Wild Salmon Policy - Strategy 2: Fish Habitat Status for the Somass-Sproat-Stamp-Ash Watershed

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Commonly-Used Abbreviations

Abbreviation	Definition
ACRD	Alberni-Clayoquot Regional District
BCCF	British Columbia Conservation Foundation
CU	Conservation unit
DFO	Fisheries and Oceans Canada
DO	Dissolved oxygen
EEM	Environmental effects monitoring
FISS	Fisheries Inventory Summary System
FRPA	Forest and Range Practices Act
GCL	Great Central Lake
GIS	Geographic information system
HWG	Habitat Working Group
IT	Impairment temperature
LWD	Large woody debris
MAD	Mean annual discharge
MoFR	Ministry of Forests and Range
PAPA	Port Alberni Port Authority
TFA	Total Forest Area
TFL	Tree Farm Licence
TRIM	Terrain resource inventory maps
UOTR	Upper optimum temperature range
WSP	Wild Salmon Policy

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1.0 INTRODUCTION

In 2005 the Government of Canada released its policy for the conservation of wild Pacific salmon. Canada's Wild Salmon Policy's (WSP) overall goal is to restore and maintain healthy and diverse salmon populations and their habitats, with three identified objectives (DFO 2005) for achieving that goal:

1. Safeguard the genetic diversity of wild pacific salmon;

2. Maintain ecosystem and habitat integrity; and

3. Manage fisheries for sustainable benefits.

The WSP's initial efforts focused on identifying functionally distinct groups of salmon, called conservation units (CUs), and defining formal benchmarks for each. (WSP Working Group 2009). Barkley Sound, Alberni Inlet, and their tributaries (i.e. Statistical Area 23) were selected as an implementation pilot for collaborative planning under the WSP. Barkley Sound and Alberni Inlet contain several Sockeye CUs, and are an important part of the larger CUs for Chinook, Coho, Pink and Chum salmon (WSP Working Group 2009).

The WSP working group selected Barkley Sound, Alberni Inlet, and their tributaries for several reasons:

- Management and assessment issues in Barkley/Alberni are not so large as to be overwhelming, yet they are representative of other areas in the Pacific region (e.g. weak-stock management and mixed-stock fishery issues, enhancement, fish-forestry interactions).
- A substantial amount of previous work has been completed on local salmon populations, their habitat, and the broader ecosystem.
- Well-established local planning processes are already in place (e.g. Somass water use planning).
- Local Stakeholder groups are established and well organized (e.g. West Coast Aquatic Management Board).

The policy 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 BC. Strategy 2, the Assessment of Habitat Status, outlines a process for identification of factors that are limiting production and high value habitats that require protection. 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).

The Somass Watershed was selected as part of a pilot program to test the protocols outlined in the document "Canada's Policy for Conservation of Wild Pacific Salmon: Stream, Lake, and Estuarine Habitat Indicators" (Stalberg et al 2009). This specific project deals with Stage 2 of the WSP strategies: Habitat Status Report.

The geographic scope of the project is the Somass River Watershed, West Coast Vancouver Island. The watershed includes the Sproat, Stamp and Ash Rivers, and Great Central, Sproat and Elsie Lakes, and all key tributary streams accessible by anadromous salmon.

The objectives of this project are to:

- Access and extract information from existing habitat resource datasets and through interviews of key individuals with knowledge of the watershed. Specific information will include:
    - Known or potential limiting factors and high value habitats
    - Possible measures to address limiting factors
    - Possible measures to maintain productivity
    - Habitat protection and protection measures undertaken

The following report will address the aforementioned objectives by dividing the watershed into four geographic regions:

- Somass River and the Somass Estuary
- Sproat Lake sub-basin (includes the Sproat River and tributary inputs)
- Great Central Lake sub-basin (includes the Stamp River and tributary inputs)
- Ash River sub-basin (includes Elsie Lake and tributary inputs)

1.1 Background

The Somass Watershed is of fundamental importance to the economy and ecological biodiversity of the west coast of Vancouver Island. The fish stocks produced by this watershed are a vital source of economic, recreational and spiritual wealth for the local native and non-native communities in the form of commercial, sport and native fisheries for both ceremonial and societal purposes. The Somass Watershed produces the majority of Sockeye on the west coast of Vancouver Island, but it also supports Chinook, Coho, Chum and (historically) Pink salmon, as well as Steelhead and Cutthroat trout (Stiff et al. 2001).

Since the late 1800's, when gold was discovered in China Creek, and the early 1900's, when sawmills proliferated along all major watercourses in the watershed, the natural resources of the Somass system have come under increasing pressure from urban, agricultural, industrial and recreational development. The fragmented state of existing information to manage

Somass water and fisheries resources, due to incomplete assembly, documentation or availability, is a major concern to resource managers who are being challenged to make decisions involving multiple fish species across multiple resource sectors (Stiff et al. 2001).

To form the foundation for any conclusive understanding of the current and cumulative impacts of development on the fish populations and other resources of the Somass Watershed, and to map a pathway for First Nations, Government agencies and stewardship groups to make sound decisions in directing future fisheries related work within this watershed, requires a substantial knowledge of the system, its features and its problems. (Stiff et al. 2001).

The seminal document of record of the Somass Watershed is contained in the Department of Fisheries and Oceans and Environment Canada Special Estuary Series No. 9, entitled: ***The Somass River Estuary, Status of Environmental Knowledge to 1980***, by Sahlaa Morris and Adelle J. Leaney (1980). The Somass River system and its estuary were identified at that time as one of British Columbia's "critical" estuaries by the Estuary Working Group based on its importance as a fisheries resource, its history of development and industry, and its vulnerability to the impacts of development due to the particular climatological, meteorological and oceanographic characteristics of the region that tend to retain the polluting effects of development and industrialization. Drawing on the notes and research of various federal and provincial agencies and private industry and citing 700 bibliographic references, the Morris and Leaney report describes and quantifies, where possible, the physical and biological aspects of the Somass River system and addresses the human use of land and water, as well as trends in water and air quality (identifying sources of contamination and the biochemical impacts on water resources and aquatic biota), and the observed effects of development on aquatic, wetland and intertidal ecologies (Stiff et al. 2001).

In 2000 a working group made up of Government, First Nations, Special Interest Groups and consultants conceived of the idea of producing and maintaining a regional database that would collate and list all available data for the Somass Watershed. MC. Wright and Associates created the database in 2001 under contract to the Hupacasath First Nation. The database was titled "Stamp-Somass Reference Catalogue". The database was to be a repository for all known data on the physical, land use, water use, fish and fisheries, impacts and issues of the Somass Watershed. The document "An Overview of existing information, past and present for the Somass Watershed, Vancouver Island, BC 2001" and the database were completed to fill the gap caused by the absence of a single complete and up-to-date account of the Somass Watershed. As stated in Stiff et al., 2001 the document by Sahlaa Morris and Adelle J. Leaney (1980) left many questions unanswered, and other questions have arisen in the last two decades since, some of which have been addressed by various researchers. As was the case for the period following the original 1980 document the 2001 report and database compiled and synthesized a considerable amount of data, however, there still remained additional data that was not part of the synthesis of information collected and entered into the 2001 database. As with many projects the vision of a database that would be updated and maintained overtime was never realized and as such, another decade has passed and a volume of new information exists that has not been collated or summarized into a document or database that identifies what if any of the limiting factors or data gaps have been addressed, or if new information has been gathered to identify geographically where previously unknown problems exist.

The following Somass River Watershed Salmon Habitat Status Report will revise the knowledge base (i.e. limiting factor and data gaps) since the last update in 2001. This document is by no means a summary of all of the information that exists but instead synthesizes information collected within the constraints of time and budget

On-going Pressures and Mitigation Since 2001

Since 2001 pressures from human activities continue to impact the productive capacity of the watershed. Significant forest extraction on private lands is occurring at a rapid rate and remains a concern for local first nations and stakeholders (Tom Tatoosh, pers. comm.). The rate of removal is likely to add significant stress to the Ash Watershed, however, this is difficult to quantify as Island Timberlands does not share information with third parties and as such a significant data gap exists on forest activities in the Ash basin. Additional pressures that have occurred in the watershed since 2001 are:

- Increased water diversion and hydroelectric development.
- Urban development (increased pressures on Great Central (float houses) and Sproat Lakes (Summer Cottages and permanent residences)).
- Water extraction (Sproat Lake).
- Continued extraction of old growth forest and increases in logging pressures on second growth stands.
- Log handling facilities continue to be used with long lasting impacts to the marine (Somass estuary) and freshwater environments (i.e. Great Central Lake).
- Continued discharge of industrial and urban effluents.

While there are multiple stressors associated with human activities there are also a number of measures that have mitigated some of the negative pressures that threaten wild salmon populations. Some of the mitigation that has occurred in the watershed includes:

- Improved logging practices on Crown lands have addressed some of the impacts of chronic sediment issues from logging road runoff, stream bank and cut slope erosion and landslides. Mitigation measures applied in the watershed (specifically the Sproat Lake and its tributaries) include the de-activation of high risk logging roads, road embankment stabilization in high risk areas of close proximity to fish habitat, installation of sediment catch basins to deal with long term effects of landslides and upgrades

and/or removal of stream crossings that effect fish migration or structures assessed as high risk of failure and could cause blockages to fish passage.
- Better protection of riparian forests.
- Restoration activities that address some of the impacts of logging by re-establishing lost connectivity to off channel habitat, construction of new habitat (marine and freshwater), and providing bank protection.
- Construction of two sedge benches in Shoemaker Bay which will provide a major source of food production and cover in the Somass estuary.

Studies in the watershed have also assisted in providing an understanding of habitat impairment as a result of logging practices that have impacted both the marine and freshwater environment. Some of the studies that furthered the understanding of forest related impacts are:

- Detailed assessments to determine the impacts of Marine Log Dumps in Barkley Sound and Alberni Inlet by B C Timber Sales Strait of Georgia Business Area.
- Stream mapping and classification to better understand the issues around habitat impairment in the Somass Watershed.

1.2 Study Area Description

The Somass watershed, floodplain and estuary have been described in detail in Morris and Leaney (1980) and Stiff et al. (2001).

The Somass Watershed drains an area of about 1,426 km^2 (Johannes, 1999) into Alberni Inlet, a coastal fjord 54.3 km long on southwestern Vancouver Island. The watershed is delineated in the northeast end of Oshinow Lake (49°31'N 125°21'W); the headwaters of the Taylor River, McBride and Drinkwater creeks (49°25'N 125°30'W) in the west; and the headwaters of Rogers and Owatchet rivers (49°19'N 124°42'W) in the east. The watershed consists of three major sub-basins: Sproat (387.5 km^2), dominated by Sproat Lake; Great Central (651 km^2), dominated by Great Central Lake; and Ash (388 km^2), draining Oshinow and Elsie Lakes (Johannes, 1999). For the purposes of this report, a fourth sub-basin is identified as the mainstem of the Somass / Stamp River to the dam at Great Central Lake. The Somass River, formed by the merger of the Stamp and Sproat Rivers, has a combined total mean annual flow of 112.5 m^3/s.

The Ash River flows through Oshinow, Elsie and Dickson Lakes. Further downstream it is joined by Lanterman, Wolf and Moran Creeks. Lanterman and Wolf Creeks begin in the Beaufort Mountain Range and Moran Creek originates from Moran Lake. Lanterman Creek flows southeast for 14.7 km, Wolf Creek south for 9.0 km and Moran Creek flows for 2.1 km before entering the Ash River (Morris and Leaney, 1980).

Great Central Lake, the most prominent feature of the Somass system, is fed by Drinkwater and McBride Creeks and drained by the Stamp River. The Stamp River emerges from the southeast corner of Great Central Lake and intercepts the Ash River 4.8 km downstream.

The Stamp River receives water from the Ash River and Great Central Lake basins and drains an area of 899 km^2. Before entering the Somass River, the Stamp is joined by Spaht, Deer and Beaver Creeks, which start in the Beaufort Mountain Range (Morris and Leaney, 1980).

The Sproat River system arises in the Vancouver Island Mountain Range with the main drainage flowing into Sproat Lake as the Taylor River, and exiting from the northeast arm of the lake as the Sproat River. Approximately 2.4 km downstream, the river merges with the Stamp River to form the Somass River then flows 4.8 km northeast and southeast into the Somass River, which flows south through the city of Port Alberni into Alberni Inlet (Morris and Leaney, 1980).

The Somass River has two major tributaries: Kitsuksis and Rogers's Creeks. Kitsuksis Creek flows southwest from the base of the Beaufort Range for about 8.3 km before discharging into the Somass River 0.8 km from the estuary. Rogers Creek begins near McLaughlin Ridge, then flows west for 17.3 km to enter the Somass River 0.5 km from the estuary (Morris and Leaney, 1980).

The Somass estuary and Alberni Inlet as a whole compose a typical highly stratified two-layered halocline system, with a seaward flow of brackish (0-25% saline) surface water generated largely by the outflow of Somass Watershed freshwater, and an inward sub-halocline flow of higher density seawater (25-32% saline) to replace that displaced by entrainment in the surface layer. The flushing rate of the thin (5 m) surface water layer is largely determined by the Somass River discharge rate, which is itself principally regulated by the dam at Great Central Lake (Morris and Leaney, 1980). However, wind mixing may deepen the upper layer, especially after a period of sustained up-inlet winds (Stiff et al. 2001).

Wild Pacific Salmon of the Somass Watershed

(Compiled from Burt and Horchik, 1999, Stiff et al., 2001, and M. Wright, pers. comm., 2011)

<u>Sockeye:</u> Adult Sockeye (*Oncorhynchus nerka*) appear in the estuary in late May and migrate up the Stamp and Sproat rivers during the period late of May to late October; DFO data indicate that 50% of returning spawners have arrived at Sproat Lake by mid-July and at Great Central Lake 1-2 weeks later. Spawning in lakes takes place usually between October and December. Emergence of fry is between late March and late May, after which juveniles rear in lakes for about a year before migrating downstream to the estuary. Smolts are known to spend little time in the estuary before going to sea.

Chinook: Most Somass River Chinook (*Oncorhynchus tshawytscha*) return at age 4 to 6 years. They arrive in the Somass estuary during late July and migrate upstream into the Sproat River, Taylor River, Gracie Creek, upper Stamp River, lower Ash River, and a few other creeks in early September. Spawning occurs from October to mid-November. Chinook fry emerge in March; some juveniles may spend up to eight weeks in freshwater while others migrate to the estuary almost immediately (Burt and Horchik, 1999). Generally, juveniles can be found in the estuary between April and August.

Coho: Adult spawning Coho (*Oncorhynchus kisutch*) usually arrive in the estuary in late August. Upstream migration is dependent upon flows but spawning generally occurs between early September and late January. Coho spawn throughout the Stamp-Somass system, to Lanterman Falls in the Ash River, primarily in the smaller tributaries. Fry emergence begins in March and ends by May. The majority of juveniles spend a year in freshwater before migrating seaward the following spring in April and May.

Chum: Chum salmon (*Oncorhynchus keta*) are the last species to migrate into the Somass River system to spawn. They enter the river during October and proceed directly upstream to their spawning grounds in the lower Somass River near the Stamp-Sproat confluence. Spawning occurs between late October and the end of November. After an incubation period of about four months, fry emerge in March and move downstream shortly thereafter. Fry are most abundant in the Somass Estuary between April and May. After feeding in intertidal waters for a short period of up to several weeks, they move seaward (Morris and Leaney 1980, Burt and Horchik 1999).

Steelhead: The Somass River has a winter and a summer run of Steelhead (*Oncorhynchus mykiss*). The summer run returns between May and October, and the winter run returns between October and April; both races spawn in the spring (late February to April) throughout the Somass system. Summer-run fish are thought to be the only race that can ascend Dickson Falls to the upper reaches (to Elsie Lake) of the Ash River; pulsed flows from the dam are timed strategically to allow fish access a few times each summer. Fry emerge from May to June and may reside in freshwater for two years after which, smolts spend little time in the estuary prior to moving seaward.

Pink Salmon:

Pink Salmon are not a native species to the Somass Watershed. Attempts were made to introduce Pink salmon from other watersheds, but were unsuccessful. The introduction of Pinks ceased and the early 1970's (Burt and Horchik 1999)

2.0 METHODS

The Somass River system was divided into four major drainages (Figure A): 1. Somass River and estuary; 2. Sproat River, Sproat Lake and tributaries; 3. Stamp River, Great Central Lake and its tributaries; 4. Ash River and its tributaries. Methods for this report adhered to those outlined in "Canada's policy for conservation of wild pacific salmon" (Stalberg et al., 2009).

2.1 Information Gathering

2.1.1 Sources

- Web sources – FISS, Habitat Wizard, BC MoFR, TFA/TFL Maps, Hectares BC, EcoCat, DFO website (CU codes and distribution data), SHIM.
- GIS data sources - (Land and Resource Data Warehouse, British Columbia Timber Sales, M.C. Wright and Associates Ltd.)
- Interviews with key knowledgeable persons (including First Nations, DFO, BC MOE, private consultants and others) – personal communication: by phone, in-person or by email survey.
- Technical Reports – habitat assessments, monitoring, prescriptions for restoration and other habitat enhancement projects.
- Water use plans, watershed and estuary management plans.

2.1.2 Data Synthesis

Information from all sources was compiled and entered into a spreadsheet by major sub-basin, using broad categories highlighting key issues such as species, life stages and habitats affected, limiting factors identified, contributors/causes, suggested solutions, productive areas, and restoration sites. This approach was used to identify redundancy across sources, thus generating consensus as to which limiting factors exist in the system, particularly where empirical evidence may currently be limited. Relevant sources and contacts were compiled into a reference list (Appendix 1). Pressure-state indicators identified in Stalberg et al., 2009 were chosen for the system, by major drainage, based on the results of the information gathering process and professional opinion. While some sub-basins had been well-studied, others lacked even basic information such as current land cover and road use area. As such, pressure-state indicators varied in the scale of detail reported and the methods used to establish an existing metric (Section 2.2). Species-specific tables were created by sub-basin for each conservation unit as well as for Steelhead. Although some habitat factors (i.e. stream cover) were abandoned by WSP habitat working groups (HWG) (Stalberg et al., 2009), those that were widely addressed among sources were included in the report (Section 2.3).

2.2 Pressure-State Indicators

This report was compiled to fulfill Strategy 2 of the Wild Salmon Policy (DFO, 2005) for anadromous salmon conservation units associated with the Somass River system. Strategy 2 involves the assessment of fish habitat to identify areas and habitats that limit and support fish production in the system (Stalberg et al., 2009). WSP Habitat Working Groups (HWG) developed a Pressure-State model describing external (mostly man-made) stressors (pressure indicators) and habitat condition status (state indicators) and quantity, which are to be assessed and monitored over broad geographic areas (Stalberg et al., 2009). Suggested metrics and benchmarks were developed for each of the nineteen pressure-state indicators proposed for river, lake and estuary habitats (Stalberg et al., 2009).

Pressure-state indicators were selected once the synthesis of data (Section 2.1.2) was complete. Appropriate indicators were chosen for each sub-basin and metrics were defined as outlined in Stalberg et al., 2009, where possible. Metrics were estimated using all relevant sources of data gathered in Section 2, in combination with GIS analyses, where possible. Pressure-state indicators selected for the Somass system are shown in Appendix 2. The status of each indicator was identified as limiting or not-limiting (or unknown) by comparing benchmarks with existing metrics, based on available data. Where a lack of data was apparent, the indicator was listed as data limited and recommendations were provided to describe which type of data/monitoring might allow the indicator status to be better addressed.

2.3 Additional Limiting Factors

A number of limiting factors were identified in each sub-basin; some of these factors overlapped with pressure-state indicators but were abandoned by HWGs in favour of those in the short-list. Many of these limiting factors were finer-scale, system-specific factors with localized effects that were identified by knowledgeable persons and/or consultant's reports associated with restoration objectives. Additional limiting factors identified in the Somass system included: stream bed composition, stream cover and complexity, nutrients, flow, high summer water temperatures, lake level manipulation, invasive species, and others.

2.4 Productive Habitats

Productive habitats were identified most readily through the information acquired from interview sources; these accounts were more current, in many cases, than electronic databases and older technical reports. Data collected through older studies and reports were also considered, however. Productive habitats were identified in GIS maps (See Figures).

2.5 GIS Mapping and Analysis

Synthesized data were used in a map-based approach to portray known impacts (Figure Set B), habitat utilization (including anadromous fish access and beach spawning habitat) (Figure Set C), and restoration and on-going habitat monitoring initiatives (Figure Set D) by watershed. Line feature analysis was used to determine habitat parameters with linear units (i.e. kilometres of accessible habitat by species and length of shoreline beach spawning habitat). Polygon analysis was used to examine pressure-state indicators requiring unit-area calculations (i.e. road density and land cover alterations).

3.0 RESULTS

A pressure-state indicator summary table is found in Appendix 2. The following sections provide the detail and rationale behind the values cited in the summary table.

3.1 Somass River and estuary

- Refer to figures B-1, C-1 and D-1

3.1.1 Pressure-State Indicators

RIVER

i. Total land cover alterations and quantity – Land cover in the Somass River estuary and lower river has been altered by urban development and industries such as timber harvest, log handling and agriculture (Figure B and B-1). The estimated land area for Somass River drainage (Somass, Kitsuksis and McCoy sub-basins) is approximately 11% of the entire system, which combined with the Ash, Stamp/GCL and Sproat systems totals 1300 km^2. Of the 139 km^2 drainage area around the river and estuary, a minimum of 3.9 km^2 (2.8%) of land alterations are from cut blocks (Table 1). As only a small percentage of cut block data were available, this value is an underestimate. Private land owners did not disclose cut block boundary areas for the project. Sources indicated that total land cover alterations, particularly around the estuary and lower river are high (Figure B-1); urban and industrial expansions will likely progress as the city of Port Alberni grows. The Somass Estuary Management Plan maps provide a good visual index of land cover alterations around the estuary. Metrics could not be calculated using GIS analyses without all of the data files, however.

ii. Watershed road development – Based on the digital TRIM (terrain resource inventory maps) available for the analysis, the total length of roads in the Somass drainage is approximately 453 km (Figure B and B-1) with a density of 3.2 km/km^2(Table 1). This density exceeds the 0.4 km/km^2 benchmark and is considered a high risk to negatively impacting fish habitat (Stalberg et al., 2009).

iii. Water extraction – For the Somass River drainage, the total volume of water licenced for use is $2.45x10^8$ m^3/year. Purposes of water use were identified as: Conservation-construction works, conservation-use of water, domestic, enterprise, fire protection, irrigation, land improvement, ponds, stock watering, storage-non-power, watering, waterworks and work camp uses (Figure B and B-1).

iv. Riparian disturbance – The percentage of the Somass River drainage with ≤30 m of riparian bank vegetation, attributed to bank encroachment as a result of development, likely exceeds the 5% benchmark provided in Stalberg et al. (2009). Accurate data for this indicator were not readily available, but there was consensus among sources that the habitat condition for fish in the Somass River is influenced largely by land use, which has resulted in extensive riparian disturbance throughout the river and estuary. Riparian corridors have been heavily impacted by industrial development (B. Rushton, pers. comm. 2011; P. Edgell, pers. comm., 2011). The existing value may be closer to 20-50% riparian disturbance, compounded by the presence of invasive plant species that have been identified throughout the Somass system (Appendix 3). The biggest concerns are where purple loosestrife, yellow flag iris, scotch broom and Himalayan blackberry are disrupting natural intertidal habitats; eradication plans are underway in certain areas of the watershed (J. Bond, pers. comm., 2011). Recurring warm water events in the Somass and its tributaries, which often coincide with the timing of adult salmon migration (P. Edgell, B. Rushton, pers. comm., 2011), are likely exacerbated by an absence of shade in much of the system. Maintaining riparian cover, which mediates water temperature in smaller streams (Teti, 2003), may ameliorate conditions for migrating adult salmon during low summer flows. All life stages for anadromous species are affected by this indicator, which is critical in the provision of shade, channel stability, cover, nutrients and food. It is likely that riparian disturbance-related habitat degradation exists as a moderate to high risk to fish production in the Somass River and estuary. Geo-referenced measurements for riparian bank width/area adjacent to channels would be time-consuming and costly to obtain. Instead, high resolution and current ortho photographs are recommended to measure values and establish a reasonably reliable metric using a GIS approach.

v. Suspended sediment – Suspended sediment was identified as a potential limiting factor in the Somass Estuary Management Plan. Activities such as dredging at Clutesi Marina, which is conducted every few years, can mobilize sediment and affect water quality. As this activity has the potential to negatively impact fish and fish habitat, particularly rearing juveniles and buried life stages, the management plan recommends that suspended sediments be monitored during dredging. High total suspended sediment (TSS) values can lead to lost productivity through adverse changes to streambed composition, reduced egg to fry survival, reduced primary and secondary production as well as gill malfunction (CCME, 2002). Depending on the time of year, elevated TSS values have the potential to affect all anadromous species and life stages when high values are observed. Baseline data for TSS was limited to one source. Burt and Horchik (1999) recorded values below detection limits at Papermill Dam in October of 1996 (value <1 mg/L (Table 2); well below the LC_{50} benchmark cited in CCME, 2002). This value was noted at other sample sites throughout the Somass-Stamp system and may be a useful baseline metric for the non-tidal parts of the Somass during early fall.

Values for TSS of treated pulp mill effluent from 2007 to 2009 were cited in Hatfield Consultants EEM Cycle Five Report (2010); these values are assumed to be taken from the treatment plant prior to discharge. Daily values for 2009 were approximately 5.9 mg/L, based on a mean discharge of 64,630 m^3/day (Hatfield Consultants EEM Cycle Five, 2010). Values from the municipal sewage treatment facility, also assumed to be from the treatment plant, indicated that TSS monthly average is 49 mg/L with an allowable maximum of 70 mg/L (Table 2). There were no estuary data found for TSS in relation to the aforementioned effluents. Background measurements for the tidal portion of the Somass River and the estuary would be required to determine whether effluent TSS values are adversely affecting water quality for juvenile and adult life stages.

vi. Water quality (*Refer to Table 2 for cited water quality values.*)
Water quality was identified as limiting in the estuary and several creeks including Cherry Creek, Lugrin Creek, and Plested Creek (B. Rushton, pers. comm.) but data were not available for these tributaries. Municipal waste (see section xiv below), which is treated by the City of Port Alberni then released into the tidal section of the lower Somass River (H. Wright, pers. comm.) as well as the effects of mill effluent (see section xv below) discharges and log handling operations (G. Rasmussen, pers. comm.) likely affect water quality for fish. The only data identified from the Somass River were from 1996 at Papermill Dam (in Burt and Horchik, 1999). Total phosphorus (9 µg/L) came within accepted benchmark values of 5-15 µg/L (Table 2). Nitrate (0.11 mg/L) came below thresholds for acute (instantaneous) and chronic (30-day ave.) values. Nitrite (0.001 mg/L) was well below the cited range of 0.02-0.06 mg/L. Somass River dissolved oxygen was 10.82 mg/L, well above the required instantaneous value for non-buried life stages. Replicate sampling over the course of the year (i.e. spring, winter, summer) is recommended to provide a better set of data with which to compare benchmarks. The upper thresholds for nutrients do not appear to be limiting based on these data, but the lower thresholds for nutrients may limit primary production.

vii. Water temperature (juveniles) –Temperature was identified as limiting in the summer months by numerous sources. Controlled discharges at Elsie Lake and Great Central Lake Dams, coupled with naturally warm summer temperatures from the Sproat River (section 3.2.1 viii) and low flows contribute to elevated stream temperatures, particularly where riparian disturbance is extensive. Sufficient representative temperature data were not found although it is highly likely that these data exist. A data set from Burt and Horchik (1999) showed point values (n=9) from the Somass River (unspecified sample locations) Oct. 25-27, 1996 ranging from 12-13°C (mean 12.1°C). For juvenile Coho and Steelhead, which may have been present in smaller tributaries during this time, these values were below the upper optimum temperature range (UOTR) of 15°C and considered a low risk (Stalberg et al., 2009). Weather data from the Robertson Creek meteorological station, a useful indicator to help approximate water temperatures (see Stiff et al., 2002), showed that October of 1996 experienced a lower than average mean monthly maximum temperature (Table 3). Summer water temperature data are needed to quantify the extent of temperature-associated risk to juveniles during the months of June to September. The use of data loggers would allow hourly temperature values to be collected throughout the year, which are required to address maximum weekly averages for upper tolerance limits of fish. A study involving juvenile Chinook in the estuary (date not specified; in Birtwell and Korstrom, 2002) suggests that temperature should be considered with dissolved oxygen (section xvi below) when examining effects on estuary-bound smolts. The study demonstrated that juvenile Chinook may select warmer water (with dilute concentrations of pulp mill effluent) over cooler, near-hypoxic waters in Alberni Inlet. Table 4 summarizes some of the temperature benchmarks outlined in Stalberg et al., 2009 and some additional thresholds from BC MOE (2001).

viii. Water temperature (migration and spawning) – This indicator has been widely addressed, particularly for the migration of Sockeye salmon, which were reported to have stopped migration in 2009 at temperatures above 19°C (BCCF, 2009; Somass Basin Watershed Management Plan, 2010). As a result of 20°C temperatures in the Somass River in 1990, Sockeye delayed their migration for several weeks and held in the estuary. Adults awaited lower river temperatures in the cooler, low dissolved oxygen-containing waters of the estuary; mass mortalities occurred as a result (Birtwell and Korstrom, 2002). As addressed in section vii above, dissolved oxygen might be examined concurrently with temperature when warm stream temperatures are imminent. Species that arrive in the early summer or hold in the estuary for several weeks until flows improve for migration may be adversely affected by elevated temperatures (Table 4 for UOTR and IT values and run timing). Based on the limited data cited in Burt and Horchik (1999), the temperatures collected October 25-27, 1996 (see section vii above) were well within the accepted limits for adult migration and spawning that year. The consensus among sources seemed to indicate that the risk to Sockeye is high in the Somass River; since 1990, five warm water events have occurred (Somass Basin Watershed Management Plan). The risk to other species in the system was not as well documented.

ix. Stream discharge –Discharge measurements for the Somass River were available for 1957-2002 (Station 08HB017; Somass near Port Alberni: 49°17'7"N; 124°52'0" W). The mean annual discharge (MAD) was 123 m^3/s for 1957-2002 with monthly means in July, August and September as 63.0, 42.8, and 48.9 m^3/s, respectively. In order to meet the recommended 20% benchmark to maintain conditions for adult migration and spawning (Stalberg et al., 2009), the minimum flows for August and September should reach at least 24.4 m^3/s. The ranges of monthly mean discharge values for the summer months were 26.8-148.0 m^3/s in July, 21.7-89.3 m^3/s in August, and 22.0-121.0 m^3/s in September. Historic values for August and September indicated that the 20% benchmark had been met or exceeded most years between 1957 and 2002. Data from 2003-2010 should be examined to determine if MAD and monthly averages for summer have changed.

x. Accessible stream length – Accessible stream length data came from a variety of sources including consultant's reports, FISS, Weyerhaeuser (presently known as Western Forest Products Ltd.) and M.C. Wright and Associates Ltd. Values are intended as estimates, as the reliability of some of the data could not be confirmed. In some cases FISS data were only provided for one of the known species in a tributary. For the Somass drainage, reports suggested approximately 7.0 km are accessible to all species (Table 5). Using GIS synthesis, which included some tributaries in the drainage (Figure C and C-1), the accessible stream value for Chinook, Sockeye and Steelhead was 9.4 km. Coho can likely access 26.5 km and Chum, 8.7 km.

xi. Key spawning areas – Burt and Horchik (1999) suggest that gradient, substrate size and conditions in reaches 2 and 3 of the Somass River are best suited for Chum; Chinook also spawn in the Somass River. Escapement survey data from DFO Stock Assessment Division could be compiled and mapped to determine the preferred spawning areas within all surveyed streams in the drainage.

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xii. Marine vessel traffic – The Port Alberni Port Authority was contacted for this information. They agreed to provide information and statistics on vessel traffic but it was not provided by the report deadline. The suggested metric for this indicator was a number of vessels per month or a vessel density (Stalberg et al., 2009).

xiii. Estuary habitat disturbance –According to the Somass Estuary Management Plan, the largest impacts to estuarine habitats have resulted from industrial development along the Port Alberni waterfront, from dyking, and from the sewage and effluent lagoons on the tidal flats. A small portion of the original delta, which includes mudflats, salt marshes, meadow-type vegetation, shrubs and a small stand of trees remains relatively undisturbed. Intertidal and sub-tidal habitats are limited (B. Rushton pers. comm., 2011) as well as shallow near-shore rearing habitats for fry and smolts and eelgrass beds (G. Rasmussen pers. comm., 2011). The recommended metric is the rate of increase in crown tenures (licences and leases) within all estuarine components (riparian, intertidal and sub-tidal) over 5 years (Stalberg et al., 2009); data for this parameter were not found.

xiv. Permitted waste management discharges –From the information that was available, as of 2009, the two permitted discharge sources identified for which data were available were the City of Port Alberni's municipal waste treatment facility and the Catalyst pulp mill. Improvements in effluent discharge quality have occurred over the past decade (City of Port Alberni website statistics; Hatfield Consultants EEM Cycle Five, 2010, Somass Estuary Management Plan). The outfall for the sewage treatment facility is in the lower Somass River; the pulp mill outfall is situated in the estuary, several hundred meters southwest of the mill (Map Fig. 4.2 in Hatfield Consultants EEM Cycle Five, 2010). The permitted discharge for the City of Port Alberni municipal waste (treated) is 34,100 m^3/day; the 2009 average is cited as 17,428 m^3/day (range 669 to 58,344 m^3/day) (City of Port Alberni, 2011). This value excludes contributions from numerous city storm drains, which discharge into the Somass River, estuary and several tributaries (City of Port Alberni, 2011). The pulp mill is currently permitted to discharge 180,00 m^3/day into the estuary (L. Cross, pers. comm., 2011). In 2009, the average discharge for treated effluent was 64,630 m^3/day at the outfall (Hatfield Consultants EEM Cycle Five, 2010). There were no known waste management discharge licences for the non-tidal portion of the Somass River.

xv. Estuary chemistry –Water and sediment chemistry is driven by a combination of natural estuarine properties and anthropogenic inputs such as vessel traffic, city storm water and treated sewage water inputs, pulp mill effluent, log handling facilities, runoff from the city and roads as well as agriculture. Returning adults (all species) and rearing juveniles (Chum, river-type Sockeye and Chinook) are affected by this indicator. The few data available were limited to those collected for the pulp mill effluent monitoring program. Overall, effluent discharges have declined and effluent quality has improved since 1993 (Hatfield Consultants EEM Cycle Five, 2010). There is anecdotal evidence that white sturgeon (*Acipenser transmontanus*) may be returning to the Somass River; though evidence that a population exists remains to be seen (J. Lane pers. comm., 2011). Refer to Hatfield, 2010 reports for C:N ratio, total nitrogen, redox potentials and sulphide values for estuary sediments; temperature, salinity, dissolved oxygen and depth water column profiles are also available. Total organic carbon (TOC) data for 2009 were available in estuary profiles in Hatfield Consultants EEM Cycle Five (2010). Total organic carbon values of 10-16% were modelled from measurements taken around the pulp mill outfall. Values of 4-6% were observed between Hoik and Hohm Islands (about 1.5 km south of the outfall). Towards Polly Point and south, values of 6-8% were observed (Table 2). Of the two reports provided by Catalyst, neither provided analyses on concentrations of any polycyclic aromatic hydrocarbons (PAH's) or polychlorinated biphenyls (PCB's) associated with pulp mill operations.

xvi. Estuary dissolved oxygen – This indicator is critical for both rearing juveniles and returning adults, which may face low oxygen conditions in the estuary during summer months. The pulp mill has monitored dissolved oxygen extensively in the estuary over the course of its operation. Some data is available that pre-dates the mill; if data gaps could be resolved, particularly for depths below the halocline, an historic baseline for DO could be established (Hatfield Consultants DO Monitoring Report, 2010). A combination of industry inputs and natural processes seem to contribute to low dissolved oxygen (DO) values in the Alberni Inlet. For detailed temporal and spatial trends, see the report (Hatfield Consultants DO Monitoring Report, 2010); benchmarks drawn from the report are summarized briefly as follows:

- Surface layer water (above the halocline; generally depth <5m and salinity <15ppt) D.O. is largely controlled by freshwater discharge from the Somass River. DO in the range of 10-12 mg/L was reported in 2009 from winter to spring (November to June); summer (July to October) DO values were in the 8-9 mg/L range. Values were above, and marginally above, benchmarks (Table 2).

- Lower layer water (below the halocline; generally depth >5m and salinity >25ppt) D.O. is largely a function of biological oxygen demand (BOD), particularly in summer months when reduced discharge from the Somass River minimizes the circulation and mixing effects of fresh water. The average DO in 2009 from winter to spring was 10 mg/L below the halocline (above benchmark values; (Table 2) with a range of <2-6 mg/L near the bottom, indicating moderate to severe hypoxic conditions. Values were 6-8 mg/L during summer months (below benchmark values) with ranges approximating between 2-4 mg/L near the bottom, indicating moderately hypoxic conditions existed.

- Dissolved oxygen values did not vary much from the outfall to 5 km downstream, and the effects of the historic fibre mat were localized and continue to be reduced. Fish likely encounter naturally low DO levels at least 4km south of the mill; a region of higher DO may exist in the upper estuary near the river.

The impact of low DO values in the estuary will likely be more severe during years of high Somass water temperatures. There is evidence that adults may be forced to find cooler, deeper water (and consequently lower in DO) in the summer months and until temperatures decrease sufficiently to successfully migrate into the system (see section vii above).

xvii. Estuarine habitat area – Areas for estuarine habitats (riparian, sedge, eelgrass and mudflat) were not calculated due to a lack of data. Comprehensive maps in the Somass Estuary Management Plan provide a visual index of habitat types, but no data files were available that could be measured using GIS analysis. A small portion of the original delta, which includes mudflats, salt marshes, meadow-type vegetation, shrubs and a small stand of trees remains relatively undisturbed (Somass Estuary Management Plan). The highly-developed nature of the estuary has changed the natural composition of most types of productive habitat. It is generally accepted that the various industries operating around the Alberni Inlet and Somass estuary have contributed to the degradation of productive habitats. The shrinking of these critical habitats has warranted restoration projects such as sedge benches (Figure D1), eelgrass beds and invasive plant species eradication plans through DFO and Ducks Unlimited BC.

3.1.2 Additional Limiting Factors

For the Somass drainage, particularly in smaller tributaries in the summer months, high water temperatures and low flows can limit fish production (B. Rushton, H. Wright and P. Edgell, pers. comm., 2011). Sediment transport and a lack of riparian vegetation also contribute to habitat degradation in smaller streams as well as the mainstem (B. Rushton and P. Edgell, pers. comm., 2011). The estuary is mainly affected by poor water quality (B. Rushton, G. Rasmussen and P. Edgell, pers. comm., 2011) and to a lesser extent, the prevalence of invasive plant species (B. Rushton and P. Edgell, pers. comm., 2011), which may outcompete native grasses and riparian plants in disturbed areas.

3.1.3 Productive Habitat and Restoration

There were numerous restoration projects proposed in the Somass Estuary Management Plan and by the 2009 update (provided by J. Bond, Ducks Unlimited) some projects had been ruled out due to contaminated soils, land title disputes and other factors. Two flood channels have been opened and a beetle release was conducted on the purple loosestrife; broom and English Ivy removal have also taken place (P. Edgell, pers. comm., 2011). The two major restoration projects constructed in the estuary are two marsh benches of 1800 m^2 and 9100 m^2 (P. Edgell, pers. comm., 2011) (Figure D and D-1). Small restoration works have been completed on Dry Creek, Kitsuksis Creek and Roger Creek but site details and specifics were not available.

3.1.4 Recommendations

- Restoration with the focus on improvement of existing productive habitats such as smaller tidal channels, eelgrass and mudflat is recommended. (P. Edgell; G. Rasmussen; H. Wright pers. comm., 2011).

Access to land use maps and/or GIS map layers for all lands (public and private) in the Somass River system is critical to establish accurate metrics for total land cover alterations, watershed road development and riparian disturbance.

- Water quality monitoring in the estuary that addresses toxins and pollutants to improve upon the existing data sets for dissolved oxygen and temperature/salinity profiles through pulp mill effluent monitoring studies.

- Effects of localized agriculture runoff might be examined – mentioned as a potential limiting factor (B. Rushton pers. comm., 2011).

3.2 Sproat Lake, river and tributaries

- Refer to figures B-2, B-3, C-2, C-2A, C-2B, C-3, D-2 and D-3

3.2.1 Pressure-State Indicators

i. Total land cover alterations – The Sproat Lake drainage has been altered by forestry as well as urban expansion and recreational usage. The area includes several sub-basins such as Taylor, Gracie, Sutton, South Sutton, St. Andrews Creeks and the Sproat River. The recurring limitation for addressing this indicator was an inability to collect all information on land cover alterations from a historical perspective through to the present land cover condition. In order to understand how land use has affected the productivity of the watershed an understanding of how these impacts are linked to other alterations is required. For example, to know that riparian habitat has been altered is only one parameter that contributes to reduced productivity. The linkage between upslope canopy removal, road construction and riparian alterations ultimately contribute to the reduced productivity of a stream or lake. Through the interview process, a common limiting factor identified in the Sproat basin was riparian disturbance. If taken at face value one could consider this as a pressure that still contributes to reduced productivity in the watershed. Through a review of the existing literature, the state of riparian habitat in many areas has been determined to be in a state of recovery and as such, it may not be contributing to the reduced health of the watershed on the scale of what it may have been one to two decades prior.

The Sproat drainage is approximately 312 km^2, representing approximately 24% of the entire Somass system (Table 1). The limited land cover data available showed only 11.4 km^2 of cut block alterations (3.7% of the drainage area). The Sproat Lake Official Community Plan (2005) identified that urban development is on the rise in this drainage, particularly around Sproat Lake. Data for the number of homes around the lake was not available, but Google Earth (data from 2001 and 2005) indicated that 562 docks were present around the lake (Figures B, B-2 and

B-3); presumably most of these are associated with a residential structure. One of the greatest threats to beach spawning habitat is pressures to allow expansion of residential development along the shoreline of the lake. Although there is information on spawner distribution along the lake shore line (Figures C-2, C-2A and C-2B), a better understanding of beach spawner distribution by depth is required so that these areas can be protected from human activities that could threaten Sockeye beach spawning populations.

ii. Watershed road development Based on the digital TRIM (terrain resource inventory maps) available for the analysis, the total length of roads in the Sproat Lake drainage is approximately 435 km (Figures B, B-2 and B-3). The density of roads is 1.4 km/km^2(Table 1), and therefore exceeds the 0.4 km/km^2 benchmark and is considered a high risk to negatively impacting fish habitat (Stalberg et al., 2009). Improved logging practices on Crown lands have been addressing the impacts of chronic sediment issues from logging road runoff, stream bank and cut slope erosion and landslides. Some of the measures that have been ongoing in the watershed (specifically the Sproat Lake and its tributaries) are the de-activation of high risk logging roads, upgrades to logging roads (road embankment stabilization in high risk areas) in close proximity to fish habitat, installation of sediment catch basins to deal with long term effects of landslides and upgrades and/or removal of stream crossings that effect fish migration or structures assessed as high risk of failure and could cause blockages to fish passage (Wright pers. comm.) Figures B-2,B-3, D-2 and D-3.

iii. Water extraction – For the Sproat Lake drainage, the total volume of water licenced for use is $2.09x10^8$ m^3/year. Purposes of water use were identified as: camps, domestic, enterprise, garbage dump, power-general, processing, pulp mills, storage-non-power, waterworks and work camp uses (Figures B and B-2, and B-3).

iv. Riparian disturbance – There is considerable information on the extent of riparian disturbance in the Sproat sub-basin. Reports by Campbell (2008), Horel (1997 and 2000), Chapman (1999), Wright (2001 and 2002), discuss the state of riparian function for specific areas in the watershed. For areas that have not been reported on, much can be inferred from air photo and satellite imagery. Tributary streams have been altered through forest harvest activities where most of the valley bottom stream or river corridors have been disturbed, except sub-basins with little historic harvesting (Taylor Sub-basins C, D and Snow Creek). Campbell (2008) reports that 0.68 km/km of mainstem channel has been logged to the banks. The harvesting of riparian areas is 30 to 60 years old and regeneration of these areas is significant (Campbell 2008). The recovery of the riparian forest is typically deciduous trees, such as alder, which can contribute to bank strength and stability and buffer the stream channel to the impacts of water temperature, but the wood is not resistant enough to provide permanent, functional wood to the channel (Campbell 2008). The riparian areas dominated by deciduous species will eventually become coniferous stands over time and will then contribute LWD to the channel. The extent of disturbance along the lake shoreline has been primarily through urban development. Based on GIS analysis of urban development around the lake, there has been an estimated 27.3 km of riparian disturbance. Although historic logging practices have negatively impacted riparian areas throughout most of the watershed, the present condition of much of this area is an advanced state of recovery (Horel 2000, Wright pers. comm. 2011).

v. Suspended sediment – This indicator is critical to the survival of multiple life stages of fish in Sproat Lake and Sproat River; water quality issues around sewage and grey water discharges (see section xii below) could lead to higher TSS values in years to come. High TSS values, during sediment transport events, can lead to lost productivity through effects such as adverse changes to streambed composition, reduced egg to fry survival, reduced primary and secondary production as well as gill malfunction (CCME, 2002). Burt and Horchik (1999) measured values below the detection limit of <1.0 mg/L in October of 1996 (Table 2). Total suspended solids were undetected at other sample sites throughout the Somass-Stamp system and may be a useful baseline metric for the early fall. Total suspended sediments are not known to negatively impact aquatic life on an appreciable scale at this time, however several tributaries in the Sproat system have undergone recurring sediment transport events, which have compromised habitat quality and presumably resulted in periods of high TSS values that could adversely affect fish and invertebrates. Bank erosion and infilling of pool habitat have been observed on various scales in the Sproat River, and tributaries such as Antler, Clutesi, Friesen, Snow, Sutton and Weiner creeks (B. Rushton, pers. comm., 2011). Taylor River and Gracie Creek have undergone habitat restoration projects (Figures D, D-2, and D-3) to address similar issues (Wright, 2002; Wright and Doucet, 2004; M.C. Wright and Associates, 2008). The assessment by Campbell (2008) found sediment hazards are low across nearly all Sproat Lake sub-basins. Suspended sediment may only be a minor threat to fish after the occurrence of periodic larger-scale erosion or slide events.

vi. Water quality (*Refer to Table 2 for cited water quality values.*)
Sproat Lake has been part of on-going nutrient enrichment studies to improve water quality for primary production (Stockner and MacIsaac, 1996). Data from these studies are likely available and could be used to a establish a metric for Sproat Lake. Available water quality data for Sproat River were limited to one set of measurements taken October 2, 1996 at two locations (Burt and Horchik, 1999). Total phosphorus (3-4 µg/L) was within accepted benchmark values of 5-15 µg/L (Table 2). Nitrate was below detection limits (<0.005 mg/L) and below thresholds for acute (instantaneous) and chronic (30-day ave.) values. Nitrite was also below detection limits (<0.001 mg/L) and below the cited range of 0.02-0.06 mg/L. Sproat River dissolved oxygen was 10.38-10.65 mg/L, well above the required instantaneous benchmark value for non-

buried life stages. Further, replicate sampling over the course of the year (i.e. spring, winter, summer) is recommended to provide a better set of data with which to compare benchmark values.

vii. Water temperature (juveniles) – Water temperatures have been identified as a limiting factor in the Sproat sub-basin. The water bodies that are affected seasonally by high water temperatures include the Sproat River (P. Edgell pers. comm., 2011), Antler, Clutesi, Friesen, Snow, Sutton and Weiner Creeks (B. Rushton pers. comm., 2011). Burt and Horchik (1999) reported values of 23°C (range 21.5-25°C) between August 10-18, 1996 (n=29). These values exceed the UOTR and IT values for juveniles of all species present during this time (Table 4). Air temperature data from Robertson Creek station indicated that the highest mean monthly maximum air temperature from 1996 to 2006 was recorded in July of 1996 (Table 3) (Environment Canada 2011). Overall, the month of August was above 25°C for every year except 2001 (mean monthly maximum 23°C). It is likely, based on the climate data available, that temperature is a recurring risk to the survival of rearing juvenile fish using Sproat River and its tributaries during the months of June to September, with the highest risk during July and August.

viii. Water temperature (migration and spawning) – The temperatures described above (section vii) are also above the UOTR and IT for all spawning adults (Table 4) and can therefore potentially affect Sproat Lake-bound species as well as Taylor River-bound late summer-run Steelhead, stream-spawning Sockeye and Chinook (in the lower Taylor). Lake-bound Sockeye are regularly subjected to warmer water temperatures in the river (BCCF, 2009), which can result in delayed migration and/or pre-spawn mortalities. The existing consensus among sources was that this system is limited largely by the higher summer water temperatures and thus presents a risk to all life stages of all species of fish. Sproat Lake, however, offers temperature refuge below the hypolimnion for fish that arrive from the estuary.

ix. Stream discharge – Discharge measurements for the Sproat River were available for 1914-2009 (Station 08HB008; Sproat near Port Alberni: 49°17'23"N; 124°54'37"W). The mean annual discharge (MAD) was 37.7 m^3/s for 1914-2009 with monthly means in July, August and September as 16.4, 7.82 and 8.6 m^3/s, respectively. In order to meet the recommended 20% benchmark to maintain conditions for adult migration and spawning (Stalberg et al., 2009), the minimum flows for August and September should reach at least 7.5 m^3/s. The ranges of monthly mean discharge values for the summer months were 2.7-39.5 m^3/s in July, 1.1-22.6 m^3/s in August, and 0.7-33.1 m^3/s in September. Out of the eighty-eight years of available data examined, 17% of years showed July flows below the 20% MAD benchmark (7.5 m^3/s). Between 57% and 59% of years showed August and September monthly means <20% MAD.

The recommended flows to allow Sockeye access to Sproat Lake range from 10-15 m^3/s (BCCF, 2009). Coho and Steelhead rearing are not a big concern in the Sproat River at this time, due to the limited productive capacity of the river for these species relative to the entire Somass system (BCCF, 2009). The Sproat River is therefore not meeting the 20% MAD benchmark for the months of August and September on a regular basis. It is common for the river to reach <10% MAD during these months (BCCF, 2009), thus compromising fish production and habitat.

x. Accessible stream length – Accessible stream length data came from a variety of sources including consultant's reports, FISS, Weyerhaeuser (presently known as Western Forest Products Ltd.) and M.C. Wright and Associates Ltd. Values provided are intended as estimates, as the reliability of some of the data could not be confirmed. In some cases FISS data were only provided for one of the known species in a tributary. For the Sproat drainage, reports suggested approximately 48.0 km are accessible to all species (Table 5). Using GIS synthesis, which included some tributaries in the drainage (Figures C, C-2A, C-2B and C-3), the accessible stream value for Coho was 40.8 km. For Sockeye and Steelhead these values were 36.4km and 26.5km, respectively. Chinook and Chum were the most data-deficient. FISS indicated Chinook can access 1.0 km of habitat, which is obviously well below the true value, and there were no data for Chum.

xi. Key spawning areas Sproat Lake has limited information on Sockeye spawner distribution for tributary and beach spawning populations (Stiff et al., 2001). The most extensive mainstem spawning for Sockeye occurs in the lower 8 km of the Taylor River and its tributaries, while Coho spawning is found in tributary streams of Sproat Lake and the Taylor River and extends to km 22 of the Taylor River (Figure C-3). Chinook distribution is limited to the lower 1km of the Taylor River.

The largest beach spawning populations are found along the southwest beaches of Taylor Arm in the vicinity of Antler and Snowy Creeks and in Two Rivers Arm in the vicinity of Gracie Creek (Stiff et al., 2001, Wright 1999). Surveys conducted in 1999 suggested distributions changed from year to year, and identified limitations of various techniques used to survey the lakeshore for spawning Sockeye (Wright and Wright, 1999). See Figures C-2, C-2A, C-2B and C-3. Escapement survey data from DFO Stock Assessment Division could be compiled and mapped to determine the preferred spawning areas within all surveyed streams in the drainage.

xii. Permitted waste management discharges – The Sproat Lake Official Community Plan (2005) identifies a need for sewage treatment for the community of Sproat Lake. Some residences likely use septic systems for sewage and grey water, but the report indicates that certain areas in the drainage are not well-suited for septic systems as the nature of the substrate may cause leaching into the lake. Shoreline residential development, camping, boating and other recreational sources have prompted a need for strict enforcement of sewage treatment regulations (see ACRD, 2005). Waste discharges (permitted or illegal) appear to be of concern for water quality in Sproat Lake at this time. A benchmark could not be generated for this indicator because a metric has not yet been established by Stalberg et al. (2009) and data are not available.

xiii. Coldwater refuge zone (Sockeye lakes) – Data for this indicator were not found. The suggested metric is the width of the zone of water below the depth of the bottom of the thermocline but above the depth of 50% oxygen saturation (Stalberg et al., 2009). DFO (K. Hyatt) likely has the data required to address this indicator.

xiv. Lake productive capacity (Sockeye lakes) – Data for this indicator were not found. DFO (K. Hyatt and J. Stockner) likely have the data required to address this indicator.

xv. Lake shore spawning area (length) – This indicator was estimated for Sproat Lake based upon 1991 shoreline surveys conducted by M.C. Wright and Associates Ltd. The entire lake shore was surveyed (approximately 100 km). Areas of no shore spawning observed totalled 38.0 km; areas of low use (1-50 fish observed) totalled 38.1 km; areas of moderate use (51-150 fish observed) totalled 13.3 km; areas of high use (≥151 fish observed) totalled 10.3 km. The total length of spawning area observed along the Sproat Lake lakeshore was therefore 61.7 km, or 61.9% of the survey area.

3.2.2 Additional Limiting Factors

For the Sproat drainage, particularly in smaller tributaries, temperature, flow, riparian vegetation, cover/complexity and channel bed stability were identified by interview sources as limiting to fish production.

3.2.3 Productive Habitat and Restoration

Productive Habitats:

- Beach spawning habitat along the Sproat Lake shoreline (Figures C-1, C-2, C-2A, C-2B and C-3).
- Taylor River to Km 22- includes off channel habitats (maps have not been developed).
- Gracie Creek – high value Sockeye spawning and Coho spawning and rearing.
- Lower Reaches of Snow and Antler Creeks.

Restoration has been completed in the watershed to address limiting factors such as loss connectivity to off channel habitat, loss of off channel habitat and sediment transport. Some of the projects are as follows (see Figures D-1, D-2):

Off Channel Restoration:

- Relic Channel Constructed 750 m of off-channel spawning and rearing habitat (1998 and 1999).
- Doran Taylor spawning channel and reconnect Croft Creek to the Taylor River - Groundwater Channel.
- Groundwater Channel upgrade and construction of a protective dyke.
- Channel reconstruction at 11km and 11.2km on Stirling Main.
- Borrow Pits (lower Taylor) -
  Pollards Pond and Groundwater Channel (upper Taylor) – Converted an abandoned borrow pit into 0.2 ha of off-channel rearing habitat (Wright 1998 and Wright 1999). An outlet channel was constructed to increase access to the pond and provide stable off-channel spawning and rearing habitat.
- T106- ground water channel, replace stream crossing to provide fish passage to upstream habitat.
- Gracie Creek mainstem restoration (800m).
- Glulam flood plain restoration (road prism pull back).

Fish Passage:

- T105- fish passage and instream channel rehabilitation.
- Beaver control structures for fish passage – Wright 2001.

Sediment Control

- Bank Protection at 24 Km lower Taylor River.
- Glulam bridge removal, total road deactivation at the Glulam, includes wood culvert removal.
- Gracie Wood bridge removal and bank restoration.
- Stirling 7 sediment basins.
- Stirling 8 Sediment removal and bank stabilization.
- Road prism stabilization above Sproat Lake.

3.2.4 Recommendations

- Additional Sockeye shoreline surveys should be completed over the spawning period to determine spawn timing. Surveys should also include a more detailed assessment of spawning by depth.

- Protection for all restoration sites.
- Continue to address sediment transport issues: stream bank erosion, road construction and de-activation, terrain instability.
- Protect recovering riparian areas (likely covered under FRPA).
- Continue to address lost connectivity and loss of off-channel rearing habitat through restoration.
- Protect remaining foreshore (e.g. beach spawning areas) from urban encroachment.
- Stop the proliferation of private docks.

3.3 Stamp River, Great Central Lake and tributaries

- Refer to figures B-4, B-5, B-6 C-4, C-5, C-6, D-4, D-5 and D-6.

3.3.1 Pressure-State Indicators

i. Total land cover alterations – The Stamp/ Great Central Lake drainage is approximately 490 km^2, representing approximately 37% of the entire Somass system (Table 1). The limited land cover data available showed only 20.8 km^2 of cut block alterations (4.2% of the drainage area).

ii. Watershed road development – Based on the digital TRIM (terrain resource inventory maps) available for the analysis, the total length of roads in the Stamp/GCL drainage is approximately 373 km (Figures B, B-4, B-5, and B-6). The density of roads is therefore 0.8 km/km^2(Table 1), and therefore exceeds the 0.4 km/km^2 benchmark and is considered a high risk to negatively impacting fish habitat (Stalberg et al., 2009).

iii. Water extraction – For the Stamp/GCL drainage, the total volume of water licenced for use is $6.12x10^8$ m^3/year. Purposes of water use were identified as: Conservation-stored water, conservation-use of water, domestic, fish hatchery, irrigation, land improvement, ponds, power-general, power- residential, processing, stock watering, storage-non-power, storage-power, waterworks uses .

iv. Riparian disturbance – Some of the most significant impacts have been to the shoreline of Great Central Lake, which have resulted from the flooding of the lake after dam construction in 1957. The extent of the flooding damage attributed to the presence of the original dam (built in 1925 – ACRD, 2011) is not known. The most significant riparian disturbance was removal of the riparian forest on all of the flood plains around the lake (Lindsey Creek, Doran Creek, McBride and Drinkwater Creeks). Rail logging operations also caused significant riparian disturbance along the lake shoreline and in Drinkwater and McBride Creeks. Other productive basins that have experienced significant riparian disturbance were Forestry Camp Creek, Fawn Point Creek and Lowery Creek. Observations obtained through interviews and existing documents identified historic riparian disturbance as extensive, however, like Sproat Lake historic impacts, these disturbances are 30 to 60 years old. Since then, regeneration of the riparian area has been significant with most of the riparian areas now dominated by deciduous trees. Eventually, succession of deciduous stands should lead to the re-establishment of conifers which, in time will lead to recruitment of LWD into channels and an increase channel complexity.

v. Permitted waste management discharges – There were no data available for waste water discharges in Great Central Lake. Very little should be expected as there is little urban development. Historically, there would have been sewage discharges to Boot Lagoon and sewage and grey water discharges from floating logging camps. Presently there is likely some sewage and grey water discharge from some of the float houses, none of which are permitted (Figures B-5 and B-6).

vi. Suspended sediment – This indicator is critical to the survival of multiple life stages of fish in Great Central Lake and Stamp River. High TSS values can lead to lost productivity through effects such as adverse changes to streambed composition, reduced egg to fry survival, reduced primary and secondary production as well as gill malfunction (CCME, 2002). Burt and Horchik (1999) stated values below detection limits in October of 1996 (values for river and GCL were both <1mg/L; well below the LC_{50} benchmark cited in CCME, 2002). These values were noted at nine other sample sites throughout the Somass-Stamp system (Table 2).

vii. Water quality (*Refer to Table 2 for cited water quality values.*)
Great Central Lake has been part of on-going nutrient enrichment studies to improve water quality for primary production (Stockner and MacIsaac, 1996) (Figures D-5 and D-6). Current data from these studies are likely available and could be used to establish a metric for Great Central Lake. Available water quality data for the Stamp River were limited to a set of measurements taken from three locations and one Great Central Lake location in 1996 (see Burt and Horchik, 1999). In the Stamp River, total phosphorus (5 µg/L) came within accepted benchmark values of 5-15 µg/L (Table 2). The concentration of nitrate was 0.005 to 0.008 mg/L which is below the acute (instantaneous) and chronic (30-day ave.) threshold values. Nitrite (0.001 mg/L) was also below the cited range of 0.02-0.06 mg/L (Table 2). Stamp River dissolved oxygen was 10.92-11.24 mg/L, well above the required instantaneous benchmark value for non-buried life stages. The Great Central Lake sample site location was unclear in the report. Total phosphorus (14 µg/L) came marginally within the accepted benchmark. Nitrate was 0.006 mg/L which is below threshold values. Nitrite (0.001 mg/L) was also below the cited benchmark range. Great Central Lake dissolved oxygen was recorded as 10.75 mg/L at the site, well above the required instantaneous benchmark value for non-buried life stages (Table 2).

viii. Water temperature (juveniles) – Insufficient temperature data were found to adequately address this indicator although it is highly likely that these data exist. A data set from Burt and Horchik (1999) showed point values (n=41) from the Stamp River (unspecified sample locations) for September 23-October 12, 1996. Values ranged from 14.5-18°C (mean 16.1°C). For juvenile Coho and Steelhead, which may have been present in smaller tributaries during this time, these values were slightly above the UOTR of 15°C but below the IT of 20°C (Table 4). Water temperature data for July and August in the Stamp River as well as from smaller tributaries are needed to adequately address the risk to juvenile life stages during summer months.

ix. Water temperature (migration and spawning) – For migrating and spawning salmon, the Stamp River water temperature values (section viii above) exceeded the UOTR values for all species, and reached the IT of 18°C for Sockeye (Table 4) based on the data set from 1996. More data are required to examine temporal trends to assess the risk of high water temperatures to fish that enter the Stamp River, particularly Great Central Lake-bound Sockeye. Some sources identified water temperature in the Stamp River as limiting to fish, particularly migrating adults. Delayed migration and pre-spawn mortalities were among some of the results observed during warm water events in the late summer (BCCF, 2009; Burt and Horchik, 1999; McColloch, 2003). Water temperature values for Great Central Lake were available for certain years and locations (M.C. Wright and Associates Ltd.) but lake temperature was not considered limiting to fish, since access to cooler hypolimnion temperatures is possible when surface waters become too warm.

x. Stream discharge – Discharge measurements for the Stamp River were available for 1914-1919 and 1959-1999 (Station 08HB009; Stamp River near GCL: 49°20'23"N; 124°58'31"W). The natural MAD was 50.8 m^3/s for 1914-1919, and 60.5 m^3/s for 1959-1999. The difference in MAD between these years is attributed to the dam and diversion of Elise Lake water into Great Central Lake, which began in 1958. While the Ash River saw a reduction in MAD, the Stamp River underwent an increase in MAD with the post-1958 regulated flow regime. In order to meet the recommended 20% benchmark to maintain conditions for adult migration and spawning (Stalberg et al., 2009), the minimum flows for August and September should reach at least 12.1 m^3/s. The monthly means in July, August and September (1959-1999) were 40.9, 30.5 and 34.6 m^3/s, respectively. The ranges of monthly mean discharge values for the summer months were 17.7-80.3 m^3/s in July, 16.3-57.2 m^3/s in August, and 16.6-73.5 m^3/s in September. Generally 15 m^3/s is adequate for migration, spawning and incubation of Chinook, Coho, Chum and Steelhead, and provides quality rearing habitat for Coho and Steelhead (BCCF, 2009). There is little concern at this time for the migration of smolts, since flows from April to June are usually adequate for downstream migration (BCCF, 2009). The Stamp River is therefore currently meeting the 20% MAD benchmark for August and September.

xi. Accessible stream length – Accessible stream length data came from a variety of sources including consultant's reports, FISS, Weyerhaeuser (presently known as Western Forest Products Ltd.) and M.C. Wright and Associates Ltd. Values provided are intended as estimates, as the reliability of some of the data could not be confirmed. In some cases FISS data were only provided for one of the known species in a tributary. For the Somass/GCL drainage, reports suggested approximately 55.0 km are accessible to all species (Table 5). Using GIS synthesis, which included some tributaries in the drainage (Figures C, C-4, C-5, and C-6), the accessible stream value for Coho was 96.7 km. For Sockeye and Steelhead these values were 58.0 km and 63.1 km, respectively. Chinook may access up to 57.1 km of habitat and there were no data for Chum.

xii. Key spawning areas – Over 70% of GCL Sockeye spawn on lakeshore beaches; the remaining fish spawn in tributary streams. Lakeshore spawning in Great Central Lake commences in mid to late October, peaks early to mid-November and is complete by early December. Spawning takes place along the lakeshore at depths of 0 to >55 m (Forestry Camp Creek beach spawning area), with most between 1 to 20m at tributary outlets (Wright 1992, Stiff et al., 2001). See Figures C-5 and C-6. Chinook spawn below the Great Central Lake Dam upstream of the lagoon at the Robertson Creek hatchery. Chinook have also been observed spawning in McBride and Drinkwater Creeks and historical use of Browns Bay Creek has also been documented. Coho use is documented for McBride and Drinkwater Creek, Doran Creek Lindsey Creek, Browns Bay Creek and in other smaller tributaries documented in Wright et al. 2002, Wright et al. 2008, Wright et al. 1993. Key spawning areas in McBride Creek are 4 km to 8.0 km, 0 to 1.5 km for Sockeye and Chinook respectively. Coho use is not well documented, but use is likely similar areas as identified for Sockeye. Key spawning areas for Doran Creek are shown in Figure C-6, specifically, Sockeye use the creek delta and the lower 300m of the creek (M.C. Wright and Associates 2002).

xiii. Coldwater refuge zone (Sockeye lakes) – Data for this indicator were not found. The suggested metric is the width of the zone of water below the depth of the bottom of the thermocline but above the depth of 50% oxygen saturation (Stalberg et al., 2009). Data for this indicator were not found. DFO (K. Hyatt and J. Stockner) likely have the data required to address this indicator.

xiv. Lake productive capacity (Sockeye lakes) – Data for this indicator were not found. DFO (K. Hyatt and J. Stockner) likely have the data required to address this indicator.

xv. Lake shore spawning area (length) – This indicator was estimated for Great Central Lake based upon shoreline surveys conducted by M.C. Wright and Associates Ltd. (Wright et al., 2002;

Wright, 2008). Approximately 81% of the entire lakeshore was surveyed (approximately 73 km of the 90 km perimeter). Areas of no shore spawning observed totalled 6.7 km; areas of low use (1-50 fish observed) totalled 35.5 km; areas of moderate use (51-150 fish observed) totalled 5.3 km; areas of high use (≥151 fish observed) totalled 25.5 km. The total length of spawning area observed along the Great Central Lake lakeshore was therefore 66.3 km, or 90.8% of the survey area (Figures C-5 and C-6). Remote Operated Vehicle (ROV) surveys completed in 1991 provided information on depth distribution of beach spawning populations at Lindsey and Forestry Camp Creeks (Wright, 1992).

3.3.2 Additional Limiting Factors

For the Stamp/GCL drainage, particularly in smaller tributaries, flow, riparian vegetation, cover/complexity, channel bed stability and tributary connectivity (from lake shore) were identified by interview sources as limiting to fish production. Other factors mentioned included water quality and temperature.

3.3.3 Productive Habitat and Restoration

Productive Habitat:

- Forestry Camp Creek supports one of the largest beach spawning population, with the deepest spawning distribution (55 m).
- Lindsey Creek - productive beach spawning.
- Doran Creek - shallow spawning (extensive) in the historic riparian zone, tributary supports Sockeye and Coho.
- North Shore beach spawning.
- McBride Creek.
- Drinkwater Creek.
- Browns Bay Creek – impacted, needs restoration.
- Fawn Point.
  Short tributary segments along the shoreline support spawning and rearing Coho and spawning Sockeye.

Restoration:

- Lake Enrichment.
- Stamp Falls fishway.
- Great Central Lake dam fishway.

3.3.4 Recommendations

- Additional studies should be done to determine the depth distribution of beach spawning populations around the lake.

- Rework the existing rule curve to reduce loss of Sockeye eggs and rearing fry salmonids along the shoreline (Wright et al., 2002).
- Assessment of the impacts of log dumps on beach spawning habitat, existing knowledge for marine log dumps have shown the impacts to be extensive (>10,000m^2). For protection of the foreshore from wood waste, all log handling activities should be direct-to-barge, which eliminates the watering and storage of log bundles in the lake. Restoration opportunities should be investigated for tributary streams (i.e. Linsey Creek, Doran Creek, McBride and Drinkwater Creeks).

3.4 Ash River, lakes and tributaries

- Refer to figures B-7, C-7 and D-7.

3.4.1 Pressure-State Indicators

i. Total land cover alterations – The Ash River drainage is approximately 364 km^2, representing approximately 28% of the entire Somass system (Table 1). The drainage includes Elsie and Oshinow Lakes and Lanterman, Wolf and East Wolf Creek sub-basins. The limited land cover data available showed only 1.8 km^2 of cut block alterations (0.5% of the drainage area). As a small percentage of cut block data were available, this value may be an underestimate. Private land owners would not disclose cut block boundary areas for the project. Sources indicated that logging activity has been extensive throughout the watershed over the past five years (J. Lane pers. comm., 2011).

ii. Watershed road development – Based on the digital TRIM (terrain resource inventory maps) available for the analysis, the total length of roads in the Ash River drainage is approximately 475 km (Figures B and B-7). The density of roads is therefore 1.3 km/km^2(Table 1), and therefore exceeds the 0.4 km/km^2 benchmark and is considered a high risk of negatively impacting fish habitat (Stalberg et al., 2009).

iii. Water extraction – Based on the water licence data available, for the Ash system, all licences issued were associated with BC Hydro and Power Authority for the following purposes: power-general and storage-power. The total volume of water permitted for use is 9.04x10^8 m^3/year.

iv. Riparian disturbance –The Ash River sub-basin has been heavily impacted by logging. Private land owners were contacted for cut block and road status data but they declined to provide the information necessary to determine the extent of riparian disturbance in the watershed. Sources indicated that recent logging operations have been dramatically reducing the existing riparian margin throughout the Ash River and its tributaries (Jim Lane, Steve Tatoosh, C. Wightman and others pers. comm., 2011). Though the extent of the riparian disturbance could not be quantified, it was highly recommended that logging operations retain what riparian margin remains in this area (C. Wightman pers. comm., 2011).

v. Water quality (*Refer to Table 2 for cited water quality values.*)

Available water quality data were limited to one set of measurements taken from two Ash River locations and one location in each of Wolf and Lanterman Creeks on October 2, 1996 (see Burt and Horchik, 1999). Total phosphorus (3-4 µg/L) came within accepted benchmark values of 5-15 µg/L (Table 2). Nitrate was 0.005 to 0.011 mg/L and came below thresholds for acute (instantaneous) and chronic (30-day ave.) values. Nitrite was below detection limits at two locations (<0.001 - 0.001 mg/L) and was below the cited range of 0.02-0.06 mg/L (Table 2). Dissolved oxygen was 10.79-11.80 mg/L, well above the required instantaneous benchmark value for non-buried life stages.

vi. Water temperature (juveniles) – Insufficient temperature data were found to adequately address this indicator although BCCF staff indicated several temperature loggers are deployed throughout the Ash River system (Figures D and D-7). A data set from Burt and Horchik (1999) showed measurements for the Ash River, Lanterman and Wolf Creeks in the early fall of 1992 and 1996. Ash River temperatures averaged 12°C (n=12) with a range of 11.5-15.5°C from October 4-13, 1992 (Griffith, 1992). This range is acceptable for rearing and overwintering Coho and Steelhead (Table 4). Temperature in Lanterman Creek was recorded August 19-29, 1996; an average of 14.1°C (n=47) and range of 12-16°C were observed (Burt and Horchik, 1999). Between September 5-17, 1996, Wolf and East Wolf Creeks had averages of 11.3°C (n=64; range 9-13°C) and 11.2°C (n=32; range 10-12.5°C), respectively. For rearing juveniles, these temperatures were within the accepted tolerance ranges and considered low risk. Any available data for this region should be complied and examined to assess the temperature-associated risk to juvenile life stages throughout the Ash system during summer months.

vii. Water temperature (migration and spawning) – The Ash River temperatures above did not include sample locations. For summer Steelhead, data from above Lanterman Falls in the summer would be desirable to determine the risk to migrating adults. In the lower Ash River, below Lanterman Falls to the Stamp River confluence, Coho spawn as well as lower numbers of Chinook. If temperature values above are representative of current averages for the early to mid-fall in the Ash River, the risk to adult Coho and Chinook would be minimal since values were only slightly above the UOTR of 14°C and well below the 20°C IT (Table 4). Current temperature data should be examined throughout the migration and spawning periods for Coho and Chinook to assess risk to fish.

viii. Stream discharge – Discharge is regulated in this system by the operation of the Elsie Lake hydro dam, which diverts approximately 11 m^3/s of Ash River-bound flow (Burt and Horchik, 1999) into Great Central Lake. Controlled discharges can limit access to upper Ash River habitat, particularly for migrating summer-run Steelhead adults, which require sufficiently high flows to pass Dickson Falls. Burt and Horchik (1999) estimated the natural MAD in the lower Ash River as 27.4 m^3/s using the regulated MAD and the diverted flow to Great Central Lake. The current regulated MAD (1959-2009) is 16.7 m^3/s (Station 08HB023 - 49°22'10"N; 124°58'58"W; WSC, 2011). Under the suggested benchmark, a minimum of 20% MAD for the natural MAD for Ash River would require a mean monthly discharge of 5.5 m^3/s during August and September. Under the regulated MAD, however, this 20% value is 3.3 m^3/s. In July, the mean monthly discharge is 6.5 m^3/s. In August and September, the values are 4.4 m^3/s (range of 3.1-11.5 m^3/s) and 4.6 m^3/s (range of 2.8-16.0 m^3/s), respectively (WSC, 2011). Therefore, under the regulated MAD, the 20% benchmark is being met; under the estimated natural MAD most years failed to meet the benchmark. During August and September, pulsed flow experiments were conducted (2005-2009) allowing two regulated discharges of 10 and 20 m^3/s over 56 and 36 hours, respectively (Lewis et al., 2010). The intent of the pulses was to facilitate summer Steelhead passage over Dickson Falls. The response by fish was generally positive; different combinations of pulses were used to identify the most effective flow for Steelhead. The August pulse of 10 m^3/s had the best response from Steelhead while the mid-late September pulse of 20 m^3/s stimulated lower Ash migration of Coho to the Lanterman Falls boundary (Lewis et al., 2010).

Lanterman and Wolf Creeks, which are not regulated by dams, have approximated MAD values of 2.1 and 1.7 m^3/s, respectively (Pellett and Gaboury, 2007). To maintain a minimum of 20% MAD in August and September, Lanterman Creek should have a flow of 0.4 m^3/s during summer months, and Wolf Creek should maintain at least 0.3 m^3/s. The means for August and September cited in Pellett and Gaboury (2007) indicated the benchmark was being met in both creeks, with discharges of 0.5 m^3/s in Lanterman Creek and 0.6 m^3/s in Wolf Creek during critical summer months. Continued monitoring of summer flows is recommended in the Ash River basin, particularly as logging activities continue to affect the nature of overland flows and channel flooding regimes.

ix. Accessible stream length – Accessible stream length data came from a variety of sources including consultant's reports, FISS, Weyerhaeuser (presently known as Western Forest Products Ltd.) and M.C. Wright and Associates Ltd. Values provided are intended as estimates, as the reliability of some of the data could not be confirmed. In some cases FISS data were only provided for one of the known species in a tributary. For the Ash River drainage, numerous reports existed and provided more reliable estimates than GIS-interpreted values. The total accessible stream length for Coho is approximately 21.5 km (Table 5) (Figures C and C-7).

Access to the reach below Dickson Falls (11.1 km above confluence) depends largely on flow conditions at Lanterman Falls (Pellett and Gaboury, 2007). For summer Steelhead, the Ash River is accessible to Elsie Lake during optimal flow conditions (total 35 km). Coho and Chinook have access up to Lanterman Falls (approx. 6 km) (Pellett and Gaboury, 2007) as do sporadic and small numbers of Chum, which are observed on occasion. Sockeye (total 8 km) can access to Lanterman Falls, and have been observed in reach 2 of Wolf Creek (Pellett and Gaboury, 2007). Lanterman, Wolf and East Wolf Creeks contain numerous log jams which may act as partial migratory barriers to adults and/or low flow barriers while juveniles may access above some of these points (Pellett and Gaboury, 2007). The recent increase in logging activity throughout the watershed (J. Lane, S. Tatoosh, C. Wightman pers. comm., 2011) which contributes heavily to channel instability and degradation (Burt and Horchik, 1999), may mean barrier locations have changed since 2007 assessments.

x. Key spawning areas – Data were not found for this indicator. For all species except summer Steelhead, spawning areas are largely governed by natural barriers in the Ash River system. Escapement survey data from DFO Stock Assessment Division and the BC Ministry of Environment (for trout species) could be compiled and mapped to determine the preferred spawning areas within all surveyed streams in the drainage. Temporal trends could also be examined as an indicator for changes to stream bed composition.

3.4.2 Additional Limiting Factors

Though many indicators of habitat degradation were highlighted through the data gathering process, many did not meet the short list of indicators proposed for the WSP. For the Ash River drainage, many of the observed impacts and temporal changes to channel habitat quality are associated with logging. Impacts to the stream bed included coarsening of gravels, bank erosion, log debris jams, siltation and infilling of pools. Limiting factors to fish production included insufficient pool depth and number, insufficient stream cover and complexity, absence of mature riparian forest as well as summer low flows (Ash River only). Interviews with Jim Lane (NTC) and Steve and Tom Tatoosh (HFN) and BCCF staff (C. Wightman, K. Pellett and J. Damborg) plus numerous reports about the Ash basin supported that extensive logging continues to be a leading cause of habitat degradation of this nature. Interview sources highlighted nutrients, water temperature, flow, riparian vegetation, cover/complexity, channel bed stability and natural fish barriers as limiting to fish production in the Ash system.

The system is also limited by the presence of steep natural barriers (section ix above). The barriers faced by anadromous salmonids in the Ash River include Lanterman, Dickson Falls and Ash Island Falls (Burt and Horchik, 1999). Lanterman Falls, 5.6 km above the Stamp confluence is the barrier for all anadromous species except summer Steelhead. Lewis and Ganshorn (2005) state that juvenile Coho have been documented once above Dickson Lake during a BCRP project in 2005; there remains the possibility, however, that the Coho were placed there since no further observations have ever been made (C. Wightman pers. comm., 2011). In the summer months, controlled flows from the hydro power diversion of Elsie Lake into GCL render Ash River barriers impassable to Steelhead without the help of pulsed flows (section viii above). Recent studies on marine-derived nutrients in Ash system lake sediments suggest that anadromy declined significantly in the system after dam operation began in 1958 (Hatfield and Bos, 2007). Blasting at Dickson Falls from 1975-1976 likely only helped Steelhead access the upper Ash (Hatfield and Bos, 2007). Additional oral history accounts from the Hupacasath First Nation supports anadromy at Elsie Lake. There are no data to support which barriers were passible to other species such as Coho and Chinook prior to 1958.

3.4.3 Productive Habitat and Restoration

- Generally, the Ash River, Lanterman, Wolf and East Wolf Creeks are considered reasonably good habitat for rearing juvenile Coho and Steelhead.
- Nutrient enrichment has been on-going with BCCF; several sites have been used to test the benefits to periphyton production of fertilizer bricks, Pollock meal, and broodstock carcasses from the Robertson Creek Hatchery (Figures D and D-7).
- Pulsed flow experiments were conducted over 5 years to facilitate summer Steelhead passage and determine optimal flows to trigger migration of Coho into the lower Ash River (section viii above)
- Temperature loggers are deployed throughout the system (Figures D and D-7) to monitor water temperature throughout the year.
- A prescription for off-channel habitat exists for the lower Ash River (Gaboury and Pellett, 2008).

3.4.4 Recommendations

- The existing prescription to construct off-channel habitat in the lower Ash River (Figure D-7) (Gaboury and Pellett, 2008) should be considered; this could boost Coho production and provide overwinter habitat for Steelhead and mainstem refuge for spawners in the lower portion of the mainstem (includes Chinook).

4.0 DATA GAPS

The metric and status for many of the pressure-state indicators were difficult to address or not addressed at all due to numerous constraints. Time and budget, which restricted the depth of research spent to acquire appropriate data, combined with a lack of cooperation from private land owners and industry were the primary sources of data gaps outlined in this report. In many cases, data likely existed to address metrics, but were unavailable based upon the timelines of the report. True data gaps were identified where exhaustive searches failed to provide easily-accessed data or the data found were not current or reliable enough to appropriately assess indicators. The following data gaps were identified for the Somass system (also refer to Appendix 2):

1. Total land cover alterations – Limited cut block data were available but most were not up to date. Private landowners were commonly not willing to provide this data for the report. It is likely that other land cover data are available, as well as current cut block data but would require cooperation from landowners or could be acquired through aerial photography.

2. Watershed road development – Limited road data were available but most were not up to date for private lands. These data likely exist, but would require cooperation from landowners or could be acquired through aerial photography.

3. Water extraction – Overall these data were easily acquired through BC MOE for the legal licences; detailed quantities and names of licensees were available. The data did not discern between consumptive use and non-consumptive uses, however.

4. Riparian disturbance – These data were among the most limited; due to the specificity of the parameter, which requires the linear measurement of stream length with <30m buffer of riparian as a result of encroachment from disturbances. This would require detailed field surveys or extensive over flights to acquire aerial photographs and detailed GIS analyses. Attempts to obtain cut block boundary data from private landowners were attempted as an index for disturbance, however private landowners were not willing to provide this data for the report.

5. Permitted waste management discharges – These data were acquired through the municipality and Catalyst pulp mill. Allowable municipal sewage effluent and pulp mill effluent discharges were all that was found for the lower Somass River and estuary. Permits for Sproat Lake and GCL were not found, but may exist. Furthermore, illegal discharges could not be accounted for.

6. Suspended sediment – Data from one report were used for the metric, but recent data were not found for the rivers and lakes in the Somass system. Data from the Clutesi Marina dredging operations, through consultant's reports, may be available. If any water quality studies have been conducted in the system recently, data should be available.

7. Water quality and estuary chemistry and contaminants– Some parameters were available in one report (i.e. total phosphorus, nitrate, nitrite, D.O.), but detailed water chemistry analyses addressing metals and contaminants were not found. It is likely that additional effluent monitoring reports exist for the pulp mill, as well as data for Sproat and Great Central Lakes associated with nutrient enrichment studies.

8. Water temperature – Temperature has been studied extensively throughout the system, but data were not easily accessible other than those provided through consultant's reports made available for this report. Data loggers maintained by BCCF at several locations throughout the system could be analysed to provide up-to-date metrics for juvenile and adult life stages. DFO has conducted climate change-related studies, which should also be examined.

9. Stream discharge – Generally indicator was not data-limited; data were easily accessed via the Water Survey of Canada online. Most stations were current (i.e. to 2007-2009). Stations were positioned in each of the four major drainages addressed in this report.

10. Accessible stream length - This indicator had numerous sources, each with different species coverage depending upon the major drainage. The FISS database was limited for species such as Chum and Chinook; coverage for smaller tributaries was also very limited. Stream class data were used from Weyerhaeuser (2000) (presently known as Western Forest Products Ltd.), but it is unlikely that these data were generated from actual stream surveys. Reports from M.C. Wright and Associates Ltd. were also used. Additional data are likely available from past watershed assessments throughout the system, but surveys would be the most precise way to determine total accessible area by each salmon CU.

11. Key spawning areas – Data were very limited for this parameter. Accessing annual snorkel survey data would provide reliable spawning locations for surveyed streams. Robertson Creek Hatchery and local recreational fishing guides might also provide information on key areas.

12. Coldwater refuge zone and lake productive capacity – This indicator, for lakes, was not addressed due to the difficulty associated with accessing data to generate the metric. Data may exist within the DFO (K. Hyatt), particularly where studies for Sproat and Great Central Lake Sockeye have been conducted.

13. Lake shore spawning area (length) – Data were available through shoreline studies conducted by M.C. Wright and Associates Ltd. on Sproat and Great Central Lakes. Additional data would be desirable, particularly across years to compare varied sizes of escapement and spawning habitat use (Sproat Lake would the first priority).

14. Marine vessel traffic – For the estuary, this indicator could not be addressed in time for the report, despite having received cooperation from the Port Alberni Port Authority (PAPA). Statistics are available through PAPA.

15. Estuary habitat disturbance – Data were not found for this indicator, though several online sources were searched. Information was only addressed based upon interview sources and the Somass Estuary Management Plan.

16. Estuary dissolved oxygen – Data from extensive studies on D.O. were available through Catalyst pulp mill (L. Cross). Baseline values (pre-dating the pulp mill) were not found, however and may not exist. Baseline data would be useful in attempting to compare anthropogenic sources (post-development) of low D.O. water with 'natural' sources associated with the properties of the estuary.

17. Estuarine habitat area – Quantity of each habitat type (riparian, sedge, eelgrass and mudflat) was not obtained. The Somass Estuary Management Plan contains maps from which habitats could be measured in GIS, provided land cover hadn't changed significantly since the photos were taken. The maps provide a classification of the various habitat units in the estuary. Alternatively, high resolution aerial photos and foot surveys could likely be conducted in the relatively small areas that have remained undisturbed.

5.0 REFERENCES

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TABLES

Table 1. Watershed area, road density, and cut block area

System	Total Area (km^2)	Lake Area (km^2)	Net Land Area (km^2)	Total Road Length (km)	Minimum Cutblock Area (km^2)	Road Density (km/km^2)	Minimum Cutblock Density (%)
Ash River	374.3	10.5	363.8	475.5	1.8	1.3	0.5
Stamp/GCL	543.2	53.4	489.8	373.1	20.8	0.8	4.2
Sproat/Taylor	354.5	42.4	312.1	435.2	0.4	1.4	0.1
Somass	139.3	0	139.3	452.6	3.9	3.2	2.8
Total	1411.3	106.3	1305	1736.4	26.9	1.3	2.1

Data were interpreted through GIS analysis with available TRIM road data. Values are based on the limited data available at the time of the assessment and may deviate slightly from true values.

Table 2. Indicator metric and benchmark values for water quality parameters

Indicator	System	Site	Existing benchmark(s)	Established metric relative to benchmark	Date data were collected	Source	Recommended ranges and values[3]
Suspended sediment (TSS)	Somass River	Papermill Dam	<1 mg/L	Below	Oct. 2, 1996	Burt and Horchik, 1999	LC_{50} = 0.27-35 g/L range in fresh water depending on life stage and species of fish; Maximum increase TSS of ≤25 mg/L (instantaneous) and ≤5 mg/L (30-d ave.) over background TSS to protect aquatic life. Source: CCME, 2002. 25 mg/L in 24 hours when background is less than or equal to 25; mean of 5 mg/l in 30 days when background is less than or equal to 25; 25 mg/ when background is between 25 and 250; 10% when background is greater than 250. Source: Stalberg et al., 2009.
	Sproat River	Two - see report	<1 mg/L	Below			
	Stamp River	Three - see report	<1 mg/L	Below			
	GCL	not given	<1 mg/L	Below			
	Ash River[2]	Four - see report	<1 mg/L	Below			
	Somass Estuary	Pulp mill[1]	5.9 mg/L	Above	2009	Calculated from Hatfield Consultants EEM Cycle Five Report, 2010	
	Somass Estuary	Pulp mill effluent[1]	6.2 mg/L	Above	2008		
	Somass Estuary	Pulp mill effluent[1]	5.2 mg/L	Above	2007		
	Somass Estuary	Sewage Outfall[5]	49.0 mg/L	Above	2009	City of Port Alberni, 2011	
Water quality: Total Phosphorus	Somass River	Papermill Dam	9 µg/L	Within	Oct. 2, 1996	Burt and Horchik, 1999	The bencmark for total phosphorus is 5-15 µg/L Source: Stalberg et al., 2009
	Sproat River	Two - see report	3-4 µg/L	Within			
	Stamp River	Three - see report	5 µg/L	Within			
	GCL	not given	14 µg/L	Within			
	Ash River[2]	Four - see report	3-4 µg/L	Within			
Water quality: Nitrate	Somass River	Papermill Dam	0.11 mg/L	Below	Oct. 2, 1996	Burt and Horchik, 1999	The bencmark (threshold) for nitrate is 3 mg/L (30-d ave.) for freshwater; 3.7 mg/L (30-d ave.) for seawater. The acute maximum limit is 31.3 mg/L for freshwater. Source: BC MOE, 2009.
	Sproat River	Two - see report	<0.005 mg/L	Below			
	Stamp River	Three - see report	0.005-0.008 mg/L	Below			
	GCL	not given	0.006 mg/L	Below			
	Ash River[2]	Four - see report	<0.005-0.011 mg/L	Below			
Water quality: Nitrite	Somass River	Papermill Dam	0.001 mg/L	Below	Oct. 2, 1996	Burt and Horchik, 1999	The bencmark (threshold) for nitrite is 0.02-0.06 mg/L (30-d ave.) for freshwater (for chloride <2 mg/L). Source: BC MOE, 2009.
	Sproat River	Two - see report	<0.001 mg/L	Below			
	Stamp River	Three - see report	0.001 mg/L	Below			
	GCL	not given	0.001 mg/L	Below			
	Ash River[2]	Four - see report	<0.001-0.001 mg/L	Below			
Water quality: Dissolved Oxygen[4]	Somass River	Papermill Dam	10.82 mg/L	Above	Oct. 2, 1996	Burt and Horchik, 1999	Minimum thresholds for instantaneous water column DO (except for buried egg/alevin) 5.0 mg/L (8.0 mg/L for 30-d ave.). For buried life stages, instantaneous water column DO 9 mg/L (11 mg/L for 30-d ave.) Interstitial DO in gravel for buried life stages is 6 mg/L (inst.) and 8 mg/L (30-d ave.). Source: BC MOE, 2011.
	Sproat River	Two - see report	10.38-10.65 mg/L	Above			
	Stamp River	Three - see report	10.92-11.24 mg/L	Above			
	GCL	not given	10.75 mg/L	Above			
	Ash River[2]	Four - see report	10.79-11.80 mg/L	Above			
Estuary Chemistry: Total Organic Carbon (TOC)	Somass Estuary	at paper mill outfall	10-16%	n/a	2009	From contour maps in Hatfield Consultants EEM Cycle Five Report, 2010	The benchmark (threshold) is ±20% change from the 30-d median background concentration. Source: BC MOE, 2011; Stalberg et al., 2009.
		Hoik Island to Hohm Island (1.5 km south of outfall)	4-6%	n/a	2009		
		Polly Point and south	6-8%	n/a	2009		
Estuary Dissolved Oxygen	Somass Estuary	Surface Water (approx. ≤5m)	10-12 mg/L	Above	Nov-June 2009	Hatfield Consultants DO Monitoring Report, 2010	Minimum thresholds for instantaneous water column DO (except for buried egg/alevin) 5.0 mg/L (8.0 mg/L for 30-d ave.). For buried life stages, instantaneous water column DO 9 mg/L (11 mg/L for 30-d ave.) Interstitial DO in gravel for buried life stages is 6 mg/L (inst.) and 8 mg/L (30-d ave.). Source: BC MOE, 2011. Moderately hypoxic if DO <5 mg/L; severely hypoxic if DO <2 mg/L (Stalberg et al., 2009.)
			8-9 mg/L	Marginally above	July-Oct 2009		
		Below halocline (approx. >5m)	10 mg/L	Above	Nov-June 2009		
			6-8 mg/L	Below	July-Oct 2009		
		Near bottom	<2-6 mg/L	Below - moderately to severely hypoxic	Nov-June 2009		
			2-4 mg/L	Below - moderately hypoxic	July-Oct 2009		

1. Sampling location assumed to be the treatment plant. Pulpmill effluent discharge should be measured against 30-d ave; values were calculated into mg/L from daily discharges and TSS in t/day units (assumed to be metric tons) - Refernce: Hatfield Consultants EEM Cycle Five Report Table 2.1 (pg 2-3).
2. Includes data from two Ash River sites and a site at each of Lanterman and Wolf Creeks.
3. All values are for all aquatic life unless otherwise specified.
4. Instantaneous water column measurements.
5. The value cited on the City of Port Alberni wesite is a monthly average. Sampling location assumed to be the treatment plant. Allowable maximum cited as 70 mg/L.

Table 3. Mean monthly maximum temperatures 1996-2006 at Robertson Creek station (49°20’14.010”N; 124°58’55.090”W; elevation 73.80m) Source: Environment Canada

Month	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	10-Yr Mean	10-Yr Min	10-Yr Max	SD
Jan	4.3	2.9	3.9	4.3	3.3	4.7	4.5	5.9	3.6	4.2	5.3	4.3	2.9	5.9	0.9
Feb	6.5	7.4	6.8	4.9	6.5	6.1	5.8	7.3	7.2	7.8	6.1	6.6	4.9	7.8	0.8
Mar	10.8	7.8	11.0	8.2	10.3	9.8	7.9	9.2	11.5	12.2	8.3	9.7	7.8	12.2	1.6
Apr	12.5	14.0	15.7	14.6	14.7	13.1	14.9	12.2		15.1	13.4	14.0	12.2	15.7	1.2
May	15.5	19.9	20.1	17.0	16.8	18.3	16.9	17.3	20.0	19.9	19.9	18.3	15.5	20.1	1.7
Jun	20.2	20.0	24.3	19.3	22.8	19.2	23.0	24.5	25.1	20.5	23.3	22.0	19.2	25.1	2.2
Jul	28.3	24.6	27.5	24.9	24.3	24.3	25.6	26.3	27.9	24.2	26.8	25.9	24.2	28.3	1.6
Aug	26.3	26.5	26.9	25.5	25.2	23.0	27.2	26.7	27.1	27.4	27.3	26.3	23.0	27.4	1.3
Sep	19.5	21.1	24.6	23.5	21.4	20.8	21.6	23.5	19.7	20.9	23.7	21.8	19.5	24.6	1.7
Oct	13.3	13.1	14.6	14.2	14.3	13.1	15.8	15.5	13.9	13.0	15.1	14.2	13.0	15.8	1.0
Nov	5.9	10.8	8.7	7.6	6.5	8.2	9.6	6.1	8.1	6.0	6.3	7.6	5.9	10.8	1.6
Dec	2.0	5.5	3.6	4.4	2.7	2.8	5.8	4.1	5.4	4.6	3.5	4.0	2.0	5.8	1.2

Table 4. UOTR and IT Temperatures by species and life stage timing

Species	Estuary (adult)	River Migration (spawner)	Spawning	Fry Emergence	Overwinter (juvenile)	Estuary (smolt)[3]
Steelhead	Spawning Range: 10-15°C[1]			Rearing Range: 16-18°C[1]; UOTR=15°C; IT=20°C[4]		
	S: May-Oct W: Oct-Apr	S: May-Oct W: Oct-Apr	Late Feb-Apr	May-June	2 years	Apr-Jun
Sockeye	UOTR=15°C; IT=18°C[2]			Rearing Range: 10-15°C[1]; UOTR=15°C; IT=20°C[4]		
	Mar-May	May-Late Oct	Oct-Dec	Late Mar-Late May	1 year in lake-type fish	Apr-May
Chinook	UOTR=14°C; IT=20°C[2]			Rearing Range: 10-10.5°C[1]; UOTR=15°C; IT=20°C[4]		
	Late Jul	Sep-Dec	Oct-Mid Nov	Mar-Apr	n/a for Somass	Apr-Aug
Coho	UOTR=14°C; IT=20°C[2]			Rearing Range: 10-15°C[1]; UOTR=15°C; IT=20°C[4]		
	Late Aug	Sep-Jan	Late Sep-Late Jan	Mar-May	≥1 year	Apr-May
Chum	UOTR=15°C; IT=21°C[2]			Rearing Range: 12-14°C[1]		
	Oct	Oct-Lat Nov	Late Oct-End Nov	Mar	n/a for species	Apr-Jun

1 Temperature optimums from BC MOE, 2001 - Towards a Water Quality Guideline for Temperature in the Province of British Columbia

2 Temperatures from Stalberg et al., 2009

3 Sockeye, Coho and steelhead spend little time in the estuary after smoltification.

4 Temperatures for stream resident juveniles from Stalberg et al., 2009

1 Temperature optimums from BC MOE, 2001 - Towards a Water Quality Guideline for Temperature in the Province of British Columbia 2 Temperatures from Stalberg et al., 2009; 3 Sockeye, Coho and Steelhead spend little time in the estuary after smoltification; 4 Temperatures for stream resident juveniles from Stalberg et al., 2009

Table 5. Accessible stream length for anadromous fish by sub-basin

Sub-basin	ASH		STAMP/GCL		SPROAT		SOMASS			
	GIS Estimate[1]	Other Estimate[2]	GIS Estimate[1]	Other Estimate[2]	GIS Estimate[1]	Other Estimate[2]	GIS Estimate[1]	Other Estimate[2]	GIS Total	Other Total
Coho	20.4	21.5	96.7	55.0	40.8	48.0	26.5	7.0	184.4	131.5
Chinook	10.9	6.0	57.1	55.0	1.0	48.0	9.4	7.0	78.4	116.0
Sockeye	0.0	8.0	58.0	55.0	36.4	48.0	9.4	7.0	103.8	118.0
Chum	0.0	6.0	0.0	55.0	0.0	48.0	8.7	7.0	8.7	116.0
Steelhead	28.5	35.0	63.1	55.0	26.5	48.0	9.4	7.0	127.5	145.0

1. Values were synthesized in ArcGIS with data from FISS, Weyerhaeuser and M.C. Wright and Associates Ltd.
2. Other estimates were derived from Burt and Horchik (1999) and Pellett and Gaboury (2008) -Ash River.
3. Summer-run Steelhead only. Winter-run likely follow access similar to Coho.