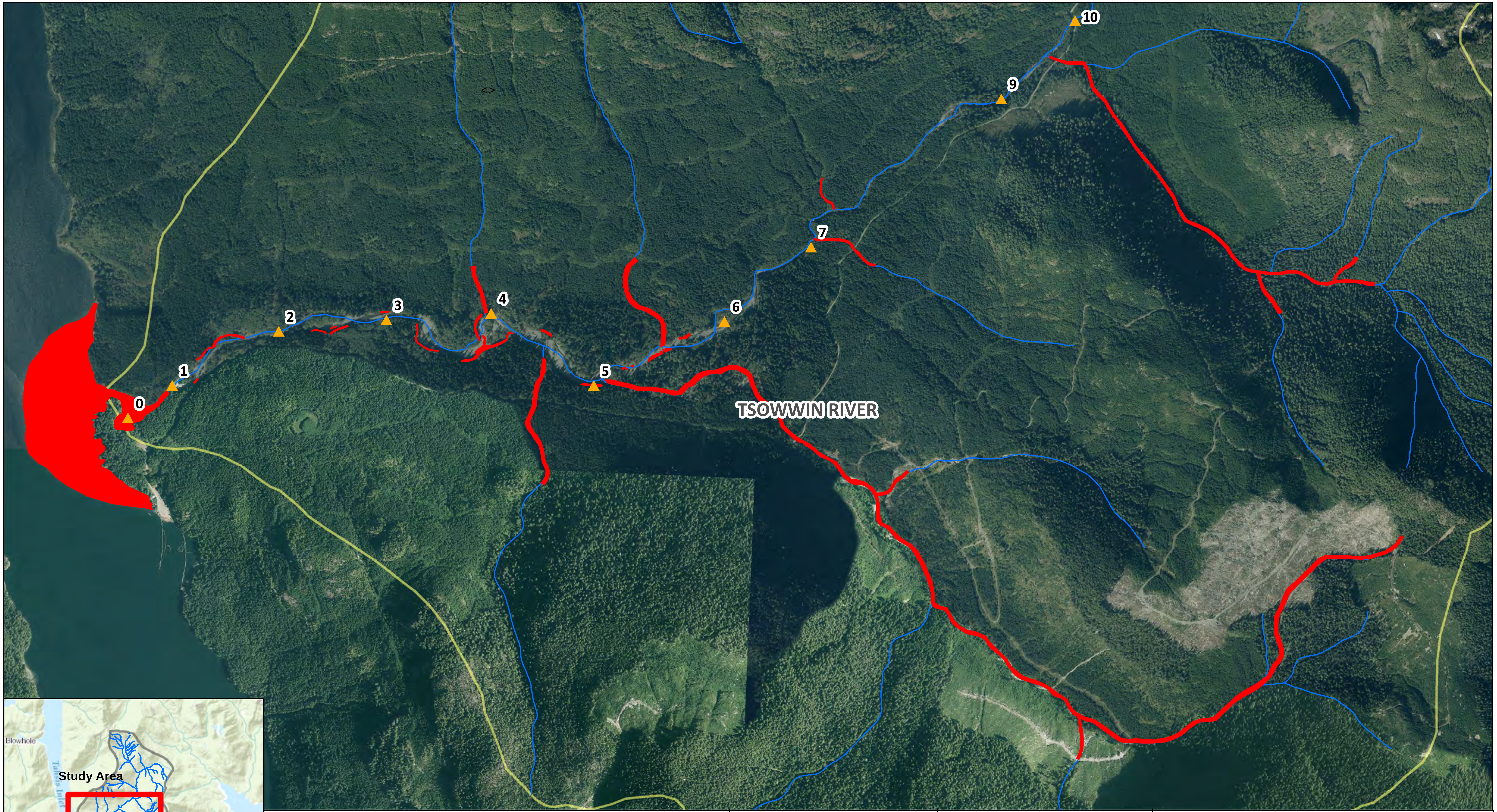
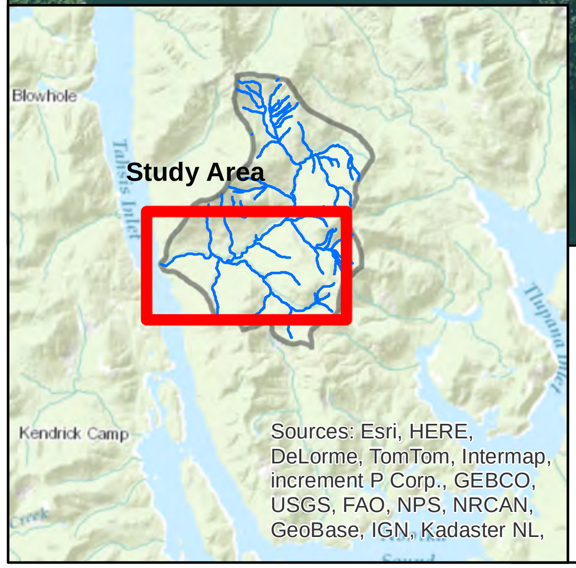
Base Map: 2013 orthophotographs courtesy of Western Forest Products

0 0.075 0.15 0.3 0.45 0.6 Kilometers

N W E S





Legend

Barrier to Fish Passage

Counting Station

Known and Modeled Juvenile Rearing

TRIM River

Watershed Boundary

MAP 7

Tsowinn River Watershed Known and Inferred Coho Habitat: Juvenile Rearing

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Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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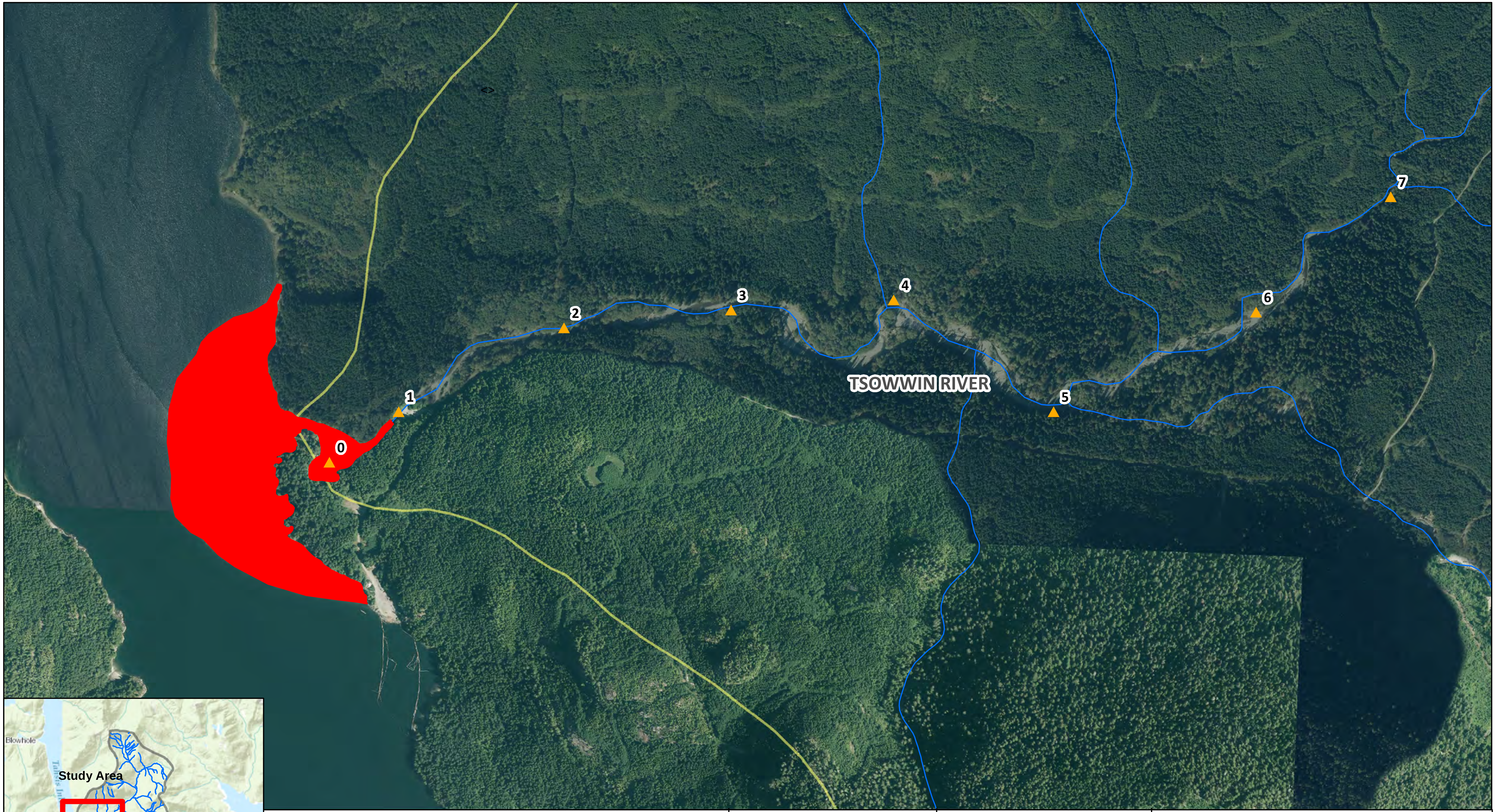
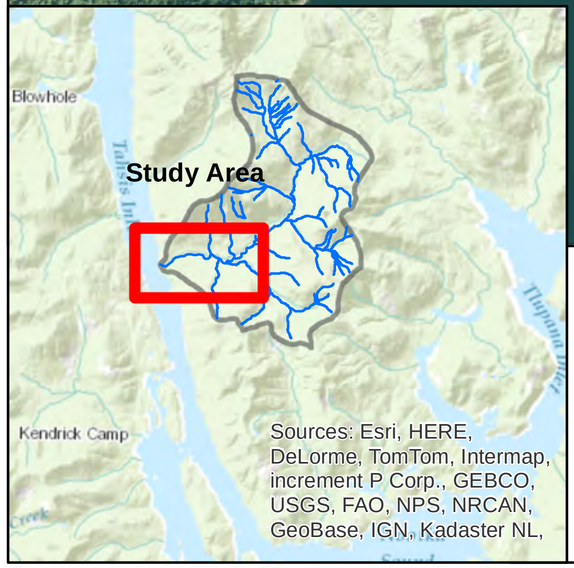
NCompas Software Development

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N W E S

Kilometers
0 0.125 0.25 0.5 0.75 1





Legend

- Barrier to Fish Passage
- Counting Station
- Known and Inferred Modeled Rearing
- TRIM River
- Watershed Boundary

MAP 8

Tsowinn River Watershed Known and Modeled Chum Habitat: Juvenile Rearing

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Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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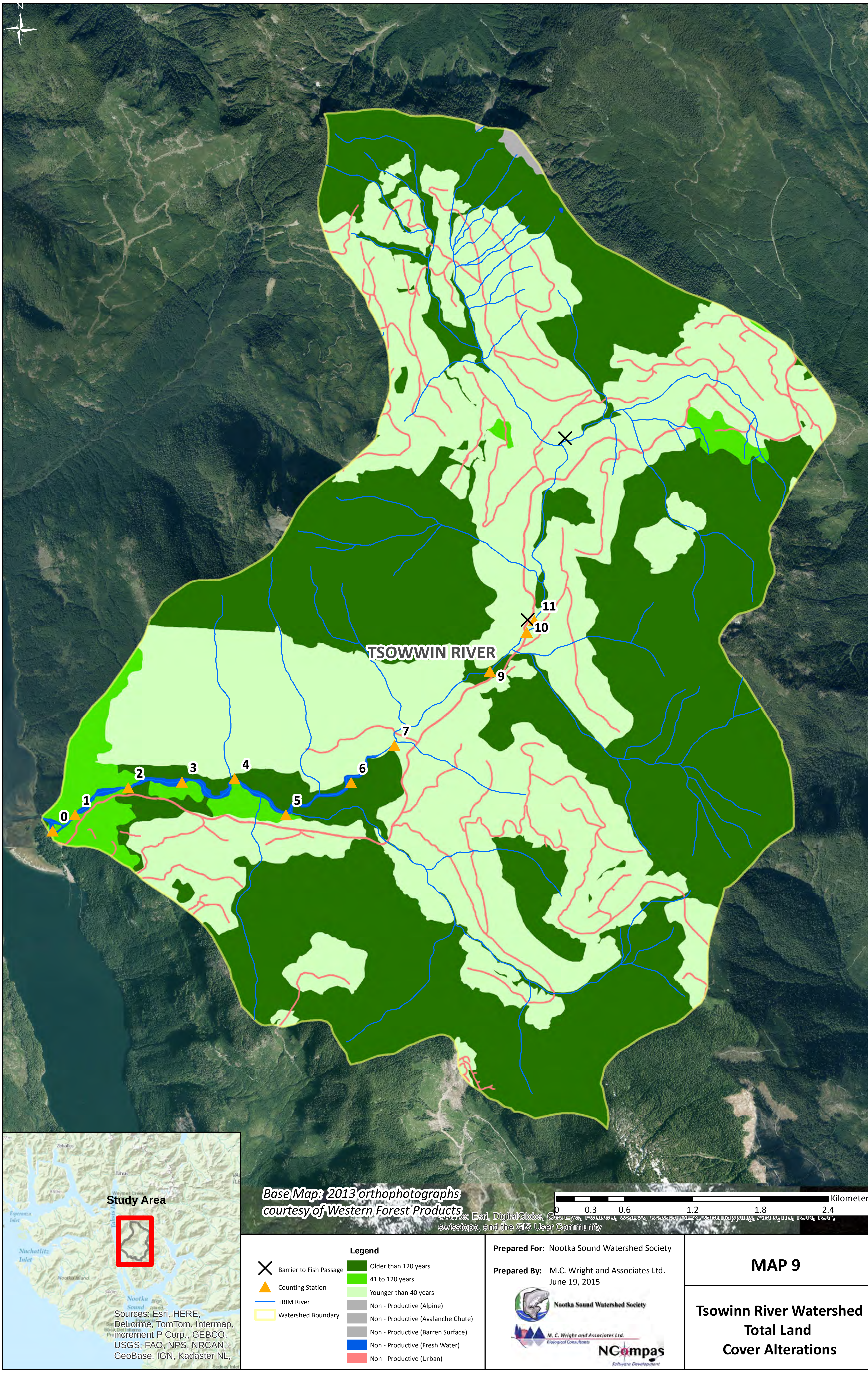
Base Map: 2013 orthophotographs courtesy of Western Forest Products

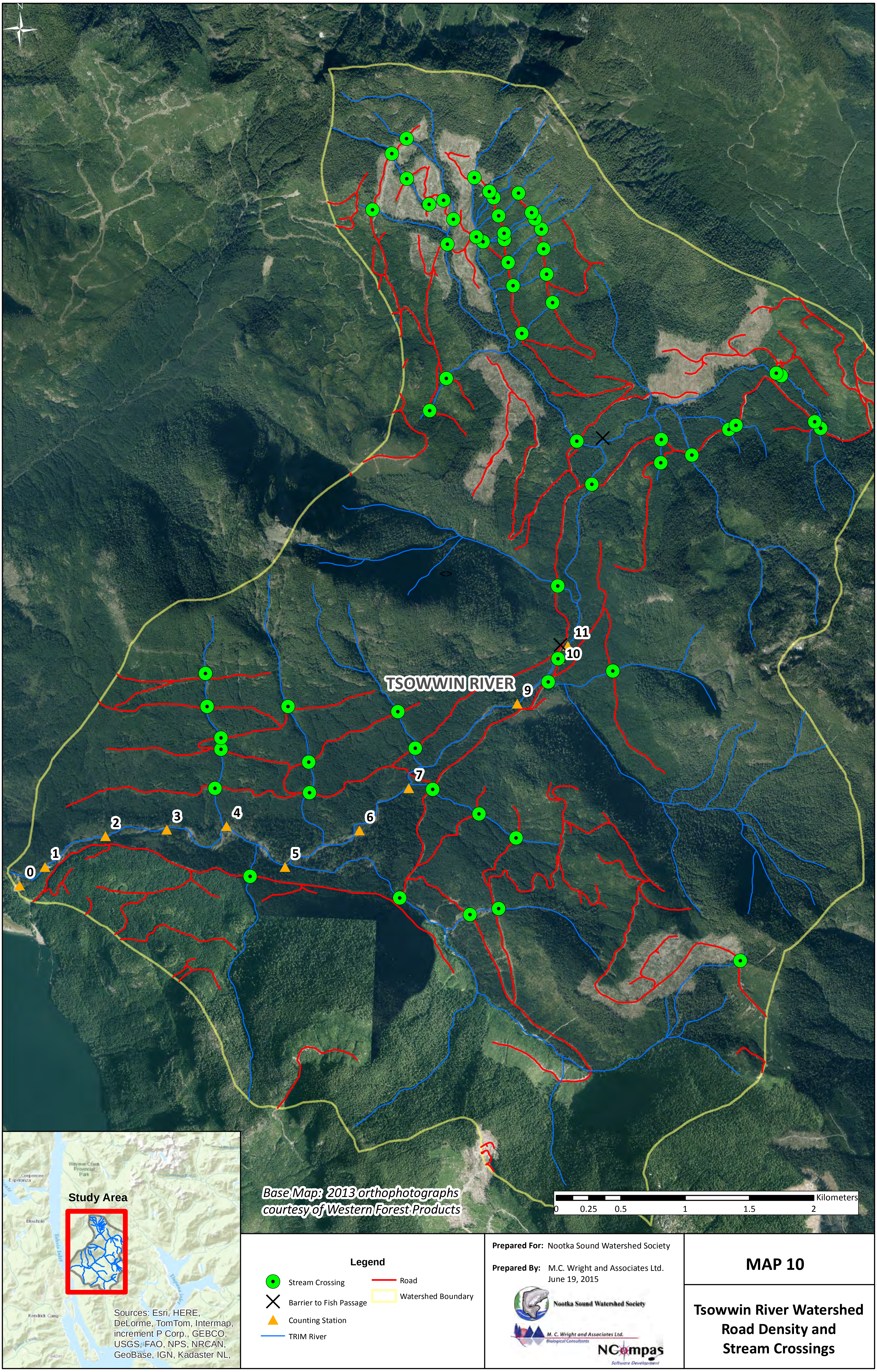
N S W E

0 0.075 0.15 0.3 0.45 0.6 Kilometers



MAP 9

Tsowinn River Watershed
Total Land
Cover Alterations


N
TSOWWIN RIVER
0
1
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10
11
Base Map: 2013 orthophotographs
courtesy of Western Forest Products
Kilometers
0 0.25 0.5 1 1.5 2
Study Area
Sources: Esri, HERE, DeLorme, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL,
Legend
Stream Crossing
Barrier to Fish Passage
Counting Station
TRIM River
Road
Watershed Boundary
Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015
Nootka Sound Watershed Society
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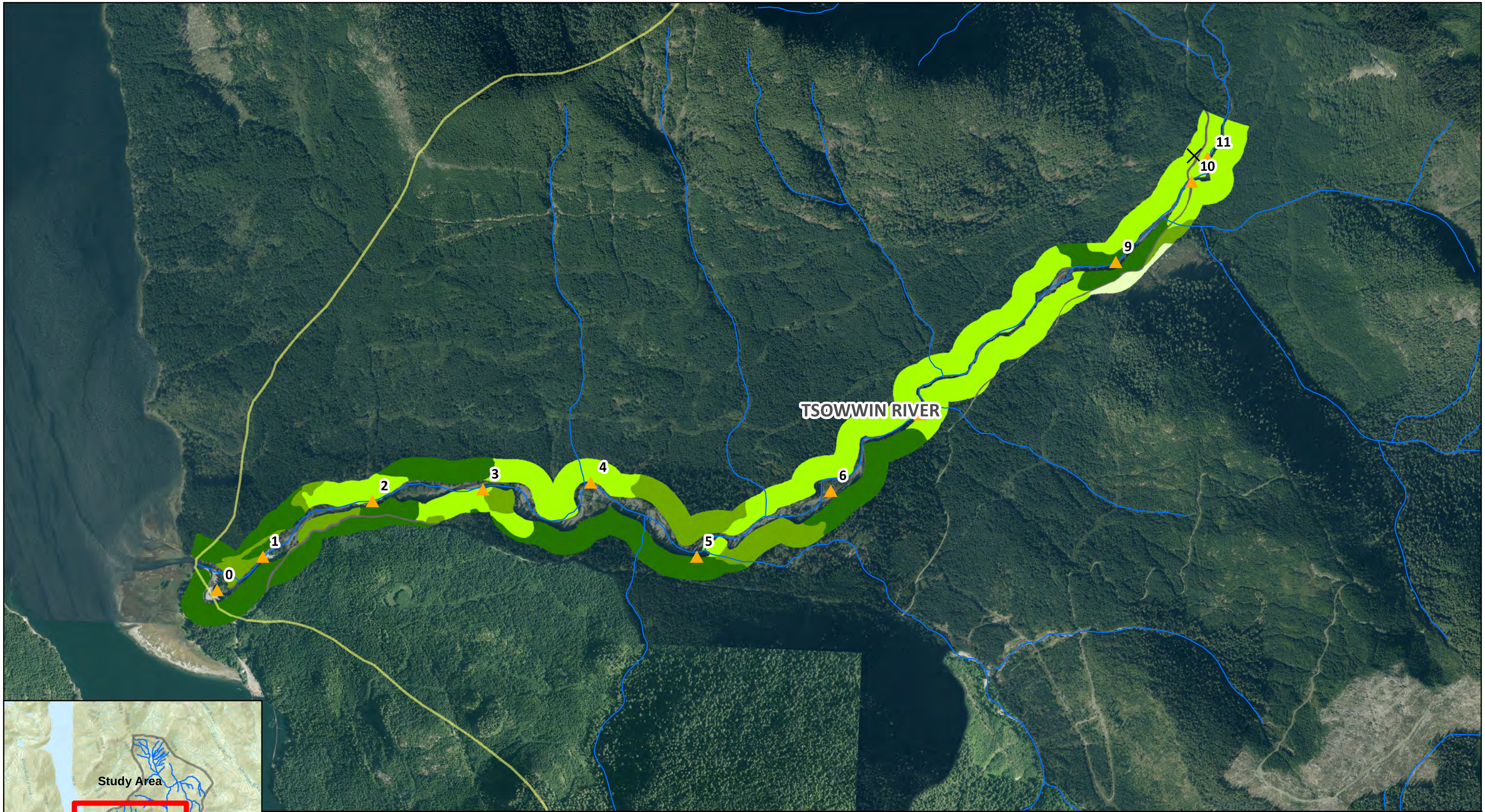
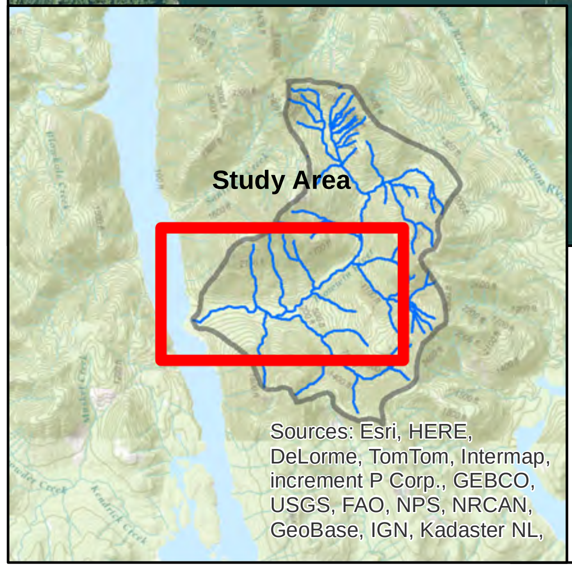
MAP 10
Tsowwin River Watershed
Road Density and
Stream Crossings





Legend

- Barrier to Fish Passage
- Counting Station
- TRIM River
- Watershed Boundary

Riparian Classification

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

MAP 11

Tsowinn River Watershed Riparian Disturbance

Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd. June19, 2015

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NCompas Software Development

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N S W E

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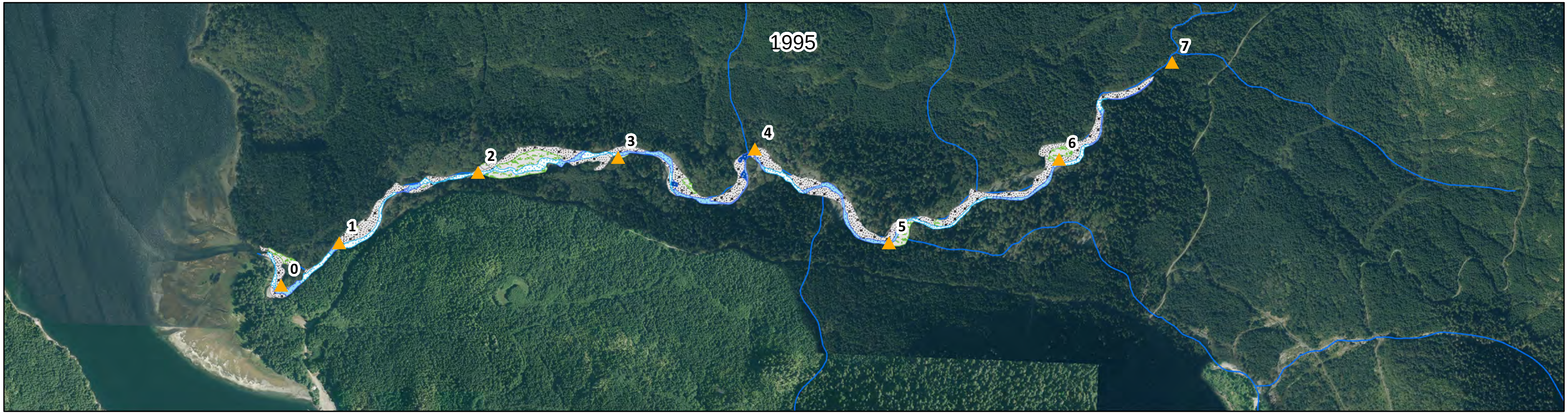

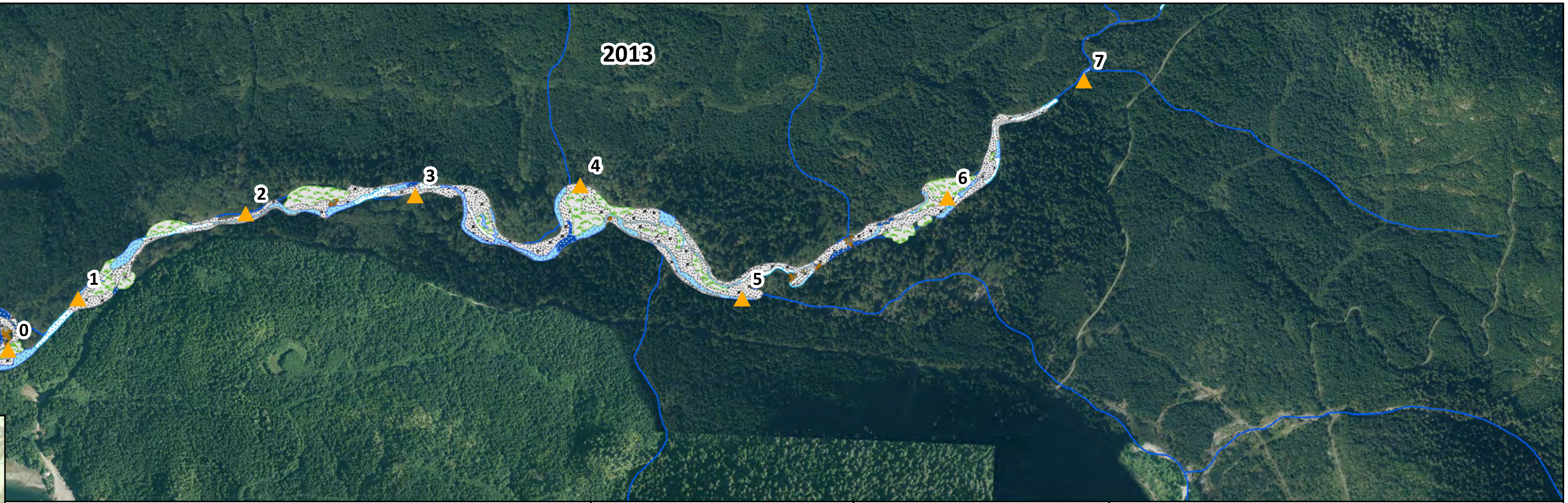

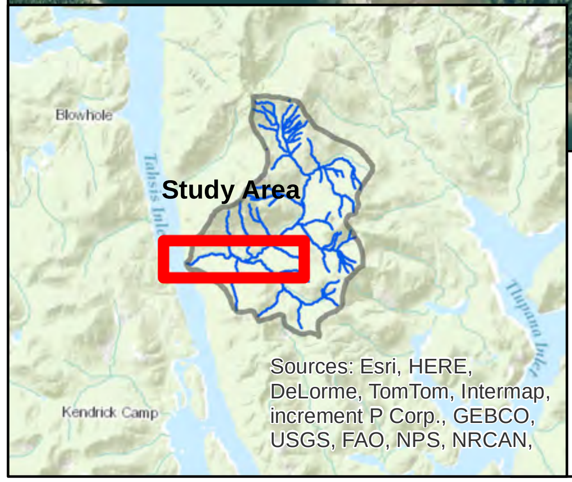

Legend

- Counting Station
- TRIM River

Habitat Type

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

MAP 12

Tsowinn River Watershed Habitat Composition 1995 vs. 2013

Prepared For: Nootka Sound Watershed Society
Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

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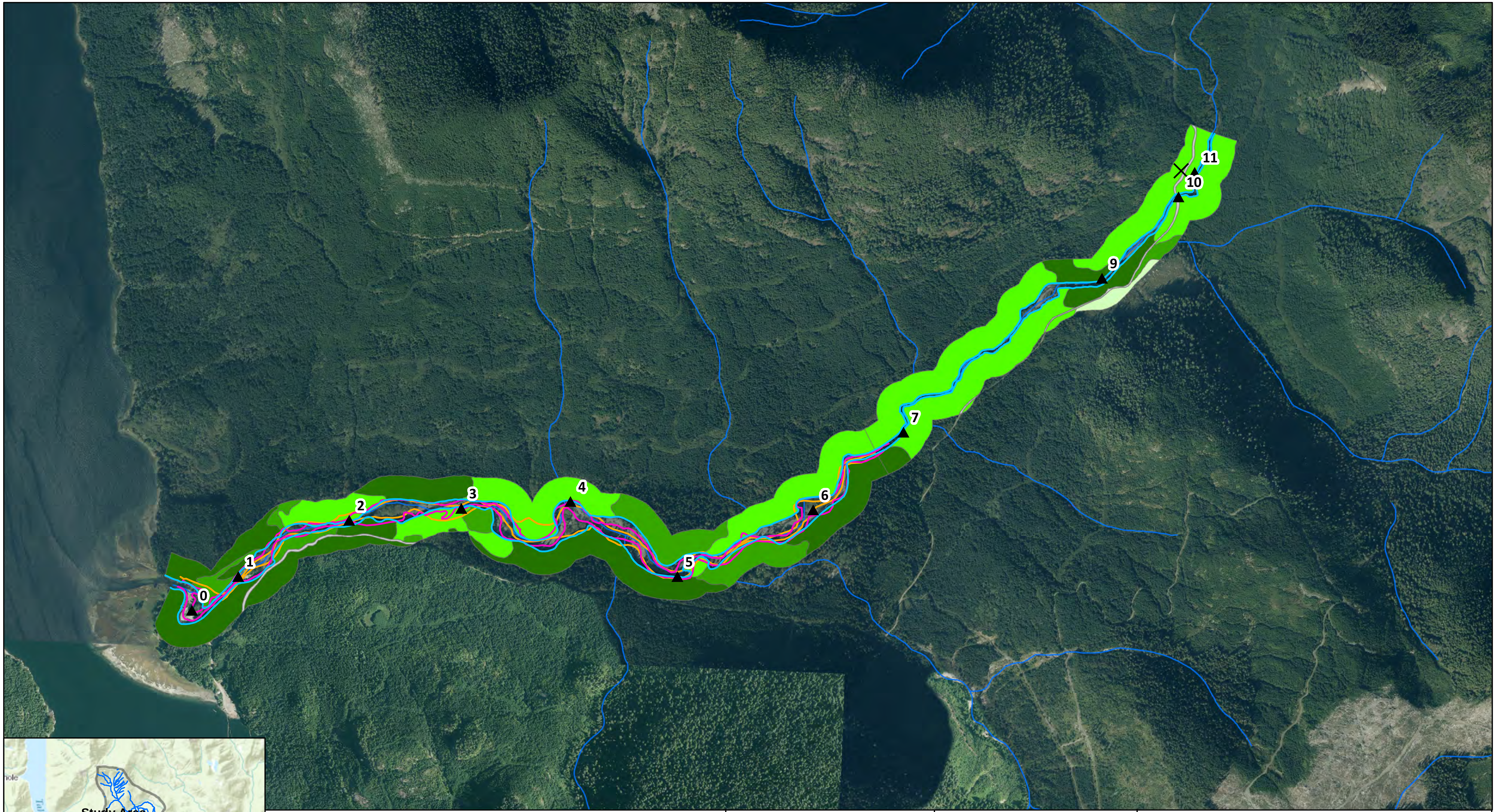
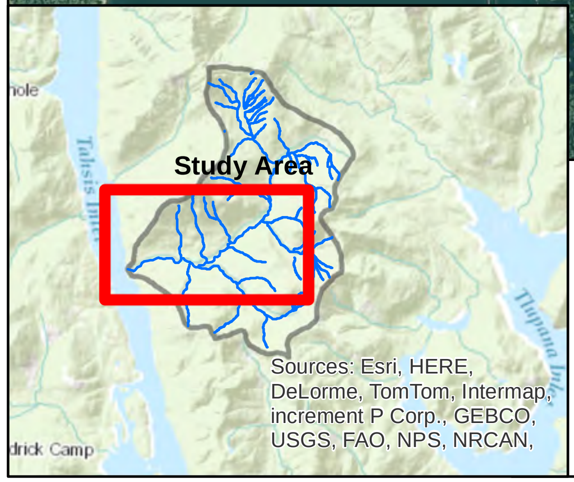
NCompas Software Development

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N W E S

0 0.1 0.2 0.4 0.6 0.8 Kilometers





Legend

Riparian Classification

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

- Barrier to Fish Passage
- Counting Station
- Bankful Width (2013)
- Bankful Width (1995)
- Bankful Width (1980)

MAP 13

Tsowinn River Watershed Channel Bank Stability 1980 to 2013

Prepared For: Nootka Sound Watershed Society

Prepared By: M.C. Wright and Associates Ltd.
June 19, 2015

Nootka Sound Watershed Society

M. C. Wright and Associates Ltd.

NCompas

Base Map: 2013 orthophotographs courtesy of Western Forest Products

N W E S

0 0.125 0.25 0.5 0.75 1 Kilometers