Appendix A – Assessment of Water Supply Availability and Risk (WSD-1)

SUMMIT
Environmental Consultants Inc.
A Member of the Associated Engineering Group of Companies

FINAL REPORT

Regional District of Okanagan-Similkameen

Similkameen River Watershed:
Assessment of Water Supply Availability and Risk (WSD-2)

June 2015

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Glossary

Hydrometric Station: A station on a river, lake, or reservoir where water quantity data is collected and recorded. Such data generally includes stage (water surface elevation) and discharge.

Losing Stream: A stream that loses water to a groundwater aquifer as it flows downstream.

Natural Flows: Streamflows that have no human influence.

Naturalized Flows: Estimates of natural flows adjusting net flows for the effects of water withdrawals and storage.

Net Flows: Streamflows that include water extractions and storage effects occurring upstream.

Streamflow Naturalization: A process of estimating natural streamflow by removing the human influence on recorded flows.

1 Introduction

Section 1 summarizes the Similkameen Watershed Plan and the objectives of the present assessment of water supply availability and risk.

1.1 PROJECT BACKGROUND

The Similkameen Valley Planning Society (SVPS) and the Regional District of Okanagan Similkameen (RDOS) are currently developing the Similkameen Watershed Plan (SWP). To support the planning process, RDOS retained Summit Environmental Consultants Inc. (Summit) to complete a number of technical studies to advance the understanding of water resources in the Similkameen watershed. This report presents the results of the water supply availability and risk technical assessment. It was completed as a component of Phase 2 of the SWP. It was preceded by the Phase 1 study, which was completed in 2014 (Summit 2014).

1.2 PROJECT OBJECTIVES

The objective of this assessment was to provide the necessary water supply and demand (WSD) information to fill the associated information gaps that were identified in the Phase 1 study (i.e. WSD-2). The specific objectives were as follows:

1. Develop estimates of natural (or naturalized) flow in the Similkameen River watershed for the current normal climate period (1981-2010) at the outflow locations of selected points of interest (note that flow estimates are to include median and 1:10-year and 1:50-year low-flow return periods);
2. Compare the outputs of the B.C. Ministry of Agriculture's Agriculture Water Demand Model against records of actual water use obtained during the Phase 1 study;
3. Identify a number of scenarios that incorporate climate change predictions, changes in agricultural land use or area, and changes in water conservation technology that are realistic for the Similkameen River watershed; and
4. Use the Agriculture Water Demand Model to predict the future agricultural water demand under the selected scenarios.

2 Methods

Section 2 summarizes the methods used to assess water availability and risk in the Similkameen River watershed.

2.1 SUB-BASIN DELINEATION

In the Phase 1 study, to address water supply and demand investigations at an appropriate scale, the Similkameen River watershed was divided into sub-basins. The delineation of sub-basins was determined based on discussions with RDOS and the locations of streamflow and water quality monitoring stations. The 10 sub-basins are as follows:

- Sub-basin #1 – Similkameen River, Manning Park to Princeton;
- Sub-basin #2 – Tulameen River;
- Sub-basin #3 – Allison Creek;
- Sub-basin #4 – Hayes Creek;
- Sub-basin #5 – Similkameen River, Princeton to Hedley (the residual area contributing to the Similkameen River from below the Tulameen River confluence to the Water Survey of Canada [WSC] hydrometric station [Station No. 08NL038] on the Similkameen River near Hedley, B.C.);
- Sub-basin #6 – Hedley Creek;
- Sub-basin #7 – Keremeos Creek;
- Sub-basin #8 – Ashnola River;
- Sub-basin #9 – Similkameen River, Hedley to the International Border (the residual area contributing to the Similkameen River from below the Similkameen River WSC hydrometric station near Hedley [WSC 08NL038] to the international border); and
- Sub-basin #10 – Similkameen River, International Border to the Mouth (the residual area contributing to the Similkameen River from below the international border to the confluence with the Okanogan River).

These sub-basins were defined to help organize the collection and cataloguing of water supply and demand information for the Phase 1 study. They each have a location at their most downstream point, and referred to as a 'point-of-interest' (POI). The sub-basin, together with their POI, formed the basis for assessing water availability and risk (Figure 2-1). The POIs are as follows:

- POI #1 – Similkameen River above the Tulameen River Confluence;
- POI #2 – Tulameen River at the Mouth;
- POI #3 – Allison Creek at the Mouth;
- POI #4 – Hayes Creek at the Mouth;
- POI #5 – Similkameen River near Hedley (at WSC 08NL038);
- POI #6 – Hedley Creek at the Mouth;
- POI #7 – Keremeos Creek at the Mouth;
- POI #8 – Ashnola River at the Mouth;
- POI #9 – Similkameen River at the International Border; and
- POI #10 – Similkameen River at the Mouth.

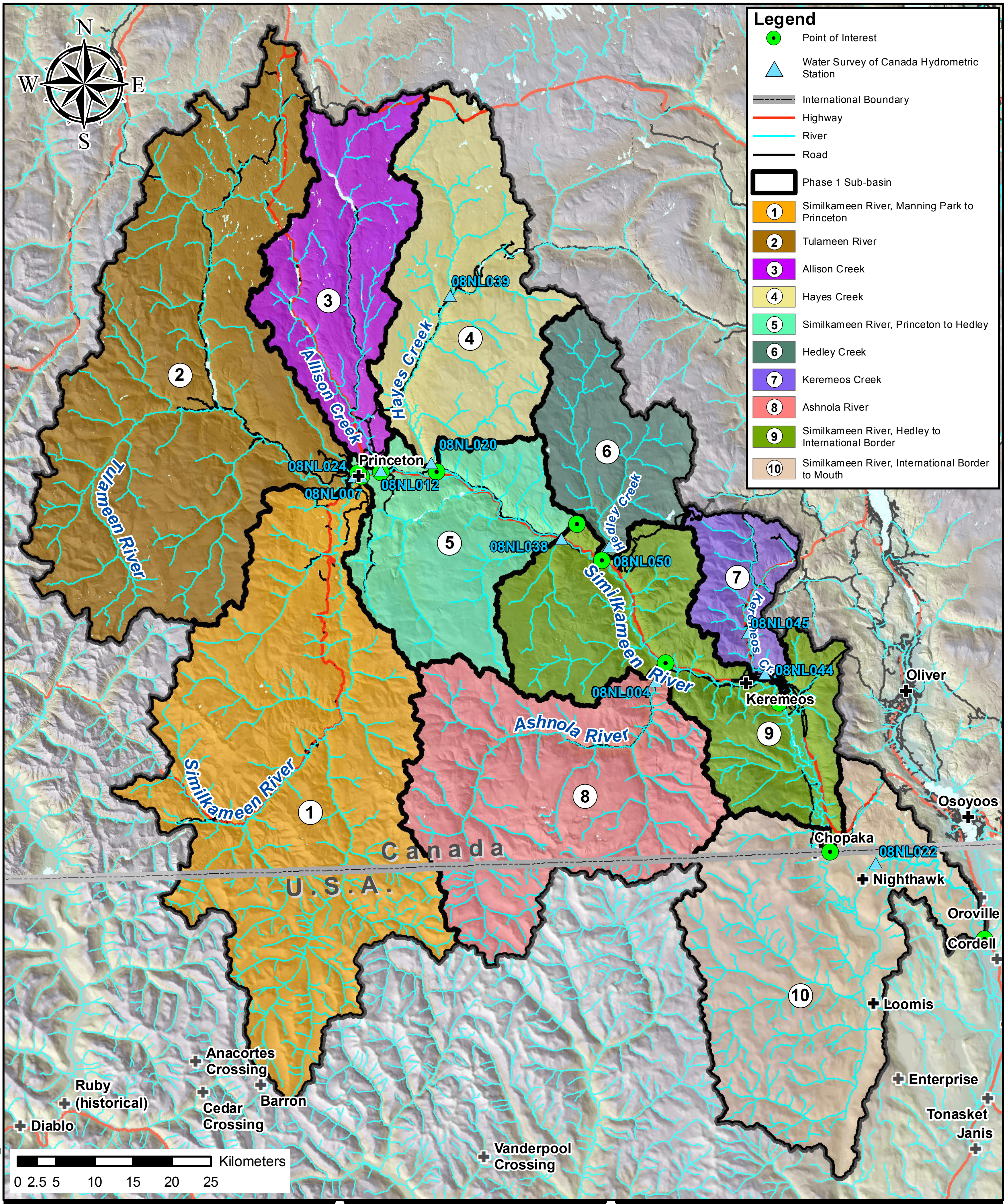

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FIGURE 2-1: SUB-BASINS AND POINTS OF INTEREST IN THE SIMILKAMEEN WATERSHED

Regional District of Okanagan Similkameen

Similkameen Watershed Plan - Phase 2

2.2 SURFACE WATER HYDROLOGY AND NATURALIZED FLOWS

This section provides a detailed description of the streamflow naturalization process for the 10 POIs within the Similkameen River watershed. The major steps are described in further detail in subsequent sections and are summarized as follows:

- Based on evaluation of available streamflow records and water use information for the Similkameen River watershed from the Phase 1 study, a standard period of 1981-2010 (on a monthly time interval) was adopted.
- After reviewing the Similkameen River watershed and considering the locations of hydrometric monitoring stations, the 10 sub-basins defined during the Phase 1 study were adopted. The sub-basins and their downstream POIs formed the basis for the streamflow and water use analyses. Net and naturalized flow outputs were developed for each of the adopted 10 sub-basins.
- Water management information for the Similkameen River watershed was analyzed and water use was estimated using information provided in the Phase 1 study.
- The streamflow data for each POI were systematically screened, data gaps were filled and scaling was carried out as required, typically by comparing records to downstream POIs or nearby streams.
- Regulated streamflow records were naturalized by accounting for water held or released from storage, and for water extracted and returned upstream of each POI.
- Potential surface water-groundwater interaction was considered based on streamflow data.
- The net and naturalized streamflows and various low-flow statistics, total water licensing, and estimates of actual water use for each POI were summarized.

2.2.1 Overview of Streamflow Naturalization

Natural or naturalized streamflows at the POIs were calculated to develop a simple water supply and demand spreadsheet summary (Section 3.2). The WSC identifies the two active hydrometric stations on the Similkameen River (at Princeton [WSC 08NL007] and near Hedley [WSC 08NL038]) and the active stations on the Tulameen River (WSC 08NL024), Hedley Creek (WSC 08NL050), and the Ashnola River (WSC 08NL004), as measuring natural flow (Figure 2-1). Each of these stations is located close to the respective POIs and, although all are noted as representing natural streamflows, naturalization procedures were still completed to understand the existing water demands within each watershed that future planning scenarios may be compared against.

Based on available streamflow records and water use information, the 1981-2010 standard period was adopted for the water availability and risk assessment. This standard period represents the most current 30-year "normal" period. The data can be compared to the most recently published climate "normal" data, and includes the years for which water use information was available from the water purveyors that were included in the Phase 1 study. A monthly time interval was selected for naturalization purposes to match available water use information.

At each of the 10 POIs, naturalized monthly streamflow was estimated by adding all upstream licensed withdrawals or actual withdrawals (if available) to recorded streamflows. During the Phase 1 study, all licensed quantities were considered alongside actual water use information for each of the sub-basins, and this information was used for naturalization purposes.

Given that the monthly distribution of withdrawals is typically not indicated in water licence data, several assumptions were necessary to distribute the total annual licensed quantities throughout the year. These assumptions were as follows:

1. The total licensed volume is evenly distributed throughout the year for the following purposes: "stockwatering," "enterprise," "mining," and "cooling."
2. For "domestic," "camps," and "waterworks" purposes, total annual licensed quantities are distributed based on the 1991-2010 mean distribution of actual domestic (indoor and outdoor) water use obtained from the Hedley Improvement District[1] during the Phase 1 study (Table 2-1).

Table 2-1 Domestic (indoor and outdoor) monthly water use distribution for the Similkameen River watershed based on records from the Hedley Improvement District, 1991-2010

Month	Usage (% of annual)	Month	Usage (% of annual)
January	5.6	July	16.3
February	4.8	August	14.9
March	5.3	September	9.2
April	6.7	October	6.1
May	10.5	November	4.6
June	11.0	December	5.0

3. For irrigation purposes, total annual licensed quantities are distributed based on 1981-2010 mean distribution of agriculture water demand estimates for each sub-basin from the B.C. Ministry of Agriculture's Agriculture Water Demand Model (Section 2.3).
4. No storage licences carry over from year to year and, for each sub-basin, the amount of water withdrawn into storage between October 1 and June 30 (i.e. general licensed dates) is based on the distribution of naturalized monthly streamflows for the sub-basin. As well, it was generally assumed that the maximum storage volume for irrigation and waterworks purposes was being stored for offstream purposes at a later date. An exception to this was the storage licence on Nickel Plate Lake (Sub-basin #6) held by the Similkameen Improvement District. During the Phase 1 study, the District reported that they store approximately 50% of their licensed volume and gradually release the stored volume during the low-flow period between August 1 and October 31 each year to supplement the amount of water available to private licence holders.
5. Instream licences were either distributed based on the naturalized monthly flow distribution of the sub-basin to which the licence pertains (i.e. power) or the total licensed volume was evenly distributed throughout the year (i.e. conservation).

[1] The Hedley Improvement District records were assumed representative for the entire Similkameen River watershed, as they represented the longest period of record for all water purveyors and only reflected domestic (indoor and outdoor) uses. Based on the Phase 1 study, most other water purveyors provide water for agriculture purposes or only had limited records available for domestic purposes.

6. Surface water licences for the United States are not incorporated, as the information was not readily available from the Washington State Department of Ecology, despite our efforts to obtain the information.
7. To provide the most accurate estimate of monthly withdrawals from each sub-basin for the standard period, the records of mean monthly actual water use for the major water purveyors (i.e. as specified in the Phase 1 study) were used in place of the purveyors' licensed amounts. In addition, for all major water purveyors using a groundwater source, the use of groundwater was considered equivalent to the use of surface water based on the assumption that the extraction of groundwater has the same effect on flow in the Similkameen River as a direct diversion of surface water would have. This assumption was based on the results of the Phase 2 surface water – groundwater interaction assessment (Summit 2015a). Due to a lack of available data on groundwater use by single homes or farms in the Phase 1 study, groundwater use by individual households and farms for domestic purposes was not included in the analysis. At the scale of the sub-basins and considering the small population base within the watershed, we assumed that groundwater use from single properties for domestic purposes is having a negligible effect on surface water flows. However, this assumption should be re-evaluated for any future aquifer-specific assessments.
8. To provide the most accurate estimate of monthly irrigation uses for each sub-basin for the standard period, the Agriculture Water Demand Model estimates of irrigation and stockwatering (i.e. livestock) water demands (surface and groundwater supplied) were used in place of licensed amounts. All irrigation supported by storage was considered based on the ratio of percentage total licensed storage to percentage total licensed irrigation, and where the percentage of storage was applied to the model estimates, storage was in accordance with Assumption #4 above, and all storage was consumptive. In addition, due to a lack of available data on water use by private farms within the watershed, the Agriculture Water Demand Model estimates were assumed to provide an appropriate estimate (Section 2.3.3).

2.2.2 Naturalized and Net Flows

A summary of the estimation procedure for mean monthly naturalized and net streamflows at the 10 POIs is provided in Appendix A, and all referenced WSC stations (in Appendix A) are shown in Figure 2-1. At each POI, the following mean annual and monthly values were estimated.[2]

- net flow (i.e. the recorded flow, referred to as "net" because it is the flow resulting after any storage and withdrawal effects);
- naturalized flow;
- total licensed quantity for both offstream and instream purposes;
- licensed quantity for offstream purposes;
- licensed quantity for instream purposes;
- licensed quantity for storage;
- estimated actual offstream use (not including major purveyors); and
- estimated actual water purveyor use (including groundwater).

[2] All estimated flows were compared to historical records at or near respective POIs when available (e.g. Allison Creek, Hayes Creek, Keremeos Creek) to ensure that estimated values were in the general range historically measured.

In addition, mean annual and monthly low flow statistics for the 1:10-year and 1:50-year return periods for the standard period were derived using the recorded net flows at the available WSC stations. Frequency analyses for the 1:10-year and 1:50-year return periods were conducted by fitting the data to each of the following four frequency distributions: Pearson type III, log Pearson type III, log normal, and Gumbel. The general procedure for estimating individual return period flows involves visually assessing the goodness-of-fit of the data to each distribution, with poor fits excluded. Based on review of each distribution, we concluded that all distribution types fitted the data reasonably well; therefore, the results from all four distributions were averaged and used to calculate the average values (and 95% confidence limits). A summary of the low-flow estimation procedure for each POI is provided in Appendix A.

2.3 AGRICULTURE WATER DEMAND MODEL

2.3.1 Model Summary

The B.C. Ministry of Agriculture (MAL) and Agriculture and Agri-Foods Canada (AAFC) developed an Agriculture Water Demand Model (AWDM) for the Canadian portion of the Similkameen River watershed (van der Gulik et al. 2013). The model was created in order to estimate current and future agriculture water demand (including both crop irrigation and livestock watering) on a property-by-property basis.

The AWDM is based on a Geographic Information System (GIS) database that contains cadastre information (showing the boundaries of land ownership), crop type, irrigation system type, soil texture, and climatic data (van der Gulik et al. 2013). This information was assembled from background information, high-resolution orthophotos, and GIS, and was confirmed by ground surveys in 2008. Land uses (including crop type and method of irrigation) were identified and water demands were estimated at the scale of the individual land parcel and finer. Accordingly, the model can provide estimates of water demand for individual crops on a parcel of land, or for an entire sub-basin or watershed, for local government jurisdictions, or for water supplier distribution areas (e.g. irrigation districts) by summing the demands within those areas.

The AWDM calculates the daily evapotranspiration demand for each parcel using a form of the Penman-Monteith equation (van der Gulik et al. 2013). It also computes the existing soil moisture and the daily precipitation. The irrigation requirement is the residual demand that cannot be met from these two sources. The climate (dataset) is the key driver of the evaporation calculations. In the Similkameen River watershed, a 1950-2010 gridded dataset[3] consisting of cells measuring 500 m by 500 m was created, and temperature (minimum, maximum, and mean) and total precipitation for each day of the year was estimated for each cell. A detailed description of how the model calculates agricultural water demands is provided by van der Gulik et al. (2013).

[3] This dataset is an update to the information presented in the Phase 1 study and by van der Gulik et al. (2013), and represents the most current AWDM results.

2.3.2 Baseline Data and Agricultural Land Base

The AWDM 1950-2010 dataset was obtained from MAL (RHF Systems Ltd. 2015a) and from the available model results, the following information was summarized:

- agricultural and livestock water demand information (surface and groundwater supplied) for each sub-basin;
- agricultural and livestock water demand information for the major water purveyors (surface and groundwater supplied) included in the AWDM; and
- land use information (including crop, irrigation, and soil type breakdown based on survey information completed in 2008) and MAL identified non-irrigated and potential agricultural lands for each sub-basin.

Information from the 1981-2010 standard period was used to support the streamflow naturalization process (Section 2.2), where required. The types of irrigable lands reported by the AWDM for the Similkameen River watershed (Canadian portion only) included alfalfa, grass, fruit, nut, and vegetable crops, turf parks, golf courses, greenhouses, and various others.[4] A summary of the AWDM results for each sub-basin (Section 2.1) is presented in Table 2-2. The tabulated water demand estimates (surface water and groundwater) are the averages for the standard period and may not be representative of current land use or use in any given year. Also, the agricultural land base is assumed constant (at 2008 levels) for the standard period, and the variation in water demands is solely related to variations in climate.

[4] Agriculture water use information for the United States was not included, as the information was not readily available from the Washington State Department of Ecology, despite our efforts to obtain the information

Table 2-2 Selected summary results for the Similkameen River watershed based on the Agriculture Water Demand Model

Sub-basin	Drainage Area (km^2)	Total Lands Irrigated (km^2)	Total Lands Not Irrigated[1] (km^2)	Potential Agricultural Lands[2] (km^2)	Agricultural Water Demand[1] (ML/yr)	Livestock Water Demand (ML/yr)
#1 – Similkameen River, Manning Park to Princeton	1,811	0.8	0.1	0.0	413	14.5
#2 – Tulameen River	1,778	3.1	0.3	2.8	2,064	21.3
#3 – Allison Creek	600	2.7	0.8	0.2	1,338	27.5
#4 – Hayes Creek	779	1.2	0.5	<0.1	555	12.2
#5 – Similkameen River, Princeton to Hedley	601	4.2	0.7	1.8	2,722	27.9
#6 – Hedley Creek	395	<0.1	0.0	0.0	2.0	0.1
#7 – Keremeos Creek	224	8.0	0.3	3.6	4,595	54.3
#8 – Ashnola River	1,060	0.0	0.0	0.0	0.0	<0.1
#9 – Similkameen River, Hedley to International Border	869	23.2	2.8	4.6	13,674	133
#10 – Similkameen River, International Border to Mouth	168	2.1	0.1	<0.1	1,357	12.0

Note:
1. Agricultural lands identified by MAL as not being irrigated.
2. Land identified by MAL that is not currently agricultural land, but is a potential agricultural area.

2.3.3 Review of Water Purveyors and Demand

The major water purveyors included in the AWDM and their associated land base are illustrated in Figure 2-2. The major purveyors are as follows:

- Fairview Heights Irrigation District;
- Keremeos Irrigation District;
- Cawston Irrigation District;
- Upper Similkameen Indian Band;
- Lower Similkameen Indian Band; and
- Private (i.e. individual residents/farmers).

The water purveyor boundaries included in the AWDM were confirmed with the Keremeos Irrigation District (KID) and Fairview Heights Irrigation District (FHID).[5] KID indicated that the land base included in the model is consistent with their irrigation service area; however, it was noted that some sections of land in the southeast and northern portions of the purveyor boundary are privately supplied (K. Huey, personal communication, 2015). Of these privately-supplied lands, a large hay field in the southeast corner of the boundary was identified as using a significant amount of water for agricultural purposes (K. Huey, personal communication, 2015). FHID indicated that the land base included within the AWDM is consistent with their irrigation service area; however, it was noted that a small section of land in the southeast corner outside the purveyor boundary was also supplied, but for domestic use only (B. Mennell, personal communication, 2015). For the Cawston Irrigation District, the land base was confirmed to be supplied by individual private wells (G. Bush, personal communication, 2015) and could, therefore, be defined as “private” in the AWDM. Lastly, for the Upper and Lower Similkameen Indian Bands, all agricultural lands fell within corresponding Indian Reserve boundaries.

For the major water purveyors listed above, during the Phase 1 study, actual water use information was only available for FHID and KID. A summary of available annual records in comparison to the estimated AWDM water demands (for agriculture and livestock) for FHID is provided in Table 2-3.[6] For KID, water use information is only available from one well of the 13 that are used for water supply; as a result, no direct comparison could be made between the AWDM water demand estimates and KIDs actual water use. However, the estimated water demand for KID is likely an overestimate since the AWDM includes lands within the KID boundary that are privately supplied. The comparison for FHID (Table 2-3) suggests that the AWDM generally underestimated the amount of water demand for the available periods of record. On average, the AWDM underestimated FHID’s annual water use by 470 ML/yr (or 0.015 m^3/s).

[5] The KID-serviced land is located in both Sub-basin #7 and Sub-basin #9 and the FHID service area includes Sub-basin #9.

[6] FHID annual water use information is only available for 2002, 2005, 2006, and 2009. For comparison purposes in Table 3-3, it was assumed that irrigation occurs between April and October annually and the estimated actual monthly records (see Table 3-2) are representative of FHID’s water use pattern in the years without data.

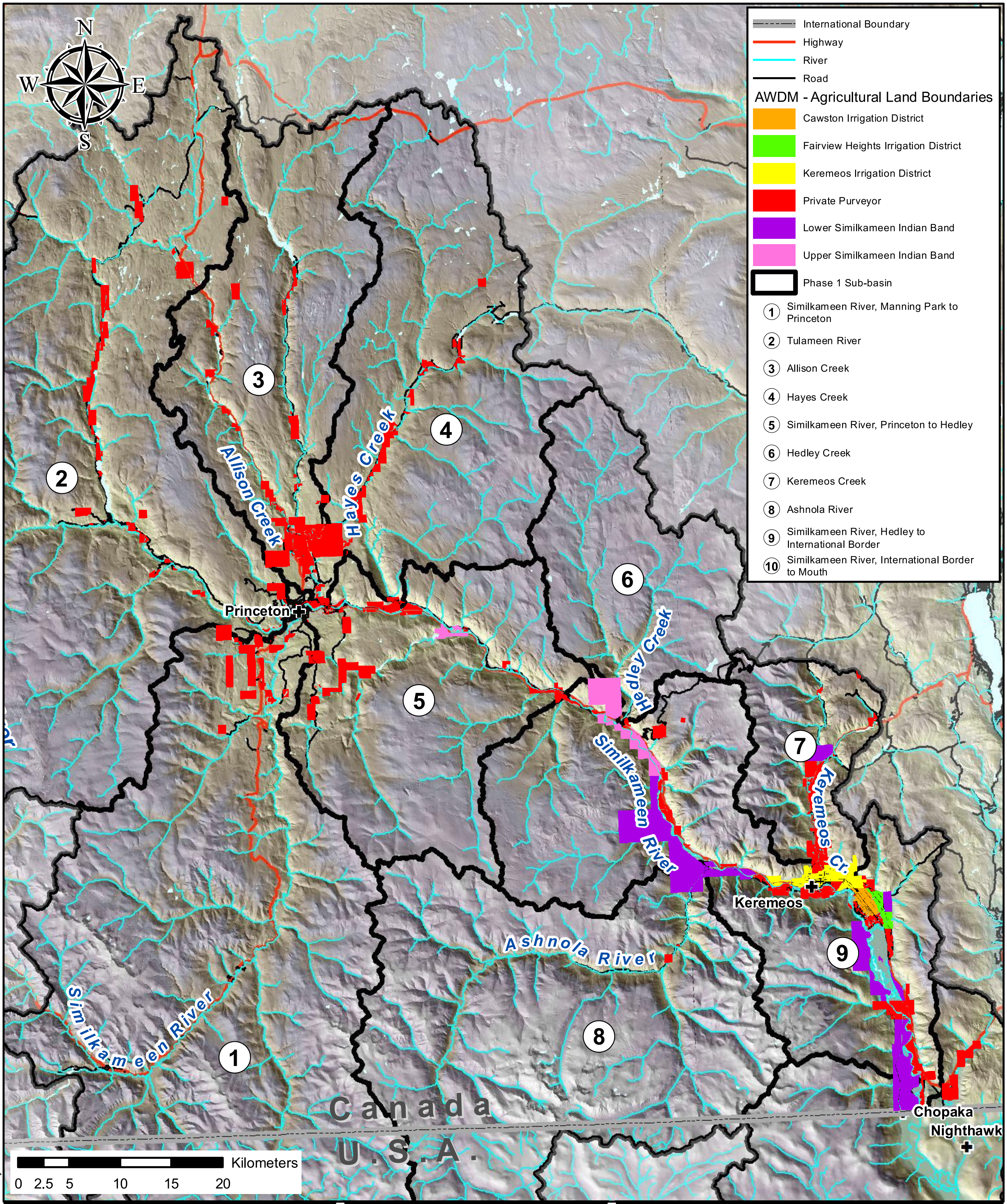

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FIGURE 2-2: WATER PURVEYORS AND LAND AREAS INCLUDED IN THE AGRICULTURE WATER DEMAND MODEL

Regional District of Okanagan Similkameen

Similkameen Watershed Plan - Phase 2

Table 2-3 Comparison of actual water use and Agriculture Water Demand Model water demand estimates for Fairview Heights Irrigation District

Year	Fairview Heights Irrigation District	
	Actual Water Use (ML)	Water Demand estimated by AWDM (ML)
2002	2,416	1,768
2003	-	2,102
2004	-	1,379
2005	2,489	1,489
2006	1,644	2,100
2007	-	1,760
2008	-	1,350
2009	2,515	1,838
2010	-	1,289

It is important to note that the AWDM is a mathematical model that estimates irrigation water demand based on climate, land use, soils, and the irrigation systems that are present. By comparison, the estimates of water use by the FHID are based on records of pumping volumes; in other words, these are estimates of actual use in the area serviced. Modelled water use would approximate actual use if all irrigators watered at optimal rates, leakage was predictable, and users did not over-water or under-water their crops. However, without detailed information for each water user in the Similkameen River watershed, the AWDM provides the best estimates of irrigation water demand and these values were used for naturalization purposes where required[7] (Section 2.2.1).

2.3.4 Future Water Demand Scenarios

A great deal of research has been conducted in southern B.C. on climate change and its influence on hydrologic regimes. Research is ongoing at several institutions (for example the Pacific Climate Impacts Consortium in Victoria, the University of Washington, and Environment Canada). These research programs have demonstrated that, in future, the climate is expected to continue warming, with more of the winter precipitation falling as rain and contributing to higher winter streamflows. Spring freshet is expected to begin earlier than it does today, and spring peaks will tend to be smaller. The summer is expected to last longer, and to be warmer and drier. These changes will result in increased irrigation demand, they may

[7] For KID, the noted overestimate was included for naturalization purposes, as the AWDM would require an update to the land base, which is outside of the scope of this study.

promote more wildfires of greater severity, and they could lead to higher incidence of forest diseases (including beetle infestations). Variability in climate and hydrology (which is already relatively high) may also increase. Given that these changes have been documented in the climate and hydrological records over the past few decades, these predictions do not represent departures from recent history, but rather a continuation of recent trends. The magnitude and extent of these changes varies with the global climate model used to drive the simulations, and also with the assumptions made about future rates of emission of carbon dioxide and other greenhouse gases; however, all models generally show similar trends.

For this study, we did not conduct any original research on climate change and implications to water demands within the Similkameen River watershed. The MAL and AAFC currently consider a number of predictive global circulation models and their downscaled predictions for use in the AWDM (Ron Fretwell, pers. comm., 2015). These model results are available to be included in the AWDM for the period 1950-2100, and based on discussions with AAFC (Denise Neilsen, pers. Comm., 2015), three predictive models were recommended for future water demand scenarios in this study (see Table 2-4). Note that predictive models involve different climate conditions (wet or dry) and different carbon dioxide emission scenarios; therefore, it is advisable that a suite of models be used for AWDM scenario purposes. It is important to note that none of the three predictive models selected for this study is considered better or worse than another; combined, they encompass a selection of available climate projections.

Table 2-4 The predictive models used for future water demand scenarios based on the Agriculture Water Demand Model

Climate Model	Projected Seasonal Changes[1]
ACCESS1-0 rcp8.5	Winter: +10% precipitation and +2°C air temperature Summer: -10% precipitation and +3°C air temperature
CanESM2 rcp8.5	Winter: +10% precipitation and +4°C air temperature Summer: -5% precipitation and +4°C air temperature
CNRM-CM5 rcp4.5	Winter: 0% precipitation and +2°C air temperature Summer: -5% precipitation and +1°C air temperature

Note:

1. Approximate projected seasonal changes based on change plots of winter and summer 1981-2000 measured values and model predicted values 2031-2050 for southern B.C. (A. Cannon, pers. comm., 2015).

With the three predictive climate models chosen, three scenarios were selected to investigate future water demands within the Similkameen River watershed. The scenarios were selected based on consideration of how varying future climate conditions and potential land use and crop-type changes could influence water demands. The scenarios are summarized as follows:

1. **Scenario A** – No change to existing agricultural land base and irrigation type (i.e. stay at 2008 surveyed levels [van der Gulik et al. 2013]) and consider climate change influences only.
2. **Scenario B** – Add irrigation to all existing and non-irrigated lands, plus potential agricultural lands identified by MAL (Table 2-2), and consider climate change influences and expanded irrigation area.

3. **Scenario C** – Maintain existing agricultural land base and irrigation type, except that 2% of the current irrigated land base in the Keremeos Creek (Sub-basin #7) and Similkameen River – Hedley to International Border (Sub-basin #9) sub-basins are converted to grape crops for three consecutive years (i.e. 6% increase in area covered by grapes) and the new grape area is then maintained at constant levels.[8] This considers climate change influences with an increase in grape production.

Scenarios A and B are similar to general planning scenarios used during Phases 2 and 3 of the Okanagan Water Supply and Demand Study (Summit 2010; Polar Geoscience Ltd. 2012), whereas Scenario C is a watershed-specific scenario that considers increased grape production in the watershed (Mount Kobau Wine Services 2014).

Each of these scenarios was tested in the AWDM using each of the predictive climate models (Table 2-4) for two future periods: 2011-2040 and 2041-2070. These periods are becoming accepted as "standard" future periods for the purposes of climate change analysis. Following this, the future water demand (surface water and groundwater) AWDM 2011-2070 dataset for each scenario was obtained from MAL (RHF Systems Ltd. 2015b) and compared to the 1981-2010 standard period. Note that, since the AWDM (for the Canadian portion of the Similkameen River watershed)[9] only estimates agricultural water demands, all scenarios were limited to this particular water purpose and water use period (i.e. irrigation - April to October).

[8] Scenario as recommended by MAL (C. Withler, pers. comm., 2015) to consider reasonable crop change within the Similkameen River watershed. Note that the crop conversion occurred to irrigated lands (i.e. polygons [Figure 2-2]) adjacent to existing grape crops that were neither a golf course nor greenhouse and assumed drip irrigation for the new grape crops (RHF Systems Ltd. 2015b). The crop change was also assumed to occur between 2016 and 2018.

[9] The United States portion of the Similkameen River watershed was not considered due to the lack of available information.

3 Results

Section 3 summarizes the results of the water availability assessment and the future water demand scenarios for the Similkameen River watershed.

3.1 GENERAL WATER QUANTITY TREND

The Similkameen River and its sub-basins exhibit year-to-year flow variability, which reflects variations in snow accumulation and melt, precipitation, and air temperature (through its effect on evapotranspiration). The annual variability in river flow for the Similkameen River watershed is similar to that of other rivers in watersheds with similar climates in southern B.C. However, the flows have generally been below average in the Similkameen River since 2001, which is consistent with the hypothesis that climate is having an effect on water resources in western North America (Summit 2014).

The WSC station on the Similkameen River near Princeton (WSC 08NL007[10]; see location in Figure 2-1) has the longest continuous data record in the watershed, and the flow values reflect runoff from a portion of the headwaters of the Similkameen River. Figure 3-1 shows the mean annual net discharge recorded since 1940 in comparison to the long-term and standard period means, while Figure 3-2 illustrates the average monthly discharge in August[11] (plus and minus one standard deviation) for each decade since the 1940s. Note that the 2001-2010 decade had the lowest August average of the 7 decades shown.

[10] The WSC indicates that this station reflects natural flows.

[11] August was selected due to the generally low river flows and high irrigation demands that can occur in August.

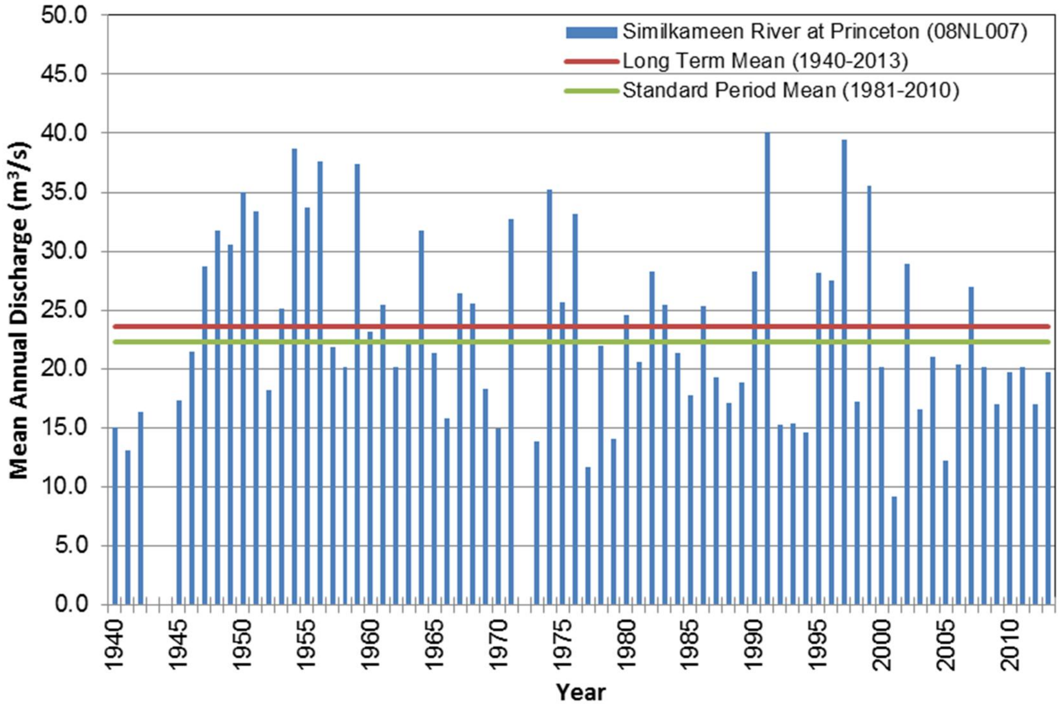


Figure 3-1 Mean annual net flow of Similkameen River at Princeton (WSC 08NL007), 1940-2013

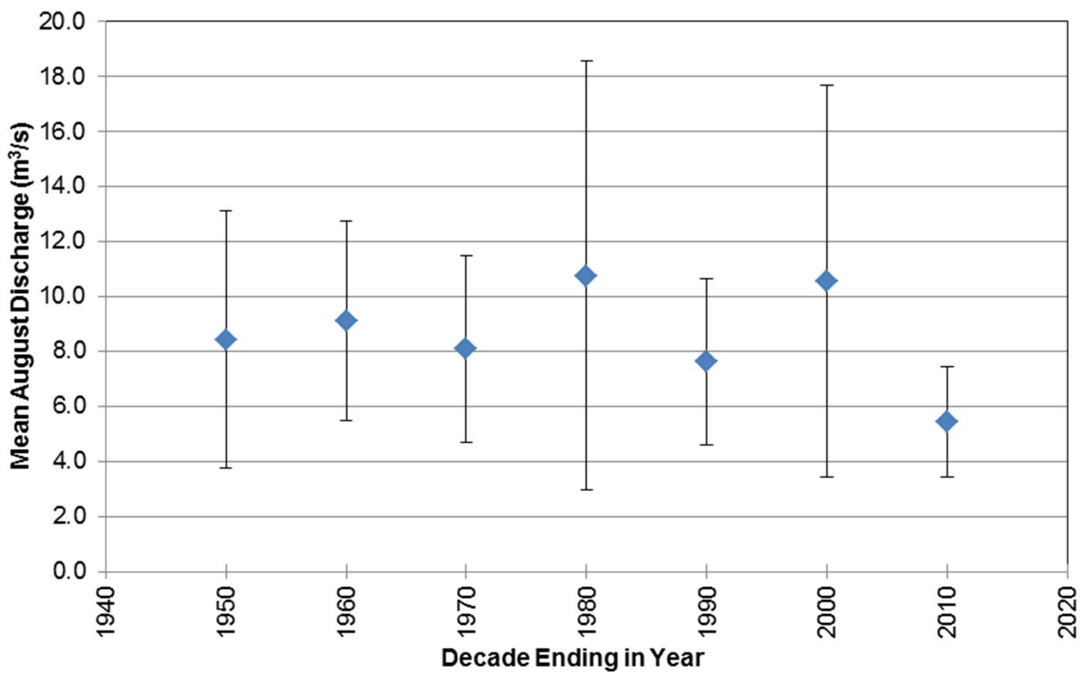


Figure 3-2 Mean August decade average discharge (±1 standard deviation) – Similkameen River at Princeton (WSC 08NL007), 1941-2010

Summit (2015b) completed a trend analysis of the Similkameen River to determine whether discharge records for the Similkameen River near Princeton (WSC 08NL007) showed a statistically significant trend. The trend was analyzed using the Mann-Kendall test (SYSTAT 2010) and the test was completed for slightly different periods than were used for naturalization: the "long-term" period was 1945-2013 and the "standard" period was 1981-2013. For each period, the test was completed for the monthly means as well as for the months of August and September individually. Summit (2015b) reported that there was generally no evidence of a positive or negative trend for either period. Summit (2015b) also ran the same tests for a synthetic dataset ("Similkameen River at Chopaka Bridge"[12]) for the standard period (1981-2013) and found no evidence of a statistically significant trend.

It appears that for the headwaters portion of the Similkameen River watershed, the annual mean for the standard period (1981-2013) is lower than the mean for the long-term period (1940-2013), but no systematic trend (upward or downward) was identified. Considering this, the results of the naturalized and net flow assessment herein likely reflect drier conditions in comparison to the long-term average for the watershed.

3.2 NATURALIZED AND NET FLOWS

3.2.1 Mean Monthly and Annual Flows

Tabular summaries and descriptions of the mean monthly and annual flows at the 10 POIs are provided in Appendix B. The annual naturalized flow, total annual licensed quantity (converted to m^3/s), estimated actual annual offstream use (converted to m^3/s), annual net flow under current conditions, and annual 1:10-year and 1:50-year return period net low flows are summarized in Table 3-1.

The results indicate that, at most POIs, net and naturalized streamflows are not very different from one another on an annual scale. This suggests that annual water use (surface water and groundwater) is low relative to the annual streamflows. This finding is consistent with WSC information, which indicates that the two active hydrometric stations on the Similkameen River (at Princeton [WSC 08NL007] and near Hedley [WSC 08NL038]) and the active stations on the Tulameen River (WSC 08NL024), Hedley Creek (WSC 08NL050), and the Ashnola River (WSC 08NL004) are all measuring "natural flow". However, findings at Keremeos Creek (POI #7) are noteworthy; data from this POI indicate some of the highest estimated actual water use values within an identified Similkameen River sub-basin (Table 2-2), as well as actual water use estimates above licensed volumes due to the use of groundwater, which is unlicensed (Table 3-1). The annual results at POI #7 indicate that the water use is high, and this, combined with the recorded zero flows near the mouth (at Station No. 08NL044 in September 1973) and fish kill investigations (MOE 2001), indicates that water availability to users and the aquatic environment could be at risk.

In addition, note that the estimated streamflows for the Similkameen River at the Mouth (POI #10) do not include water use information from the United States, and flows at this location are considered regulated due to the natural regulation during high-flow periods associated with Palmer Creek and Palmer Lake, as identified by the WSC (L. Campo, pers. comm., 2015) and the Washington State Department of Ecology

[12] This dataset was estimated for Summit (2015b) by scaling the estimated net flows for the POI at the international border (i.e. POI #9) (reported herein) to Chopaka Bridge (approximately 10 km upstream).

(2004). Considering this, the combination of all upstream POIs (#5, #6, #7, #8) and scaling to the international border is likely to more accurately reflect the hydrograph shape at the international border (POI #9) than scaling the records back from the hydrometric station on the Similkameen River near Nighthawk, U.S. (WSC 08NL022), to the international border.[13] Overestimation of flows at the international border is likely occurring due to the estimation procedure used; however, with no site-specific information available, the estimates are considered reasonable approximations.

On a monthly scale, the results are generally consistent with the annual results (see Table 3-1) as stated above. At most POIs, the net and naturalized streamflows are similar, even during the peak irrigation months (July to September). In addition, for Hedley Creek (POI #6), the net flows during August to October are higher than the naturalized flows due to flow releases from Nickel Plate Lake by the Similkameen Improvement District. However, for Allison Creek (POI #3) during August and for Keremeos Creek (POI #7) during July to September, net flows are approximately 40% to 65% of the naturalized flow. This suggests that water use and availability in these sub-basins could be a concern during the summer to early fall periods under low-flow conditions.

An overall summary of the results and a water availability risk assessment for each POI is provided in Section 3.2.3.

[13] Note that the hydrograph at POI #10 (based on scaled records from the WSC station below Palmer Lake) features an attenuated peak in May and June, which is consistent with a regulation influence.

Table 3-1 Annual average naturalized flow, total licences, actual offstream use, and annual net low flows at the 10 points-of-interest in the Similkameen River watershed for the standard period (1981-2010)

Point-of-Interest[1]	Drainage Area (km^2)	Median Annual Naturalized Flow (m^3/s)	Total Annual Licences for Offstream Use (m^3/s)	Estimated Actual Annual Offstream Use[2] (m^3/s)	Median Annual Net Flow (m^3/s) [% of naturalized]	10-year Annual Net Low Flow (m^3/s) [% of naturalized]	50-year Annual Net Low Flow (m^3/s) [% of naturalized]
Similkameen River above the Tulameen River Confluence (POI #1)	1,811	20.7	0.500	0.467	20.3 [98.1%]	13.6 [65.7%]	10.6 [51.2%]
Tulameen River at the Mouth (POI #2)	1,778	18.5	0.209	0.090	18.4 [99.5%]	13.6 [73.5%]	11.5 [62.2%]
Allison Creek at the Mouth (POI #3)	600	1.02	0.113	0.049	0.968 [94.9%]	0.668 [65.5%]	0.548 [53.7%]
Hayes Creek at the Mouth (POI #4)	779	3.84	0.080	0.023	3.82 [99.5%]	1.74 [45.3%]	0.843 [22.0%]
Similkameen River near Hedley (at WSC Station No. 08NL038) (POI #5)	5,569	43.8	0.949	0.742	43.1 [98.4%]	30.4 [69.4%]	25.4 [58.0%]
Hedley Creek at the Mouth (POI #6)	395	2.55	0.053	0.055	2.50 [98.0%]	1.26 [49.4%]	0.778 [30.5%]
Keremeos Creek at the Mouth (POI #7)	224	0.608	0.071	0.092	0.500 [82.2%]	0.216 [35.5%]	0.066 [10.8%]
Ashnola River at the Mouth (POI #8)	1,060	6.86	0.436	0.001	6.86 [100%]	4.58 [66.8%]	3.60 [52.5%]
Similkameen River at the International Border (POI #9)	8,117	60.8	3.59	1.46	59.4 [97.6%]	41.5 [68.3%]	34.5 [56.7%]
Similkameen River at the Mouth[3] (POI #10)	9,271	60.7	3.63	1.51	59.2 [97.5%]	40.8 67.2%]	33.0 [54.4%]

Note:

1. Note that net flow records are considered synthetic (i.e. estimated) for Allison Creek, Hayes Creek, Keremeos Creek, and Similkameen River at the International Border, since no WSC (or United States Geological Survey) hydrometric stations are located in close proximity to the POI. For all other POIs, there are WSC records for a location nearby.
2. Estimated actual annual offstream water use includes both individual surface water licensed use and average groundwater use (groundwater use is unlicensed) by major purveyors. The small amount of domestic groundwater use by private users is not included.
3. Note that naturalized flows do not consider water use within the United States, as this information was not available at the time of this report. In addition, flows at the mouth are considered naturally regulated due to the backwatering of Palmer Creek and Palmer Lake during peak flow conditions.

3.2.2 Low-Flow Conditions

In addition to information about water availability and use under average annual and monthly conditions, water use planning requires information on streamflows during periods of low flow. On an annual basis, the lowest flows in the Similkameen River and its tributaries occur in winter (February) and during early fall (September). The magnitudes of low flows vary from year to year, and planning decisions must consider flows during periods of drought, and must take into account the probability that an extreme low flow will occur.

Estimates of the 1:10-year and 1:50-year return period mean monthly low flows for the standard period were calculated for each POI (Appendix B). In any given year, the probabilities that low flows less than or equal to these values will occur are 10% (the 1:10-year) and 2% (the 1:50-year). Based on the results for each POI, the mean monthly net low flows represent approximately 40% to 80% of the median monthly naturalized flows under a 1:10-year return period, and approximately 20% to 65% under a 1:50-year return period. Also, note that for Keremeos Creek (POI #7), the 1:50-year period net monthly low flows were estimated to be zero between September and March.

With agriculture a significant water user within the Similkameen River watershed, examining the critical July to September period when water demands are the highest is important for planning purposes. Based on the results reported herein, the mean July to September 1:10-year low flows are roughly 45% of the median monthly values, and the 1:50-year low flows are approximately one-third of the median monthly values.

The median annual and median September naturalized, net, and 1:10-year and 1:50-year return period net flows for each POI are shown in Figures 3-3 and 3-4, respectively. The significant reduction in flows during the low-flow periods has generally been thought to reflect increased water use; however, some of this reduction is also likely attributed to the climatic variation of the region. As discussed in Section 3.1, over the last decade, August river flows in the Similkameen River watershed have generally been lower, on average, than in previous decades (Figure 3-2). Rivers in semi-arid regions (such as the Similkameen River watershed) can be sensitive to changes in rainfall; therefore, the low flows in the Similkameen River watershed are likely to be influenced to a greater degree by the climatic variability of the watershed. These results are similar to the nearby Okanagan and Kettle River watersheds, where variation in flows has been attributed to a combination of water use and climate influence. For example, the 1:10-year and 1:50-year return period low flows during the July to September period in the Kettle River watershed are approximately 33% and 20% of the median monthly naturalized flows (Summit 2012).

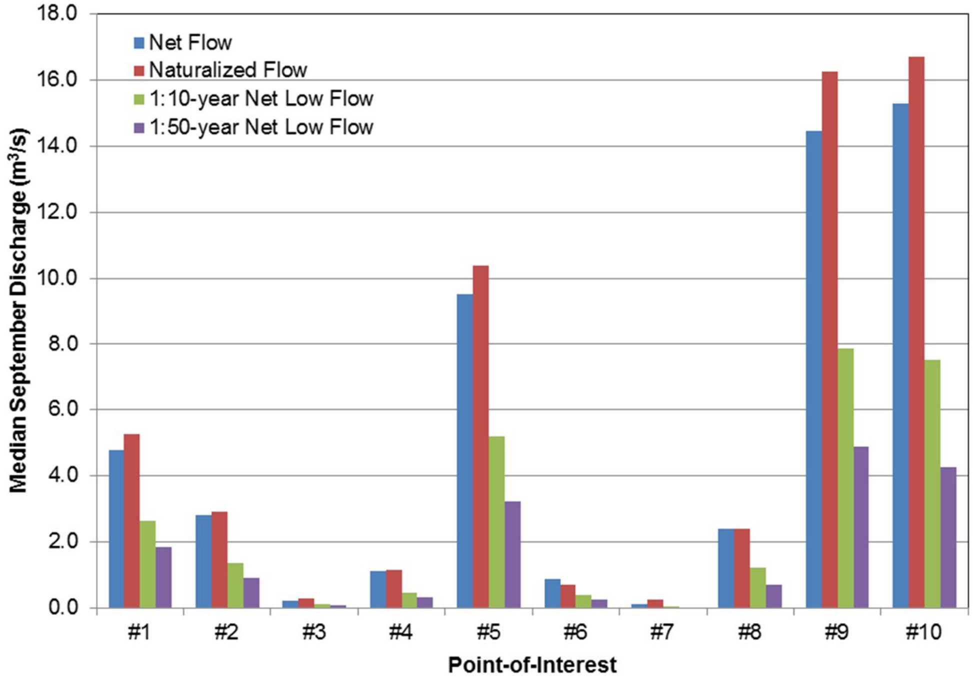


Figure 3-3 **Comparison of median annual net and naturalized flow to the 1:10-year and 1:50-year net flows for the Similkameen River watershed points-of-interest**

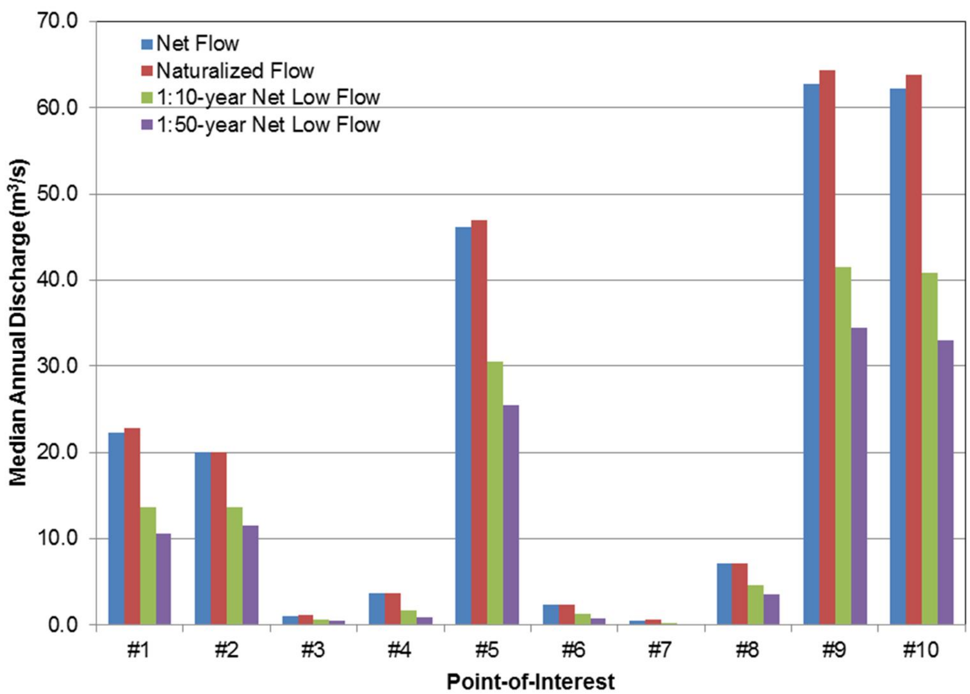


Figure 3-4 **Comparison of median September net and naturalized flow to the 1:10-year and 1:50-year net flows for the Similkameen River watershed points-of-interest**

3.2.3 Net and Naturalized Flow Summary

The following points summarize the hydrology of the Similkameen River watershed presented in the preceding parts of Section 3.2 and in Appendix B:

- Because of relatively limited regulation, available flow information for the majority of sub-basins of the Similkameen River watershed, except Keremeos Creek (POI #7) and Similkameen River at the Mouth (POI #10), is considered, by federal monitoring agencies in the U.S. and Canada, to reflect “natural” conditions.
- For the headwaters portion of the Similkameen River watershed (WSC 08NL007), the annual mean of the standard period is lower than that of the long-term period (1940-2013), and most recent August decadal flows (2001-2010) are the lowest in comparison with all other available decades recorded. This suggests that the results reflect drier conditions within the watershed in the 2001-2010 period.
- For the Similkameen River watershed at the International Border (POI #9), on an annual basis, net flows are estimated to be 2.4% smaller than naturalized flows. The following are the estimated median naturalized and net annual flows at the 10 POIs in the Similkameen River watershed for the 1981-2010 standard period:

		Naturalized Flow	Net Flow
o	Similkameen River above the Tulameen River Confluence	20.7 m^3/s	20.3 m^3/s
o	Tulameen River at the Mouth	18.5 m^3/s	18.4 m^3/s
o	Allison Creek at the Mouth	1.02 m^3/s	0.968 m^3/s
o	Hayes Creek at the Mouth	3.84 m^3/s	3.82 m^3/s
o	Similkameen River near Hedley	43.8 m^3/s	43.1 m^3/s
o	Hedley Creek at the Mouth	2.55 m^3/s	2.50 m^3/s
o	Keremeos Creek at the Mouth	0.608 m^3/s	0.500 m^3/s
o	Ashnola River at the Mouth	6.86 m^3/s	6.86 m^3/s
o	Similkameen River at the International Border	60.8 m^3/s	59.4 m^3/s
	Similkameen River at the Mouth (Canada water use only)	60.7 m^3/s	59.2 m^3/s

- For the Similkameen River at the International Border (POI #9), the lowest flows generally occur during February and September. Given that agriculture is identified as a significant water user in the watershed, for planning purposes it is important to examine the July to September period when water demands are the highest. The following are the estimated median naturalized and net flows at the 10 POIs in the Similkameen River watershed for the 1:10-year and 1:50-year return period September net low flows:

		Naturalized Flow	1:10-year Flow	1:50-year Flow
o	Similkameen River above the Tulameen River Confluence	5.27 m^3/s	2.64 m^3/s	1.84 m^3/s
o	Tulameen River at the Mouth	2.92 m^3/s	1.37 m^3/s	0.904 m^3/s

o Allison Creek at the Mouth	0.295 m^3/s	0.104 m^3/s	0.072 m^3/s
o Hayes Creek at the Mouth	1.15 m^3/s	0.481 m^3/s	0.333 m^3/s
o Similkameen River near Hedley	10.4 m^3/s	5.21 m^3/s	3.23 m^3/s
o Hedley Creek at the Mouth	0.719 m^3/s	0.391 m^3/s	0.271 m^3/s
o Keremeos Creek at the Mouth	0.259 m^3/s	0.010 m^3/s	0.000 m^3/s
o Ashnola River at the Mouth	2.40 m^3/s	1.22 m^3/s	0.708 m^3/s
o Similkameen River at the International Border	16.3 m^3/s	7.87 m^3/s	4.88 m^3/s
o Similkameen River at the Mouth (Canada water use only)	16.7 m^3/s	7.51 m^3/s	4.27 m^3/s

Of particular note are the estimated low flows in Keremeos Creek, which are consistent with measured records collected by the WSC; and with recent historical events (zero flow and a fish kill investigation completed by the B.C. Ministry of Environment in 2001).

- Offstream licences account for 5.9% of the median annual naturalized flow for the Similkameen River at the International Border (POI #9). The percentages of naturalized annual flow represented by (Canadian) water licences for offstream use and by actual use (including groundwater) for the 10 POIs are as follows:

	Licensed for Offstream Use	**Actual Use**
o Similkameen River above the Tulameen River Confluence	2.4%	2.3%
o Tulameen River at the Mouth	1.1%	0.5%
o Allison Creek at the Mouth	11.1%	4.9%
o Hayes Creek at the Mouth	2.1%	0.6%
o Similkameen River near Hedley	2.2%	1.7%
o Hedley Creek at the Mouth	2.1%	2.1%
o Keremeos Creek at the Mouth	11.8%	15.4%
o Ashnola River at the Mouth	6.3%	<0.1%
o Similkameen River at the International Border	5.9%	2.5%
o Similkameen River at the Mouth (Canada water use only)	6.0%	2.5%

Of particular note is the estimated actual use in Keremeos Creek, which is greater than the volume licensed for withdrawal from surface sources due to the large use of groundwater within the sub-basin. In addition, a number of water purveyors have identified that they have moved to groundwater and are maintaining their surface water licences but are no longer using surface water as a source.

- On an annual basis, approximately 55.7 m^3/s of flow is not presently licensed for offstream or instream use in the Similkameen River watershed above the International Border (POI #9). Note that the term “not licensed” means that this is the remaining naturalized flow (under average conditions) that is not held under a water licence. The flows not currently licensed for offstream or instream use are as follows:

	Annual Flow Not Currently Licensed for Instream or Offstream use
o Similkameen River above the Tulameen River Confluence	20.2 m^3/s
o Tulameen River at the Mouth	18.2 m^3/s
o Allison Creek at the Mouth	0.865 m^3/s
o Hayes Creek at the Mouth	3.05 m^3/s
o Similkameen River near Hedley	41.9 m^3/s
o Hedley Creek at the Mouth	2.24 m^3/s
o Keremeos Creek at the Mouth	0.470 m^3/s
o Ashnola River at the Mouth	6.3 m^3/s
o Similkameen River at the International Border	55.7 m^3/s
o Similkameen River at the Mouth (Canada water use only)	55.8 m^3/s

As described earlier, in the July to September period, and especially under below-average flow conditions, the streamflows are significantly reduced in comparison to median annual flows. Any further surface water withdrawals above what is presently occurring during this period could impact downstream users and aquatic life; therefore, sub-basin water availability reviews should occur prior to any agricultural build out and/or development expansion.

Also, note that for Hayes Creek (December to March) and Allison Creek (August), on a monthly basis the combined offstream and instream licensed volumes were estimated to be greater than the naturalized flow. This could suggest over-allocation during these streamflows; however, these results are related to a large instream licence for Hayes Creek and could also reflect the estimation procedure, as the monthly licence distribution was estimated for all POIs.

3.3 WATER AVAILABILITY AND RISK

Based on the results of the net, naturalized, and low-flow summary for the 10 POIs, a qualitative water availability risk review was completed for each POI. For this review, **risk** was defined as the inability of a surface water resource to provide the necessary volume of water to meet human requirements **under median conditions for the standard period**. Note that only median conditions were considered, as water conservation measures are generally implemented during low-flow conditions (e.g. 1:10-year and 1:50-year low flows) and, as a result, water use patterns in low flow years may differ from those in average years.

For the risk assessment, a rating of low, medium, or high was assigned, with:

- *Low* indicating small risk (i.e. water use and offstream licensing is low compared to naturalized flow [i.e. ≤15%];
- *Moderate* indicating medium risk (i.e. water use and offstream licensing is moderate compared to naturalized flow [i.e. >15% and ≤40%]); and
- *High* indicating a large risk (i.e. water use and offstream licensing close to or above available flow [>40%]).

Note that environmental flow needs[14] (EFN) within the Similkameen River watershed were not included in the risk assessment, since specific EFN studies have not been completed. In addition, since surface water availability can change on a seasonal basis, risk was assessed at a monthly timescale. Note that POI #10 – Similkameen River at the Mouth was not assessed for risk because water use information for the United States portion of the watershed was not available.

The findings for water availability risk for each POI are summarized in Table 3-2, including comments related to each rating. The risk assessment included all water licences and assumed that all licences were currently in use. This was done as a conservative measure; it is known that some water purveyors no longer use surface water for supply purposes (Section 2.2.1 and the Phase 1 study).

[14] "Environmental Flow Needs" (EFN) has replaced the old term In-stream Flow Needs (IFN).

Table 3-2 Water availability risk for defined points-of-interest in the Similkameen River watershed

Point-of-Interest	Water Availability Risk Rating	Rating Comments
Similkameen River above the Tulameen River Confluence (POI #1)	Low	• Surface water licensing (offstream) accounts for 2% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 2% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for 1% (May) to 11% (September) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for 1% (May) to 9% (September) of the median monthly naturalized streamflow.
Tulameen River at the Mouth (POI #2)	Low	• Surface water licensing (offstream) accounts for 1% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <1% (May) to 15% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% (May) to 7% (August) of the median monthly naturalized streamflow.
Allison Creek at the Mouth (POI #3)	High	• Surface water licensing (offstream) accounts for 11% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 5% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <1% (May) to 112% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for 1% (April) to 34% (August) of the median monthly naturalized streamflow.
Hayes Creek at the Mouth (POI #4)	Moderate (but considered Low due to the small actual water use and agricultural land base identified by MAL[1])	• Surface water licensing (offstream) accounts for 2% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <1% (May) to 23% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% (May) to 6% (August) of the median monthly naturalized streamflow.
Similkameen River near Hedley (at WSC Station No. 08NL038) (POI #5)	Low	• Surface water licensing (offstream) accounts for 2% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 2% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <1% (May) to 15% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% (May) to 9% (August) of the median monthly naturalized streamflow.
Hedley Creek at the Mouth (POI #6)	Low	• Surface water licensing (offstream) accounts for 2% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 2% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <0.5% (May) to 11% (January) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% (May) to 12% (August) of the median monthly naturalized streamflow.
Keremeos Creek at the Mouth (POI #7)	High	• Surface water licensing (offstream) accounts for 12% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 15% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for 3% (May) to 55% (September) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for 3% (May) to 72% (August) of the median monthly naturalized streamflow.
Ashnola River at the Mouth (POI #8)	Moderate (but considered Low due to the very small actual water use and no identified agricultural lands by the MAL[1])	• Surface water licensing (offstream) accounts for 6% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for <0.5% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for <1% (for the winter months) to 38% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% of the median monthly naturalized streamflow.
Similkameen River at the International Border (POI #9)	Moderate	• Surface water licensing (offstream) accounts for 6% of the median annual naturalized streamflow and actual water use (groundwater and surface water) accounts for 2% of the median annual naturalized streamflow. • Surface water licensing (offstream) accounts for 2% (May) to 39% (August) of the median monthly naturalized streamflow and actual water use (groundwater and surface water) accounts for <1% (May) to 15% (August) of the median monthly naturalized streamflow.

Note:

1. See Table 2-2 in Section 2.3.2.

3.4 FUTURE WATER DEMAND SCENARIOS

After net and naturalized streamflow were evaluated for each of the POIs, potential changes in agricultural water use in the watershed were assessed. The three scenarios described in Section 2.3.4 were used for this purpose. A comparison of water use in the 1981-2010 standard period with water use in the two future periods (2011-2040 and 2041-2070) was completed for each scenario to provide a concept of how agricultural water use may change in the future.[15] Future water demand information was available for each sub-basin (Table 2-2); however, standard period comparisons were only completed for the Canadian portion of the Similkameen River watershed and for the Keremeos Creek sub-basin. These two comparisons represent different watershed scales, and were intended to provide a total watershed perspective and a sub-basin perspective. Also, Keremeos Creek sub-basin was evaluated due to its low flows, high water demands, and high water availability risk rating. Since the standard period dataset was developed based on recorded climate information (van der Gulik et al. 2013), whereas future climates were estimated with models, direct comparison between datasets is limited to evaluation of the trends.

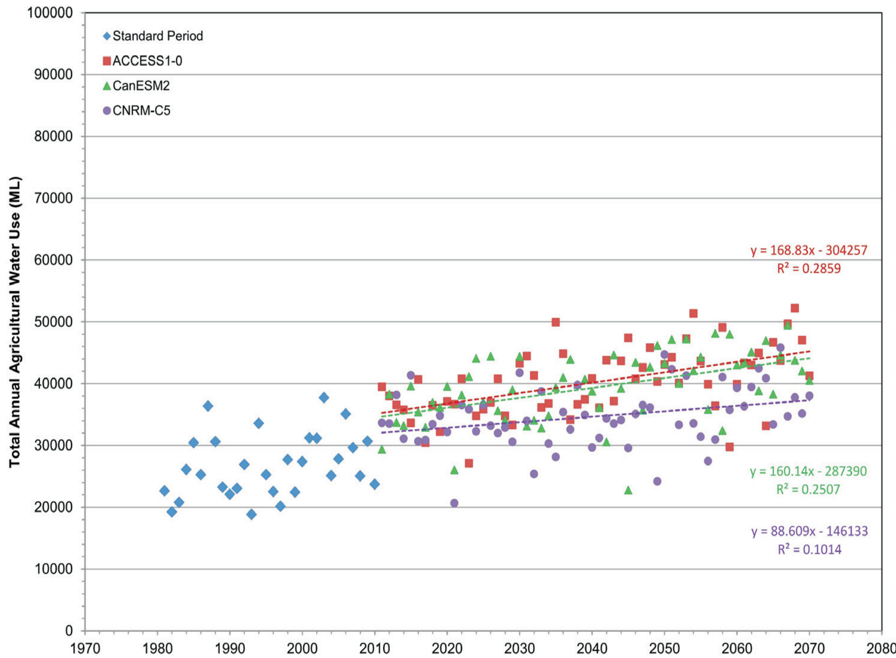
Figure 3-5 shows an overview of the projected water demands relative to the standard period for the Canadian portion of the Similkameen River watershed and for the Keremeos Creek sub-basin under each scenario on an annual basis. Figures 3-6 and 3-7 show the monthly results for the Similkameen River watershed and for Keremeos Creek sub-basin, respectively. The presentation of the scenario results is consistent with similar analyses for the Okanagan Basin by Polar Geoscience Ltd. (2012).

The annual and monthly results indicate that there is variability in the water demands under all scenarios, and that relates to climate variability between years. The modelling results for the entire Similkameen River watershed and the Keremeos Creek sub-basin can be summarized as follows:

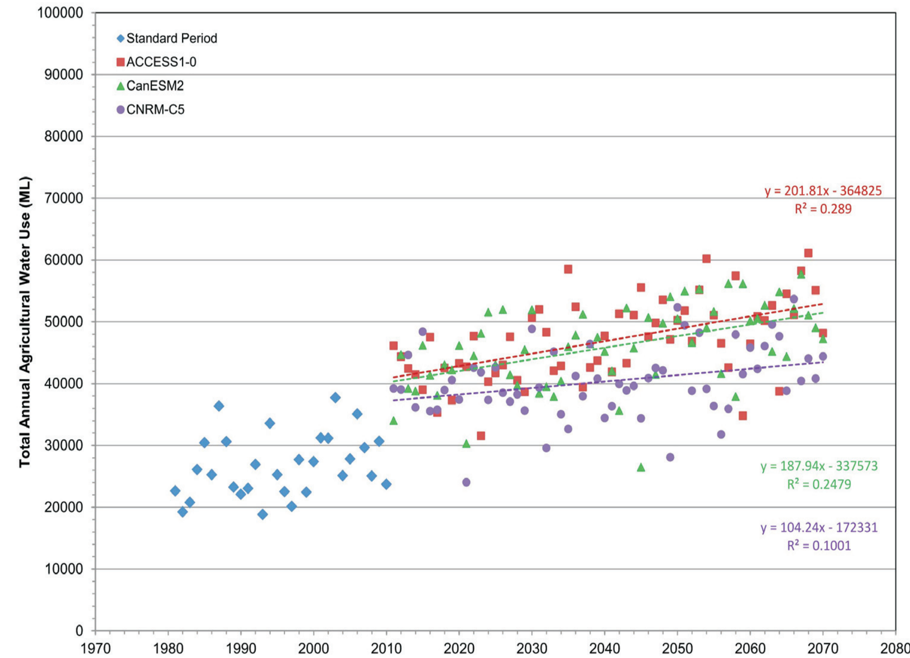
- There is a trend towards increasing water demand in the future under each scenario.
- Under climate change only (Scenario A, Figures 3-5, 3-6, and 3-7), the annual agricultural water demand trend[16] is predicted to increase by approximately 16-28% for the entire watershed between 2011-2070, and by approximately 12-20% for the Keremeos Creek sub-basin between 2011-2070.
- Under climate change and expanded irrigated area (Scenario B, Figures 3-5, 3-6, and 3-7), the annual agricultural water demands are predicted to be 16% greater than for Scenario A for the entire watershed, and 5% greater than Scenario A for the Keremeos Creek sub-basin. In addition, the predicted agricultural water demand trends for the future period are consistent with Scenario A.

[15] For monthly comparisons, the annual soil moisture deficit (i.e. the amount of water that a farmer adds to the soil at the end or beginning of the growing season to bring the moisture content back up to full), identified as month 0 by the AWDM, was not included, since the soil moisture deficit cannot be consistently applied to an individual month or months between the predictive model results.

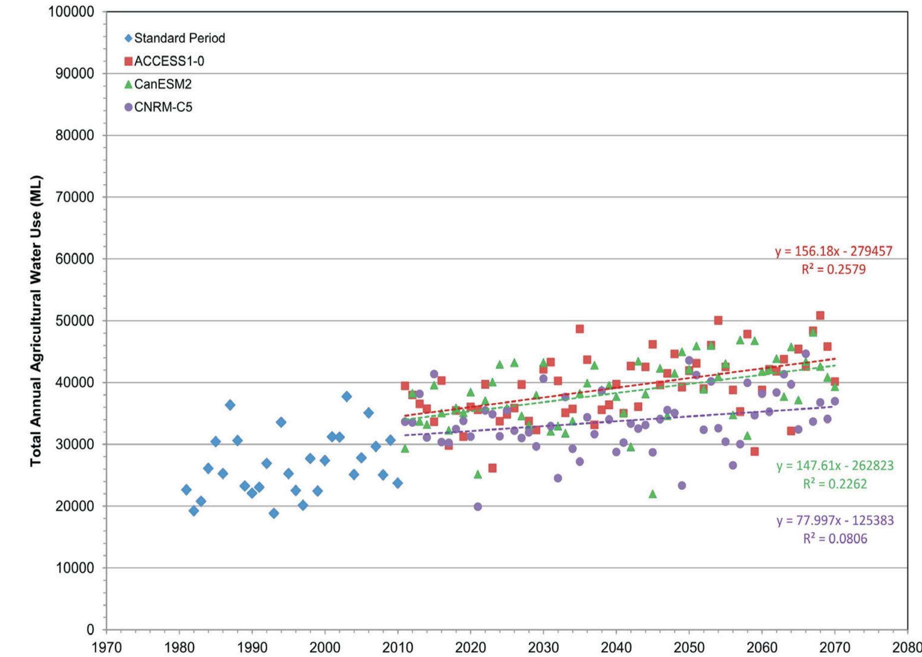
[16] The trend of the 2011-2070 period for all scenarios was estimated using a line of best fit.



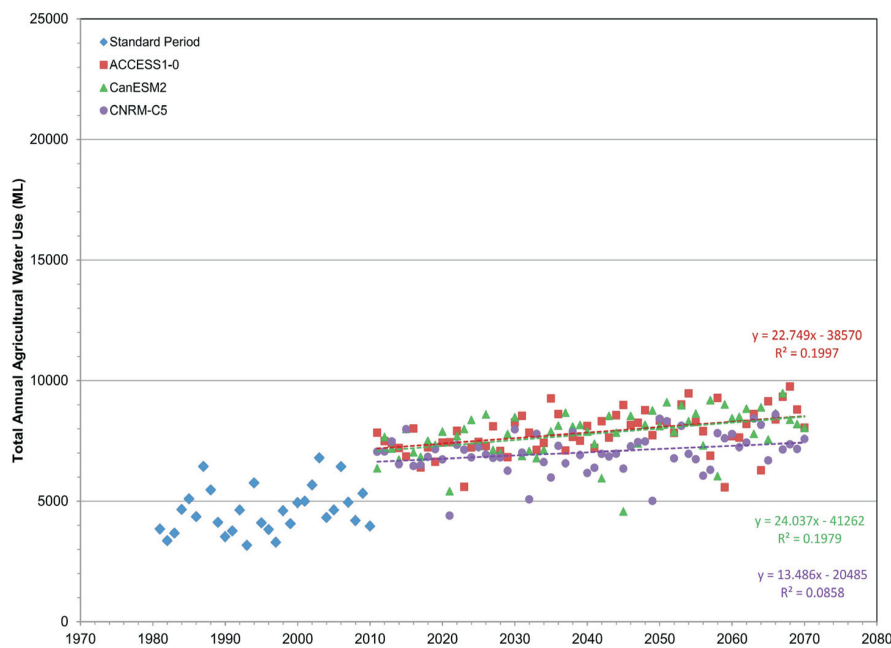
(A) Comparison of annual agricultural water demands under Scenario A for the Canadian portions of the Similkameen River watershed.



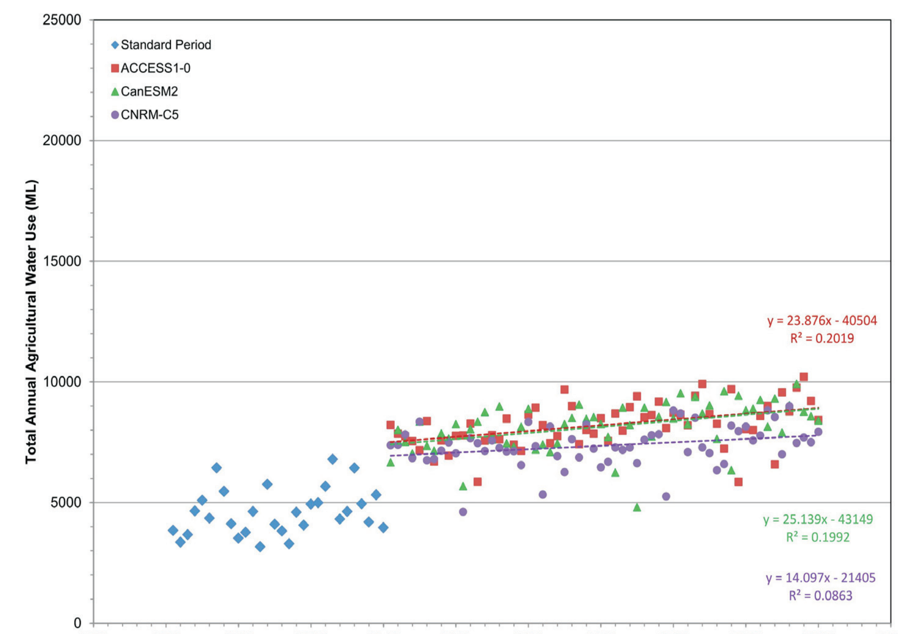
(B) Comparison of annual agricultural water demands under Scenario B for the Canadian portions of the Similkameen River watershed.



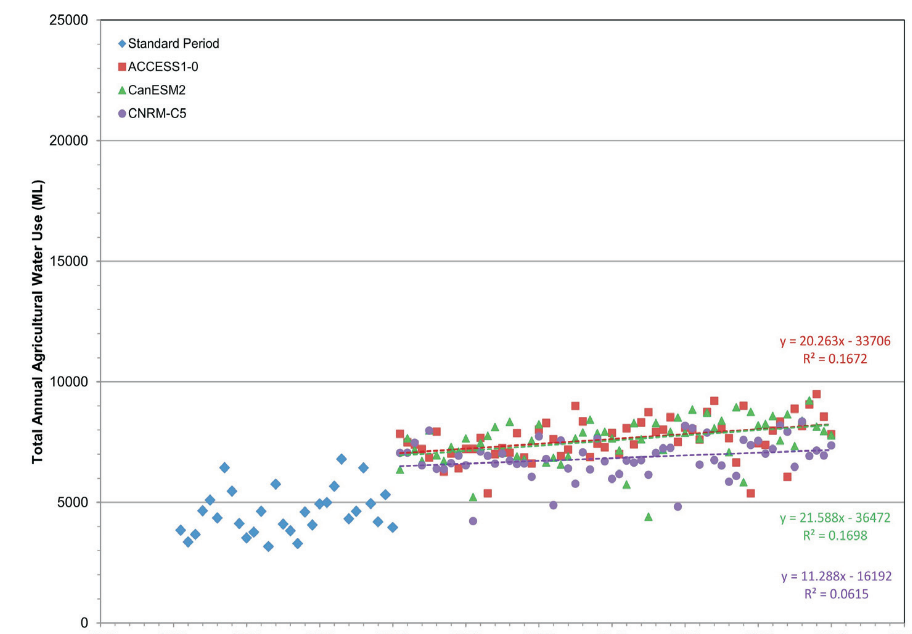
(C) Comparison of annual agricultural water demands under Scenario C for the Canadian portions of the Similkameen River watershed.



(D) Comparison of annual agricultural water demands under Scenario A for the Keremeos Creek sub-basin.



(E) Comparison of annual agricultural water demands under Scenario B for the Keremeos Creek sub-basin.



(F) Comparison of annual agricultural water demands under Scenario C for the Keremeos Creek sub-basin.

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DATE: **March 2015**

DRAWN BY: **DL**

DATA SOURCES:

Ministry of Agriculture - Agriculture Water Demand Model

SCENARIOS:

Scenario A - climate change only
Scenario B - climate change plus expanded irrigated areas
Scenario C - climate change plus increased grape production

PREPARED FOR:

Regional District of Okanagan-Similkameen

Figure 3-5: Projected annual agricultural water demands for 2011-2070 relative to the standard period (1981-2010) under the three future water demand scenarios for the Canadian portions of the Similkameen River watershed and for Keremeos Creek sub-basin

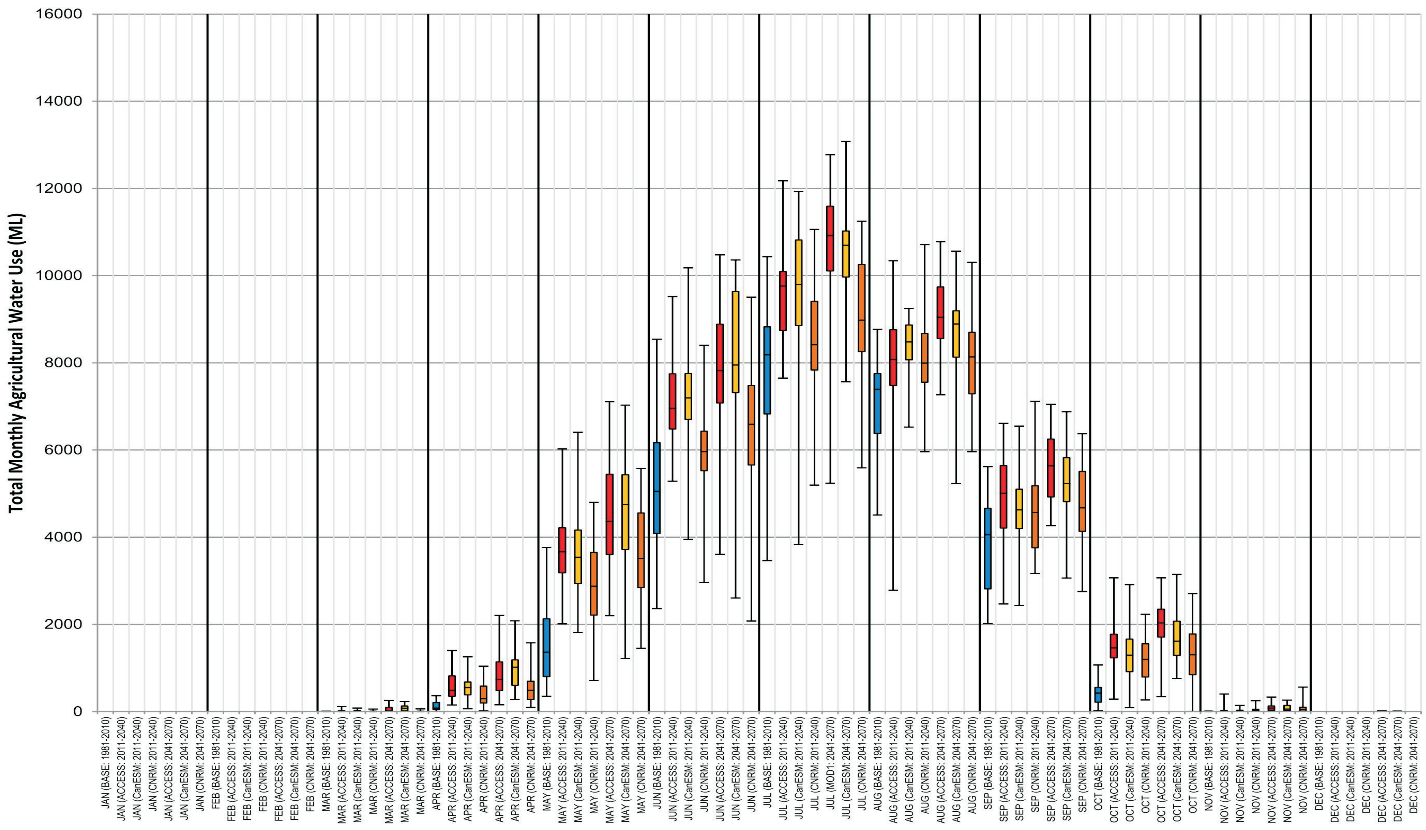
PROJECT NO.: **2014-8149.000.001**

DRAWNING NO. **1 of 1**

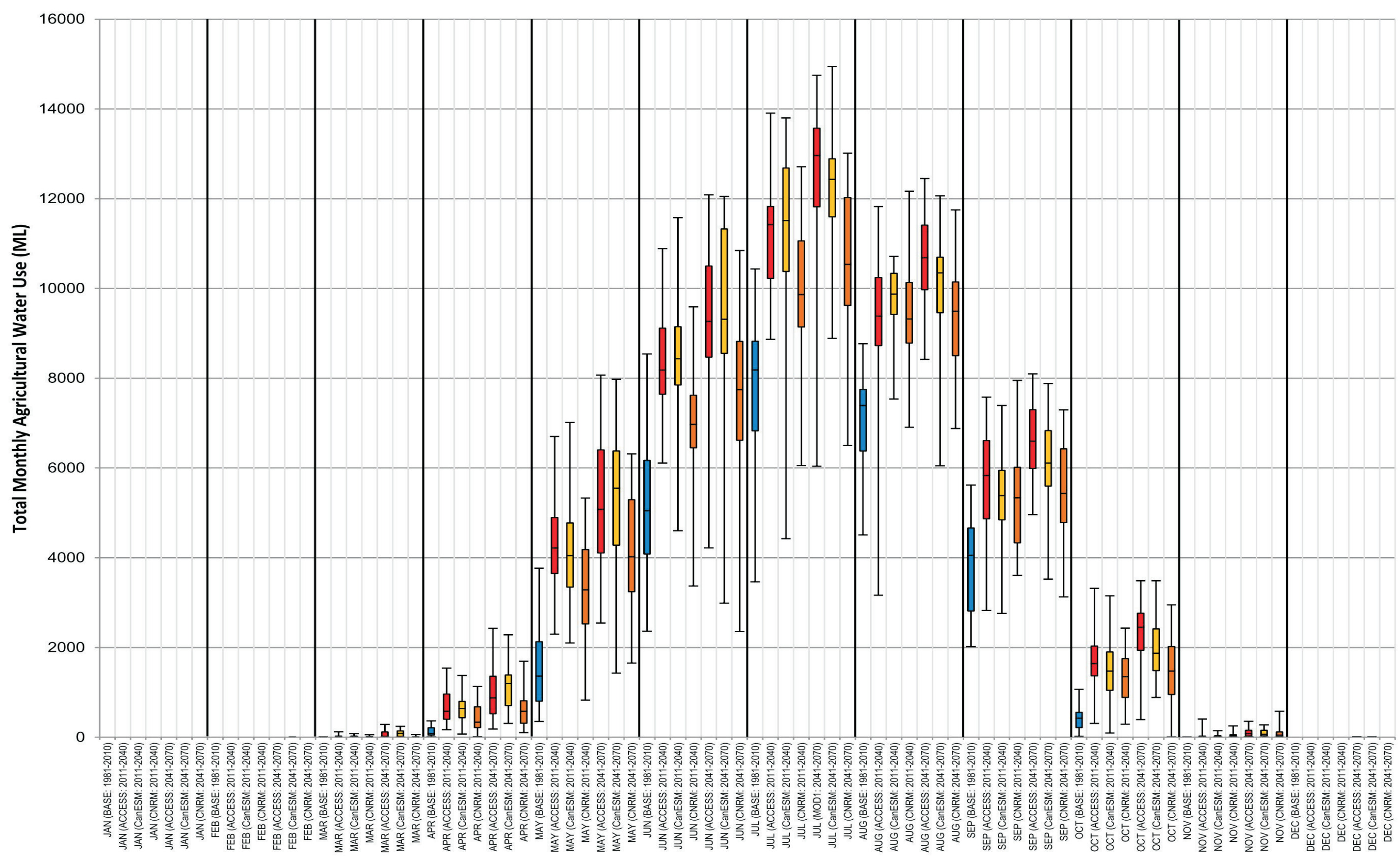
FILE: **Figure 3-5.cdr**

PROJECT:

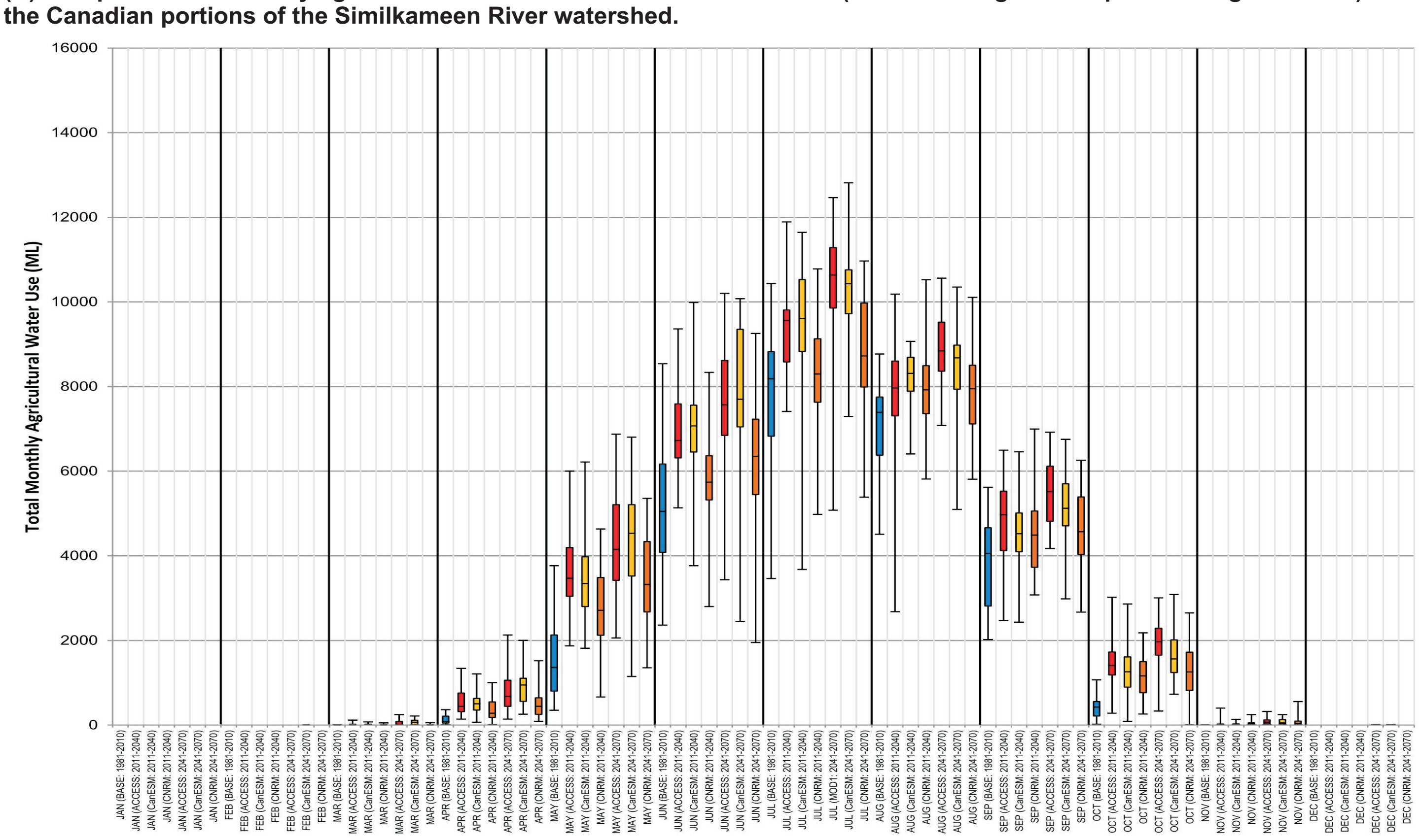
Similkameen Watershed Plan - Phase 2



(A) Comparison of monthly agricultural water demands under Scenario A (climate change only) for the Canadian portions of the Similkameen River watershed.



(B) Comparison of monthly agricultural water demands under Scenario B (climate change and expanded irrigation area) for the Canadian portions of the Similkameen River watershed.



(C) Comparison of monthly agricultural water demands under Scenario C (climate change and increased grape crops) for the Canadian portions of the Similkameen River watershed.

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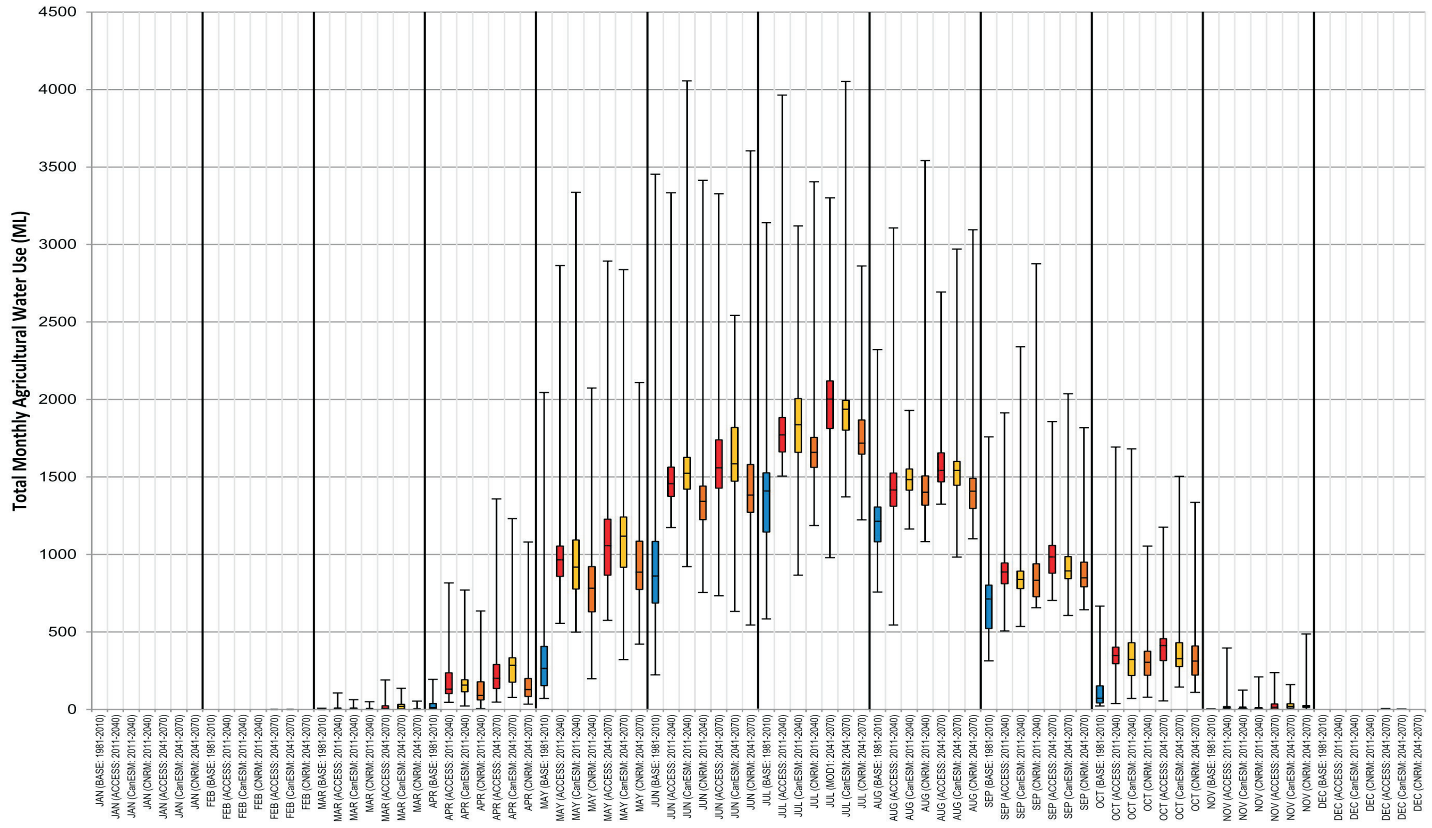
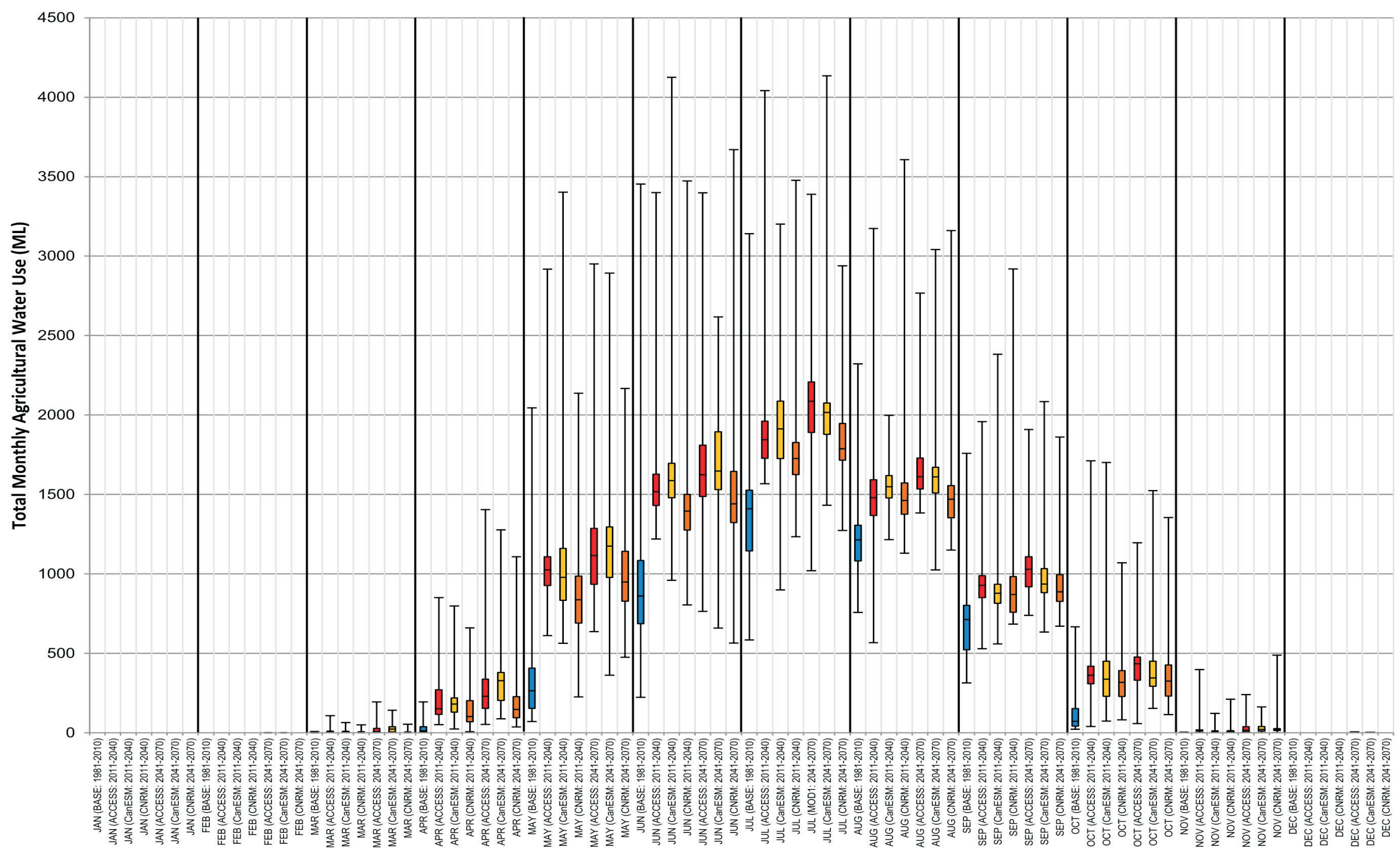
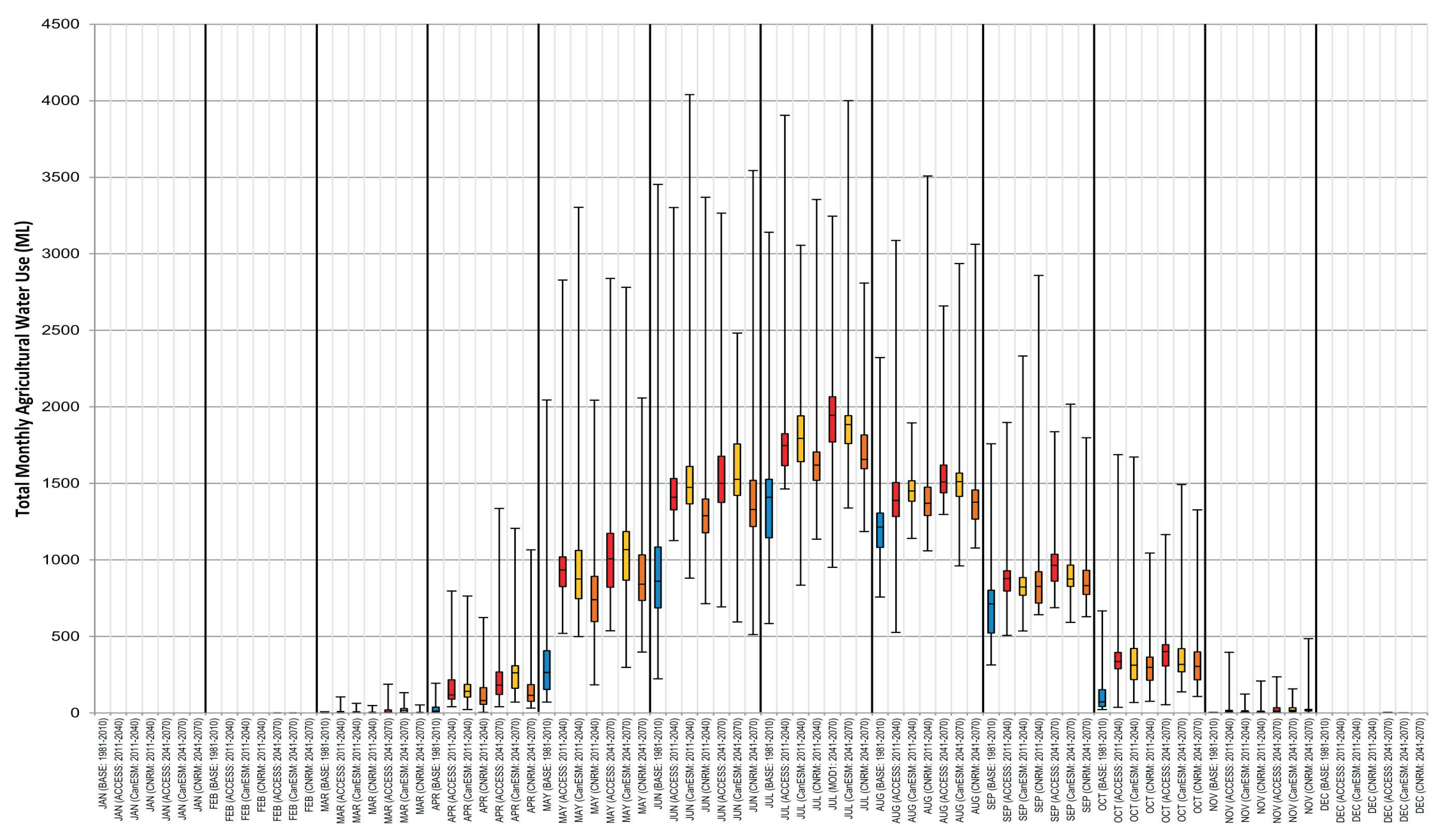
DATE: **March 2015**	**Figure 3-6: Projected monthly agricultural water demands for 2011-2070 relative to the standard period (1981-2010) under the three future water demand scenarios for the Canadian portions of the Similkameen River watershed**
DRAWN BY: **DL**	
DATA SOURCES: **Ministry of Agriculture - Agriculture Water Demand Model**	PREPARED FOR: **Regional District of Okanagan-Similkameen**



(A) Comparison of monthly agricultural water demands under Scenario A (climate change only) for Keremeos Creek sub-basin.



(B) Comparison of monthly agricultural water demands under Scenario B (climate change and expanded irrigation area) for Keremeos Creek sub-basin.



(C) Comparison of monthly agricultural water demands under Scenario C (climate change and increased grape crops) for Keremeos Creek sub-basin.

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DATE: **March 2015**

DRAWN BY: **DL**

DATA SOURCES: **Ministry of Agriculture - Agriculture Water Demand Model**

Figure 3-7: Projected monthly agricultural water demands for 2011-2070 relative to the standard period (1981-2010) under the three future water demand scenarios for Keremeos Creek sub-basin

PREPARED FOR: **Regional District of Okanagan-Similkameen**

- Under climate change and an increase in grape crops (Scenario C, Figures 3-5, 3-6, and 3-7), the annual agricultural water demands are predicted to be less than in Scenarios A and B for the entire watershed by 2% and 16% between 2011-2070, respectively, and for the Keremeos Creek sub-basin by 3% and 7% between 2011-2070, respectively. In addition, the predicted agricultural water demand trends for the future period are consistent with Scenarios A and B.
- Under all scenarios, the monthly water demands and variability increases in the future periods. In addition, the predicted future climate suggests that there will be warmer temperatures in the late winter/early spring; therefore, agricultural water requirements may shift to earlier in the year in comparison to the standard period.

The results are consistent with predicted climate change for the South Okanagan-Similkameen Region, as noted in the Phase 1 study which indicates that, in future, warmer annual air temperatures and warmer, drier conditions are anticipated during the summer. Also, the findings for Scenario B are as expected with increased irrigated areas being added to the sub-basins, and the results for Scenario C are also as expected with increased grape crops and the corresponding change to drip irrigation systems.

Based on the results, increased water demands are predicted for the future. This could impact water availability in the Canadian portion of the Similkameen River watershed, which could, in turn, influence the water availability risk ratings for each of the POIs (Table 3-2). In particular, with increased monthly variability predicted in the future and warmer, drier summers, risk ratings could increase from low to moderate and from moderate to high for a number of the POIs. For POIs already rated as high, water shortages could occur more frequently than is already observed.

4 Summary and Recommendations

Section 4 provides a summary of the water availability and risk assessment for the Similkameen River watershed and recommendations to support the Similkameen Watershed Plan.

4.1 SUMMARY

The SVPS and RDOS are currently developing the SWP. Based on the Phase 1 study, SVPS and RDOS understand where the existing information data gaps are and which gaps need to be filled to balance the health of the watershed with future development plans and growth. Accordingly, RDOS concluded that it was necessary to fill the highest-priority gaps (as specified in the Phase 1 study) in order to continue with development of the SWP. RDOS identified this work as Phase 2 of the SWP, and this report represents the filling of one of the highest-priority gaps: the need to understand water availability and risk for the Similkameen River watershed.

In the Phase 1 study, to address water supply and demand investigations at an appropriate scale, the Similkameen River watershed was divided into 10 sub-basins. The sub-basins and their downstream points-of-interest (POIs) formed the basis for the assessment of water availability and risk. The POIs were as follows:

- POI #1 – Similkameen River above the Tulameen River Confluence;
- POI #2 – Tulameen River at the Mouth;
- POI #3 – Allison Creek at the Mouth;
- POI #4 – Hayes Creek at the Mouth;
- POI #5 – Similkameen River near Hedley (at WSC 08NL038);
- POI #6 – Hedley Creek at the Mouth;
- POI #7 – Keremeos Creek at the Mouth;
- POI #8 – Ashnola River at the Mouth;
- POI #9 – Similkameen River at the International Border; and
- POI #10 – Similkameen River at the Mouth (Canada water use only).

At each POI, the following median annual and monthly values were estimated for a standard period (1981-2010) using available streamflow records, actual water use information, water demand estimates from the Agriculture Water Demand Model (AWDM), and water licences:

- Net flow;
- Naturalized flow;
- Total licensed quantity for both offstream and instream purposes;
- Licensed quantity for offstream purposes;
- Licensed quantity for instream purposes;
- Licensed quantity for storage;
- Estimated actual offstream use (not including major purveyors); and
- Estimated actual water purveyor use (including groundwater).

A water availability risk review was then completed. Risk was defined as the inability of a surface water resource to provide the necessary volume of water to meet human requirements under median conditions for the standard period (using a monthly timescale). Risk ratings of low, medium, and high were assigned to each sub-basin based on water use and licensing compared with naturalized flows. The risk ratings were:

- Low for POIs #1 (Similkameen River above the Tulameen River Confluence), #2 (Tulameen River), #4 (Hayes Creek), #5 (Similkameen River near Hedley), #6 (Hedley Creek), and #8 (Ashnola River);
- Moderate for POI #9 (Similkameen River at the International Border); and
- High for POIs #3 (Keremeos Creek) and #7 (Allison Creek).

In addition to the water availability risk review for each POI, 3 scenarios were selected to investigate future water demands within the Similkameen River watershed using 3 climate models. The scenarios were selected to consider how varying future climate conditions and potential land use and crop type changes could influence water demands from 2011-2070 in comparison with the 1981-2010 standard period. The 3 scenarios included:

1. Scenario A – No change to existing agricultural land base and irrigation type and considering climate change influences only;
2. Scenario B – Add irrigation to all existing and non-irrigated lands, plus potential agricultural lands and consider climate change influences and expanded irrigation area; and
3. Scenario C – Maintain existing agricultural land base and irrigation type, except that 2% of the currently irrigated land base in the Keremeos Creek and Similkameen River – Hedley to International Border sub-basins get converted to grape crops for 3 consecutive years (i.e. 6% increase in total) and is then maintained at constant levels. This considers climate change influences with an increase in grape production.

Comparisons were only completed for the Canadian portion of the Similkameen River watershed and for the Keremeos Creek sub-basin. The results indicate that there is variability in the water demands under all scenarios related to climate variability between years and that there was a trend towards increasing water demand in the future under each scenario. Under Scenario B, the annual agricultural water demands are predicted to be greater than for Scenario A for the entire watershed by 16% between 2011-2070 and the Keremeos Creek sub-basin by 5% between 2011-2070. Conversely, under Scenario C, the annual agricultural water demands are predicted to be less than for Scenarios A and B for the entire watershed by 2% and 16% between 2011-2070, respectively, and the Keremeos Creek sub-basin by 3% and 7% between 2011-2070, respectively.

4.2 RECOMMENDATIONS

There is a reasonable degree of confidence in the net and naturalized flow estimates for the 10 POIs, though limitations (or absence) of sub-basin information dictated that certain estimates and a number of assumptions were required. All the information provided in this report is valuable to the continuing development of the SWP. However, to further improve the understanding of water availability and risk within the Similkameen River watershed, the following recommendations could be considered:

- **Hold discussions with the WSC to determine long-term hydrometric monitoring plans**. A substantial amount of streamflow information is available for the Similkameen River watershed, but an understanding of any anticipated program expansion or reduction would be beneficial for planning purposes. Additional hydrometric stations on Allison Creek, Keremeos Creek, and the Similkameen River at/near the International Border or Keremeos would provide added support to the SWP. This recommendation is consistent with information gap WSD-4 in the Phase 1 study.

- **Complete a detailed surface-groundwater interaction assessment within the Keremeos Creek sub-basin**. As identified by Summit (2015a) and herein, Keremeos Creek has documented occurrences of zero flows and fish kills near the mouth of the sub-basin, while creek flows have been documented in the upper and intermediate portions of the sub-basin at the same time. It is currently unknown whether Keremeos Creek is a losing stream or whether observed low flows are related to water use (surface and groundwater). A detailed investigation of the connection between the surface and groundwater systems would provide additional information to support water management planning within the sub-basin. This recommendation is consistent with others by Summit (2015a).

- **Update the water availability and risk review with new water use information (as it becomes available)**. The work completed herein included all available information collected during the Phase 1 study. However, if new information becomes available in future (e.g. Lower and Upper Similkameen Indian Bands' actual water use, actual water use and water rights information for the United States), the information for relevant sub-basins should be updated accordingly.

- **Develop future water demand scenarios**. As identified in the Phase 1 study, planning scenarios for population growth, economic development, and climate (i.e. information gap WSD-1) should still be considered for the SWP. These scenarios will support long-term growth strategies for the SWP, as well as future water availability requirements and associated risk.

- **Complete an environmental flow needs assessment**. For the water availability and risk review completed herein, environmental flow needs[17] (EFN) were not considered because no specific studies have been done for the Similkameen River watershed. To provide a complete assessment of water availability and risk, EFNs must be determined. Consequently, a detailed investigation of EFNs is necessary for future planning purposes. This recommendation is consistent with information gap F-2 in the Phase 1 study, and such an investigation will likely support new water licensing requirements under the *Water Sustainability Act*.

[17] "Environmental Flow Needs" (EFN) has replaced the old term In-stream Flow Needs (IFN). Under Section 15 of the draft *Water Sustainability Act*, "the decision maker must consider the environmental flow needs of a stream in deciding an application in relation to the stream or an aquifer the decision maker considers is reasonably likely to be hydraulically connected to that stream".

References

B.C. Ministry of Environment (MOE). 2001. Keremeos Creek Report (Draft). September 2001.

Bush, George. Cawston Irrigation District. Personal email communication with Drew Lejbak of Summit, January 2015.

Campo, Lynne. Water Survey of Canada. Personal email communication with Drew Lejbak of Summit, January 2015.

Cannon, Alex. Pacific Climate Impacts Consortium. Personal email communication with Ron Fretwell of RHF Systems Ltd. and Denise Neilsen of Agricultural and Agri-Foods Canada, January 2015.

Glorioso, Moss & Associates. 2010. Strategy for a Sustainable Similkameen Valley (2011-2020). Prepared for the SVPS, April 2010.

Huey, Kevin. Town of Princeton. Personal communication with Drew Lejbak of Summit, March 2015.

Mennell, Brian. Fairview Heights Irrigation District. Personal email communication with Drew Lejbak of Summit, January 2015.

Mount Kobau Wine Service. 2014. 2014 B.C. Wine Grape Acreage Report. August 2014.

Neilsen, Denise. Agriculture and Agri-Foods Canada. Personal email communication with Ron Fretwell of RHF Systems Ltd., January 2015.

Polar Geoscience Ltd. 2012. Phase 3 Okanagan Basin Water Supply and Demand Project: Projected Water Supply and Use in the Okanagan Basin (2011-2040) – Okanagan Basin Water Accounting Model Results. Prepared for Okanagan Basin Water Board with federal funding support through Natural Resources Canada's Regional Adaptation Collaborative Program. March 2012.

RHF Systems Ltd. 2015a. Agriculture Water Demand Model: Similkameen Data Extracts and Summaries – January 14, 2015. Prepared for Summit, January 2015.

RHF Systems Ltd. 2015b. Agriculture Water Demand Model: Similkameen Data Extracts and Summaries – February 20, 2015. Prepared for Summit, February 2015.

Summit Environmental Consultants Inc. (Summit). 2015a. Similkameen Valley Watershed Plan Phase 2: Groundwater – Surface Water Interaction Study. Prepared for the RDOS, March 2015.

Summit Environmental Consultants Inc. (Summit). 2015b. Similkameen Watershed Plan Phase 2: Water Quality Assessment. Prepared for the RDOS, March 2015.

Summit Environmental Consultants Inc. (Summit). 2014. Similkameen Watershed Plan: Phase 1 Report. Prepared for RDOS and SVPS, January 2014.

Summit Environmental Consultants Inc. (Summit). 2012. Kettle River Watershed Management Plan: Phase 1 Technical Assessment. Prepared for the Regional District of Kootenay Boundary, July 2012.

Summit Environmental Consultants Inc. (Summit). 2010. Okanagan Water Supply and Demand Project: Phase 2 Summary Report. Prepared for the Okanagan Basin Water Board, July 2010.

Systat Software Inc. (SYSTAT). 2010. Systat 13. www.systat.com.

van der Gulik, T., Neilsen, D., Fretwell, R., and A. Petersen. 2013. Agriculture Water Demand Model: Report for the Similkameen Watershed. Funded by Canada-British Columbia Water Supply Extension Program, April 2012.

Washington State Department of Ecology (WSDOE). 2004. Lower Similkameen River – Arsenic Total Maximum Daily Load. Publication No. 03-10-074. January 2004.

Withler, Carl. B.C. Ministry of Agriculture. Personal email communication with Hugh Hamilton of Summit, January 2015.

Appendix A – Net and Naturalized Flow and Water Use Estimation Procedures

Table A-1 Summary of net streamflow and water use estimation procedures for the 10 points-of-interest within the Similkameen River watershed

Point-of-Interest	Upstream Drainage Area (km^2)	Net Flow Estimation Procedure[1]	Actual Water Use and Water Licensing Estimation Procedure[2]	Low Flow Estimation Procedure
Similkameen River above the Tulameen River Confluence (POI #1)	1,811	• Continuous (i.e. January to December) hydrometric records were available close to the POI by the WSC station "Similkameen River at Princeton" (Station No. 08NL007; Drainage Area = 1,810 km^2; Period of Record = 1939-present; Natural). • The 1981-2010 WSC records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• No major water purveyors are located within the sub-basin and no actual water use records or estimates were available for private landowners. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL007 and frequency analysis techniques.
Tulameen River at the Mouth (POI #2)	1,778	• Continuous hydrometric records available at the POI by WSC station "Tulameen River at Princeton" (Station No. 08NL024; Drainage Area = 1,780 km^2; Period of Record = 1950-present; Natural).	• Prior to 2008, the Town of Princeton (the Town) used a combination of surface water from the Tulameen River and groundwater (from wells downstream of the Similkameen River confluence) (Summit 2014). No records were available for water use by the Town during the standard period, but 2011-2013 groundwater records indicate that the total volume used in 2012 was equivalent to approximately 50% of the Town's Tulameen River licensed volume. It was assumed that prior to 2008, the surface water/groundwater use was 50% per water source and that the average water use between 2011-2013 was representative of the Town's use during the standard period. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL024 and frequency analysis techniques.
Allison Creek at the Mouth (POI #3)	600	• Discontinued seasonal (i.e. May to October) hydrometric records were available close to the POI by the WSC station "Allison Creek near Princeton" (Station No. 08NL012; Drainage Area = 593 km^2; Period of Record = 1971-1983; Regulated). • Comparing the 1971-1983 mean seasonal discharge measured at WSC 08NL012 to the equivalent period measured by WSC station "Similkameen River near Hedley" (Station No. 08NL038; Drainage Area = 5,580 km^2; Period of Record = 1965-present; Natural), the WSC 08NL012 represented 2.3% of the flow recorded at WSC 08NL038. Note that the Allison Creek confluence is located approximately 30 km upstream of WSC 08NL038. • Assuming that the 1971-1983 mean seasonal discharge estimate was consistent for the standard period (1981-2010), the mean seasonal discharge at WSC 08NL012 was estimated for each year using the WSC 08NL038 records. • Following this, the ratio of seasonal (May to October) discharge to annual discharge was calculated for nearby WSC station "Siwash Creek near Princeton" (Station No. 08NL039; Drainage Area = 263 km^2; Period of Record = 1967-present; Regulated) and was assumed consistent between watersheds. Note that a unit discharge comparison between WSC 08NL012 and nearby WSC stations (using the 1971-1983 period) determined that the most reasonable correlation was with WSC 08NL039 (r^2=0.78). • The monthly distribution for each year recorded by WSC 08NL039 was assumed representative of the Allison Creek sub-basin. However, for the standard period, WSC 08NL039 records were only available for 1998-2010. • As such, to estimate WSC 08NL039 records for the missing standard period (i.e. 1981-1997), a unit discharge comparison between WSC 08NL039 and nearby WSC stations (using the 1998-2010 period) determined that the most reasonable correlation with WSC 08NL039 was with WSC station "Hedley Creek near the Mouth (Station No. 08NL050; Drainage Area = 388 km^2; Period of Record = 1973-present; Natural) (r^2=0.77). • Following this, the WSC 08NL039 ratios of the mean annual discharge for each year between 1981-1997 to the mean 1998-2010 annual discharge were calculated. These ratios and monthly distributions were assumed the same for WSC 08NL039 and ultimately used to estimate values at WSC 08NL012. • The estimated 1981-2010 WSC 08NL012 records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• The Allison Lake Improvement District reported only withdrawing water from Anderson Creek up until 2008 and not from Allison or Hackett Creeks (i.e. licensed streams). After 2008, water was supplied by a groundwater well with records available from 2008-2012 (Summit 2014). Annual water use records were available from 2008 to 2012 (Summit 2014). It was assumed that the mean 2008-2012 water use represented withdrawals for the missing years of the standard period and the monthly water use distribution pattern for the Missezula Lake Waterworks District was adopted. • The Missezula Lake Waterworks District withdrawals water from Missezula Lake for recreational properties. Water use records were available from 2008 to 2012 (Summit 2014). It was assumed that the mean 2008-2012 water use represented withdrawals of the missing years of the standard period; • The Similkameen Improvement District noted that their water licences are currently not being used (Summit 2014). • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• With only estimated streamflow records available at the POI, it was assumed that the low flow characteristics recorded by WSC 08NL045 (Hedley Creek sub-basin) were reasonable approximations for the Allison Creek sub-basin. • The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL045 and frequency analysis techniques. • The ratio of 1:10-year and 1:50-year mean monthly net flow return periods to the median monthly net flows for WSC 08NL045 was assumed the same at the POI.

Point-of-Interest	Upstream Drainage Area (km²)	Net Flow Estimation Procedure[1]	Actual Water Use and Water Licensing Estimation Procedure[2]	Low Flow Estimation Procedure
Hayes Creek at the Mouth (POI #4)	779	• Discontinued seasonal (i.e. May to October) hydrometric records were available close to the POI by the WSC station "Hayes Creek near Princeton" (Station No. 08NL020; Drainage Area = 751 km²; Period of Record = 1943-1949; Natural); however, the records were dated and not directly applicable to the standard period. • Following this, WSC 08NL039 located within the sub-basin was assumed to represent the watershed characteristics. For the standard period, WSC 08NL039 records were available from 1998-2010 and estimated records were available from 1981-1997 (see POI #3). • The WSC 08NL039 records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• Osprey Lake Waterworks District (OLWD) provides seasonal water supply to recreational properties. No water use records were available; therefore, OLWDs full licensed use was assumed to occur between April to October and the same as the AWDM irrigation distribution for the sub-basin. • The Similkameen Improvement District noted that their water licences are currently not being used (Summit 2014). • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• With only estimated streamflow records available at the POI, it was assumed that the low flow characteristics recorded by WSC 08NL045 were reasonable approximations for the Hayes Creek sub-basin (similar to Allison Creek sub-basin).
Similkameen River near Hedley (POI #5)	5,569	• Continuous hydrometric records available at the POI by WSC 08NL038.	• POI includes water use identified in all sub-basins upstream. • The Town of Princeton's groundwater wells are located downstream of the Tulameen River confluence. Prior to 2008, 50% of the mean 2011-2013 water use records were assumed to reflect groundwater withdrawals, while after 2008, the mean 2011-2013 water use records were assumed to reflect annual water use patterns (see POI #2 for further description). • The Similkameen Improvement District noted that their water licences are currently not being used (Summit 2014). • No water use information was available for the Upper Similkameen Indian Band (Summit 2014). Water use estimated following Section 2.2.1. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL038 and frequency analysis techniques.
Hedley Creek at the Mouth (POI #6)	395	• Continuous hydrometric records were available close to the POI by the WSC 08NL050. • The 1981-2010 WSC records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• Apex Mountain Resort has used surface water for daily operations since 1982. Between 1982-2000 water was sourced from Keremeos Creek and from 2001-2010 water was sourced from Keremeos Creek and Nickel Plate Lake (in the Hedley Creek sub-basin). Annual water use records were available from 1982-2010 and monthly water use records available from 2002-2010, including total creek and lake usage for 2010 (Summit 2014). Assuming the 2010 lake and creek usage pattern was consistent for all years, the 2001-2010 lake water use records were estimated. • No information was available for the Apex Circle Water System (Summit 2014). Water is sourced from a deep groundwater well; therefore, it was assumed that there would be limited connectivity to the surface water system and water use was not considered further. • The Hedley Improvement District used surface water for water supply purposes until 1972, when groundwater became the main source of supply (Summit 2014). Monthly water use records were available from 1991-2010 and the average monthly water use was assumed to reflect the missing years in the standard period. • The Similkameen Improvement District (SID) reported that they store approximately 50% of their storage licensed volume in Nickel Plate Lake for Apex Mountain Resort and to supplement the amount of water available to private licence holders downstream (Summit 2014). SID also noted that they gradually release the stored volume during the low flow period between August 1 to October 31 each year to supplement the amount of water available to downstream. This water regulation pattern was assumed consistent across the standard period. • No water use information was available for the Upper Similkameen Indian Band (Summit 2014). Water use estimated following Section 2.2.1. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL045 and frequency analysis techniques.

Point-of-Interest	Upstream Drainage Area (km^2)	Net Flow Estimation Procedure[1]	Actual Water Use and Water Licensing Estimation Procedure[2]	Low Flow Estimation Procedure
Keremeos Creek at the Mouth (POI #7)	224	• Discontinued continuous hydrometric records were available close to the POI by the WSC station "Keremeos Creek at Middle Bench Road" (Station No. 08NL044; Drainage Area = 221 km^2; Period of Record = 1971-1977; Regulated). • Comparing the 1971-1977 mean monthly discharge measured at the active WSC station "Keremeos Creek below Willis Intake" (Station No. 08NL045; Drainage Area = 181 km^2; Period of Record = 1971-present; Regulated) to the WSC 08NL044 records, a strong correlation was determined between locations (r^2=0.98). The associated correlation equation was assumed to reflect conditions during the standard period. Note that the correlation indicated that streamflows were consistently lower at the downstream location, suggesting that water use or losses to groundwater could be occurring and causing reduced flows (see Summit [2015a] for further discussion on this topic). • Mean monthly net flows at WSC 08NL044 were estimated using WSC 08NL045 records available for the standard period and the correlation equation. • The estimated WSC 08NL044 records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• Apex Mountain Resort has used surface water from Keremeos Creek for daily operations since 1982. Between 1982-2000 water was sourced from Keremeos Creek and from 2001-2010 water was sourced from Keremeos Creek and Nickel Plate Lake (in the Hedley Creek sub-basin). Annual water use records were available from 1982-2010 and monthly water use records available from 2002-2010, including total creek and lake usage for 2010 (Summit 2014). Assuming the 2010 lake and creek usage pattern was consistent for all years, the 2001-2010 creek water use records were estimated. • The Olalla Community Water System used surface water for water supply purposes until the early 1980s, when groundwater was used to help supplement water supply (Summit 2014). In the late 1990s, groundwater became the main water supply. Monthly water use records were available from 2006-2012 and the average monthly water use was assumed to reflect the missing years in the standard period. • The Similkameen Improvement District noted that their water licences are currently not being used (Summit 2014). • The Keremeos Irrigation District noted that their water licences are currently not being used (Summit 2014). • No water use information was available for the Lower Similkameen Indian Band (Summit 2014). Water use estimated following Section 2.2.1. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL045 and frequency analysis techniques. • The correlation between WSC 08NL045 and WSC 08NL044 was assumed to reflect low flow conditions and was used to estimate the 1:10-year and 1:50-year mean monthly net flow return periods at the POI.
Ashnola River at the Mouth (POI #8)	1,060	• Continuous hydrometric records were available close to the POI by the WSC station "Ashnola River near Keremeos" (Station No. 08NL004; Drainage Area = 1,050 km^2; Period of Record = 1947-present; Natural). • The 1981-2010 WSC records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• The Keremeos Irrigation District noted that their water licences are currently not being used (Summit 2014). • No water use information was available for the Lower Similkameen Indian Band (Summit 2014). Water use estimated following Section 2.2.1. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL004 and frequency analysis techniques.

Point-of-Interest	Upstream Drainage Area (km^2)	Net Flow Estimation Procedure[1]	Actual Water Use and Water Licensing Estimation Procedure[2]	Low Flow Estimation Procedure
Similkameen River at the International Border (POI #9)	8,117	• Due to the natural regulation of Similkameen River streamflows by Palmer Lake (below the international border) during high flow periods (Lynne Campo, pers. comm., 2015; Department of Ecology 2004), recorded streamflows by the WSC station "Similkameen River near Nighthawk" (Station No. 08NL022; Drainage Area = 9,190 km^2; Period of Record = 1928-present; Regulated) likely do not accurately reflect the streamflow conditions at the international border. • As such, the standard period streamflows at POIs #5, # 6, #7, and #8 were combined and were scaled to the POI assuming the same unit discharge as measured by the combination of all the POIs.	• POI includes water use identified in all sub-basins upstream. • The Keremeos Irrigation District noted that their water licences are not being used, but they are supplying water to their distribution area by 13 wells located near the Similkameen River in the Village of Keremeos. Monthly water use records were available from 2006-2012 from one well (i.e. Fairview well). Since the total water use was not available for all 13 wells, the estimated water demands by the AWDM for the Keremeos Irrigation District was assumed to reflect the standard period for irrigation and double the Fairview well's annual water use during the non-irrigation season (November – March) was used to represent domestic use (K. Huey, personal communication, 2015). • The Fairview Heights Irrigation District (FHID) noted that surface water has not been used since 1976 and instead water is supplied through groundwater from five wells (Summit 2014). Annual water use records were available for 2002, 2005-2006, and 2009 and the average annual water use was assumed to reflect the missing years in the standard period. Also, the average monthly water use pattern by the Keremeos Irrigation District was assumed to reflect the FHIDs pattern. • The Similkameen Improvement District noted that their water licences are currently not being used (Summit 2014). • The Cawston Irrigation District does not supply water in the Cawston area (Summit). All water supply requirements are provided by private wells. • No water use information was available for the Upper and Lower Similkameen Indian Bands (Summit 2014). Water use estimated following Section 2.2.1. • Private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The POI "Similkameen River near Hedley" is the largest upstream contributor to this POI; therefore, it was assumed that the ratio of 1:10-year and 1:50-year mean monthly net flow return periods to the median monthly net flows for WSC 08NL022 reflected low flow characteristics at the POI.
Similkameen River at the Mouth (POI #10)	9,271	• Continuous hydrometric records were available close to the POI by the WSC station "Similkameen River near Nighthawk" (Station No. 08NL022; Drainage Area = 9,190 km^2; Period of Record = 1928-present; Regulated). • The 1981-2010 WSC records were scaled to the POI assuming the same unit discharge as measured by the WSC station.	• POI includes water use identified in all sub-basins upstream; • Water rights and water use within the United States portion of the watershed not included. • No water use information was available for the Lower Similkameen Indian Band (Summit 2014). Water use estimated following Section 2.2.1. • All private water licence distribution and actual water use and management estimation followed procedures outlined in Section 2.2.1. • Actual irrigation (surface and groundwater sources) and stockwatering uses by private landowners within the sub-basin assumed equal to the AWDM estimates for the standard period.	• The 1:10-year and 1:50-year mean monthly net flow return periods for the standard period were derived using the recorded net flows at WSC 08NL022 and frequency analysis techniques. • The ratio of 1:10-year and 1:50-year mean monthly net flow return periods to the median monthly net flows for WSC 08NL022 was assumed the same at the POI.

Note:

1. All WSC station locations are shown in Figure 2-1 (Section 2.1) of the main report.
2. All cited reports are included in the reference section of the main report.