February 3, 2012

PHASE I - SHUSWAP RIVER WATERSHED SUSTAINABILITY PLAN

Technical Assessment of the Shuswap River Watershed

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Report Number: 1114920047-002-Rev0
Distribution:
Regional District of North Okanagan – 2 Bound Copies and 1 PDF Copy
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Executive Summary

As requested by the Regional District of North Okanagan (RDNO), Golder Associates Ltd. (Golder) in collaboration with our sub-consultant Mr. Phil Epp, Consulting Hydrologist, is pleased to provide this Technical Assessment of the Shuswap River Watershed, mainly located in Electoral Areas “D” (Rural Lumby), “E” (Cherryville), and “F” (Rural Enderby) of the RDNO, in the Southern Interior of British Columbia. This Technical Assessment is part of Phase I of the larger Shuswap River Watershed Sustainability Plan (SRWSP), led by the RDNO, which involves an in-depth planning process with significant stakeholder and public engagement to establish a long-term vision for the management of the watershed, identify issues and data gaps, and develop objectives and actions for its future management.

The purpose of this Technical Assessment is to establish a watershed profile for the Shuswap River Watershed, with a specific focus on its water quality, water quantity, and condition of riparian areas. This Technical Assessment was restricted to a desktop evaluation of the available information for the Shuswap River Watershed with baseline data and geographic information system mapping as the deliverables. The amount of information for this watershed is substantial. As such, and in consultation with the RDNO, primary efforts were focused on characterizing the water quality, water quantity, and condition of riparian areas associated with the main sub-drainages of this watershed.

The Shuswap River Watershed is dominated by the Shuswap River and includes all of its direct and indirect sub-drainages. The Shuswap River originates from Joss Pass between Joss Mountain and Davis Peak in the Sawtooth Range of the Monashee Mountains. From its headwaters, the Shuswap River flows approximately 150 kilometres (km) down into the Shuswap Highlands and through two large lakes, Sugar Lake and Mabel Lake, before discharging into Mara Lake, which is a tributary lake of Shuswap Lake. The Shuswap River is commonly divided into the following three main sub-watersheds:

- the Upper Shuswap River Watershed (114,750 ha), which starts at Joss Pass and flows south, discharging into Sugar Lake (key sub-drainages: Greenbush Creek, Spectrum Creek, Outlet Creek);
- the Middle Shuswap River Watershed (292,403 ha), which starts at the Sugar Lake outlet and flows south and then north again into Mabel Lake (key sub-drainages: Cherry Creek, Ferry Creek, Duteau Creek, Bessette Creek, Wap Creek); and,
- the Lower Shuswap River Watershed (112,963 ha), which starts at the Mabel Lake outlet and flows to the west towards Enderby, eventually flowing north and discharging into Mara Lake (key sub-drainages: Kingfisher Creek, Trinity Creek, Fortune Creek).

Each of these three identified sub-watersheds is characterized by unique biophysical and anthropogenic (i.e., human caused) regimes. As such, a separate profile has been developed for each sub-watershed as part of this Technical Assessment. The following sections provide a summary of the water quality, water quantity, and riparian areas results and discussion for the Shuswap River Watershed, with specific reference to each of the identified sub-watersheds.
TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

Water Quality

A high-level review of existing water quality data within the Shuswap River Watershed was undertaken as part of this Technical Assessment based on data presented in historical monitoring reports (academic, government, and consultant) concerning water usage, agriculture, industry, waste management, academic, and commercial stakeholders. These studies have predominantly focused on Mara Lake, Mabel Lake, Sugar Lake, Bessette Creek, Fortune Creek, and Brash Creek. Additional water quality data were obtained from BC Ministry of the Environment water wells in the Shuswap River Watershed, as well as from information warehoused in the RDNO’s WaterTrax online database.

Water quality data for the Shuswap River Watershed were reviewed for broad trend and gap analysis, and were not subject to reinterpretation. As such, the water quality assessment in this Technical Assessment does not constitute a “source to tap” evaluation. Water quality comments are restricted largely to the following key parameters, where data were available: chloride and sodium (proxy for potential road salt impact; considered a conservative parameter for contaminant plume migration), nutrients (nitrate, nitrite, ammonia, ammonium, and phosphorous), and microbial parameters (E. coli and total coliforms).

While the overall water quality of the Shuswap River Watershed is considered “good,” water quality impacts have been observed for nutrients and microbial parameters predominantly attributed to anthropogenic activities. Water quality in the Upper Shuswap River Watershed largely reflects nutrient and microbial impacts related to non-intensive agricultural and livestock activities as well as increased turbidity associated with high energy tributaries and freshet. Middle and Lower Shuswap River Watershed water quality data sets indicate an increasing impact to water resources from anthropogenic activities, largely consisting of elevated nutrients (waste management, septic disposal, agriculture, livestock). The limited nature of groundwater quality information prevents a detailed assessment of aquifer water quality.

An extensive data mining and data warehousing program would greatly increase the amount of useful data available for interpretation and monitoring. Similarly, establishing a more comprehensive, consistent suite of analytical parameters and establishing a regular monitoring program for both surface water and groundwater at key locations across the Shuswap River Watershed would allow for the determination of representative background water quality and evaluation of short term and long term trends in water quality.

A preliminary risk assessment was conducted for the Upper, Middle, and Lower Shuswap River Watershed based on land use designations, proximity to water sources, BC Contaminated Site Inventory Data, and data provided by the RDNO. This preliminary assessment identified potential areas of concern, largely related to intensive agriculture, waste management and wastewater treatment, and industry found within the Middle and Lower Shuswap River Watersheds. The Upper Shuswap River Watershed is considered to reflect a much lower risk to water quality due to the relatively minimal recreational, residential, and industrial infrastructure. Moderate and high risk rankings were given to land uses within the more densely populated areas within the Middle and Lower Shuswap River Watershed, such as those surrounding Lumby and Enderby, respectively. A limited “windshield” field program is recommended to confirm and revise the preliminary risk rankings.
Water Quantity: Surface Water

The regional hydrology of the Shuswap River Watershed is influenced by the topographical and climatic characteristics of the area, which in turn determine annual runoff and surface water flows. The climate of this area is characterized by warm to hot summers and cold winters, with relatively dry conditions in the warmer valley bottoms of the Lower Shuswap River Watershed and much wetter and cooler conditions at higher elevations and particularly in the mountainous areas of the Upper Shuswap River Watershed. Freshet surface water flows in the Shuswap River begin in April with the melting of the lower elevation snowpack, increase in May as snowmelt moves to the higher elevations, then peak and start to decline in June with the completion of the melt. Flows decline rapidly in July and then diminish more slowly into fall and winter. January and February are generally the lowest flow months of the year. Tributary streams follow the same general flow pattern, although freshet peaks occur earlier in May in the lower elevation tributaries of the Middle and Lower Shuswap River Watershed. Annual surface runoff from the Upper Shuswap River exceeds 1000 mm/year, but diminishes to less than 200 mm/year in the lower elevations and drier conditions of the Lower Shuswap River.

There are surface flow records for 34 Water Survey of Canada (WSC) hydrometric stations in the Shuswap River Watershed, which are used to characterize the annual, monthly, and daily flows of this area. The earliest flow records for the Shuswap River from the WSC station near Enderby date from 1911 so there is a long history of information available for this system. Unfortunately, considerable gaps exist in the hydrometric data available as only six of the stations are still active, only 14 have more than 10 years of flow records, there are no hydrometric stations upstream of the outlet of Sugar Lake, and there are no active stations in tributaries with unregulated flows. Re-establishment of several hydrometric stations on other tributaries with high water use (e.g., Fortune Creek) and several tributaries with natural flows that may have water use but are not affected by water storage (e.g., Trinity Creek, Ferry Creek and Cherry Creek) would be beneficial to provide a wider picture of how flows are changing in the developed portion of the Shuswap River Watershed. Establishment of new hydrometric stations on streams in the Upper Shuswap River Watershed and upper areas of the Middle Shuswap River Watershed would also provide valuable information on flow trends in the Shuswap River, as these together provide more than 50% of the water in the watershed.

There are a total of 1,215 licenses for surface water use in the Shuswap River Watershed recorded with the BC Ministry of Environment. More than 95% of the allocated water is licensed to agricultural use for irrigation and water utility use for irrigation and waterworks. Water utility water use is largely supported by large reservoirs that store freshet flows that are then released for diversion in summer, while the majority of farm irrigation licences rely on instream flows. Overall water allocation relative to stream flow is relatively low. If all water licences were fully utilized, annual water use would total close to 4 m$^3$/s, which is less than 5% of the mean annual flow recorded at the WSC station in the Shuswap River near Enderby. Further, most water utilities use much less water than they are licensed for (average use is 34% of allocation), so the total annual water use is estimated to be equivalent to 1.4 m$^3$/s. Overall water use does not appear to be an issue relative to flow; however, summer use is up to 2.5 times higher than the annual use due to agricultural and domestic irrigation, and summer flows are much lower. As such, water use in late summer and early fall has the ability to significantly reduce instream flows in some tributary streams of the Shuswap River Watershed.

Minimum instream flow thresholds are a measure or estimate of the lowest instream flows required to support aquatic ecosystem values. Only three portions of the Shuswap River Watershed have documented instream flow thresholds that are either accepted as targets or have been recommended: Middle Shuswap River between
Sugar Lake and Shuswap Falls, Bessette Creek, and Duteau Creek. Target flows are generally met in the Shuswap River, but in Bessette Creek, mean flows in fall are just high enough to meet the targets for fall spawning and minimum flows fall far short. There are no current hydrometric records for Duteau Creek to compare to the targets. Other Shuswap River Watershed tributaries with substantial water use (or potential for increased water use) and high fish values (e.g., Fortune Creek, Trinity Creek, Ferry Creek) would also benefit from water use planning with respect to instream flow targets or thresholds.

Historic surface flow trends have been analyzed using the flow records for the six active WSC hydrometric stations, which include three stations on the Shuswap River and three stations in the Bessette Creek sub-drainage. The three Shuswap River stations have long terms records, so trends were determined based on the full records (up to 99 years) for long term trends, the past 60 years for medium term trends, and the past 30 years for short term trends. The three stations in the Bessette Creek sub-drainage were all established in the 1970s, so only the 30 year trends were determined for the Bessette Creek stations. Annual flows in the Shuswap River show little change over the long term, but are trending lower over the middle and short terms. Seasonal flows show increasing winter discharge, with a trend to earlier freshet flows and decreasing summer flows, with the rate of decrease in summer flows highest over the past 30 years.

The Bessette Creek trends are similar to the Shuswap River short term trends, but show more variation and more extreme trends, likely due in part to water use and regulation, but may also indicate that some tributaries are even more vulnerable to change than the watershed as a whole as shown by the Shuswap River. While a number of factors including water use, forest harvesting, and forest health issues are part of the explanation for the stream flow trends, the most significant factor in the recent trends appears to be climate change. Future (year 2040) annual and monthly flows were projected for the Shuswap River near Enderby using the short, medium and long term trends; however, these should be used with a high degree of caution as trends change over time as reflected in the trend differences over the three time periods used in the assessment. However, the projected trend to earlier freshet and lower summer flows suggests that there will be implications for water supply in tributary streams that will need to be addressed.

**Water Quantity: Groundwater**

Existing aquifer information for the Shuswap River Watershed was limited to aquifers generally identified within the Lumby and Enderby/Armstrong areas within the watershed. As such, and for the purpose of assessing the order of magnitude of potential groundwater flow within the watershed, Golder redefined the alluvial and fluvial (collectively referred to as unconsolidated) aquifers, as well as the bedrock aquifers. Based on the aquifer re-delineation, a total of 24 unconsolidated aquifers were identified, with seven (7) located within the Upper Shuswap River Watershed, ten (10) located in the Middle Shuswap River Watershed and seven (7) located in the Lower Shuswap River Watershed. Key assumptions in the re-delineation of the aquifers were i) groundwater from the upland bedrock dominated areas recharge lower unconsolidated aquifers within the Shuswap River valley bottom; and ii) groundwater flow linkages were identified based on the assumption that groundwater generally follows a subdued replica of surface topography. Both unconfined and confined aquifers were lumped into the same aquifer classification for assessment purposes. A review of available aquifer parameter characteristics, along with literature review and professional experience resulted in a preliminary estimate of aquifer parameters within each unconsolidated aquifer so that groundwater flow estimates could be assessed.
Results of the preliminary groundwater flow assessment indicated that approximately 2 m³/s of groundwater flow was available within the Upper Shuswap River Watershed, 6 m³/s of groundwater flow was available within the Middle Shuswap River Watershed and 0.7 m³/s of groundwater flow was available within the Lower Shuswap River Watershed. This suggests that all groundwater could be accounted for within approximately one order of magnitude, if estimates of hydraulic conductivity, saturated thickness, and hydraulic gradient (and to a lesser extent porosity) could be refined and evaluated more thoroughly through further investigation. Two areas of note in regards to groundwater flow are the areas around the Village of Lumby and the City of Armstrong, where groundwater may be leaving the Shuswap River Watershed and entering the Okanagan Basin Watershed.

Groundwater use or consumption data was also reviewed as part of this Technical Assessment. As groundwater extraction is not licensed in BC, estimates of groundwater use were made using several methods, consisting of contacting known groundwater users to obtain groundwater extraction rates, including the Village of Lumby, City of Armstrong, City of Enderby, RDNO, and several waterworks districts within the Township of Spallumcheen; approximation of the annual extraction rate based on using the number of legal lots within each sub-watershed, and RDNO’s subdivision servicing bylaw water provision requirements; and an approximation of annual extraction rates based on population data and average per capita water use values. Based on the results of the groundwater consumption estimates it was inferred that the potential groundwater use in the Upper Shuswap River Watershed was approximately 0.003 m³/s. Total groundwater use in the Middle Shuswap River Watershed was estimated to be as high as approximately 0.22 m³/s, and accounted for groundwater withdrawals from the Village of Lumby’s three high capacity groundwater wells (0.01 m³/s) and other private water wells (estimated to use a potential 0.21 m³/s). The total estimated potential groundwater use of 0.22 m³/s represented approximately 3.5% of the total groundwater flow within the Middle Shuswap River Watershed. The total groundwater use in the Lower Shuswap River Watershed was estimated to be as high as approximately 0.3 m³/s, and accounted for groundwater withdrawals from private wells (based on the number of parcels and the subdivision servicing bylaw groundwater provisions) and municipal water wells. This could represent up to approximately 44% of the total groundwater flow within the Lower Shuswap River Watershed.

Results of the groundwater assessment portion of this Technical Assessment identified that significant data gaps exist in regards to understanding groundwater flow characteristics and aquifer parameters, which are both key in developing an understanding of groundwater quantities in the area. As additional information is made available, refinement and re-evaluation of the aquifers delineated as part of this assessment should be conducted, with some focus placed on understanding potential groundwater leaving the Shuswap River Watershed through the Lumby and Armstrong areas.

**Riparian Areas**

The condition of riparian areas of the Shuswap River varies in level and source of impact between the upper, middle, and lower sections of this stream. No detailed ecological studies such as sensitive habitat inventory and mapping (SHIM) or foreshore inventory and mapping (FIM) have been completed for the Upper or Middle Shuswap River. Based on Golder’s preliminary orthophoto interpretation, approximately 11.5% or 11,520 m of Upper Shuswap River riparian area is disturbed within 30 m of the approximate high water mark (HWM; includes both streambanks). This disturbance is related almost exclusively to forestry operations, including both clearcut areas and their associated access roads and bridge crossings. More disturbances are present in the higher elevations of this sub-drainage. Typical effects of forestry operations include increased erosion and undercut banks at stream crossings, reduced shading and nutrient input to the stream where riparian buffers have not
been maintained, and increased short-term large woody debris (LWD) inputs to the stream resulting in debris jams at the inlets of side channels.

Agricultural activities are the largest cause of disturbance to the Middle Shuswap River, particularly in its lower reaches downstream of its confluence with Bessette Creek. Based on Golder’s preliminary orthophoto interpretation, approximately 28.4% or 32,387 m of Middle Shuswap River riparian is disturbed within 30 m of the approximate HWM. In addition to agricultural operations, which account for approximately 14.7% of the disturbance to the Middle Shuswap River riparian area, other disturbances include roadways (4.2%), rural developments (3.9%), forestry operations (3.4%), recreational developments (1.4%), and hydroelectric dam facilities (0.8%). Impacts to the riparian and instream areas as a result of these disturbances include loss of spawning habitat through filled and diverted side channels and oxbows, reduced shading and nutrient input to the stream through riparian vegetation clearing, and sedimentation, and general degradation where cattle have unrestricted access to the channel. The Middle Shuswap River has also been affected by the construction of hydroelectric dams, specifically Peers Dam at Brenda Falls near the outlet of Sugar Lake and Wilsey Dam located 31 km downstream at Shuswap Falls, which flooded the upstream riparian habitat and created a complete barrier to fish passage.

In the absence of detailed ecological studies, all of the Upper and Middle Shuswap River riparian areas identified as disturbed during the interpretation of recent orthophotos have been preliminarily ranked as a high priority for restoration. The areas identified as natural during the orthophoto interpretation have been ranked as a low priority for restoration. Additional, ground-truthed assessments would be required to further characterize the riparian areas of these sections of the Shuswap River and move beyond this preliminary two class prioritization system. Golder recommends that the next step in prioritizing restoration areas for these sections of the Shuswap River is to conduct detailed inventory, mapping, and aquatic habitat indexing similar to that completed for the Lower Shuswap River, particularly for the heavily impacted Middle Shuswap River as a priority. This type of assessment provides high resolution information about the riparian condition of both sides of the stream and allows for a restoration analysis that prioritizes the segments of each streambank based on their restoration potential. Alternatively, resources could be more efficiently used by focusing subsequent surveys on the areas identified by this Technical Assessment as a high priority for restoration. At a minimum, these areas should be ground-truthed to confirm the disturbance of all the areas identified as disturbed during the orthophoto interpretation.

Previous impacts to the Lower Shuswap River are primarily related to agriculture and rural development. These anthropogenic activities have resulted in the removal of much of the riparian habitat associated with this stream, particularly downstream of Enderby. According to the recent FIM and SHIM completed for the Lower Shuswap River (Hawes et al. 2011), only 41% of the left bank and 14% of the right bank (looking downstream) are considered to be in a natural state, and 30% of the length of the Lower Shuswap River is affected by a high level of impact and has poor riparian condition. Bank erosion and instability are common throughout the Lower Shuswap River as a result of riparian vegetation clearing and anthropogenic encroachment, and are likely exacerbated by increased recreational power boat use in this section of the stream. As detailed FIM and SHIM data are available for this section of the stream, Golder did not complete an orthophoto interpretation for the Lower Shuswap River. Golder recommends that the next step in prioritizing restoration areas in the Lower Shuswap River is to conduct a feasibility assessment of the restoration opportunities available at each of the 18 segments prioritized by Hawes et al. (2011). The purpose of the feasibility assessment would be to provide a deliverable that outlines the costs and priority of each restoration project should additional funding come
available. The deliverable could also be circulated to potential stakeholders and environmental stewardship groups that were interested in completing a restoration project on the Lower Shuswap River. A feasibility assessment could also be completed for the other two sections of the Shuswap River following additional inventory and mapping.

Conclusion

This desktop-based assessment provides baseline data and geographic information system mapping for the Shuswap River Watershed to allow for monitoring and comparisons in future years. It also provides a data gap analysis by identifying where more information is needed, and provides an overview of long-term trends in water quality and quantity within the system, where data are available. This assessment provides a scientific base to guide decisions made in Phases II and III of the SRWSP, which will consist of the development of the sustainability plan and the implementation and monitoring of the plan, respectively, with ongoing stakeholder input.
Study Limitations

This draft report was prepared for the exclusive use of the Regional District of North Okanagan (RDNO) and is intended to provide a Technical Assessment of the Shuswap River Watershed, located in Electoral Areas “D,” “E,” and “F” of the RDNO. The purpose of this Technical Assessment is to establish a watershed profile for the Shuswap River Watershed, with a specific focus on the water quality, water quantity, and the condition of riparian areas in this watershed.

The scope of work for this Technical Assessment is described in Golder’s proposal titled Confidential Proposal for Regional District of North Okanagan: Technical Assessment of the Shuswap River Watershed, dated March 25, 2011, and Golder’s scope change titled Updated Project Schedule and Requested Work Scope Additions, Shuswap River Watershed Technical Assessment, dated June 2, 2011. The inferences concerning the conditions of the Shuswap River Watershed are based on information obtained from a desk-top review of the available information including interpretation of orthophotos and interviews with knowledgeable persons. No fieldwork or ground-truthing was completed as part of the scope of work of this Technical Assessment.

Any predictions or conclusions provided are based on a reasonably good understanding of the current conditions in the Shuswap River Watershed. However because of the limited available data, in particular related to hydrology and hydrogeology, some uncertainty exists with respect to predictions. In evaluating the water quality, water quantity, and riparian areas of the Shuswap River Watershed, Golder has relied in good faith on information provided by the third parties noted in this report. We accept no responsibility for any deficiencies, misstatements or inaccuracies contained in this report as a result of omissions, misinterpretations, or fraudulent acts of others.

The findings and conclusions documented in this report have been prepared for the specific application to this project and have been developed in a manner consistent with the level of care normally exercised by environmental professionals currently practicing under similar conditions in this jurisdiction. Golder makes no other warranty, expressed or implied. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. Golder accepts no responsibility for damages, if any suffered by any third party as a result of decisions made or actions based on this report.
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TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

1.0 INTRODUCTION

As requested by the Regional District of North Okanagan (RDNO), Golder Associates Ltd. (Golder) in collaboration with our sub-consultant Mr. Phil Epp, Consulting Hydrologist, is pleased to provide this Technical Assessment of the Shuswap River Watershed, mainly located in Electoral Areas “D” (Rural Lumby), “E” (Cherryville), and “F” (Rural Enderby) of the RDNO, in the Southern Interior of British Columbia (Figure 1).

This Technical Assessment is part of Phase I of the larger Shuswap River Watershed Sustainability Plan (SRWSP), led by the RDNO, which involves an in-depth planning process with significant stakeholder and public engagement to establish a long-term vision for the management of the watershed, identify issues and data gaps, and develop objectives and actions for its future management. Based on feedback from previously held stakeholder and public workshops, the following draft vision statement has been developed for the Shuswap River Watershed Sustainability Plan (RDNO 2011):

“working together to sustain a healthy, resilient watershed where ecosystems are protected and restored and environmental and cultural values are respected. Through the management of human activities, impacts on the watershed will be minimized, ensuring that wildlife, habitat and people thrive.”

This Technical Assessment serves as an initial step towards a sustainable, healthy watershed. The purpose of this Technical Assessment is to establish a watershed profile for the Shuswap River Watershed, with a specific focus on the characteristic water quality and water quantity, and the condition of riparian areas within three sections of this watershed:

- the Upper Shuswap River Watershed, defined as the section between the Shuswap River headwaters and the Sugar Lake outlet;
- the Middle Shuswap River Watershed, defined as the section between the Sugar Lake outlet and the Mabel Lake outlet; and,
- the Lower Shuswap River Watershed, defined as the section between the Mabel Lake outlet and the Mara Lake inlet.

This desktop-based assessment provides baseline data and geographic information system (GIS) mapping for the watershed to allow for monitoring and comparisons in future years. It also provides a data gap analysis by identifying where more information is needed, and provides an overview of long-term trends in water quality and quantity within the system, where data is available. Finally, this assessment provides a scientific base to guide decisions made in Phases II and III of the Shuswap River Watershed Sustainability Plan, which will consist of the development of the sustainability plan and the implementation and monitoring of the plan, respectively, with ongoing stakeholder input.
1.1 Project Team and Acknowledgements

The Project Team consisted of four key groups (Hydrology, Hydrogeology, Bioscience and GIS), consisting of the following individuals:

Hydrology
- Murray Fitch, M.A.Sc., P. Eng., Golder Senior Water Resources Engineer;
- Phil Epp, M.Sc., P.Ag., Senior Consulting Hydrologist;

Hydrogeology
- Jacqueline Foley, M.Sc., Geo.L., Golder Project Director and Senior Hydrogeologist;
- Tracy McMunn, M.Sc., P.Geo., Golder Hydrogeologist;
- Mark Bietting, B.Sc., Golder Hydrogeologist;

Bioscience
- Darryl Arsenault, M.Sc., R.P.Bio., Golder Project Manager and Senior Fisheries Biologist;
- Josie Symonds, M.Sc., R.P.Bio., Golder Project Coordinator and Biologist; and,

GIS
- Jamie Goodier, B.Tech., Golder GIS Analyst.

Additional acknowledgement is given to the following individuals: Tom Lenarcic, Zee Marcolin, Laura Frank and Anna Page of RDNO; Alan Caverly, Christian St. Pierre, and Brian Robertson of the BC Ministry of Forests, Lands and Natural Resource Operations (MFLNRO); and, Dean Watts and Bob Harding of Fisheries and Oceans Canada (DFO), each of whom have made valuable contributions to this assessment.

1.2 Scope of Work

The scope of work for this Technical Assessment consisted of a desktop-based assessment of available water quality, water quantity, and riparian areas data for the Shuswap River Watershed. This scope of work is outlined in the RDNO’s request for proposal (RFP) titled Request for Proposal: Technical Assessment of the Shuswap River Watershed (RDNO 2011), and is further described in Golder’s proposal titled Confidential Proposal for Regional District of North Okanagan: Technical Assessment of the Shuswap River Watershed, dated March 25, 2011 (Golder 2011a), and Golder’s scope change titled Updated Project Schedule and Requested Work Scope Additions, Shuswap River Watershed Technical Assessment, dated June 2, 2011 (Golder 2011c).

1.3 Report Organization

Following the executive summary and this introductory section, Section 2.0 of this Technical Assessment provides a detailed account of the methods used and documents consulted to complete this assessment. Section 3.0 provides a general description of the biophysical resources of the Shuswap River Watershed, including its watershed hierarchy, eco-classification, climate, geology and soils, hydrology, hydrogeology,
Sections 4.0, 5.0, and 6.0 provide a detailed report on the current watershed profile, specifically as related to the water quality, water quantity, and condition of riparian areas within the Upper, Middle, and Lower sections of the Shuswap River Watershed, respectively. Section 7.0 provides a trend analysis and projected water availability for the Shuswap River Watershed, while Section 8.0 identifies gaps and provides recommendations for next steps in this watershed. The report closure is provided in Section 9.0, and the references cited and acronyms used in this Technical Assessment are provided in Sections 10.0 and 11.0 respectively. Labelled section dividers have been provided to allow for easy identification of the start of level one section headings. This document includes in-text figures (e.g., graphs, charts) as well as large GIS-based figures at the end of the text.
2.0 METHODS

The methods for this desktop-based Technical Assessment involved a review of the applicable background information available for the Shuswap River Watershed. The amount of information for this system is substantial; as such, and in consultation with the RDNO, primary efforts were focused on characterizing the water quality, water quantity, and condition of riparian areas associated with the Shuswap River, with a secondary focus on key tributaries to this river (e.g., Bessette Creek, Duteau Creek, Kingfisher Creek, Wap Creek). The following sections detail Golder’s methods to gather, interpret, and disseminate information for this Technical Assessment.

2.1 Annotated Bibliography

Golder completed an annotated bibliography as a first deliverable for this Technical Assessment. The purpose of this annotated bibliography was to determine if the essential resources related to the Shuswap River Watershed’s water quality, water quantity, and riparian areas had been consulted. Golder assembled resources for the annotated bibliography using the following methods:

- search of reports available through EcoCat (i.e., Ecological Reports Catalogue), a comprehensive database hosted by the BC Ministry of Environment (MoE) (2011c) that provides public access to available digital reports and publications relevant to terrestrial and aquatic ecology, floodplain mapping, and groundwater;
- search of published literature available through Web of Science, a comprehensive academic database that provides access to citations and digital copies of journal articles, conference proceedings, and other publications in the peer-reviewed literature;
- search of Golder’s internal library to identify previously completed reports related to the Shuswap River Watershed;
- internet searches for government documents, consultant reports, and websites related to the Shuswap River Watershed; and,
- interviews with government personnel to identify other resources not available through internet searches.

The completed annotated bibliography is provided in Appendix A. This annotated bibliography was provided by the RDNO to the Technical Advisory Committee (TAC) assembled for this Technical Assessment for comment, and to identify any additional key resources that should be consulted as part of this Technical Assessment. Several additional resources were acquired as a result of this process.

2.2 Watershed Biophysical Description

A background information review was completed to assemble previously published information about the Shuswap River Watershed. The following information sources were reviewed to complete the watershed biophysical description:

- The British Columbia Ecoregion Classification (Demarchi 2011);
- Ecosystems of British Columbia (Meidinger and Pojar 1991);
- A Guide to Site Identification and Interpretation for the Kamloops Forest Region (Lloyd et al. 1990);
- Canadian Climate Normals of Averages 1971-2000 (Environment Canada 2011a);
Based on the results of the information review, an overview description of the watershed hierarchy (i.e., natural sub-regions and drainages), eco-classification, climate, geology and soils, hydrology, hydrogeology, ecology (i.e., vegetation, wildlife, fish, and habitat), and land use of the Shuswap River Watershed was developed. This information was mapped using an ArcGIS platform, where applicable.

2.3 Water Quality

A high-level review of existing water quality data within the Shuswap River Watershed was undertaken as part of this Technical Assessment.

2.3.1 Surface Water Quality

Surface water quality monitoring programs have been undertaken in the Shuswap River Watershed by, or on behalf of, various stakeholders including multiple levels of government (i.e., municipal, regional, provincial, and federal), agriculture, industry, waste management, academic, and commercial stakeholders. These surface water quality monitoring programs have predominantly focused on Mara Lake, Mabel Lake, Sugar Lake, Bessette Creek, Duteau Creek, Fortune Creek, and Brash Creek.

The scope and breadth of the historical surface water quality monitoring programs varies considerably, as do the analytical methods contained therein, and for the purposes of this study the following main sources have been reviewed:

- published reports including, but not limited to, consultant reports, annual monitoring reports, and governments studies;
- RDNO’s WaterTrax database system; and,

Water quality data for the Shuswap River Watershed were reviewed for broad trend and gap analysis, and were not subject to reinterpretation as this was beyond the scope of this Technical Assessment. Water quality comments are restricted largely to the following key parameters, where data were available: chloride and sodium (proxy for potential road salt impact; considered a conservative parameter for contaminant plume migration), nutrients (nitrate, nitrite, ammonia, ammonium, and phosphorous), and microbial parameters (E. coli and total coliforms).

The WaterTrax database system utilized by RDNO contains limited water quality data for the Greater Vernon (Duteau Creek), Grindrod and Mabel Lake water supply systems. Water quality data were extracted from the database and reviewed for broad trends. These data are discussed under the appropriate sections.

Insufficient data exist for reliable water quality trend conclusions relative to land use and industrial, commercial, and agricultural activity.

2.3.2 Groundwater Quality

The quality of groundwater is often dependent on localized conditions and influenced by numerous factors including the composition of the overburden/bedrock materials, the depth to and age of the groundwater, location of the predominant recharge source (surface water versus precipitation, and land uses in the area. It should be noted that even groundwater within the same aquifer can have different water quality characteristics depending on well details (screen depth and pumping rates) and influences from surface water sources. As such, groundwater quality for the entire watershed area cannot be generalized or even segmented into large generalized areas. As long-term historical groundwater quality information is limited, the focus of this discussion is on general groundwater quality, with comments provided regarding the potential for groundwater quality to be influenced by anthropogenic causes, should data be available.

The following provides information sources used to examine groundwater quality:

Water Quality Framework and Overview

The Ambient Groundwater Quality Monitoring and Assessment in BC: Current Status and Future Directions report issued by the BC MoE (Cui and Wei 2000) reviewed broad water quality trends at selected locations in BC for selected water quality parameters. The Ambient Groundwater Quality Monitoring and Assessment Program (AGQMAP) was implemented to target non-point source contamination, and has accumulated large volumes of groundwater data which have been used to monitor groundwater quality trends and, to a lesser extent, identify potential contaminant sources.

The AGQMAP utilized Aquifer Classification mapping and the Province of BC’s Water Quality Check Program to identify nitrate loading impacts throughout the province, and specific contaminants of concern in various localities and aquifers. The AGQMAP identified elevated concentrations of arsenic, fluoride, and nitrate at various locations within the Shuswap River Watershed and, where data were available, these parameters were included as part of the review undertaken in this Technical Assessment.

In addition to identifying additional key potential contaminants of concern, Cui and Wei (2000) outline a series of recommendations to develop a framework for developing a cohesive, comprehensive water quality monitoring program targeted at community aquifer systems that are vulnerable to contamination and have high water use
demand. This program included recommendations for the implementation of quality assurance/quality control (QA/QC) measures, sampling strategies and methodologies, and collection of appropriate background water quality data, along with discussion related to data compilation and analysis.

2.3.3 BC Contaminated Sites Regulation Site Registry Search

The BC MoE maintains a database called the Site Registry, which contains information regarding the environmental condition of land in BC. The Site Registry contains information specific to the conditions of the Contaminated Site Regulation (CSR, BC Reg. 375/96) including the regulations, administrative actions, and subsequent environmental investigations that have occurred for a particular property. Historical information on file prior to the implementation of the CSR (pre-1997) with regard to environmental investigation may or may not be included on the database; furthermore, this information may not be inclusive for all properties and regions. If a property is not listed on the Site Registry that does not indicate the absence of contamination; rather, it indicates that the BC MoE does not have any information on file. More detailed information can be obtained from the BC government regarding the activities and status of individual sites for a nominal fee. The information contained in this Technical Assessment was purchased in June 2011, and is current to that date.

2.3.4 Preliminary Risk Assessment

A generalized groundwater and surface water quality risk assessment was undertaken for the Shuswap River Watershed based on the following criteria:

- limited land use designation provided by the RDNO (which, at this time consisted only of land identified within the agricultural land reserve (ALR));
- location (proximity of land use to a community or surface water source);
- BC MoE Contaminant Site Inventory data; and,
- industry, agriculture, commercial, and waste management activities.

The available information was reviewed, sorted and assigned a combined preliminary risk ranking of high, moderate or low for groundwater and surface water. Water quality concerns within the Shuswap River watershed are predominantly related to nutrients (and nutrient loading), turbidity, and microbiological parameters, activities and land uses that may act as potential point sources for impacts related to nutrients (such as agricultural, waste disposal, livestock, golf courses). As such, these land uses were identified as generally having a higher weighting than activities that may act as other contaminant sources (hydrocarbons and heavy metals, predominantly). Relative sizing of the potential point source (i.e., service station versus bulk fuel station; private septic field versus communal disposal fields, etc.) were also taken into consideration, when information was available. The risk ranking matrix is provided in the table below. Note this risk ranking is preliminary and is based on the reviewed data set. A review of the numerical water quality data set provided (as discussed in Sections 4.2, 5.2, and 6.2), resulted in no moderate or high risk sites being identified with the watershed. As water quality data was general, limited, and was not always identified with a specific sampling location, a risk ranking for specific sampling locations could not be provided.

As additional information is received, the ranking can be refined and adapted.
Table 1: Preliminary Risk Ranking Criteria

<table>
<thead>
<tr>
<th>Location</th>
<th>Remote Areas*</th>
<th>Close Proximity to Community/Surface Water Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Ranking**</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Land Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• BC MoE CSR property</td>
<td></td>
<td>• BC MoE CSR property</td>
</tr>
<tr>
<td>• Forestry/logging areas</td>
<td></td>
<td>• Private service stations</td>
</tr>
<tr>
<td>• Schools</td>
<td></td>
<td>• Commercial businesses</td>
</tr>
<tr>
<td>• Churches</td>
<td></td>
<td>• Road salts</td>
</tr>
<tr>
<td>• Municipal and Community Buildings</td>
<td></td>
<td>• Agriculture</td>
</tr>
<tr>
<td>• Administrative Buildings</td>
<td></td>
<td>• Golf course</td>
</tr>
<tr>
<td>• Campgrounds, Parks</td>
<td></td>
<td>• Septic fields (smaller population), Mobile Home Parks</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Remote areas are located away from more densely populated areas, generally within the upper reaches of the watershed.

** Some land uses have been identified within two or more risk ranking categories and final risk ranking will be dependent on issues related to that land use (i.e., the risk ranking of agricultural properties will be dependent on type of agriculture, farming practices, size of lands, proximity to surface water sources; the risk ranking of a contaminated site as per the CSR will be dependent of the status of that property and the contaminant of concern; etc.)

The results of this risk assessment are discussed in the water quality sections for each section of the Shuswap River Watershed (i.e., Upper, Middle and Lower).

2.4 Water Quantity

The methods used to assess water quantity in the Shuswap River Watershed involved numerous approaches that were dependent on whether surface water or groundwater were being evaluated, and were based on the data available from the BC MoE and WSC resources listed previously. An assessment of the water quantity consisted of: (i) an evaluation of the quantity of water that is present within the watershed, (ii) an evaluation of the uses (e.g., utilities, individual domestic supply, agricultural, storage and other consumptive and non-consumptive uses) of water within the watershed, and (iii) a comparison of the two (i.e., quantity versus consumption). The following sections provide a summary of the methods used to evaluate surface water and groundwater quantity within the Shuswap River Watershed.

2.4.1 Surface Water

Surface water flows and allocated surface water were both estimated as part of this Technical Assessment as described in the following sections.
**Estimate of Surface Water Flows**

The surface water flows within the Shuswap River Watershed were documented for the Shuswap River and several of its tributaries using the available data from 34 WSC hydrometric stations (Environment Canada 2011c). Available monthly and daily hydrometric data were compiled in tabular and graphical formats. These data were used as the basis for the existing surface flows in water balance calculations for long term trend analysis and were an integral part of considerations such as water availability and impacts to fish and aquatic life. This database provides the starting point for naturalizing flows, that is, evaluating the volume of water that would be present in the watershed in the absence of water use.

The hydrometric data records are highly variable among stations in terms of length of records and the periods during which flows were recorded, ranging in length from one year to 76 years, and covering a period from 1911 to 2009, the last year of published WSC data at the time of a data compilation. Data are only summarized in this Technical Assessment for stations with at least six years of record, as the year to year variability in flows reduces the usefulness of shorter term records. The stations with the longest records and the most complete range of years are three stations on the Shuswap River near Enderby, near Lumby and at the outlet of Sugar Lake. Records for stations with less than 20 years of data were naturalized by comparing the same years in the longer term Shuswap River records to the entire Shuswap records and then adjusting the short term station flows by the proportion of those years to the long term records. This increased or decreased the actual mean flows from the short term records by up to 5%. Mean annual flows for stations with seasonal records were assumed to be 60% of the average April to September flows. The basis of this assumption is that, for stations on the Shuswap River with year-round records, annual mean flows range from 55% to 65% of the seasonal (April to September) mean flows.

Mean annual flows have also been naturalized to calculated mean annual discharge values for these stations by adding the estimated annual surface and groundwater usage to the mean annual flows as calculated from the hydrometric data. Naturalized flows represent the volume of surface water that would be expected to flow each year at the hydrometric station sites in the absence of water withdrawals from surface and groundwater.

**Estimate of Allocated Surface Water**

Currently in BC, only surface water is regulated through the use of a surface water license; groundwater use is not licensed or regulated. The most common document for allocating surface water is the water license. However, other water rights in the Shuswap River Watershed may also be documented through water allocation restrictions and Water Act reserves. The following sections describe the sources used to estimate allocated water in the Shuswap River Watershed in greater detail.

**Water Licenses**

The BC MoE (2011h) provides a web-based BC Water Licenses Query tool that allows searching for water licenses using a variety of search criteria such as stream name, license number, purpose, quantity, water district/precinct, and watershed. License details such as restrictions on use (e.g., timing of use for irrigation licenses) and special clauses are also viewable on the scanned licenses directory that is accessible through the water licenses query tool. A water license search for the Shuswap River Watershed conducted using this query identified a total of 1,215 licenses in the Vernon-Mara and Vernon-Lumby precincts. These precincts approximate the Lower Shuswap River and Middle Shuswap River Watersheds, respectively, with the exception that the Vernon-Mara precinct also includes: (i) the Mara Lake and Mara Lake tributary licenses that are
downstream of the Shuswap River Watershed; and (ii) the Mabel Lake licenses that are in the Middle Shuswap River Watershed. These licenses were downloaded into Microsoft Excel workbooks where the Mara licenses were removed from the Lower Shuswap River Watershed workbook and the Mabel Lake licenses were moved to the Middle Shuswap River Watershed workbook. Water licenses were then sorted by purpose within each sub-watershed and analysed by use.

Water usage is licensed in three different types of units depending on the purpose: metres cubed per second (m³/s), metres cubed per day (m³/day), and metres cubed per year (m³/year). For comparison purposes, the volumes for each use have been converted to standard units of m³/s where applicable in this Technical Assessment. Irrigation type licenses (Irrigation and Irrigation Local Authority) are for seasonal (April to September) use, while all others are for year round use, so the conversion to m³/s is shown on both a seasonal and an annual basis. The annual m³/s equivalent reflects the average annual consumption, which can be compared to the mean annual flow or mean annual discharge to compare allocation to surface flows on an annual basis. The seasonal m³/s equivalent reflects the volume of consumption that can be expected on a high irrigation demand day in summer, which can be compared to the associated July and August mean monthly flows.

Water license uses are divided into either consumptive or non-consumptive uses. Consumptive uses divert water from the source to be used for purposes such as irrigation or domestic use. Some of the diverted water is used outside of the Shuswap River Watershed (e.g., diversions from Duteau Creek to Greater Vernon and from Fortune Creek to the Armstrong area) and therefore, is totally removed from the watershed, while other consumptive uses within the watershed have a component of return flow; for example, sewage treatment plant discharges, on-site sewage disposal (i.e., septic) systems, and irrigation all return some of the used water back into the landscape. The majority of the water allocated to consumptive uses is thought of as having been removed from surface flows, however, and as such, reduces instream flows accordingly. In contrast, non-consumptive uses such as storage, power generation, and conservation use the allocated water and may alter the timing of flows, but generally do not remove the water from the streams, other than possibly over very short distances. As such, non-consumptive uses do not reduce instream flows on an annual basis, although storage can substantially alter monthly and daily flows, particularly if the storage volume is large relative to the total volume of the source.

**Water Allocation Restrictions**

A water allocation restriction is a management tool used by the BC MoE Water Stewardship Division to alert their staff of current or potential water allocation concerns. Examples of water allocation restrictions include specifying minimum fish flow clauses in a water license and suspending additional licenses on a watercourse. A water allocation restriction is initiated when an investigation of a watercourse indicates that the source is nearing or has reached full allocation and is considered, along with all other relevant information, when making future water allocation decisions (BC MoE 2005a). A complete list of the water allocation restrictions in British Columbia is available online (BC MoE 2009). A search of this list was completed to determine if there were any water allocation restrictions in the Shuswap River Watershed.

**Water Act Reserves**

A Water Act reserve is a means for the BC government to protect the public interest and set priorities for future allocation of water from a particular stream or within all or part of a drainage system (BC MoE 2005b). These...
reserves withhold all or part of the unrecorded water of a stream from being diverted and used under a water license. A Water Act reserve may do the following: (i) enable a person to investigate stream suitability for any purpose; (ii) make provision for a water supply for a waterworks, irrigation, or power purpose; (iii) hold water for the use of the Crown for any purpose; or (iv) affect a treaty entitlement of a First Nation (BC MoE 2005b). A complete list of the Water Act reserves in British Columbia is available online (BC MoE 2009). A search of this list was completed to determine if there were any Water Act reserves in the Shuswap River Watershed.

2.4.2 Groundwater

In order to assess and provide comments regarding groundwater quantity within the Shuswap River Watershed, a hydrogeological analysis was completed that included an evaluation of information from the BC MoE observation well network, BC Water Resource Atlas (BC MoE 2011a), and BC WELLS database (BC MoE 2011b) to aid in the characterization and delineation of bedrock and alluvial/fluvial aquifers, and basic conceptualizing of regional runoff and recharge relationships.

Based on this information review, a generalized preliminary conceptual model applicable to the Shuswap River Watershed was developed identifying the interactions between the various components of the groundwater cycle within the watershed. Development of the preliminary conceptual model was based on general hydrogeological principles, data obtained from raw data sources, other studies in the watershed, and the following set of hydrogeological assumptions adopted for this Technical Assessment:

- groundwater is present at some depth beneath the ground surface at all locations within the watershed;
- groundwater flow is topographically driven at the regional scale, such that this flow converges toward the valley bottom from the sides of the valley, and eventually drains in the same direction as the surface drainage system; and,
- on an annual basis, the change in storage of groundwater is relatively small in proportion to total storage and groundwater recharge and discharge; this relationship means that annual groundwater flow is likely to have considerably less temporal variation than surface water flows.

In development of the conceptual model, and recognizing that groundwater is essentially ubiquitous in the subsurface, it was necessary to redefine aquifers to cover 100% of the entire Shuswap River Watershed area, to allow for continuity of groundwater flow and in turn, the delineation and future calculation of the watershed-wide water balance. Within the watershed, upland areas (defined herein as being above an elevation of approximately 800 metres above sea level (masl)) account for a very large portion of the watershed footprint (approximately 77%); these upland areas have been identified to represent bedrock aquifers and act as groundwater recharge zones to valley bottom aquifers. The remaining 23% of the watershed is accounted for with alluvial and fluvial aquifers within the valley bottom, which likely discharge to local streams, creeks and lakes within the aquifer footprint.

The conceptual modeling process required the preliminary delineation between upland recharge areas and valley bottom discharge areas (i.e., alluvial and/or fluvial aquifers/ also referred to as unconsolidated aquifers). For the purposes of this Technical Assessment, we did not consider recharge to deep-seated bedrock fracture-flow systems as part of the total recharge, due to the relatively large area and long timeframe (hundreds to thousands of years) to reach valley bottom aquifers; we also did not consider storage in the upland areas as a potential source of groundwater; this is considered a typical standard of practice for this type of assessment.
Delineation of the aquifers was based on the following criteria:

- all aquifers were divided along obvious or natural boundaries for calculation of groundwater flow across common boundaries;
- upland, bedrock aquifers generally followed topographic catchments;
- unconfined and confined unconsolidated aquifers, as well as aquitards (i.e., alluvial systems with low hydraulic conductivity), were collectively lumped into one category (unconsolidated);
- hydraulic properties were assigned to unconsolidated aquifers to the extent existing data allowed, and estimated for areas where there were no data, based on professional judgement, published literature values, and well-established physical relationships throughout the watershed;
- bedrock and unconsolidated aquifers were created for portions of the watershed where aquifers were not previously delineated; and,
- based on the existing topography, some bedrock aquifers did not discharge to unconsolidated aquifer systems, but directly to a surface water body.

It is possible that many of the newly delineated bedrock aquifers (for which there are no data other than mapping of bedrock type) may not actually be capable of transmitting sufficient quantities of water to wells. Such bedrock aquifers are typically smaller in footprint area, located at lower elevations of the watershed, and are probably more important in the role that they play in representing barriers to shallow alluvial groundwater flow. These systems were identified primarily to provide continuity of coverage for the entire watershed as a platform on which to base further study and investigation.

Delineation of the unconsolidated aquifers for this Technical Assessment and development of the initial estimates of aquifer parameters that were used in creating a conceptual model for groundwater flow in the watershed have allowed for preliminary estimates of groundwater availability. The methods used to estimate groundwater flow and use in this watershed are described in the following sections. Considerable data refinement will be required before this preliminary conceptual model can be considered robust enough to be valid for the entire Shuswap River Watershed.

**Estimate of Groundwater Flow**

The Shuswap River Watershed’s unconsolidated aquifers were characterized to estimate groundwater discharge (as surface water flow) through the alluvial and fluvial sediments found in the river valley bottoms between each of the three lakes (i.e., Sugar, Mabel, and Mara), as well as the basin catchments of Sugar and Mabel Lakes. Based on the delineation of the aquifer boundaries (as outlined above), Darcy’s Law was applied to determine discharge rates for each unconsolidated aquifer as follows (Freeze and Cheery 1979):
\[ Q = K i A \]

Where \( Q \) = groundwater flow [volume/time]
\( K \) = hydraulic conductivity [length/time]
\( i \) = hydraulic gradient (dimensionless) [length/length]
\( A \) = cross sectional area (aquifer width \( W \) * saturated thickness \( b \)) [length²]

The following sections describe the approach used to assign unconsolidated aquifer properties during the characterization of the groundwater in the Shuswap River Watershed. Due to vast data gaps, the generalized conceptual model presented herein should be regarded as a place from which to take further study, investigation and data refinement; in many cases the assumptions and inferences made cannot be validated by the current body of knowledge for the watershed.

**Hydraulic Conductivity**

Hydraulic conductivity is typically the single most significant aquifer property controlling the solution to the Darcy equation. Hydraulic conductivity values for each unconsolidated aquifer were primarily based on literature values (Freeze and Cherry 1979; Fetter 2001) for the various inferred depositional environments encountered along the Shuswap River Watershed. Where possible, these literature values were refined based on existing hydraulic conductivity values for discrete locations within the watershed.

**Aquifer Geometry: Thickness, Width and Length**

Saturated thickness was interpreted based on cross-sections interpreted from BC WELLS database well logs (BC MoE 2011b). When information regarding subsurface conditions encountered at well locations was not available, aquifer thicknesses were inferred based on either the extrapolation of the topographic gradient or professional judgment. Aquifer width and length were constrained by the physical limits of the aquifer as mapped for this study. Specifically, the width was typically assigned as the average width of the aquifer measured perpendicular to the known or inferred groundwater flow direction. The aquifer length was measured parallel to the dominant flow direction through the potential aquifer material of the valley bottom. In some cases, such as in suspected v-shaped filled valleys, the transmissive width and length were adjusted from the mapped extent based upon well log data or the assumption that in the subsurface, the transmissive width or length of aquifers was less than the surface expressions generated by the assumed 800 masl elevation threshold.

**Hydraulic Gradient**

Hydraulic gradients were determined using the following two methods: (i) measurement of the topographic gradient and calculation of the hydraulic gradients within specific aquifers, based on water level data, and/or (ii) flood plain mapping data (where available). Note that water level data were collected and reviewed from available sources noted previously and were generally not representative of water levels in the same period of time (i.e., day, month, year). The gradient applied was decided based on professional judgment, and was occasionally adjusted up or down during the evaluation process.
Porosity
Porosity values for each unconsolidated aquifer were primarily based on literature values (Freeze and Cherry 1979; Fetter 2001) for the various inferred depositional environments encountered along the Shuswap River Watershed. In most cases, porosity was assumed to be a default value of 30% (equivalent to a medium-grained sand to fine gravel).

Identifying Aquifer Linkages
Regional aquifer flow directions and linkages were identified by assessing local groundwater flow direction and inferring groundwater no flow boundaries and groundwater divides throughout the Shuswap River valley.

Due to vast data gaps, significant refinement of the data in each aquifer and truthing the existing information was beyond the prescribed work scope for this Technical Assessment. While some studies do exist which would allow for this refinement, the task of validating gradient, porosity and hydraulic conductivity for the individual aquifers and watershed regions were beyond the scope of this project.

Estimate of Groundwater Use
Currently in BC, groundwater use is not licensed or regulated. Without local metering, or an accurate account of how many water wells are in use in the Shuswap River Watershed, it is difficult to quantify the total annual groundwater used. In order to estimate groundwater use for the Shuswap River Watershed, the following tasks were conducted:

- Known groundwater users were contacted to obtain groundwater extraction rates, including Village of Lumby, City of Armstrong, City of Enderby, RDNO, and several waterworks districts within the Township of Spallumcheen. However, contacting individual, private groundwater users owning and/or operating private wells was beyond the prescribed work scope for this level of study;

- A preliminary approximation of the annual extraction rate was estimated based on using the number of legal lots within each sub-watershed, and RDNO’s subdivision servicing bylaw water provision requirements. The subdivision servicing bylaw (Bylaw No. 726) states that each lot should be able to provide a minimum groundwater extraction rate of 6,550 litres per day (L/day). This volume is equivalent to one Imperial gallon per minute/day/lot and is similar to that of neighbouring regional districts including the Columbia Shuswap Regional District and Thompson-Nicola Regional District. Note, it is anticipated that this method identifies larger potential groundwater extraction volumes than the other methods, as it assumes that each parcel withdraws a minimum of 6,550 L/day; in reality, it is likely that many parcels do not have a groundwater well identified with it, with that those that do have a well likely withdrawing less than 6,550 L/day.

- A preliminary approximation of annual extraction rates was estimated based on population data and average per capita water use values, as follows:
  - Population data were reviewed for the Shuswap River Watershed. Based on population statistics provided by the RDNO for the 2006 Census year, the populations in Table 2 were identified as potential groundwater users.
Table 2: Potential Groundwater Users in the Shuswap River Watershed

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>Area (km²)</th>
<th>Population</th>
<th>No. of Potential Groundwater Users*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Village of Lumby</td>
<td>5.27</td>
<td>1,634</td>
<td>1,634</td>
</tr>
<tr>
<td>Township of Spallumcheen</td>
<td>254.9</td>
<td>4,960</td>
<td>1,240</td>
</tr>
<tr>
<td>City of Enderby</td>
<td>4.23</td>
<td>3,073</td>
<td>1,044</td>
</tr>
<tr>
<td>Area 'C'</td>
<td>301</td>
<td>3,947</td>
<td>1,974</td>
</tr>
<tr>
<td>Area 'D'</td>
<td>1,797</td>
<td>2,837</td>
<td>1,419</td>
</tr>
<tr>
<td>Area 'E'</td>
<td>2,613</td>
<td>934</td>
<td>467</td>
</tr>
<tr>
<td>Area 'F'</td>
<td>1,767</td>
<td>4,444</td>
<td>2,222</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6,742.4</strong></td>
<td><strong>21,829</strong></td>
<td><strong>10,000</strong></td>
</tr>
</tbody>
</table>

Source: RDNO provided 2006 Census Data for each electoral area, with the exception of Enderby which is based on 2010 population data from the water utility.

* With the exception of the Village of Lumby, which is solely supplied by groundwater, and the Township of Spallumcheen and the City of Enderby, it was assumed that approximately 50% of the population obtains their water from a groundwater source. As the Township of Spallumcheen is partially outside the Shuswap River Watershed, it was assumed that 25% of the population obtains its water from a groundwater source. The City of Enderby supplements its surface water source with approximately 34% groundwater (2010). As such, 34% of the population was assumed to obtain its water from groundwater.

** Area C was included in the population estimate as a portion of Electoral Area C is located within the Shuswap River Watershed.

It is assumed that 60% of the population (i.e., 6,000 people) is located within the Lower Shuswap Watershed while the remaining 40% of the population (i.e., 4,000 people) are located within the Middle Shuswap Watershed. It was assumed that the population in the Upper Shuswap River Watershed is negligible.

- An estimate of water use from varying resources identified the consumption rates per person per day provided in Table 3.

Table 3: Estimate of Consumption Rates per Person per Day

<table>
<thead>
<tr>
<th>User Location</th>
<th>L/per person/per day*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okanagan average</td>
<td>675</td>
</tr>
<tr>
<td>Okanagan summer average</td>
<td>1000</td>
</tr>
<tr>
<td>Village of Lumby</td>
<td>579</td>
</tr>
<tr>
<td>BC average</td>
<td>490</td>
</tr>
<tr>
<td>Canadian average</td>
<td>329</td>
</tr>
</tbody>
</table>

* As the Village of Lumby is solely supplied by groundwater, and based on a known annual groundwater extraction rate of approximately 345,418 m³/year (roughly 250,000 gallons per day) to the approximate 1,634 residents over 750 connections, an estimated per capita demand for the Shuswap River Watershed can be estimated.

- Estimates of groundwater use were made by multiplying the population within each area with the per capita consumption rates in Table 3.
2.5 Riparian Areas

The methods used to assess the condition of riparian areas in the Shuswap River Watershed first included a background information review to collect and evaluate available published and grey literature (e.g., government documents, consultant reports, stewardship group websites) related to fish habitat assessment, riparian areas, and restoration initiatives in the Shuswap River Watershed. The applicable information for each section of the Shuswap River Watershed was summarized separately, first at the watershed level and then with a specific focus on the main stem of the Shuswap River.

At the watershed level, Matthews and Bull (2003) identified focal sub-drainages within the Shuswap River Watershed that are priorities for the protection of fish stocks and fish habitat. They evaluated 79 sub-drainages, using provincially set watershed boundaries within this larger watershed, based on the following criteria: (i) the presence or absence of focal fish species, which included salmonid species due to their wide distribution, sensitivity to environmental change, and cultural significance, and species of management concern; (ii) the sensitivity (i.e., potential for extirpation) of each species or stock; and, (iii) the natural capacity of the sub-drainage to produce fish relative to the rest of the watershed. Based on these criteria, the significance of each sub-drainage as a habitat protection focus area was determined using a four class ranking system: low, medium, high, or very high. Those sub-drainages that ranked high or very high for habitat protection were then assessed to determine their level of previous habitat alteration due to agriculture, urban development, forestry, or water level drawdown using a similar four class ranking system. Candidate sub-drainages for habitat restoration were identified as those sub-drainages with high or very high rankings for habitat protection that were also significantly impacted by habitat alteration. The results of this assessment are presented and reinterpreted in this Technical Assessment to provide a preliminary prioritization of riparian and instream fish habitat restoration opportunities at the sub-drainage scale within the Shuswap River Watershed.

Orthophoto interpretation was then completed to evaluate the condition of riparian areas along the Upper and Middle Shuswap River. The most recent orthophotos available from Bing Maps (~2007) were used. Riparian areas were classified at a scale of approximately 1:750 into one of the following classes, based on the condition of the riparian area within a 30 m buffer from the assumed high water mark (HWM) of the streambank: natural (e.g., vegetated, stream mouth, eroded bank) or disturbed (e.g., agriculture, hydroelectric, forestry, rural, road). This orthophoto interpretation is considered to be a preliminary assessment at a relatively coarse scale, and field ground-truthing would be required to confirm the accuracy of the interpretation. Golder notes that orthophoto interpretation of the Upper Shuswap River was only completed downstream from its confluence with Greenbush Creek as upstream of this location, the Upper Shuswap River narrows substantially and is relatively undisturbed. Forestry operations within the Upper Shuswap River have created a patchwork of different aged stands that complicate interpretation from the available orthophotos. This section of the stream is also more sinuous with multiple island, bar, oxbow, and side channel features, which further complicates identification of the true

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1 There were some small inconsistencies between the sub-drainage names identified by Matthews and Bull (2003) and the provincial gazetted watershed names. We have followed the gazezette names (i.e., Nicklen Creek rather than Harris Creek, Bill Fraser Creek rather than Fraser Creek), but have included Greenbush Creek as the common name for the sub-drainage identified as Watershed Code 128-835500-93600. Three sub-drainages (Burton Creek, Hummingbird Creek, Mara Creek) identified by Matthews and Bull (2003) are located outside of the Shuswap River Watershed boundary used in this Technical Assessment and so are not assessed here. Two sub-drainages with gazetted names (Dale Creek and Gilbert Creek) were not ranked by Matthews and Bull (2003), and one sub-drainage (Brush Creek) ranked by Matthews and Bull (2003) could not be located within the Shuswap River Watershed boundary based on the gazetted watershed names.

2 Disturbed areas here refer only to these areas that are anthropogenically disturbed and do not include naturally disturbed areas.
streambank HWM. Orthophoto interpretation was not completed for the Lower Shuswap River, as high quality inventory and mapping data are available for this section of the stream (Hawes et al. 2011).

Based on the results of the background information review and the orthophoto interpretation, a preliminary prioritization of riparian and instream fish habitat restoration opportunities along the Shuswap River was developed. Any gaps in the information available or areas for future research that were identified during the assessment of the condition of riparian areas in the Shuswap River Watershed were recorded and summarized in the applicable section of this Technical Assessment.
3.0 WATERSHED BIOPHYSICAL DESCRIPTION

The Shuswap River Watershed is characterized by its natural sub-regions and identified sub-drainages, as well as by the specific biophysical conditions present throughout the watershed. The following sections provide an overview description of the watershed hierarchy, eco-classification, climate, geology and soils, hydrology and hydrogeology, ecology, and land use of the Shuswap River Watershed. Where available, specific information for each sub-watershed of the Shuswap River Watershed (i.e., Upper, Middle, Lower) is provided separately in Sections 4.0, 5.0, and 6.0, respectively.

3.1 Watershed Hierarchy

A watershed is defined as an area over which all surface water drains into the same body of water. A watershed can consist of a single stream, or can be made up of multiple streams (i.e., sub-drainages), hierarchically organized into larger and larger watersheds. The following sections describe the watershed hierarchy surrounding the Shuswap River Watershed.

3.1.1 Shuswap Watershed

The Shuswap Watershed consists of 13 main sub-drainages, as identified in Table 4 and Figure 2, the largest of which is the watershed associated with the Shuswap River.

Both Bessette Creek and Wap Creek are large, direct tributaries of the Shuswap River; as such, the watersheds associated with these two streams have been included as part of the Shuswap River Watershed for this Technical Assessment³, as shown on Figure 2. The rest of the watersheds listed in Table 4 are located downstream of the Shuswap River Watershed, within the Shuswap Watershed. This greater watershed contributes to Shuswap Lake, which flows into the South Thompson River and eventually the Fraser River, before discharging into the Pacific Ocean, as shown on Figure 1.

Table 4: Main Sub-drainages of the Shuswap Watershed

<table>
<thead>
<tr>
<th>No.</th>
<th>Stream Name</th>
<th>Area (ha)*</th>
<th>Location Relative to Shuswap River</th>
<th>Included in Shuswap River Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shuswap River</td>
<td>406,566</td>
<td>Not applicable</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Adams River / Lake</td>
<td>286,011</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>South Thompson</td>
<td>218,880</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>Salmon River</td>
<td>155,322</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>Scotch Creek</td>
<td>61,522</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Seymour River</td>
<td>80,951</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>7</td>
<td>Bessette Creek</td>
<td>79,393</td>
<td>Tributary</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Eagle River</td>
<td>81,420</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>9</td>
<td>Momich River / Cayenne Creek</td>
<td>47,739</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>10</td>
<td>Perry River</td>
<td>43,645</td>
<td>Downstream</td>
<td>No</td>
</tr>
<tr>
<td>11</td>
<td>Wap Creek</td>
<td>34,157</td>
<td>Tributary</td>
<td>Yes</td>
</tr>
</tbody>
</table>

³ The Shuswap River, Bessette Creek, and Wap Creek Watersheds are collectively gazetted as the Upper Shuswap Watershed in the British Columbia Watershed Atlas (BC MFLNRO 2011).
3.1.2 Shuswap River Watershed

The Shuswap River Watershed is dominated by the Shuswap River and includes all of its direct and indirect tributaries as shown on Figure 3. This watershed straddles two main geographic features: the steeply sloped Monashee Mountains on the east side of the system and the less rugged Shuswap Highlands on the west side. The Shuswap River originates from Joss Pass between Joss Mountain and Davis Peak in the Sawtooth Range of the Monashee Mountains. From its headwaters, the Shuswap River flows approximately 150 kilometres (km) down into the Shuswap Highlands and through two large lakes, Sugar Lake and Mabel Lake, before discharging into Mara Lake, which is an extension of Shuswap Lake. The Shuswap River is commonly divided into the following three main sub-watersheds, as shown on Figure 3:

1. the Upper Shuswap River Watershed (114,750 ha), which starts at Joss Pass at the northern extent of the Sawtooth Range of the Monashee Mountains and flows south, discharging into Sugar Lake;
2. the Middle Shuswap River Watershed (292,403 ha), which starts at the Sugar Lake outlet and flows south and then north again into Mabel Lake; and,
3. the Lower Shuswap River Watershed (112,963 ha), which starts at the Mabel Lake outlet and flows to the west towards Enderby, eventually flowing north and discharging into Mara Lake.

Each of these three identified sub-watersheds is characterized by unique biological and anthropogenic (i.e., human-caused) regimes. As such, a separate profile has been developed for each sub-region as part of this Technical Assessment.

3.1.3 Shuswap River Watershed Sub-Drainages

The Shuswap River Watershed is comprised of at least 122 sub-drainages, including 31 sub-drainages in the Upper Shuswap River Watershed, 67 sub-drainages in the Middle Shuswap River Watershed (including 15 from the Bessette Creek Watershed and seven from the Wap Creek Watershed), and 23 sub-drainages in the Lower Shuswap River Watershed, plus the Shuswap River sub-drainage that flows through all three sub-regions. These sub-drainages include named sub-drainages associated with large direct and indirect tributaries of the Shuswap River, as well as small unnamed sub-drainages, as shown on Figure 4.

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*RDNO (1975) divided the Shuswap River Watershed into three different sections as follows: Upper (headwaters to Mabel Lake outlet), Middle (Mabel Lake outlet to City of Enderby), and Lower (City of Enderby to Mara Lake inlet). We have employed the naming convention most relevant from a hydrologic perspective and commonly used in recent decades.
3.2 Eco-Classification

Broad descriptions of British Columbia’s biophysical characteristics are based on the Ecoregion Classification System and the Biogeoclimatic Ecosystem Classification (BEC) System. The eco-classification of the Shuswap River Watershed using these two systems is described in the following sections and shown on Figure 5.

3.2.1 Ecoregion Classification

The Ecoregion Classification System provides a systematic review of small-scale ecological relationships in British Columbia. This system has five hierarchical levels based on macroclimatic processes and physiography: ecodomains and ecodivisions place British Columbia in a global context, while ecoprovinces, ecoregions, and ecosections relate the province to other parts of North America or the Pacific Ocean (Demarchi 2011). The ecosections present in the Shuswap River Watershed are shown on Figure 5.

The majority of this watershed is located in the Southern Interior Mountains ecoprovince of the Humid Continental Highlands ecodivision in the Humid Temperate ecodomain (BC MFLNRO 2011). The higher eastern elevations of the Upper Shuswap River Watershed are located within the Central Columbia Mountains ecosection of the Northern Columbia Mountains ecoregion. The rest of the Upper Shuswap River Watershed and the majority of the Middle Shuswap River Watershed, excluding the Bessette Creek Watershed, are located in the Shuswap River Highlands ecosection of the Columbia Highlands ecoregion. These two ecosections are described as follows in Demarchi (2011):

- **Central Columbia Mountains Ecosection:** This ecosection is characterized by high ridges and mountains with mainly narrow valleys and trenches, and is underlain by a variety of rocks, including sedimentary, metamorphic, gneiss and granitic batholiths. This ecosection has high precipitation from the valley bottoms to the upper slopes, which brings high humidity and rain in the summer or deep snow in the winter. Cold Arctic air seldom invades this area, being protected by mountain systems on all sides, although large Arctic systems overwhelm the entire area for short periods in the winter. Small glaciers are found along the eastern margin of the Shuswap watershed and larger glaciers persist further east in this ecosection.

- **Shuswap River Highland Ecosection:** This moist highland ecosection is characterized by steep-sided, gentle or moderate rolling uplands and ridges that are dissected by the circuitous Shuswap River and Shuswap Lake waterways. Westward-moving glaciers influenced the topographic and geological conditions of this area. Moist Pacific air is able to penetrate deep into the western-facing interior valleys of this ecosection, otherwise that moist air rises over this highland creating rainshadows or alternately, slopes with heavy precipitation. In the winter heavy snowfall occurs in this ecosection, especially when coupled with cold Arctic air.

As shown on Figure 5, the remainder of the Shuswap River Watershed is located in the Southern Interior ecoprovince of the Semi-Arid Steppe Highlands ecodivision in the Dry ecodomain (BC MFLNRO 2011). Within the Thompson Okanagan Plateau ecoregion, three ecosections are present in the Shuswap River Watershed. The valley bottom associated with Bessette Creek in the Middle Shuswap River Watershed is located in the Northern Okanagan Basin ecosection. The southern, higher elevation areas of the Middle Shuswap River Watershed are located in the Northern Okanagan Highland ecosection. The valley bottom associated with the Lower Shuswap River south of its confluence with Cooke Creek is located in the Shuswap Basin ecosection. These three ecosections are described as follows in Demarchi (2011):
Northern Okanagan Basin Ecosystem: This ecosystem is characterized by a wide trench and foothills located between the Thompson Plateau to the west and the Northern Okanagan Highlands to the east. This ecosystem is in a rainshadow of the Thompson Plateau and the Coast Mountains to the west. Surface heating in the summer creates convective currents that aid in keeping this area cloud-free and dry. In the summer hot subtropical air can overwhelm this area and bring hot dry conditions. Winters are typically cool, and cold dense Arctic air seldom invades here from the north.

Northern Okanagan Highland Ecosystem: This is a cool, moist, rolling upland ecosystem that is transitional in height from the lower plateaus to the west and the higher mountains to the east where several river valleys dissect the upland surface. Much of the area is underlain by gneiss bedrock and differential weathering has produced gentle step-like slopes. In addition, glacial ice covered the greatly rounded summits and upland and deposited a mantle of drift.

Shuswap Basin Ecosystem: This ecosystem is characterized by rolling plateau uplands, steep sided plateau walls, and large inter-plateau lowlands. It has a dry montane climate, except in areas where topographic shading provides an environment for the Interior Cedar-Hemlock forests. Vegetation zones generally reflect the wide low elevation basins and rolling upland surface. Sagebrush-steppe occupies the slopes, in the South Thompson and upper Salmon rivers basins, above that the Ponderosa Pine, Meadow-Steppe is dominated by Lodgepole pine forests, occurs over most of the uplands and only the higher areas have the colder, moister Engelmann Spruce - Subalpine Fir forests.

3.2.2 Biogeoclimatic Ecosystem Classification

The BEC System delineates BC into zones that are founded on local climatic processes and landforms reflected by the presence of specific plant and animal communities (Meidinger and Pojar 1991). As shown on Figure 5, the Shuswap River Watershed is located within five BEC zones. Valley bottoms at lower elevations are primarily located within the Interior Douglas-Fir (IDF) zone, while adjacent mountainous slopes are in the Interior Cedar Hemlock (ICH) zone and Montane Spruce (MS) zone, and upper mountainous peaks are in the Engelmann Spruce Subalpine Fir (ESSF) zone. At higher elevations, valley bottoms are primarily located in the ICH zone, adjacent mountainous slopes and peaks are in the ESSF zone, and the highest peaks are in the Interior Mountain-heather Alpine (IMA) zone.

3.3 Climate

The Shuswap River Watershed is affected by both modified maritime and continental climatic conditions. East flowing maritime air from the Pacific Ocean loses much of its moisture over the Coast and Cascade Mountains but also over the Monashee Mountains located immediately east of the Shuswap River Watershed, contributing to higher precipitation in this area compared to the drier Southern Interior Plateau, located to the south of the watershed (Homenuke and Groves 2005). The climate of the Shuswap River Watershed is further modified by frequent outbreaks of cold, dense, south flowing Arctic air during the winter and early spring, and hot, dry north flowing air from the southerly-located Great Basin in the summer (Demarchi 2011). As described in Section 3.2.1, these larger systems vary in their effects to the climate of the different ecosystems of the Shuswap River Watershed.

Six Environment Canada weather stations are located within or near the Shuswap River Watershed that represent some of the range in climate data within the watershed from 1971 to 2000. Table 5 provides location
information for each weather station, as well as the average annual temperature, total precipitation, and precipitation as snowfall recorded at each station. Total annual precipitation determines the volume of water that is potentially available for runoff, infiltration to aquifers and surface flows, and temperatures determine the proportion of the runoff that falls as snow and the timing of snowmelt; thus, these climatic variables are the driving factors that determine volume and timing of surface flows. Temperatures are also a significant factor in evapotranspiration which reduces growing season surface flows and the volume of water that infiltrates, becoming groundwater. The Enderby, Lumby, and Silver Star weather stations are located in the Shuswap River Watershed, while the Revelstoke weather station is located in the Columbia drainage to the east, and the Armstrong and Vernon weather stations are located in the Okanagan drainage to the west. These weather stations are primarily located at lower elevations near town centers and show a general trend towards increased precipitation at more easterly locations and at higher elevations.

Table 5: Environment Canada Weather Stations within or near the Shuswap River Watershed

<table>
<thead>
<tr>
<th>Station Name</th>
<th>Ecosystem</th>
<th>Elevation (masl)</th>
<th>Temperature (°C)*</th>
<th>Total Precipitation (mm)*</th>
<th>Precipitation as Snowfall (mm)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Armstrong North</td>
<td>Shuswap Basin</td>
<td>373</td>
<td>7.2</td>
<td>488</td>
<td>128</td>
</tr>
<tr>
<td>Enderby</td>
<td>Shuswap Basin</td>
<td>354</td>
<td>7.5</td>
<td>500</td>
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<tr>
<td>Lumby Sigalet Road</td>
<td>Shuswap River Highland</td>
<td>560</td>
<td>6.7</td>
<td>628</td>
<td>165</td>
</tr>
<tr>
<td>Vernon Coldstream Ranch</td>
<td>Northern Okanagan Basin</td>
<td>482</td>
<td>7.4</td>
<td>484</td>
<td>128</td>
</tr>
<tr>
<td>Silver Star</td>
<td>Shuswap River Highland</td>
<td>1,572</td>
<td>2.7</td>
<td>868</td>
<td>619</td>
</tr>
<tr>
<td>Revelstoke Airport Road</td>
<td>Central Columbia Mountains</td>
<td>450</td>
<td>6.9</td>
<td>945</td>
<td>425</td>
</tr>
</tbody>
</table>

Source: Canadian Climate Normals or Averages 1971-2000 for Armstrong, Lumby, Vernon, and Revelstoke, and average of available Climate Data Online for Enderby and Silver Star (Environment Canada 2011a).

* Temperature and precipitation values are average annual values; units are degrees centigrade (°C) and millimetre (mm).

Climatic information for areas of the Shuswap River Watershed not serviced by weather stations (i.e., most remote or higher elevation sites) can be derived from both the Ecoregion and BEC classification systems. The Shuswap River Watershed is characterized by a range in climatic conditions, from the very dry North Okanagan Basin, Shuswap Basin and slightly moister North Okanagan Highland ecossections in the southern and western areas of the watershed, to the wetter and cooler Shuswap River Highland ecossection, which covers the majority of the watershed, followed by the wet Central Columbia Mountains ecossection at the highest elevations on the eastern margin of the watershed (Demarchi 2011).

Lower elevation valley bottoms in the Shuswap River Watershed in the IDF zone typically have a relatively dry, continental climate attributed to the rainshadow created by westwardly mountain ranges. As a result, areas of the watershed in this zone experience warm, dry summers and a relatively long growing season commonly characterized by a substantial growing season moisture deficit (Meidinger and Pojar 1991). Winters in these areas are typically cool with low to moderate snowfall. Annual average precipitation ranges from 295 mm to 834 mm with a mean of 476 mm, and annual average temperature ranges from 2.5 °C to 7.9 °C with a mean of
5.0 °C (Lloyd et al. 1990). Similar to the IDF zone, lower elevation slopes and higher elevation valley bottoms in the Shuswap River Watershed in the ICH zone typically experience warm dry summers. Annual average temperature ranges from 2.1 °C to 7.8 °C with a mean of 4.8 °C (Lloyd et al. 1990). Areas of the Shuswap River Watershed in the ICH zone typically experience a wetter climate than areas in the IDF; however, with cooler wet winters, abundant snowfall, and an annual average precipitation range from 430 mm to 1,724 mm with a mean of 919 mm (Lloyd et al. 1990).

Areas of the Shuswap River Watershed that occupy the ESSF zone typically experience considerably cooler and snowier climatic conditions than areas in either the IDF or ICH zones. Annual average temperature in the ESSF zone ranges from -1.3 °C to 4.0 °C with a mean of 0.5 °C (Lloyd et al. 1990). Annual average precipitation ranges from 514 mm to 2,402 mm, with a mean of 1,239 mm, and up to 70% of the total precipitation is received as snowfall (Lloyd et al. 1990). Areas of the Shuswap River Watershed that occupy the MS zone have climates that are intermediary to the IDF and ESSF zones, with annual average temperatures between 0.5 °C and 4.7 °C and annual average precipitation between 380 and 900 mm (Meidinger and Pojar 1991). Areas of the Shuswap River Watershed that occupy the IMA zone are even cooler than the ESSF zone.

3.4 Geology and Soils

The geology and soils of the Shuswap River Watershed vary with the diverse topographical features present in this area. As shown in Figure 6, the bedrock geology of the Shuswap River Watershed is dominated by Paleozoic undivided metamorphic rocks from the Shuswap Assemblage (MFLNRO 2011). Other common bedrock geology classes include Upper Triassic sedimentary rocks from the Nicola Group, as well as Lower Paleozoic paragneiss metamorphic rocks from the Monashee Complex, and Eocene undivided volcanic rocks from the Kamloops Group (MFLNRO 2011). Quaternary geology has been identified with the Shuswap River Watershed, primarily in association with the valley bottoms and floodplains of the following streams, as shown in Figure 6: the Shuswap River between its headwaters and Mabel Lake, the outlet of Sugar Lake, Cherry Creek, Springs Creek, Bessette Creek, Sowsap Creek, Trinity Creek, Tsuius Creek between its confluence with Whip Creek and Mabel Lake, Wap Creek, Fortune Creek, and Shuswap River between its confluence with Trinity Creek and Mara Lake. Deposits of these origins generally consist of variable combinations of silt, clay, sands and gravels. Fault lines have also been identified throughout the Shuswap River Watershed as shown on Figure 6.

The dominant soils types of the Shuswap River Watershed are shown in Figure 7. A key to these soil types is provided in Appendix B, which describes the soil texture, terrain materials, soil drainage, ecological moisture regime, range of slopes, bedrock groupings, soil taxonomy, and elevational range of each type (Belsham and Kowall 1973). Within the IDF zone, the dominant soil types on zonal sites are orthic or dark gray luvisols, and eutric or dystric brunisols, overlying morainal deposits derived from basic volcanic bedrock; these soils typically have a medium to high nutrient status (Lloyd et al. 1990). The dominant soil types of the ICH zone are humo-ferric podzols, with dystric brunisols and brunisolic gray luvisols in moist subzones, and ferro-humic podzols in wet subzones (Lloyd et al. 1990). Zonal sites of the MS zone are dominated by brunisolic or orthic gray luvisols and eutric brunisols, with humo-ferric podzols and dystric brunisols in wetter subzones (Meidinger and Pojar 1991). The soils of the ESSF zone are predominantly humo-ferric podzols or dystric brunisols, with ferro-humic podzols or sombric brunisols in wet subzones (Lloyd et al. 1990).
3.5 Hydrology

Regional hydrology is influenced by the specific topographical and climatic characteristics of an area, which determine annual runoff and surface water flows. Anthropogenic modifications such as dams, reservoirs, weirs, and other flow-regulating structures, as well as water allocation to anthropogenic uses, also influence regional hydrology by altering the flow characteristics of streams. Surface flows within the Shuswap River Watershed are primarily in a westerly to southwesterly direction in the Upper and Middle Shuswap River Watersheds, then westerly to northwesterly in the Lower Shuswap Watershed, and are modified by numerous dams, as shown on Figure 8. Surface flow data is captured at hydrometric stations, which are or were located on the Shuswap River and its larger tributary streams as shown on Figure 8. Surface flows in the Shuswap River Watershed are modified by water licenses, which are shown on Figure 9. This region has a long, but interrupted history of flow records dating back as far as the early 1900s. The following sections describe the regional hydrology of the Shuswap River Watershed based primarily on this hydrometric station data.

3.5.1 Annual Runoff

The change in surface runoff throughout the Shuswap River Watershed, as influenced by the topographical and climatic characteristics, is demonstrated by the annual runoff isolines shown on Figure 8. These lines represent the normal annual runoff for 1961 to 1990 in mm (BC MFLNRO 2011). The runoff lines are very general, cutting across valleys instead of following elevation contours, but they do illustrate a west to east trend in runoff. For example, annual runoff varies from less than 100 mm/year at Enderby, to 200 mm/year east of Lumby, to 500 mm/year near Cherryville, to greater than 1000 mm/year upstream of Sugar Lake.

3.5.2 Water Survey of Canada Hydrometric Stations

Surface flows throughout the Shuswap River Watershed are recorded at Water Survey of Canada (WSC) hydrometric stations (Environment Canada 2011c). There are six active (i.e., still operating) and 28 inactive (i.e., discontinued, historic data only) hydrometric stations within the Shuswap River Watershed. In addition, there is also one inactive station that measured the Vernon Irrigation District diversion out of Duteau Creek into the Okanagan Basin, as well as several active and inactive stations used to measure water levels in lakes and reservoirs. The locations and station numbers for all of the WSC hydrometric stations are shown on Figure 8. In addition, the RDNO initiated seasonal surface flow measurements at three sites in the upper Duteau Creek sub-drainage in 2008 (G2O Services 2010). Pertinent information including status, period of record, and drainage area for all of these WSC and RDNO stations is provided in Table 6, which is sorted by the length of flow record. The data and analyses in subsequent sections is based on data records to the end of the year 2009, which was the last year of published WSC data at the time of writing of this report. Graphical data for 2010 and 2011 for the active Shuswap River stations can be viewed on the WSC Real-time Hydrometric Data website (Environment Canada 2011c). As these data are unverified and in graphical format, they were not included in the analyses.
<table>
<thead>
<tr>
<th>Station Name</th>
<th>Station No.</th>
<th>Flow Record</th>
<th>Total No. Years*</th>
<th>Status</th>
<th>Measure</th>
<th>Type</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuswap River near Enderby</td>
<td>08LC002</td>
<td>1911-1936, 1960-2009</td>
<td>76</td>
<td>Active</td>
<td>Continuous</td>
<td>Regulated</td>
<td>4690</td>
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<tr>
<td>Duteau Creek near Lavington</td>
<td>08LC006</td>
<td>1919-1921, 1935-1996</td>
<td>58</td>
<td>Inactive</td>
<td>Continuous</td>
<td>Regulated</td>
<td>193</td>
</tr>
<tr>
<td>Vance Creek below Deafies Creek</td>
<td>08LC040</td>
<td>1970-2009</td>
<td>40</td>
<td>Active</td>
<td>Continuous</td>
<td>Natural</td>
<td>73</td>
</tr>
<tr>
<td>Shuswap River at Outlet of Mabel Lake</td>
<td>08LC019</td>
<td>1927-1936, 1951-1979</td>
<td>39</td>
<td>Inactive</td>
<td>Continuous</td>
<td>Regulated</td>
<td>4040</td>
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<tr>
<td>Bessette Creek above Beaverjack Creek</td>
<td>08LC039</td>
<td>1970-1972, 1975-2009</td>
<td>38</td>
<td>Active</td>
<td>Continuous</td>
<td>Regulated</td>
<td>769</td>
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<tr>
<td>Bessette Creek above Lumby Lagoon Outfall</td>
<td>08LC042</td>
<td>1973-2009</td>
<td>37</td>
<td>Active</td>
<td>Continuous</td>
<td>Regulated</td>
<td>632</td>
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<td>Fortune Creek near Armstrong</td>
<td>08LC035</td>
<td>1911-1912, 1959-1984</td>
<td>26</td>
<td>Inactive</td>
<td>Continuous</td>
<td>Regulated</td>
<td>41</td>
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<td>Bessette Creek near Lumby</td>
<td>08LC005</td>
<td>1919, 1943-1948, 1965-1983</td>
<td>25</td>
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<td>Seasonal</td>
<td>Regulated</td>
<td>253</td>
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<tr>
<td>VID Diversion near Lavington</td>
<td>08LC007</td>
<td>1919-1921, 1935-1951, 1964-1966</td>
<td>23</td>
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<td>Regulated</td>
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<td>Ferry Creek near Lumby</td>
<td>08LC034</td>
<td>1959-1977</td>
<td>18</td>
<td>Inactive</td>
<td>Seasonal</td>
<td>Natural</td>
<td>145</td>
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<tr>
<td>Brash Creek near Enderby</td>
<td>08LC004</td>
<td>1915-1917, 1959-1968</td>
<td>12</td>
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<td>Continuous</td>
<td>Natural</td>
<td>33</td>
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<td>Fortune Creek at Stepney</td>
<td>08LC031</td>
<td>1950-1960</td>
<td>11</td>
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<td>132</td>
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<td>Cherry Creek near Cherryville</td>
<td>08LC049</td>
<td>1982-1990</td>
<td>9</td>
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<td>Natural</td>
<td>503</td>
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<tr>
<td>Larch Hills Creek near Mara</td>
<td>08LC021</td>
<td>1934, 1945-1948, 1951-1953</td>
<td>8</td>
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<td>Seasonal</td>
<td>Natural</td>
<td>13</td>
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<tr>
<td>Duteau Creek at Outlet of Haddo Lake</td>
<td>08LC014</td>
<td>1921, 1973-1979</td>
<td>8</td>
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<td>Seasonal</td>
<td>Regulated</td>
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<td>Creighton Creek near Lumby</td>
<td>08LC033</td>
<td>1959-1966</td>
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<td>Inactive</td>
<td>Seasonal</td>
<td>Natural</td>
<td>38</td>
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<tr>
<td>Violet Creek near Grindrod (Lower Station)</td>
<td>08LC030</td>
<td>1946-1953</td>
<td>7</td>
<td>Inactive</td>
<td>Seasonal</td>
<td>Natural</td>
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<td>Violet Creek near Grindrod (Upper Station)</td>
<td>08LC020</td>
<td>1934, 1945-1949</td>
<td>6</td>
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<td>Seasonal</td>
<td>Natural</td>
<td>13</td>
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<tr>
<td>Trinity Creek near the Mouth</td>
<td>08LC050</td>
<td>1985-1990</td>
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<td>Type</td>
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<td>Johnson Creek near Mara</td>
<td>08LC026</td>
<td>1946-1953</td>
<td>6</td>
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<td>21</td>
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<td>Blurton Creek near Mara</td>
<td>08LC025</td>
<td>1946-1953</td>
<td>6</td>
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<td>Seasonal</td>
<td>Natural</td>
<td>19</td>
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<td>Gardom Creek near Grindrod</td>
<td>08LC036</td>
<td>1960-1964</td>
<td>5</td>
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<td>Seasonal</td>
<td>Natural</td>
<td>26</td>
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<td>Trinity Creek above Diversion</td>
<td>08LC048</td>
<td>1981-1984</td>
<td>4</td>
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<td>43</td>
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<td>Shuswap River below Skookumchuk Rapids</td>
<td>08LC032</td>
<td>1955-1956</td>
<td>2</td>
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<td>Seasonal</td>
<td>Regulated</td>
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<tr>
<td>Monashee Creek near Cherryville</td>
<td>08LC022</td>
<td>1938-1939</td>
<td>2</td>
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<td>Seasonal</td>
<td>Natural</td>
<td>311</td>
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<tr>
<td>Ptarmigan Creek near Lumby</td>
<td>08LC028</td>
<td>1946</td>
<td>1</td>
<td>Inactive</td>
<td>Seasonal</td>
<td>-</td>
<td>-</td>
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<td>Paradise Creek near Lumby</td>
<td>08LC015</td>
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<td>Seasonal</td>
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<td>08LC010</td>
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<td>-</td>
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<td>Dermont Creek near Lavington</td>
<td>08LC017</td>
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<td>Seasonal</td>
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<td>Seasonal</td>
<td>-</td>
<td>-</td>
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<tr>
<td>Bongard Creek near Mara</td>
<td>08LC029</td>
<td>1946</td>
<td>1</td>
<td>Inactive</td>
<td>Seasonal</td>
<td>-</td>
<td>13</td>
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<td>Curtis Creek above Aberdeen Reservoir</td>
<td>RDNO</td>
<td>2008-2009</td>
<td>2</td>
<td>Active</td>
<td>Seasonal</td>
<td>Natural</td>
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<tr>
<td>Duteau Creek above Grizzly Swamp</td>
<td>RDNO</td>
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</tr>
<tr>
<td>Heart Creek above Aberdeen Reservoir</td>
<td>RDNO</td>
<td>2008-2009</td>
<td>2</td>
<td>Active</td>
<td>Seasonal</td>
<td>Includes diversion</td>
<td>-</td>
</tr>
</tbody>
</table>

* Hydrometric stations are ordered by length of flow record to the end of 2009.
The longest running station is No. 08LC002 (Shuswap River near Enderby), which had 76 years of record between 1911 and 2009. Archived hydrometric data for all of the WSC hydrometric stations are available online, and daily and monthly (including annual) data sets can be viewed or downloaded for each station (Environment Canada 2011b). Most of the monthly and daily data for stations with at least six years of data have been downloaded and formatted in a series of Microsoft Excel workbooks. Examples of the annual, monthly and daily flow charts and summarized flow data are included in the sections for each sub-watershed.

Real-time hydrometric data for the three active Shuswap River stations can also be viewed online (Environment Canada 2011c). This data is posted within four hours of the time of measurement and therefore can be used to check current flows, with the disclaimer that it is preliminary data that has been transmitted automatically with limited verification for review and quality assurance. Experience with comparing real-time flows to subsequent archived data has shown that the real-time data is generally accurate, although significant adjustments may occur when the data is reviewed prior to archiving.

3.5.3 Annual and Monthly Flows

Figure 10 shows the annual surface flows at the four WSC stations along the Shuswap River between Enderby and Sugar Lake for available years between 1913 and 2009. WSC Station No. 08LC002 (Shuswap River near Enderby) is the longest running station with 76 years of record and is the most downstream station on the Shuswap River. This station is located in the Lower Shuswap River Watershed, but is upstream of Mara Lake and therefore does not measure all flow in this watershed. WSC Station No. 08LC019 (Shuswap River at the Outlet of Mabel Lake) has 39 years of data to 1979, and coincides with the lower boundary of the Middle Shuswap River Watershed. WSC Station No. 08LC003 (Shuswap River near Lumby) has 73 years of data and is located upstream of Mabel Lake in the Middle Shuswap River Watershed. WSC Station No. 08LC018 (Shuswap River at the Outlet of Sugar Lake) has 47 years of data and coincides with the downstream boundary of the Upper Shuswap River Watershed.

![Figure 10: Mean Annual Flows at Four WSC Stations on the Shuswap River](image-url)
All of the mean annual surface flow records for WSC stations in the Shuswap River Watershed contain data gaps. The data does illustrate, however, that there is an association in the relative volume of flows among the four stations, that the outflow at Sugar Lake is close to half of the flow near Enderby, and that there is substantial year to year variation in the annual flow records. Annual flows near Enderby range from a low of 52.4 m$^3$/s in 1929 to a high of 126 m$^3$/s in 1999. Even higher annual flows may have been experienced in 1997 (for which annual data are unavailable for the Enderby station), as 1997 annual flows were 10 to 15% higher than 1999 at the upstream stations. Figure 10 also demonstrates the historic drought flows of 1929 to 1931 in relation to the recent dry years of 2003 and 2009. The mean annual flow in the Shuswap River near Enderby was 52.4 m$^3$/s in 1929, 56.7 m$^3$/s in 1930, and 70.3 m$^3$/s in 1931, compared to 76.1 m$^3$/sec in 2003 and 71.8 m$^3$/s in 2009.

Figure 11 shows the mean monthly surface flows at the same four WSC stations along the Shuswap River between Enderby and Sugar Lake for available years between 1913 and 2009. The monthly flow pattern is comparable at the four stations. Freshet begins in April with the melting of the lower elevation snowpack, increases in May as snowmelt moves to the higher elevations and peaks and starts to decline in June with the completion of the melt. Flows decline rapidly in July and then diminish more slowly into fall and winter. January and February are generally the lowest flow months of the year. As shown in Figure 11, flows generally increases with increased watershed area. The exception to this pattern is that river flows at the outlet of Mabel Lake and near Enderby are almost equal between August and December. This result is explained by the fact that the station near Mabel Lake was discontinued in 1979 and as such does not reflect the full flow trends that are discussed for the other three stations in Section 7.1.

![Figure 11: Mean Monthly Flows at Four WSC Stations on the Shuswap River](image-url)
Monthly flows vary from year to year more significantly than do annual flows. Figure 12 shows, as an example, monthly flow statistics for Station No. 08LC002 (Shuswap River near Enderby). Minimum flows can be as low as 25% of the mean monthly flows in spring when freshet is late, and maximum flows can be as high as 300% of mean monthly flows in late summer in wet years.

![Figure 12: Range in Monthly Flows at WSC Station No. 08LC002 (Shuswap River near Enderby Station)](image)

3.5.4 Daily Flows

Daily flow charts and tables are useful for looking at detailed flows within months (particularly those with highly variable flows from month start to end like July), daily maximum flows for flooding considerations, seven day low flows for drought considerations, and for comparing specific years to each other or against the historic statistical numbers. Figure 13 shows the mean daily surface flows at the WSC Station No. 08LC002 (Shuswap River near Enderby) along with the lower quartile (P25) and upper quartile (P75) (exceeded three years in four and one year in four, respectively) daily flows and the minimum and maximum daily flows, plus the actual daily flows from 1930 and 2009 as examples.
Figure 13 includes both 2009, the most recent very dry year, and 1930, the middle year of what is commonly thought of as the most severe drought since climate records were started in BC. It is interesting to note that while the 2009 flows were above the median from January through March and peak flows in early June equalled the median, flows dropped rapidly to levels in July and August that were comparable to 1930 and by early September were almost the lowest since 1911. Flows then recovered to the 25th percentile when wetter conditions returned in fall. Similar daily flow comparisons can be made for all of the WSC stations for the years during which they have data. Unfortunately only six WSC hydrometric stations are still active, which limits comparison of recent years to historic flows to the three active Shuswap River stations and the three active stations in the Bessette Creek sub-basin.

3.6 Hydrogeology

The following sections provide a description of the hydrogeology of the Shuswap River Watershed.

3.6.1 Provincial Aquifers

There are 26 provincially identified aquifers in the Shuswap River Watershed as identified in Figure 14; of these, eight are listed as being bedrock aquifers and 18 are unconsolidated aquifers, which can include both confined and unconfined aquifers. Fourteen aquifers are located in the Lower Shuswap River Watershed predominantly through the north-south trending valley between Armstrong, Enderby, Grindrod and Mara Lake, with a few smaller aquifers noted towards Mabel Lake in the Kingfisher area. There are 10 aquifers located in the Middle Shuswap River Watershed predominantly through the east-west trending valley between Lumby, Lavington and Coldstream with some smaller aquifers noted in the Cherryville area. There are no provincial aquifers located in the Upper Shuswap River Watershed. More information including the geometry and provincial classification...
system which ranks productivity, demand, and vulnerability of each aquifer are discussed in the specific profile for each sub-watershed.

3.6.2 BC MoE Observation Wells

Throughout the province the BC MoE maintains a network of groundwater observation wells. Four are located within the Shuswap River Watershed, as shown in Figure 15. These four monitoring wells (three located in the Lower Shuswap River Watershed and one located in the Middle Shuswap River Watershed) provide a measure of historical depth to groundwater, through either manual or digital recording. Borehole logs for these wells are provided in Appendix C. Time series plots of the individual wells relevant to this Technical Assessment are provided in Section 5.0 for the Middle Shuswap River Watershed and Section 6.0 for the Lower Shuswap River Watershed. There are no BC MoE observation wells located in the Upper Shuswap River Watershed. The following table summarizes information regarding BC MoE observation wells within the Shuswap River Watershed.

Table 7: BC MoE Provincial Observations Wells

<table>
<thead>
<tr>
<th>Well ID No.</th>
<th>Location</th>
<th>Period of Record</th>
<th>Status</th>
<th>Location in Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>294</td>
<td>Lumby (Whitevale Rd and Horner Rd)</td>
<td>1986-12 to 2011-02</td>
<td>Active</td>
<td>Middle Watershed</td>
</tr>
<tr>
<td>47</td>
<td>Silver Star (Sovereign Lake Rd)</td>
<td>1965-11 to 2010-07</td>
<td>Active</td>
<td>Lower Watershed</td>
</tr>
<tr>
<td>118</td>
<td>Armstrong (Back Enderby Rd)</td>
<td>1971-08 to 2010-07</td>
<td>Active</td>
<td>Lower Watershed</td>
</tr>
<tr>
<td>122</td>
<td>Enderby (Hwy 97A)</td>
<td>1971-10 to 2010-04</td>
<td>Active</td>
<td>Lower Watershed</td>
</tr>
</tbody>
</table>

Source: BC MoE (2011g).

3.6.3 Preliminary Conceptual Model

Our conceptual model describing groundwater recharge, groundwater flow and groundwater discharge in the watershed was limited to the recharge of alluvial and/or fluvial aquifers (unconsolidated aquifers) located in the valley bottoms. Groundwater in these unconsolidated aquifers, which are mainly identified between the three lakes (Sugar, Mabel and Mara) and in the larger tributary valleys, is derived from the Shuswap River itself and contributions from the upland aquifer systems (both bedrock and unconsolidated) within adjoining area(s) immediately up gradient. Natural recharge to these systems is through infiltration of precipitation, stream losses, and recharge from adjacent upgradient aquifers. The recharge from the shallow upland aquifer zone to the fluvial and alluvial systems which make up the unconsolidated aquifer network is assumed to be constant, whereas stream losses are seasonally variable and proportional to runoff, with the majority occurring following snowmelt and runoff.

The threshold value for determining where unconsolidated deposits and bedrock existed was selected to be 800 masl. This value was partially adopted from the Okanagan basin pilot study water balance study (Summit 2005) as the elevation where precipitation exceeds evapotranspiration and a net addition of groundwater would be expected. The Project Team evaluated the validity of using this number in the North Okanagan, where the climate is slightly wetter and cooler. We found that the threshold of 800 masl generally holds true for the Upper Shuswap River Watershed and portions of the Middle Shuswap River Watershed, but could be over estimating potential aquifer areas in the Lower Watershed. However, when selecting a lower threshold of 600 masl or 700 masl as a potential threshold for aquifer delineation, some areas which are known to have provincially
identified aquifers and numerous water wells were excluded. As such, an 800 masl elevation threshold for unconsolidated aquifers was utilized, with manual correction of the aquifer geometry data for portions of the Middle Shuswap River Watershed and the Lower Shuswap River Watershed aquifers, made through visual orthophoto interpretation, flood plain mapping, cross sectional diagrams and professional judgement. Figure 16 depicts the areas of the Shuswap River Watershed above and below 800 masl.

3.6.4 Unconsolidated Aquifers

Based on the re-delineation of the unconsolidated aquifers within the Shuswap River Watershed, a total of 24 unique unconsolidated aquifers were identified in this Technical Assessment. They are listed as follows and shown on Figure 17:

- Upper Shuswap River Watershed U01 through U07;
- Middle Shuswap River Watershed M08 through M17; and
- Lower Shuswap River Watershed L18 through L24.

Regional aquifer flow directions and linkages were identified between the 24 aquifers, with the arrows shown on Figure 17 denoting the groundwater flow direction within the study area. This map illustrates the general direction of groundwater flow between unconsolidated aquifers. No arrows are used on the maps to depict bedrock to unconsolidated groundwater flow; this is rather, depicted through the use of the adopted aquifer numbering system. For example, Bedrock Aquifer U02A flows to adjacent unconsolidated Aquifer U02. The single anomaly in the aquifer numbering system is Bedrock Aquifer UDR (Upper Direct Recharge), which is inferred to recharge the Shuswap River, rather than being associated with an unconsolidated aquifer. It is important to note that only two-dimensional (horizontal) flow linkages were considered in this study. Considerably more data and analysis would be required to develop three dimensional linkages (i.e., the vertical component of flow between adjacent aquifers, as well as components of horizontal flow in discrete aquifer layers).

The general geometry, sizes, number of upland bedrock recharge areas and general groundwater flow directions will be discussed in the sections pertaining to each of the Upper, Middle, and Lower Shuswap River Watershed.

3.6.5 Annual Groundwater Flows

Estimates of volumetric discharge for each aquifer and each section of the Shuswap River Watershed were made to assess potential flow volumes and assist with the preliminary estimates of groundwater allotment and consumption. While considerable data would need to be incorporated into this conceptual model to begin validating the data, the discharges for each region ranged from approximately 2 m³/s for the Upper Shuswap River Watershed, 6 m³/s for the Middle Shuswap River Watershed, and 0.7 m³/s for the Lower Shuswap River Watershed. This suggests that all groundwater could be accounted for within approximately one order of magnitude if estimates of hydraulic conductivity, saturated thickness, and hydraulic gradient (and to a lesser extent porosity) could be refined and evaluated more thoroughly through further investigation.
3.7 Ecology

The ecological components of the Shuswap River Watershed include the plant, wildlife, and fisheries species and communities present and their interactions with one another. The specific assemblage of species present at a certain location is influenced by the existing environmental conditions, as well as the level of anthropogenic disturbance present at that location. The following sections describe these features in greater detail with a specific focus on the species and assemblages associated with aquatic and riparian habitat.

3.7.1 Vegetation

The plant species present in the Shuswap River Watershed are influenced by the prevailing climatic and topographic conditions, which define the BEC zones present. The majority of this watershed is characterized by three BEC zones: IDF, ICH, and ESSF. Within zonal sites of the IDF, the vegetation present consists primarily of mature interior Douglas-fir (Pseudotsuga menziesii var. glauca) forests, with lodgepole pine (Pinus contorta), ponderosa pine (P. ponderosa), and trembling aspen (Populus tremuloides) as common seral species (Lloyd et al. 1990). The understory in this zone is characterized by abundant pinegrass (Calamagrostis rubescens), with birch-leaved spirea (Spirea betulifolia), heart-leaved arnica (Arnica cordifolia), soapbush (Cotoneaster uva-ursi), and kinnikinnick (Arctostaphylos uva-ursi) (Lloyd et al. 1990). Large grassland communities dominated by bluebunch wheatgrass and fescue species are also present throughout much of this zone. Wetter sites in the IDF are characterized by a canopy of interior Douglas-fir and hybrid white spruce (Picea engelmannii x glauca) and an understory dominated by black gooseberry (Ribes lacustre), red-osier dogwood (Cornus stolonifera), black twinberry (Lonicera involucrata), and prickly rose (Rosa acicularis) (Lloyd et al. 1990). Zonal sites of the IDF are drier than those of the ICH.

The vegetation of the ICH zone in the Shuswap River Watershed is typically characterized by dense conifer forests dominated by western redcedar (Thuja plicata) and western hemlock (Tsuga heterophylla), with common seral species including interior Douglas-fir, lodgepole pine, trembling aspen, and paper birch (Betula papyrifera) (Lloyd et al. 1990). The understory of zonal sites is typically dominated by shrub species such as black huckleberry (Vaccinium membranaceum), queen’s cup (Clintonia uniflora), bunchberry (Cornus canadensis), and twinflower. Drier subzones within the ICH have a greater cover of moss species, particularly red-stemmed feathermoss (Pleurozium schreberi), and wetter subzones have a greater cover of herbs such as oak fern (Gymnocarpium dryopteris), one-leaved foamflower (Tiarella trifoliata var. unifoliata), rosy twistedstalk (Streptopus lanceolatus), five-leaved bramble (Rubus pedatus), and skunk cabbage (Lysichiton americanum). Riverine areas in the ICH zone are characterized by marsh wetland and riparian systems with trembling aspen, black cottonwood (P. balsamifera trichocarpa), willows (Salix spp.), sedges, and horsetails.

The ESSF zone areas of the Shuswap River Watershed is dominated by mature forests of Engelmann spruce (Picea engelmannii) and subalpine fir (Abies lasiocarpa) at its lower and middle elevations, transitioning to subalpine parkland at higher elevations (Lloyd et al. 1990). Lodgepole pine is common in drier areas, while mountain hemlock (Tsuga mertensiana) is characteristic of wet subzones of the Monashee Range. The understory of zonal sites is characterized by black huckleberry, white-flowered rhododendron (Rhododendron albiflorum), and five-leaved bramble. Grouseberry (Vaccinium scoparium) is common in drier subzones, while oval-leaved blueberry (V. Ovalifolium), false azalea (Menziesia ferruginea), and oak fern are characteristic of wetter subzones. Subalpine grassland and subalpine meadows dominated by herbaceous species occur throughout the ESSF. Where avalanche tracks occur in this zone, the vegetation is dominated by tall shrub species such as Sitka alder (Alnus crispa spp. sinuata). Deciduous trees are uncommon in the ESSF.
According to the BC Conservation Data Centre, there are 37 plant species of management concern, including 11 red-listed and 26 blue-listed species, that use the IDF, ICH, and/or ESSF zones within the RDNO. Plant species of management concern that have been recorded within or near the Shuswap River Watershed are listed in Table 8. These records are depicted in Figure 18.

### Table 8: Plant Species of Management Concern Occurrence Records within Shuswap River Watershed

<table>
<thead>
<tr>
<th>Class</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>BC Status*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pink agoseris</td>
<td>Agoseris lackschewitzii</td>
<td>Blue</td>
</tr>
<tr>
<td>Dicot</td>
<td>Giant helleborine</td>
<td>Epipactis gigantea</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Orange touch-me-not</td>
<td>Impatiens aurella</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Flat-topped broomrape</td>
<td>Orobanche corymbosa ssp. mutabilis</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Tweedy's willow</td>
<td>Salix tweedyi</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Blunt-sepaled starwort</td>
<td>Stellaria obtusa</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Northern violet</td>
<td>Viola septentrionalis</td>
<td>Red</td>
</tr>
<tr>
<td>Monocot</td>
<td>Fox sedge</td>
<td>Carex vulpinoidea</td>
<td>Blue</td>
</tr>
<tr>
<td></td>
<td>Porcupinegrass</td>
<td>Hesperostipa spartea</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Yellow widelip orchid</td>
<td>Liparis loeselii</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Brown beak-rush</td>
<td>Rhynchospora capillacea</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Moonwort</td>
<td>Mountain moonwort</td>
<td>Red</td>
</tr>
<tr>
<td></td>
<td>Crested wood fern</td>
<td>Dryopteris cristata</td>
<td>Blue</td>
</tr>
</tbody>
</table>


* BC status defined by BC CDC (2011) where red-listed species are native species that have or are candidates for extirpated, endangered, or threatened status in BC, and blue-listed species are native species considered to be of special concern in BC.

### 3.7.2 Ecological Communities

Sensitive ecosystems within the RDNO typically include the following habitats: wetlands, riparian forests, broadleaf woodlands, coniferous woodlands, old forests, grasslands, and sparsely vegetated ecosystems (e.g., rocky outcrops, talus slopes). Sensitive Ecosystem Inventory (SEI) was conducted in 2007 along a 1 km band on either side of a section of the Middle Shuswap River between the Peers Dam at the Sugar Lake outlet and Wilsey Dam at Shuswap Falls (Minor 2007b), and is currently in the process of being ground-truthed and finalized, with the final report to be completed for March 2012. No other SEI or terrestrial ecosystem mapping (TEM) has been completed within the Shuswap River Watershed (BC MFLNRO 2011); however, all of the above-listed sensitive ecosystems are likely present within the Shuswap River Watershed.

Of particular interest to this Technical Assessment of the Shuswap River Watershed is the presence of riparian ecosystems associated with the Shuswap River and its tributaries. Riparian ecosystems are defined as moist ecosystems that are significantly influenced by adjacent water bodies such that they are distinct from adjacent upland communities (Iverson et al. 2008). These communities are often linear in nature (e.g., banding streams or lake foreshores), and are often influenced by flooding, sediment deposition, erosion, and groundwater flows associated with the adjacent water body (Iverson et al. 2008). These ecosystems are important because they support species and ecological communities of management concern, they support high biodiversity, they are
sensitive to disturbance, they influence adjacent water quality, and they provide flood and erosion protection (Iverson et al. 2008).

According to the BC CDC (2011), there are six red-listed and five blue-listed riparian communities that occur in the IDF or ICH zones within the RDNO and no riparian communities of management concern that occur in the ESSF zone. These communities are listed in Table 9 along with their provincial status and their priority within the province’s six-class Conservation Framework. In addition to these riparian communities, there are 24, 14, and 12 ecological communities of management concern that occur in the IDF, ICH, and ESSF zones, respectively, within the RDNO.

Table 9: Riparian Communities of Management Concern in the Shuswap River Watershed

<table>
<thead>
<tr>
<th>English Name</th>
<th>BEC Zone</th>
<th>BC Status*</th>
<th>BC Priority**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black cottonwood – Douglas-fir / common snowberry – red-osier dogwood</td>
<td>IDF</td>
<td>Red</td>
<td>1</td>
</tr>
<tr>
<td>Trembling aspen / common snowberry / mountain sweet-cicely</td>
<td>IDF</td>
<td>Red</td>
<td>1</td>
</tr>
<tr>
<td>Trembling aspen / common snowberry / Kentucky bluegrass</td>
<td>IDF</td>
<td>Red</td>
<td>2</td>
</tr>
<tr>
<td>Douglas-fir / Douglas maple – red-osier dogwood</td>
<td>IDF</td>
<td>Red</td>
<td>2</td>
</tr>
<tr>
<td>Western redcedar – Douglas-fir / false Solomon’s seal</td>
<td>IDF</td>
<td>Red</td>
<td>2</td>
</tr>
<tr>
<td>Western redcedar – Douglas-fir / red-osier dogwood</td>
<td>IDF</td>
<td>Blue</td>
<td>2</td>
</tr>
<tr>
<td>Black cottonwood / common snowberry – roses</td>
<td>IDF, ICH</td>
<td>Red</td>
<td>1</td>
</tr>
<tr>
<td>Sitka willow / Sitka sedge</td>
<td>ICH</td>
<td>Blue</td>
<td>2</td>
</tr>
<tr>
<td>Western redcedar – western hemlock / common horsetail</td>
<td>ICH</td>
<td>Blue</td>
<td>2</td>
</tr>
<tr>
<td>Mountain alder / red-osier dogwood / lady fern</td>
<td>ICH</td>
<td>Blue</td>
<td>3</td>
</tr>
<tr>
<td>Mountain alder / common horsetail</td>
<td>ICH</td>
<td>Blue</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: BC Species and Ecosystems Explorer (BC CDC 2011).

* BC status defined by BC CDC (2011) where red-listed species are native species that have or are candidates for extirpated, endangered, or threatened status in BC, and blue-listed species are native species considered to be of special concern in BC.

** BC conservation priority assigned to each species or ecological community under the provincial Conservation Framework, between 1 (highest) and 6 (lowest) for each of the three Conservation Framework Goals, with the value shown representing the highest priority across all three Goals (BC CDC 2011).

3.7.3 Wildlife Species and Habitat

The wildlife species assemblage present in the Shuswap River Watershed is influenced by the habitat types available, which are a function of the prevailing climatic, topographic, and therefore vegetative regimes. Factors that influence wildlife use of the IDF zone include its relatively short, cool winters and variable-canopy forests (Meidinger and Pojar 1991). As the IDF is situated at lower elevations with less extreme weather conditions and smaller snowpacks than either the ICH or ESSF, this zone provides important winter range for ungulate species such as mule deer (wildlife scientific names are provided in Table 10 below), white-tailed deer, and elk that seasonally migrate from these cooler zones (Meidinger and Pojar 1991). The conifer-dominated forests of the IDF also provide winter habitat for non-migratory passerine birds, and breeding habitat for cavity-nesting species (Meidinger and Pojar 1991).
Wildlife use of the ICH is influenced by this zone’s climatic conditions, as well as its dense conifer forests, which provide abundant summer foraging opportunities for bird species that eat conifer seeds and bark-inhabiting insects (Meidinger and Pojar 1991). This zone, as well as the ESSF zone, provide productive bear habitat, as these species are able to access high quality foraging habitat during the summer and avoid the winter period through hibernation. While many ungulate species avoid the cool, snowy conditions of the ICH during the winter month, caribou migrate through the ICH on their way to higher elevation ESSF habitats where the snowpacks provide lichen foraging opportunities and refuge from predators. The steep topography of the ESSF restricts the species of wildlife that are able to use this zone, but also creates unique habitat opportunities. For example, avalanche tracks in the ESSF zone are often exploited as summer foraging habitat by ungulate and bear species (Meidinger and Pojar 1991).

Riparian habitats provide a number of unique wildlife habitat values due to their high productivity and structural complexity. These ecosystems are highly productive sites for insect and other invertebrate species (Iverson et al. 2008), and therefore are also exploited by invertebrate-eating wildlife species. Riparian habitat also provides breeding habitat for some amphibian species, and important foraging and thermoregulation opportunities for snake species. With their abundance of deciduous trees, riparian habitats also provide niche opportunities such as tree cavities for cavity nesting birds, snags for raptor stick nests and perching, and roosting sites for bats. These productive habitats are often characterized by dense, shrubby vegetation that provide both forage and shelter opportunities for bird and small mammals species. Riparian habitat also provides cover, browse, and calving areas for ungulate species, and travel corridors for a variety of species (Meidinger and Pojar 1991). The lower elevation riparian habitats are typically more productive in the IDF and ICH zones compared to the ESSF (Meidinger and Pojar 1991). Representative wildlife species of riparian habitats in the IDF, ICH, and ESSF are provided in Table 10.

Table 10: Representative Wildlife Species of Riparian Habitats in the IDF, ICH, and ESSF Zones

<table>
<thead>
<tr>
<th>Class</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Status</th>
<th>BEC Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphibian</td>
<td>Western toad</td>
<td>Anaxyrus boreas</td>
<td>Blue</td>
<td>IDF, ICH, ESSF</td>
</tr>
<tr>
<td></td>
<td>Pacific chorus frog</td>
<td>Pseudacris regilla</td>
<td>Yellow</td>
<td>ICH</td>
</tr>
<tr>
<td></td>
<td>Columbia spotted frog</td>
<td>Rana luteiventris</td>
<td>Yellow</td>
<td>IDF, ICH, ESSF</td>
</tr>
<tr>
<td></td>
<td>Long-toed salamander</td>
<td>Ambystoma macrodactylum</td>
<td>Yellow</td>
<td>IDF, ESSF</td>
</tr>
<tr>
<td>Reptile</td>
<td>Northern rubber boa</td>
<td>Charina bottae</td>
<td>Yellow</td>
<td>IDF, ICH</td>
</tr>
<tr>
<td></td>
<td>Common garter snake</td>
<td>Thamnophis sirtalis</td>
<td>Yellow</td>
<td>IDF, ICH, ESSF</td>
</tr>
<tr>
<td></td>
<td>Western terrestrial garter snake</td>
<td>Thamnophis elegans</td>
<td>Yellow</td>
<td>ICH</td>
</tr>
<tr>
<td></td>
<td>Northern alligator lizard</td>
<td>Elgaria coerulea</td>
<td>Yellow</td>
<td>IDF, ICH</td>
</tr>
<tr>
<td></td>
<td>Western painted turtle</td>
<td>Chrysemys picta pop. 2</td>
<td>Blue</td>
<td>IDF</td>
</tr>
<tr>
<td>Bird</td>
<td>American kestrel</td>
<td>Falco sparverius</td>
<td>Yellow</td>
<td>IDF, ICH</td>
</tr>
<tr>
<td></td>
<td>Bald eagle</td>
<td>Haliaeetus leucocephalus</td>
<td>Yellow</td>
<td>IDF, ICH</td>
</tr>
<tr>
<td></td>
<td>Osprey</td>
<td>Pandion haliaetus</td>
<td>Yellow</td>
<td>IDF</td>
</tr>
<tr>
<td></td>
<td>Canada goose</td>
<td>Branta canadensis</td>
<td>Yellow</td>
<td>IDF</td>
</tr>
<tr>
<td></td>
<td>Trumpeter swan</td>
<td>Cygnus buccinator</td>
<td>Yellow</td>
<td>IDF</td>
</tr>
<tr>
<td></td>
<td>Tundra swan</td>
<td>Cygnus columbianus</td>
<td>Blue</td>
<td>ICH</td>
</tr>
<tr>
<td></td>
<td>Common loon</td>
<td>Gavia immer</td>
<td>Yellow</td>
<td>ICH</td>
</tr>
<tr>
<td></td>
<td>Eared grebe</td>
<td>Podiceps nigricollis</td>
<td>Yellow</td>
<td>IDF, ICH</td>
</tr>
</tbody>
</table>
According to the BC Conservation Data Centre, there are 62 wildlife species of management concern, including 17 red-listed and 45 blue-listed species, which use the IDF, ICH, and/or ESSF zones within the RDNO. Wildlife species of management concern for which there are provincial occurrence records within or near the Shuswap River Watershed are listed in Table 11. These records are depicted in Figure 18. In addition to these species, the blue-listed great blue heron (Ardea herodias herodias) has also been observed in the Shuswap River Watershed between Shuswap Falls and Mabel Lake (Davis and Weir 2004). Recent specific surveys for western screech-owl (Megascops kennicottii macfarlanei) have confirmed a previously unknown breeding subpopulation of this species along the Middle Shuswap River (Davis and Weir 2004). A maternal colony of approximately 60 to 70 blue-listed Townsend’s big-eared bats has also been identified on the north side of the Middle Shuswap River (Kellner and van Oort 2007). Wildlife Habitat Areas have been designated for species of management concern in the Shuswap River Watershed, including two for western screech-owl on the Middle Shuswap River near its
confluence with Woodward Creek (8-261 and 8-262), and five for caribou on the Upper Shuswap River near Joss Mountain (8-226 to 8-230).

Table 11: Wildlife Species of Management Concern Occurrence Records in the Shuswap River Watershed

<table>
<thead>
<tr>
<th>Class</th>
<th>Common Name</th>
<th>Scientific Name</th>
<th>BC Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amphibian</td>
<td>Great Basin spadefoot</td>
<td>Spea intermontana</td>
<td>Blue</td>
</tr>
<tr>
<td>Reptile</td>
<td>Western skink</td>
<td>Plestiodon skiltonianus</td>
<td>Blue</td>
</tr>
<tr>
<td>Bird</td>
<td>Bobolink</td>
<td>Dolichoonyx oryzivorus</td>
<td>Blue</td>
</tr>
<tr>
<td>Bird</td>
<td>Western screech-owl</td>
<td>Megascosps kennicottii macfarlanie</td>
<td>Red</td>
</tr>
<tr>
<td>Mammal</td>
<td>Caribou</td>
<td>Rangifer tarandus pop. 1</td>
<td>Red</td>
</tr>
</tbody>
</table>

* BC status defined by BC CDC (2011) where red-listed species are native species that have or are candidates for extirpated, endangered, or threatened status in BC, and blue-listed species are native species considered to be of special concern in BC.

3.7.4 Fish and Aquatic Habitat

The Shuswap Watershed is one of the most important salmon-producing systems in British Columbia and provides for a wide variety of residential and anadromous fish species. Table 12 provides a list of the fish species that have been recorded in the Shuswap River and a selection of its tributaries and adjacent lakes, including the family, scientific name, and conservation status of each species. These data are derived from FISS (MoE 2011e) fish distribution queries for these waterbodies, which show that fewer fish species are present in the upper sub-drainages compared to Shuswap River and its associated lakes.
## Table 12: Fish Species Distributions in Select Tributaries of the Shuswap River Watershed

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Family</th>
<th>Status</th>
<th>Shuswap River</th>
<th>Mara Lake</th>
<th>Mabel Lake</th>
<th>Wap Creek</th>
<th>Bessette Creek</th>
<th>Cherry Creek</th>
<th>Sugar Lake</th>
<th>Spectrum Creek</th>
<th>Greenbush Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longnose sucker</td>
<td><em>Catostomus catostomus</em></td>
<td>Catostomidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bridgelip sucker</td>
<td><em>Catostomus columbianus</em></td>
<td>Catostomidae</td>
<td>Yellow</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Largescalke sucker</td>
<td><em>Catostomus macrocheilus</em></td>
<td>Catostomidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sucker spp.</td>
<td><em>Catostomus spp.</em></td>
<td>Catostomidae</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Prickly sculpin</td>
<td><em>Cottus asper</em></td>
<td>Cottidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Slimy sculpin</td>
<td><em>Cottus cognatus</em></td>
<td>Cottidae</td>
<td>Yellow</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sculpin spp.</td>
<td>-</td>
<td>Cottidae</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Lake chub</td>
<td><em>Couesius plumbeus</em></td>
<td>Cyprinidae</td>
<td>Yellow / DD</td>
<td>X**</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Common carp</td>
<td><em>Cyprinus carpio</em></td>
<td>Cyprinidae</td>
<td>Exotic</td>
<td>X**</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Peamouth</td>
<td><em>Mylocheilus caurinus</em></td>
<td>Cyprinidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Northern pikeminnow</td>
<td><em>Ptychocheilus oregonensis</em></td>
<td>Cyprinidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Longnose dace</td>
<td><em>Rhinichthys cataractae</em></td>
<td>Cyprinidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Leopard dace</td>
<td><em>Rhinichthys falcatus</em></td>
<td>Cyprinidae</td>
<td>Yellow / NAR</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Redside shiner</td>
<td><em>Richardsonius balteatus</em></td>
<td>Cyprinidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Dace spp.</td>
<td>-</td>
<td>Cyprinidae</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Burbot</td>
<td><em>Lota lota</em></td>
<td>Lotidae</td>
<td>Yellow</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cutthroat trout</td>
<td><em>Oncorhynchus clarkii lewisi</em></td>
<td>Salmonidae</td>
<td>Blue / SC</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pink salmon</td>
<td><em>Oncorhynchus gorbuscha</em></td>
<td>Salmonidae</td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Coho salmon</td>
<td><em>Oncorhynchus kisutch</em></td>
<td>Salmonidae</td>
<td>Yellow / E</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rainbow trout</td>
<td><em>Oncorhynchus mykiss</em></td>
<td>Salmonidae</td>
<td>Yellow</td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td>X*</td>
<td>X</td>
<td>X*</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Kokanee</td>
<td><em>Oncorhynchus nerka</em></td>
<td>Salmonidae</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Sockeye salmon</td>
<td><em>Oncorhynchus nerka</em></td>
<td>Salmonidae</td>
<td>Yellow / E</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chinook salmon</td>
<td><em>Oncorhynchus tshawytscha</em></td>
<td>Salmonidae</td>
<td>Yellow / T</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
<th>Family</th>
<th>Status</th>
<th>Shuswap River</th>
<th>Mara Lake</th>
<th>Mabel Lake</th>
<th>Wap Creek</th>
<th>Bessette Creek</th>
<th>Cherry Creek</th>
<th>Sugar Lake</th>
<th>Spectrum Creek</th>
<th>Greenbush Creek</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mountain whitefish</td>
<td><em>Prosopium williamsoni</em></td>
<td><em>Salmonidae</em></td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Bull trout</td>
<td><em>Salvelinus confluentus</em></td>
<td><em>Salmonidae</em></td>
<td>Blue / C</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lake trout (char)</td>
<td><em>Salvelinus namaycush</em></td>
<td><em>Salmonidae</em></td>
<td>Yellow</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Whitefish spp.</td>
<td>-</td>
<td><em>Salmonidae</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Other fish spp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
<tr>
<td><strong>Total Fish Species</strong></td>
<td></td>
<td></td>
<td></td>
<td>22</td>
<td>22</td>
<td>15</td>
<td>12</td>
<td>11</td>
<td>4</td>
<td>14</td>
<td>3</td>
<td>7</td>
</tr>
</tbody>
</table>

Source: Fisheries Information Summary System (BC MoE 2011e).

* These records indicate that both resident and hatchery production fish are present.

** Additional species accounts supplied by Darryl Arsenault (Golder Associates Ltd., pers. comm.) and Brian Robertson (BC MFLNRO, pers. comm.).
As shown in Table 12, rainbow trout have been stocked in most of the selected tributaries and adjacent lakes. Kokanee have also been stocked in Sugar Lake (Chamberlain et al. 2001). Chinook salmon and coho salmon are also cultured at the Shuswap River Hatchery, located at Shuswap Falls, where activities include broodstock collection, adult holding and spawning, incubation, juvenile rearing, coded-wire tagging, and release of these two species. The Middle and Lower Shuswap River supports a unique sub-population of coho salmon, and Bessette Creek has been identified by DFO to be of special conservation concern (Interior Fraser Coho Recovery Team 2006). Matthews and Bull ranked the significance of each of the main sub-drainages of the Shuswap River Watershed for habitat protection for fisheries based on the presence and sensitivity of important fish as well as the capacity of the sub-drainage to produce fish; the results of this ranking are provided in Figure 19.

All four salmon species listed in Table 12 are historically present and known to spawn in the Shuswap River below Shuswap Falls, which originally formed a partial barrier to fish passage, although records of chinook salmon and sockeye salmon above the falls prior to dam construction exist (Anonymous 2003). No fish ladder or other passage structure is present at the Wilsey Dam, which has created a complete barrier to passage for all salmon species since 1929; as shown in Table 12, no salmon species are present in any of the selected sub-drainages upstream of Bessette Creek. Feasibility studies have identified the Wilsey Dam as a candidate facility for anadromous reintroduction, with a specific focus on chinook salmon and coho salmon (Bengeyfield et al. 2001; Wilsey Dam Fishway Steering Committee 2005). Peers Dam at Brenda Falls just below the outlet of Sugar Lake also acts as a barrier to fish passage; however, it is believed that Brenda Falls was a natural barrier prior to dam construction (Bengeyfield et al. 2001). Chinook salmon have been released by DFO into the Middle Shuswap River above Wilsey Dam in at least three occasions (1977, 1993, 1995) as part of restoration efforts in this section of the stream (Anonymous 2003).

As shown in Table 12, numerous federal and provincial fish species of management concern are present in the Shuswap River Watershed. Bull trout (Salvelinus confluentus) is known to spawn throughout the Shuswap River Watershed, with confirmed observations of this species in the Middle Shuswap River both below and above Wilsey Dam, in the Upper Shuswap River, and in Cherry Creek, Sugar Lake, Sitkum Creek, Vigue Creek, Gates, Creek, Lindmark Creek, and Greenbush Lake (Chamberlain et al. 2001). However, low population levels of this species between the two hydroelectric dams, due to isolation, creates an extirpation risk for this species (Chamberlain et al. 2001). Dolly varden was once considered the same species as bull trout. Species records in Sugar Lake and Mabel Lake formally referred to as Dolly varden have been changed in the above table to reflect current fish nomenclature and distribution knowledge (McPhail 2007). In addition to bull trout, rainbow trout and kokanee are identified as regionally important species in the BC MoE Okanagan Region (Matthews and Bull 2003); these two species are known throughout much of the study area. The abundant side channels throughout the Shuswap River are particularly important spawning areas for kokanee (Chamberlain et al. 2001).

Instream flows for fisheries are directly related to natural water availability (i.e., rainfall, snow melt, groundwater) and human water use. Consumptive water use, such as for irrigation, industrial, or domestic purposes, reduces instream flow and has the potential to negatively impact fish and fish habitat if instream flows are reduced too much. Storage reservoirs can be used to store water from higher flow periods like spring freshet to supply water during lower flow periods, but diversion of water into storage during low flow winter months and excessive diversion into storage during freshet on smaller streams can also have negative implications for fish and fish habitat. Minimum instream flow thresholds are a measure or estimate of the instream flows required to support aquatic ecosystem values. In general, flows within the Shuswap River Watershed change throughout the year, with high flows during spring freshet and much lower flows in late summer and winter. Fish and ecosystem
requirements change accordingly with species and life stage requirements that have been shaped by the flow regimes. Flow thresholds are often set on a monthly or even weekly basis over a calendar year. During periods when instream flows exceed the thresholds, additional water could be available for allocation without negatively impacting fish and fish habitat. Conversely, when instream flow thresholds are not being met, the stream could be considered to be fully allocated and water conservation and management strategies should be considered to bring instream flows up to the thresholds. It must be noted that there is a wide range in natural flow conditions and that in dry and drought years, even full natural flows may not be sufficient to meet the thresholds at all times of the year.

3.8 Land Use

Diverse and historical land uses are present in the Shuswap River Watershed. Settlement by non-First Nations peoples occurred in conjunction first with historical fur-trading routes in the early 1800s and subsequently with gold and silver extraction activities in the mid to late 1800s, particularly in the Cherry and Monashee Creek sub-drainages (RDNO 1975). Various mineral tenures are currently held, particularly west of the Upper Shuswap River in association with Tsusui Creek, Kingfisher Creek, and Harris Creek, as well as near Wap Creek, Monashee Creek, Cherry Creek, and Creighton Creek (BC MFLNRO 2011). Extensive forestry activities were initiated throughout the Lower and Middle Shuswap River Watersheds following the construction of a sawmill in Enderby in 1894 (RD NO 1975). These activities have since expanded throughout the Upper Shuswap River Watershed and logging continues to be a major economic driver in the area. Forestry activities include both crown land logging by large companies and private land logging, the latter of which is particularly prevalent in the Middle and Lower watersheds.

Agricultural activities in the Shuswap River Watershed commenced in the early 1900s, including orchard and irrigation establishment, which failed to be as profitable as areas to the south in the Okanagan Valley (RDNO No date). Ranching and farming activities were later adopted in the area and continue to dominate the fertile valley and bench areas of the Shuswap River Watershed, particularly south and west of Mabel Lake. These agricultural activities include beef, swine, and dairy production, as well as associated services such as meat packing and feed mills (RDNO 2005). In addition, active range tenures are held throughout the Shuswap River Watershed, particularly on crown lands west of the Upper Shuswap River and in both the Middle and Lower Shuswap River Watersheds (BC MFLNRO 2011). A substantial amount of the private land in the Shuswap River Watershed is within the Agricultural Land Reserve (ALR), and a wide range of agricultural activities are encouraged (RDNO No date). Land within the ALR, as well as locations of potential sources of contamination in the Shuswap River Watershed are shown on Figure 20.

Extensive settlement of the Shuswap River Watershed occurred in the early to mid 1900s as a result of improved transportation routes and the arrival of electricity (RDNO 1975). The majority of communities within the Shuswap River Watershed are serviced by municipal and/or private water sources, both using surface water and groundwater. Sewage disposal facilities range from individual septic fields discharging untreated waste to ground, to small communal disposal systems for manufactured homes and small resorts, to larger communal sewage disposal system, the latter two having varying levels of treatment prior to surface water or ground disposal.

Table 13 summarizes water and sewer services for several communities within the Shuswap River Watershed.
### Table 13: Community Water and Sewer Services

<table>
<thead>
<tr>
<th>Watershed Area</th>
<th>Community</th>
<th>Water</th>
<th>Sewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Shuswap River Watershed</td>
<td>Area around Sugar Lake</td>
<td>Private wells and surface water licenses</td>
<td>Private septic disposal fields</td>
</tr>
<tr>
<td></td>
<td>Cherryville</td>
<td>Private wells and small private and municipal community supply systems</td>
<td>Private septic disposal fields; small communal disposal systems</td>
</tr>
<tr>
<td>Middle Shuswap River Watershed</td>
<td>Mable Lake</td>
<td>Municipal source (surface water) owned and operated by RDNO; small private communal supply systems; private wells</td>
<td>Community disposal system owned and operated by Lumby; some private septic fields</td>
</tr>
<tr>
<td></td>
<td>Lumby</td>
<td>Municipal source (groundwater) owned and operated by Lumby and private wells</td>
<td>Private septic disposal fields</td>
</tr>
<tr>
<td></td>
<td>Whitevale</td>
<td>Municipal source (groundwater) owned and operated by RDNO; private wells</td>
<td>Private septic disposal fields</td>
</tr>
<tr>
<td>Lower Shuswap River Watershed</td>
<td>Kingfisher</td>
<td>Private wells; small community supply systems</td>
<td>Private septic disposal fields; small communal disposal systems</td>
</tr>
<tr>
<td></td>
<td>Enderby</td>
<td>Municipal source (surface water and groundwater) owned and operated by Enderby; private wells</td>
<td>Private septic disposal fields and community disposal system owned and operated by Enderby.</td>
</tr>
<tr>
<td></td>
<td>Grindrod</td>
<td>Municipal source (surface water) owned and operated by RDNO; private wells</td>
<td>Private septic disposal systems</td>
</tr>
<tr>
<td></td>
<td>Mara</td>
<td>Private wells; small community supply systems</td>
<td>Private septic disposal systems; small communal disposal systems</td>
</tr>
</tbody>
</table>

* A small communal sewage disposal field is represented by mobile home parks, lodges, etc., and is typically smaller than a small community sewage disposal system. Private septic fields are maintained by the owner.

Hydroelectric dams have formed a key part of the power supply in this area since 1929. Peers (aka Sugar Lake) Dam, located at Brenda Falls at the outlet of Sugar Lake, provides impounded water storage, while Wilsey Dam, located 31 km downstream at Shuswap Falls, is a diversion dam that provides power generation for the Shuswap Falls generating station (Anonymous 2003). This station generates between 1.1 and 4.7 million kilowatt hour (kWH), with a monthly contribution of less than 0.1% of the BC Hydro integrated hydroelectric grid system (Hirst 1991). These dams have resulted in substantial alterations of the Shuswap River, particularly by forming barriers to fish passage.

Numerous all-season recreational opportunities are present throughout the Shuswap River Watershed and form part of the tourism industry, including hiking, biking, skiing, horseback riding, climbing, wildlife viewing, boating, fishing, hunting, snowmobiling, and recreational vehicle use. Dedicated areas for many of these activities exist. Provincial Parks within the Shuswap River Watershed include Monashee, Echo Lake, Denison-Bonneau, Vance Creek, Silver Star, Mabel Lake, Wap Creek, Mount Griffith, Kingfisher Creek, Skookumchuck Rapids, and Shuswap River Islands, and numerous forestry recreation sites are also present. Provincial Ecological Reserves within the Shuswap River Watershed include Upper Shuswap River, Mount Griffith, and Kingfisher Creek, and Protected Areas include Greenbush Lake Protected Area and Enderby Cliffs.
4.0 UPPER SHUSWAP RIVER WATERSHED

This section provides a watershed profile for the Upper Shuswap River Watershed, which is the portion of the Shuswap River Watershed above the Sugar Lake outlet including the sub-drainages associated with the Upper Shuswap River and its direct and indirect tributaries (Figure 3). This section is divided into four parts, including a watershed description, and an assessment of the status of water quality, water quantity, and riparian areas in the Upper Shuswap River Watershed.

4.1 Watershed Description

The following sections provide a general description of the Upper Shuswap River Watershed, as well as a description of its hydrogeology and the land uses present.

4.1.1 General

The Upper Shuswap River Watershed is the most upstream portion of the Shuswap River Watershed between its headwaters (~1,675 masl) and the Sugar Lake outlet (~602 masl), located 60 km south, as shown in Figure 21. The headwaters of the Shuswap River originate from Joss Pass, a narrow valley between Joss Mountain and Davis Peak in the Sawtooth Range of the Monashee Mountains, approximately 19 km southwest of Revelstoke, British Columbia. Within its headwater reaches, this stream has an average channel width of 8 to 10 m, a relatively steep channel gradient of 4% to 9.3%, and channel substrates consisting of cobbles and gravels (Summit 1996). Below the headwater reaches, the Upper Shuswap River parallels Greenbush Creek within a wide, low gradient valley before these two streams join. Greenbush Creek is the most upstream of the major tributaries to the Upper Shuswap River, and water flows below the confluence of these two streams are substantially greater than higher up in the system (Summit 1996). Below Greenbush Creek, the Upper Shuswap River is once again confined to a relatively narrow valley with a floodplain width of approximately 70 m and a gradient between 0.5% and 2.4% (Summit 1996). Key sub-drainages within this section of the stream include Lindmark Creek, and further downstream Vanwyk Creek, then Gagney Creek.

Within its upper reaches, the Upper Shuswap River is primarily confined to a single channel. Further downstream, however, the Upper Shuswap River broadens and becomes irregularly meandering. The low channel gradient of <1% and the abundance of side channels in this section of the stream provide excellent fish spawning and rearing habitat (Summit 1996). Key sub-drainages of the Upper Shuswap River in this area include Gates Creek and further downstream Vigue Creek. Below this latter sub-drainage, the stream floodplain broadens substantially to up to 2 km wide with a channel width of 40 to 50 m (Summit 1996). Through this section, the Upper Shuswap River is increasingly winding with multiple remnant oxbow, side channel, island, and gravel bar features. The channel gradient is <1% and substrates consist of cobbles and gravels with some fine materials (Summit 1996). The most downstream sub-drainages connecting to the Upper Shuswap River above Sugar Lake are Spectrum Creek and Kate Creek. The Upper Shuswap River flows through Sugar Lake, and named sub-drainages to this lake include Sugar Creek, Sitkum Creek, and Outlet Creek on the eastern side of this lake, and Sprockton Creek on the western side of this lake.

The sub-drainages of the Upper Shuswap River can be grouped into two general morphologies based on whether they enter this stream from the Monashee Mountains to the east or from the Shuswap Highlands to the west. Sub-drainages to the east of the Upper Shuswap River are generally characterized by large, fourth order streams with moderate gradients that provide high quality spawning, rearing, and overwintering habitat for fish
(Scarborough and Couture 1998). Although the Peers Dam prevents fish passage from the lower reaches of the Shuswap River into Sugar Lake and the Upper Shuswap River, these two latter waterbodies are sufficiently sized to support adfluvial and fluvial fish stocks in addition to resident stocks, particularly of rainbow trout. In contrast, the sub-drainages to the west of the Upper Shuswap River are generally characterized by small, second or third order streams with steep gradients that restrict fish access to the first reach of the stream (Scarborough and Couture 1998). These western streams are also more likely to be affected by anthropogenic disturbances such as forestry activities and roadways, compared to the eastern streams.

4.1.2 Hydrogeology

There are no provincially identified aquifers or BC MoE observation wells in the Upper Shuswap River Watershed. Based on the methods described in the conceptual model in Section 2.4.2, seven discrete unconsolidated aquifers were delineated in the Upper Watershed which are numbered U01 through U07 (Figure 17). The area north and upstream of the beginning of Aquifer U1 is considered to be representative of direct recharge (Upper Direct Recharge (UDR)) to the Shuswap River from the mountainous slopes (i.e., bedrock aquifers) and is conceptualized to not recharge any alluvial or fluvial sediments, but rather directly discharge or provide recharge to the Shuswap River. In terms of the unconsolidated aquifers, U1 provides recharge to U2 while U2 provides recharge to U3. Five unconsolidated aquifers (U03, U04, U05, U06 and U07) discharge directly to Sugar Lake. The linkages of groundwater flow between unconsolidated aquifers are shown on Figure 22, below and on Figure 17.

Figure 22: Upper Shuswap River Watershed Aquifer Linkages

Aquifer characteristics of the upper Shuswap River Watershed are poorly understood, as information is minimal. In terms of the hydraulic gradients in the aquifers surrounding Sugar Lake, local gradients are inferred to be highly influenced by Lake levels, which are controlled at the outlet of Sugar Lake. Hydraulic gradients in the area of U01, U02 and the upper portion of U03 are controlled by water elevations within the Shuswap River.

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5 Fluvial fish spend their entire lifecycle in streams, while adfluvial fish spawn in streams but spend the majority of their lifecycle in lakes.
4.1.3 Land Use

The main land uses of the Upper Shuswap River Watershed are forestry operations and recreational opportunities. Tolko Industries Ltd. (previously Riverside Forest Products Ltd.) and Gorman Bros. Lumber Ltd. are the main forestry operators in this area (Weyerhaeuser et al. 2007). Sugar Lake Forest Service Road\(^6\) (FSR) is a main logging road that parallels the Upper Shuswap River and numerous secondary logging roads are present throughout this section of the watershed. Recreational opportunities in the Upper Shuswap River Watershed include hiking, horseback riding, climbing, fishing, hunting, snowmobiling, cat skiing, heli-skiing, and all-terrain vehicle use. Monashee Provincial Park near Spectrum Creek and BC MoF recreational sites at Sugar Lake and Greenbush Lake are present within the Upper Shuswap River Watershed. A small portion of the Upper Shuswap River is conserved in an Ecological Reserve located halfway between the Vanwyk Creek and Gates Creek sub-drainages. As of 1996, no large-scale mining operations or no water licenses were present in the Upper Shuswap River Watershed (Summit 1996). There is one mine or pit landmark located in the Spectrum Creek sub-drainage, and several mineral tenures are present throughout the watershed (BC MFLNRO 2011).

4.2 Water Quality

The following sections provide an overview of water quality in the Upper Shuswap River Watershed, as well as the results of the BC CSR Site Registry search and the risk assessment.

4.2.1 Overview

Water quality information for the Upper Shuswap River Watershed reviewed as part of this Technical Assessment is limited to surface water quality related to Sugar Lake largely based on the following two sources:


Overall, the water quality of Sugar Lake was characterized as “very good” and is described as quite clear and quite low in nutrients, phytoplankton, and zooplankton (Bryan and Jensen 1999). Sugar Lake is considered to be an oligotrophic lake, characterized by little biological production, despite nitrogen concentrations that fall outside the typical oligotrophic range (an average of 198 micrograms per litre (µg/L) in Sugar Lake versus typically <100 µg/L for oligotrophic lakes). Nitrogen to phosphorous ratios were typically observed to be greater than 14:1 throughout the year and, as such, phosphorous was identified as the limiting nutrient. Water samples for Sugar Lake were typically collected during freshet where sediment and organic nitrogen transport is considered to be highest.

A generalized trend analysis was undertaken for several key parameters at Sugar Lake, including sulphate, silica, sodium, calcium, alkalinity, magnesium and turbidity. Increasing trends were observed for sodium, calcium, alkalinity, and magnesium while decreasing trends were noted for specific conductance (as a proxy for total dissolved ions), acidity, and turbidity. Of note, the decreasing trend in specific conductance is inconsistent with the increasing trend in conductive parameters (sodium, calcium, alkalinity, and magnesium). Chloride

\(^6\) Also referred to as Shuswap Forest Service Road.
concentrations reported in Bryan and Jensen (1999) were close to the reportable detection limit and, consequently, are not statistically reliable for trend analysis. Anecdotal discussion in that report suggests that road salting activities are minimal upstream of Sugar Lake due to the limited residential and industrial development present. While the water quality data does suggest the potential for some road salting related impacts (elevated sodium), insufficient evidence exists to attribute the potential impacts to anthropogenic sources.

For the purposes of establishing a regional baseline background water quality benchmark, Bryan and Jensen (1999) considered Sugar Lake a potential control site due to the minimal water quality impacts and relatively low degree of upstream development.

4.2.2 BC Contaminated Sites Regulation: Site Registry Search

There is one property in the Upper Shuswap River Watershed that is filed with the BC MoE CSR Site Registry as described below in Table 14. This Site is considered inactive with respect to the CSR Registry with no further action required.

Table 14: Upper Shuswap River Watershed BC CSR Site Registry Search

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Common Name</th>
<th>Address</th>
<th>City</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>7020</td>
<td>Monashee Powder Adventures</td>
<td>Greenbush Lake Road</td>
<td>Cherryville</td>
<td>Inactive - No Further Action</td>
</tr>
</tbody>
</table>

4.2.3 Risk Assessment

As shown on Figure 20, and discussed in Table 14, only one property within the Upper watershed was identified in the CSR Site Registry: an inactive recreation site. The site is located a considerable distance from any major tributary to the Shuswap River and based on its land use (recreation site) and on its low likelihood to adversely impact the water quality in the Upper Shuswap River Watershed, it is ranked as a low risk (Figure 20).

4.3 Water Quantity

The following sections characterize the water quantity of the Upper Shuswap River Watershed, including the surface water flows, groundwater flows, estimate of water use and allocation, estimate of flow and allotment versus consumption, and minimum instream flow thresholds for this watershed.

4.3.1 Surface Water Flows

Only one WSC station, the Shuswap River at the outlet of Sugar Lake, is present in the Upper Shuswap River Watershed. Flow statistics (including monthly and annual mean flow, minimum flow, maximum flow and unit runoff) for this station are summarized in Table 15.
Table 15: Summary of Surface Water Flows by WSC Station in the Upper Shuswap River Watershed

<table>
<thead>
<tr>
<th>WSC Station No. 08LC011</th>
<th>Shuswap River at Outlet of Sugar Lake</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>16.8</td>
<td>17.5</td>
<td>17.1</td>
<td>31.4</td>
<td>80.4</td>
<td>118</td>
<td>66.5</td>
<td>27.8</td>
<td>23.5</td>
<td>21.8</td>
<td>20.9</td>
<td>17.7</td>
<td>38.5</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>27.3</td>
<td>46.6</td>
<td>38.0</td>
<td>80.8</td>
<td>150</td>
<td>192</td>
<td>130</td>
<td>89.7</td>
<td>73.2</td>
<td>57.6</td>
<td>43.9</td>
<td>38.3</td>
<td>55.0</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>5.84</td>
<td>5.07</td>
<td>5.53</td>
<td>8.25</td>
<td>40.0</td>
<td>66.5</td>
<td>13.3</td>
<td>16.2</td>
<td>10.0</td>
<td>10.8</td>
<td>7.96</td>
<td>6.72</td>
<td>23.6</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m$^3$/s) 38.5  Net Unit Runoff (mm) 1074
Estimated Surface Water Use (m$^3$/s) 0.0  Groundwater Use (m$^3$/s) -
Naturalized Mean Annual Discharge (m$^3$/s) 38.5  Naturalized Net Unit Runoff (mm) 1074
As there is no substantial estimated surface water or groundwater use in the Upper Shuswap River Watershed above this station (as discussed in more detail in Section 4.3.3), the naturalized mean annual discharge was assumed to be equal to the mean annual flow. The net unit runoff at this station is more than double the runoff from the contributing watersheds downstream of the station.

Sugar Lake is a hydroelectric reservoir, which does not alter the mean annual flow or net unit runoff from this WSC station, but does somewhat alter monthly flows due to reservoir operations. The large volume of runoff (mean annual flow of 1,214 million m$^3$/year) (Environment Canada, 2011c) relative to the storage volume of 133.7 million m$^3$/year (Homenuke and Groves 2005) limits the effects of regulation on downstream flows such that a relatively natural hydrograph is maintained downstream of Sugar Lake. There is little capacity to attenuate peak flows in this reservoir, but low flows in summer, fall and winter can easily be increased above natural levels when there is available stored water in the reservoir. Reservoir operations and operating rules are described in the BC Hydro Water Use Plan for this facility (Homenuke and Groves 2005).

### 4.3.2 Groundwater Flows

The estimated groundwater flows through the individual aquifers varies, as shown in Table 16, from approximately 0.05 m$^3$/s to 1.2 m$^3$/s, with an overall groundwater flow rate within the Upper Shuswap River Watershed as being on the order of 2 m$^3$/s (across an inferred cross-sectional area of aquifer). This is approximately one order of magnitude less than that of the minimum annual surface flow value of 23.6 m$^3$/s, as noted in Table 15, which can be considered reasonable when comparing groundwater flows as a percentage of surface water flows.

<table>
<thead>
<tr>
<th>Aquifer</th>
<th>Saturated Thickness (m)</th>
<th>Aquifer Width (m)</th>
<th>Hydraulic Gradient (m/m)*</th>
<th>Saturated Hydraulic Conductivity (m/s)</th>
<th>Q -Discharge (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U01</td>
<td>20</td>
<td>2,000</td>
<td>0.009</td>
<td>5.00E-04</td>
<td>0.18</td>
</tr>
<tr>
<td>U02</td>
<td>20</td>
<td>2,000</td>
<td>0.002</td>
<td>5.00E-04</td>
<td>0.05</td>
</tr>
<tr>
<td>U03</td>
<td>20</td>
<td>2,000</td>
<td>0.008</td>
<td>5.00E-04</td>
<td>0.15</td>
</tr>
<tr>
<td>U04</td>
<td>10</td>
<td>12,100</td>
<td>0.019</td>
<td>5.00E-04</td>
<td>1.17</td>
</tr>
<tr>
<td>U05</td>
<td>10</td>
<td>7,200</td>
<td>0.019</td>
<td>5.00E-04</td>
<td>0.70</td>
</tr>
<tr>
<td>U06</td>
<td>10</td>
<td>1,000</td>
<td>0.020</td>
<td>5.00E-04</td>
<td>0.10</td>
</tr>
<tr>
<td>U07</td>
<td>10</td>
<td>1,000</td>
<td>0.003</td>
<td>5.00E-04</td>
<td>0.02</td>
</tr>
<tr>
<td><strong>Total Groundwater Flow to Sugar Lake</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>2.14</strong></td>
</tr>
</tbody>
</table>

* Hydraulic gradients for U04, U05 and U07 were adjusted an order of magnitude downward to account for the influence of water levels at Sugar Lake on local hydraulic gradients.

### 4.3.3 Estimate of Water Use / Allocation

The following sections provide the results of the estimate of water use and allocation in the Upper Shuswap River Watershed based on water licenses, water allocation restrictions, Water Act reserves, and groundwater uses. As shown in these sections, little information is available for this watershed.
Water Licenses
A search for water licenses using the BC Water License Query (BC MoE 2011h) identified that there are no high use water licenses in the Upper Shuswap River Watershed. However, there are nine domestic water licenses on or near Sugar Lake and two enterprise licenses, one of which also has a commercial power authorization. The water use associated with each of these is inconsequential relative to the surface flows in the Upper Shuswap River Watershed. BC Hydro also has a Storage (Power) water license on Sugar Lake in the amount of 148,000,000 m$^3$/year. These water licenses are depicted in Figure 9.

Water Allocation Restrictions
A search of the complete list of water allocation restrictions in British Columbia identified that there are no water allocation restrictions in the Upper Shuswap River Watershed (BC MoE 2009).

Water Act Reserves
A search of the complete list of Water Act reserves in British Columbia identified that there are no Water Act reserves in the Upper Shuswap River Watershed (BC MoE 2009).

Groundwater Use
Although no confirmed groundwater uses are known in the Upper Shuswap River Watershed, it is possible that some private seasonal homes/cabins used for recreational purposes use groundwater through either drilled or dug wells. A total of 42 parcels have been identified within the Upper Shuswap River Watershed. Based on the RDNO's subdivision servicing bylaw, each parcel must be able to provide a minimum of 6,550 L/day (7.6x10$^{-6}$ m$^3$/s). As such, and assuming that each parcel withdraws the maximum allotted groundwater, it can be inferred that the potential groundwater use in the Upper Shuswap River Watershed is approximately 0.003 m$^3$/s. Actual usage is likely less than this as the majority of the parcels in the Upper Shuswap River Watershed are likely representative of seasonal homes that are not occupied year around.

4.3.4 Estimate of Flow / Allotment versus Consumption
As there are no confirmed agricultural, municipal, or community uses of surface water in the Upper Shuswap River Watershed, a detailed estimate of flow / allotment versus consumption cannot be provided.

A preliminary estimate of potential groundwater use within the Upper Shuswap River Watershed of 0.003 m$^3$/s represents approximately 0.1% of the estimated groundwater flows in the Upper Shuswap River Watershed. Although data is limited, it can be inferred that the consumption of surface water and groundwater is significantly less than actual flows in the area.

Total groundwater flows for the Upper Shuswap River Watershed, which are driven by topographical gradients and along the run of river to the outflow of Sugar Lake, provide an estimate of total flow on the order of 75,000,000 m$^3$/year. The only licensed user in the Upper Shuswap River Watershed with any significance is the storage license of BC Hydro for Sugar Lake, which allows 143,000,000 m$^3$/year to be allotted as a non-consumptive use of water. Even if the estimates of groundwater flow are off by up an order of magnitude, the groundwater estimates do not account for storage in lakes, rivers and streams which alone would be adequate in satisfying the BC Hydro license. Therefore, as there are no consumptive uses of water which would divert
natural flows from the outflow of the Upper Shuswap River Watershed, the allotment and consumption of water in this area does not raise any cause for concern.

### 4.3.5 Minimum Instream Flow Thresholds

No streams in the Upper Shuswap River Watershed have existing or recommended instream flow thresholds. Planning for fish protection requires setting of instream flow thresholds throughout the Upper Shuswap River Watershed streams with high fish values and existing and/or potential water use. Recommended methods for setting additional instream flow thresholds or targets are described and discussed in Appendix F.

### 4.4 Riparian Areas

This section of the Shuswap River Technical Assessment provides a preliminary assessment of the condition of riparian areas along the Upper Shuswap River, as well as identifying previous restoration works that have been completed within this section of the stream. Based on the results of this assessment, a preliminary prioritization of riparian areas of the Upper Shuswap River for restoration works was then completed.

#### 4.4.1 Riparian Areas Condition

The following sections describe previous impacts to the riparian areas of the Upper Shuswap River, as well as restoration activities that have already been completed throughout this section of the stream.

**Previous Impacts**

Previous impacts to the Upper Shuswap River are primarily related to hydroelectric dam construction and forestry operations. Peers Dam was constructed at Brenda Falls, located approximately 0.5 km downstream of the Sugar Lake outlet, in 1929. Construction of this dam resulted in loss of spawning habitat at the Sugar Lake outlet, flooding of 653 ha of riparian, wetland, and upland area adjacent to Sugar Lake, and flooding along a 7 km length of the Shuswap River (Anonymous 2003). This dam raised the water level of Sugar Lake by 7 m and increased the lake area from 1,564 to 2,217 ha. While this increase in instream habitat could be seen as a positive effect, fluctuating water levels within this lake as a result of dam operation have resulted in reduced productivity of the littoral zone and isolation of the riparian shoreline from the wetted habitat (Anonymous 2003). This dam also resulted in habitat impacts to the tributaries to this lake over a total of 11 km (Anonymous 2003).

Forestry operations and associated road construction have also adversely impacted the Upper Shuswap River Watershed. Most of these effects have been restricted to the western side of this watershed or in the valley bottom associated with the Upper Shuswap River. Forestry operations near the Upper Shuswap River prior to the 1950s were restricted to below this stream’s confluence with Vigue Creek (Summit 1996). However, by the 1990s, forestry operations were present throughout all reaches of the Upper Shuswap River from its headwaters to Sugar Lake (Summit 1996). Typical effects of forestry operations include increased erosion and undercut banks at stream crossings, reduced shading and nutrient input to the stream where riparian buffers have not been maintained, and increased large woody debris (LWD) inputs to the stream resulting in debris jams at the inlets of side channels. Where sufficiently sized, these debris jams can decrease flows to side channels resulting in loss of spawning and rearing habitat.

As part of the Watershed Restoration Program (WRP) for the Upper Shuswap River, Summit (1996) completed a stream assessment that examined the instream and riparian condition of 60 sites along this stream that had
potentially been degraded by forestry activities. They first coded each site at a scale of 1:50,000 during a helicopter survey based on the potential impact to the stream (i.e., water quality issues, fish barrier, habitat degradation), the likely cause of the problem (i.e., streambank erosion, culvert, debris, bank protection), the land use activity likely contributing to the problem (i.e., forestry, agriculture, roadways, residential, natural, uncertain), and the estimated degree of impact (i.e., high, medium, low, unknown). They then ground-truthed 13 sites identified as having a high degree of impact to the stream as a result of either forestry or uncertain land use activities, and retained eight of these sites as confirmed, highly impacted areas. These sites are mapped on Figure 23 to Figure 26, and summarized in Table 17.

Table 17: Summary of Recorded Highly Degraded Sites in the Upper Shuswap River

<table>
<thead>
<tr>
<th>Site No.</th>
<th>Impact Type</th>
<th>Site Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Spawning habitat, water quality</td>
<td>Large debris jam blocking main channel and side channel, bank erosion, channel scouring</td>
</tr>
<tr>
<td>26</td>
<td>Spawning habitat, water quality</td>
<td>Large debris jam blocking main channel and side channels, bank erosion and instability</td>
</tr>
<tr>
<td>33 and 34</td>
<td>Spawning habitat, water quality</td>
<td>Cutblock with no riparian buffer, deactivated bridge, gravel pile bridge support in channel, debris accumulation, bank erosion</td>
</tr>
<tr>
<td>37 and 38</td>
<td>Spawning habitat, water quality, fish passage</td>
<td>Cutblock with no riparian buffer, islands logged, bank erosion and slumping, degraded side channels, landslides and sediment deposition</td>
</tr>
<tr>
<td>39 and 40</td>
<td>Spawning habitat, water quality</td>
<td>Cutblock with no riparian buffer, road within stream channel, bridge partially washed out, road grading depositing sediment into channel, channel constricted, bank erosion</td>
</tr>
</tbody>
</table>


No previous Sensitive Habitat Inventory and Mapping (SHIM), Foreshore Inventory and Mapping (FIM), SEI, or TEM has been completed for the Upper Shuswap River. In the absence of these or other recent detailed ecological assessments, Golder conducted an orthophoto interpretation of the Upper Shuswap River as a relatively coarse, preliminary assessment of riparian conditions throughout this sub-drainage. The results of this orthophoto interpretation are provided on Figure 23 to Figure 26. Approximately 11.5% (11,520 m) of the riparian areas of this stream have been disturbed within 30 m of the approximate HWM (includes both streambanks). This disturbance is related almost exclusively to forestry operations, including both clearcut areas (9.6%; 9,687 m) and their associated access roads and bridge crossings (1.8%; 1,832 m). More disturbances are present in the higher elevations of this sub-drainage. While some forestry operations near the Upper Shuswap River have maintained a minimum 30 m setback from this stream, other operations were conducted within the riparian area and resulted in denudation.

**Restoration Works**

Little to no previous restoration work appears to have been completed along the Upper Shuswap River. Although Summit (1996) recommended simultaneous restoration of all of the sites described in Table 17, the orthophoto interpretation appears to confirm that no restoration activities have yet been completed in these areas. No documentation of restoration activities along the Upper Shuswap River was available through the BC MoE’s EcoCat reports catalogue website or through targeted internet searches. Any restoration activities within the Upper Shuswap River were likely concentrated on tributaries, rather than on debris clearing and riparian planting...
on the mainstem of this stream (Phil Epp, BC MoE Ecosystems Branch (retired), pers. comm.). The only stewardship group that appears to be interested specifically in the Upper Shuswap River Watershed is the Cherryville Water Stewards, a group of local residents primarily concerned with water quality in the Upper and Middle Shuswap River. This group has not completed any restoration initiatives to date within the Upper Shuswap River (Hank Cameron, Cherryville Water Stewards, pers. comm.).

4.4.2 Riparian Areas Prioritization

The preliminary prioritization of riparian areas for restoration works was first completed at the broader sub-drainage scale within the entire Upper Shuswap River Watershed based on the results of Matthews and Bull (2003). A preliminary prioritization of the riparian areas of the Upper Shuswap River specifically was then determined based on the limited information available on previous impacts and restoration works.

Upper Watershed

A total of ten sub-drainages within the Upper Shuswap River Watershed were identified by Matthews and Bull (2003) as having high or very high significance as a habitat protection focus area. These sub-drainages are listed in Table 18 and comprise 64% of the area occupied by the Upper Shuswap River Watershed. Of these ten sub-drainages, only the Upper Shuswap River has been identified as a highly significant sub-drainage for restoration. However, this one sub-drainage comprises 31% of the Upper Shuswap River Watershed. The results of Matthews and Bull’s (2003) restoration prioritization at the watershed level are depicted on Figure 27.

Table 18: Priority sub-drainages for restoration within the Upper Shuswap River Watershed, including the Upper Shuswap River and its direct and indirect sub-drainages, listed in alphabetical order.

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Area (ha)</th>
<th>Significance for Protection</th>
<th>Level of Habitat Alteration</th>
<th>Significance for Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gates Creek</td>
<td>4,292</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Greenbush Creek</td>
<td>7,356*</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Kate Creek</td>
<td>2,507</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Lindmark Creek</td>
<td>4,459</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Shuswap River (Upper)</td>
<td>35,648*</td>
<td>Very High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Sitkum Creek</td>
<td>5,336</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Star Creek</td>
<td>4,489</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Valerian Creek</td>
<td>940</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Vanwyk Creek</td>
<td>3,011</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Vigue Creek</td>
<td>4,831</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Source: modified from Matthews and Bull (2003).
* These sub-drainage areas were calculated as part of this Technical Assessment based on the sub-watershed boundaries defined in this report and the sub-drainage boundaries available from iMapBC (BC MFLNRO 2011).

Upper Shuswap River

In the absence of other information, all of the degraded sites identified by Summit (1996) as having a high degree of impact to the Upper Shuswap River as a result of forestry have been preliminarily ranked as a high priority for restoration, as these sites do not appear to have been restored. As well, all of the areas identified on
Figure 23 as disturbed during the interpretation of recent orthophotos have been preliminarily ranked as a high priority for restoration. The areas identified as natural during the orthophoto interpretation have been ranked as a low priority for restoration. Additional assessments would be required to further characterize the riparian areas of the Upper Shuswap River and move beyond this preliminary two class prioritization system. Gaps in the available data include the absence of any recent detailed ecological studies (i.e., SHIM, FIM, SEI, TEM) for any portion of the Upper Shuswap River Watershed. Specifically, these additional assessments should include ground-truthing and confirmation of all the areas identified as disturbed during the orthophoto interpretation.
5.0 MIDDLE SHUSWAP RIVER WATERSHED

This section provides a watershed profile for the Middle Shuswap River Watershed, which is the portion of the Shuswap River Watershed between the Sugar Lake outlet and the Mabel Lake outlet including the sub-drainages associated with the Middle Shuswap River and its direct and indirect tributaries. This watershed profile is divided into four sections, including a specific description and an assessment of the status of water quality, water quantity, and riparian areas in the Middle Shuswap River Watershed.

5.1 Watershed Description

The following sections provide a general description of the Middle Shuswap River Watershed, as well as a description of its hydrogeology and the land uses present.

5.1.1 General

The Middle Shuswap River Watershed is the portion of the watershed between the Sugar Lake outlet (~602 masl) and the Mabel Lake outlet (~393 masl), located 53 km downstream, as shown in Figure 28. Approximately 0.5 km downstream of Sugar Lake is Peers Dam, a 13 m high and 98 m long hydroelectric storage dam at Brenda Falls (Anonymous 2003). Between the Sugar Lake outlet and Peers Dam, the Shuswap River has a gradient of 2.1% (Summit 1996). This stream flows southwest for the next 15 km to Cherryville between the Silver Hills area of the Shuswap Highlands to the west and the Cherry Ridge area of the Monashee Mountains to the east, through the Shuswap Valley. This section of the Shuswap River has a low channel gradient of 3 to 4%, a channel width of 20 to 30 m, and channel substrate consisting of coarse gravel and small cobbles (Summit 1996). Good rainbow trout rearing habitat is present in this section, although a dated fisheries assessment determined that this section is underutilized by this species, potentially due to a lack of spawning habitat (Griffith 1979). Key sub-drainages within this section of the Shuswap River include, from upstream to downstream, Reiter Creek, Holstein Creek, Schunter Creek, Specht Creek, and Cherry Creek. Notable geographic features within this section of the Shuswap River include bridge crossings at Peers Dam and near Reiter Creek.

From Cherryville, the Middle Shuswap River flows northeast through the Shuswap Valley to Shuswap Falls. This section of the stream has a low channel gradient of 2%, bank heights of 1 to 2 m, a channel width of 40 to 70 m, and channel substrates consisting of coarse gravel and small cobbles (Summit 1996). Fish habitat features such as spawning gravels for large anadromous species, deep pools, and cover features are present throughout this meandering section of the stream (Summit 1996). Griffith (1979) notes that much fewer fish were observed in this section of the Middle Shuswap River compared to upstream of Cherry Creek; however. the 30 m high and 40 m long Wilsey Dam at Shuswap Falls creates a barrier to fish movement in the Shuswap River Watershed (Anonymous 2003). Key sub-drainages of the Middle Shuswap River between Cherryville and Shuswap Falls include Ferry Creek, Bonneau Creek, and Woodward Creek. Notable geographic features within this section of the Shuswap River include a bridge crossing near the unincorporated area of Shuswap Falls.

Downstream of Wilsey Dam, the Shuswap River flows north to Mabel Lake around the Silver Hills area of the Shuswap Highlands. This section of the stream has a low gradient of <1% and flows through a wide floodplain with abundant side channel and oxbow features (Summit 1996). The fish habitat present in the Middle Shuswap River downstream of the Wilsey Dam is particularly important, as this dam functions as a barrier to fish passage to upstream habitats. Chinook salmon are known to spawn in well defined areas of the Middle Shuswap River,
particularly within 3.5 km of the Wilsey Dam (ARC Environmental Ltd. (ARC) 2001). More recently, DFO stock assessment information for the Middle Shuswap River has been digitized (Golder 2011b). In summary, 501,068 m² of river bed is used for spawning by chinook salmon, 663,869 m² is used by coho salmon, and 634,769 m² is used by sockeye salmon. The total combined area, including overlap, of salmon spawning habitat in the Middle Shuswap River is 1,050,994 m². The highest quality spawning habitat, and most utilized by all three species, appears to be within 6.0 km of Wilsey Dam (Golder 2011b).

Kokanee also spawn in the Middle Shuswap River but typically use side channels for spawning rather than the mainstem of the stream, while coho salmon use both the mainstem and side channels (ARC 2001). The Middle Shuswap River below Wilsey Dam also provides sockeye spawning habitat (spawning capacity = 545,600 adults), with Mabel Lake functioning as a juvenile rearing area (rearing capacity = 809,000 spawning equivalents) for this stock (DFO 1997). Key sub-drainages of the Middle Shuswap River between Shuswap Falls and the Mabel Lake outlet include, from upstream to downstream, Bessette Creek, Bigg Creek, Ireland Creek, Sowsap Creek, Latewos Creek, Smyth Creek, Tsuius Creek, Wap Creek, and Noisy Creek.

Surface water flows from the Middle Shuswap River Watershed, in the area of Duteau Creek, are diverted out of the watershed, and into the neighbouring Okanagan Basin Watershed. The proportion of use is highest in the Duteau Creek tributary where the estimated water usage (mostly diverted out of the Shuswap River Watershed to the Okanagan Basin through Greater Vernon Water (GVW) Utility) is equivalent to almost 50% of the remaining mean annual flow; this indicates that 33% of the naturalized flow is being diverted on an annual basis. The flows in Duteau Creek, and as a result Bessette Creek below the Duteau confluence at Lumby, are highly regulated by releases from storage reservoirs in upper Duteau Creek. Nevertheless, the estimated water usage in Bessette and its tributaries relative to flow is higher than any other sub-basin in the Shuswap River Watershed upstream of Mara Lake and summer flows in both Duteau and lower Bessette Creek are highly dependent on the balance between storage releases and consumption. The activities regarding the Duteau Creek diversion are discussed further in Section 5.3.4 regarding surface flow versus consumption and again in Section 5.3.5 regarding minimum instream flow thresholds.

5.1.2 Hydrogeology

The following sections provide a summary of the hydrogeology in the Middle Shuswap River Watershed, summarizing provincially identified aquifers, aquifer linkages as identified during this Technical Assessment, and BC MoE observation wells information.

Aquifers

Based on the methods described in the conceptual model in Section 2.4.2, ten discrete unconsolidated aquifers were delineated in the Middle Watershed which are numbered M08 through M17 (Figure 17). The aquifers are located between the outlet of Sugar Lake and the inlet of the Shuswap River to Mable Lake. The linkages of groundwater flow between aquifers are shown on Figure 29, below, and on Figure 17.
Aquifer parameters such as hydraulic conductivity and hydraulic gradient are relatively unknown for the Middle Shuswap River Watershed, with the following exceptions:

1. According to Golder (2007), the direction of groundwater flow in a deeper, confined aquifer in the area of Lumby (Aquifer M11) has been identified to flow in a southerly direction, contradictory to the direction of surface water flow in the area, which is to the north/northeast. In addition, Golder (2008) indicates that the groundwater flow direction in the confined aquifer in the area of Whitevale flows to the northwest towards Duteau Creek. These groundwater flow directions (to the south and northwest) are contrary to the direction of groundwater flow identified in Figure 29, which indicates groundwater flowing from M11 towards M12 (to the northeast). Although the deeper confined aquifer in this area can be inferred to flow to the south (Lumby) and to the northwest (Whitevale), it is anticipated that shallow groundwater flow direction in these areas is likely in the same direction as surface water flows, to the northeast. Figure 17 illustrates the possible groundwater flow in this area being both to in a northerly (shallow groundwater) to westerly (deeper groundwater) direction.

2. Hydraulic conductivity values for the Lumby confined aquifer were identified to be approximately $1 \times 10^{-3}$ m/s (Golder 2007) and between $7.5 \times 10^{-4}$ m/s and $8 \times 10^{-6}$ m/s for the unconfined aquifer (Piteau 1996), with an average hydraulic gradient of the unconsolidated aquifer of approximately $6 \times 10^{-4}$ m/s. A hydraulic conductivity of $5 \times 10^{-4}$ m/s has been used in the estimation of groundwater flows for Aquifer M11, as it is within the same order of magnitude as identified in the Lumby area.

Aquifers M08, M09, M10 and M13 are associated with the Shuswap River with hydraulic gradients within these valley bottom aquifers controlled by river elevations. Aquifers M13 through M17 all discharge directly to Mabel Lake.

There are ten provincially identified aquifers listed in the BC Water Resources Atlas within the Middle Shuswap River Watershed (BC MoE 2011a). Aquifer M09 includes the rural area of Cherryville where three BC MoE provincial aquifers have been mapped (one unconsolidated and two bedrock aquifers). Aquifer M11 includes the Villages of Lumby and Lavington where the six BC MoE provincially designated aquifers have been mapped. The remaining two BC MoE provincially mapped aquifers are located within the area of M12.

The locations of the BC MoE provincial aquifers are shown in Figure 14 and summarized in Table 19, below, which indicates the aquifer name (including provincial classification and risk ranking values) aquifer materials,
TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

Two of the provincial aquifers are bedrock aquifers while the remaining eight are aquifers within unconsolidated materials, consisting mainly of sand and gravel aquifers. Based on the provincial vulnerability ranking of high to low, it can be inferred that these aquifers consist of shallow unconfined aquifers to deeper confined aquifers.

The three largest sand and gravel aquifers are Aquifer Nos. 316, 317 and 318, which are located in the Bessette River valley between Lavington to the west, Lumby in the central valley and Shuswap Falls to the east. The western-most edge of Aquifer No. 317 abuts the watershed boundary of the Okanagan Basin and the Coldstream Creek valley Aquifer No. 352. Aquifer No. 317 is listed as having a low vulnerability while Aquifer No. 316 is listed as having a high vulnerability. In some areas, Aquifers 317 and 316 overly each other, while in other locations they are overlain by two smaller aquifers (including Aquifer No. 315 and 314, with 315 indicating a high vulnerability and 314 indicating a low vulnerability).

BC MoE Observation Well Data

There is one BC MoE Observation Well located in the Middle Shuswap River Watershed, Well ID 294, which is located in Lumby within Aquifer M11 of the Middle Shuswap River Watershed and within BC MoE Aquifer Nos. 314, 316 and 317. The location of this well is depicted on Figure 15.

---

1 BC MoE vulnerability identification of low vulnerability infers that the aquifer is of moderate depth below ground surface and likely overlain by a relatively continuous confining layer that acts to "protect" the aquifer from potential surface contamination. Alternately, a high vulnerability infers that the aquifer is shallow in nature and does not have an overlying confining layer, making it more vulnerable to surface contamination.
Observation Well 294 (located near Lumby, BC)

Groundwater levels at Observation Well 294 have been monitored from 1986 to 2011; this observation well is currently active. According to the borehole log for this well (included in Appendix C), the observation well is completed in an unconfined sand and gravel aquifer at a depth of 29.87 metres below ground surface (mbgs).

Groundwater levels during this monitoring period were noted to range from a high of 7.50 metres below ground surface (mbgs) in 1999 to a low of approximately 9.50 mbgs in 2008. Groundwater levels fluctuated seasonally by approximately 1 to 1.5 m and were generally noted to increase between the spring and early summer, and decrease during the late summer through later winter. Seasonal groundwater lows were generally identified in the winter with seasonal groundwater highs identified in the early summer.

Between 2000 and 2004 an overall decreasing trend was noted; however, between 2004 and 2005 groundwater levels returned to a similar level and fluctuation that had been noted in previous years. Between 2005 and 2008 groundwater levels decreased steadily to a new low level of 9.5 metres below ground surface (mbgs). Since 2008 the groundwater levels appear to be slightly increasing, although have not as yet, returned to the same level and amplitude of fluctuation seen prior to 2004. The depth to groundwater versus time is presented in Figure 30.

![OBS WELL 294 - LUMBY (WHITEVALE RD. & HORNER RD.)](image)

Figure 30: Depth to Groundwater versus Time for BC MoE Observation Well 294 located near Lumby

5.1.3 Land Use

Land use within the Middle Shuswap River Watershed is predominately related to agricultural and hydroelectric power generation, which are described in greater detail in Section 5.4.1. Other land uses include forestry, rural residential, and recreation. Tolko Industries and Weyerhaeuser are the main forestry operators in the Middle Shuswap River Watershed (Weyerhaeuser et al. 2007) and cut blocks, although concentrated in the Silver Hills area between Mabel Lake and the Upper Shuswap River, are present throughout this sub-region. Private land logging also occurs in this sub-watershed. Recreational opportunities in the Middle Shuswap River Watershed
include hiking, camping, wildlife viewing, paddling, fishing, snowmobiling, and all-terrain vehicle use. Mount Griffith Provincial Park and Ecological Reserve are located at the north end of the Middle Shuswap River Watershed at Wap Creek, Mabel Lake Provincial Park is located on the east side of Mabel Lake, Echo Lake Provincial Park is located at Echo Lake near Cherryville, and Silver Star Provincial Park is located on the western side of the Middle Shuswap River Watershed at Vance Creek. Numerous BC MoF recreational sites are located throughout the Middle Shuswap River Watershed including at Wap Lake, Frog Falls, Noisy Creek, Cascade South, Haggkvist Lake, Sigalet Lake, Holstein Lake, Kathy Lake, Cherryville, Denison Lake, and several other sites in the Duteau Creek sub-drainage.

5.2 Water Quality

The following sections provide an overview of water quality in the Middle Shuswap River Watershed, as well as the results of the BC CSR Site Registry search and the risk assessment.

5.2.1 Overview

Water quality in the Middle Shuswap River Watershed was assessed based on information collected from the following main sources:

- Water Quality Trends in Mara, Mabel, and Sugar Lakes 1971-1998 (Bryan and Jensen 1999);
- Water Quality in the Shuswap River between Mable and Mara Lakes, 1977 (Nordin 1978);
- 2008 Water Quality Objectives Attainment: Bessette Creek Watershed (Summary Report);
- Shuswap-Mabel Area, Bessette Creek Water Quality Assessment and Objectives, Technical Appendix (Swain 1991);
- BC MoE Well 294 (Lumby); and,
- Mabel Lake Water System and Duteau Creek (Greater Vernon Water) data from RDNO’s WaterTrax database.

As with the Upper and Lower Shuswap River Watersheds, water quality data presented in the sources above varies in methodology and presentation and were not subject to reinterpretation during this assessment. For the purposes of this Technical Assessment, water quality information within the Middle Shuswap River Watershed is broken down into the following sources or areas of interest: MoE Well 294 (Lumby), Bessette Creek, Mabel Lake Water System, Duteau Creek (Greater Vernon Water), and Mabel Lake.

Historical water quality concerns within the Middle Shuswap River Watershed have largely involved nutrient loading (nitrogen cycle parameters and phosphorous), suspended sediment and turbidity, and microbial parameters (E. coli and total coliforms).

The Middle Shuswap River Watershed includes, or has immediately adjacent to it, multiple permitted discharges including municipal waste water from the Village of Lumby, sawmill discharge, storm water run-off, chlorophenate wood processing facilities, and mining/mill operations.
MoE Observation Well 294 (Lumby)

Limited water quality data is available for MoE Observation Well 294, consisting of generally fewer than 20 samples. Nutrient concentrations are elevated above concentrations observed in the others parts of the Study Area that are interpreted to be relatively un-impacted, with average nitrate concentrations of less than 5 mg/L, and average phosphorous less than 0.04 mg/L. Turbidity was measured six times, yielding an average concentration of less than 0.4 NTU. Coliforms were detected multiple times, with a maximum concentration of 2 counts/100 mL. Overall, the water quality at MoE Observation Well 294 is considered to reflect only minimal impact.

Raw water quality results for MoE Observation Well 294 are presented in tabular form in Appendix D.

It is recommended that the RDNO consider implementation of comprehensive groundwater quality sampling at this observation well in order to characterize groundwater quality in this area, including: full metal scans, nutrients, microbial parameters, turbidity, and suspended solids. Alternately, the RDNO could consider sampling one of their existing community water supply wells in the general area (Whitevale).

Bessette Creek

Licensed water withdrawals for domestic consumption and irrigation uses have been issued off Bessette Creek, and water quality in the Bessette Creek is vulnerable to impacts associated with intensive livestock farming, mining, logging, timber processing, and municipal waste from the Village of Lumby.

Nutrient loading assessments have been undertaken related to farming and livestock activities.

Water quality in Bessette Creek has been characterized as alkaline (average pH values greater than 7). No anthropogenic sources for elevated metals concentrations have been identified in the vicinity of Bessette Creek in previous reports and, as such, are not considered to be a suite of parameters of concern. Sewage disposal, landfills, and sawmills can be sources for elevated metals concentrations and, while not identified as potential metals sources in previous reports, they should be considered as potential anthropogenic sources for elevated metals concentrations in future groundwater and surface water assessments. Chloride and sulphate concentrations have been observed to be elevated in Bessette Creek; however, concentrations remained below 10 mg/L chloride and 18 mg/L sulphate and well below the BC Drinking Water Standards (250 mg/L for chloride, and 500 mg/L aesthetic objective for sulphate).

Nitrate and nitrite concentrations from samples collected at Bessette Creek have been below applicable BC Drinking Water Standards (Swain 1991). Elevated phosphorous concentrations have been observed, with values greater than 0.2 mg/L, suggesting a potential impact from land use activities adjacent to or upgradient/upstream of Bessette Creek.

Turbidity values have been observed to exceed the criteria of 1 nephelometric turbidity unit (NTU), and some studies (Swain 1991) have partially attributed these exceedances to suspended solids discharged by the Village of Lumby. However, it should also be noted that elevated turbidity is a common occurrence in surface waters during spring freshet and storm events, due to high energy flows within surface waters causing erosion and surface water runoff.

Microbiology results indicate elevated concentrations of fecal coliforms and E. coli, with concentrations generally exceeding the 90th percentile objective (100 counts / 100 mL) upstream of the Village of Lumby Wastewater
Treatment Plant (WWTP) and exceeding the maximum objective (200 counts/100 mL) and the 90th percentile objective downstream from the WWTP. The higher concentrations downstream may reflect impact from the WWTP and/or riparian-area cattle and livestock activities.

Bessette Creek water quality results indicate nutrient and turbidity impacts from anthropogenic sources in the Middle Shuswap Watershed; however, the majority of the water is withdrawn for non-drinking water uses.

**Mabel Lake Water System and Duteau Creek (Greater Vernon Water)**

Water quality data for the Mabel Lake Water System and for Duteau Creek (part of the Greater Vernon Water system), provided by RDNO's online database WaterTrax, was reviewed for the selected parameters which have been identified in previous studies as potential water quality issues in the Middle Shuswap. These parameters were grouped as follows:

- Chloride, pH, and calculated parameters (alkalinity, conductivity, hardness);
- Nutrients (nitrogen cycle parameters, phosphorous);
- Microbiology (*E. coli*, total coliforms, fecal coliforms); and,
- Turbidity and suspended solids.

Trend plots were developed for each of these groupings, and are presented in Appendix D as Figure D1 through Figure D4 for Mable Lake, and Figures D5 through D8 for Duteau Creek).

Data in WaterTrax for the Mabel Lake Water System is available from 2005 to 2011 for selected parameters, and from 2003 to 2011 for Duteau Creek for selected parameters, based on a search of all active and inactive sampling points within the RDNO database.

The water quality results retrieved from the WaterTrax database, much like the data reviewed from historical reports, were reviewed and are presented without reinterpretation or assessment of sampling or analytical methods and procedures, consideration for detection limits, or quality assurance/quality control results. The water quality results were compared against the BC Water Quality Guidelines, where applicable, based on the routine built into the WaterTrax database. Golder has assumed reliance on the data, as presented.

**Mabel Lake Water System**

Conductivity and pH results are presented on Figure D1 for the Mabel Lake Water System. Conductivity values ranged from 89 µS/cm to a 140 µS/cm between 2005 and 2011, while pH ranged from 6.37 to 7.76. A total of five samples were below the aesthetic pH criteria of between 6.5 to 8.5 for drinking water. Alkalinity, hardness, and chloride data were not available.

Relatively limited nutrient data are available for the Mabel Lake Water System from 2007 to 2011, from the Pumphouse Raw Water Line sampling location. The concentrations of nutrient parameters are presented on Figure D2. Nitrate concentrations ranged from 0.05 mg/L to 0.07 mg/L, below the criteria (10 mg/L), and nitrite concentrations were below detection limits. Total phosphorous concentrations ranged from 0.01 to 0.04 mg/L, and total dissolved phosphorous ranged from 0.01 mg/L to 0.02 mg/L.
There was one total coliform detection over the sampling period, 1 count / 100 mL at 6 Walker Road on July 9, 2009. There were no other exceedances of microbial parameters and insufficient data exist for statistical analysis. The results are shown on Figure D3.

Turbidity data for the Mabel Lake Water System are shown on Figure D4. Turbidity values range from 0.08 NTU to 3.18 NTU, with 23 exceedances of the 1 NTU criteria. Average concentrations at all sampling locations were below 1 NTU.

**Duteau Creek (Greater Vernon)**

Conductivity and pH results are presented on Figure D5 for the Duteau Creek system. Conductivity values ranged from approximately 30 µS/cm to 550 µS/cm between 2003 and 2011 at the various sampling locations. Average conductivity values range from approximately 250 µS/cm to 450 µS/cm. Water quality results indicate an average pH values ranging from 7.5 to 8.1. A total of 32 exceedances of the pH drinking water criteria were observed during this period, excluding two suspected anomalous values. Alkalinity, hardness, and chloride data were not available.

Limited nutrient data are available from 2006 to 2011 for the Duteau Creek system, from two distribution locations: Kal Lake Distribution and Upland Distribution. Although the Kal Lake Distribution source originates from Kalamalka Lake (outside the Shuswap River Watershed), the water is distributed within the Shuswap River Watershed, and as such, has been included. The concentrations of nutrient parameters are presented on Figure D6. Nitrate, nitrite and ammonia (total, as N) were only analyzed during two sampling rounds at the Upland Distribution sampling point. Nitrate and was detected at a concentration of 1.45 mg/L (September, 2007), and ammonia was detected at a concentration of 0.05 mg/L (May, 2008). The remaining Upland samples were reported below detection limits.

Nitrate concentrations in the Kal Lake Distribution samples ranged from 0.02 mg/L to 0.217 mg/L, with an average of 0.217 mg/L, and nitrite concentrations were below detection limits. There were no exceedances of the nitrate criteria (10 mg/L). Total phosphorous concentrations ranged from below detection limits to 0.05 mg/L, and total dissolved phosphorous ranged from below detection limits to 0.055 mg/L.

There were three total coliform detections over the sampling period, excluding an overgrowth sample:

- 2 counts / 100 mL at “2001 43rd Street Sample Station (24-87-MD, 17FFC)” on August 23, 2011;
- 5 counts / 100 mL at “Amber (24-88-MD, 181B0)” on November 1, 2004; and,
- 15 counts / 100 mL at “Amber (24-88-MD, 181B0)” on September 15, 2005.

The overgrowth sample was analyzed on September 13, 2005 and the September 15, 2005 is interpreted as a confirmatory sample. A third sample collected on September 22, 2005 yielded no counts. The results are shown on Figure D7.

Turbidity data for the Duteau Creek system are shown on Figure D8. Turbidity values range from 0.18 NTU to 26.4 NTU. Average concentrations at all sampling locations ranged from 0.72 NTU to 1.59 NTU, with 5 of the 10 sampling locations exhibiting average turbidity concentrations below the 1 NTU criteria.
**Mabel Lake**

Increasing trends in sulphate, sodium, calcium, alkalinity, and magnesium have been observed in Mabel Lake, with associated decreasing trends in specific conductance and turbidity. These trends are largely similar to those observed in upstream Sugar Lake. Nutrient concentrations and trends (nitrogen parameters and phosphorous) are similar to those observed at Sugar Lake, while inorganic parameters (major ions and dissolved metals) are generally higher than those observed in upstream locations.

The north basin of Mabel Lake is subject to run-off from logging operations and only minimal residential and recreational activities. Road salting activities are not interpreted to reflect a significant source of impact to Mabel Lake due to the limited upstream residential and commercial development.

Water quality associated with the Shuswap River Watershed, between Mable Lake and Mara Lake is discussed in Section 6.2.

### 5.2.2 BC Contaminated Sites Regulation: Site Registry Search

There are 23 properties in the Middle Shuswap River Watershed that have records filed with the BC MoE CSR Site Registry as described below in Table 20. Of these 23, ten are listed as having an active status suggesting that they are currently undergoing assessment or investigation. Detailed information regarding these sites is available from the BC government for a nominal fee. This information is current to June, 2011 and is updated monthly.

<table>
<thead>
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<th>Address</th>
<th>City</th>
<th>Status</th>
</tr>
</thead>
<tbody>
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<td>2470</td>
<td>Frank’s General Store</td>
<td>1193 Highway 6</td>
<td>Cherryville</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>7800</td>
<td>Cherryville Highways Yard Site</td>
<td>748 Highway 6</td>
<td>Cherryville</td>
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<tr>
<td>2520</td>
<td>Cherry Wreckers Recyclers</td>
<td>181 Campbell Road</td>
<td>Cherryville</td>
<td>Inactive - No Further Action</td>
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<tr>
<td>4352</td>
<td>Unauthorized Fill Site</td>
<td>266 Creighton Valley Road</td>
<td>Lumby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>2513</td>
<td>Lumby Storm Sewer</td>
<td>Storm Sewer Discharge on Highway 6</td>
<td>Lumby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>3813</td>
<td>Esso Bulk Plant</td>
<td>2087 Norris Avenue</td>
<td>Lumby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>3810</td>
<td>Esso Cardlot</td>
<td>1840 Vernon Street</td>
<td>Lumby</td>
<td>Active - Under Assessment</td>
</tr>
<tr>
<td>3812</td>
<td>Lumby Shell</td>
<td>1862 Vernon Street</td>
<td>Lumby</td>
<td>Active - Under Assessment</td>
</tr>
<tr>
<td>5975</td>
<td>Marcel’s Automotive</td>
<td>2001 Miller Street</td>
<td>Lumby</td>
<td>Inactive - No Further Action</td>
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<tr>
<td>7370</td>
<td>Highways Yard Site</td>
<td>2006 Glencaird Street</td>
<td>Lumby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>2474</td>
<td>Lumby Turbo Station, # 8559</td>
<td>2085 Vernon Street</td>
<td>Lumby</td>
<td>Active - Under Assessment</td>
</tr>
<tr>
<td>12300</td>
<td>2087 Vernon Street</td>
<td>2087 Vernon Street</td>
<td>Lumby</td>
<td>Active - Under Assessment</td>
</tr>
<tr>
<td>2512</td>
<td>Riverside Forest Products</td>
<td>4280 Highway 6</td>
<td>Lumby</td>
<td>Inactive - Remediation Complete</td>
</tr>
<tr>
<td>4836</td>
<td>Chevron Card Lock</td>
<td>4054 Highway 6</td>
<td>Lumby</td>
<td>Inactive - Remediation Complete</td>
</tr>
</tbody>
</table>
## 5.2.3 Risk Assessment

As shown in Table 20, a total of 23 sites were identified in the BC CSR registry within the Middle Shuswap River Watershed. Of those 23 sites, approximately 1/3 are identified as having a high risk ranking, due to their land use (bulk fuel, highway maintenance yards, industrial uses, landfills) and close proximity to a surface water source or community. Land use data provided by the RDNO has indicated additional sources of potential impact to groundwater quality in the Middle Watershed, with a high concentration of sites in the vicinity of the Village of Lumby. These additional sources consist of various commercial and municipal uses, and service stations, sawmills and landfills.

Increased industrial, agricultural, commercial, and residential activities in the Lumby area pose an elevated risk to groundwater and surface water quality and resources. This increased potential is reflected by the higher risk assigned to many of the sites in this watershed. Risk rankings for sites with the potential to impact water quality within the Middle Shuswap River Watershed are provided on Figure 20.

## 5.3 Water Quantity

The following sections characterize the water quantity of the Middle Shuswap River Watershed, including the surface water flows, groundwater flows, estimate of water use and allocation, estimate of flow and allotment versus consumption, and minimum instream flow thresholds for this watershed.

### 5.3.1 Surface Water Flows

Flow statistics for WSC stations in the Middle Shuswap River Watershed with six or more years of monthly flow records are summarized in Table 21. For stations with less than 20 years of data, mean annual flows were adjusted by comparing the same years in the longer term Shuswap River records to the entire Shuswap records and then adjusting the short term station flows by the proportion of those years to the long term records. This increased or decreased the actual mean flows from the short term records by up to 5%. Mean annual flows for stations with seasonal records were assumed to be 60% of the average April to September flows. The basis of
this assumption is that, for stations on the Shuswap River with year-round records, annual mean flows range from 55% to 65% of the seasonal (April to September) mean flows.

Table 21 also provides the estimated surface water and groundwater use (where available and as discussed further in Section 5.3.3), which were added to the mean annual flow to calculate the naturalized mean annual discharge for each station. The naturalization was only applied to the annual flows, as proportioning water use to monthly flows is beyond the scope of this study. It must be stressed that calculations of mean annual flow, net unit runoff, naturalized mean annual discharge and naturalized net unit runoff from short term, seasonal records for stations that were discontinued decades ago (e.g., Creighton Creek) carry a high degree of uncertainty. The results for these stations are approximations only and may have large error margins. The accuracy of the calculated values varies with the available data sets and ranges from possibly ±50% for the shortest seasonal sets of old data to less than ±5% for currently active stations with long term data sets.
Table 21: Summary of Surface Water Flows by WSC Station in the Middle Shuswap River Watershed

### WSC Station No. 08LC049 | Cherry Creek near Cherryville
Inactive | Flow Record: 1982-1990 | No. of Years: 9

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Mean Flow (m³/s)</th>
<th>Max Flow (m³/s)</th>
<th>Min Flow (m³/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jan</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Feb</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>9.09</td>
<td>22.6</td>
<td>28.4</td>
<td>13.9</td>
<td>5.32</td>
<td>4.11</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>8.57</td>
<td>14.5</td>
<td>4.14</td>
</tr>
<tr>
<td><strong>Mar</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>14.5</td>
<td>31.3</td>
<td>47.1</td>
<td>25.8</td>
<td>8.17</td>
<td>5.97</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>18.7</td>
<td>47.1</td>
<td>2.94</td>
</tr>
<tr>
<td><strong>Apr</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.14</td>
<td>17.4</td>
<td>9.59</td>
<td>4.67</td>
<td>2.94</td>
<td>2.15</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.35</td>
<td>9.59</td>
<td>7.35</td>
</tr>
</tbody>
</table>

- Mean Annual Flow (m³/s): **8.57**
- Net Unit Runoff (mm): **537**
- Estimated Surface Water Use (m³/s): **0.07**
- Groundwater Use (m³/s): **-**
- Naturalized Mean Annual Discharge (m³/s): **8.64**
- Naturalized Net Unit Runoff (mm): **542**

### WSC Station No. 08LC003 | Shuswap River near Lumby

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Jan</strong></td>
<td>21.0</td>
<td>20.0</td>
<td>20.3</td>
<td>40.4</td>
<td>112</td>
<td>159</td>
<td>81.8</td>
<td>35.2</td>
<td>29.2</td>
<td>28.6</td>
<td>26.7</td>
<td>23.0</td>
<td>50.3</td>
</tr>
<tr>
<td><strong>Feb</strong></td>
<td>36.5</td>
<td>58.6</td>
<td>47.4</td>
<td>95.9</td>
<td>203</td>
<td>264</td>
<td>166</td>
<td>80.5</td>
<td>86.8</td>
<td>66.8</td>
<td>51.7</td>
<td>46.7</td>
<td>74.5</td>
</tr>
<tr>
<td><strong>Mar</strong></td>
<td>6.3</td>
<td>6.8</td>
<td>7.2</td>
<td>9.9</td>
<td>58.6</td>
<td>77.9</td>
<td>36.0</td>
<td>20.5</td>
<td>14.0</td>
<td>13.1</td>
<td>9.7</td>
<td>7.7</td>
<td>31.3</td>
</tr>
</tbody>
</table>

- Mean Annual Flow (m³/s): **50.3**
- Net Unit Runoff (mm): **793**
- Estimated Surface Water Use (m³/s): **0.19**
- Groundwater Use (m³/s): **-**
- Naturalized Mean Annual Discharge (m³/s): **50.5**
- Naturalized Net Unit Runoff (mm): **796**

- Incremental Net Unit Runoff (mm): **434**
WSC Station No. 08LC034 | Ferry Creek near Lumby
Inactive | Flow Record: 1959-1977 | No. of Years: 18

Mean | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
Mean | 0.23 | 0.21 | 0.24 | 0.57 | 3.06 | 3.96 | 0.94 | 0.47 | 0.50 | 0.50 | 0.45 | 0.31 | 0.95
Max | 0.34 | 0.30 | 0.31 | 1.05 | 5.23 | 7.81 | 1.93 | 1.09 | 1.29 | 1.23 | 0.82 | 0.49 | 1.52
Min | 0.18 | 0.18 | 0.15 | 0.21 | 1.10 | 1.60 | 0.28 | 0.17 | 0.18 | 0.22 | 0.25 | 0.18 | 0.63

Mean Annual Flow (m³/s)** 0.97 Net Unit Runoff (mm) 211
Estimated Surface Water Use (m³/s) 0.06 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 1.03 Naturalized Net Unit Runoff (mm) 224

WSC Station No. 08LC033 | Creighton Creek near Lumby
Inactive | Flow Record: 1959-1966 | No. of Years: 8

Mean | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
Mean | - | - | - | 0.23 | 1.09 | 1.01 | 0.28 | 0.13 | 0.24 | 0.18 | 0.10 | - | 0.41
Max | - | - | - | 0.50 | 1.88 | 1.51 | 0.45 | 0.28 | 0.62 | 0.40 | 0.16 | - | 0.73
Min | - | - | - | 0.06 | 0.71 | 0.39 | 0.12 | 0.04 | 0.03 | 0.04 | 0.03 | - | 0.18

Mean Annual Flow (m³/s)** 0.29 Net Unit Runoff (mm) 240
Estimated Surface Water Use (m³/s) 0.00 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 0.29 Naturalized Net Unit Runoff (mm) 240

WSC Station No. 08LC006 | Duteau Creek near Lavington
Inactive | Flow Record: 1919-1921, 1935-1996 | No. of Years: 58

Mean | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year
--- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | ---
Mean | 0.14 | 0.16 | 0.24 | 1.10 | 2.42 | 1.57 | 0.53 | 0.30 | 0.35 | 0.23 | 0.22 | 0.18 | 0.67
Max | 0.55 | 0.96 | 1.55 | 4.49 | 6.96 | 8.50 | 4.42 | 1.56 | 2.07 | 0.92 | 0.70 | 0.55 | 1.43
Min | 0.00 | 0.00 | 0.00 | 0.07 | 0.06 | 0.05 | 0.01 | 0.01 | 0.00 | 0.02 | 0.00 | 0.00 | 0.14

Mean Annual Flow (m³/s) 0.67 Net Unit Runoff (mm) 110
Estimated Surface Water Use (m³/s) 0.33 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 1.00 Naturalized Net Unit Runoff (mm) 163
WSC Station No. 08LC0005 | Bessette Creek near Lumby
Inactive | Flow Record: 1919, 1943-1948, 1965-1983 | No. of Years: 25

<table>
<thead>
<tr>
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<th>Apr</th>
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<th>Jun</th>
<th>Jul</th>
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<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
<td>6.71</td>
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<td>0.51</td>
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<td>2.88</td>
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<tr>
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<td>-</td>
<td>2.10</td>
<td>10.4</td>
<td>14.0</td>
<td>6.38</td>
<td>2.80</td>
<td>1.68</td>
<td>-</td>
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</tr>
<tr>
<td>Min</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.09</td>
<td>2.93</td>
<td>2.76</td>
<td>0.22</td>
<td>0.02</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
<td>1.01</td>
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</table>

Mean Annual Flow (m³/s) 1.73
Estimated Surface Water Use (m³/s) 0.15
Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 1.88
Naturalized Net Unit Runoff (mm) 215

WSC Station No. 08LC042 | Bessette Creek above Lumby Lagoon Outfall
Active | Flow Record: 1973-2009 | No. of Years: 37

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
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<tbody>
<tr>
<td>Mean</td>
<td>0.69</td>
<td>0.73</td>
<td>1.21</td>
<td>3.71</td>
<td>11.4</td>
<td>9.87</td>
<td>2.92</td>
<td>1.06</td>
<td>1.22</td>
<td>1.18</td>
<td>1.10</td>
<td>0.80</td>
</tr>
<tr>
<td>Max</td>
<td>1.29</td>
<td>1.65</td>
<td>2.78</td>
<td>11.7</td>
<td>22.1</td>
<td>23.1</td>
<td>14.2</td>
<td>5.49</td>
<td>4.00</td>
<td>3.61</td>
<td>3.26</td>
<td>1.87</td>
</tr>
<tr>
<td>Min</td>
<td>0.19</td>
<td>0.28</td>
<td>0.43</td>
<td>0.81</td>
<td>6.60</td>
<td>1.07</td>
<td>0.52</td>
<td>0.19</td>
<td>0.25</td>
<td>0.28</td>
<td>0.37</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m³/s) 3.03
Estimated Surface Water Use (m³/s) 0.56
Groundwater Use (m³/s) 0.01
Naturalized Mean Annual Discharge (m³/s) 3.60
Naturalized Net Unit Runoff (mm) 234

WSC Station No. 08LC040 | Vance Creek below Deafies Creek
Active | Flow Record: 1970-2009 | No. of Years: 40

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.1</td>
<td>0.12</td>
<td>0.29</td>
<td>1.09</td>
<td>1.90</td>
<td>1.10</td>
<td>0.41</td>
<td>0.18</td>
<td>0.13</td>
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<td>0.14</td>
<td>0.12</td>
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<tr>
<td>Max</td>
<td>0.29</td>
<td>0.60</td>
<td>1.00</td>
<td>2.90</td>
<td>3.73</td>
<td>2.20</td>
<td>1.36</td>
<td>0.78</td>
<td>0.59</td>
<td>0.37</td>
<td>0.43</td>
<td>0.37</td>
</tr>
<tr>
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<td>0.03</td>
<td>0.04</td>
<td>0.19</td>
<td>0.62</td>
<td>0.22</td>
<td>0.10</td>
<td>0.05</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
<td>0.19</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m³/s) 0.48
Estimated Surface Water Use (m³/s) 0.02
Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 0.50
Naturalized Net Unit Runoff (mm) 215
### WSC Station No. 08LC039 | Bessette Creek above Beaverjack Creek

**Active** | Flow Record: 1970-1972, 1975-2009 | No. of Years: 38

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Year</th>
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<tbody>
<tr>
<td>Mean</td>
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<td>0.93</td>
<td>1.67</td>
<td>4.65</td>
<td>13.2</td>
<td>11.1</td>
<td>3.38</td>
<td>1.28</td>
<td>1.41</td>
<td>1.40</td>
<td>1.37</td>
<td>1.01</td>
<td>3.51</td>
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<tr>
<td>Max</td>
<td>1.69</td>
<td>1.89</td>
<td>4.03</td>
<td>12.7</td>
<td>27.9</td>
<td>25.1</td>
<td>15.0</td>
<td>7.10</td>
<td>4.54</td>
<td>4.32</td>
<td>3.68</td>
<td>2.22</td>
<td>8.43</td>
</tr>
<tr>
<td>Min</td>
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<td>0.37</td>
<td>0.58</td>
<td>0.85</td>
<td>7.04</td>
<td>1.51</td>
<td>0.61</td>
<td>0.16</td>
<td>0.33</td>
<td>0.42</td>
<td>0.46</td>
<td>0.38</td>
<td>1.51</td>
</tr>
</tbody>
</table>

- **Mean Annual Flow (m³/s):** 3.51
- **Net Unit Runoff (mm):** 144
- **Estimated Surface Water Use (m³/s):** 0.65
- **Groundwater Use (m³/s):** 0.01
- **Naturalized Mean Annual Discharge (m³/s):** 4.17
- **Naturalized Net Unit Runoff (mm):** 171

*Mean annual flows estimated at 60% of mean seasonal (i.e., April to September) flows.

**Flows for stations with less than 20 years of record were adjusted by comparison to the longer terms Shuswap River records.

### WSC Station No. 08LC019 | Shuswap River at Outlet Mabel Lake

**Inactive** | Flow Record: 1927-1936, 1951-1979 | No. of Years: 39

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.6</td>
<td>29.8</td>
<td>27.7</td>
<td>50.5</td>
<td>159</td>
<td>264</td>
<td>157</td>
<td>65.3</td>
<td>50.1</td>
<td>49.0</td>
<td>45.6</td>
<td>38.5</td>
<td>81.1</td>
</tr>
<tr>
<td>Max</td>
<td>48.1</td>
<td>43.7</td>
<td>41.7</td>
<td>125</td>
<td>285</td>
<td>413</td>
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<td>185</td>
<td>150</td>
<td>124</td>
<td>96.9</td>
<td>72.0</td>
<td>115</td>
</tr>
<tr>
<td>Min</td>
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<td>11.8</td>
<td>13.3</td>
<td>15.5</td>
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<td>181</td>
<td>73.6</td>
<td>36.8</td>
<td>23.3</td>
<td>20.7</td>
<td>19.1</td>
<td>13.0</td>
<td>47.8</td>
</tr>
</tbody>
</table>

- **Mean Annual Flow (m³/s):** 81.1
- **Net Unit Runoff (mm):** 633
- **Estimated Surface Water Use (m³/s):** 0.95
- **Groundwater Use (m³/s):** -
- **Naturalized Mean Annual Discharge (m³/s):** 82.0
- **Naturalized Net Unit Runoff (mm):** 640
- **Incremental Net Unit Runoff (mm):** 489
5.3.2 Groundwater Flows

The estimated flows through the individual aquifers varies from approximately 0.05 m$^3$/s to 2.2 m$^3$/s, with an overall groundwater flow rate within the Middle Shuswap River Watershed as being on the order of 6 m$^3$/s. According to the preliminary groundwater flow estimates, it can be inferred that two thirds of the groundwater flow that discharges into Mable Lake originates from Aquifers M14 and M15, which are located on the west and east side of Mable Lake, respectively. The larger flow estimates for these two aquifers (M14 and M15) are primarily due to steeper hydraulic gradients and significant aquifer widths in comparison to the other aquifers in this section of the watershed. A summary of the aquifer parameters used in the preliminary estimation of the groundwater flows in the Middle Shuswap River Watershed are provided in the following table.

Table 22: Estimated Groundwater Flows in the Middle Shuswap River Watershed

<table>
<thead>
<tr>
<th>Aquifer Name</th>
<th>Average Depth to Groundwater* (m)</th>
<th>Average Depth of Well* (m)</th>
<th>Saturated Thickness (m)</th>
<th>Aquifer Width (m)</th>
<th>Horizontal Gradient (m/m)</th>
<th>Saturated Hydraulic Conductivity (m/s)</th>
<th>Q - Discharge (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M08</td>
<td>30</td>
<td>42</td>
<td>13</td>
<td>800</td>
<td>0.015</td>
<td>5.00E-04</td>
<td>0.07</td>
</tr>
<tr>
<td>M09</td>
<td>22</td>
<td>50</td>
<td>28</td>
<td>2000</td>
<td>0.010</td>
<td>5.00E-04</td>
<td>0.28</td>
</tr>
<tr>
<td>M10</td>
<td>19</td>
<td>36</td>
<td>17</td>
<td>2000</td>
<td>0.005</td>
<td>5.00E-04</td>
<td>0.08</td>
</tr>
<tr>
<td>M11</td>
<td>15</td>
<td>29</td>
<td>14</td>
<td>4000</td>
<td>0.019</td>
<td>5.00E-04</td>
<td>0.56</td>
</tr>
<tr>
<td>M12</td>
<td>15</td>
<td>29</td>
<td>14</td>
<td>2000</td>
<td>0.008</td>
<td>5.00E-04</td>
<td>0.11</td>
</tr>
<tr>
<td>M13</td>
<td>9</td>
<td>28</td>
<td>20</td>
<td>3000</td>
<td>0.002</td>
<td>5.00E-04</td>
<td>0.06</td>
</tr>
<tr>
<td>M14**</td>
<td>No Existing Wells</td>
<td>5</td>
<td>2000</td>
<td>5.00E-04</td>
<td>0.041</td>
<td>2.03</td>
<td></td>
</tr>
<tr>
<td>M15**</td>
<td>No Existing Wells</td>
<td>5</td>
<td>11000</td>
<td>5.00E-04</td>
<td>0.081</td>
<td>2.23</td>
<td></td>
</tr>
<tr>
<td>M16</td>
<td>No Existing Wells</td>
<td>5</td>
<td>9000</td>
<td>5.00E-04</td>
<td>0.035</td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>M17</td>
<td>No Existing Wells</td>
<td>5</td>
<td>1500</td>
<td>5.00E-04</td>
<td>0.012</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

The total groundwater flow to Mable Lake (approximately 6 m$^3$/s) is approximately 1 order of magnitude less than that of the minimum annual surface flow value as noted in Table 21, which states the minimum normalized flow at the outflow of Mabel Lake is between 47 and 81 m$^3$/s.

5.3.3 Estimate of Water Use / Allocation

The following sections provide the results of the estimate of water use/allocation in the Middle Shuswap River Watershed based on water licenses, groundwater use, water allocation restrictions, and Water Act reserves.

Water Licenses

The results of the water licenses query for the Middle Shuswap River Watershed are summarized in Table 23. These water licenses are depicted in Figure 9. As some licenses include water use for two or more purposes (e.g., irrigation and domestic use), the total number of licensed water uses exceeds the total number of licenses.
A review of the volumes associated with the different uses in Table 23 indicates that the majority of the allocated water in the Middle Shuswap River Watershed is associated with licenses issued to water utilities via Irrigation (Local Authority) and Waterworks (Local Authority) licenses, and to individuals via Irrigation licenses. On an annual basis, 96.9% of the consumptive volume associated with water licenses in this watershed are for these three purposes.

Table 23: Summary of Water Licenses by Use in the Middle Shuswap River Watershed

<table>
<thead>
<tr>
<th>Use</th>
<th>No. of Licenses</th>
<th>Volume</th>
<th>Volume Units</th>
<th>Seasonal m³/s Equivalent*</th>
<th>% of Seasonal Total</th>
<th>Annual m³/s Equivalent*</th>
<th>% of Annual Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Consumptive Uses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camps</td>
<td>1</td>
<td>9</td>
<td>m³/day</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Domestic</td>
<td>221</td>
<td>743</td>
<td>m³/day</td>
<td>0.009</td>
<td>0.2</td>
<td>0.009</td>
<td>0.5</td>
</tr>
<tr>
<td>Enterprise</td>
<td>7</td>
<td>89</td>
<td>m³/day</td>
<td>0.001</td>
<td>0.0</td>
<td>0.001</td>
<td>0.1</td>
</tr>
<tr>
<td>Fire Protection</td>
<td>3</td>
<td>0.002</td>
<td>m³/s</td>
<td>0.002</td>
<td>0.0</td>
<td>0.002</td>
<td>0.1</td>
</tr>
<tr>
<td>Greenhouses</td>
<td>1</td>
<td>3</td>
<td>m³/day</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Institutions</td>
<td>1</td>
<td>7</td>
<td>m³/day</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Irrigation**</td>
<td>202</td>
<td>14,356,111</td>
<td>m³/year</td>
<td>1.662</td>
<td>29.9</td>
<td>0.455</td>
<td>27.3</td>
</tr>
<tr>
<td>Irrigation (Local Authority)**</td>
<td>3</td>
<td>31,862,639</td>
<td>m³/year</td>
<td>3.688</td>
<td>66.4</td>
<td>1.010</td>
<td>60.6</td>
</tr>
<tr>
<td>Land Improvement</td>
<td>1</td>
<td>148,018</td>
<td>m³/year</td>
<td>0.005</td>
<td>0.1</td>
<td>0.005</td>
<td>0.3</td>
</tr>
<tr>
<td>Mineral Trading-Bath</td>
<td>1</td>
<td>45</td>
<td>m³/day</td>
<td>0.001</td>
<td>0.0</td>
<td>0.001</td>
<td>0.0</td>
</tr>
<tr>
<td>Ponds</td>
<td>2</td>
<td>5,169</td>
<td>m³/year</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Processing</td>
<td>1</td>
<td>2,472</td>
<td>m³/day</td>
<td>0.029</td>
<td>0.5</td>
<td>0.029</td>
<td>1.7</td>
</tr>
<tr>
<td>Residential Lawn/Garden</td>
<td>3</td>
<td>3,269</td>
<td>m³/year</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Stock Watering</td>
<td>45</td>
<td>273</td>
<td>m³/day</td>
<td>0.003</td>
<td>0.1</td>
<td>0.003</td>
<td>0.2</td>
</tr>
<tr>
<td>Watering</td>
<td>3</td>
<td>66,608</td>
<td>m³/year</td>
<td>0.002</td>
<td>0.0</td>
<td>0.002</td>
<td>0.1</td>
</tr>
<tr>
<td>Waterworks (Local Authority)</td>
<td>11</td>
<td>4,752,856</td>
<td>m³/year</td>
<td>0.151</td>
<td>2.7</td>
<td>0.151</td>
<td>9.0</td>
</tr>
<tr>
<td><strong>Total Consumptive Uses</strong></td>
<td>506</td>
<td>-</td>
<td>-</td>
<td>5.552</td>
<td>100</td>
<td>1.668</td>
<td>100</td>
</tr>
<tr>
<td><strong>Non-Consumptive Uses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conservation (Construction Works)</td>
<td>2</td>
<td>0.025</td>
<td>m³/s</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Conservation (Use of Water)</td>
<td>5</td>
<td>0.442</td>
<td>m³/s</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Power (Commercial and Residential)</td>
<td>10</td>
<td>1.045</td>
<td>m³/s</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
<tr>
<td>Power (General)</td>
<td>2</td>
<td>31</td>
<td>m³/s</td>
<td>0.000</td>
<td>0.0</td>
<td>0.000</td>
<td>0.0</td>
</tr>
</tbody>
</table>
**Table 24: Summary of High Volume Water Licenses by Use and Sub-drainage in the Middle Shuswap River Watershed**

<table>
<thead>
<tr>
<th>Sub-drainage</th>
<th>Irrigation (Private) (m³/year)</th>
<th>Local Storage* (Private) (m³/year)</th>
<th>Irrigation (Local Authority) (m³/year)</th>
<th>Waterworks (Local Authority) (m³/year)</th>
<th>Waterworks (Local Authority) Storage (m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuswap River (Sugar Lake to WSC Lumby)**</td>
<td>1,840,142</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shuswap River (WSC Lumby to Mabel Lake)</td>
<td>2,454,132</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Currie Creek</td>
<td>424,300</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Monashee Creek</td>
<td>37,004</td>
<td>12,335</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cherry Creek</td>
<td>1,806,308</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Ferry Creek</td>
<td>390,396</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Duteau Creek</td>
<td>659,431</td>
<td>-</td>
<td>21,994,799</td>
<td>4,209,536</td>
<td>32,884,577</td>
</tr>
<tr>
<td>Creighton Creek</td>
<td>2,145,367</td>
<td>141,850</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bessette Creek (above 978,890)</td>
<td>978,890</td>
<td>821,683</td>
<td>9,867,840</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Groundwater Use

Groundwater use in the Middle Shuswap River Watershed consists of a variety of residential, agricultural, community and industrial uses. Confirmed uses consist of the following:

- Village of Lumby – operates three high capacity groundwater wells which operate alternately to provide approximately 345,418 m³/year (946 m³/day or 0.01 m³/s).

- Community of Whitevale – operates one well with a yearly extraction of approximately 36,700 m³ (100 m³/day or 0.001 m³/s) (Golder, 2008).

- Private Water Users – numerous individual wells are present in the Middle Shuswap River Watershed area. A total of approximately 2,700 parcels have been identified within the Middle Shuswap River Watershed. Based on the RDNO’s subdivision servicing bylaw, and assuming that each parcel has a groundwater well and withdraws the minimum allotted groundwater, it can be inferred that the potential groundwater use in the Middle Shuswap River Watershed is approximately 0.21 m³/s. This water use estimation is likely representative of the maximum water use, as the BC MoE Water Resource Atlas indicates that there are only approximately 776 wells in the area. Based on the 776 wells identified in the watershed and on the minimum pumping rate per well (as per the RDNO’s subdivision servicing bylaw), the potential groundwater extraction rate of groundwater is approximately 0.06 m³/s. Note, not all private water wells are identified on the Water Resource Atlas.

- Based on an estimated population of approximately 4,000 (representing 40% of the population as identified in Table 2 and on per capita water consumptions provided in Table 3, potential groundwater use within the Middle Shuswap River Watershed ranges from 0.02 m³/s to 0.05 m³/s. This is approximately an order of magnitude less than the groundwater use rate as identified using parcel numbers and the subdivision servicing bylaw groundwater requirements. It is a similar order of magnitude when compared against the number of water wells within the watershed and the subdivision servicing bylaw groundwater requirements.
The following table summarizes potential groundwater use based on population in the Middle Shuswap River Watershed.

Table 25: Groundwater Consumption Estimates for Middle Shuswap River Watershed Population

<table>
<thead>
<tr>
<th>Water Use Averages</th>
<th>L/per person/per day</th>
<th>L/day</th>
<th>m³/day</th>
<th>m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okanagan average</td>
<td>675</td>
<td>2,700,000</td>
<td>2,700</td>
<td>0.03</td>
</tr>
<tr>
<td>Okanagan summer average</td>
<td>1000</td>
<td>4,000,000</td>
<td>4,000</td>
<td>0.05</td>
</tr>
<tr>
<td>Shuswap Watershed average (based on Lumby groundwater usage rates)</td>
<td>579</td>
<td>2,316,000</td>
<td>2,316</td>
<td>0.03</td>
</tr>
<tr>
<td>BC average</td>
<td>490</td>
<td>1,960,000</td>
<td>1,960</td>
<td>0.02</td>
</tr>
<tr>
<td>Canadian average</td>
<td>329</td>
<td>1,316,000</td>
<td>1,316</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* The Middle Shuswap River Watershed consists of approximately 4,000 users.

**Water Allocation Restrictions**

There are 38 sources in the Middle Shuswap River Watershed that have water restrictions noted. Many of these restrictions are on very small sources. Some of the larger sources with restrictions are Bessette Creek, Creighton Creek, and Vance Creek. Details for these sources are provided in Appendix E.

**Water Act Reserves**

A search of the complete list of Water Act reserves in British Columbia identified that there are no Water Act reserves in the Middle Shuswap River Watershed (BC MoE 2009).

5.3.4 **Estimate of Flow / Allotment versus Consumption**

The following sections provide an estimate of surface water allotment and groundwater flow versus consumption in the Middle Shuswap River Watershed.

**Surface Water**

Estimated surface water use is low relative to the mean annual flow of the Shuswap River. Surface water use is 1.2% of mean annual flow at the outlet of Mabel Lake and less at the Shuswap River near Enderby. Cherry Creek also shows low estimated water use at less than 1% of mean annual flow. In contrast, Ferry Creek has an estimated surface water use of 5.7% mean annual flow, and because summer use is about 2.5 times higher than annual use due to high volumes of irrigation in August, summer water use is about 30% of mean monthly August flows and 83% of the minimum monthly August flows. This means that if monthly flows were naturalized, water use in August would be about 24% of the mean natural August flow and close to 50% of the minimum natural August flow. The highest estimated annual water use relative to flows occurs in Bessette Creek and its tributaries. Near its mouth, the estimated annual water use is 18.5% of the mean annual flow and 16% of the naturalized annual flow. Summer use is proportionally much higher relative to the August flows, but direct comparison is not valid because the summer flow is partially regulated by releases from storage from the Duteau Creek system that offset some of the summer water use. The water stored in reservoirs on the Duteau Creek
system was collected from the high spring freshet flows and provides regulated releases for downstream licenses and fisheries flows.

For the Middle Shuswap River Watershed, many of the communities and developed rural areas rely on surface water utilities as the primary source of water for domestic and irrigation purposes. The below list of licenses to surface water utilities was generated from the overall list of surface water licenses from Table 23 Water purveyors were contacted to provide estimates of actual usage to compare to the amounts the licenses are permitted to extract.

Table 26: Validation of Surface Water Utility Licenses in the Middle Shuswap River Watershed

<table>
<thead>
<tr>
<th>Community</th>
<th>License Number(s)</th>
<th>Source Name</th>
<th>Quantity Allotted (m³/year)*</th>
<th>Actual Usage (m³/year)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greater Vernon Water Utility</td>
<td>C025665; C025909; C124618; C032119; C032123; C032119; C032123; C017839</td>
<td>Duteau Creek; McAuley Creek</td>
<td>35,242,513</td>
<td>14,274,000</td>
</tr>
<tr>
<td>Mabel Lake Water Utility</td>
<td>C113054; C113055; C117714</td>
<td>Mabel Lake</td>
<td>290,381</td>
<td>18,509</td>
</tr>
<tr>
<td>Lumby</td>
<td>C025674</td>
<td>Duteau Creek</td>
<td>829,661</td>
<td>0 (now on groundwater)</td>
</tr>
<tr>
<td>Silver Star Water Utility</td>
<td>C122226; C122250</td>
<td>Vance Creek; Lost Creek 1</td>
<td>252,938</td>
<td>17,642</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>36,615,494</td>
<td>14,310,151</td>
</tr>
</tbody>
</table>

* In all cases the actual usage amounts are represented by 2010 values.

The amount consumed represents 39% of the allotted amounts of water for the Middle Watershed. Usage by GVW, the largest user, only uses 41% of their allotted amount, which is diverted from the Shuswap River Watershed to the Okanagan Watershed. However, most of the water stored in the Duteau Creek system is collected during the high spring flows, which also provides fisheries flow to Duteau Creek in the summer dry months.

**Groundwater**

Total groundwater use in the Middle Shuswap River Watershed is estimated to range from 0.03 m³/s to as high as approximately 0.22 m³/s, the latter accounting for groundwater from private wells using parcel numbers and possible extraction rates. The estimated discharge through Aquifer M11 (within the Lumby area) is inferred to be 0.56 m³/s and the Lumby usage is on the order of 0.01 m³/s, which represents approximately 2% of the total flow through that aquifer. Some of the groundwater in the Lumby area may be flowing towards the south and eventually southwest, leaving the Shuswap River Watershed and entering the Okanagan Basin Watershed. The total estimated potential groundwater use of 0.22 m³/s represents approximately 3.5% of the total groundwater flow within the Middle Shuswap River Watershed.

**5.3.5 Minimum Instream Flow Thresholds**

Based on a literature review and discussions with fisheries staff from DFO and BC MFLNRO, three portions of the Middle Shuswap River Watershed have documented instream flow thresholds that are either accepted as
targets or have been recommended: Middle Shuswap River between Sugar Lake and Shuswap Falls, Bessette Creek, and Duteau Creek. Planning for fish protection requires setting of instream flow thresholds throughout many of the other streams in the Middle Shuswap River Watershed with high fish values and existing and/or potential water use. Recommended methods for setting additional instream flow thresholds or targets are described and discussed in Appendix F.

Middle Shuswap River

The Shuswap River water use planning process for BC Hydro's Shuswap Falls and Sugar Lake Project was initiated in March 2000, completed in April 2002, and revised for acceptance by the BC Comptroller of Water Rights and signed on August 18, 2005 (Homenuke and Groves 2005). This Project includes the section of the Middle Shuswap River between Wilsey Dam, its spillway and headpond, and the generating station at Shuswap Falls, and Peers Dam, which impounds the Upper Shuswap River to form the Sugar Lake Reservoir over the original Shuswap Lake. The operating conditions proposed in this Water Use Plan (WUP) reflect the many interests represented by members of the Consultative Committee for this WUP, including fisheries, dam safety, flood routing, wildlife, recreation, heritage resources, power, and economic development (Homenuke and Groves 2005).

The proposed operating conditions for these facilities are expected to continue to augment flows for fish from the fall through to the spring as well as provide for continued recreational opportunities on the Sugar Lake Reservoir and the Middle Shuswap River. It is also expected that the better management of operating levels in Sugar Lake Reservoir will benefit fish and aquatic productivity in the reservoir. In addition, the proposed installation of a new headpond structure at Wilsey Dam is expected to benefit fish downstream of Wilsey Dam by improving the stability of downstream flows in the river during unplanned outages. A new fish passage structure at Wilsey dam is also under consideration.

The operating conditions include minimum discharges (i.e., instream flow thresholds) below Wilsey Dam or the Shuswap Generating facility of 16 m³/s from August 15 to December 31, and of 13 m³/s from January 1 to August 14 (Homenuke and Groves 2005). In both time periods, these discharges reflect the minimum required and there will be no direction to reduce flows to these rates of discharge unless required due to low inflow conditions. BC Hydro is confident that it can maintain or exceed these flows 95% of the time based on the 27 years of recorded inflow. It is expected that flows will approach the minimum rates only during very dry years and that in other years flows are expected to be higher. During the January 1 to March 31 period, flow reduction will take place by natural means once the storage in Sugar Lake Reservoir has been used and discharge equals natural inflows. During the freshet period, it is anticipated that the minimum daily average discharge will almost always be exceeded due to natural inflows and storage limitations (Homenuke and Groves 2005).

The mean annual discharge (MAD) at the Shuswap River near Lumby WSC station (No. 08LC003) is approximately 50 m³/s. As such, the minimum discharges are approximately equivalent to 32% MAD from August 15 to December 31, and 25% MAD from January 1 to August 14. It should be noted that the BC Hydro water use is non-consumptive, and as such the thresholds are primarily directed at ensuring that filling of storage in Sugar Lake does not result in undue downstream low flows and timing releases to maintain higher flows for fall salmon spawning. Thresholds do not need to address higher freshet flows for ecosystem maintenance because despite the large storage capacity in Sugar Lake, freshet volumes are much higher and spill over the
dam at Sugar Lake reservoir annually. A relatively natural hydrograph is maintained below the BC Hydro facilities as seen in the flow records for the Shuswap River near Lumby WSC station.

**Bessette Creek**

The Government of British Columbia introduced the Fish Protection Act in May 1997 as a key element of the BC Fisheries Strategy to save British Columbia's fish stocks. This legislation is intended to balance the needs of fish with the needs of people, to the benefit of both. The Act focuses on four major objectives: ensuring sufficient water for fish, protecting and restoring fish habitat, improving riparian protection and enhancement, and stronger local government powers in environmental planning (BC MoE 2011d). The process of designating “sensitive streams” throughout the province was led by the BC Ministry of Environment, Lands and Parks (MELP), and in 2001, Bessette Creek was recommended as a "candidate sensitive stream." The profile for this tributary to the Middle Shuswap River describes its fisheries values and recovery potential, and discusses water licensing information in the context of hydrologic information and resultant water shortages for fish (Anonymous 2001). Included in the profile are the following minimum fish flow requirements (i.e., instream flow thresholds): 20% MAD for rearing and overwintering, 10% MAD for short-term survival, and 30% MAD for migration and spawning.

MAD varies throughout the watershed, increasing with downstream distance as tributaries join to form larger streams. The MAD at the Bessette Creek above Beaverjack Creek WSC station (No. 08LC039) is approximately 4.2 m$^3$/s. As such, the minimum fish flow requirements are approximately equivalent to 0.84 m$^3$/s for rearing and overwintering, 0.42 m$^3$/s for short-term survival, and 1.26 m$^3$/s for migration and spawning.

Bessette Creek has not yet been designated as a “sensitive stream” under the Fish Protection Act and as such the fish flow requirements are recommendations only. Nevertheless, the entire Bessette Creek watershed (including Duteau Creek, see next section) remains as one of the highest priorities in the Shuswap River Watershed for fish and fish habitat from a fisheries value and water use perspective (Tara White, BC MFLNRO Senior Fisheries Biologist, pers. com.). As is the case with Duteau Creek, these recommendations also do not address the higher freshet flows required to maintain channel functions. This is an important consideration that should be addressed when these recommendations are updated given that there are storage reservoirs in the Duteau, Nicklen, and Vance Creek sub-drainages, and there is a likelihood of further considerations for storage as water demands in the Vernon area increase in the future.

**Duteau Creek**

GVW, a function of the RDNO, uses a series of reservoirs in Upper Duteau Creek to store and regulate water. Water releases are regulated at a small reservoir (Headgates), where water is either released to Duteau Creek and eventually into the Shuswap River or is diverted to the GVW system, which is within the Okanagan River Watershed.

Flows that are released to Duteau Creek are by a combination of managed releases at Headgates through the low level outlet pipe and overflow from the spillway. Spillage via the spillway is normally restricted to the freshet periods. There are typically two annual freshet periods, the first being the lower freshet which is from the watershed below GVW’s three Aberdeen plateau reservoirs. The utility attempts to capture the lower freshet in the Headgates reservoir and divert it to the Goose Lake reservoir in the lower valley. GVW captures the second, upper freshet that begins later in the spring in their Aberdeen Plateau reservoirs. Spill from the upper freshet occurs after the Aberdeen reservoirs have filled to maximum capacity.
Flows to Duteau Creek need to account for downstream licenses for irrigation, stock watering and domestic use, release of water for the two DFO held conservation licenses which total 0.071 m$^3$/s on an annual basis, as well as the base flows for fish. The DFO target fish protection flows (i.e., instream flow thresholds) as referenced in McNeil (1991) and confirmed by Watts (2011) are 0.057 m$^3$/s from January 1 to March 31, 0.113 m$^3$/s from April 1 to August 31, and 0.142 m$^3$/s from September 1 to December 31. These recommended flows are only directed towards minimum flows to sustain the fish populations. They do not address the higher freshet flow requirements that are needed to maintain hydraulic functions that are necessary to sustain complex fish habitat and stream processes over the longer term. The DFO target fish protection flows are incorporated into the GVW operating procedures for flow releases at Headgates as well as releases for downstream licenses.

5.4 Riparian Areas

This section of the Shuswap River Technical Assessment provides a preliminary assessment of the condition of riparian areas along the Middle Shuswap River, as well as identifying previous restoration works that have been completed within this section of the stream. Based on the results of this assessment, a preliminary prioritization of riparian areas of the Middle Shuswap River for restoration works was then completed.

5.4.1 Riparian Areas Condition

The following sections describe previous impacts to the riparian areas of the Middle Shuswap River as well as restoration activities that have already been completed throughout this section of the stream.

Previous Impacts

Previous impacts to the Middle Shuswap River are primarily related to hydroelectric dam construction, agriculture, and forestry operations. The Wilsey Dam flooded 7 ha of riparian and instream habitat over a length of 3.7 km above the dam to create the headpond, and resulted in a complete barrier to fish passage of all four anadromous salmon species and potentially certain stocks of migratory adfluvial resident species that were historically present above the Shuswap Falls (Anonymous 2003). As a result, at least 20 km of former spawning, rearing, and overwintering habitat is now isolated from these salmonid stocks. Both the Peers Dam and the Wilsey Dam limit LWD, gravel, and organics recruitment to downstream areas of the Shuswap River, although the Wilsey Dam may also serve to trap fine sediments thereby improving downstream spawning habitat (Anonymous 2003). Hydroelectric dam construction has also resulted in substantial alterations of the wildlife habitat values associated with the Middle Shuswap River, particularly for those species whose life cycles depend on riparian, wetland, or instream habitat. For example, flow alterations as a result of operation of the Peers Dam has affected benthic insect production (Anonymous 2003), which can have radiating effects through higher trophic levels. These flow alterations may have also resulted in the loss of amphibian breeding habitat from the Middle Shuswap River (Davis and Weir 2004).

Agricultural activities are the largest cause of disturbance to the Middle Shuswap River in its lower reaches downstream of its confluence with Bessette Creek. This section of the Middle Shuswap River is located in a wide, fertile floodplain used extensively for hay production and ranching operations. Impacts to the riparian and instream areas include loss of spawning habitat through filled and diverted side channels and oxbows, reduced shading and nutrient input to the stream through riparian vegetation clearing, and sedimentation, and general degradation where cattle have unrestricted access to the channel. Forestry operations and associated road construction have also adversely impacted the Middle Shuswap River in various areas though increased erosion.
and undercut banks at stream crossings, reduced shading and nutrient input to the stream where riparian buffers have not been maintained, and increased LWD inputs to the stream resulting in debris jams at the inlets of side channels. Where large enough, these debris jams can decrease flows to side channels resulting in loss of spawning and rearing habitat. Forestry impacts include both large-scale clearcutting operations as well as selective logging on private property. In addition to these impacts, high power boat use in the lower reaches of the Middle Shuswap River and on Mabel Lake was noted to be an erosion concern during the SRWSP Initial Stakeholders Workshop on December 2, 2010.

As part of the Upper Shuswap River Stream Assessment\(^8\), Summit (1996) identified and ground-truthed 15 sites identified as having a high degree of impact to the Middle Shuswap River as a result of either forestry or uncertain land use activities, and retained three of these sites as confirmed, highly impacted areas. Site 15 and Site 45 from their report are large debris jams that are blocking side channels, and Site 56 is a logged riparian area with undercut banks; all three sites were resulting in adverse impacts to salmonid spawning habitat and water quality. These sites are mapped on Figure 31 to Figure 36. Summit (1996) recommended selective restoration of the debris jams to improve fish habitat but to limit the potential for subsequent bank erosion. Based on interpretation of recent orthophotos, large debris jams are still present throughout many side channels in the Middle Shuswap River.

Preliminary SEI and SHIM was conducted for a 1 km band on either side of the section of the Middle Shuswap River between Peers Dam and Wilsey Dam (Minor 2007b), and is currently in the process of being ground-truthed and finalized, with the final report to be completed for March 2012. No previous FIM or TEM has been completed for the mainstem of the Middle Shuswap River to quantify or map previous impacts. However, Schleppe (2010) completed a detailed foreshore inventory and mapping of Mabel Lake, which included assigning an aquatic habitat index (AHI) rank based on biophysical, fisheries, shoreline vegetation, and modification parameters to each segment of the shoreline. He found that 11% of 8.8 km of the Mabel Lake shoreline is disturbed, with the dominant disturbances including single family residential, rural, and park developments resulting in altered shorelines and riparian vegetation clearing. Docks, retaining walls, and groynes were the most common type of shoreline modifications. Approximately 10% of the shoreline was considered to be highly impacted, with a further 5.7% considered to be moderately impacted.

In the absence of recent detailed ecological assessments for the entire Middle Shuswap River, Golder conducted an orthophoto interpretation of this section of the stream as a relatively coarse, preliminary assessment of riparian condition. The results of this assessment are mapping on Figure 31 to Figure 36. Approximately 28.4% (32,387 m) of the riparian areas of this stream have been disturbed within 30 m of the approximate HWM (includes both streambanks). This disturbance comes from a variety of land use activities including agricultural operations (14.7%; 16,774 m), roadways (4.2%; 4,834), rural developments (3.9%; 4,459 m), forestry operations (3.4%; 3,895 m), recreational developments (e.g., golf courses, parks; 1.4%; 1,552 m), and hydroelectric dam facilities (0.8%; 872 m). Disturbance as a result of forestry operations is primarily restricted to the western side of the upper portion of the Middle Shuswap River within 5 km of Sugar Lake. Agricultural disturbances were abundant throughout the lower reaches of this stream downstream of its confluence with Bessette Creek.

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\(^{8}\) The Upper Shuswap River as defined in Summit (1996) includes both the Upper and Middle Shuswap River sections defined in this Technical Assessment.
**Restoration Works**

Numerous restoration works have been previously completed along the Middle Shuswap River. These works have primarily been concentrated on improving salmonid spawning habitat in the side channels and tributaries of this large, high-energy stream, as works within the mainstream of the Middle Shuswap River would be susceptible to destruction during freshet. The most common types of restoration projects include riparian planting of conifer and deciduous trees, shrubs, and willow stakes; riparian exclusion fencing to restrict cattle access to the Middle Shuswap River and its side channels; channel modifications to increase habitat complexity including the installation of spawning gravels and deep pool features; and measures to connect disassociated side channels back to the mainstem of the Middle Shuswap River. Many of these restoration works have been completed by the Whitevalley Community Resource Centre\(^9\) (Whitevalley), an environmental stewardship group that has been conducting restoration works in the Lumby area since 1997, particularly along the Middle Shuswap River and its tributaries (i.e., Bessette Creek, Creighton Creek, Duteau Creek, Harris Creek, Ireland Creek, Vance Creek, Cherry Creek). The Cherryville Water Stewards have also been active in the Middle Shuswap River Watershed, and much of their restoration activities have focused on bank stabilization projects along Cherry Creek (Hank Cameron, Cherryville Water Stewards, pers. comm.).

Restoration works completed along the Middle Shuswap River and its side channels are summarized in Table 27 and the locations of these projects, where known, have been mapped on Figure 31 to Figure 36. Much of the funding for these restoration works has come from the Bridge-Coastal Fish and Wildlife Restoration Program.

**Table 27: Past Restoration Works on the Middle Shuswap River and its Side Channels**

<table>
<thead>
<tr>
<th>Year</th>
<th>Stream Location</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Middle Shuswap River</td>
<td>Bank stabilization and erosion control; habitat structure construction (71 structures over 950 m); riparian exclusion fencing; riparian planting</td>
<td>Minor (2007a)</td>
</tr>
<tr>
<td>2006</td>
<td>Huwer Groundwater Channel</td>
<td>Riparian planting; riparian protection from beaver activity</td>
<td>Minor (2007c)</td>
</tr>
<tr>
<td>2006</td>
<td>Middle Shuswap River*</td>
<td>Riparian planting</td>
<td>Minor (2007c)</td>
</tr>
<tr>
<td>2006</td>
<td>Ireland Creek Side Channel</td>
<td>Riparian planting</td>
<td>Minor (2007c)</td>
</tr>
<tr>
<td>2006</td>
<td>Maltman Channel*</td>
<td>Riparian planting; riparian protection from beaver activity</td>
<td>Minor (2007c)</td>
</tr>
<tr>
<td>2006</td>
<td>Proctor Channel</td>
<td>Riparian protection from beaver activity</td>
<td>Minor (2007c)</td>
</tr>
<tr>
<td>2004</td>
<td>Middle Shuswap River**</td>
<td>Restoration works (specific activities not reported)</td>
<td>Whitevalley (2006)</td>
</tr>
<tr>
<td>2003</td>
<td>Middle Shuswap River</td>
<td>Bank stabilization and erosion control; habitat structure construction</td>
<td>Minor (2007a)</td>
</tr>
<tr>
<td>2003</td>
<td>Ireland Creek Side Channel</td>
<td>Channel habitat complexing with rocks, trees, and other LWD; riparian planting; riffle construction</td>
<td>Minor (2003a)</td>
</tr>
<tr>
<td>2002</td>
<td>Proctor Channel</td>
<td>Reconnect Proctor Channel to Shuswap River; settling pond construction; riparian planting; riparian exclusion</td>
<td>Minor (2003b)</td>
</tr>
</tbody>
</table>

\(^9\) Website: http://www.whitevalley.ca/. Email: info@whitevalley.ca.
### 5.4.2 Riparian Areas Prioritization

A prioritization of riparian areas for restoration works was first completed at the broader sub-drainage scale within the entire Middle Shuswap River Watershed based on the results of Matthews and Bull (2003). A preliminary prioritization of the riparian areas of the Middle Shuswap River specifically is then provided based on the limited information available on previous impacts and restoration works.

#### Middle Shuswap River Watershed

A total of 13 sub-drainages within the Middle Shuswap River Watershed were identified by Matthews and Bull (2003) as having high or very high significance as a habitat protection focus area. These sub-drainages are listed in Table 28 and comprise 57% of the area occupied by the Middle Shuswap River Watershed. Of these 13 sub-drainages, seven have been identified as highly significant for restoration. These sub-drainages comprise 41% of the Middle Shuswap River Watershed. The results of Matthews and Bull’s (2003) restoration prioritization at the watershed level are depicted in Figure 37.

#### Table 28: Priority Sub-drainages for Restoration within the Middle Shuswap River Watershed

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Area (ha)</th>
<th>Significance for Protection</th>
<th>Level of Habitat Alteration</th>
<th>Significance for Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bessette Creek</td>
<td>11 762</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Cavanaugh Creek</td>
<td>2534</td>
<td>High</td>
<td>High</td>
<td>?</td>
</tr>
<tr>
<td>Cherry Creek</td>
<td>15 359</td>
<td>High</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Creighton Creek</td>
<td>10 818</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Derry Creek</td>
<td>5083</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Duteau Creek</td>
<td>11 482</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Nicklen (aka Harris) Creek</td>
<td>13 675</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Stream Name</td>
<td>Area (ha)</td>
<td>Significance for Protection</td>
<td>Level of Habitat Alteration</td>
<td>Significance for Restoration</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Iron Creek</td>
<td>1171</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Latewhos Creek</td>
<td>5033</td>
<td>High</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Monashee Creek</td>
<td>11 459</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Noisy Creek</td>
<td>5980</td>
<td>High</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Railroad Creek</td>
<td>4032</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Shuswap River (Middle)</td>
<td>46 576*</td>
<td>Very High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Wap Creek</td>
<td>21 073</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>West Harris Creek</td>
<td>2008</td>
<td>High</td>
<td>?</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Source: modified from Matthews and Bull (2003).
* This sub-drainage area was calculated as part of this Technical Assessment based on the sub-watershed boundaries defined in this report and the sub-drainage boundaries available from iMapBC (BC MFLNRO 2011).

**Middle Shuswap River**

In the absence of other information, all of the degraded sites identified by Summit (1996) as having a high degree of impact to the mainstem of the Middle Shuswap River as a result of forestry have been preliminarily ranked as a high priority for investigation and/or restoration, as these sites appear to not yet have been restored. As well, all of the areas identified in Figure 31 to Figure 36 as disturbed during the interpretation of recent orthophotos have been preliminarily ranked as a high priority for restoration. The areas identified as natural during the orthophoto interpretation have been ranked as a low priority for restoration. The Cherryville Water Stewards have also identified the Middle Shuswap River between Cherry Creek and Reiter Creek as a high priority area for restoration due to the presence of unstable banks (Hank Cameron, Cherryville Water Stewards, pers. comm.). Additional assessments would be required to further characterize the riparian areas of the Middle Shuswap River and move beyond this preliminary two class prioritization system. Specifically, the results of the SEI for the section of the Middle Shuswap River between Wilsey Dam and Sugar Lake, to be released in March 2012, will likely provided the detailed, ground-truthed ecological information required to better prioritize the riparian areas for restoration. In addition to these restoration areas on the mainstem of the Middle Shuswap River, five areas at Mabel Lake were identified as a high priority for restoration as part of the Mabel Lake FIM (Schleppe 2011). Based on the desktop review completed for this Technical Assessment, Golder is not aware of any additional high priority areas for restoration on the Middle Shuswap River.
6.0 LOWER SHUSWAP RIVER WATERSHED

This section provides a watershed profile for the Lower Shuswap River Watershed, which is the portion of the Shuswap River Watershed between the Mabel Lake outlet and the Mara Lake inlet including the sub-drainages associated with the Lower Shuswap River and its direct and indirect tributaries. This watershed profile is divided into four sections, including a specific description and an assessment of the status of water quality, water quantity, and riparian areas in the Lower Shuswap River Watershed.

6.1 Watershed Description

The following sections provide a general description of the Lower Shuswap River Watershed, as well as a description of its hydrogeology and the land uses present.

6.1.1 General

The Lower Shuswap River Watershed is the portion of the watershed between the Mabel Lake outlet (~393 masl) and the terminus of the Shuswap River at the Mara Lake inlet (~347 masl), located 72.7 km downstream, as shown in Figure 38. The Shuswap River predominantly flows southwest, then west from the Mabel Lake outlet to the City of Enderby between the northerly Hunters Range area and the southerly Trinity Hills area of the Shuswap Highland. Key sub-drainages of the Lower Shuswap River within this section of the stream include, from upstream to downstream, Kingfisher Creek, Delorne Creek, Cooke Creek, Fall Creek, Barnes Creek, Trinity Creek, Ashton Creek, Brash Creek, and Fortune Creek. Notable geographic features within this section of the Shuswap River include the Skookumchuck Rapids, located downstream of Kingfisher Creek outlet, Shuswap River Islands, and bridge crossings at Ashton Creek (unincorporated area) and Enderby. From Enderby, the Shuswap River flows northeast in a relatively wide floodplain though Grindrod to Mara Lake around the Hunters Range. Key sub-drainages within this section of the Lower Shuswap River Watershed include Blurton Creek and Johnson Creek. Notable geographic features within this section of the Shuswap River include bridge crossings at Grindrod and Mara (unincorporated areas).

The Lower Shuswap River is an important fisheries resource as this stream provides spawning habitat for all four salmon species present in the Shuswap Watershed. The Lower Shuswap River is a major sockeye salmon spawning stream with a spawning capacity of 713,000 adults (DFO 1997). Rearing habitat for juvenile sockeye salmon from this stock is provided by Mara Lake and Shuswap Lake, which collectively have a rearing capacity of 4,019,000 spawning equivalents for this and other stocks (DFO 1997). The Lower Shuswap River also is a major chinook salmon producer (>1000 spawners) and an important coho salmon producer (>100 spawners) in the area (DFO 1997). This stream also supports a very small stock of pink salmon, which is not present in either the Middle or Upper Shuswap River Watersheds (DFO 1997). Based on AHI rankings, fish habitat quality ranges substantially in the Lower Shuswap River, with the best habitat generally located further upstream (Hawes et al. 2011). No spawning habitat was identified in the highly disturbed section of the Lower Shuswap River downstream of Enderby, where cover is limited to instream vegetation and deep pools (Hawes et al. 2011). The Kingfisher Interpretive Centre and Hatchery, located at the confluence of Cooke Creek with the Lower Shuswap River, contributes to chinook and coho production in the Shuswap area.
6.1.2 Hydrogeology

The following sections provide a summary of the hydrogeology in the Lower Shuswap River Watershed, summarizing provincially identified aquifers, aquifer linkages as identified during this Technical Assessment and BC MoE observation wells information.

Aquifers

Based on the methods described in the conceptual model in Section 2.4.2, seven discrete unconsolidated aquifers were delineated in the Lower Watershed which are numbered L18 through L22 (Figure 17). The aquifers are located between the outlet of Mable Lake and the inlet of the Shuswap River to Mara Lake. The linkages of groundwater flow between aquifers are shown on Figure 39, below and on Figure 17.

![Aquifer Linkages Diagram](image)

Aquifer L21 includes the community of Ashton Creek and Aquifer L23 includes the communities of Enderby and Grindrod. The north south trending valley, which is the location of Aquifers L22, L23 and L24 include the area where most of the provincially designated aquifers in the Lower Watershed are located.

The unconsolidated aquifers identified within the Lower Shuswap River Watershed are associated with the Shuswap River with hydraulic gradients within these valley bottom aquifers controlled by river elevations. Only aquifer L24 is identified to discharge directly to Mara Lake.

According to the BC MoE, there are 14 provincially identified aquifers listed in the BC MoE Water Resources Atlas within the Lower Shuswap River Watershed. Aquifer L21 includes the rural community of Ashton Creek where two BC MoE provincial aquifers have been mapped (one unconsolidated aquifer, MoE Aquifer Number 113; and one bedrock aquifer, MoE Aquifer Number 804). Aquifer L22 includes the area between the Town of Armstrong and the City of Enderby where four MoE Provincial Aquifers including 106, 111, 113 and 849 have been mapped. The remaining eight BC MoE provincially mapped aquifers are located within valley and upland, bedrock areas associated with L23 and L24.

The locations of the provincial aquifers are shown in Figure 14. Five of these are listed as bedrock aquifers ranging in size from 2.3 km² to 21.4 km² (geometric mean of 6.3 km²) and are listed as having low to moderate productivity. The remaining nine aquifers are listed as sand and gravel and range in size from 1.7 km² to 143.2 km² (geometric mean of 12.8 km²) and are listed as having moderate to high productivity.

The largest bedrock aquifer is Aquifer No. 107 which includes the western slopes of the valley wall west of Enderby in the Gardom Lake area. This aquifer crosses the boundary of the watershed and is partially shared by the most northern area of the Okanagan Watershed of the Deep Creek sub-basin. The only bedrock aquifer with...
a notation of high vulnerability is Aquifer No. 805, which is 2.3 km$^2$ and located west of Mabel Lake near the outflow.

The largest sand and gravel aquifer is Aquifer No. 111 which occupies the north-south trending valley between Mara Lake and Okanagan Lake. Aquifer No. 111 is shared between the Okanagan Watershed and the Shuswap River Watershed with approximately 58% of the aquifer lying in the Shuswap River Watershed. This regional aquifer is listed as having moderate productivity, moderate demand and low vulnerability. In the Shuswap River Watershed Aquifer No. 111 is overlain by two smaller sand and gravel aquifers (Provincial Aquifers 114 and 849), which are listed as having high and moderate vulnerability. The only other aquifer listed as having a high vulnerability is Aquifer No. 108, which is 10.8 km$^2$ in area and crosses the watershed boundary shared with the Salmon River Watershed.

These aquifers are summarized below in Table 29, which indicates the aquifer name (including provincial classification and risk ranking values) aquifer materials, descriptive location, demand, productivity, vulnerability and overall size. In some cases the alluvial aquifers and bedrock aquifers overlap.

<table>
<thead>
<tr>
<th>Aquifer Name</th>
<th>Aquifer Materials</th>
<th>Descriptive Location</th>
<th>Demand</th>
<th>Productivity</th>
<th>Vulnerability</th>
<th>Size (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>806 IIB (8)</td>
<td>Sand and Gravel</td>
<td>Shuswap River - east of Enderby</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>1.7</td>
</tr>
<tr>
<td>114 IIIA (9)</td>
<td>Sand and Gravel</td>
<td>South of Mara Lake</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>3.5</td>
</tr>
<tr>
<td>108 IIIA (11)</td>
<td>Sand and Gravel</td>
<td>4 kilometres southeast of Salmon Arm</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>10.8</td>
</tr>
<tr>
<td>113 IIIC (9)</td>
<td>Sand and Gravel</td>
<td>Ashton Creek</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>11.5</td>
</tr>
<tr>
<td>103 IIA (14)</td>
<td>Sand and Gravel</td>
<td>Parkinson Lake</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>11.7</td>
</tr>
<tr>
<td>849 IIB (9)</td>
<td>Sand and Gravel</td>
<td>NE of Armstrong</td>
<td>Low</td>
<td>Moderate</td>
<td>Moderate</td>
<td>13.9</td>
</tr>
<tr>
<td>102 IIC (11)</td>
<td>Sand and Gravel</td>
<td>Hullcar</td>
<td>Moderate</td>
<td>High</td>
<td>Low</td>
<td>15.1</td>
</tr>
<tr>
<td>109 IIIC (10)</td>
<td>Sand and Gravel</td>
<td>Highway 97B</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>35.4</td>
</tr>
<tr>
<td>111 IIC (11)</td>
<td>Sand and Gravel</td>
<td>Lower Shuswap River Valley</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>143.2</td>
</tr>
<tr>
<td>805 IIB (9)</td>
<td>Bedrock</td>
<td>West of Mabel Lake – East of Enderby</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>2.3</td>
</tr>
<tr>
<td>112 IIIC (7)</td>
<td>Bedrock</td>
<td>2 kilometres northeast of Enderby</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>2.7</td>
</tr>
<tr>
<td>804 IIC (7)</td>
<td>Bedrock</td>
<td>Shuswap River – east of Enderby</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>5.7</td>
</tr>
<tr>
<td>110 IIIIB (8)</td>
<td>Bedrock</td>
<td>Grandview Bench</td>
<td>Low</td>
<td>Low</td>
<td>Moderate</td>
<td>13.5</td>
</tr>
<tr>
<td>107 IIB (9)</td>
<td>Bedrock</td>
<td>Gardom Lake to Enderby</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>21.4</td>
</tr>
</tbody>
</table>

**BC MoE Observation Wells**

There are three BC MoE Observation Wells located in the Lower Watershed; Well ID 47: Silver Star; Well ID 122: Enderby; and Well 118: Armstrong. Both observation wells 122 and 118 are located within MC MoE Aquifer
111, while Observation Well 047 is located in an area within Silver Star where the aquifers are not currently mapped.

**Observation Well 47 (near Silver Star, BC)**

Groundwater levels at Observation Well 47 have been monitored from 1965 to 2010. Observation Well 047 is completed in an unmapped, bedrock aquifer to a depth of 91.4 m. Since 1966, the groundwater level in the well has ranged from a high of 0.5 m below ground level in May 1969, to a low of 10.6 m below ground level in May 1975. The hydrograph shows that groundwater levels follow a general seasonal pattern, with maximum groundwater levels occurring yearly during May and June and minimum groundwater levels occurring in March and April. The difference between maximum and minimum groundwater levels in one season ranges from approximately 2.0 to 9.5 metres. Groundwater levels for this well have remained stable over the long-term. The borehole log is contained in Appendix C and the depth to groundwater versus time is presented below in Figure 40.

![Figure 40: Depth to Groundwater versus Time for BC MoE Observation Well 047 located near Silver Star](image)

**Observation Well 122 (near Enderby, BC)**

Groundwater levels at Observation Well 122 have been monitored from the early 1970s to 2010. Observation Well 122 is completed in an unconsolidated aquifer consisting of thick layers containing variable amounts of silt, sand and gravel to a depth of 317 mbgs where bedrock was encountered to a further depth of 319 mbgs where drilling was terminated. The borehole log, contained in Appendix B, indicates that the well was artesian (as having a groundwater elevation higher than ground surface) at the time of drilling. Groundwater levels at Observation Well 122 have been highly variable over the period of record; however, since 2006 a steady decline has been noted even when factoring in seasonal variability. The borehole log is contained in Appendix C and the depth to groundwater versus time is presented below in Figure 41.
Groundwater levels at Observation Well 118 have been monitored from the early 1970s to 2010. Observation Well 118 is completed in an unconsolidated aquifer consisting of thick layers containing variable amounts of silt, sand and gravel to a depth of 471 mbgs where bedrock was encountered to a further depth of 478 mbgs where drilling was terminated. Groundwater levels at Observation Well 118 have been highly variable over the period of record; however, since 2006 a steady decline has been noted even when factoring in seasonal variability. The borehole log is contained in Appendix C and the depth to groundwater versus time is presented below in Figure 42.
6.1.3 Land Use

Agricultural and rural developments are significant land uses at lower elevations of the Lower Shuswap River Watershed, particularly downstream of Enderby, and forestry operations are also a main land use in the upper tributaries on the Lower Shuswap River Watershed. Tolko Industries Ltd. and Weyerhaeuser are the main operators and private land logging also occurs in this sub-watershed. The City of Enderby discharges treated sewage into this stream. Recreational opportunities in the Lower Shuswap River Watershed include hiking, camping, biking, paddling, fishing, skiing, wildlife viewing, climbing, snowmobiling, and all-terrain vehicle use. Provincial parks within this area include Shuswap River Islands Provincial Park, Skookumchuck Rapids Provincial Park, Silver Star Provincial Park, Hidden Lake Recreational Reserve, Kingfisher Creek Ecological Reserve, Mara Meadows Ecological Reserve, and Enderby Cliffs Protected Area. Numerous BC MoF recreational sites are located throughout the Lower Shuswap River Watershed.

6.2 Water Quality

The following sections provide an overview of water quality in the Lower Shuswap River Watershed, as well as the results of the BC CSR Site Registry search and the risk assessment.

6.2.1 Overview

Water quality in the Lower Shuswap River Watershed was assessed based on information collected from the following main sources:

- Water Quality in the Shuswap River between Mable and Mara Lakes, 1977 (Nordin 1978);
- Water Quality Assessment and Objectives for the Brash Creek Community Watershed, Technical Report, June 2011 (Phippen and Jensen 2011);
- Shuswap and Mara Lakes Aquatic/Development Fringe Study: Existing Information Research and Analysis (December 2000 - March 2003) (Krotz 2003);
- BC MoE Wells 47 (Silver Star), 118 (Armstrong), and 122 (Enderby); and,
- Grindrod Water System data from RDNO’s WaterTrax database.

As with the Upper and Middle Shuswap River Watersheds, water quality data presented in the sources above varies in methodology and presentation and was not subject to reinterpretation during this assessment. For the purposes of this Technical Assessment, water quality within the Lower Shuswap River Watershed is broken down into sources or areas of interest: Mara Lake, Kingfisher Creek, Fortune Creek, Brash Creek, the City of Enderby and the Village of Grindrod, and BC MoE Water Wells.

Historical water quality concerns within the Lower Shuswap River Watershed have largely involved nutrient loading (nitrogen cycle parameters and phosphorous), suspended sediment and turbidity, and microbial parameters (*E. coli* and total coliforms).
Generally, concentrations of suspended solids and nutrients increase downstream through the Lower Shuswap River Watershed from Mabel Lake through Enderby, and total flow (flux) is considered to be the dominant control on relative contributions from the various tributaries and surface water bodies.

Relatively low flows have been historically observed in the creeks between Mabel Lake and the City of Enderby, indicating limited contribution to the overall volume of the Shuswap River. Similarly, the low flow in Fortune Creek indicates a small contribution to the total volume of the Shuswap system (Nordin 1978).

**Kingfisher Creek**

Kingfisher Creek is located in the northern portion of the Lower Shuswap River Watershed and has been interpreted as the primary source for elevated suspended solids, with roughly an order of magnitude higher suspended solids concentrations at the mouth of Kingfisher Creek compared to samples collected in the Shuswap River upstream of Kingfisher Creek. Nutrient concentrations, while elevated in Kingfisher Creek samples, are typically lower than those observed downstream (Fortune Creek, for example). The relatively high flows from Kingfisher Creek result in increased nutrient loadings, on the order of four to five times those estimated from Fortune Creek.

**Brash Creek**

The Brash Creek community watershed is not currently a domestic water supply source for the City of Enderby, but had been so in the past, at which point the water supply was chlorinated prior to distribution. Land use within the Brash Creek watershed includes forestry (timber harvesting), agriculture and range use, and recreation (Phippen and Jensen, 2011).

The majority of the land within the Brash Creek community watershed is crown land (approximately 88%), and there are no licensed discharges within the watershed. Logging roads provide access to recreational areas throughout the watershed, and the close proximity of roads to water sources (including, but not restricted to Brash Creek) increases the potential for surface water run-off containing suspended solids, thereby increasing turbidity in the receiving waters. The close proximity of roads to surface water bodies also increases access for cattle or wildlife, thereby increasing the potential for nutrient loading (nitrogen and phosphorous) and microbial impacts (E. coli, Giardia lamblia, and Cryptosporidium).

**Fortune Creek**

As discussed above, low flow in Fortune Creek limits the potential impacts to the Shuswap River system. In addition, it is understood that the City of Armstrong diverts water from Fortune Creek, representing a diversion from the Shuswap River system to the Okanagan watershed. Dissolved solids concentrations have been observed to be elevated in Fortune Creek, possibly due to the relatively low flows and resulting increased evaporation causing a higher residual in the stream. The lands surrounding Fortune Creek range from relatively undeveloped to agricultural areas with high density feed lots and crop fertilization to recreational land uses.

Elevated concentrations of suspended solids have been noted in Fortune Creek, similar to those observed in Kingfisher Creek; however, the low flow of Fortune Creek limits the impact on downstream receptors. The elevated suspended solids impact the suitability of Fortune Creek water as a potential water supply.
Fortune Creek water quality monitoring stations have typically yielded elevated nutrient concentrations that can be attributed to the septic disposal systems in the area which, outside of the City of Enderby, represent the dominant waste disposal method, and agricultural land uses.

Nitrogen concentrations, while elevated, are lower in Fortune Creek than any of the other streams monitored in the Lower Sub-Watershed with the nitrogen primarily in the form of organic nitrogen.

**Grindrod and City of Enderby**

Water quality data for Grindrod, provided by RDNO's online database WaterTrax, was reviewed for the selected parameters which have been identified in previous studies as potential water quality issues in the Lower Shuswap River at various points throughout the Grindrod Water System. These parameters were grouped as follows:

- Chloride, pH, and calculated parameters (alkalinity, conductivity, hardness);
- Nutrients (nitrogen cycle parameters, phosphorous);
- Microbiology (E. coli, total coliforms, fecal coliforms); and,
- Turbidity and suspended solids.

Trend plots were developed for each of these groupings, and are presented in Appendix D as Figure D9 through Figure D12.

Data in WaterTrax for the Grindrod Water System is available from 2002 to 2011 for selected parameters, based on a search of all active and inactive sampling points within the RDNO database.

The water quality results retrieved from the WaterTrax database, much like the data reviewed from historical reports, were reviewed and are presented without reinterpretation or assessment of sampling or analytical methods and procedures, consideration for detection limits, or quality assurance/quality control results. The water quality results were compared against the BC water quality guidelines, where applicable, based on the routine built into the WaterTrax database. Golder has assumed reliance on the data, as presented.

Alkalinity and hardness data were not identified in the database extraction for the Grindrod Water System. A total of nine pH exceedances were observed during the assessed period throughout the water supply system, with seven results below the criteria (6.5 to 8.5), and two above the criteria. No conductivity exceedances were identified. Chloride and conductivity results are shown on Figure D5.

Nitrate (as N), nitrite (as N), o-phosphate, and both total phosphorous and total dissolved phosphorous data is available during the study time interval at various sampling points throughout the Grindrod Water System. The water quality results for nutrient parameters are presented on Figure D6. Comparison to BC Drinking Water Quality Guidelines indicates no exceedances for nitrate (10 mg/L) or nitrite (1 mg/L), and phosphorous does not have applicable criteria. The highest nitrate concentration observed during the review period was 0.24 mg/L, and nitrite concentrations were below detection limits (0.01 mg/L).

There were two coliform detections reported during the study period, recorded on August 9, 2005 at the Jack Wallace Residence sampling location (fecal coliforms 1 count/100 mL, and total coliforms 1 count/100 mL), as shown on Figure D7. As these were the only detections of microbial parameters and as the Grindrod Water
system has full treatment with clarification, filtration and chlorination, it is likely that this sample was compromised and does not represent an impact to the water supply.

Turbidity values ranged from 0.09 NTU (Grindrod Water Treatment Plant) to a maximum of 16 NTU at the Grindrod Water Treatment Facility Effluent Pond. Turbidity values for sampling locations interpreted to monitor water distribution points indicate a maximum concentration of 0.73 NTU (Figure D8); however, water in the distribution system is filtered and does not represent water from the Shuswap River.

Water quality in Enderby has been reported as generally “good”, with increased potential for impact towards Mara Lake (Bryan and Jensen 1999). Municipal waste discharge, municipal storm water, intensive livestock farms, dairy operations, and timber processing activities all present potential sources of nutrient and microbiological impact in the Enderby area, and have been noted in previous studies.

**Mara Lake**

Water quality in Mara Lake represents downstream water quality coming from the Lower Shuswap River Watershed. Studies undertaken in and around Mara Lake have identified nutrient loading (nitrogen cycle parameters and phosphorous), suspended sediment and turbidity, and microbial (*E. coli* and total coliforms) concerns with respect to drinking water quality and potential impacts to aquatic life and recreation. Elevated nutrient concentrations have been attributed to increased agricultural activity in the area and possible impact from septic disposal systems.

**BC MoE Observation Wells 118 and 122**

Limited water quality is available for BC MoE Observation Wells 118 (Armstrong), and 122 (Armstrong), consisting of generally fewer than 5 samples for any given parameter.

Nutrient concentrations are at background concentrations, with average nitrate concentrations of less than 0.003 mg/L at both wells. Turbidity was not measured at either location, nor were microbial parameters. Concentrations of major ions and indicators (chloride, sodium, and sulphate, for example) were also observed to be at background concentrations. Overall, the water quality at MoE Observation Well 118 and 122 is considered to be representative of background, un-impacted groundwater.

Raw water quality results for MoE Observation Wells 118 and 122 are presented in tabular form in Appendix D.

**6.2.2 BC Contaminated Sites Regulation: Site Registry Search**

There are 19 properties in the Lower Shuswap River Watershed that have records filed with the BC CSR Site Registry as described below in Table 30 and shown on Figure 20. Of these 19, ten are listed as having an active status, suggesting that they are currently undergoing assessment or investigation. Detailed information regarding these sites is available from the BC government for a nominal fee. This information is current to June, 2011 and is updated monthly.
Table 30: Lower Shuswap River Watershed BC CSR Site Registry Search

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Common Name</th>
<th>Address</th>
<th>City</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>6682</td>
<td>Mara Foodliner</td>
<td>7702 Highway 97a Rr 1 Site 1 Comp 13</td>
<td>Mara</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>3403</td>
<td>Brodoway Residence</td>
<td>6591 Highway 97a</td>
<td>Enderby</td>
<td>Inactive - Remediation Complete</td>
</tr>
<tr>
<td>511</td>
<td>Forest Grove Service Station</td>
<td>6594 Highway 97a Site 19 Comp 26 RR1</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>5556</td>
<td>Baird Bros Concrete Plant</td>
<td>Highway 97b</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>8776</td>
<td>Historic Saw Mill - Brickyard Road</td>
<td>275, 305, 321, 327 and 335 Brickyard Road</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>5804</td>
<td>1006 George Street</td>
<td>1006 George Street</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>2557</td>
<td>Enderby Gate Station-BC Gas</td>
<td>1000 High Street</td>
<td>Enderby</td>
<td>Inactive - Remediation Complete</td>
</tr>
<tr>
<td>5782</td>
<td>Canadian Pacific Railyard</td>
<td>Mill Avenue</td>
<td>Enderby</td>
<td>Inactive - Remediation Complete</td>
</tr>
<tr>
<td>2531</td>
<td>Former Enderby Service Station</td>
<td>802 George Street</td>
<td>Enderby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>2501</td>
<td>Petro Canada Station</td>
<td>700 George Street</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>2522</td>
<td>Former Chevron Property</td>
<td>608 Hubert Avenue</td>
<td>Enderby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>2500</td>
<td>Esso Keylock (Former Bulkplant)</td>
<td>401 Vernon Street</td>
<td>Enderby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>2436</td>
<td>Parkview Place Project</td>
<td>707-3rd Avenue Also Known As 500 To 506 George Street</td>
<td>Enderby</td>
<td>Inactive - Remediation Complete</td>
</tr>
<tr>
<td>7371</td>
<td>Highways Yardsite</td>
<td>204 Old Vernon Road</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>9447</td>
<td>120 And 122 Vernon Street</td>
<td>120 And 122 Vernon Street</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>2442</td>
<td>Riverside Forest Products - Ashton Creek</td>
<td>Mabel Lake Road</td>
<td>Enderby</td>
<td>Inactive - No Further Action</td>
</tr>
<tr>
<td>8545</td>
<td>Ashton Creek Store</td>
<td>895 Mabel Lake Road</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>2359</td>
<td>Enderby VorTac Site/TC</td>
<td>Enderby VorTac Site</td>
<td>Enderby</td>
<td>Active - Under Remediation</td>
</tr>
<tr>
<td>2524</td>
<td>Back Enderby Road-Private Well</td>
<td>4634 Back Enderby Road</td>
<td>Armstrong</td>
<td>Inactive - No Further Action</td>
</tr>
</tbody>
</table>
6.2.3 Risk Assessment

As shown in Table 30, a total of 19 sites were identified in the BC CSR registry within the Lower Shuswap River Watershed, including 10 active sites. This is partly reflective of the increased industrial activity associated with the Highway 97 corridor. Of the 19 sites, several are within the ALR; in addition, there are three landfills (Armstrong/Spallumcheen RDF, Ashton Creek RDF, and Kingfisher RDF) and one Sewage Treatment Plant (not listed above). These have been identified as having a high risk ranking, due to their land use (bulk fuel, highway maintenance yards, industrial uses, landfills) and close proximity to a surface water source or community.

Similar to the risk assessment undertaken for the Middle Shuswap River Watershed, land uses with increased potential for nutrient loading, suspended solids, or microbial impacts were ranked as high risk if located in close proximity to a surface water source or community. As such, waste management facilities, intensive agriculture, golf courses, and livestock activities were typically ranked higher than private service stations or smaller commercial land uses. Risk ranking for sites located within the Lower Shuswap River Watershed are shown on Figure 20.

6.3 Water Quantity

The following sections characterize the water quantity of the Lower Shuswap River Watershed, including the surface water flows, groundwater flows, estimate of water use and allocation, estimate of flow and allotment versus consumption, and minimum instream flow thresholds for this watershed.

6.3.1 Surface Flows

Flow statistics for WSC stations in the Lower Shuswap River Watershed with six or more years of monthly flow records are summarized in Table 31. For stations with less than 20 years of data, mean annual flows were adjusted by comparing the same years in the longer term Shuswap River records to the entire Shuswap records and then adjusting the short term station flows by the proportion of those years to the long term records. This increased or decreased the actual mean flows from the short term records by up to 5%. Mean annual flows for stations with seasonal records were assumed to be 60% of the average April to September flows. This approach is consistent with that used in the Middle Shuswap River Watershed analysis, where average annual flows were found to range from 55% to 65% of the seasonal average flow.

Table 31 also provides the estimated surface water use and groundwater use (where available and as discussed further in Section 6.3.3), which were added to the mean annual flow to calculate the naturalized mean annual discharge for each station. The naturalization was only applied to the annual flows, as proportioning water use to monthly flows is beyond the scope of this assessment. It must be stressed that calculations of mean annual flow, net unit runoff, naturalized mean annual discharge, and naturalized net unit runoff from short term, seasonal records for stations that were discontinued decades ago (e.g., Fortune Creek near Stepney) contain a high degree of uncertainty. The results for these stations are approximations only and may have large error margins. The accuracy of the calculated values varies with the available data sets and ranges from possibly ±50% for the shortest seasonal sets of old data to less than ±5% for currently active stations with long term data sets.
## Table 31: Summary of Surface Water Flows by WSC Station in the Lower Shuswap River Watershed

### WSC Station No. 08LC050 | Trinity Creek near the Mouth
Inactive | Flow Record: 1985-1990 | No. of Years: 6

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2.95</td>
<td>3.68</td>
<td>2.41</td>
<td>0.72</td>
<td>0.25</td>
<td>0.23</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.71</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>4.56</td>
<td>5.25</td>
<td>6.51</td>
<td>1.20</td>
<td>0.33</td>
<td>0.35</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.98</td>
<td>2.38</td>
<td>0.57</td>
<td>0.26</td>
<td>0.14</td>
<td>0.09</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Mean Annual Flow (m³/s)</strong></td>
<td>1.04</td>
<td><strong>Net Unit Runoff (mm)</strong></td>
<td>173</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Estimated Surface Water Use (m³/s)</strong></td>
<td>0.03</td>
<td><strong>Groundwater Use (m³/s)</strong></td>
<td>-</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Naturalized Mean Annual Discharge (m³/s)</strong></td>
<td>1.08</td>
<td><strong>Naturalized Net Unit Runoff (mm)</strong></td>
<td>179</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

### WSC Station No. 08LC002 | Shuswap River near Enderby
Active | Flow Record: 1911-1936, 1960-2009 | No. of Years: 76

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
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<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>34.9</td>
<td>34.2</td>
<td>38.0</td>
<td>73.7</td>
<td>191</td>
<td>281</td>
<td>164</td>
<td>65.5</td>
<td>48.8</td>
<td>46.6</td>
<td>47.4</td>
<td>39.4</td>
<td>87.5</td>
</tr>
<tr>
<td><strong>Max</strong></td>
<td>60.5</td>
<td>96.2</td>
<td>85.1</td>
<td>155</td>
<td>323</td>
<td>494</td>
<td>318</td>
<td>200</td>
<td>148</td>
<td>139</td>
<td>110</td>
<td>96.4</td>
<td>126</td>
</tr>
<tr>
<td><strong>Min</strong></td>
<td>14.5</td>
<td>11.2</td>
<td>13.2</td>
<td>17.8</td>
<td>94.3</td>
<td>142</td>
<td>73.2</td>
<td>34.7</td>
<td>24.9</td>
<td>20.2</td>
<td>19.4</td>
<td>16.8</td>
<td>52.4</td>
</tr>
<tr>
<td><strong>Mean Annual Flow (m³/s)</strong></td>
<td>87.5</td>
<td><strong>Net Unit Runoff (mm)</strong></td>
<td>588</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Estimated Surface Water Use (m³/s)</strong></td>
<td>1.08</td>
<td><strong>Groundwater Use (m³/s)</strong></td>
<td>-</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Naturalized Mean Annual Discharge (m³/s)</strong></td>
<td>88.6</td>
<td><strong>Naturalized Net Unit Runoff (mm)</strong></td>
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</tr>
<tr>
<td><strong>Incremental Net Unit Runoff (mm)</strong></td>
<td>317</td>
<td></td>
<td></td>
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</tbody>
</table>
WSC Station No. 08LC004 | Brash Creek near Enderby
Inactive | Flow Record: 1915-1917, 1959-1968 | No. of Years: 12

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
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<th>Nov</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.07</td>
<td>0.07</td>
<td>0.15</td>
<td>0.74</td>
<td>1.41</td>
<td>1.46</td>
<td>0.49</td>
<td>0.16</td>
<td>0.19</td>
<td>0.20</td>
<td>0.11</td>
<td>0.08</td>
</tr>
<tr>
<td>Max</td>
<td>0.14</td>
<td>0.14</td>
<td>0.42</td>
<td>1.50</td>
<td>2.14</td>
<td>2.04</td>
<td>1.02</td>
<td>0.50</td>
<td>0.86</td>
<td>0.50</td>
<td>0.19</td>
<td>0.14</td>
</tr>
<tr>
<td>Min</td>
<td>0.04</td>
<td>0.03</td>
<td>0.04</td>
<td>0.23</td>
<td>0.89</td>
<td>0.69</td>
<td>0.16</td>
<td>0.06</td>
<td>0.02</td>
<td>0.03</td>
<td>0.03</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m³/s)** 0.40 Net Unit Runoff (mm) 387
Estimated Surface Water Use (m³/s) 0.00 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 0.40 Naturalized Net Unit Runoff (mm) 387

WSC Station No. 08LC031 | Fortune Creek near Stepney
Inactive | Flow Record: 1950-1960 | No. of Years: 11

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.81</td>
<td>4.80</td>
<td>4.54</td>
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<td>-</td>
<td>-</td>
<td>1.91</td>
<td>7.25</td>
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<td>3.44</td>
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<td>0.48</td>
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<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Min</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.17</td>
<td>2.21</td>
<td>1.24</td>
<td>0.22</td>
<td>0.02</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m³/s)** 1.04 Net Unit Runoff (mm) 249
Estimated Surface Water Use (m³/s) 0.07 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 1.11 Naturalized Net Unit Runoff (mm) 266

WSC Station No. 08LC035 | Fortune Creek near Armstrong
Inactive | Flow Record: 1911-1912, 1959-1984 | No. of Years: 26

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.06</td>
<td>0.06</td>
<td>0.07</td>
<td>0.50</td>
<td>3.34</td>
<td>2.41</td>
<td>0.48</td>
<td>0.11</td>
<td>0.15</td>
<td>0.18</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>Max</td>
<td>0.18</td>
<td>0.13</td>
<td>0.16</td>
<td>1.56</td>
<td>5.19</td>
<td>5.53</td>
<td>1.29</td>
<td>0.51</td>
<td>0.73</td>
<td>1.03</td>
<td>0.48</td>
<td>0.24</td>
</tr>
<tr>
<td>Min</td>
<td>0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.04</td>
<td>1.82</td>
<td>0.86</td>
<td>0.07</td>
<td>0.04</td>
<td>0.01</td>
<td>0.00</td>
<td>0.02</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Mean Annual Flow (m³/s) 0.62 Net Unit Runoff (mm) 477
Estimated Surface Water Use (m³/s) 0.05 Groundwater Use (m³/s) -
Naturalized Mean Annual Discharge (m³/s) 0.68 Naturalized Net Unit Runoff (mm) 518
## TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

**WSC Station No. 08LC020 | Violet Creek near Grindrod (Upper Station)**

Inactive | Flow Record: 1934, 1945-1949 | No. of Years: 6

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
</tbody>
</table>

- **Mean:**
  - Surface Flows (m$^3$/s)
  - **Max:**
  - Min:

*Mean annual flows estimated at 60% of mean seasonal (i.e., April to September) flows.
**Flows for stations with less than 20 years of record were adjusted by comparison to the longer terms Shuswap River records.

### Surface Flows (m$^3$/s)

#### WSC Station No. 08LC020

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
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</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.10</td>
</tr>
</tbody>
</table>

#### WSC Station No. 08LC021 | Larch Hills near Mara Lake

Inactive | Flow Record: 1934, 1945-1948. 1951-1953 | No. of Years: 8

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
</tr>
</tbody>
</table>

- **Mean:**
  - Surface Flows (m$^3$/s)
  - **Max:**
  - Min:

### Surface Flows (m$^3$/s)

#### WSC Station No. 08LC021

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.24</td>
</tr>
</tbody>
</table>

#### Estimated Surface Water Use (m$^3$/s)

#### Groundwater Use (m$^3$/s)

#### Naturalized Mean Annual Discharge (m$^3$/s)

#### Naturalized Net Unit Runoff (mm)
The naturalized net unit runoff at the WSC Shuswap River station near Enderby is 596 mm/year, but the incremental net unit runoff for the area below Mabel Lake is only 317 mm/year. This fits reasonably well with the nearby tributaries, with naturalized net unit runoff calculated at 179 mm for Trinity Creek, 387 mm for Brash Creek and 518 mm for the higher elevation Fortune Creek station.

6.3.2 Groundwater Flows

The estimated flows through the individual aquifers varies from approximately 0.01 m$^3$/s to 0.32 m$^3$/s, with an overall groundwater flow rate within the Lower Shuswap River Watershed as being on the order of approximately 0.68 m$^3$/s. According to the preliminary groundwater flow estimates, it can be inferred that half of the groundwater flow that discharges into Mara Lake originates from Aquifer L20, which extends from Trinity Valley northward to the Shuswap River. The larger flow estimate for this aquifer is primarily due to steeper hydraulic gradients controlled by Trinity Creek.

A summary of the aquifer parameters used in the preliminary estimation of the groundwater flows in the Lower Shuswap River Watershed are provided in Table 32.

Table 32: Groundwater Flows in the Lower Shuswap River Watershed Aquifers

<table>
<thead>
<tr>
<th>Aquifer Name</th>
<th>Average Depth to Groundwater (m)</th>
<th>Average Depth of Well (m)</th>
<th>Saturated Thickness (m)</th>
<th>Aquifer Width (m)</th>
<th>Horizontal Gradient (m/m)</th>
<th>Saturated Hydraulic Conductivity (m/s)</th>
<th>Q - Discharge (m$^3$/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>L18</td>
<td>8</td>
<td>19</td>
<td>11</td>
<td>1,000</td>
<td>0.0338</td>
<td>5.00E-04</td>
<td>0.19</td>
</tr>
<tr>
<td>L19</td>
<td>8</td>
<td>19</td>
<td>11</td>
<td>6,000</td>
<td>0.0023</td>
<td>5.00E-04</td>
<td>0.08</td>
</tr>
<tr>
<td>L20</td>
<td>12</td>
<td>28</td>
<td>16</td>
<td>2,000</td>
<td>0.0203</td>
<td>5.00E-04</td>
<td>0.32</td>
</tr>
<tr>
<td>L21</td>
<td>12</td>
<td>28</td>
<td>16</td>
<td>4,000</td>
<td>0.0008</td>
<td>5.00E-04</td>
<td>0.03</td>
</tr>
<tr>
<td>L22</td>
<td>8</td>
<td>21</td>
<td>13</td>
<td>8,000</td>
<td>0.0008</td>
<td>5.00E-04</td>
<td>0.04</td>
</tr>
<tr>
<td>L23</td>
<td>8</td>
<td>21</td>
<td>13</td>
<td>6,000</td>
<td>0.0004</td>
<td>5.00E-04</td>
<td>0.01</td>
</tr>
<tr>
<td>L24</td>
<td>9</td>
<td>22</td>
<td>13</td>
<td>2,000</td>
<td>0.0004</td>
<td>5.00E-04</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The total groundwater flow discharging to Mara Lake (approximately 0.68 m$^3$/s) is slightly greater than, but on the order of the minimum normalized flow at the inlet of Mara Lake, which is between 0.119 m$^3$/s and 0.439 m$^3$/s.

6.3.3 Estimate of Water Use / Allocation

The following sections provide the results of the estimate of water use/allocation in the Lower Shuswap River Watershed based on surface water licenses, groundwater uses, water allocation restrictions, and Water Act reserves.

Water Licenses

The results of the water licenses query for the Lower Shuswap River Watershed are summarized in Table 33. These water licenses are depicted in Figure 9. As some licenses include water use for two or more purposes (e.g., irrigation and domestic use), total number of licensed water uses exceeds the total number of licenses. A review of the volumes associated with the different uses in Table 34 indicates that the majority of the allocated
For data uses such as flow naturalization purposes where the annual surface flow records are adjusted for consumptive water use, the licensed use needs to be assigned to specific sub-drainages. The information available from the water licenses query specifies the name of the source. However, while some licenses are
located on gazetted streams, many water licenses are associated with very small streams or springs that are not easily identified to a particular area of the Shuswap River Watershed. Given the level of effort required to identify the location of each of the non-obvious sources within the Upper, Middle, and Lower Shuswap River Watersheds, the summary of licenses within the Lower Shuswap River Watershed was focused only on the licenses for the two purposes that make up the majority of the surface water use, as shown in Table 34. It should be noted though that much of the water used by the water utilities that are associated with the Waterworks (Local Authority) licenses is supported by storage as reflected in the Storage (Non-Power) use. The water is typically stored during high runoff in spring freshet and released to augment flows during the irrigation season so that a simple comparison of flow versus seasonal allocation is not valid for licenses backed by storage. As such, the water volume associated with waterworks storage, as well as the relatively small volume of storage associated with the individual irrigation licenses, are also provided in Table 34.

Table 34: Summary of High Volume Water Licenses by Use in the Lower Shuswap River Watershed

<table>
<thead>
<tr>
<th>Sub-drainage</th>
<th>Irrigation (m³/year)</th>
<th>Local Storage* (m³/year)</th>
<th>Waterworks (Local Authority) Storage** (m³/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuswap River (Mabel Lake to WSC Enderby***)</td>
<td>2,958,193</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Shuswap River (WSC Enderby*** to Mara Lake)</td>
<td>7,664,848</td>
<td>25,286</td>
<td>6,924,022</td>
</tr>
<tr>
<td>Kingfisher Creek</td>
<td>46,256</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Trinity Creek</td>
<td>1,674,819</td>
<td>6,167</td>
<td>-</td>
</tr>
<tr>
<td>Ashton Creek</td>
<td>188,759</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brash Creek</td>
<td>55,507</td>
<td>-</td>
<td>829,661</td>
</tr>
<tr>
<td>Fortune Creek</td>
<td>716,405</td>
<td>9,868</td>
<td>5,644,187</td>
</tr>
<tr>
<td>Gardom Lake</td>
<td>128,640</td>
<td>-</td>
<td>1,258,150</td>
</tr>
<tr>
<td>Gardom Creek</td>
<td>470,227</td>
<td>40,236</td>
<td>-</td>
</tr>
<tr>
<td>Violet Creek</td>
<td>192,423</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bongard Creek</td>
<td>247,929</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Blurton Creek</td>
<td>325,182</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Johnson Creek</td>
<td>108,805</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>**Total</td>
<td>14,777,993</td>
<td>81,557</td>
<td>13,397,870</td>
</tr>
</tbody>
</table>

* Local Storage refers to the relatively small volume of storage associated with the individual irrigation licenses.
** Waterworks Storage refers to the volume of storage associated with the water utility's Local Authority licenses.
*** WSC Enderby refers to the WSC Station No. 08LC002 on the Shuswap River near Enderby.

Groundwater Use

Groundwater use in the Lower Shuswap River Watershed consists of a variety of residential, agricultural, community and industrial uses. Confirmed uses consist of the following:
City of Enderby – The City of Enderby relies on groundwater as a supplemental source to its surface water source of the Shuswap River, through the use of two high capacity groundwater wells. In 2010, the City of Enderby used 217,496 m³/year (596 m³/day; 0.007 m³/s) of groundwater which represents 34% of their treated, distributed water to a population of 3,073 at 1,380 connections.

Private Water Users – numerous individual wells are present in the Lower Shuswap River Watershed area. A total of approximately 4,000 parcels have been identified within the Lower Shuswap River Watershed, including those in the Enderby area. Based on the RDNO’s subdivision servicing bylaw, and assuming that each parcel has a groundwater well and withdraws the maximum allotted groundwater, it can be inferred that the potential groundwater use in the Lower Shuswap River Watershed is approximately 0.30 m³/s. According to a query of the BC MoE Water Resource Atlas, approximately 795 wells are identified within the Lower Shuswap River Watershed. Based on this number of wells and the subdivision servicing bylaw minimum groundwater requirement, the estimated groundwater use is approximately 0.06 m³/s.

Based on an estimated population of approximately 6,000 (representing approximately 60% of the population as identified in Table 2 and on per capita water consumptions provided in Table 3, potential groundwater use within the Lower Shuswap River Watershed ranges from 0.02 m³/s to 0.07 m³/s. This is approximately an order of magnitude less than the groundwater use as identified using parcel numbers and the subdivision servicing bylaw groundwater requirements. However, it is within the same order of magnitude when applying the subdivision servicing bylaw groundwater requirement to the number of reported wells in the Lower Shuswap River Watershed. The following table summarizes potential groundwater use based on population in the Lower Shuswap River Watershed.

<table>
<thead>
<tr>
<th>Population*</th>
<th>L/per person/per day</th>
<th>L/day</th>
<th>m³/day</th>
<th>m³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okanagan average</td>
<td>675</td>
<td>4,050,000</td>
<td>4,050</td>
<td>0.05</td>
</tr>
<tr>
<td>Okanagan summer average</td>
<td>1000</td>
<td>6,000,000</td>
<td>6,000</td>
<td>0.07</td>
</tr>
<tr>
<td>Shuswap Watershed average (based on Lumby groundwater usage rates)</td>
<td>579</td>
<td>3,474,000</td>
<td>3,474</td>
<td>0.04</td>
</tr>
<tr>
<td>BC average</td>
<td>490</td>
<td>2,940,000</td>
<td>2,940</td>
<td>0.03</td>
</tr>
<tr>
<td>Canadian average</td>
<td>329</td>
<td>1,974,000</td>
<td>1,974</td>
<td>0.02</td>
</tr>
</tbody>
</table>

* The Lower Shuswap River Watershed consists of approximately 6,000 users.

**Water Allocation Restrictions**

There are 64 sources in the Lower Shuswap River Watershed that have water restrictions noted. Many of these restrictions are on very small sources. Some of the larger sources with restrictions are Gardom Creek, Gardom Lake, Putnam Creek, Fortune Creek, and Ashton Creek. Details for these sources are provided in Appendix E.
**Water Act Reserves**

A search of the complete list of Water Act Reserves in British Columbia revealed that there is one Water Act Reserve in the Lower Shuswap River Watershed. This reserve, dated Sept 25, 1975, is on Violet Creek upstream of Ecological Reserve No. 42, and reserves all of the water upstream of that point from being taken, used, or acquired under the Water Act (BC MoE 2009).

### 6.3.4 Estimate of Flow / Allotment versus Consumption

The following sections provide an estimate of surface water allotment and groundwater flow versus consumption in the Lower Shuswap River Watershed.

**Surface Water**

Estimated surface water use is low relative to mean annual flow at all of the stations reviewed. Estimated water use is only 1.2% of mean annual flow at the Shuswap River near Enderby and is highest on the upper Fortune Creek site where it is estimated at 8.6% of mean annual flow. Summer water use can be up to 2.5 times higher than annual use. At the Shuswap River near Enderby station, the summer use comprises only about 4% of the mean monthly August flow and less than 8% of the minimum monthly August Flow. At the Trinity Creek WSC station, however, the estimated summer use is 37% of the mean monthly August flow and 67% of the minimum monthly August flow in a very short term data set. These use comparisons change to 23% of naturalized mean August flows and 35% of the naturalized minimum August Flows. Fortune Creek has even higher summer use percentages, but the flows are highly regulated through releases from storage such that a direct comparison is not valid.

In the Lower Shuswap River Watershed, many of the communities and developed rural areas rely on surface water utilities as the primary source of water for domestic and irrigation purposes. The below list of licenses to surface water utilities was generated from the overall list of surface water licenses from Table 33. Water purveyors were contacted to provide estimates of actual usage to compare to the amounts the licenses are permitted to extract.

**Table 36: Validation of Surface Water Utility Licenses in the Lower Shuswap River Watershed**

<table>
<thead>
<tr>
<th>Community</th>
<th>License Number</th>
<th>Stream Name</th>
<th>Quantity Allotted (m^3/year)</th>
<th>Actual Usage (m^3/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Enderby</td>
<td>C002361; C110679</td>
<td>Brash Creek; Shuswap River</td>
<td>7,466,952</td>
<td>412,712</td>
</tr>
<tr>
<td>City of Armstrong</td>
<td>C063519; C002286; C019430; C033449; C063519</td>
<td>Big Swamp Creek; Fortune Creek</td>
<td>3,700,289</td>
<td>1,697,000</td>
</tr>
<tr>
<td>Grindrod Utility</td>
<td>C110885</td>
<td>Shuswap River</td>
<td>286,731</td>
<td>28,000</td>
</tr>
<tr>
<td>Township of Spallumcheen</td>
<td>C033451; C033457</td>
<td>Fortune Creek</td>
<td>58,076</td>
<td>No response</td>
</tr>
<tr>
<td>Mountainview Waterworks</td>
<td>C039515 through C039524</td>
<td>Kendry Creek</td>
<td>19,911</td>
<td>No response</td>
</tr>
<tr>
<td>Stepney Waterworks District</td>
<td>C009438; C022410</td>
<td>Glanzier Creek</td>
<td>67,202</td>
<td>36,961</td>
</tr>
</tbody>
</table>
Community | License Number | Stream Name | Quantity Allotted (m³/year) | Actual Usage* (m³/year)
--- | --- | --- | --- | ---
Silver Star Waterworks District | C019215; C033453; C042043; C049565 | Fortune Creek | 186,673 | 0**
Highland Park Waterworks District | C033455 | Fortune Creek | 36,505 | 0**
Lanadwone Waterworks District | C033545 | Fortune Creek | 32,356 | 0**
Total | | | 11,854,700 | 2,174,673

* In all cases the actual usage amounts are represented by 2010 values. The Stepney Waterworks District Values are from 2005.
** Probably inactive as they are serviced by the City of Armstrong.

The amount consumed represents 18% of the allotted amounts of surface water for the Lower Watershed; however, it is important to note that the usage by the City of Armstrong and several of the Township of Spallumcheen Waterworks Districts, all serviced by Fortune Creek, is diverted from the Shuswap River Watershed to the Okanagan Basin Watershed.

**Groundwater**

In 2010, the City of Enderby used 217,496 m³/year. The aquifers delineated in the vicinity of the City of Enderby, L22 and L23, were found to have an average groundwater discharge of approximately $9\times10^5$ m³/year. It is therefore inferred that groundwater extractions in this area could potentially represent approximately 23% the flow through the aquifer at that location.

Total groundwater use in the Lower Shuswap River Watershed ranges from approximately 0.03 m³/s to as high as approximately 0.30 m³/s (based on potential groundwater withdrawals from private water wells). This higher possible groundwater extraction rate represents approximately 44% of the total groundwater flow within the Lower Shuswap River Watershed, which represents a significant potential withdrawal that could result in the lowering of the water level within the aquifer over time.

**6.3.5 Minimum Instream Flow Thresholds**

No streams in the Lower Shuswap River Watershed have existing or recommended instream flow thresholds. Planning for fish protection requires setting of instream flow thresholds throughout the Lower Shuswap River Watershed streams with high fish values and existing and/or potential water use. Recommended methods for setting additional instream flow thresholds or targets are described and discussed in Appendix F.

**6.4 Riparian Areas**

This section of the Shuswap River Technical Assessment provides a preliminary assessment of the condition of riparian areas along the Lower Shuswap River, as well as identifying previous restoration works that have been completed within this section of the stream. Based on the results of this assessment, a preliminary prioritization of riparian areas of the Lower Shuswap River for restoration works was then completed.
6.4.1 Riparian Areas Condition

The following sections describe previous impacts to the riparian areas of the Lower Shuswap River, as well as restoration activities that have already been completed throughout this section of the stream.

Previous Impacts

Previous impacts to the Lower Shuswap River are primarily related to agriculture and rural development. Much of the Lower Shuswap River basin was historically logged to provide agricultural land prior to 1928; analysis of air photos from this date indicate that cultivated fields were present along about 29% of the Lower Shuswap River at that time, compared to about 35% in 2007 (Hawes et al. 2011). However additional clearing has occurred for other anthropogenic development in the last eight decades, as over 50% of the Lower Shuswap River was forested in 1928, compared to only about 25% in 2007 (Hawes et al. 2011). All of agricultural operations, rural developments, and roadway construction have resulted in the removal of much of the riparian habitat associated with this stream, particularly downstream of Enderby. Impacts to the riparian and instream areas as a result of vegetation removal include loss of spawning habitat through filled and diverted side channels and oxbows, reduced shading and nutrient input to the stream through riparian vegetation clearing, and sedimentation and general degradation where cattle have unrestricted access to the channel.

Hawes et al. (2011) completed a detailed inventory, mapping, and aquatic habitat index of the Lower Shuswap River following an adapted FIM and SHIM protocol for large river systems. Their assessment included a centreline survey and streambank mapping to characterize the riparian condition of each bank. Data collected included primary shore type, shore modifiers, land use, livestock access, relative condition, riparian vegetation type, and bank stability. The level of impact to each bank of the Lower Shuswap River was also ranked as part of the FIM as either low (<10%), medium (10-40%), or high (>40%); these results are provided on Figure 43 to Figure 50. They found that only 41% of the left bank and 14% of the right bank (looking downstream) are considered to be in a natural state, and that 30% of the length of the Lower Shuswap River is affected by a high level of impact and has poor riparian condition. They also found that more than three quarters of the 242 streambank modifications (e.g., boat launches, bridges, docks, livestock access, bank stabilization) recorded on the Lower Shuswap River are located downstream of Enderby. Bank erosion and instability are common throughout the Lower Shuswap River as a result of riparian vegetation clearing and anthropogenic encroachment, and are likely exacerbated by increased recreational power boat use in this section of the stream (Hawes et al. 2011). As high quality SHIM data are available for this entire section of the stream, Golder did not complete an orthophoto interpretation for the Lower Shuswap River.

Restoration Works

Few restoration works have been documented along the Lower Shuswap River. Several environmental stewardship groups operate within the Lower Shuswap River. Kingfisher Interpretive Centre Society (KICS) is a non-profit, volunteer driven community-based salmon hatchery and environmental education centre. KICS is involved with interactive, hands-on ecological education, featuring salmon and watershed restoration. This group has completed some restoration initiatives to date within the Lower Shuswap River (Shona Brush, KICS, pers. comm.). Lower Shuswap Stewardship Society (LSSS)10 is another environmental stewardship group located in Enderby, BC that is involved in water quality monitoring on the Lower Shuswap River as well as fisheries and

10 Website: http://www.lowershuswap.org/. Email: lowershuswap@gmail.com
habitat restoration projects. They completed chinook habitat restoration on Blurton Creek in 2010 including tree planting, riparian fencing, and channel complexing, but have not yet completed any restoration initiatives along the Lower Shuswap River. They are, however, interested in conducting future high priority restoration works in this system in conjunction with other stakeholders (Jean Clark, LSSS Chairperson, pers. comm.). Whitevalley also completed restoration activities at Blurton Creek in 2008 to 2009, but does not appear to have completed any restoration initiatives along the Lower Shuswap River (Whitevalley 2006).

6.4.2 Riparian Areas Prioritization

The preliminary prioritization of riparian areas for restoration works was first completed at the broader sub-drainage scale within the entire Lower Shuswap River Watershed based on the results of Matthews and Bull (2003). A prioritization of the riparian areas of the Lower Shuswap River specifically is then provided based on the results of the detailed restoration analysis completed by Hawes et al. (2011) as well as the information available on previous impacts and restoration works.

**Lower Watershed**

A total of eight sub-drainages within the Lower Shuswap River Watershed were identified by Matthews and Bull (2003) as having high or very high significance as a habitat protection focus area. These sub-drainages are listed in Table 12 and comprise 78% of the area occupied by the Lower Shuswap River Watershed. Of these seven sub-drainages, five have been identified as highly significant for restoration. These five sub-drainages comprise 59% of the Lower Shuswap River Watershed. The results of Matthews and Bull’s (2003) restoration prioritization at the watershed level are depicted in Figure 51.

<table>
<thead>
<tr>
<th>Stream Name</th>
<th>Area (ha)</th>
<th>Significance for Protection</th>
<th>Level of Habitat Alteration</th>
<th>Significance for Restoration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashton Creek</td>
<td>2,447</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Brash Creek</td>
<td>2,564</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Cooke Creek</td>
<td>3,924</td>
<td>High</td>
<td>?</td>
<td>Medium</td>
</tr>
<tr>
<td>Fortune Creek</td>
<td>14,256</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Hunters Creek</td>
<td>4,247</td>
<td>High</td>
<td>?</td>
<td>Medium</td>
</tr>
<tr>
<td>Kingfisher Creek</td>
<td>11,238</td>
<td>Very High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Shuswap River (Lower)</td>
<td>36,231*</td>
<td>Very High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Trinity Creek</td>
<td>13,303</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Source: modified from Matthews and Bull (2003).
* This sub-drainage area was calculated as part of this Technical Assessment based on the sub-watershed boundaries defined in this report and the sub-drainage boundaries available from iMapBC (BC MFLNRO 2011).

**Lower Shuswap River**

The *Lower Shuswap River Inventory, Mapping, and Aquatic Habitat Index* (Hawes et al. 2011) was recently completed and is the first detailed assessment of this section of the stream. This type of assessment provides high resolution information about the riparian condition of both sides of the stream. The final task of their assessment was a restoration analysis that prioritized the segments of each streambank based on their
restoration potential following a modified version of methodology previously used for Okanagan Lake and other lake systems. Hawes et al.’s (2011) restoration analysis involved comparing the real AHI value based on current riparian conditions to the potential AHI value that could be achieved if riparian planting, bank restoration, bank stabilization, and bioengineering activities were completed. As a result of this process, they identified 11 stream segments with high priority and seven stream segments with moderate priority for restoration. The locations of each of these restoration segments are mapped in Figure 43 to Figure 50. These segments include, as examples, streambanks along power corridors that are highly eroded and causing sedimentation of the stream, areas where agricultural activities are encroaching on the riparian area, and a segment where a dam was previously deactivated and never fully restored. Based on the desktop review completed for this Technical Assessment, Golder is not aware of any additional high priority areas for restoration on the Lower Shuswap River. However, several tributaries on the north side of this stream have experienced heavy flooding and bed load movement resulting in loss of fish habitat, and therefore may be additional priority areas for restoration (Brian Robertson, BC MFLNRO, pers. comm.).
7.0 TREND ANALYSIS AND PROJECTED WATER AVAILABILITY

7.1 Trend Analyses

The intent of this section is to describe and briefly discuss trends in the surface water flow data available for the Shuswap River. The section evaluates historic trends and therefore may serve useful as a short-term planning tool. A rigorous evaluation of climate change effects on Shuswap Watershed hydrology was outside the scope of this evaluation, but is discussed in general terms in Section 7.2.4. The numerical values associated with the trends in Section 7.3 should be used with considerable caution for planning over the medium or long term. Longer term trends in hydrology are governed by complex phenomena. The climate-related effects include increased temperature (and therefore increased evaporation, evapotranspiration and earlier spring melt), altered precipitation (which may increase or decrease) and over the longer term, possibly changes in runoff due to altered vegetation. Similarly, the effects of forest harvesting and the mountain pine beetle are not explicitly addressed in the numerical trend analysis, though they are discussed in general terms in Section 7.2.2 and 7.2.3, respectively.

A review of the annual and monthly flow data available for the 34 Water Survey of Canada (WSC) stations within the Shuswap River Watershed indicates that there is a large variation in both year to year mean annual flows and in year to year mean monthly flows. For the Lower Shuswap River near Enderby, for example, the mean annual flows vary from a low of 52.4 m$^3$/sec in 1929 to a high of 126 m$^3$/sec in 1999. Annual flows in 1997 were likely even higher (annual flows at the upstream Shuswap River hydrometric stations were 10 to 15% higher in 1997), but are not reported for 1997 at the station near Enderby. The mean monthly flows for August show an even greater range, varying from a low of 24.9 m$^3$/sec in 1930 to a high of 148 m$^3$/sec in 1976. Annual flows are influenced primarily by annual precipitation, while the patterns of monthly flows within a year are influenced by precipitation and monthly temperatures, particularly in relation to timing and duration of freshet flows. The annual and monthly data also show trends in flow over the period of record for each station. Annual trends are not necessarily obvious, but many stations show increasing late winter and early spring flows which are offset by decreasing summer and early fall flows.

The high inter-annual variability masks trends, and influences measured trends, particularly for shorter data sets where low or high values at the beginning or end of the data series can skew the trend lines. The best data sets for trend analyses are the active stations with long term data. Within the Shuswap River Watershed, there are three active Shuswap River stations with records commencing in 1911 (near Enderby), 1913 (near Lumby) and 1926 (outlet of Sugar Lake), and three active Bessette Creek and tributary stations with records starting between 1970 and 1973. WSC data for these six stations from the start of records to 2009 (the last year of published data) were used for the annual and monthly trend analyses, which are described in the following sections. No attempt was made to naturalize the measured flows for the trend analyses. Consumptive water use has increased significantly over the longer frame as populations have increased and more water licenses were issued. However, the overall volume of consumptive water use is still relatively small when compared to the average annual volume of the Shuswap River (estimated annual water use is only 1.2% of mean annual flow and estimated summer water use is 4% of the mean August flow), and the inherent uncertainty in trying to estimate annual consumption for each year over the last 100 years is unlikely to improve the accuracy of the trend analyses if naturalization was attempted.
7.1.1 Annual Variations

Mean annual flow trends for the Shuswap River were analyzed over three periods: the entire available dataset (i.e., 1913 to 2009), the last 60 years (i.e., 1950 to 2009), and the last 30 years (i.e., 1980 to 2009). The purpose of these multiple analyses was to determine the longer term trends, as well as to investigate more recent trends. Recent trends may be more applicable for projecting future changes in the short term, but are not necessarily good predictors of the longer term. The annual data points and trend lines for these three periods are provided in Figure 52, Figure 53, Figure 54, respectively. All three stations on the Shuswap River show a small increase in mean annual flow over the entire available dataset and a trend towards decreasing flows over the two more recent periods.

![Figure 52: Shuswap River Mean Annual Flow Data and Trend Lines from three WSC Stations for the Entire Dataset (1913 to 2009)](image1)

![Figure 53: Shuswap River Mean Annual Flow Data and Trend Lines from three WSC Stations for the Last 60 Years (1950 to 2009)](image2)
Mean annual flow trends for Bessette Creek and its tributary Vance Creek were only analyzed over the most recent period, the last 30 years (i.e., 1980 to 2009), as there are only a few complete years of data prior to 1980. The annual data points and trend lines for this period are provided in Figure 55. All three stations for Bessette Creek show a trend towards decreasing flows over the past 30 years.
The average annual rate of change and total change for each trend was calculated in Excel using least squares best-fit exponential trend lines. The results of these calculations for each WSC station over the three time periods (where available) are provided in Table 38. While neither the annual trend rates nor the total changes in mean annual flow are large, these results show that annual flows are trending lower, particularly over the past three decades and more so in the Bessette Creek sub-drainage compared to the Shuswap River sub-drainage. While neither the annual trend rates nor the total changes in mean annual flow are large, these results show a slight increase in average annual flows over the entire 1913 to 2009 period, but decreasing annual flows since 1950, and particularly so over the past three decades. The recent flow trends are even more pronounced in the Bessette Creek sub-drainage compared to the Shuswap River sub-drainage. Reconciling these apparently contradictory results suggests that there was a trend towards increasing flows towards the middle of the century, followed by a trend towards decreasing flows since then. As discussed in Section 7.2.1, it is unlikely that the recent trends reflect greatly increasing water usage, as the highest proportion of water use is associated with irrigation of agricultural land, most of which was developed decades ago.

Table 38: Trends in Mean Annual Flows for the Shuswap River and Bessette Creek Sub-drainages

<table>
<thead>
<tr>
<th>Sub-drainage</th>
<th>WSC Station</th>
<th>1913 to 2009</th>
<th>1950 to 2009</th>
<th>1980 to 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Rate</td>
<td>Total Change</td>
<td>Annual Rate</td>
<td>Total Change</td>
</tr>
<tr>
<td>Shuswap River</td>
<td>Enderby</td>
<td>0.05%</td>
<td>5%</td>
<td>-0.08%</td>
</tr>
<tr>
<td></td>
<td>Lumby</td>
<td>0.09%</td>
<td>9%</td>
<td>-0.04%</td>
</tr>
<tr>
<td></td>
<td>Sugar Lake</td>
<td>0.04%</td>
<td>4%</td>
<td>-0.08%</td>
</tr>
<tr>
<td>Bessette Creek</td>
<td>Bessette 1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bessette 2</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Vance</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

7.1.2 Seasonal Flow Variations

Mean seasonal flow trends for the Shuswap River were analyzed over three periods: the entire available dataset (i.e., 1913 to 2009), the last 60 years (i.e., 1950 to 2009), and the last 30 years (i.e., 1980 to 2009). As with the mean annual flows, the purpose of these multiple analyses was to determine the longer terms trends and to investigate the more recent trends to provide a range for projecting future changes (over the short term). The monthly (January, April, and August) data points and trend lines for the Enderby WSC station for these three periods are provided in Figure 56, Figure 57, and Figure 58, respectively. The Enderby WSC station data are used as an example, as the data for this station are similar to the data reported for the other two Shuswap River WSC stations (not provided).

Winter flows, as represented by the January data, are rising for all three time periods on the Shuswap River, with minimal differences between the longer and shorter periods. The April data indicate a trend towards an earlier freshet. The results show that freshet flows have risen over the two longer term periods, but no trend is visible over the past 30 years. Late summer and fall flows, as represented by the August data, are decreasing over all three time periods, with a greater rate of decline over the past 30 years.
Figure 56: Shuswap River Mean Monthly Flow Data and Trend Lines from the Enderby WSC Station for the Entire Available Dataset (1913 to 2009)

![Graph of Shuswap River Mean Monthly Flow Data and Trend Lines from the Enderby WSC Station for the Entire Available Dataset (1913 to 2009)](image)

Figure 57: Shuswap River Mean Monthly Flow Data and Trend Lines from the Enderby WSC Station for the Last 60 Years (1950 to 2009)

![Graph of Shuswap River Mean Monthly Flow Data and Trend Lines from the Enderby WSC Station for the Last 60 Years (1950 to 2009)](image)
Consistent with the approach used for the annual trend analysis, seasonal trends were estimated in Excel using least squares best-fit exponential trend lines. Monthly trends at the Enderby WSC station over the three time periods are provided in Table 39. The 1913 to 2009 results show a substantial increase in winter flows and a shift to earlier freshet flows. January to April flows are all up markedly, with the greatest increase occurring in March when flows are now averaging more than 150% more than in 1911. The increased winter and early freshet flows are offset by a modest decrease in flows from June through September flows.

The shorter term trends over the past 30 years for the Shuswap River indicate that the trends in monthly flows have changed over time. Winter flows are still increasing at similar annualized rates, but the April to June freshet flows show very small changes over this time period. Summer flows have decreased noticeably over the past 30 years, with July to September flows now averaging more than 20% less than just 30 years ago, with annual rates of change of -0.8% to -0.9% near Enderby. However, measured since 1911, the rate of change in September flows is much less.
### Table 39: Trends in Shuswap River Mean Monthly Flow from the Enderby WSC Station for the Entire Available Dataset (1911 to 2009)

<table>
<thead>
<tr>
<th>Month</th>
<th>1911 to 2009</th>
<th>1950 to 2009</th>
<th>1980 to 2009</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Rate</td>
<td>Total Change</td>
<td>Annual Rate</td>
</tr>
<tr>
<td>January</td>
<td>0.41%</td>
<td>49%</td>
<td>0.05%</td>
</tr>
<tr>
<td>February</td>
<td>0.69%</td>
<td>96%</td>
<td>0.46%</td>
</tr>
<tr>
<td>March</td>
<td>0.97%</td>
<td>158%</td>
<td>1.00%</td>
</tr>
<tr>
<td>April</td>
<td>0.41%</td>
<td>49%</td>
<td>0.95%</td>
</tr>
<tr>
<td>May</td>
<td>-0.01%</td>
<td>-1%</td>
<td>0.28%</td>
</tr>
<tr>
<td>June</td>
<td>-0.12%</td>
<td>-11%</td>
<td>-0.03%</td>
</tr>
<tr>
<td>July</td>
<td>-0.18%</td>
<td>-16%</td>
<td>-0.03%</td>
</tr>
<tr>
<td>August</td>
<td>-0.12%</td>
<td>-11%</td>
<td>-0.35%</td>
</tr>
<tr>
<td>September</td>
<td>-0.09%</td>
<td>-8%</td>
<td>-0.70%</td>
</tr>
<tr>
<td>October</td>
<td>0.00%</td>
<td>0%</td>
<td>-0.40%</td>
</tr>
<tr>
<td>November</td>
<td>0.13%</td>
<td>14%</td>
<td>0.25%</td>
</tr>
<tr>
<td>December</td>
<td>0.25%</td>
<td>28%</td>
<td>-0.05%</td>
</tr>
</tbody>
</table>

The average annual rate of change and total change for all twelve months over the past 30 years for the three Shuswap River WSC stations are shown in Table 40.

### Table 40: Trends in Shuswap River Mean Monthly Flow from the Enderby, Lumby, and Sugar Lake WSC Stations for the Last 30 Years (1980 to 2009)

<table>
<thead>
<tr>
<th>Month</th>
<th>Enderby Annual Rate</th>
<th>Enderby Total Change</th>
<th>Lumby Annual Rate</th>
<th>Lumby Total Change</th>
<th>Sugar Lake Annual Rate</th>
<th>Sugar Lake Total Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>0.50%</td>
<td>16%</td>
<td>0.25%</td>
<td>8%</td>
<td>0.50%</td>
<td>16%</td>
</tr>
<tr>
<td>February</td>
<td>0.80%</td>
<td>26%</td>
<td>0.60%</td>
<td>19%</td>
<td>1.20%</td>
<td>41%</td>
</tr>
<tr>
<td>March</td>
<td>0.05%</td>
<td>1%</td>
<td>0.06%</td>
<td>2%</td>
<td>0.50%</td>
<td>16%</td>
</tr>
<tr>
<td>April</td>
<td>0.05%</td>
<td>1%</td>
<td>-1.10%</td>
<td>-27%</td>
<td>-0.80%</td>
<td>-21%</td>
</tr>
<tr>
<td>May</td>
<td>-0.22%</td>
<td>-6%</td>
<td>0.10%</td>
<td>3%</td>
<td>0.15%</td>
<td>4%</td>
</tr>
<tr>
<td>June</td>
<td>0.02%</td>
<td>2%</td>
<td>-0.35%</td>
<td>-10%</td>
<td>-0.35%</td>
<td>-10%</td>
</tr>
<tr>
<td>July</td>
<td>-0.90%</td>
<td>-23%</td>
<td>-1.30%</td>
<td>-32%</td>
<td>-1.10%</td>
<td>-27%</td>
</tr>
<tr>
<td>August</td>
<td>-0.89%</td>
<td>-23%</td>
<td>-1.70%</td>
<td>-39%</td>
<td>-1.16%</td>
<td>-29%</td>
</tr>
<tr>
<td>September</td>
<td>-0.80%</td>
<td>-21%</td>
<td>-1.00%</td>
<td>-25%</td>
<td>-0.70%</td>
<td>-18%</td>
</tr>
<tr>
<td>October</td>
<td>0.35%</td>
<td>11%</td>
<td>0.60%</td>
<td>19%</td>
<td>0.90%</td>
<td>30%</td>
</tr>
<tr>
<td>November</td>
<td>0.38%</td>
<td>12%</td>
<td>-0.20%</td>
<td>-6%</td>
<td>0.20%</td>
<td>6%</td>
</tr>
<tr>
<td>December</td>
<td>0.33%</td>
<td>10%</td>
<td>-0.35%</td>
<td>-10%</td>
<td>-0.40%</td>
<td>-11%</td>
</tr>
</tbody>
</table>
The average annual rate of change and total change for all twelve months over the past 30 years for the three Bessette Creek WSC stations are shown in Table 41. Comparison of the Bessette and Vance Creek monthly flow trends over the past 30 years also shows similar trends among the stations, but more variation and more extreme trends than among the Shuswap River stations. The smaller catchment areas and the higher degree of flow regulation relative to overall flow are likely responsible for the greater variation in monthly trends among Bessette Creek stations. Vance Creek has less water use as a percentage of naturalized mean annual flow than Bessette Creek (3.5% as compared to 15.5%) and the stored water in the Vance Creek sub-drainage is used for the Silver Star development rather than being released into the stream and then re-diverted below. As such, Vance Creek flows are much less regulated than Bessette Creek flows, and while the Vance Creek flows are not fully natural, water use does not appear to be a large factor in the Vance Creek trends.

Table 41: Trends in Bessette Creek Mean Monthly Flow from the Bessette 1, Bessette 2, and Vance WSC Stations for the Last 30 Years (1980 to 2009)

<table>
<thead>
<tr>
<th>Month</th>
<th>Bessette 1 (above Beaverjack Creek)</th>
<th>Bessette 2 (below Lumby)</th>
<th>Vance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual Rate</td>
<td>Total Change</td>
<td>Annual Rate</td>
</tr>
<tr>
<td>January</td>
<td>-0.05%</td>
<td>-1%</td>
<td>0.35%</td>
</tr>
<tr>
<td>February</td>
<td>-1.10%</td>
<td>-27%</td>
<td>-0.52%</td>
</tr>
<tr>
<td>March</td>
<td>-1.00%</td>
<td>-25%</td>
<td>-0.70%</td>
</tr>
<tr>
<td>April</td>
<td>0.25%</td>
<td>8%</td>
<td>-0.10%</td>
</tr>
<tr>
<td>May</td>
<td>0.30%</td>
<td>9%</td>
<td>0.04%</td>
</tr>
<tr>
<td>June</td>
<td>-0.23%</td>
<td>-6%</td>
<td>-0.60%</td>
</tr>
<tr>
<td>July</td>
<td>-3.80%</td>
<td>-67%</td>
<td>-4.70%</td>
</tr>
<tr>
<td>August</td>
<td>-3.10%</td>
<td>-60%</td>
<td>-2.80%</td>
</tr>
<tr>
<td>September</td>
<td>-2.20%</td>
<td>-48%</td>
<td>-2.10%</td>
</tr>
<tr>
<td>October</td>
<td>-1.10%</td>
<td>-27%</td>
<td>-1.00%</td>
</tr>
<tr>
<td>November</td>
<td>-0.70%</td>
<td>-18%</td>
<td>-0.40%</td>
</tr>
<tr>
<td>December</td>
<td>-0.40%</td>
<td>-11%</td>
<td>-0.20%</td>
</tr>
</tbody>
</table>

7.2 Trend Discussion

The annual and monthly trend analyses demonstrate that Shuswap River flows have changed over the past century, and that the flow trends are still continuing to change. Flows can change due to a variety of natural and man-made factors. Land use changes such as forest harvesting, urban development and agriculture, along with the domestic and agricultural water consumption can cause changes in flow volumes and flow patterns. Climate change and forest health issues (like the mountain pine beetle) can also have major impacts on flow volumes and flow patterns.
7.2.1 Consumptive Water Use

The first licenses for consumptive water use of surface water within the Shuswap River Watershed area upstream of Mabel Lake were issued in 1883. Many more licenses have been issued since, as well as construction and use of groundwater wells, so water use is certainly a factor in the long term trends. Relative to the trend periods, within the Shuswap watershed area, 44% of the licensed volume was allocated by 1950 and 80% was allocated by 1980. In the Bessette Creek sub-drainage, 73% of the license volume was allocated by 1950 and 98% was allocated by 1980.

Annual water use within the watershed is relatively small when compared to the average annual flow in the Shuswap River near Enderby, with licensed water allocation use equivalent to less than 5% of the mean annual flow and estimated actual use even lower at 1.2% of mean annual flow. Water use will also have gradually increased from the late 1800s to the present, so the effect of water use on the annual trends should be a slight lowering of the slope of the trend lines. Without water use, the overall change in the annual trend line would be up to 2% higher on the long term trend, and less than 1% higher on the 30 year trend, so water use is not a large factor in explaining the annual trends.

Summer water use is a larger factor in summer flow trends as much of the water use is for irrigation during the summer months, and late summer flows are lower than the mean annual flows. The flow equivalent of the licensed summer water use could be reducing August flows in the Shuswap River near Enderby by as much as 5% over the long term. It is unlikely though that irrigation use has increased significantly over the past 30 years, as most of the agricultural land was developed many decades ago, and agricultural equipment and practices are generally becoming more efficient. Thus, while consumptive water use could be responsible for a significant portion of the long term decline in late summer flows, the declines in late summer and fall flows of the last 30 years are likely due to another factor, particularly in the Bessette Creek sub-drainage where only 2% of the licensed volume has been allocated over the past 30 years. Also, the July to September declines at the Sugar Lake outlet (which is above virtually all of the consumptive water use) are similar or even greater, indicating that the summer declines over the past 30 years largely reflect something other than consumptive water use.

7.2.2 Forest Harvesting

Numerous studies have shown that forest harvesting alters the volume and timing of flows in BC watersheds. The most noticeable effect is that total watershed yield is increased, particularly in spring. This is seen both as an increase in peak flows and sometimes a shift to earlier freshet flows. In the Penticton Creek study for example, Winkler (2010) indicated up to 50% increases in water yield following clearcutting as a result of increased snow accumulation (10 to 25%), increased rainfall reaching the soil surface during the growing season (approximately 30%), and a reduction in water lost through transpiration and soil surface evaporation (approximately 15 to 30%). Pike et al. (2004) also indicate that contrary to popular opinion, forest harvesting does not result in lower summer flows, consistent with the reduced evapotranspiration and increased precipitation reaching the ground as per Winkler's findings.

The hydrological results of a particular forest harvesting event (e.g., a specific clearcut) are relatively short lived, as the hydrologic impacts return to pre-harvest levels as the newly planted trees increase in size and re-establish the hydrologic functions. The change is gradual, but full or close to full hydrologic recovery occurs within about 20 years.
Forest harvesting has undoubtedly been a factor in the longer term flow trends within the Shuswap watershed. Land clearing started with the early settlers in the late 1800s, and forest harvesting gradually expanded throughout most of the forested portions of the watershed. Forest harvesting may be the largest factor in the trend to a small increase in flow over the long term, and is likely also responsible for the shift to increasing and earlier freshet flows in the 1950 to 2009 trends.

The area affected by forest harvesting has been at a relatively steady state over the past several decades though as the Forest Practices Code and the subsequent Forest and Range Practices Act regulated forest harvesting practices. Forest harvesting is continuing, but the hydrologic effects of new clearcuts are now offset by hydrologic recovery in older harvested areas. As such, forest harvesting is not likely to be a large factor in the flow trends seen over the past 30 years.

7.2.3 Forest Health (Mountain Pine Beetle) Issues

The location and volume of forest harvesting has often been aimed at controlling forest pests such as the spruce budworm, the Douglas-fir tussock moth, and most recently, the mountain pine beetle. Over the past decade, mountain pine beetle outbreaks have reached epidemic proportions in some parts of British Columbia, with vast areas of dead forests and widespread salvage harvesting operations. Mountain pine beetle hydrological impacts are intermediate between those of a clearcut and the normal hydrology of a fully canopied forest. The degree of impact is related to the amount of forest canopy disturbance. A few dead trees have little effect, while loss of the complete upper story (but retention of ground cover and some intermediate story) will have an intermediate effect, and salvage logging is the same as clearcutting.

Forest health impacts are similar to and cumulative to the hydrologic impacts of forest harvesting. As such, forest health issues also do not explain the recent (30 year) trends in flows.

Increasing levels of pine beetle outbreaks in the Shuswap Watershed, leading to increases in dead and dying forests and increases in the overall area affected by forest harvesting as a result of salvage logging would alter future hydrology by increasing flows as described for forest harvesting. As with forest harvesting, the hydrologic changes would be reversed when the new forest becomes hierologically functional and forest cover returns to a steady state.

7.2.4 Climate Change

The BC MoE describes past climate change in British Columbia as follows on its website (http://www.env.gov.bc.ca/cas/impacts/bc.html#past):

*British Columbia’s climate has changed over the last 50-100 years. Historic data suggest that many parts of the province are already starting to experience some of the impacts of climate change. Impacts observed during the 20th century include:

1. Average annual temperature warmed by 0.6°C at the coast, 1.1°C in the interior and 1.7°C in the north (between 1895 and 1995);
2. Minimum temperatures increased by 0.9°C at the coast, 1.3 to 1.7°C in the interior and 2.1°C in northern BC (between 1895 and 1995);
3. Growing degree days, a measure of the heat energy available for plant and insect growth, increased by 5 to 13% (between 1895 and 1995);

4. Precipitation increased in southern BC by 2 to 4% per decade (between 1929 and 1998);

5. Sea surface temperature increased by 0.9 to 1.8°C (between 1914 and 2001);

6. Snow depth and snow water content decreased in some parts of BC (between 1935 and 2000); and,

7. Lakes and rivers throughout BC became free of ice earlier in the spring (between 1945 and 1993).

British Columbia trends based on records of 50 to 60 years or longer are more strongly associated with climate change."

While no detailed climate change studies were found for the Shuswap River Watershed, a detailed climate change assessment was recently completed in the neighbouring Okanagan basin (van der Gulik et al. 2010). Figure 59 shows the observed mean annual temperature and precipitation values (bolded purple line) vs. the values predicted by an assortment of Global Climate Models (GCM). Observed temperature appears to be increasing in concert with the models, while precipitation has increased more than predicted by most models and are consistent with the BC summary above. Figure 60 shows the projected changes in temperature and precipitation to the year 2100. Figure 61 and Figure 62 show the temperature and precipitation data from the Shuswap area climate stations for comparison to the Okanagan historic values in Figure 59. The trends in the Shuswap watershed data are comparable to the Okanagan, suggesting that similar climate change should be expected in the Shuswap as what has been modeled for the Okanagan.
Figure 59: Mean Annual Temperature and Precipitation from Observations and Downscaled GCMs during 1961-2006 in the Okanagan Basin (Reprinted with Permission from van der Gulik et al. 2010); Bold Lines are the Actual Observations and Lighter Lines are from GCMs
Figure 60: Mean Annual Temperature and Precipitation from Downscaled GCMs between 2000 and 2010 in the Okanagan Basin (Reprinted with Permission from van der Gulik et al. 2010)
Figure 61: Mean Annual Temperatures at Four Climate Stations between 1970 and 2006

Figure 62: Mean Annual Precipitation and Four Climate Stations between 1970 and 2006
Pike et al. (2008a) summarized the hydrologic impacts of climate change in Canada as:

- a decrease in mean annual streamflow;
- an increase in mean monthly streamflow across Canada in March and April, with decreases in summer and fall;
- a decrease in annual minimum daily mean streamflow in southern Canada, with increases in northern BC and Yukon Territory;
- a decrease in annual maximum daily mean streamflow;
- an earlier starting date of spring high-flow season;
- an earlier date of annual maximum daily mean streamflow; and,
- an earlier centroid (date) of annual streamflow.

The Shuswap River trends shown in Figure 56 to Figure 58 and Table 36 to Table 39 are consistent with this summary, suggesting that climate change may be a key factor responsible for the recent (30 year time period) trends in the Shuswap River Watershed.

As a result of current trends and future climate projections, the following high-level hydrologic-related changes may be expected to occur (Pike et al. 2008b):

- increased atmospheric evaporative demand;
- altered vegetation composition affecting evaporation and interception;
- increased stream/lake temperatures;
- increased frequency/magnitude of storm events and disturbances;
- decreased snow accumulation and accelerated melt;
- accelerated melting of permafrost, lake ice, and river ice;
- glacier mass balance (advance/recession) adjustments; and,
- altered timing and magnitude of streamflow (peak flows, low flows).

These projected changes will continue the current trends well into the future as the global climate change models show little variation in trend over the coming decades.

7.3 Water Availability

Based on the above, climate change is expected to continue resulting in continuation of the trends shown over the past 30 to 100 years in the Shuswap watershed.

Table 42 extrapolates monthly flows forward for 30 years using the trend calculations for the 30, 60 and 99 year flow periods to project mean monthly flows in 2040 at the WSC Shuswap River station near Enderby and Table 43 shows the percentage change for each month over that period. The tables show a range of projections
based on the short, medium and long term trends, and it is difficult to say with any certainty as to which of the trends (if any) is the most likely to provide future direction. The long term trend uses the most data which includes a number of shorter term climate cycles and is less influenced by extreme years due to the longer record. The short term trend on the other hand is most reflective of recent trends and perhaps best demonstrates the impacts of climate change. Given those considerations, these projections should be considered as a range of possible outcomes with the expectation that the actual changes will be somewhere within the range.

Table 42: Projected Mean Monthly Flows (m³/sec) for Year 2040 at WSC Station 08LC002 (Shuswap River near Enderby) based on 30, 60, and 99 Year Flow Trends

<table>
<thead>
<tr>
<th>Period*</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Year Trend</td>
<td>47</td>
<td>56</td>
<td>51</td>
<td>90</td>
<td>177</td>
<td>268</td>
<td>103</td>
<td>42</td>
<td>31</td>
<td>52</td>
<td>59</td>
<td>49</td>
<td>81</td>
</tr>
<tr>
<td>60 Year Trend</td>
<td>39</td>
<td>48</td>
<td>72</td>
<td>129</td>
<td>219</td>
<td>233</td>
<td>135</td>
<td>53</td>
<td>33</td>
<td>38</td>
<td>55</td>
<td>43</td>
<td>85</td>
</tr>
<tr>
<td>99 Year Trend</td>
<td>46</td>
<td>53</td>
<td>69</td>
<td>98</td>
<td>190</td>
<td>257</td>
<td>143</td>
<td>60</td>
<td>45</td>
<td>47</td>
<td>52</td>
<td>47</td>
<td>91</td>
</tr>
</tbody>
</table>

* Periods are 30 year (1980-2009), 60 year (1950-2009), and 99 year (1911-2009).

Table 43: Projected Change in Mean Monthly Flows from 2009 to 2040 at WSC Station 08LC002 (Shuswap River near Enderby) based on 30, 60, and 99 Year Flow Trends

<table>
<thead>
<tr>
<th>Period*</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Annual</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 Year Trend</td>
<td>18%</td>
<td>27%</td>
<td>2%</td>
<td>2%</td>
<td>-7%</td>
<td>0%</td>
<td>-24%</td>
<td>-24%</td>
<td>-23%</td>
<td>13%</td>
<td>13%</td>
<td>11%</td>
<td>-6%</td>
</tr>
<tr>
<td>60 Year Trend</td>
<td>3%</td>
<td>14%</td>
<td>36%</td>
<td>34%</td>
<td>10%</td>
<td>-9%</td>
<td>-9%</td>
<td>-10%</td>
<td>-20%</td>
<td>-12%</td>
<td>8%</td>
<td>2%</td>
<td>-2%</td>
</tr>
<tr>
<td>99 Year Trend</td>
<td>15%</td>
<td>23%</td>
<td>33%</td>
<td>13%</td>
<td>0%</td>
<td>-4%</td>
<td>-5%</td>
<td>-3%</td>
<td>-4%</td>
<td>0%</td>
<td>4%</td>
<td>9%</td>
<td>2%</td>
</tr>
</tbody>
</table>

* Periods are 30 year (1980-2009), 60 year (1950-2009), and 99 year (1911-2009).

These 30 year future flow projections show that while average annual flows in the Shuswap River are not likely to change substantially (trend range is from -6% in the short to +2% in the long term trend), winter (November to February) average flows are expected to continue to increase noticeably, ranging from +7% and +13% based on the medium and long term trends to +17% based on the short term trend, freshet (April to June) average flows may show little change (short term is -1% and long term is 3%) to a significant increase (medium term trend is +12)%), and summer (July to September) average flow could continue to significantly decrease as the trends range from -4% on the long term to -13% and -23% on the medium and short terms.

Similar or even greater changes in flows can be expected in the Shuswap River tributaries. The flows in the Shuswap River are essentially the sum of all the tributary flows, so tributaries could be assumed to have similar projected flow trends. Bessette and Vance Creeks, however, show a greater decrease in average annual flows at about 15% over the past 30 years. There is little change in the overall average trends for winter and freshet flows in Bessette Creek, but the trends in summer and early fall flows have shown decreases of more than 50% over the past 30 years. Bessette Creek in particular is subject to significant flow regulation such as diversions into storage, releases from storage, water withdrawals for domestic and irrigation, and discharge of treated sewage effluent back into the creek below Lumby. As such, it is harder to project future tributary flows when the existing flows are so subject to regulation. The larger decrease in annual flows and the much larger decrease in summer flows in the Bessette Creek sub-drainage do suggest though that the future flow reductions will be more extreme in some tributaries than in the mainstem Shuswap River.
Trends to lower annual flows do not appear to be much cause for water supply concern except in tributary streams like the Bessette tributaries and Fortune Creek where a significant proportion of the annual flow is diverted into storage for summer use. Changes in seasonal flows will have even greater implications for water supply, particularly in the tributaries where there is a limited water supply. Decreasing summer and early fall flows in the tributaries will reduce the ability to use natural flows for water supply and will require increased use of water released from storage to meet water consumption needs, particularly if minimum instream flow thresholds are to be met. Expansion of existing storage reservoirs or construction of new reservoirs will be possible in some tributaries, but challenging in others due to both terrain suitability and runoff considerations. Even filling of existing reservoirs in some tributaries may become challenging if the overall volume of winter and freshet flows are reduced.

7.4 Cautionary Notes Regarding Flow Trend Calculations

The high inter-annual variability in mean annual flows, and in particular with mean monthly flows, results in the calculated flow trends being highly sensitive to the time periods used for the trend analyses. Trends change over time, as demonstrated by the Shuswap River results. Hydrometric stations also have varying periods of record depending on when they were established and how they were operated. Some stations started with only seasonal records, and some have gaps in the data records when the station was temporarily discontinued for a few years or perhaps was damaged or otherwise inactive for a shorter period of time.

To eliminate bias, a 30 year period was chosen as the basis for the trend analyses. Environment Canada uses a 30 year period for reporting climate data normal's, the periods of record for the Bessette Creek hydrometric stations are just a few years longer than 30 years, and the periods of record for the Shuswap River hydrometric stations are a little longer than 90 years.

The magnitudes of extreme flow events early or late in the time periods may have a substantial impact to the calculated trends, particular for shorter analysis periods. The last year with published hydrometric records is 2009, which was a very dry year. The years 2009 and 2003 (which was even drier and still relatively close to the end of the 30 year period), may be strongly influencing the strongly negative summer flow trends in Bessette and Vance Creek. A new analysis period, with the inclusion of results from several wetter years, like 2010 and particularly 2011, could cause a small but noticeable change in the trend magnitude.

All of the WSC stations used to calculate the trends also show varying effects of water use and flow regulation, which undoubtedly alters some of the calculated results. Unfortunately, there are no hydrometric stations in tributaries with more natural flows in the Shuswap watershed that could be used for more precise trend calculations.

To reiterate, the trend results need to be considered as approximations of the rate of future (and particularly short-term) flow change, but not as absolute predictions of future flow volumes. Updating the calculations in a few years with more recent data would be useful to confirm ongoing validity of the trend analyses.
8.0 GAP ANALYSIS AND RECOMMENDATIONS

This section outlines data gaps encountered while undertaking this Technical Assessment, as well as direction for further study. Data gaps and associated recommendations are presented in tabular format below.

8.1 Water Quality

The data gaps related to the water quality of the Shuswap River Watershed that were identified as part of this Technical Assessment, as well as recommendations to fill these gaps, are provided in Table 44.

<table>
<thead>
<tr>
<th>Area of Watershed</th>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Access to the numerous water quality reports that may be available (through consultant reports, small studies for septic field programs, strata developments, small constructions projects, etc.) is limited and is only available in hard copy format, generally held within property files for individual legal lots.</td>
<td>An extensive data mining and data warehousing program would greatly increase the amount of useful data available for interpretation and monitoring. This program should strive to obtain “private” data (i.e.: consultant reports, etc.) in native (Excel compatible) format.</td>
</tr>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Water quality parameters that are currently being analyzed for are limited and generally consist of nutrients, microbial parameters, and limited metals (major ions).</td>
<td>Consideration should be made to establishing a consistent suite of parameters to be monitored at select surface water and groundwater locations including, but not limited to: nutrients, microbial parameters, select metals and major ions, turbidity and suspended solids. At locations with known or suspected water quality impacts outside of this suite, the list of parameters should be expanded.</td>
</tr>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Preliminary Risk Rankings provided in this report are based primarily on land use designations, proximity to water sources, and assumed intensity and type of activity.</td>
<td>A limited “windshield” field investigation to confirm and revise the Preliminary Risk Rankings is recommended.</td>
</tr>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Insufficient digital data is available to identify all public and private sources of waste disposal and wastewater discharge within the Shuswap River Watershed.</td>
<td>Efforts should be made to identify all public and private waste management and processing facilities, and waste (and waste water) treatment facilities to generate a GIS layer. This would greatly assist in the evaluation of potential current and future water quality issues and potential sources for existing impacts. This should include as many private waste discharges (e.g., septic fields) as possible.</td>
</tr>
<tr>
<td>Upper Shuswap River Watershed</td>
<td>No groundwater quality data, and limited surface water quality data has been identified for the Upper Shuswap River Watershed.</td>
<td>A water quality sampling program should be undertaken in the Upper Shuswap River Watershed, surface and groundwater in this area would be representative of baseline watershed water quality, representing the upper reaches, and more pristine conditions, of the watershed.</td>
</tr>
</tbody>
</table>
### Area of Watershed Data Gaps Recommendations

<table>
<thead>
<tr>
<th>Area of Watershed</th>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle and Lower Shuswap River Watershed</td>
<td>Incomplete parameter suites and only short term monitoring of MoE observation wells; limited groundwater quality information exists</td>
<td>Consideration should be given to implementation of comprehensive groundwater quality sampling at existing BC MoE wells in order to characterize groundwater quality in this area, including: full metal scans, nutrients, microbial parameters, turbidity, and suspended solids. Consideration should be made to installing several additional groundwater water monitoring wells throughout the Shuswap River Watershed at select locations for long term water quality monitoring and assessment.</td>
</tr>
</tbody>
</table>

### 8.2 Water Quantity

The following sections described the data gaps and recommendations related to water quantity in the Shuswap River Watershed.

#### 8.2.1 Surface Water

The data gaps related to the surface water of the Shuswap River Watershed that were identified as part of this Technical Assessment, as well as recommendations to fill these gaps, are provided in Table 45.

**Table 45: Surface Water Quantity Data Gaps and Recommendations**

<table>
<thead>
<tr>
<th>Area of Watershed</th>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Lack of agricultural water consumption data. Agricultural water use for irrigation may be even higher than the water use by water utilities, but there is no use reporting requirement. This results in considerable uncertainty regarding actual usage as usage was simply estimated at 90% of license volume, and there is no accounting for agricultural use of groundwater.</td>
<td>RDNO should consider the development of an Agriculture Demand Model, including a land use inventory system, to be constructed in conjunction with the Ministry of Agriculture, who has completed similar models for the Okanagan and Similkameen Watersheds. This Model uses gridded climate and soils information together with crops and equipment by parcel to provide historic and future (based on climate models) calculations of required water for each land parcel.</td>
</tr>
<tr>
<td></td>
<td>Lack of water use management planning tools.</td>
<td>Development of a Water Use Management Plan</td>
</tr>
<tr>
<td></td>
<td>Lack of adequate flood plain mapping on Shuswap River Sub-drainage</td>
<td>Incorporate available CAD data to GIS shape files and collect additional data to fill in gaps</td>
</tr>
</tbody>
</table>

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## Area of Watershed

<table>
<thead>
<tr>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>An insufficient number of hydrometric stations exist within the watershed.</td>
<td>Re-establishment of several hydrometric stations on other tributaries with high water use (e.g. Fortune Creek) and several tributaries with natural flows that may have water use but are not affected by water storage (e.g. Trinity Creek, Ferry Creek and Cherry Creek) would be beneficial to provide a wider picture of how flows are changing in the developed portion of the watershed.</td>
</tr>
<tr>
<td>The Middle Shuswap River below the Wilsey Dam is the only section of river with formalized instream flow thresholds for aquatic resources, and only Duteau Creek and Bessette Creek have recommended instream flow targets.</td>
<td>Minimum instream flow thresholds or targets should be considered for all tributaries with moderate to high water use (or potential for increased water use) and moderate to high fisheries values (e.g. Fortune Creek, Trinity Creek, Ferry Creek).</td>
</tr>
<tr>
<td>Insufficient information exists on either flows from the Upper Shuswap River Watershed (other than outlet of Sugar Lake) or from the Wap Creek end of Mabel Lake; together, these provide more than 50% of the water in the watershed.</td>
<td>Establishment of new hydrometric stations in these two areas would over time provide valuable information on flow trends in the Upper Shuswap River Watershed and upper areas of the Middle Shuswap River Watershed that are so influential in determining the flows in the Shuswap River.</td>
</tr>
</tbody>
</table>

### 8.2.2 Groundwater

The data gaps related to the groundwater of the Shuswap River Watershed that were identified as part of this Technical Assessment, as well as recommendations to fill these gaps, are provided in Table 46.

#### Table 46: Groundwater Quantity Data Gaps and Recommendations

<table>
<thead>
<tr>
<th>Area of Watershed</th>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Shuswap River Watershed</td>
<td>Aquifer characteristics (hydraulic gradients, hydraulic conductivity, thickness, etc.) are widely unknown for the Shuswap River Watershed, with discrete information available for select locations (i.e. Lumby).</td>
<td>As aquifer characteristics are assessed for private properties, in regards to the RDNO’s subdivision servicing bylaw, the data should be placed into a data base system for future analyses. In addition, additional characterization of groundwater parameters could be undertaken in the area of existing wells. Focus should be given to characterizing aquifer characteristics in the Lower Shuswap River Watershed, as the volume of groundwater is significantly lower than the other areas of the watershed, with extractions potentially representing approximately 44% of the flow through the aquifer.</td>
</tr>
<tr>
<td></td>
<td>Limited information exists in regards to groundwater usage in the private sector (i.e. industry, agriculture,)</td>
<td>Efforts should initially be focused on assessing consumption rates for larger groundwater users such as agricultural users and industry, as refinement of</td>
</tr>
</tbody>
</table>
8.3 Riparian Areas

The data gaps related to the riparian areas of the Shuswap River Watershed that were identified as part of this Technical Assessment, as well as recommendations to fill these gaps, are provided in Table 47.

Table 47: Riparian Area Data Gaps and Recommendations

<table>
<thead>
<tr>
<th>Area of Watershed</th>
<th>Data Gaps</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Shuswap River Watershed</td>
<td>Absence of recent detailed ecological studies (e.g., SHIM, FIM) for all the streams in this sub-watershed. Preliminary assessment of riparian conditions for the Upper Shuswap River only was completed as part of this Technical Assessment.</td>
<td>As a minimum, ground-truthing of the disturbed riparian areas identified for the Upper Shuswap River should be completed. The next step in prioritizing restoration areas of the Upper Shuswap River is to conduct detailed inventory, mapping, and aquatic habitat indexing similar to that completed for the Lower Shuswap River. Key tributaries in this watershed could also be similarly assessed.</td>
</tr>
<tr>
<td>Middle Shuswap River</td>
<td>Absence of recent detailed ecological studies (e.g., SEI, TEM) for the entire sub-watershed</td>
<td>SEI and TEM could be conducted for the Upper Shuswap River Watershed.</td>
</tr>
<tr>
<td></td>
<td>Absence of recent detailed ecological studies (e.g., SHIM, FIM) for the majority of streams in this sub-watershed. Preliminary assessment of</td>
<td>As a minimum, ground-truthing of the disturbed riparian areas identified for the Middle Shuswap River should be completed. The next step in prioritizing restoration areas of the Middle Shuswap River is to</td>
</tr>
<tr>
<td>Area of Watershed</td>
<td>Data Gaps</td>
<td>Recommendations</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Watershed</td>
<td>riparian conditions for the Middle Shuswap River only was completed as part of this Technical Assessment.</td>
<td>conduct detailed inventory, mapping, and aquatic habitat indexing similar to that completed for the Lower Shuswap River. Key tributaries (e.g., Bessette Creek, Duteau Creek, Cherry Creek) in this watershed should also be similarly assessed.</td>
</tr>
<tr>
<td>Absence of recent detailed ecological studies (e.g., SEI, TEM) for the majority of this sub-watershed</td>
<td></td>
<td>SEI and TEM could be conducted for the remaining areas of the Middle Shuswap River Watershed.</td>
</tr>
<tr>
<td>Lower Shuswap River Watershed</td>
<td>While detailed SHIM and FIM are available for the Lower Shuswap River, the restoration analysis did not quantify the feasibility of completing restoration activities at each identified segment.</td>
<td>The next step in prioritizing restoration areas for the Lower Shuswap River is to conduct a feasibility assessment that would include a detailed scoping and cost estimate of the specific restoration activities required at each segment, as well as a prioritization of restoration activities at each segment if funding constraints required a phased approach to restoration activities. The purpose of the feasibility assessment would be to provide a deliverable that could be circulated to potential stakeholders and environmental stewardship groups should funding come available.</td>
</tr>
<tr>
<td>Absence of recent detailed ecological studies (e.g., SHIM, FIM) for the majority of streams in this sub-watershed (excluding the Lower Shuswap River).</td>
<td></td>
<td>Orthophoto interpretation and ground-truthing of the disturbed riparian areas identified for key tributaries of the Lower Shuswap River could be completed.</td>
</tr>
<tr>
<td>Absence of recent detailed ecological studies (e.g., SEI, TEM) for the entire sub-watershed</td>
<td></td>
<td>SEI and TEM could be conducted for the Lower Shuswap River Watershed.</td>
</tr>
</tbody>
</table>
9.0  CLOSURE

We trust that this Technical Assessment provides you with the information that you require at this time. Should you require additional information or have any questions, please do not hesitate to contact the undersigned at your earliest convenience.

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11.0 ACRONYMS

AGQMAP  Ambient Groundwater Quality Monitoring and Assessment Program
AHI    aquatic habitat index
ALR    agricultural land reserve
BC CDC  British Columbia Conservation Data Centre
BC MoE  British Columbia Ministry of Environment
BC MELP British Columbia Ministry of Environment, Lands, and Parks
BC MFLNRO British Columbia Ministry of Forests, Lands, and Natural Resource Operations
BEC    Biogeoclimatic Ecosystem Classification
COSEWIC Committee on the Status of Endangered Wildlife in Canada
CSR    Contaminated Site Regulation
DEM    digital elevation model
DFO    Fisheries and Oceans Canada
ESSF   Engelmann Spruce Subalpine Fir BEC zone
FIM    foreshore inventory and mapping
FISS   Fisheries Information Summary System
FSR    forest service road
GIS    geographic information system
GCM    Global Climate Model
GVW    Greater Vernon Water
ha     hectare
HWM    high water mark
ICH    Interior Cedar Hemlock BEC zone
IDF    Interior Douglas-Fir BEC Zone
IMA    Interior Mountain-heather Alpine BEC zone
KICS   Kingfisher Interpretive Centre Society
km     kilometre
kWH    kilowatt hour
### TECHNICAL ASSESSMENT OF THE SHUSWAP RIVER WATERSHED

L \quad \text{litre}

LSSS \quad \text{Lower Shuswap Stewardship Society}

LWD \quad \text{large woody debris}

m^{3}/\text{day} \quad \text{metres cubed per day}

m^{3}/\text{s} \quad \text{metres cubed per second}

m^{3}/\text{year} \quad \text{metres cubed per year}

MAD \quad \text{mean annual discharge}

masl \quad \text{metres above sea level}

mbgs \quad \text{metres below ground surface}

mm \quad \text{millimetre}

MS \quad \text{Montane Spruce BEC zone}

NTU \quad \text{nephelometric turbidity unit}

QA/QC \quad \text{quality assurance / quality control}

RDNO \quad \text{Regional District of North Okanagan}

RFP \quad \text{request for proposal}

SEI \quad \text{sensitive ecosystem inventory}

SHIM \quad \text{sensitive habitat inventory and mapping}

sp. / spp. \quad \text{species (singular) / species (multiple)}

SRWSP \quad \text{Shuswap River Watershed Sustainability Plan}

TAC \quad \text{Technical Advisory Committee}

TEM \quad \text{terrestrial ecosystem mapping}

TRIM \quad \text{terrain resource inventory mapping}

UDR \quad \text{upper direct recharge}

µg/L \quad \text{micrograms per litre}

WRP \quad \text{Watershed Restoration Program}

WSC \quad \text{Water Survey of Canada}

WUP \quad \text{Water Use Plan}

WWTP \quad \text{wastewater treatment plant}