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Report

Regional District of Kootenay Boundary

KETTLE RIVER WATERSHED MANAGEMENT PLAN: PHASE 1 TECHNICAL ASSESSMENT

November 2012

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November 16, 2012
File: 2011-8049.000

Mark Andison
Director, Planning and Development
Regional District of Kootenay Boundary
202 - 843 Rossland Ave.
Trail, BC V1R 4S8

Re: KETTLE RIVER WATERSHED MANAGEMENT PLAN: PART 1 TECHNICAL ASSESSMENT

Dear Mr. Andison:

Summit Environmental Consultants Inc. is pleased to provide the final report for the Kettle River Technical Assessment, which is Part 1 of the Kettle River Watershed Management Plan.

The report includes a summary of existing information on surface water hydrology, water licensing, climate, groundwater, water quality, fish and fish habitat, and riparian habitat. In addition, it provides estimates of current actual water use compared to the licensed volumes, as well as data on groundwater use by the major water utilities in the Kettle River watershed and estimates of the natural flow at seven points of interest in the watershed. Estimates of late summer flows during periods of drought (10-year and 50-year low flows) have also been calculated and compared to the threshold values below which fish habitat becomes significantly constrained.

In general, there is enough water resources information for the Regional District of Kootenay Boundary to move forward with the watershed planning process, although there are a number of information gaps that should be addressed in 2012 to support the plan. The report includes recommendations for addressing those gaps, as well as for on-going monitoring to support water management decision making.

Please contact me if you have any questions.

Yours truly,

Signature on original

Hugh Hamilton, Ph.D., P.Ag.
Senior Environmental Scientist

REPORT

Executive Summary

The Kettle River is one of British Columbia's Heritage Rivers. An international river, it crosses the Canada-US border three times before flowing south through Washington State. Approximately 75% of the watershed area of 11,000 square kilometres is within Canada. The hydrologic regime of the Kettle River is typical of interior watersheds, dominated by snowmelt in the spring. Flows are significantly reduced by mid-summer when demand from water users is high. Watershed residents have expressed concerns about water supply for communities and flow for fish, which are exacerbated by uncertainty about the implications of climate change. Other local water concerns include water quality (both surface and groundwater) and the health of riparian ecosystems.

To address these concerns and uncertainty over water resources, the Regional District of Kootenay Boundary (RDKB) is developing a **Watershed Management Plan** for the Kettle River basin. Phase 1 of the plan is a Technical Assessment intended to summarize existing information in a single "State of the Kettle River Watershed" document. Phase 1 will lead into Phase 2, which will set planning goals, actions, and policy that can be implemented to maintain the health of the watershed in the long term. This document is the report of the **Phase 1 Technical Assessment**. It has been prepared for the project Technical Advisory Committee (TAC) and Stakeholder Advisory Committee (SAC), and was completed primarily using existing data and reports.

Surface Water and Water Licences

The Kettle River watershed hydrologic regime exhibits very large differences between high flows in the spring and early summer and low flows from mid-summer through winter. Climate change projections for the RDKB indicate warmer annual average temperatures, less rainfall in summer, and a decrease in snowfall as more of the winter/spring precipitation falls as rain. As a result, stream flows from late fall to early spring are expected to be slightly greater, while flows in late spring, summer and early fall are expected to be smaller, thus adding to the current constraints on fish and water users in late summer. Spring runoff will likely occur sooner on average and annual total water yield will likely increase.

There are 994 current licences (at 826 points-of-diversion) for surface water in the Canadian portion of the watershed (with 1,100+ more in the U.S.), with irrigation as the largest licensed volume followed by domestic use. Off-stream licenses account for 57,765 ML/yr, storage is 7,351 ML/yr, and conservation is 1,352 ML/yr. There are relatively few dams in the watershed and none are major structures. Cascade Power holds a license for power generation on the Kettle River near Cascade that has not been developed. In anticipation, a Water Reserve has been created for the Kettle River that gives precedence to other water uses over this power license.

The water licences tell us the volume of water that licence holders could use. For this study estimates of actual use have been developed by obtaining the records from the community water utilities in the watershed and from the Ministry of Agriculture's recent irrigation demand model. The major finding from the analysis of the use records is that even though the major water suppliers have surface water licenses, they mostly use groundwater and many of the largest licenses have not been used for many years.

The data records from water suppliers were used to estimate the natural flows at selected points (known as POIs) where flow data are available. The results indicate that on an annual basis the average flow is only slightly less than the natural (pre-development) flows. However, average August flows at the study POIs range from 74% to 96% of the naturalized flows. Near the final crossing of the Kettle River into the U.S., the average August flow is estimated to be 83% of the naturalized flow. This is a conservative (i.e. low) estimate, made by assuming the groundwater withdrawals near Grand Forks are in reality drawing water out of the river. In an average year the net flow in August is likely in the range of 85%-90% of natural flow at this location.

In addition to information about water supply under average conditions, water use planning requires information on stream flows during periods of low flow. The lowest flows in the Kettle River and its tributaries usually occur in August and September. The magnitudes of those low flows vary from year to year, and planning decisions must consider flows during periods of drought and understand the probability that an extreme low-flow will occur. Estimates of the 1-in-10 year and 1-in-50 year return period monthly low flows have been calculated for each POI, and the minimum 7-day net low flows (7Q10 and 7Q50) were estimated where there are adequate data. In the critical July to September period when water demand is highest, the monthly 10-year net low flows are about one-third of the average and the 50-year net low flows are about 20% of the average monthly flow (see Fisheries and Aquatic section below for summary of fish flow needs).

Previous studies and research on the Grand Forks aquifer suggest that some sections the Kettle and larger tributaries are “losing streams”, where a portion of the flow infiltrates to ground. However, beyond Grand Forks this process is not well understood and this is a key information gap that should be addressed, beginning with areas of existing or projected high groundwater demand.

Floodplain mapping is in place for the major inhabited areas along the Kettle River, showing the 20-year and 200-year flood elevations. The existing floodplain mapping is based on data from before 1996, and there would be value in updating it to include data collected since then for developed areas and to consider the effects of climate change.

Groundwater

Relative to other watersheds in southern B.C., groundwater makes up a significant proportion of agricultural and domestic water use in the Kettle River watershed. The provincial government has mapped a total of 15 aquifers in the watershed, all located along or in proximity to the valley bottoms where agricultural activities and communities are concentrated. Most of the mapped aquifers are sand and gravel deposits ranked as having moderate-high productivity and moderate-high vulnerability to contamination from surface activities. The demand on these aquifers is either low or moderate, with the exception of the Grand Forks aquifer where demand is high. Given this high demand, the Grand Forks aquifer has been studied in detail, and there is a very good base of information for the aquifer. Less is known about aquifers in other parts of the watershed.

There are more than 1,400 wells in the B.C. water well database in the Kettle River watershed. Registration of drilled wells is not mandatory, so the actual number is likely higher, although it isn’t known how many are not in use or have been closed. About half of all known wells are in Sub-Basin 6, which includes the Grand Forks aquifer. Of the well records with reported yields, more than 85% have yields of 100 USgpm or less.

The aquifers in the Kettle River watershed are re-charged by a number of processes, the most significant being infiltration from streams and rivers where they flow across sand and gravel alluvial deposits. For the Grand Forks aquifer, it has been estimated that 11-20% of flow in the Kettle River is transferred to groundwater during freshet. Some of that water moves back to the river as baseflow from mid-autumn through the winter. There is some indication that this pattern is repeated at Beaverdell, Westbridge, and Midway, but it has not been studied at the same level of detail as at Grand Forks. The aquifers are hydraulically connected to the Kettle River, evidenced by the parallel rise and fall of river and groundwater levels, and trends in groundwater level generally mirror trends in river level. At Grand Forks and Beaverdell groundwater level data have been collected since 1977 and 1989 respectively. Water levels have varied over this period, but no statistically significant trend is apparent at Grand Forks. At Beaverdell there is a very slight decreasing trend.

Although the Grand Forks aquifer is re-charged by the Kettle River during freshet, there is evidence that groundwater pumping in the latter part of the summer begins to induce additional re-charge from the river and reduce flows compared to natural (pre-development) conditions. This makes little difference annual water yield (total flow in a year), but in late summer the average flow is less than the estimated natural flow. Note, however, that the water suppliers in the area do not use their surface water licences, and the reduction in flow as a result of groundwater use is less than if they did pump from the river.

Similar to much of B.C., there is relatively little information on groundwater quality in the public domain, again with Grand Forks being an exception. Nitrate has been the contaminant of greatest interest. Concentrations of nitrate-N have exceeded the 10 mg/L drinking water guideline, especially in the southeast part of the aquifer.

Water Quality

Surface water quality in the Kettle River is sampled every two weeks at two stations that are run by the Canada-B.C. water quality monitoring program; downstream of Midway and downstream of Grand Forks. A recent (2009) summary report concluded that water quality at both sites was very similar and “generally good”. The parameters that regularly exceed water quality guidelines at these sites are water temperature (for both aquatic life and drinking water), fluoride (aquatic life), and some metals (aquatic life). With metals, the concentrations of the metals that exceed guidelines were strongly correlated with turbidity and thus likely bound to suspended sediments and organic matter. As such, these metals are not available for uptake by biota. Statistically significant increasing trends were found at one or both sites for turbidity, total hardness, total phosphorus, total molybdenum, dissolved chloride, dissolved fluoride, and fecal coliforms. Statistically significant decreasing trends were found at one or both sites for total colour, specific conductivity, and several metals.

There are relatively few point (i.e. end-of-pipe) discharges in the Kettle River watershed. Treated effluent from the Greenwood wastewater treatment plant is discharged to ground adjacent to Boundary Creek. Statistical analysis of “upstream-downstream” data found no significant difference between the upstream and downstream sites, indicating that the wastewater is not having a detectable effect on the creek for the measured parameters. All of the parameters assessed met the applicable water quality guidelines for aquatic life protection. The wastewater facility at Midway discharges treated effluent to the Kettle River. In the most-recent Canada-B.C. water quality assessment report, several variables that may be indicative of wastewater inputs were found to have increased slightly at this site over 1990-2007, including fecal coliforms, total phosphorus, and dissolved chloride. The City of Grand Forks WWTP discharges reclaimed water to the Kettle River. Total phosphorus increased very slightly over 1990-2007, but none of the other parameters that could be linked to municipal wastewater showed evidence of a trend.

Water quality in Christina Lake is regularly monitored because of the lake’s value for both aquatic life and recreation, and site-specific Water Quality Objectives (WQO) have been set. The most recent WQO attainment report (2006 data) found that the WQO were met 97% of the time, with minor excursions for dissolved oxygen and Secchi depth. In addition to water quality sampling by government and dischargers, several community groups have been monitoring water quality. The Boundary Environmental Alliance has measured several metals, including uranium, in the tissue of freshwater mussels. The Christina Lake Stewardship Society carries out Secchi depth and water quality sampling in Christina Lake.

Although our understanding of water quality in the basin is well served by regular monitoring at the Canada-B.C. sites, Christina Lake, and near the WWTPs; most of the data are concentrated in the southern third of the watershed. Less is known about water quality in tributaries.

Fisheries and Aquatic Habitat

The Kettle River supports several fish species, with most of the management effort focussed on rainbow trout and whitefish, with a more recent additional focus on speckled dace due to its endangered status under the *Species at Risk Act*. Of the 39 fish species present in the watershed, two are provincially red-listed (speckled dace and Umatilla dace) and five are provincially blue-listed (westslope cutthroat trout, cutthroat trout, bull trout, chiselmouth and shorthead sculpin). Westslope cutthroat trout, Columbia sculpin, and shorthead sculpin are listed as being of “Special Concern” under the federal *Species at Risk Act*, while speckled dace are listed as “Endangered”.

There is a century-long history of fish stocking in the watershed, reflecting the local importance of the sport fishery and possibly a long-standing recognition of low sport fish abundance. Rainbow trout in particular have been stocked in the watershed many times and over many years, primarily with stocks from elsewhere in B.C. This may have affected the robustness of the native stocks, but this hypothesis has not been tested. The Kettle River and its tributaries are currently managed for conservation of wild stocks and for recreational fishing, and stocking is limited to lakes.

The population of adult rainbow trout is estimated to be below carrying capacity. In recent decades a progressive deterioration of the Kettle River sport fish fishery has been identified, indicated by decreasing abundance and size of rainbow trout present. These declines have been attributed in previous reports to interactions between natural and anthropogenic factors; chiefly seasonal low flow, high water temperatures, decreased habitat availability, and over-fishing. No single factor appears to be driving the decline in fish numbers and size; rather it is their combined effect on adult recruitment and survival.

Recent studies (2010-2011) sponsored by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) have confirmed that there are substantial reductions in rainbow trout parr rearing habitat under low flow conditions and suggest that these flow conditions in the lower portions of the watershed are significantly exacerbated by water withdrawal. However, the work conducted for this report indicates that current water usage may not as influential as other studies have suggested because of water suppliers’ use of groundwater instead of surface water. Nevertheless, under below-average conditions, late summer flows fall below the 10% of Mean Annual Discharge (10% MAD) threshold where fish habitat availability and quality both decline significantly. The 10-year net low flows in September range between 3.6% MAD and 5.7% MAD, and the September 50-year net low flows range from 1.0% MAD to 3.0% MAD.

The MFLNRO studies have also documented variations in water temperature and shown that air temperature exerts the greatest influence on water temperature in late summer. The FLNRO studies aim to identify thresholds for regulation and closure of the fishery, determine minimum stream flow requirements and targets for protection of fish stocks; and specify management strategies to protect fish and fish habitat during critical low flow periods. Work is scheduled to be completed in 2013.

Speckled dace are abundant in the Kettle River watershed, but there are no assessments of population trends. This species is less affected by water temperature than are the salmonids in the watershed and prefer shallow, slow water over deeper fast water, and so may be less affected by current and predicted low flows than are rainbow trout.

Information Availability and Gaps

Despite the relatively low human population of the Kettle River watershed, there is a solid information base that can support water resource management decisions. This is because of its status as an international river and the history of irrigated agriculture in the watershed. The numbers of streamflow monitoring and long-term water quality monitoring stations are above average for B.C., but those stations are concentrated in the southern part of the basin near the border. At present, there are only two Environment Canada climate stations, both in the valley bottom. The recent development of a climate model by federal researchers enables a better understanding of climate variation in the watershed, but better coverage in the mid- to high elevations would be of benefit to confirm the model estimates. Building on the climate model, the Ministry of Agriculture's Irrigation Demand Model (IDM) and the water use records obtained for this study have improved the understanding of actual water use compared to a few years ago (Note that only the initial IDM estimates were available when this report was prepared. Future model runs will generate results for a broader range of conditions).

There is good groundwater data for the Grand Forks aquifer, leading to a reasonable understanding of surface water-groundwater interaction in this area. Less is known about these processes in other areas. The information base for fisheries is also reasonably good, augmented over the past three years by a focussed MFLNR study on low flows and water temperatures, and by monitoring of the effectiveness of LWD structures. Nevertheless, some information gaps remain. Although it is generally understood that riparian function has been affected by land use practices, only selected areas have been studied, limiting the ability to set priorities for management or restoration. A CWS study of riparian wildlife function is in progress.

To summarize, there is sufficient information for RDKB to begin moving forward with Part 2 of the Watershed Management Plan, although there are a number of important data gaps that should be addressed. Recommendations for additional technical studies fall into two categories: 1) those that should take place in the near future to support the management plan process, and 2) longer-term monitoring to support future water resource decision making.

Recommendations to Support the Watershed Management Plan

Technical studies that should be completed or started in 2012 to support the Watershed Management Plan are:

<u>Groundwater-Surface Water Interaction</u>

- An office-based assessment of surface water-groundwater interaction for valley-bottom areas outside of the Grand Forks aquifer, combined with updates of the existing and projected demand for groundwater from valley aquifers. This assessment will determine whether field studies or new Observation Wells are needed to better understand groundwater resource availability if the population grows, new economic activity is introduced, and/or the climate changes.
- Develop estimates of return flows from irrigation.

<u>Irrigation Demand</u>

- Complete additional studies with the Ministry of Agriculture Irrigation Demand Model to determine demand in average years and under one or more climate change scenarios (to date the model has only been run for 2003). Complete field audits and farmer/rancher interviews to assess how well the model matches with actual irrigation rates.

<u>Water Quality</u>

- A reconnaissance-level water and sediment quality sampling program (4 samples per year for 2 years) should be completed in tributary streams that are currently the focus of mineral exploration.

<u>Fisheries</u>

- Conduct creel surveys in 2012 to update current angler use and fishing effects for both summer and winter fisheries; and
- Carry out a radio-telemetry study of adult and sub-adult rainbow trout to identify critical habitats that support summer rearing, spawning, and overwintering; and to confirm the fate of adult fish through the summer period, including whether they depart the river or die in response to ambient conditions.

<u>Riparian Habitat and Function</u>

- Summarize the results of the on-going riparian habitat assessment being completed by CWS and integrate that information with the high-level inventory of riparian cover completed for this study. The results should then be reviewed with stakeholders who are familiar with riparian condition in the watershed to set priorities for additional assessment, as needed.

In addition to these recommended technical studies, RDKB should work with the TAC and SAC to develop of a number of population and economic growth scenarios for the Kettle River watershed. Once scenarios are in place it will be possible to estimate water demand and compare the demand to what is known about water supply.

Recommendations for Longer-term Assessment and Monitoring

- At least one new automated climate monitoring station should be installed at mid- to high elevation to augment the two existing low-elevations stations. The number and preferred location(s) of new stations should be determined in consultation with Environment Canada.
- A Farmwest climate station in rural Grand Forks should be installed as it would be of value to support irrigation planning and water conservation.
- Re-establish streamflow monitoring on Boundary Creek. Automated water quality monitoring systems should be installed at the same site to obtain continuous turbidity, temperature, and conductivity data to assess how often water quality meets guidelines.
- Conduct water quality monitoring at the former Canada-BC station at Gilpin, on the Kettle River downstream of Grand Forks to assess potential changes from historical data (1980-1994) and to compare to data from the Carson site upstream of Grand Forks.
- Depending on the findings of the groundwater-surface water data analyses recommended above, re-establish the decommissioned groundwater Observation Well at Midway or establish a new well at another suitable location between Midway and Westbridge.
- Install an additional groundwater Observation Well in the Grand Forks aquifer, as recommended by Wei et al. (2010).
- Continue with the fisheries studies that have been sponsored by MFLNRO over 2010-2011 to address the questions originally identified by Oliver (2001).

Acknowledgements

Summit Environmental Consultants Inc. thanks the people that provided information used in preparation of this report, especially the representatives of water suppliers who met with the study team and provided water use data - Sasha Bird (City of Grand Forks), Jim Lewall (Christina Waterworks District), Brian Schneider (Covert Irrigation District), Maurice Valcourt (Big White Water Utility Ltd.), Randy Smith (City of Greenwood), Murray Knox (Grand Forks Irrigation District), Toby Pike (Southeast Kelowna Irrigation District (SEKID), Steve Babakaiff (SION Improvement District), Robert Black (Sutherland Creek Waterworks District), John Boltz (Village of Midway), and Otto Grunewald (Bridesville Waterworks District).

The results of the Kettle Valley irrigation demand model were provided by Ted Van der Gulik (Ministry of Agriculture) and Ron Fretwell. The climate data are courtesy of Alex Cannon (Environment Canada) and Denise Neilsen (Agriculture and Agri-Food Canada). Others who provided key information included Al Grant (Boundary Environmental Alliance), Fred Marshall (Consulting Forester), Rusty Post (Washington Department of Ecology), Tara White (MFLNRO), Lisa Tedesco (MFLNRO), Michael Noseworthy (MFLNRO), and Phil Epp (Consultant). We also thank the members of the Kettle River Watershed Management Plan Technical Advisory Committee (TAC) for their guidance, and for the TAC members, RDKB staff, and MFLNRO staff who provided their thoughtful reviews of the draft report. The project was directed by Mark Andison, MCIP, Director of Planning for the Regional District of Kootenay Boundary.

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List of Abbreviations

7Q10	1-in10 year 7-day low flow
7Q50	1-in-50 year 7-day low flow
AAFC	Agriculture and Agri-Food Canada
AET	Actual Evapotranspiration
AGWMN	Ambient Ground Water Monitoring Network
B.C.	British Columbia
BCEAA	British Columbia Environmental Assessment Act
BMP	Best Management Practice (or Beneficial Management Practice)
CABIN	Canadian Aquatic Bio-monitoring Network
DFO	Fisheries & Oceans Canada
EC	Environment Canada
EFP	Environmental Farm Plan
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
EMS	Environmental Monitoring System (a database)
GCM	General Circulation Model
IDZ	Initial dilution zone
IFN	In-stream Flow Needs
IPP	Independent Power Project
LWD	Large Woody Debris
MAD	Mean annual discharge
MAL	Ministry of Agriculture and Lands (now Ministry of Agriculture)
ML	Megalitre (1,000,000 L or 1,000 m^3)
MMER	Metal Mining Effluent Regulation (*Fisheries Act*)
MOE	Ministry of Environment
MFLNRO	Ministry of Forests, Lands & Natural Resources Operations (also MOF, MOFR)
MSR	Municipal Sewage Regulation
NPS	Non-point source (pollution)
OWN	Observation Well Network
OWNI	Observation Well Network Information database
OWSDP	Okanagan Water Supply & Demand Project
PCIC	Pacific Climate Impacts Consortium
PDO	Pacific Decadal Oscillation
PET	Potential Evapotranspiration
QA/QC	Quality Assurance/Quality Control
RDKB	Regional District of Kootenay Boundary
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
USEPA	United States Environmental Protection Agency
USGS	United States Geologic Survey
WAP	Watershed Assessment Procedure

WDOE	Washington Department of Ecology
WQG	Water Quality Guidelines
WQO	Water Quality Objectives
WSC	Water Survey of Canada

REPORT

1 INTRODUCTION

1.1 PROJECT BACKGROUND

The Kettle River is rated as one of British Columbia's 20 Heritage Rivers by the B.C. Heritage Rivers System (BC Parks, 2010). An international river, it crosses the Canada-US border three times before flowing south through Washington State where it joins the Columbia River at Lake Roosevelt (Map 1). Approximately 75% of the total watershed area of 11,000 square kilometres is within Canada. Major tributaries of the Canadian Kettle River are West Kettle River, Rock Creek, Boundary Creek, Granby River, and Christina Creek.

The headwaters of the Kettle River are in the Monashee Mountains, but the valley bottoms and much of the southern part of the watershed are located within some of the driest biogeoclimatic zones in the province of British Columbia. As a result, agriculture in the Boundary region is dependent on irrigation, some of which is drawn from surface water and some from groundwater. Other economic and land use activities also extract water from the Kettle River and its tributaries and connecting aquifers, as do municipal water suppliers and individuals. The hydrological regime of the Kettle River is typical of interior watersheds, dominated by snowmelt in the spring. However, natural flows are significantly reduced by August and September when demand from irrigators and other water users remains high. Watershed residents have recently expressed concerns about water supply and flow for fish, which are exacerbated by the uncertainty about the implications of a warming climate. These concerns about water supply during low flow periods run parallel to concerns about water quality, partly because of potentially diminished capacity for dilution. Concerns over water quality also relate to land use activities in the watershed, existing and proposed point discharges, and loss of riparian function. The public concern over these issues has led to the Kettle River consistently being rated by the Outdoor Recreation Council of British Columbia as one of the province's most endangered rivers (Outdoor Recreation Council of B.C., 2011)

To address these concerns and uncertainty over water resources, the Regional District of Kootenay Boundary (RDKB) has elected to develop a **Watershed Management Plan** for the Kettle River basin. Provincial and federal government agencies and other stakeholders will also participate in development of the plan, which will be completed in two phases. Phase 1 is a Technical Assessment intended to summarize existing information in a single "State of the Kettle River Watershed" document, and to identify any information gaps that could constrain water planning. These gaps would be addressed as needed based on level of priority. Phase 1 will lead into Phase 2, which will set planning goals, actions, and policy that can be implemented to maintain the health of the watershed in the long term.

In March 2011 the RDKB retained Summit Environmental Consultants Inc. (Summit) to complete the Phase 1 Technical Assessment and prepare the State of the Kettle River Watershed report. The project terms of Reference (TOR) is provided in Appendix A. This document is the report of the **Phase 1 Technical**

Assessment. It has been prepared for the Phase 1 Technical Advisory Committee (TAC) and Stakeholder Advisory Committee (SAC).

1.2 PHASE 1 PROJECT OBJECTIVES

The general objectives of the Phase 1 Technical Assessment are to:

1. Describe the existing (as of 2011) water and water-related resources in the Canadian part of the Kettle River watershed by compiling data from existing studies, published reports, databases, and government agencies and other stakeholders who have collected data on the watershed;
2. Assess what is known about water quantity (both surface water and groundwater), water quality, aquatic and riparian habitat, and general watershed health;
3. Identify and prioritize any data gaps that would need to be filled to better enable Phase 2 to proceed;
4. Present the findings and recommendations in a “State of the Kettle River Watershed Report”; and
5. Present the findings in person to RDKB Directors and the Stakeholder Advisory Committee (SAC)

The major tasks that were completed to meet these objectives are:

1. A project initiation meeting and two mid-project meetings with the TAC;
2. Assembly and review of background information and development of a watershed description;
3. Inventory of existing streamflow, climate, aquifer, groundwater well, and water quality data in the Kettle River watershed, and identification of any spatial or temporal gaps in the data records;
4. Summary of previous studies on the water resources of the Kettle River watershed;
5. Technical analyses using existing data to address specific questions in the project terms of reference.
6. Identification of any physical, biological, social, or economic information needs that currently constrain RDKB’s ability to move forward with Part 2 of the Watershed Management Plan;
7. Development of recommendations for further technical studies to address those information needs; and
8. Preparation of the project report (i.e. this report), and presentation of the key findings to the TAC and SAC.

1.3 GUIDANCE FROM THE TECHNICAL ADVISORY COMMITTEE

The Technical Assessment was directed by the Technical Advisory Committee that was assembled by RDKB to guide the consulting team. The TAC members and their affiliations are listed in Table 1-1. Section 2.3 outlines the meetings and discussions that took place over the course of the project.

Table 1-1
Technical Advisory Committee Members

Agency or Organization	**Member**	**Department/Branch**
Regional District of Kootenay Boundary	Mark Andison	Planning and Development
	Jeff Ginalias	Planning and Development
	Bill Baird	Director (Elected Official) & Chair, Stakeholder Advisory Committee
B.C. Ministry of Agriculture	Ted Van der Gulik	Sustainable Agriculture Management
	Carl Withler	Sustainable Agriculture Management
B.C. Ministry of Forests, Lands and Natural Resources Operations (MFLNRO)	Tara White	Fish and Wildlife Section
	Conrad Pryce	Water Allocation
	Lester Vermiere	Resource Management
Okanagan Nation Alliance	Heidi McGregor	Fisheries Department
Grand Forks Irrigation District	Murray Knox	Manager
City of Grand Forks	Sasha Bird	Technical Services & Utilities
Fisheries and Oceans Canada	Dean Watts	Habitat & Enhancement
Interior Health Authority	Cheryl Unger	Drinking Water Protection

1.4 REPORT STRUCTURE

The structure of this report is based on the project terms of reference (Appendix A). A draft report outline was provided to the TAC in July 2011. The comments that were received were used to develop the current Table of Contents, which was accepted by the TAC.

- Section 2.0 describes the methods that were used to complete the study.
- Section 3.0 provides an overview description of the Kettle River watershed.
- Section 4.0 addresses surface water hydrology and water use, and includes summaries of studies on instream flow needs and flood risk.
- Section 5.0 concerns groundwater resources and use, including groundwater-surface water interactions.
- Section 6.0 summarizes existing information on water quality.
- Section 7.0 summarizes information on fish and fish habitat, including riparian habitat.
- Section 8.0 discusses the state of knowledge about water resources in the Kettle River watershed and identifies the gaps in the information base that may need to be addressed to better facilitate watershed planning.
- Section 9.0 contains the recommendations to address key gaps and for the technical components of future Phase 2 work.

1.5 REGULATORY CONTEXT

1.5.1 Federal

Under the Canadian Constitution, the provinces are "owners" of the water resources and have wide responsibilities in their day-to-day management. The Federal government is responsible through the Canada *Water Act,* for setting the framework for federal-provincial and international water management agreements, as well as for a number of specific management areas, notably navigation, shipping, and fisheries management. The Canadian federal legislation that is important to the Kettle River includes the *International Boundary Waters Treaty Act, Fisheries Act, International Rivers Improvement Act,* and *Navigable Waters Protection Act.* The *Canadian Environmental Protection Act* (CEPA) also includes provisions that govern water quality.

1.5.2 Provincial and Local

Water management in British Columbia is guided by the *Water Act*. It encompasses water allocation (licensing), changes or transfers of water licences, construction in and adjacent to water bodies, water management and planning, and drought management. There are three regulations under the *Water Act*: the Water Regulation (which controls water allocation), the Groundwater Protection Regulation, and the Dam Safety Regulation.

Since 2004 Section 4 of the B.C. *Water Act* enables the creation of water management plans. Specifically, Section 62 (1) states:

62 (1) The minister may, by order, designate an area for the purpose of developing a water management plan if the minister considers that a plan will assist in addressing or preventing
(a) conflicts between water users,
(b) conflicts between water users and in-stream flow requirements, or
(c) risks to water quality.

According to Nowlan and Bakker (2007), Water Management Plans are intended for areas of the province where the Minister of Environment believes that such a plan would assist in preventing or dealing with water management conflicts or serious risks to water quality. The key attribute of Section 4 plans is that they can be made legally enforceable by being approved by Provincial Cabinet. As RDKB and the community moves forward with its water management planning process, it can consider the advantages and disadvantages of eventually making the watershed management plan legally binding under Section 4 of the *Water Act.*

B.C. is currently working towards modernization of the *Water Act.* The modernization process has four goals:

- Protect stream health and aquatic environments
- Improve water governance arrangements
- Introduce more flexibility and efficiency in the water allocation system
- Regulate ground water use in priority areas and for large withdrawals

All four goals have implications for the Kettle River Water Management Plan. Development of the plan itself is part of the move towards improved water governance since it provides a basis for land and water use decisions. The move towards groundwater regulation is important because of the apparent links between surface water and groundwater in the valleys. The criteria for when groundwater extraction would need to be authorized are still under discussion[1]. A draft of the updated *Water Act* is expected sometime in 2012.

1.5.3 Other Provincial Legislation and Regulations

In addition to the *Water Act*, there are more than a dozen other provincial and federal acts that are relevant to water management. The key ones with respect to water planning in the Kettle River watershed include the *Environmental Management Act, Forest and Range Practices Act, Fish Protection Act* (including the Riparian Areas Regulation), *Local Government Act*, and *Drinking Water Protection Act* (including the Drinking Water Protection Regulation).

[1] See http://livingwatersmart.ca/water-act/

1.5.4 Columbia Basin Treaty

The Columbia River Treaty between Canada and the United States was ratified in 1964. As a tributary to the Columbia River system, the Kettle River is covered by the Treaty. The Treaty is currently being re-negotiated for 2014 since the original treaty was for 60 years (i.e. to 2024) and both countries must give 10 years notice before changing the treaty.

2 METHODS

2.1 INFORMATION ASSEMBLY

2.1.1 Library and Database Searches

The databases and sources of information that were searched are:

- B.C. Ministry of Environment Cross-Linked Information Resources (CLIR) database. This includes the Ecological Reports Catalogue (EcoCAT), the Ministry of Forests library, the Environmental Protection Information Resources e-Library (EIRS EP); the Biodiversity / Environmental Information Resources e-Library (EIRS BD) and two species-at-risk databases.
- B.C. Ministry of Forests on-line Hydrology library in Kamloops;
- B.C. Ministry of Agriculture information on-line library;
- Federal government databases containing streamflow, climate, and water quality data;
- Provincial databases containing snow, water quality, and species-at-risk data;
- A general Internet search using key words including combinations of words and phrases including “Kettle River”, the names of major tributaries, water, hydrology, groundwater, climate change, irrigation, fish, fish habitat, hydro-power, and others; and
- Summit’s in-house library.

2.1.2 Telephone and E-Mail Discussions

In addition to the on-line and library information searches and TAC discussions, representatives of government agencies and community groups, consultants, and researchers who have been active in the watershed were contacted to determine the availability of reports and data files not in the public domain. The contacts also provided information on issues of concern and information regarding studies that are in progress.

2.1.3 Meetings with Water Suppliers and Fieldwork

The major water suppliers in the Kettle River watershed were contacted to arrange meetings to obtain and review information on actual water use. During July 2011 we met with the major water suppliers and records of actual water use were obtained, reviewed and summarized. Some water suppliers were not available to meet in person; therefore, a telephone interview was conducted and water use data was provided by e-mail.

This technical assessment is drawn almost completely on existing information. Field work was limited to brief visits by the study team to a few key sites within the watershed, and a half-day reconnaissance of Boundary Creek riparian areas with Mr. Fred Marshall, a local Professional Forester who is very familiar with the area.

2.2 TECHNICAL ANALYSES

2.2.1 Sub-basin Definition

To address study requirements at an appropriate scale, we divided the Canadian portion of the Kettle River basin into sub-basins. Using ArcGIS, we mapped sub-basin watershed boundaries to a minimum 1:20,000 scale. The final product is a completely geo-referenced map for the entire watershed and each individual sub-basin.

After reviewing the watershed (Figure 2-1) and considering the locations of streamflow and water quality monitoring stations, we adopted eight (8) sub-basins for the study:

- Sub-basin #1 - The West Kettle River;
- Sub-basin #2 - The Kettle River upstream of Westbridge;
- Sub-basin #3 - Residual area #1 contributing to the Kettle River upstream of the first border crossing near Midway;
- Sub-basin #4 - Boundary Creek;
- Sub-basin #5 - Residual area #2, contribution to the Kettle River below the Boundary Creek confluence and the return back into Canada near Grand Forks;
- Sub-basin #6 - Granby River;
- Sub-basin #7 - Residual area #3, contribution between the border crossing near Grand Forks and the third and final border crossing south of Christina Lake; and
- Sub-basin #8 – Residual area #4, contribution between the border crossing near Cascade and the confluence of Deep Creek.

In addition, there are four portions of the Kettle River watershed located in the United States that required consideration:

- The portion of Myers Creek upstream of Midway;
- The portion between Midway and Grand Forks;
- The portion between Grand Forks and the Cascade border crossing; and
- The portion between the Cascade border crossing and the confluence of Deep Creek.

The sub-basins and their downstream points-of-interest (POI) formed the basis for the streamflow and water use analyses. For the adopted 8 sub-basins, we developed outputs at the following seven (7) locations:

- The West Kettle River at Mouth;
- The Kettle River at West Kettle Confluence;
- The Kettle River at Midway International Boundary;

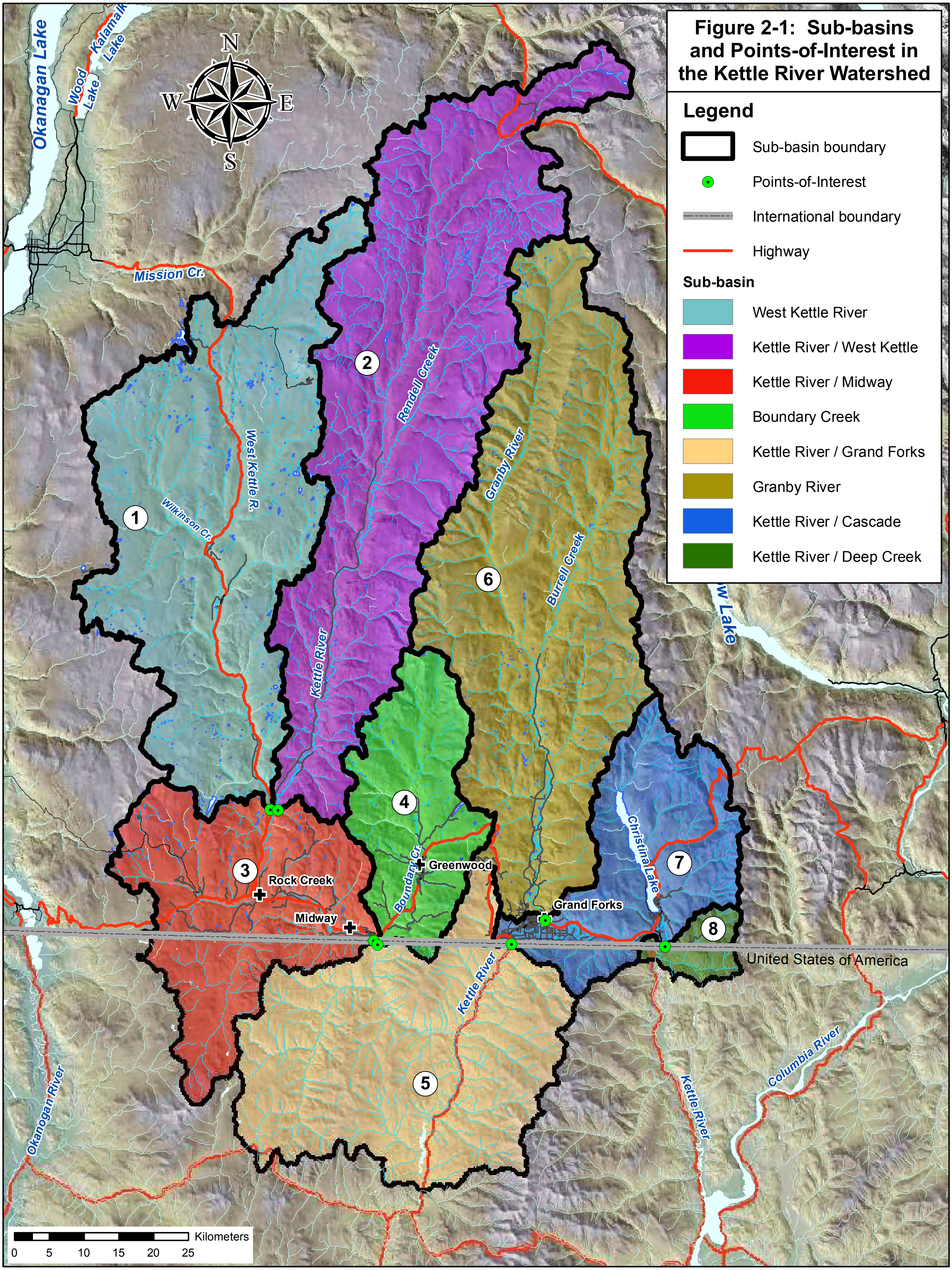


Figure 2-1: Sub-basins and Points-of-Interest in the Kettle River Watershed
Legend
Sub-basin boundary
Points-of-Interest
International boundary
Highway
Sub-basin
West Kettle River
Kettle River / West Kettle
Kettle River / Midway
Boundary Creek
Kettle River / Grand Forks
Granby River
Kettle River / Cascade
Kettle River / Deep Creek
Okanagan Lake
Wood Lake
Kalamalka Lake
Mission Cr.
West Kettle R.
Wilkinson Cr.
Rendell Creek
Kettle River
Granby River
Burrell Creek
Rock Creek
Midway
Greenwood
Boundary Cr.
Grand Forks
Christina Lake
United States of America
Okanogan River
Columbia River
Kettle River
1
2
3
4
5
6
7
8
N
S
E
W
Kilometers
0 5 10 15 20 25

- Boundary Creek at Mouth;
- The Kettle River at Grand Forks International Boundary;
- Granby River at Mouth; and
- The Kettle River at Cascade International Boundary.

2.2.2 Other Analyses

The methods used to complete other technical analyses for this study are described within Sections 4.0 through 7.0 below.

2.3 TECHNICAL ADVISORY COMMITTEE MEETINGS

There were three meetings with the TAC before this report was prepared. The project initiation meeting took place on April 13, 2011. Mid-project progress meetings took place on July 12 and October 19, 2011. The consulting team prepared and distributed a brief progress memo before the two mid-project meetings so that any TAC members who could not make the meeting were informed of progress. The mid-project meetings began with a short presentation from the consulting team and also included updates on parallel projects by TAC representatives from MFLNRO and MAL. In addition, the TAC provided comment and suggestions for information sources. For each meeting a record of the meeting was compiled by a RDKB staff member and circulated in draft to the TAC for comment.

3 WATERSHED DESCRIPTION

3.1 LOCATION, ADMINISTRATIVE JURISDICTIONS, AND ACCESS

The Kettle River watershed is located in the Southern Interior of B.C., between the Okanagan Valley to the west and the Columbia River valley to the east (Map 1). The Canadian part of the watershed is mostly within in the Regional District of Kootenay Boundary, specifically Areas E (Boundary Country), D (Rural Grand Forks), and C (Christina Lake). A small portion of the northern part of the watershed is in the Regional District of North Okanagan Area D. Incorporated communities in the watershed include the City of Grand Forks, City of Greenwood, and Village of Midway. In addition, there are six irrigation, waterworks, and improvement districts that operate under the authority of the B.C. *Local Government Act*. They are:

- Grand Forks Irrigation District
- SION Improvement District
- Covert Irrigation District
- Christina Lake Waterworks District
- Sutherland Creek Waterworks District; and
- Southeast Kelowna Irrigation District.

Highway 3 passes through the watershed and provides access to the major communities of Rock Creek, Midway, Greenwood, Grand Forks, and Christina Lake. Highway 33 connects with Highway 3 at Rock Creek and is the primary travel route from Rock Creek to Kelowna. The Kettle River watershed occupies portions of Ferry and Stevens Counties in Washington State. U.S. border crossings are at Ferry (near Midway), Danville (near Grand Forks), and Laurier (south of Christina Lake).

3.2 Geology and Physiography

3.2.1 Bedrock Geology

The Kettle River Watershed lies in the Omineca Belt of the Canadian Cordillera. The Omineca Belt is a land mass that consists of the rocks that made up the continental margin of North America more than 200 million years ago. The rocks were lifted up and deformed when the a smaller land mass, called the Intermontane Belt, collided with the North American continent 150 to 200 million years ago as a result of tectonic plate movements. The bedrock in the Kettle River Watershed consists of rocks from the older land mass of the continental margin that are generally older than 250 million years and newer igneous rocks, 50 to 100 million years old, that formed from magma created during the aforementioned collision (Logan and Vilkos 2002). Since the formation of those rocks, subsequent erosion of the land surface over millions of years has worn away a significant depth of rock in the area, exposing the current bedrock that was formed and deformed deep inside the earth.

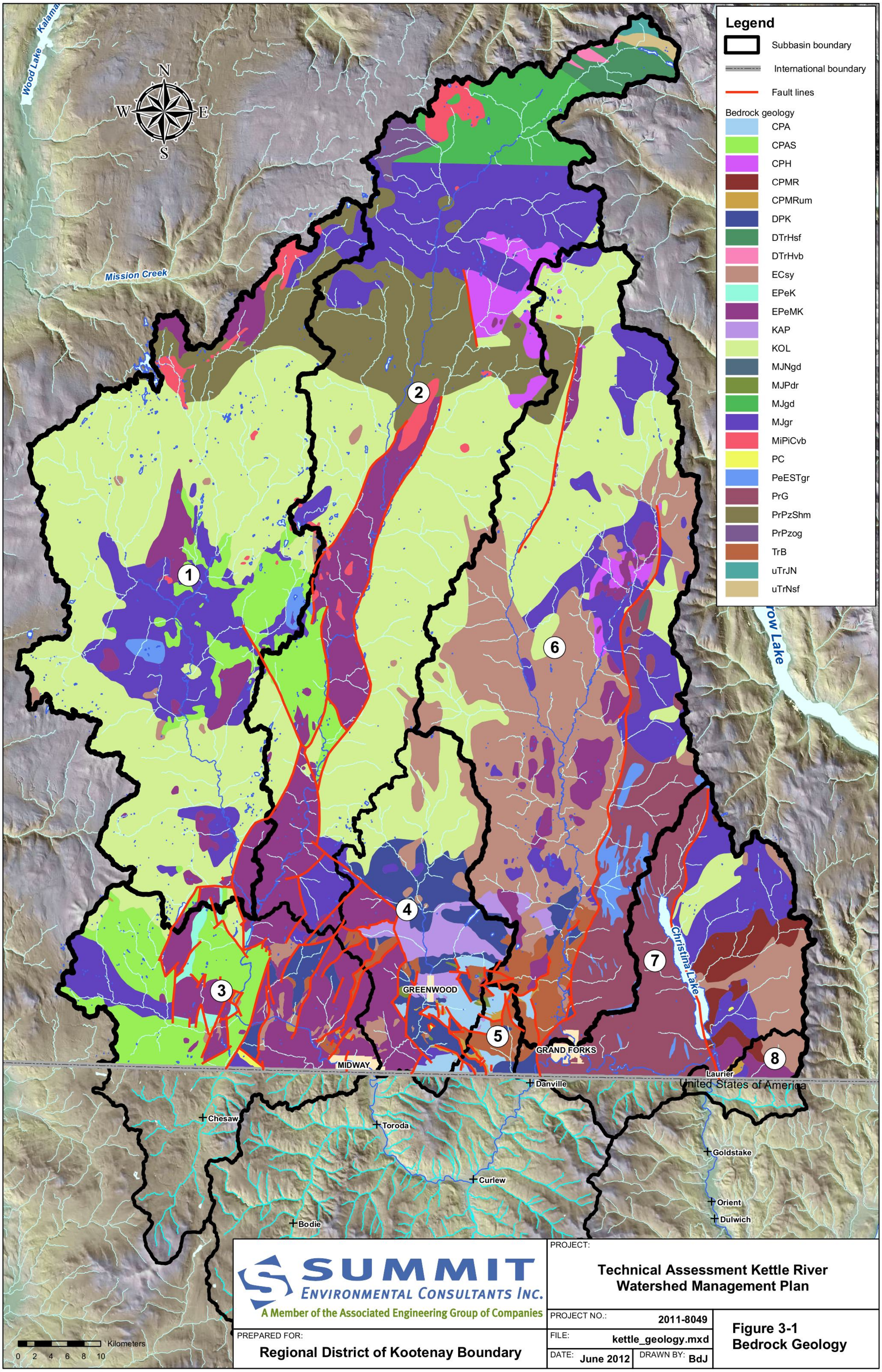
Figure 3-1 is a generalized map of the bedrock geology of the watershed. The map legend is presented in Table 3-1. As evident from the map, the geology is complex and consists of a variety of igneous intrusive rocks, metamorphic rocks, and sedimentary and metasedimentary rocks. Faults are common (red lines on Figure 3-1), with some coinciding with river valleys. For example, Christina Lake is situated along a fault line.

3.2.2 Surficial Geology and Landforms

The Kettle River Watershed is dominated by north-south trending mountain ranges and valleys of the Okanagan Highland and the Monashee Mountains. It is bound to the west by the Okanagan valley and to the east by the Arrow Lakes of the Columbia River Valley. The valleys have been carved out by glaciers from the last glacial period and therefore glacially-derived sediments are predominant throughout the watershed. Higher elevations feature exposed bedrock with glacial till, intermediate elevations and slopes are overlain by glacial till with glaciofluvial and colluvium deposits in the tributary valleys (Figure 3-2). The floodplains of the West Kettle River, Kettle River, Granby River and Burrell Creek have been extensively re-worked since the glaciers retreated and are mostly covered with fluvial sediments and colluvium that were originally derived from occasional slope collapse.

3.3 SOILS

The properties of soils in the Kettle River watershed vary significantly as a function of the climate, parent material, and topography that is present. Soils developed in the lower elevation areas with natural grassland vegetation and a dry climate are dominated by chernozemic soils, primarily Dark Brown and Black Chernozems (Sprout and Kelley 1964, Valentine 1986). Moving up from the valley bottom, Eutric and Dystric Brunisols are dominant, whereas the wetter forested areas include a mixture of Gray Luvisols and Humo-Ferric Podzols. Alpine areas and steep slopes tend to have areas with poorly-developed Regosols and Brunisols.



SUMMIT ENVIRONMENTAL CONSULTANTS INC.

A Member of the Associated Engineering Group of Companies

PREPARED FOR:

Regional District of Kootenay Boundary

PROJECT:

Technical Assessment Kettle River Watershed Management Plan

PROJECT NO.: 2011-8049

FILE: kettle_geology.mxd

DATE: June 2012

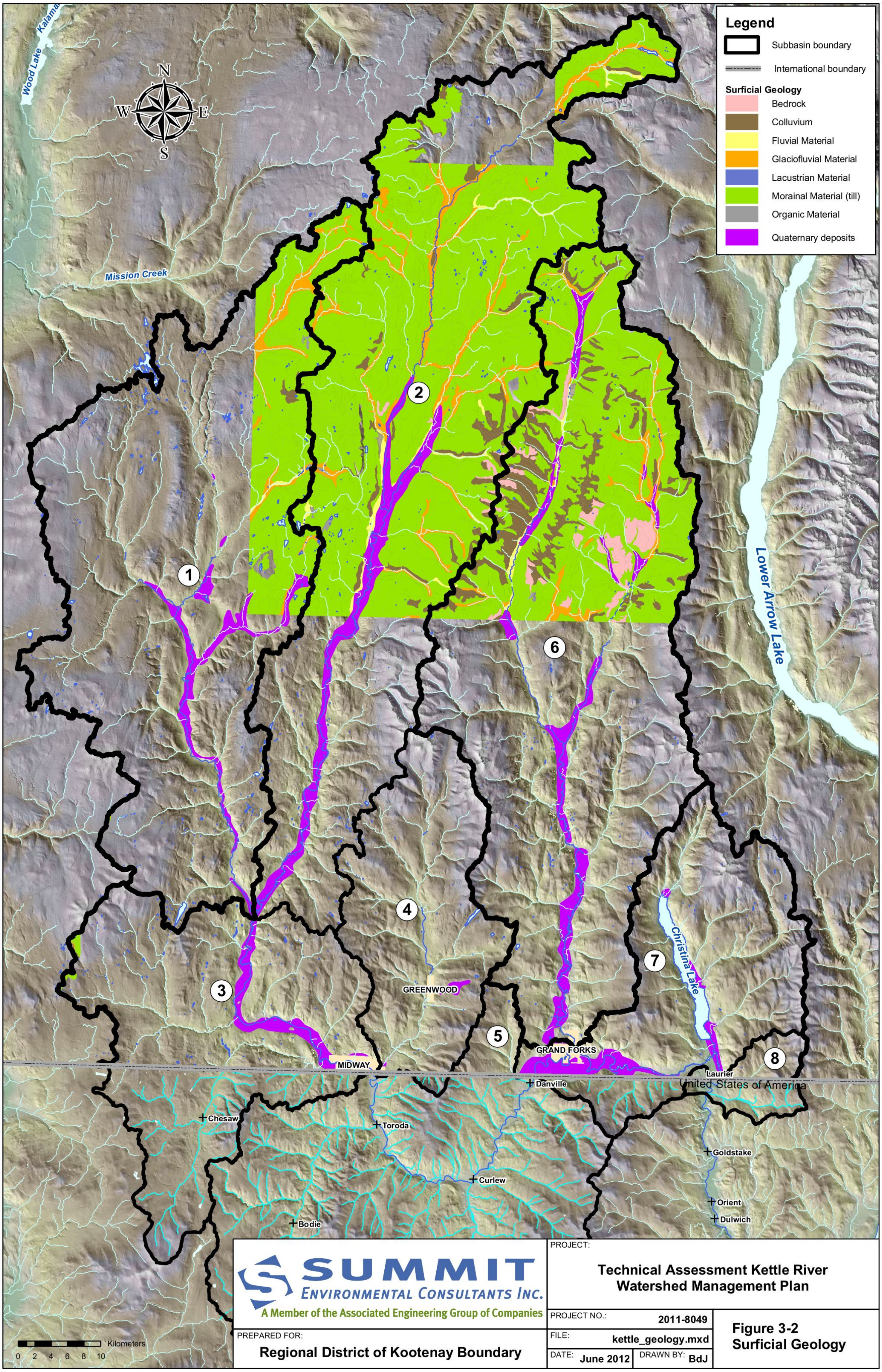
DRAWN BY: BdJ

Figure 3-1
Bedrock Geology

Table 3-1
Bedrock geology map legend

MAP CODE	STRATIGRAPHIC AGE	ROCK TYPE
CPA	Carboniferous to Permian	undivided sedimentary rocks
CPAS	Carboniferous to Permian	greenstone, greenschist metamorphic rocks
CPH	Carboniferous to Permian	volcaniclastic rocks
CPMR	Carboniferous to Permian	mudstone, siltstone, shale, fine clastic sedimentary rocks
CPMRum	Carboniferous to Permian	ultramafic rocks
DPK	Devonian to Permian	chert, siliceous argillite, siliciclastic rocks
DTrHsf	Devonian to Triassic	mudstone, siltstone, shale fine clastic sedimentary rocks
DTrHvb	Devonian to Triassic	basaltic volcanic rocks
ECsy	Eocene	syenitic to monzonitic intrusive rocks
EPeK	Eocene	mudstone, siltstone, shale fine clastic sedimentary rocks
EPeMK	Eocene	undivided volcanic rocks
KAP	Cretaceous	granodioritic intrusive rocks
KOL	Cretaceous	intrusive rocks, undivided
MiPiCvb	Miocene to Pliocene	basaltic volcanic rocks
MJgd	Middle Jurassic	granodioritic intrusive rocks
MJgr	Middle Jurassic	granite, alkali feldspar granite intrusive rocks
MJNgd	Middle Jurassic	granodioritic intrusive rocks
MJPdr	Middle Jurassic	dioritic intrusive rocks
PC	Permian	mudstone, siltstone, shale fine clastic sedimentary rocks
PeESTgr	Paleocene to Eocene	granite, alkali feldspar granite intrusive rocks
PrG	Proterozoic	paragneiss metamorphic rocks
PrPzog	Proterozoic to Paleozoic	orthogneiss metamorphic rocks
PrPzShm	Proterozoic to Paleozoic	metamorphic rocks, undivided
TrB	Triassic	undivided sedimentary rocks
uTrJN	Upper Triassic to Lower Jurassic	undivided volcanic rocks
uTrNsf	Upper Triassic	mudstone, siltstone, shale fine clastic sedimentary rocks

Source: B.C. Ministry of Energy and Mines (2011).



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FILE: kettle_geology.mxd

DATE: June 2012

DRAWN BY: BdJ

Figure 3-2
Surficial Geology

3.4 CLIMATE

3.4.1 Climate Normals and Monitoring

Environment Canada currently operates two climate stations within the Kettle River watershed and publishes the data. These stations are at Grand Forks and Beaverdell (the station is referred to as Beaverdell North). Data are also available for about 10 other stations that have been operated for some period of time, but most are close to one of the existing sites. To illustrate how the climate varies, Table 3-2 provides selected climate normal data for the climate stations at Grand Forks (532 m elevation) and Beaverdell North (838 m) (Environment Canada, 2007). Beaverdell is cooler than Grand Forks as expected based on elevation and latitude, but it also receives less precipitation. This is because of its position on the lee side of the highlands between the Kettle and Okanagan Valleys.

Table 3-2 includes an estimated value for potential evapotranspiration (PET), calculated from the normal temperature data using the Priestley-Taylor equation and procedures in Shuttleworth (1993), assuming grass and pasture coverage. The average moisture deficit for the May to September period, which is the monthly precipitation minus the PET value, is 441 mm and 367 mm for Grand Forks and Beaverdell respectively. This is an indication the amount of irrigation water that is needed to satisfy plant demand. At both sites there is a deficit situation on average from April to October, and the P-PET difference is sufficient to create an overall annual moisture deficit (-294 mm at Grand Forks and -240 mm at Beaverdell). Moving up in elevation, however, there is an annual moisture surplus and annual P exceeds PET even in dry years.

In addition to Environment Canada, several other agencies collect climate data. The Ministry of Transportation (MOT) operates weather stations at three locations near the margins of the watershed (Anarchist Summit, McCullough, and Paulson Summit), collecting precipitation, temperature, and wind speed data. The Farmwest.com web site provides weather data from monitoring stations to serve the agricultural community in B.C. (www.farmwest.com). However, none of these stations are in the Kettle River watershed although there are several in the west Kootenays and in the east side of the Okanagan. Seasonal weather stations are operated by the B.C. Wildfire Management Branch to track fire related weather and drying characteristics. These stations are located in various places, but the data are only available by request.

There are currently five active snow survey stations in the watershed (Table 3-3), of which one (Grano Creek) is a snow pillow where the data are sent by satellite to MOE at least every three hours. In addition to the five active stations, there are data for three discontinued stations that were all in the Trapping Creek watershed, covering some portion of 1966 to 1999. The Grano Creek snow data are available in near real-time through the River Forecast Centre web site[2]. The four snow courses were established between 1949 and 1973, and therefore provide good long-term data.

[2] See http://bcrfc.env.gov.bc.ca/data/asp/realtime/asp_pages/asp_2e07p.html

Table 3-2
Climate Normal (1971-2000) Summary: Selected Kettle River Watershed sites

Climate variable	Grand Forks	Beaverdell North
Elevation above sea level (m)	531.9	838.2
January daily average temperature (°C)	-5.0	-7.0
July daily average temperature (°C)	19.5	16.0
Days with max. temperature >20°C	122.0	103.3
Annual average precipitation (mm)	509.8	482.0
Annual average rainfall (mm)	391.1	329.1
Annual average snowfall (mm water equivalent)	118.7	152.9
Potential Evapotranspiration (mm)*	804	722
May-September moisture deficit (mm)**	-441	-367
October to April moisture surplus (mm)**	147	128
Extreme daily rainfall (mm) on record	47.8	33.6
Extreme daily snowfall (cm) on record	40.6	28.0
Average snow depth in January (cm)	17.0	32.0
Days annually with precipitation ≥5 mm	35.6	32.9
Days annually with precipitation ≥10 mm	10.6	9.8
Degree days annually >15°C	403.9	126.6

*Calculated from climate normal data and procedures in Shuttleworth (1993).
** Sum of monthly P minus PET values for the months indicated.

Table 3-3
Active snow survey and snow pillow sites in the Kettle River watershed

Number	Name	Elev. (m)	Latitude	Longitude	Year Installed	Platform ID Number
2E01	Monashee Pass	1,387	50° 5'	118° 30'	1949	na
2E02	Carmi	1,254	49° 29'	119° 5'	1963	na
2E03	Big White Mountain	1,672	49° 43'	118° 58'	1966	na
2E06	Bluejoint Mountain	1,990	49° 32'	118° 31'	1973	na
2E07P*	Grano Creek	1,874	49° 33'	118° 40'	1997	434BB2A8

*Note: Stations ending in “P” are snow pillow stations. na – not applicable

3.4.2 Climate Modelling within the Watershed

Climate modeling for the Canadian portion of the Kettle River watershed has been initiated by Environment Canada. To model the climate diversity throughout the watershed, existing data from climate stations in and around the watershed from 1961-2006 have been used to develop a climate dataset on a 500 m by 500 m grid (van der Gulik, Neilsen, & Fretwell, 2010). Each grid cell contains air temperature (minimum, maximum, and mean) and total precipitation for each day of the year from 1961-2006.

The development of the climate dataset was completed in conjunction with the development of an Agriculture Demand Model for the Kettle River watershed by the Ministry of Agriculture and Agriculture and Agri-Food Canada (described in Section 4.2.2). The climate dataset is used by the Agriculture Demand Model to calculate a daily reference evapotranspiration rate, irrigation rate, and other agro-climatic indices for each grid cell.

When this report was prepared, model outputs for only 2003 were available. Figure 3-3 presents the results of the 2003 average annual air temperature, total precipitation (P), and potential evapotranspiration (PET) across the entire Canadian portion of the Kettle River watershed modelled by Cannon and Nielsen (2003). The year 2003 was the warmest and driest on record, which is why it was selected for the initial climate modelling. Future model runs will estimate normal and cooler than normal conditions, and also develop projections of future climate under several climate change scenarios. Of interest in Figure 3-31 is the difference between the modelled P and PET values. Modelled precipitation in 2003 in the upper elevation northern part of the watershed was >800 mm while PET was <800 mm. However is about 70-80% of the watershed PET>P.

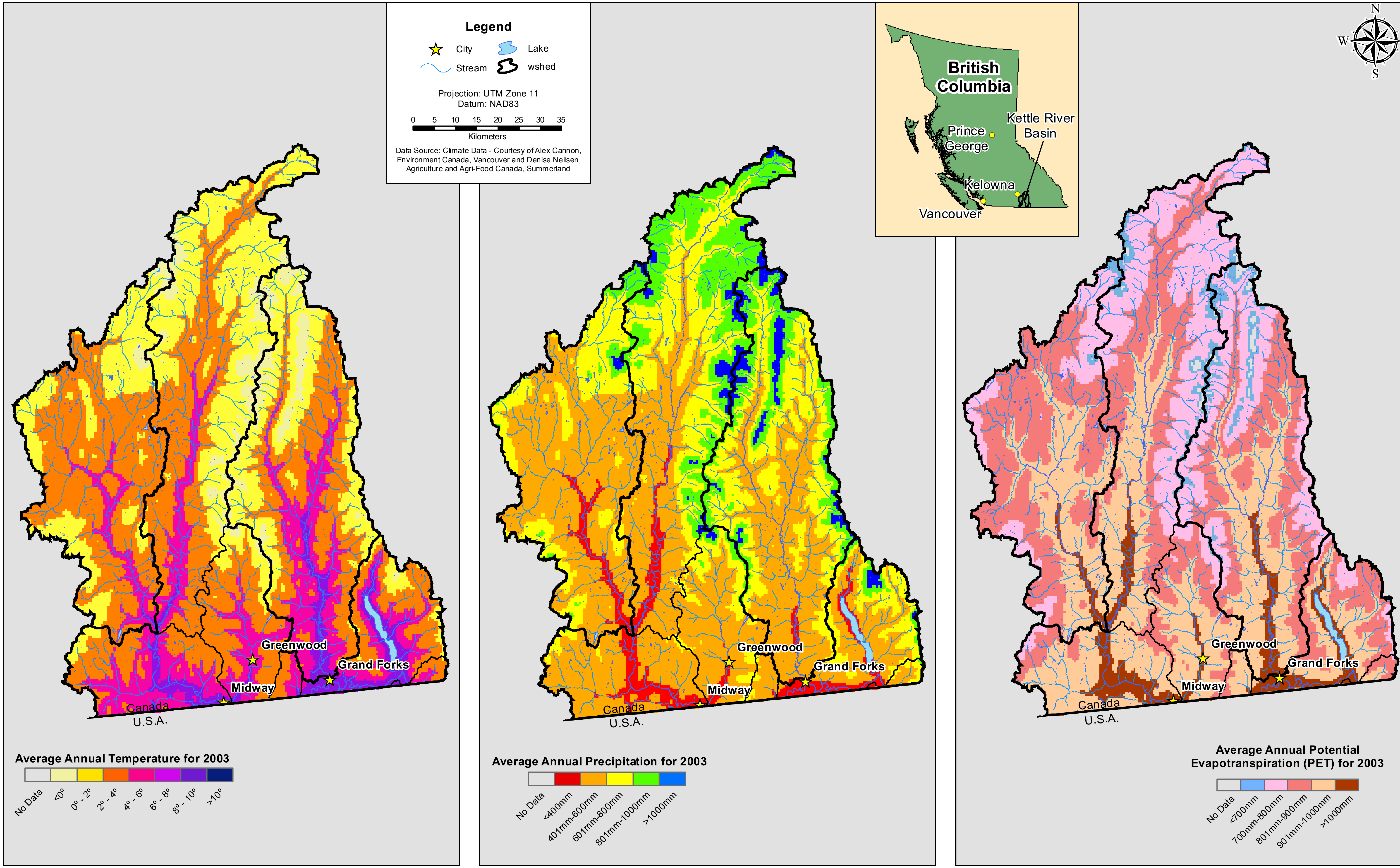

Figure 3-3. Modelled Annual Air Temperature, Precipitation, and Potential Evapotranspiration of the Kettle River watershed (2003).

3.4.3 Climate Change

The global climate is warming in response to increases in greenhouses gasses in the atmosphere. Projections for the Kootenay-Boundary region show average temperatures increasing gradually to about 3°C by the 2080s (Pacific Climate Impacts Consortium 2011). There is a small increase in average annual precipitation but this is biased by more rain (not more snow) in the winter and less rainfall is projected in summer. In response to the projected changes in temperature and lower summer rainfall, both residential and agricultural water demand will likely increase. Warmer temperatures and longer growing season would potentially increase local agricultural opportunities, but could mean that irrigation begins earlier and extends later than at present. Additional information on climate change and implications for water resources are outlined in Section 4.5.

3.5 REGIONAL AND WATERSHED SURFACE WATER HYDROLOGY AND LAKES

The Kettle River is one of the larger tributaries to the Columbia River, with a total length of approximately 282 km. From its headwaters in the highlands of the Monashee Mountains, the Kettle River flows south through the Christian Valley to Westbridge, where it meets the West Kettle River (Map 1). The river continues south to Rock Creek and turns east, passing through Midway and crossing the border into the United States. The river flows back into Canada at Danville near Grand Forks, until it crosses the border again at Laurier, south of Christina Lake. Major tributaries to the Kettle River (on the Canadian side) include West Kettle River, Boundary Creek and the Granby River.

The majority of the Kettle River watershed (on the Canadian side) is located within the Okanagan Highland Hydrologic Zone (#23), while a small portion of the watershed (at its easternmost boundary) falls within the Lower Columbia Basin Hydrologic Zone (#22) (Obedkoff, 2003). Streams within the watershed are generally characterized by a snowmelt dominated peak rising in April or May and peaking sometime in late May or June. In addition, short duration peak flows can be initiated by localized rainfall events. Low flows generally occur from the end of November to March, and in hot summer months, with the lowest flows commonly occurring in late summer and again in winter. Figure 3-4 presents the mean daily discharge at three Water Survey of Canada (WSC) stations on the Kettle River for the period 1975-2010, showing how discharge increases with watershed area. Note that the discharges values presented in Figure 3-4 are averages. Information on the magnitude and frequency of below average flows is provided in Section 4.0.

There are three lakes (as classified by MOE) in the watershed as well as a number of smaller lakes and ponds. The largest and most well-known lake is Christina Lake. It is about 25 square kilometres in surface area with a tributary drainage of approximately 470 square kilometres (Ministry of Environment 1977). It is considered a deep lake, averaging about 36 m deep with a maximum depth of 54 m. The other two lakes are Jewel Lake (0.8 km^2), which is 10 km northeast of Greenwood, and Conkle Lake (1.3 km^2) near Bridesville. In addition to these natural lakes, there are a number of small reservoirs that are referred to locally as lakes. Reservoirs are described in Section 4.6.

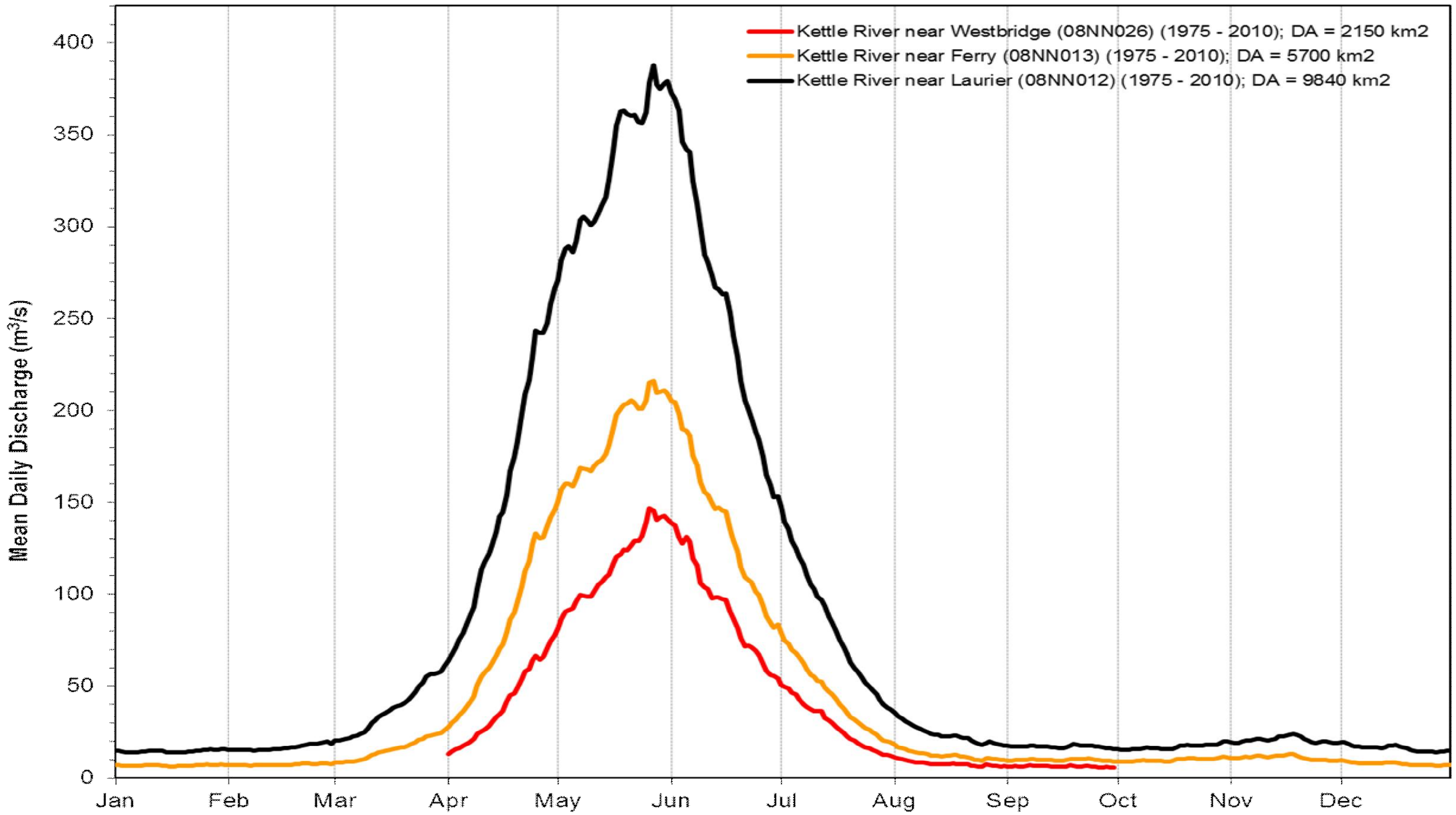

Figure 3-4
Kettle Mean Daily Discharge Comparison (1975 – 2010)

3.6 GROUNDWATER

Groundwater reflow moves very slowly, ranging from 1 to 10,000 metres per year, and therefore groundwater resources and processes are not easily generalized over the size of the Kettle River watershed. Only a small proportion of the watershed area (less than about five percent) has been assessed by the provincial Ministry responsible for water management in B.C., to determine the presence and type of aquifers. However, the area that has been assessed and mapped (Map 2) includes most of the populated area and the agricultural land base that is irrigated (i.e. the valley bottoms).

Based on the physiography and geology of the watershed (Section 3.2) it is apparent that the highland and mountainous areas are dominated by bedrock aquifers that yield low volumes of groundwater, and that the floodplains and alluvial fans near the valley bottoms contain aquifers in the unconsolidated sediments (silts, sands and gravels). The climatic conditions and physiography of the watershed likely mean that the depth to the groundwater table is within about 10 m of the surface in the low-elevation, alluvial aquifers. Groundwater flow direction is generally defined by topography, moving from higher to lower lying areas, and follows the direction of flow of streams in valley bottoms.

Over 1,400 wells are recorded as present in the Kettle River watershed, although many are private wells with minimal groundwater extraction. There are only a few wells (located in high demand areas) that are used to extract large amounts of groundwater from aquifers. Provincial maps showing the presence of wells and aquifers is limited to agricultural valley bottoms and population centres, where water demand is much higher than in outlying rural or forested areas. Much less is known, therefore, about groundwater resources at middle and high elevations. Many of the public water suppliers rely on groundwater extraction, and there has been interest for some time on how to best manage agricultural demand and public domestic water supply in the Grand Forks area. For this reason, the Grand Forks Aquifer has been studied for several decades (e.g. Wei et al. 2010).

Additional information on groundwater resources in the Kettle River watershed is provided in Sections 6 and 6 below.

3.7 ECOSYSTEMS

3.7.1 Biogeoclimatic Zones

Most of the mainstem rivers in the project area flow through the Interior Douglas fir (IDF) biogeoclimatic zone, with Montane Spruce (MS) and Interior Cedar-Hemlock (ICH) at higher elevations (Figure 3-5). Within the US, the Kettle River mainstem flows through the Okanogan-Colville Xeric Valleys & Foothills ecoregion. Within the Kettle River watershed biogeoclimatic zones range from small patches of Ponderosa Pine Bunch Grass (PPBG), which contains some of Canada's hottest and driest zones, to the cool, wet Engelmann Spruce – Subalpine Fir (ESSF) zone at high elevations (Government of British Columbia, 2011; Meidinger & Pojar, 1991).

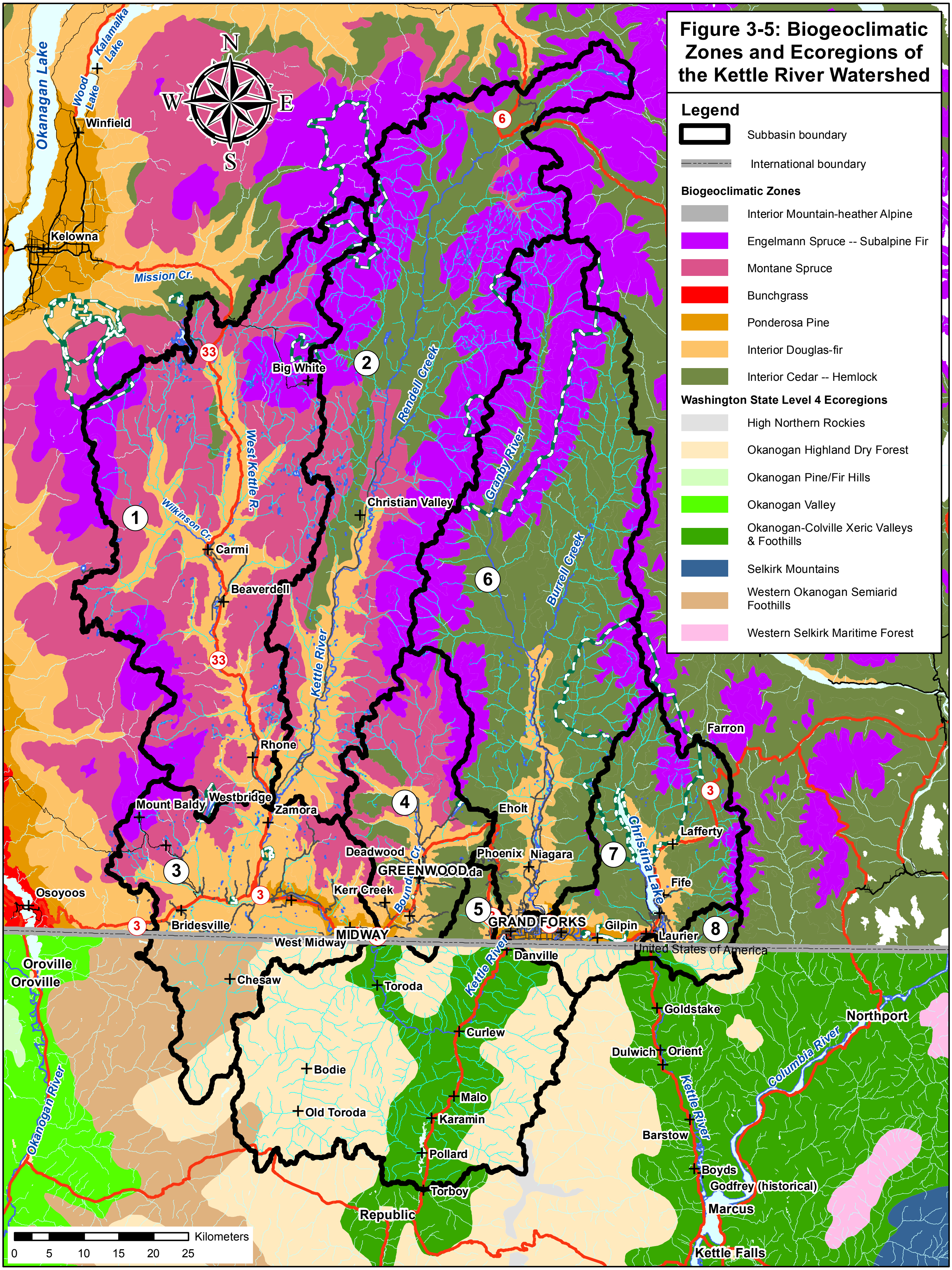

Figure 3-5: Biogeoclimatic Zones and Ecoregions of the Kettle River Watershed

The IDF is found along the bottom of the tributary valleys. It characterized by short, cool winters, long dry summers, and extensive Douglas-fir forests containing various amounts of canopy cover. In the southern sections of the Kettle watershed, the south facing IDF slopes remain bare of snow throughout the winter months; in the northern sections, the thick forest canopies intercept snowfall, leaving the litter-fall and understory open for ungulate foraging (Meidinger & Pojar, 1991). As a result, the IDF is an important winter range for many ungulate species. Species such as mule deer, white-tailed deer, bighorn sheep and rocky mountain elk travel upwards of 80 km to reach IDF winter ranges.

The MS zone is located at mid-elevations in the Kettle Valley watershed, especially along the Kettle and West Kettle Rivers. The MS zone is defined by cool snowy winters, short warm summers, and sloping topography. During the summer and fall the avalanche tracks within the MS contain lush vegetation that is important summer foraging areas for many species. Species found in this zone include moose, mule deer, caribou, grizzly and black bears, squirrels, pika and birds (J. Paul & Associates Inc. et al., 1998; Meidinger & Pojar, 1991).

The ICH zone is located at mid-elevations, upslope of the MS zone along the Kettle River and replacing the MS zone along the Granby River. The ICH zone is characterized by cool, long, snowy winters and warm, dry summers. As in the MS, most large ungulates forage within the ICH during the summer and fall; then migrate to the lower IDF zone for the winter. The exception to this is Caribou, which will forage in the ICH in the late summer and early fall, and then spend winter in the ESSF. The vegetation community of the ICH is lush; it includes abundant patches of huckleberry and blueberry, which are required for the high-protein and energy rich diets required by bears. As a result the most common large mammals found in the ICH are grizzly and black bears.

The ESSF is found at high elevations within the watershed and is defined by wet cool summers, long cold snowy winters, and extremely steep topography. Mature ESSF forests are important to furbearing species such as Marten, Fisher, Red Squirrel, and Wolverines. The ESSF forests are also very important to caribou, as the boreal lichens within them are the sole food source during the winter. As noted above, the ESSF contains important summer foraging habitat for bears, resulting in a high concentration of bears within this zone.

3.7.2 Riparian Areas – Species and Ecosystems at Risk

Riparian habitats are the transitional areas between aquatic and upland terrestrial habitats. The high soil moisture contents within such environments support the development of diverse and complex plant communities, which in turn, provide increased food and cover for wildlife compared to adjacent upland areas. Riparian areas represent a relatively small proportion of the Kettle River watershed, but are used by a broad range of wildlife species, including a number that are dependent on these areas.

Wildlife such as beavers, turtles and toads live in water for much or key portions of their lives, and use riparian areas for feeding or breeding. Other species such as moose, coyote, and mink are opportunistic users of riparian areas. Large animals, such as ungulates, bears and wolverines, and badgers have wide-ranging territories; and often travel along riparian corridors during diurnal (between foraging and bedding sites) and/or seasonal migrations (moving from summer ranges to winter ranges). Since riparian areas include high quality cover, food and water, riparian territories are heavily used by some small-range species such as rodents and small birds.

Key listed species that are known to depend on the riparian areas of the Kettle River watershed include the red-listed Lewis woodpecker, Western screech owl, and Tiger salamander; and the blue-listed Spadefoot toad, and western rattlesnake (Tedesko, pers. comm. 2011). Bobolinks (blue list) utilize wet meadows in the Grand Forks area (Luszcz, pers. comm. 2011). Although there is no species-specific information regarding Kettle River watershed bat populations, they are known to inhabit and depend on the riparian areas within the watershed (Tedesko pers. comm. 2011). Outside of riparian areas, there is little published information on wetlands for the watershed.

3.8 FISHERIES RESOURCES

3.8.1 Species and Stocks Present

There have been 39 fish species identified in the Kettle River watershed, of which 30 are native species and nine were introduced (Ministry of Environment, 2011a); (Appendix D, Table D-1). Oliver (2001) provides a thorough review of the species present and their distributions throughout the main sub-basins.

While the watershed is currently managed for the benefit of wild stocks, stocking of fish has occurred over the past 100 years, with most stocking of rainbow trout, with lesser amounts of brook trout, kokanee and cutthroat trout and single stocking records for brown trout, lake trout, longnose sucker, perch, and redside shiner (Ministry of Environment, 2011a). Appendix D includes a list of the date range, frequency, and species stocked for each applicable watercourse within the watershed (Appendix D, Table D-2). The only stocking that is currently done in the watershed on the B.C. side of the border is of a few lakes. The main Kettle River and tributaries are not stocked.

3.8.2 Species of Management Interest

The fisheries management objectives for the Kettle River are to conserve and restore wild fish stocks and their habitat; and to improve the quality of angling and ensure a recreational fishery for future generations.

The Kettle River watershed supports several important fish stocks including rainbow trout, mountain whitefish, and eight species at risk, two of which are provincially red-listed[3] (speckled dace and Umatilla dace) and six are provincially blue-listed[4] (westslope cutthroat trout, cutthroat trout, bull trout, chiselmouth and shorthead and Columbia sculpin) (CDC 2008). Westslope cutthroat trout and shorthead and Columbia sculpin are all listed as “Special Concern” under Schedule 1 of the federal *Species at Risk Act*, while speckled dace are federally listed as “Endangered”.

The recreational fishery in the Thompson/Okanagan and Kootenay regions is an important economic driver in the region, generating millions of dollars in spending by anglers (T. White, Pers. Comm., 2012). The Kettle River provides one of the few river fishing opportunities in the Boundary region, with the focus of fishers being on large (sometimes >50 cm length) fluvial rainbow trout.

Rainbow trout and mountain whitefish are the main species of interest for the B.C. government’s Fisheries Program and have been the focus of the majority of the studies and reclamation efforts in the watershed to date. Numerous studies have been conducted to assess factors limiting wild trout production. Introduced char (brown and brook trout) are also important parts of the fishery in some parts of the watershed, but are a lower management priority than the native species.

Westslope cutthroat trout are present in the Kettle River watershed below Cascade Falls and were introduced into three headwater lakes in the Granby River sub-basin, but are not major components of the sport fishery nor are they the focus of management planning.

The Kettle River is the only watershed in Canada with speckled dace, with a recent detailed assessment indicating that the species is abundant in the watershed (estimated population of 940,000) (Batty 2010). It is also widely distributed in the western United States. The closely related Umatilla dace’s distribution in Canada is limited to the short section of the Kettle River downstream of Cascade Falls. Batty (2010) found speckled dace in a broad range of habitats (i.e. water depths, velocities and substrate sizes), but identified a preference for slow, shallow habitats. No habitat constraints in the Kettle River have been confirmed for this species.

The Umatilla dace is endemic to the Columbia River basin, including the Kettle River downstream of Cascade falls. To date, sampling efforts for Umatilla Dace have provided no indication of abundance or population size. Qualitative assessments suggest that Umatilla Dace remain present where they were historically reported. The greatest identified threats to this species within its Canadian range are altered flow regimes related to hydropower projects and flow extraction (COSEWIC 2010a).

[3] Red-listed species are those indigenous species, subspecies or ecological communities that have, or are candidates for Extirpated, Endangered, or Threatened status in British Columbia.
[4] Blue-listed species are those indigenous species, subspecies or ecological communities that are particularly sensitive or vulnerable to human activities or natural events. Blue-listed taxa are at risk, but are not Extirpated, Endangered or Threatened.

Little is known about population trends for chiselmouth in BC. They are found in dry interior basins of the Fraser and Columbia Rivers. Within British Columbia their distribution is limited to warmer than average lakes and streams (Pearson and Healey 2012).

There have been no empirical population estimates of Shorthead Sculpin within Canada, but available data support the notion that this species is locally abundant throughout most parts of its restricted Canadian range; although the Canadian portion of the Kettle River population (downstream of Cascade Falls) is apparently the smallest in Canada and the most likely to face impacts from high water temperatures (COSEWIC 2010b).

Columbia sculpin is endemic to the Columbia River basin. Most populations in large rivers tributary to the Columbia, such as the Kettle River, appear to be stable. Within the Kettle River, this species is found only downstream of Cascade Falls.

3.8.3 Sportfish Habitat and Survival Constraints

This section contains a summary of the identified habitat and survival constraints to the key sport fish in the watershed, especially in the lower watershed. The Habitat Conservation Trust Fund (HCTF) is currently funding a three-year study to identify thresholds for regulation and closure of the fishery; determine minimum instream flow thresholds for fish and aquatic life; and specify operational strategies to protect fish and fish habitat during critical low flow periods. This project will be completed in 2013 and will identify minimum instream flow needs for fish and fish habitat, for use in water use planning.

In recent decades there has been a deterioration of the Kettle River sport fish (rainbow trout and mountain whitefish) fishery due to the decreasing abundance and size of sport fish present (Oliver, 2001; Andrusak, 2009). These declines have been attributed to interactions between natural and anthropogenic factors; chiefly seasonal low flow, high water temperatures, decreased habitat availability, and over-fishing. No single factor appears to be driving the decline in fish numbers and size, rand it is their combined effect that is influencing adult survival. Oliver (2001) speculates that available habitat in the Kettle River basin is underutilized due to the cumulative effects of the above factors. A lack of deep water habitats for adult and sub-adult rainbow trout during low flow and high temperature periods appears to be one of the critical factors (T. White, Pers. Comm., 2012).

Other of the species of management concern are also sensitive to the above noted natural and anthropogenic factors; although some, such as the dace are less sensitive to water temperature than are salmonids.

Flow

River flows affect the availability of habitat by altering the water depth, velocity, wetted area and other physical conditions that influence fish habitat. When flows are critically low, reductions in water quality, habitat capability, and food production can occur (McPhail, 2007). For all life stages of fish there are extreme high and low flow conditions that limit the availability of desirable habitat. The low flow conditions present in the Kettle River during late summer through winter in many years result in a low abundance of habitat. Fish kills in the river have been reported in 1991, 1992, 1998, 2003, 2006 and 2009, during particularly low flow periods. An assessment of the potential effects of low flows on rainbow trout parr rearing habitat has been conducted since 2010 and includes some consideration of speckled dace rearing habitat (Epp and Andrusak 2011, 2012).

Based on mean monthly flows (Appendix C), the lowest flows of the year generally occur in September, with slightly higher flows in August and through the winter. Although the effects of low flows in the Kettle have been most studied during the summer, the low flows that occur in winter are likely to affect fish survival as well (Oliver, 2001; Epp & Andrusak, 2011).

An analysis of rainbow trout parr rearing habitat at selected locations indicated that wetted habitat availability is most suitable at flows of about 20% of the long term mean annual discharge (% MAD), with most of the wetted habitat still available and of reasonable quality at 10% MAD (Epp & Andrusak, 2011). At flows less than 10% MAD parr rearing habitat availability and quality appear to decline rapidly (Epp & Andrusak, 2011).

A more thorough discussion of low flow effects on fish habitat and instream flow needs is included in upcoming Section 4.3.6.

Water Temperature

Epp and Andrusak (2011) examined water temperatures in the Kettle River and found water temperatures in late July and August as high as 24°C, which is high enough to cause sub-lethal and lethal effects in some fish. Such effects may include progressive decrease in swimming ability, decreases in digestive and metabolic capabilities, lowered tolerances to oxygen debts, decreases in growth rates, and decreased egg viability (Beitinger, Bennett, & McCauley, 2000; Brett, 1969).

It should be noted that periods of high water temperatures usually coincide with annual periods of low flow; however fluctuations in water temperature do not correlate with the changes in flow during this low flow period, rather with changes in air temperature (Epp & Andrusak, 2011). However, in early summer there is sufficient flow to suppress the effects of high air temperatures (Epp & Andrusak 2012).

Habitat Capability

In addition to the potential effects of low flows on habitat, the presence of extensive shallow glides that dominate some river reaches reportedly affects habitat capability in the Kettle River (Oliver, 2001). These shallow habitats are not suitable for adult trout holding during the summer, when deep pools provide critical habitat. The lack of habitat diversity has been related to the low abundance and uneven distribution of large woody debris (LWD), which can contribute to the creation of deep pools. Pools provide velocity and temperature refuges and overhead cover, and can be an important source of particulate organic matter used by primary producers. The clearing of riparian areas for logging and agricultural uses has decreased large woody debris accumulations within the Kettle watershed, which has had adverse effects on the complexity of the stream habitats (Slaney at al. 2001).

Adult Survivorship

Each of the above variables may contribute to the low survivorship of adult fish within the Kettle watershed fisheries. Low flows result in less physical space for rearing; high temperatures decrease fish survivorship and fecundity; and a lack of high quality physical adult habitat may result in departure of some adult fish and reduced growth and/or survival of others. In addition, mortality due to fishing reduces the proportion of larger, more fecund, adults in the population. Oliver (2001) identified skewed proportions of both older and younger age classes of rainbow trout that may reflect the effects of fishing. Oliver (2001) recommends that management goals for the fishery be realistic, considering the identified productivity constraints on the population.

The relative importance of each of the identified factors has yet to be quantified, although fish regulations have been modified to reduce the mortality of adult rainbow trout in some sections of the river and instream works have been constructed to improve adult holding habitat in some areas.

3.9 LAND USE AND COMMUNITIES

3.9.1 Agriculture

Agriculture is an important component of the economy of the Kettle River watershed. According to the 2011 Agricultural Census of Canada, the total area of farms that is planted in crops is 5,040 ha in Areas D and E of RDKB (Statistics Canada 2012). (Note: the watershed boundaries and the RDKB boundaries are not the same, but the agricultural areas in the watershed are almost all within these two Areas). Cattle ranching is the largest agricultural activity based on the area of crop land, with a significant portion of the agricultural land in alfalfa, alfalfa mixtures, or hay (Table 3-4).

There were approximately 7,800 cows and calves in the watershed in 2011, compared to 960 sheep and lambs, 680 horses, and 130 pigs. These totals are all less than what was reported in the 2006 census. Average farm sizes increases moving from east to west. The average farm size in 2011 is 46 ha in Area D and 242 ha in Area E.

Much of the agriculture in the Kettle River watershed depends on irrigation. Table 3-4 shows the areas in Area D and E that are irrigated for hay and pasture, field crops, fruits, and vegetables compared to all forms of agriculture and the entire RDKB. The total irrigated area in Areas D and E was 2,674 ha in 2011, down from the 3,050 ha reported in the 2006 census. In Area D (Rural

Grand Forks), hay/pasture accounts for 80% of 2011 irrigated land, field crops 12%, and other types of agriculture 8%. In Area E (Boundary Country) hay and pasture makes up 94% of the irrigated land, with the remaining 6% distributed among a variety of crops.

3.9.2 Forestry

The commercial forest industry has been operating in Kettle River watershed since the late 1800s and early 1900s; today, it is one of the main industries within the area. The watershed includes two neighbouring Timber Supply Areas (TSA). The northwest corner of the watershed is within the Okanagan TSA; the remainder is within the Boundary TSA (Ministry of Environment, 2011b). In addition to a number of small licensees, woodlot owners, and other types of forest licensees, there is one Timber Farm Licence (TFL8) within the watershed, which is held by International Forest Products Ltd (Interfor) (Boyce, 2009).

TFL8 is divided into two blocks, both of which occur within the Boundary Forest District. Block 1 (or 'south block') north of Greenwood, and block 2 (or 'north block') in the Trapping Creek and Carmi Creek drainages north of Beaverdell. Combined, the Allowable Annual Cut (AAC) for the blocks is 186,000 cubic metres per year (Boyce, 2009).

3.9.3 Mining

Early development within the Kettle River watershed was the direct result of the mining industry. In the 1890s mining efforts were focused on two key areas within the Valley, Lightning Peak and Mount Franklin (Ministry of Energy and Mines 1997). The demands of the mining and logging industries soon led CP rail to build the Kettle Valley Railway (KVR). Construction of the KVR was completed in 1915. Although its importance and use deteriorated over time, sections remained active through the next half century. The final section of the KVR was deactivated in the late 1980s.

As of autumn 2011 there were over 1,300 mineral claims, and approximately 150 placer claims issued for the watershed. Based on a search of the Mining Association of B.C. web site and the 2011 B.C. Mines and Minerals Overview (Britton et al. 2011), there are only three operating mines, all of which are quarries for industrial minerals:

- Mighty White Dolomite Ltd. – Rock Creek (limestone mining and quarrying)
- Roxul (West) Inc. – Winner (gabbro for insulation)
- Imasco Minerals Inc. – Lime Creek (limestone quarry)

No prospective mines are rated as being in advanced exploration or are currently going through a formal environmental assessment and permitting process (Mining Association of B.C.) However, there are five mine development projects that are well advanced. They are the Greenwood Gold

Table 3-4
Agricultural crop and irrigation areas in 2011 census – Areas D and E

Crop	Statistic	Area D	Area E	RDKB Total (all 5 areas)
Land in crops	Total farms	105	119	251
	hectares	1.515	3,925	5,716
Alfalfa & Alfalfa Mixtures	farms reporting	53	75	139
	hectares	580	2,095	2,803
Other tame hay	farms reporting	35	39	84
	hectares	685	1,309	2,131
Vegetables	farms reporting	16	11	31
	hectares	14	7	23
Fruit, berries, nuts	farms reporting	14	10	31
	hectares	17	10	35
Irrigation				
Irrigated Hay & Pasture	farms reporting	68	74	155
	hectares	650	1,753	2,530
	% of all irrigation	80%	94%	84%
Irrigated Field Crops	farms reporting	14	7	23
	hectares	97	X	155
	% of all irrigation	12%	-	5.5%
Vegetables	farms reporting	13	5	20
	hectares	17	X	21
	% of all irrigation	2.1%	-	0.8%
Fruit	farms reporting	12	7	24
	hectares	13	7	23
	% of all irrigation	1.6%	0.4%	0.8%
Other irrigated	farms reporting	4	6	12
	hectares	32	X	83
	% of all irrigation	4.0%	-	3.0%
All Irrigation	farms reporting	94	93	209
	hectares	808	1,866	2,812
	% of all irrigation	100%	100%	100%

Source: Statistics Canada (2012). x – Details suppressed for privacy reasons.

project (Grizzly Discoveries Ltd.), Greenwood-Wild Rose gold-silver-copper project (Golden Dawn Minerals), GK gold project (Bitterroot Resources Ltd.), Beaverdell Silver property (Molycor Gold Corp.), and the Eholt copper-gold project (Open Gold Corp.) (Britton et al. 2011).

3.9.4 Recreation and Conservation

The Kettle Valley Watershed entirely encompasses two relatively large Provincial Parks, which are the Granby Provincial Park (40,845 ha), and the Gladstone Provincial Park (39,387 ha)(Ministry of Environment, 2011b). It also contains portions of both the Myra-Bellevue (7,829 ha) and Graystokes (11,958 ha) Provincial Parks. Other protected areas within the watershed include the Kettle River Recreational area, the Big White Ecological Reserve, and seven minor parks, most of which are along the highways in the southern parts of the valley (BC Parks, 2011). The majority of the Crown land base outside of private land and the protected areas is included in licensed Guide-Outfitter areas. Hunting is popular with both local people and visitors.

Recreational fishing within the Kettle Valley has been very popular for many years (see Section 7.0). The Kettle and West Kettle provide low gradient, meandering areas, which are otherwise rare within the B.C. Interior (Andrusak, 2008). Furthermore, access to these areas and to Christina Lake is readily available, from both Highway 3 and 97. Older literature and opinion within the angling community is that the Kettle once supplied “good fishing”, however no reliable documentation of this has been found (Andrusak, 2009).

Other recreational activities that occur on Crown Land include snowmobiling, off-road vehicle use, hiking, horseback riding, camping, cross-country skiing, alpine skiing (at Big White in Area E), and general touring on resource roads. Paddlers frequent the Kettle, West Kettle, and Granby Rivers.

3.9.5 Communities and Population

The main communities in the watershed and their populations from the 2011 Canadian census are:

- City of Grand Forks – 3,985 (4,036 in 2006)
- City of Greenwood – 708 (625 in 2006)
- Village of Midway – 674 (621 in 2006)
- Area C, Christina Lake including the unincorporated village of Christina Lake – 1,391 (1,435 in 2006)
- Area D, Rural Grand Forks – 3,187 (3,176 in 2006)
- Area E, Boundary Country including Bridesville, Rock Creek, Beaverdell, and Westbridge – 1,970 (2,234 in 2006).

The total permanent population of the Canadian part of the watershed is about 11,920 people, down slightly (1.7%) from 12,130 in 2006. In the summer this is bolstered by lakeside cabin users, especially on Christina Lake. In the winter the Area E population is increased by the residents and visitors to the Big White and Mount Baldy ski resorts.

BC Stats is projecting small population increases for the watershed area for the next 10 years (BC Stats 2011a). The combined population of the Grand Forks and Kettle Valley Local Health Areas[5] is projected to grow by 117 people between 2011 and 2016 (2%) and by 390 people between 2016 and 2021 (3%) (Table 3-5). A significant portion of the growth is expected to come from retirees. In 2010 about 22% of the population in RDKB was 65 years old or older. In 2036 that figure is projected to rise to about 36% (BC Stats 2011b).

At present, there are no reports with projected changes in economic development activities that directly correlate to increased demand for water (Andison, pers. comm. 2012). As outlined in Section 3.9.5, there are several mining properties in development but they have not entered the formal regulatory process for new mines. The 2011 Agricultural census indicates a slight decline in agricultural activity since 2006, but this may reflect normal fluctuations in markets rather than a long term trend. Part 2 of the Watershed Management Plan should include development of a number of growth scenarios to then be assessed for effects on water demand (e.g. no growth, the best estimate of growth from BC Stats, and double the best estimate).

Table 3-5
Population projections 2016 and 2021: Grand Forks and Kettle Valley Local Health Areas

Year	Grand Forks Health Area	Kettle Valley Health Area	Total	Percent increase from previous
2011	8,905	3,726	12,631	-
2016	9,088	3,790	12,878	2.0%
2021	9,387	3,881	13,268	3.0%

3.10 AMERICAN STUDIES ON THE KETTLE RIVER WATERSHED

The American portion of the Kettle River watershed is completely located within Washington State. As in Canada, the American Kettle has important ecological values and is a source of water for agriculture and small communities. In 1995, faced with more than 50 pending applications for new water rights (the equivalent of water licences in B.C.), the Washington Department of Ecology (WDOE) commissioned an Initial Watershed Assessment for the Kettle watershed (Dames and Moore/Cosmopolitan Engineering 1995). The watershed is called Water Resources Inventory Area 60 (WRIA 60) for administrative purposes. That 1995 report found that:

[5] BC Stats and Statistics Canada use different spatial units for sub-Regional analyses, which is why the 2011 population estimates for the watershed vary slightly.

- Irrigated agriculture and domestic use accounted for most of the out-of-stream use of water, with heaviest use in summer.
- About 10% of the water allocation was from groundwater. Unlike B.C., a permit is needed in the U.S. to withdraw groundwater.
- As of 1995, there were 634 water rights permits in the basin; 514 for surface water and 120 for groundwater, totalling 3.2 m^3/s (114 cfs).
- Water quality general met State water quality standards, except for water temperature in the lower reach (after the river flows out of Canada for the last time). Non-point source water quality degradation was noted in some places.
- Slight overall decreases in river flows were noted over the period since the 1950s.

In 2000 a consortium of U.S. Federal agencies completed an Environmental Impact Statement (EIS) that compared three alternatives for managing federal lands and water resources in the Interior Columbia Basin, including the Kettle River watershed (USDA et al. 2000). The EIS includes a description of the existing environment, a comparison of the three alternatives, assessments of the environmental, social and economic impacts of each alternative, and the recommended decision. The selected alternative (S2) was chosen because it was judged to be the best strategy for restoring the health of forest, rangeland, and the aquatic-riparian-hydrologic ecosystems in the study area.

In 2006 the WDOE established the Office of the Columbia River (OCR) to “aggressively develop water supplies for instream and out-of-stream uses” including permitting new water rights, securing water for drought relief, and managing water for instream flows to benefit fish. In 2011 the OCR, working with Washington State University, completed the Columbia River Long-Term Water Supply and Demand Forecast (WDOE 2011). The Kettle River (WRIA 60) is one of the sub-basins that were forecasted. The report concluded that:

- Both municipal/domestic and irrigation demands are quite small in WRIA 60.
- Municipal demand is forecast to increase by 38% by 2030 but the total municipal demand is still considered modest.
- By 2030, despite climate change effects, the unregulated tributary supply generated within the Washington State portion of the watershed is projected to be adequate.
- *Upstream (i.e. Canadian) portions of the watershed are expected to continue to provide water supply, but demands in Canada could affect that supply* (emphasis added).
- Irrigation demand for water is projected to be well within the available supply in 2030.
- About 26% of the current and 2030 projected irrigation demand is from agricultural operations within 1.6 km of the Kettle River main stem.
- Only one fish species listed under the U.S. Endangered Species Act, Bull trout, is potentially present in the U.S. Kettle River watershed, but it is not known for certain whether it spawns or rears there.

Additional discussion on the implications of water demand in the U.S. for the Canadian portion of the watershed is contained in Section 4.0.

4 WATER QUANTITY – SURFACE WATER

4.1 Water Licences

4.1.1 Summary of Existing Licences

A total of 994 current licences (at 827 points-of-diversion) have been issued on streams, springs, and lakes within the entire Canadian portion of the Kettle River watershed (Map 1; Table 4-1).

Table 4-1 Water licence summary of the Canadian portion of the Kettle River watershed

Sub-basin	No. Water Licences	No. of Points of Diversion	Licensed Offstream Volume (ML)	Licensed Storage Volume (ML)	Licensed Conservation Volume (ML)
1	89	71	8,106	5,997[a]	580
2	96	84	6,193	265[b]	31
3	278	270	18,560	896[b]	n/a[c]
4	136	113	4,365	125	697
5	18	17	440	n/a[c]	n/a[c]
6	87	67	4,978	3.7	n/a[c]
7	279	192	11,523	64[b]	44
8	11	13	34	n/a[c]	n/a[c]
Total	**994**	**827**	**54,199**	**7,351**	**1,352**

Notes:

a. Licensed storage supports irrigation and waterworks licences. Note that the Southeast Kelowna Irrigation District (SEKID) holds 5,240 ML of the total licensed volume for storage purpose on waterbodies within the West Kettle River watershed; however, the licensed storage occurs within SEKID's reservoirs within the Okanagan Basin;
b. Includes the water use purpose "ponds"; and
c. n/a = not applicable; no licences have been issued for conservation or storage purposes.

Licences have been issued for off-stream uses, including domestic, irrigation, waterworks, stockwatering, enterprise, mining, snow making, and processing purposes, as well as for storage and conservation purposes. For most off-stream use licences (i.e. domestic, waterworks), the period of use is from January to December, while for the majority of irrigation licences, the period of use is from April to the end of September. A summary of individual licenses for each sub-basin is provided in Table B-1 of Appendix B.

In B.C. the licensed volumes are reported using a variety of units based on their historical application (e.g. acre-feet for irrigation). For consistency, this report has converted all units to megalitres per year (ML/yr). One ML is one million litres or 1,000 m^3 (or 220,000 Imperial gallons). The tables and text just use ML for simplicity, but readers should be aware that the values are the annual licensed volumes.

Current surface water licensing[6] and water use data for the United Stated portion of the Kettle River watershed is difficult to obtain and many data sources tend to be scattered in many places. However, the report on the Kettle River watershed (United States portion only) by Dames & Moore Inc. and Cosmopolitan Engineering Group (1995) provided useful water licence information and data. In 1995, a total volume of 46,956 ML was licensed on streams, springs, and lakes within the United States portion of the Kettle River watershed (to the confluence with the Columbia) for off-stream uses including domestic, irrigation, stockwatering, commercial and industrial, fire protection, railway, and other. However, assuming that the licensed volumes have not changed since 1995, the total surface water licensed volumes[7] for the four portions of the Kettle River watershed located in the United States are estimated as follows:

- 463 ML - the portion of Myers Creek upstream of the Midway International Boundary (Sub-basin #3;
- 24,417 ML - the portion between the Midway and Grand Forks International Boundaries (Sub-basin #5);
- 43 ML - the portion between the Grand Forks and the Cascade International Boundaries (Sub-basin #7); and
- 3,712 ML - the portion between the Cascade International Boundary and the confluence of Deep Creek (Sub-basin #8).

This totals 28,635 ML compared to 54,199 ML in Canada (Table 4-1). On an area basis, the Canadian surface licences average 7.0 ML/km^2 while the U.S. surface water rights average 10.8

[6] Surface water licenses are referred to as surface water rights in the United States.
[7] Surface water rights for the Kettle River watershed were not reported by Dames & Moore & Cosmopolitan Engineering Group (1995) for the sub-basins defined in this investigation. Accordingly, the spatial representation of the surface water rights provided by Dames & Moore and Cosmopolitan (1995) was used to estimate the percentage of the total licensed volume for each sub-basin. It was then assumed that 93% of the surface water rights were associated with irrigation purposes, while 3% were associated with commercial purposes, and 4% with domestic purposes, as reported by Dames & Moore and Cosmopolitan Engineering Group (1995).

ML/km^2. The lower average for Canada reflects the large portion of the watershed without significant agricultural activity.

4.1.2 Agricultural Licences

A total of 437 water licences have been issued in the Canadian portion of the Kettle River watershed for irrigation purposes (supported and unsupported by storage), for a total volume of 50,428 ML (Table B-1 of Appendix B). The largest licensed water use sector in each sub-basin is irrigation, with Residual Area #1 (sub-basin #3) having the highest licensed volume of 13,724 ML (supported and unsupported by storage).

Southeast Kelowna Irrigation District (SEKID) is the water purveyor that holds the largest water licenses in Sub-basin #1 for a total of 9,557 ML; however, approximately 5,240 ML of that total is supported by storage licences. Currently, the only water source that is diverted from the Kettle River watershed into the Okanagan Basin is on Stirling Creek. The diversion occurs during freshet from October to June 15 and stored in reservoirs in the Okanagan Basin. Thereafter, water is diverted for the purpose of irrigation. Other water purveyors within the watershed with irrigation licences include the City of Grand Forks, Grand Forks Irrigation District, SION Improvement District, Covert Irrigation District, and Sutherland Creek Waterworks District. Please note that “residential lawn and garden” and “watering” purposes were included under irrigation purposes (Table B-1 of Appendix B); however, their licensed volumes are relatively small (35.5 ML for residential lawn and garden and 233 ML for watering).

In addition to irrigation, a total of 56 stockwatering licences are present within the watershed equating to 102 ML (Table B-1 of Appendix B). Residual Area #1 (Sub-basin #3) contains the largest licensed stockwatering volume, which is held by the Ministry of Forests and Range.

4.1.3 Domestic Licences

A total of 422 domestic water licences have been issued throughout the watershed for a total volume of 9,431 ML (Table B-1 of Appendix B). Of the 422 domestic water licenses, 395 are for domestic purposes (mostly individuals) while the other 27 are issued for waterworks (i.e. water suppliers). However, the total volume licensed for waterworks is much larger than the volume licensed for domestic use (8,906 ML and 525 ML, respectively). The Village of Midway (sub-basin #3) has the largest volume (4,314 ML) licensed for waterworks. Other main water suppliers licensed for withdrawal include the City of Grand Forks, Christina Waterworks District, SION Improvement District, and Sutherland Creek Waterworks District.

4.1.4 Industrial and Commercial Licences

A total of 14 industrial, commercial, and institutional (ICI) water licences have been issued in the watershed for a total volume of 421 ML (Table B-1 of Appendix B). Various ICI purposes include enterprise, snowmaking, institutions, mining, and processing. Of these purposes, the largest volume licensed is for mining processes (335 ML) within the Wild Rose property in the Boundary Creek watershed near Greenwood (Sub-basin #4). This licence is held by a private individual for the processing of gold ore (Caron 2005); however, it is not known if active mining or exploration is still occurring on the Wild Rose property at this time.

4.1.5 Other Licences

Throughout the watershed, a total of 61 water licenses have been issued for conservation, camps, fire protection, ponds, storage, and power purposes for a total volume of 21,737 ML (Table B-1 of Appendix B).

Storage purposes account for the largest licensed volume for a total of 7,351 ML. SEKID holds storage licences in Sub-basin #1 for a total of 5,240 ML to support irrigation demands in the Okanagan Basin, while Big White Water Utility Ltd. is licensed to divert 597 ML for storage purposes. For conservation purposes (e.g. to retain flows for fish), a total of 1,352 ML has been licensed for storage in the Kettle River basin.

In 2007 Powerhouse Developments Inc. was granted a water licence for a total of 2,838 ML for the purpose of power generation on the Kettle River near Cascade, B.C. The "project" was known as the Cascade Heritage Project and was subsequently reviewed by a committee of federal and local governments, and First Nations. In addition, public meetings were held to obtain public input. As a result, a bulk water reserve was created for the Kettle River and its tributaries (Order-in-Council 673, the Province of British Columbia 2006). In summary, the reserve is to ensure that the water rights of the power licence holder (Powerhouse Developments Inc.) are always subordinate to the rights of any water licences for purposes other than power production that may be acquired in the future on the Kettle River or its tributaries. The reserve also includes a provision that Powerhouse Developments Inc. may acquire a water licence for power development; however, it would be subject to the reserve (Note: the Cascade Power Project received a five year extension to its environmental assessment certificate in August 2011. They would have to begin construction by 2016 or the certificate would expire).

In addition to the power licence issued for the Cascade Heritage Project, four licences have been issued for residential power production within the watershed for a total of 8.4 ML.

4.2 Estimates of Actual Water Use – Surface Water

Water records were obtained from the main water suppliers in the Kettle River watershed and organized by supplier and source type (surface water or groundwater). Water use data (for each water supplier's period of record) were converted to annual values (in ML). Table B-2 of Appendix B summarizes the source type, purpose, period of record, and actual water use for the main water suppliers.

4.2.1 Water Supplier Records

Big White Water Utility Ltd. (Sub-basin #1)

Big White ski resort has been using surface water for 48 years since they began operations in 1963. Currently, water operations are managed by Big White Water Utility Ltd. Water is diverted from Trapping and Hallam Creeks between April 1st and June 30th and stored in two reservoirs (Rhonda Lake and Powder Basin). Water is withdrawn from the two reservoirs and gravity fed to domestic and commercial users during the operational season (November to April). Big White Water Utility Ltd. holds surface water withdrawal licences for a total of 659 ML [597 ML for storage to support waterworks offstream purposes, 50 ML for waterworks (unsupported by storage), 8 ML for enterprise, and 4 ML for snowmaking]. The actual annual average water use based on the period of record during 2004 – 2011 is estimated to be 250 ML (or 38% of its offstream licensed volume of 659 ML).

Bridesville Waterworks District (Sub-basin #3)

Water is supplied to the Town of Bridesville by groundwater from one well, where water is pumped to a cistern, and then gravity-fed to domestic users. Pumping volumes are not recorded; consequently, no water use records were available for the study. No water licences are currently held by the district.

City of Grand Forks (Sub-basin #7)

Water is supplied to the City of Grand Forks by groundwater from five main wells, where water is pumped to reservoirs and gravity-fed to users. End uses include domestic, ICI, and irrigation. In addition, winter bleeding occurs (from approximately 5% of connections) and in 2009 it was estimated to be approximately 8% of the total annual water use (Urban Systems Ltd. 2011). The City of Grand Forks currently holds surface water licences for a total of 2,329 ML (2,323 ML for waterworks, 5.0 ML for ponds, and 1.3 ML for irrigation); however, surface water has not been used as a water supply since 1995 when the intake on a small creek was deactivated. The use of the main licences on the Kettle and Granby Rivers stopped in the 1960s or early 1970s, at least 40 years ago.

Of note is the conditional water license used by Pacific Abrasives and Supply Inc., who use 25.4 ML from the Granby River for processing purposes (Bird 2011). The actual annual range of water withdrawal (from groundwater) based on the period of record during 2006 - 2010 is estimated to be 1,765 – 3,513 ML, with an average of 2,639 ML.

City of Greenwood (Sub-basin #4)

Water is supplied to the City of Greenwood and to the neighbouring community of Anaconda by groundwater from three main wells, with domestic and commercial end uses. The City of Greenwood historically held surface water licences on several creeks; however, the licences were abandoned. Only one year (2009) of actual water use (from groundwater) was available for the study, for a total volume of 636 ML, which is based on an engineer's estimate.

Christina Waterworks District (Sub-basin #7)
Christina Lake is the main source of water for the town site at the south end of Christina Lake. Water from the lake is pumped to three reservoirs and gravity-fed to users, with domestic and commercial end uses. Christina Waterworks District holds surface water licences for a total of 621 ML (599 ML for waterworks and 22 ML for residential lawn and garden). The actual annual range of water withdrawal based on the period of record during 2007 - 2010 is estimated to be 282 – 380 ML, with an average of 331 ML (or from 45% to 61% of their licensed volume, with an average of 54%). Christina Waterworks District formerly obtained part of their supply from Moody Creek but has not done so for about five years.

Covert Irrigation District (Sub-basin #7)
Since approximately 1980, groundwater has been the main water source for the Covert Irrigation District. Water is pumped from two main wells and distributed for domestic (to 39 homes) and irrigation (~200 acres) purposes. The Covert Irrigation District holds one surface water licence on July Creek for total of 355 ML for the purpose of irrigation; however, this license has not been used prior to 1980. The actual annual range of water withdrawal (from groundwater) based on the period of record during 2006 - 2010 is estimated to be 106 – 253 ML, with an average of 179 ML.

Grand Forks Irrigation District (Sub-basin #7)
Water is obtained by the Grand Forks Irrigation District from 11 groundwater wells and distributed for domestic and irrigation purposes (domestic use is for 300 homes and is estimated to be 1% of the irrigation demand). The Grand Forks Irrigation District holds surface water licenses for a total of 4,261 ML for the purpose of irrigation; however, these licenses have not been used since 1989 (approximately 22 years). The actual annual range of water withdrawal (from groundwater) based on the period of record from 1995 - 2010 is 2,207 – 3,630 ML, with an average of 2,919 ML.

Mount Baldy Waterworks Inc. (Sub-basin #3)
Mt. Baldy Waterworks Inc. was not able to be contacted during this investigation; however, background information and estimated water use was determined from a report prepared for the utility (Summit 2006). The Mt. Baldy Ski Resort relies on surface water for their daily operations; accordingly, Mt. Baldy Waterworks Inc. holds surface water licences on McKinney Creek for a total of 238 ML (123 ML for storage and 111 ML for waterworks). The estimation of water use for Mt. Baldy Resort by Summit (2006) is for the entire year for a total of 17.4 ML, or roughly 16% of its licensed offstream volume. Mount Baldy Waterworks also has a drilled well that is their primary water source (Unger, pers. comm. 2012), explaining the use of only 16% of their surface allocation.

SION Improvement District (Sub-basin #7)
Since 1967, groundwater has been the main source of water for SION Improvement District. Water is pumped from six main wells to two reservoirs and gravity-fed to users, with domestic and

irrigation end uses. SION Improvement District holds surface water licences for a total of 644 ML (595 ML for irrigation and 49 ML for waterworks); however, the licences have never been used for water withdrawal. The actual annual range of water withdrawal (from groundwater) based on the period of record 2006 - 2010 is estimated to be 1,227 – 1,738 ML, with an average of 1,483 ML.

Southeast Kelowna Irrigation District (SEKID) (Sub basin #1)

SEKID is located in the Okanagan Basin and is one of the five water utilities serving the City of Kelowna. To augment their water supply, SEKID is licensed to withdraw water on some creeks and lakes in the West Kettle River watershed for a total of 9,972 ML (5,240 ML for storage to support irrigation, 4,317 ML for irrigation (unsupported by storage), and 415 ML for waterworks). The diversion of water from the West Kettle River watershed occurs via the Stirling Creek diversion ditch into the Hydraulic Creek watershed (and eventually into McCulloch Reservoir) in the Okanagan Basin. This diversion is licensed to occur from October to June 15 for storage purposes and from April to September for irrigation purposes, but is dependent upon ice conditions within the diversion ditch; therefore, it the diversion generally occurs from April to September (Dobson Engineering Ltd. 2009).

Based on the period of record 2004 – 2008, the actual annual range of water volume diverted from Stirling Creek is estimated to be 1,462 – 3,374 ML, with an average of 2,418 ML (or 15% to 34% of the licensed volume, with an average of 24%) (Dobson Engineering Ltd. 2009).

Sutherland Creek Waterworks District (Sub-basin #7)

Prior to 2007, surface water was the main source of water for Sutherland Creek Waterworks District. Water was withdrawn from Sutherland Creek and stored in two reservoirs and then gravity-fed to users. Sutherland Creek Waterworks District holds surface water licenses on Sutherland Creek for a total of 281 ML (249 ML for waterworks and 32 ML for irrigation). The actual annual range of water withdrawal (from surface water) based on the period of record during 2002 - 2006 is estimated to be 222 – 299 ML, with an average of 264 ML (or from 79% to 107% of its licensed volume, with an average of 94%). From 2007 to present, groundwater has been the main source of water for the district. Water is pumped from two main wells to two reservoirs and then gravity-fed to users. Because 2007 was a transition year, a separation between surface water use and groundwater use is not available. For the period of record 2008 – 2010, the actual annual water withdrawal (from groundwater) is estimated to be 230 – 270 ML, with an average of 248 ML.

Village of Midway (Sub-basin #3)

Prior to 1995, the majority of water supply to the Village of Midway was from privately owned groundwater wells. Since 1996, two main groundwater wells (a summer well and a winter well) have operated to supply domestic, parks, and commercial end users. The actual annual average water withdrawal (from groundwater) for the period of record 1996 - 2010 is estimated to be 391 ML. The Village of Midway holds surface water licenses for a total of 4,314 ML for waterworks.

Prior to 2009, this licensed volume was leased out for irrigation purposes; however, actual water volumes are not available.

Other Water Users

Many individuals hold surface water licences for various purposes throughout the watershed. Since no information is available on actual water use by these licensees, for the purposes of this analysis we have assumed that actual water use is equal to the licensed quantity. However, for the purpose of irrigation, a usage factor of 47.5% was applied, which is based on the average irrigated lands usage factors reported in the 1981 and 2003 agricultural censuses (Aqua Factor Consulting Inc, 2004) (discussed further in upcoming section 4.2.2). This usage factor is similar to what has been documented in the Okanagan Basin (Summit Environmental Consultants 2009) and Nicola River watershed (Summit Environmental Consultants 2007).

4.2.2 Agricultural Census of Canada

As introduced in Section 3.9.1, the Agricultural Census of Canada provides a statistical picture of Canada's farm sector, based on questionnaires that are supposed to be completed by any person responsible for operating a farm or agricultural operation (Statistics Canada 2012). The Agricultural Census of Canada is completed every five years. Information relevant to water planning includes total farm area, the areas in crops, and the total area irrigated by crops.

For the Kettle River watershed, Agricultural Census of Canada information is available for Areas D and E of RDKB. Since much of the agriculture in the Kettle River watershed depends on irrigation from surface and groundwater sources, and the Agricultural Census of Canada data on water use has been used to check the water supplier's records. For example, the comparison of total area irrigated to the total crop lands provides some insight into how actual water use compares to the licensed amount. Therefore, for the 1981-2010 standard period adopted for this study, the ratio of areas under irrigation to the reported crop areas for the RDKB are presented in Table 4-2.

Table 4-2
The ratio of crop land areas under irrigation to reported irrigation areas reported by the Agricultural Census of Canada for the Regional District of Kootenay Boundary.

Year	Ratio of area under irrigation to reported cropland area
1981	0.480
1986	0.493
1990	0.401
1995	0.492
2000	0.449
2006	0.492
2011	0.486

Notes:
a. Ratios from 1981-2000 as reported byAqua Factor Consulting Inc. (2004)
b. 2006 and 2011 ratios calculated from Agricultural Census of Canada statistics

Based on the ratio of areas under irrigation to the reported irrigable areas for the RDKB, Aqua Factor Consulting Inc. (2004) estimated usage factors for areas under irrigation licence adjusted for abandoned or cancelled irrigation licences. For the standard period of this study, usage factors were available for 1981 and 2003 at 50% and 45%, respectively (Aqua Factor Consulting Inc. 2004). These usage factors were used by Aqua Factor Consulting Inc. (2004) to estimate the lands under irrigation; however, for this study, the average usage factor of those two years (i.e. 47.5 %) was assumed to represent the total water use of an irrigation licence (which is similar to the percentage of total crop area that is irrigated from the most recent census of 48.6%)[8]. The

[8] Note that at the time of this report, limited water demand information from the Ministry of Agriculture's Agriculture Demand Model (section 4.2.3) was available (i.e. water demand information for 2003 was only available – the driest year during the standard period). Therefore, it was assumed that the usage factors reported by Aqua Factor Consulting Inc. (2004) provide a reasonable estimate agricultural water use for the standard period. When available, the results from the model can be used to update this estimate.

sensitivity of the resulting estimates of naturalized flow to this single factor is discussed in Section 4.4.2.

4.2.3 Agriculture Demand Model – Ministry of Agriculture

Agriculture Demand Model - Overview

Recently, the Ministry of Agriculture and Agriculture and Agri-Foods Canada completed the initial development of an Agricultural Water Demand Model for the Canadian portion of the Kettle River watershed (van der Gulik *et al.* 2011). The model, which is currently available in draft form, was developed to provide current and future agriculture (including both crop irrigation and livestock watering) water demands on a property by property and total basin basis, similar to the recent Okanagan Water Demand Model that estimates agricultural and all indoor and outdoor water demands in the Okanagan Basin (Summit 2010).

The Agriculture Water Demand Model 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.* 2011). This information was assembled from background information as well as high resolution orthophotos and GIS, and was confirmed by ground surveys in 2010. Land uses (including crop type and method of irrigation) were identified and water demands were estimated at the scale of individual land parcels and finer. Accordingly, the model can provide estimates of water demand for individual crops on a parcel of land, or for an entire watershed, local government jurisdictions, or water supplier areas (e.g. irrigation districts) by summing the demands within those areas.

The Agriculture Demand Model calculates the daily evapotranspiration demand for each parcel using a form of the Penman-Monteith equation. It also computes the existing soil moisture and the daily precipitation, and the irrigation requirement is the leftover demand that can't be met from these two sources. The climate dataset is the key dataset that drives the evapotranspiration calculations. In the Kettle River watershed, a 1961-2006 gridded dataset consisting of cells measuring 500 m by 500 m was created, including temperature (minimum, maximum, and mean) and total precipitation for each day of the year. A detailed description of how the model calculates agricultural water demands is provided by van der Gulik *et al.* (2011).

It is important to note that the Agriculture Demand Model <u>is a mathematical model</u> that <u>estimates</u> irrigation water demand based on climate, land use, soils, and the irrigation systems that are present. By comparison, the estimates of water use in Section 4.2.1 are based on the water suppliers' records of pumping volumes, thereby providing an estimate of actual use in the area serviced by those suppliers. The records and the model should be used together when determining the range of water use, with the model enabling an understanding of where the irrigation water is applied. 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. The model is an improvement over previous estimates, but an inventory of actual use on a sample of farms, ranches and non-farm sites (e.g. golf courses) would be beneficial to test the model and extend the data beyond agriculture.

The Okanagan Water Balance Model developed during Phase 2 of the Okanagan Water Supply and Demand Project linked water demands on the land to extractions from water sources (e.g. streams, lakes and aquifers) by mapping "water use areas" and identifying the source(s) of water supplying each of the delineated areas. This could also be done in the Kettle River watershed to link the model results to the water suppliers' records.

Agriculture Demand Model – 2003 Results

At the time of this report, the Agriculture Demand Model results for the Kettle River watershed were only available for 2003, as it represented the hottest and driest year on record. Van der Gulik *et al.* (2011) indicated that in 2003 for the Canadian portion of the Kettle River watershed, approximately 5.5% of the watershed is considered agricultural lands (both Agricultural Land Reserve (ALR) and other active agricultural land) and that only 9% of the agricultural lands were being irrigated.

The types of irrigable lands reported by the Agriculture Demand Model included alfalfa crops, forage crops, apple orchards, pasture lands, golf courses, turf parks, vegetable crops, plus various others. In total, forage crops including alfalfa and grass made up approximately 85% of all irrigable agricultural lands, somewhat higher than what was indicated in the 2006 census (Section 3.9.1). The total agricultural water demand for 2003 was estimated to be approximately 41,572 ML, including 41,311 ML for agricultural crops and 261 ML for livestock (van der Gulik *et al.* 2011). The Agriculture Demand Model draft report estimated that 62% of water demand was supplied by surface water licences. Based on the 2003 results, it was estimated that 51% of the total volume of irrigation licences was being used [i.e. 25,777 ML (62% of total agricultural demand of the 41,572 ML supplied by surface water) compared to 50,428 ML under irrigation licence (both supported and unsupported by storage)]. This result is slightly higher than the 49% usage factor from the most recent Agricultural Census of Canada information (Section 4.2.2). A further discussion on the implications of the irrigation licence estimate on water use and streamflow naturalization is provided in upcoming Section 4.3.6.

A summary of the Agricultural Water Demand model results for each sub-basin in 2003 is presented in Table 4-3. Reported values are for the total drainage areas above the seven POIs. The total estimated agricultural use, when converted to ML per square kilometres, is relatively similar among the sub-basins (Table 4-3), with the West Kettle watershed indicating the lowest average agricultural use (87% of the overall average of 1,032 ML/km^2) and Granby indicating the highest (115% of average). Again, readers are reminded that the estimates in Table 4-3 are for 2003, the hottest and driest on record, and are not representative of typical use. The Ministry of Agriculture is currently developing estimates for a range of climate scenarios with the model and the data will be available in 2012.

Table 4-3
Selected results from the Kettle River Watershed Agriculture Demand Model - 2003

Point-of-Interest	Drainage Area[1] (km^2)	Total Agricultural Lands[2] (km^2)	Total Lands Irrigated (km^2)	Agricultural Water Use (ML)	Livestock Water Use (ML)	Total Use (ML)	Total Water Use[5] (ML/km^2)
West Kettle River at Mouth (Sub-basin #1)	1898	55.3	4.2	3,740	50	3,790	2.0
Kettle River above West Kettle Confluence (Sub-basin #2)	2221	49.2	5.7	6,300	41	6,341	2.9
Kettle River at the Midway International Boundary (Sub-Basin #3)	5065	309	21.2	21,050	177	21,227	4.2
Boundary Creek at Mouth (Sub-basin #4)	596	47.3	n/a[3]	n/a	n/a	n/a	n/a
Kettle River at the Grand Forks International Boundary (Sub-basin #5)	7783	358	24.1	24,200	180	24,380	3.1
Granby River at Mouth (Sub-basin #6)	2061	49.8	5.3	6,300	15	6,315	3.1
Kettle River at the Cascade International Boundary (Sub-basin #7)[4]	9844	456	39.9	41,300	250	41,550	4.2

Note:
1. Total drainage area includes portions of the sub-basin within the United States;
2. Total agricultural lands (both ALR and other active agricultural land) within the Canadian portion of each sub-basin only;
3. Information was not available at the time of this study;
4. This includes agricultural information for the Canadian portion of Residual Area #4 (Sub-basin #8); and
5. This includes water use for the Canadian portion of the Kettle River watershed only.

4.3 Surface Water Hydrology and Naturalized Flows

This section presents an analysis of the hydrology of the Kettle River watershed. Current monthly flows and "naturalized" flows at the POIs of the adopted sub-basins are presented and discussed. The details of the methodology used to naturalize flows are presented in Appendix C. The major steps were:

- On the basis of the evaluation of available hydrometric records and water use information for the Kettle River watershed, a standard period for the baseline analyses of 1981-2010 (30 years) was adopted;
- After reviewing the Kettle River watershed and considering the locations of hydrometric monitoring stations, eight (8) sub-basins were adopted. The sub-basins and their downstream POIs formed the basis for the streamflow and water use analyses. For the adopted 8 sub-basins net and naturalized flow outputs were developed for seven (7) POIs;
- Compiling, analyzing, and estimating water use and management information in both the Canadian and United States portions of the Kettle River watershed;
- Systematically screening the streamflow data for each POI and filling in data gaps and scaling as required, typically by comparing records to downstream POIs or nearby streams;
- Regulated streamflow records were naturalized by accounting for water held and released from storage, and water extracted and returned upstream of each POI;
- Considering surface water-groundwater interaction in the streamflow data; and
- Summarizing the net and naturalized streamflows and various low flow statistics, total water licensing, estimates of actual water use for each POI.

4.3.1 Streamflow Naturalization Overview

Natural or naturalized streamflows at the POIs of the sub-basins were calculated in to develop a simple water balance model (Section 4.3.2) for each of the sub-basins.

Map 1 and Table 4-4 present the active and discontinued federal government (Water Survey of Canada – WSC) stations in the Kettle River watershed and those within a two kilometre buffer around its boundaries. Assessment of the locations and years of records for the hydrometric stations indicated that the Kettle River mainstem and its tributaries are blessed with relatively good hydrometric data and that many of the stations have very long streamflow records and several stations are still active. These records facilitated the analysis of natural (i.e. measured flow in a non-regulated stream), regulated (i.e. the net flow of a stream including water extractions and storage effects occurring upstream), and naturalized flows (i.e. estimated natural flows by adjusting measurements of regulated flows for the effects of water storage and withdrawal).

Based on available hydrometric records and water use information, we adopted a standard period for the baseline analyses of 1981-2010. This standard period represents a 30-year "normal" period, which can be compared to the most recently published climate "normals" (i.e. 1971-2000) and includes the years for which water use information is available from water suppliers.

Naturalized monthly streamflows at each of the sub-basin POIs were estimated by adding all upstream licensed and actual withdrawals to the recorded regulated flows. To determine upstream withdrawals from each POI, all licensed quantities or estimates of actual water use were compiled and organized for each of the sub-basins and converted to metric units (i.e. ML) (Sections 4.1 and 4.2). A further description of the naturalization process for each sub-basin is provided in Appendix C.

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

1. The total licensed volume is evenly distributed throughout the year for the following purposes: “stockwatering”, “enterprise”, “commercial”, “institutions”, “mining”, and “processing”;
2. For “domestic”, “camps”, and “waterworks” (unsupported by storage) purposes, total annual licensed quantities were distributed based on the 2002-2010 mean distribution of actual domestic (indoor and outdoor) water use obtained from Sutherland Creek Waterworks District, presented in Table 4-5.
3. For “irrigation” (unsupported by storage), “watering”, and “residential lawn and garden” purposes, the annual licensed quantities were distributed based on the 2006-2010 mean distribution of actual irrigation water use obtained from SION Improvement District, presented in Table 4-6. In addition, based on agricultural census information for the Kettle River watershed presented by Aqua Factor Consulting Inc. (2004) (Section 4.2.2), it was assumed that approximately 47.5% of the licensed volume for irrigation was being utilized for all individual license holders (based on the mean usage factors from 1981 and 2003);
4. All storage licences were assumed not to carry over from year to year and that water is withdrawn into storage between October 1 and June 30 for each sub-basin (general licensed dates) based on the distribution of naturalized monthly streamflows for the sub-basin of interest. As the majority of the storage licences are associated with irrigation, it was assumed that 47.5% of the storage volume (used to support irrigation) was actually being diverted, while the maximum storage volume for waterworks purposes was being diverted. As there is limited storage capacity within the Kettle River watershed, all storage diversions were assumed to represent an offstream use (i.e. the stored water is not released back to the river). However, an exception was made for “conservation – stored water” licences, in that water was assumed to be withdrawn into storage between April 1 and June 30 based on the distribution of naturalized monthly streamflows for the sub-basin of interest and that water is released from storage based on the distribution of actual water use for domestic purposes;

Table 4-4 Hydrometric stations in the Kettle River watershed or within two kilometres of the watershed

Station no.	Station name	Status	Lat	Long	Drainage area (km^2)	Years	Period of Record	Regulation Type
08NM240	TWO FORTY CREEK NEAR PENTICTON	**Active**	49.65	-119.40	5	29	1983-2011	Natural
08NM241	TWO FORTY-ONE CREEK NEAR PENTICTON	**Active**	49.65	-119.39	4.5	29	1983-2011	Natural
08NM242	DENNIS CREEK NEAR 1780 METRE CONTOUR	**Active**	49.62	-119.38	3.73	27	1985-2011	Natural
08NN002	GRANBY RIVER AT GRAND FORKS	**Active**	49.04	-118.44	2050	98	1914-2011	Natural
08NN003	WEST KETTLE RIVER AT WESTBRIDGE	**Active**	49.17	-118.97	1870	98	1914-2011	Regulated
08NN012	KETTLE RIVER NEAR LAURIER	**Active**	48.98	-118.22	9840	83	1929-2011	Natural
08NN013	KETTLE RIVER NEAR FERRY	**Active**	48.98	-118.77	5700	84	1928-2011	Natural
08NN015	WEST KETTLE RIVER NEAR MCCULLOCH	**Active**	49.70	-119.09	230	53	1949-2011	Natural
08NN019	TRAPPING CREEK NEAR THE MOUTH*	**Active**	49.56	-119.05	144	47	1965-2011	Natural
08NN023	BURRELL CREEK ABOVE GLOUCESTER CREEK	**Active**	49.59	-118.31	224	38	1974-2011	Natural
08NN026	KETTLE RIVER NEAR WESTBRIDGE	**Active**	49.23	-118.93	2150	37	1975-2011	Regulated
08NN028	LOST HORSE CREEK NEAR CHRISTIAN VALLEY	**Active**	49.37	-118.85	28.5	14	1998-2011	Natural
08NM011	HYDRAULIC CREEK AT OUTLET OF MCCULLOCH RESERVOIR	Discontinued	49.78	-119.18	-	68	1919-1986	Regulated
08NM068	HOWARD CREEK NEAR PENTICTON	Discontinued	49.61	-119.35	-	1	1930	Regulated
08NM207	MYRA DITCH BELOW KLO CREEK	Discontinued	49.75	-119.27	-	13	1973-1985	Regulated
08NM212	STIRLING CREEK DIVERSION TO MCCULLOCH RESERVOIR	Discontinued	49.73	-119.22	-	8	1977-1984	Regulated
08NM213	MCCULLOCH RESERVOIR AT MCCULLOCH DAM	Discontinued	49.78	-119.18	-	14	1973-1986	Regulated
08NM215	FISH LAKE AT THE OUTLET	Discontinued	49.81	-119.19	-	5	1973-1977	Regulated
08NM216	BROWNE LAKE RESERVOIR ABOVE THE DAM	Discontinued	49.82	-119.19	-	5	1973-1977	Regulated
08NM217	LONG MEADOW LAKE RESERVOIR ABOVE THE DAM	Discontinued	49.81	-119.17	-	5	1973-1977	Regulated
08NN001	BOUNDARY CREEK AT GREENWOOD	Discontinued	49.08	-118.69	479	68	1913-1980	Regulated
08NN004	KETTLE RIVER AT KETTLE VALLEY	Discontinued	49.06	-118.94	4560	9	1914-1922	Natural
08NN005	KETTLE RIVER AT CARSON	Discontinued	49.00	-118.50	6730	10	1913-1922	Natural
08NN006	KETTLE RIVER AT CASCADE	Discontinued	49.02	-118.21	8960	47	1916-1962	Regulated
08NN007	ROCK CREEK NEAR ROCK CREEK	Discontinued	49.06	-119.00	280	64	1921-1984	Regulated

Table 4-4 (Continued)

Station no.	Station name	Status	Lat	Long	Drainage area (km^2)	Years	Period of Record	Regulation Type
08NN008	PASS CREEK NEAR GRAND FORKS	Discontinued	49.19	-118.47	-	1	1921	Natural
08NN009	DAN O'REA CREEK NEAR GRAND FORKS	Discontinued	49.03	-118.37	7.77	1	1921	Natural
08NN010	MYERS CREEK AT INTERNATIONAL BOUNDARY	Discontinued	49.00	-119.02	207	55	1923-1977	Regulated
08NN011	BOUNDARY CREEK NEAR MIDWAY	Discontinued	49.00	-118.76	593	49	1929-1977	Regulated
08NN014	CHRISTINA CREEK AT OUTLET OF CHRISTINA LAKE	Discontinued	49.04	-118.21	492	57	1944-1990	Natural
08NN016	SUTHERLAND CREEK NEAR FIFE	Discontinued	49.07	-118.19	88.1	14	1960-1973	Natural
08NN017	CHRISTINA LAKE NEAR GRAND FORKS	Discontinued	49.04	-118.21	-	2	1914-1915	Natural
08NN018	JULY CREEK NEAR GRAND FORKS	Discontinued	49.01	-118.54	45.6	10	1965-1974	Regulated
08NN020	TRAPPING CREEK AT 1220 M CONTOUR	Discontinued	49.67	-118.91	22.8	12	1970-1981	Natural
08NN021	MOODY CREEK NEAR CHRISTINA	Discontinued	49.05	-118.27	13.5	14	1971-1984	Natural
08NN022	WEST KETTLE RIVER BELOW CARMI CREEK	Discontinued	49.48	-119.11	1170	24	1973-1996	Natural
08NN024	KETTLE RIVER NEAR GRAND FORKS	Discontinued	49.02	-118.41	8830	18	1974-1991	Natural
08NN025	WEST KETTLE RIVER AT BEAVERDELL	Discontinued	49.43	-119.09	1190	3	1974-1976	Natural
08NN027	BEAVERDELL CREEK NEAR BEAVERDELL	Discontinued	49.49	-119.03	-	9	1976-1984	Regulated

Table 4-5
Domestic (indoor and outdoor) monthly water use distribution for the Kettle River watershed

Month	Usage (% of annual)	Month	Usage (% of annual)
January	3.6	July	23.3
February	3.3	August	21.6
March	2.9	September	10.4
April	3.8	October	4.3
May	8.8	November	2.5
June	12.7	December	2.8

Table 4-6
Irrigation monthly water use distribution for the Kettle River watershed

Month	Usage (% of annual)	Month	Usage (% of annual)
January	0	July	32.0
February	0	August	29.1
March	0	September	13.0
April	0.9	October	2.4
May	10.9	November	0
June	11.7	December	0

5. All storage licences were assumed not to carry over from year to year and that water is withdrawn into storage between October 1 and June 30 for each sub-basin (general licensed dates) based on the distribution of naturalized monthly streamflows for the sub-basin of interest. As the majority of the storage licences are associated with irrigation, it was assumed that 47.5% of the storage volume (used to support irrigation) was actually being diverted, while the maximum storage volume for waterworks purposes was being diverted. As there is limited storage capacity within the Kettle River watershed, all storage diversions were assumed to represent an offstream use (i.e. the stored water is not released back to the river). However, an exception was made for “conservation – stored water” licences, in that water was assumed to be withdrawn into storage between April 1 and June 30 based on the distribution of naturalized monthly streamflows for the sub-basin of interest and that water is released from storage based on the distribution of actual water use for domestic purposes;
6. All instream licences (i.e. power and conservation) were distributed based on the naturalized monthly distribution of the sub-basin the licence is located in;
7. Surface water licences for the relevant sub-basins within the United States were estimated following the surface water rights information provided by Dames & Moore Inc. and Cosmopolitan

Engineering Group (1995). Only offstream licences were considered and similar to Canadian water licences, all surface water rights associated with irrigation were assumed to be using 47.5% of their licensed volume; and

8. The records of mean monthly actual water use obtained and estimated for the major water purveyors (Section 4.2) were used in place of their licensed amounts to provide the most accurate estimate of monthly withdrawals from each sub-basin for the standard period. In addition, for all major water purveyors utilizing a groundwater source, the use of groundwater was not separated from the use of surface water on the assumption that the extraction of groundwater has the same effect on the flow in the Kettle River as a direct diversion of surface water, following Aqua Factor Consulting Inc. (2004). Please note that due to the lack of available data on groundwater use by single homes or farms within the Kettle River watershed, groundwater use by individual households and farms was not included in the analysis. At the scale of the sub-basins, we have assumed that groundwater use from single properties is having a negligible effect on surface water flows. This assumption should be re-evaluated for any future aquifer-specific assessments.

4.3.2 Naturalized and Net Flows

Mean Monthly and Annual Flows

Summaries of the mean monthly flows at the seven POIs are provided in Appendix C. For each POI the summary provides estimated mean annual and monthly values of the following:

- Net flow (i.e. the recorded flow; it is called “net” because it is the flow after any storage and withdrawal effects);
- Naturalized flow;
- Total licensed quantity for both offstream and instream use;
- Licensed quantity for offstream use;
- Licensed quantity for instream use;
- Licensed quantity for storage (conservation) use;
- Estimated actual licensed offstream use (not including major purveyors); and
- Estimated actual water purveyor use (including groundwater).

Annual Flows for Wet and Dry Years

An example of the year-to-year variability in monthly flows of the standard period within the Kettle River watershed is represented by the natural flows measured in the Granby River[9] (Sub-basin #6). Tables 4-7 and 4-8 present the wet and dry runoff as percentages of the mean annual runoff for the selected return periods calculated using the B.C. Ministry of Environment’s Flood Frequency Analysis Program (version 1.1).

[9] The unit discharge of the Granby River is higher than that of the Kettle River watershed as a whole. Some of the difference is likely attributed to increased precipitation in the Granby watershed, as well as larger surface-groundwater interactions along the Kettle River. However, for this study, it is assumed that the Granby River runoff pattern and return period variation during wet years is representative across the entire Kettle River watershed.

Table 4-7
Scaling factors for mean annual and monthly runoff during wet years

Return Period of non-exceedance of annual runoff (years)	Probability of non-exceedance of annual runoff (%)	Percentage of mean annual runoff (%)
5	0.20	120
10	0.10	135
20	0.05	148
50	0.02	164

Table 4-8
Scaling factors for mean annual and monthly runoff during dry years

Return Period of non-exceedance of annual runoff (years)	Probability of non-exceedance of annual runoff (%)	Percentage of mean annual runoff (%)
5	0.20	78
10	0.10	69
20	0.05	63
50	0.02	57

Based on Table 4-7, a wet year with a 5-year return period runoff, for example, would have an annual runoff equal to 120% of the naturalized mean annual runoff.

4.3.3 Trends in River Discharge over Time

The Kettle River exhibits high year-to-year variability in flows, reflecting variations in snow accumulation and melt, precipitation, and air temperature through its effect on evapotranspiration (see Section 4.3.4). The annual variability in river flow the Kettle watershed is similar to other rivers in watersheds with similar climates in southern B.C. However, the flows since 1999 have been below average, which is consistent with the hypothesis that climate warming is having an effect on water resources in western North America. The WSC on the Kettle River at Laurier has the longest continuous data record in the watershed. Figure 4-1 shows the average monthly discharge in August, plus and minus one standard deviation, for each decade since the 1930s. The 2001-2010 decade had the lowest August average, suggesting a downward trend, and the lowest variability.

To determine whether a statistically significant trend is present, the discharge data from the WSC Kettle River at Laurier and Granby River stations were analyzed using the Mann-Kendall test (Systat 2010) based on procedures in Helsel and Hirsch (1991). These stations were selected for analysis because they have the longest continuous data records (trend tests are not feasible if the data are not spaced evenly in time). The test was completed using the monthly means for the entire period of record, the monthly means for the most-recent normal period (1981-2010), and just the August means for the full record (see Figure 4-8) and 1981-2000. The results are in Table 4-9. Trends are considered significant where $p \leq 0.05$.

Looking at the entire available data record, there is no evidence of a trend, either upwards or downwards, in any of the four data sets that were assessed. When only the 1981-2010 (standard period) data are assessed, a significant downward trend was identified in the Kettle River monthly flows at Laurier, the August monthly flows at Laurier, and the Granby River monthly flows (Table 4-9). Of the three statistically significant trends, the Sen's slope values (which indicate the magnitude of the trend) are more pronounced in the Kettle River data (Table 4-9).

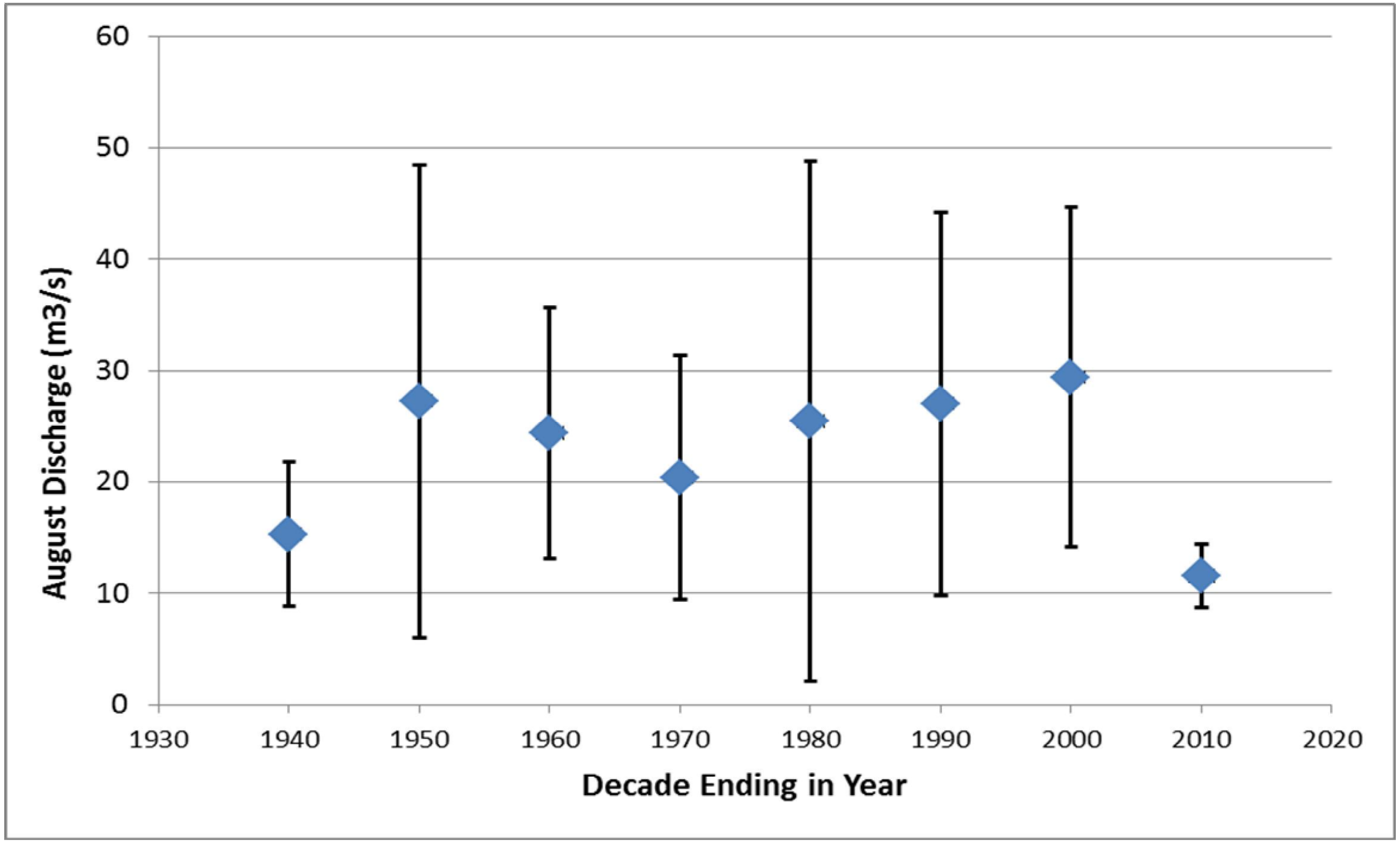

Figure 4-1
Decade average discharge (±1 standard deviation) – Kettle River at Laurier (1931-2010)

Table 4-9
River discharge trend statistics – Kettle River at Laurier and Granby River

Variable	Period	Mann-Kendall Statistic	P – value (downward trend)	Sen's Slope**	Kendall Tau Statistic	Is there a significant* trend?
Kettle at Laurier – all monthly flows	1929 - 2010	6.98	0.754	0.001	0.015	No
	1981 - 2010	-7,249	0.001	-0.034	-0.112	**Yes - downward**
Kettle at Laurier – August monthly flows	1930 - 2010	-53	0.416	-0.011	-0.016	No
	1981 – 2010	-148	0.004	-0.750	-0.340	**Yes – downward**
Granby – all monthly flows	1967 - 2010	-3165	0.217	-0.001	-0.023	No
	1981 – 2010	-4681	0.020	-0.007	-0.072	**Yes - downward**
Granby – August Monthly flows	1967 - 2010	-93	0.176	-0.036	-0.098	No
	1981 - 2010	-132	0.010	-0.135	-0.303	No

*Considered significant where p≤0.05. ** Sen's slope units are $m^3/s/yr$ for August trends; $m^3/s/month$ for monthly trends.

4.3.4 Low Flow Conditions

In addition to information about water supply and demand under average conditions, water use planning requires information on stream flows during periods of low flow. On an annual basis, the lowest flows in the Kettle River and its tributaries occur in August or September. The magnitudes of those low flows vary from year to year, and planning decisions must consider flows during periods of drought and understand the probability that an extreme low flow will occur. Figure 4-2 shows the mean August net flow from 1930 to 2010 at the WSC Station “Kettle River near Laurier”, illustrating the year-to-year variability in August flows (note that 2003 at 6.13 m^3/s had the lowest August flows on record, with an estimated return interval of 82 years; 2007 was the third lowest August flow on record). Also, of note, is that for approximately the last decade (2000-2010), the mean monthly August flows have all been below the long term mean (1930-2010) (Figure 4-2).

Estimates of the 1-in-10 year and 1-in-50 year return period mean monthly net low flows for the standard period have been calculated for each POI. In any given year the probability of low flows of these magnitudes occurring is 10% and 2% respectively. The mean monthly net low flows for the 1-in-10 year and 1-in-50 year return period low flows for the standard period at the seven POIs are provided in Appendix C. The mean monthly net low flows were estimated for each month for the West Kettle watershed (Sub-basin #1), Kettle River above West Kettle River Confluence (Sub-basin #2), and the Granby River (Sub-basin #6) using the B.C. MOE’s Flood Frequency Analysis Program (version 1.1), as presented in section 4.3.2. These three sub-basins represent the POIs with the most complete data records. The other POIs have less data, therefore the percentage of the monthly net low flows to the mean monthly net flows were used to estimate the low flows for each respective month at those POIs.

As an indication of extreme low flows, the minimum 7-day net low flows [i.e. 1-in10 year (7Q10) and 1-in-50 year (7Q50) return periods] for the standard period were estimated for the Granby River. The minimum 7-day net low flow represents the minimum 7-day net flow over the course of one year. For the Granby River, the minimum 7-day net low flow generally occurs each year sometime between September and November. The 7Q10 in the Granby River is 0.911 m^3/s (this flow has a 10% chance of occurring in any given year), and the 7Q50 is 0.641 m^3/s (this flow has 2% chance of occurrence in any given year).

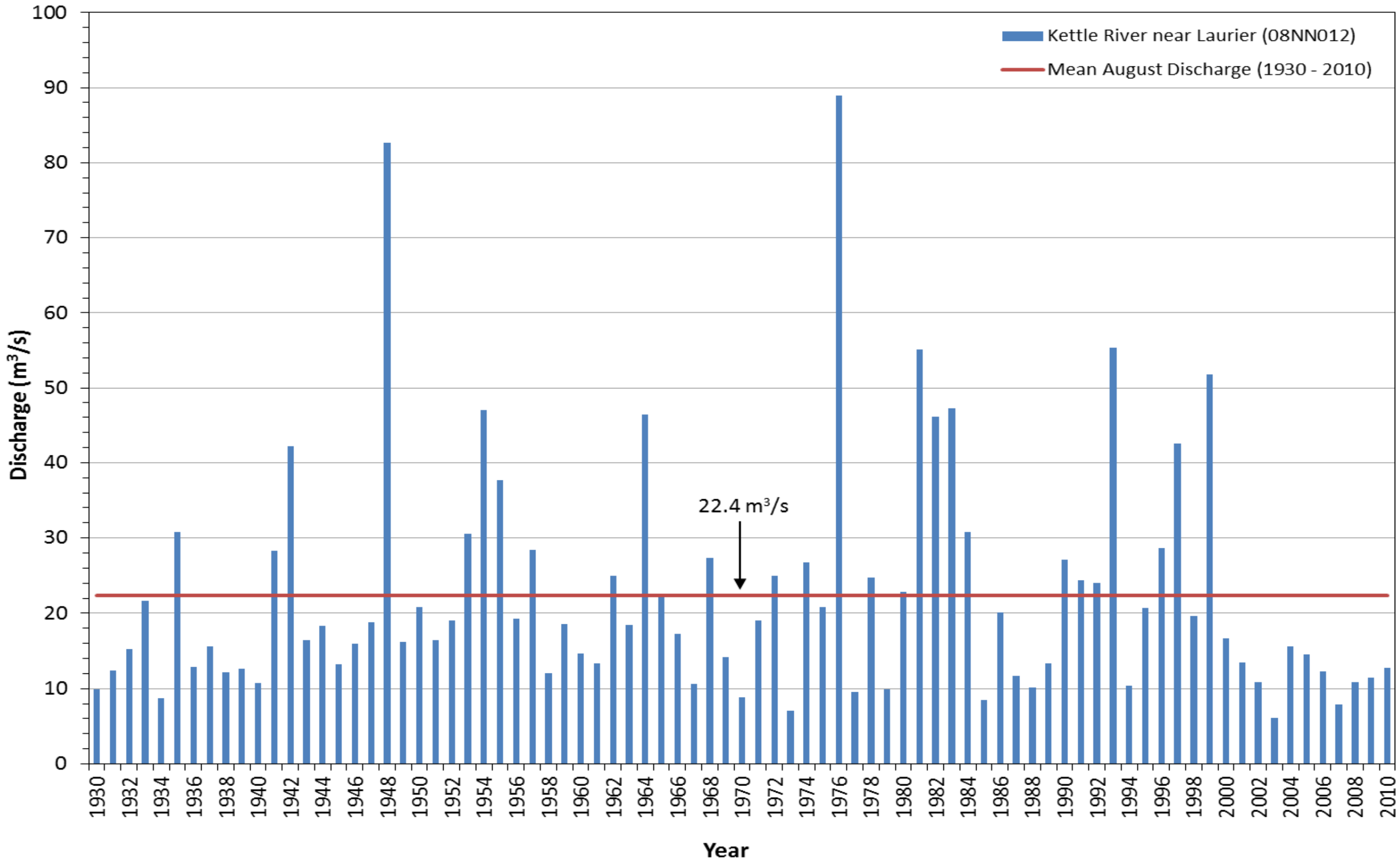

Figure 4-2
Mean monthly August net flow at Kettle River near Laurier (1930 - 2010)

Table 4-10
Low flow statistic comparison for the Granby River (Sub-basin #6)

Month	Mean monthly naturalized flow (m^3/s)	Mean monthly net flow (m^3/s)	10-year monthly net low flow (m^3/s)	50-year monthly net low flow (m^3/s)
January	5.04	5.04	1.84	1.36
February	5.79	5.79	2.10	1.35
March	17.5	17.5	4.63	0.984
April	63.4	63.4	36.4	16.4
May	123	123	91.9	82.5
June	94.9	94.8	48.0	27.3
July	26.7	26.5	8.47	4.36
August	5.96	5.80	2.06	1.41
September	3.82	3.74	1.22	0.895
October	4.81	4.80	1.52	1.15
November	7.38	7.38	1.76	0.744
December	5.63	5.62	2.10	1.73

Based on Table 4-10, for the Granby River (Sub-basin #6), the mean monthly net low flows represent 25-85% of the mean monthly naturalized flows under a 10-year return period and 5%-67% under a 50-year return period**. In the critical July to September period when water demand is highest, the 10-year flows are about one-third of the average and the 50-year low flows are about 20% of the average monthly flow**. In addition, the minimum 7-day net low flow is 24% and 17% respectively of the September average for the 10-year and 50-year return periods.

The mean annual and mean September naturalized, net, and 1-in-10 year and 1-in-50 year return period net flows for all of the POIs are presented in Figure 4-3. The results for all of the POIs are similar to the Granby River results presented earlier, in that the 1-in-10 year and 1-in-50 year net low flow statistics are significantly lower than the mean net and naturalized flows. The significant reduction in flows during low flow periods has been associated to increased water use by other studies (e.g. Oliver 2001; Andrusak 2006); however, some of this reduction is also likely attributed to the climatic variability of the region as well. As discussed in Section 4.3.3, over the last decade, river flows within the Kettle River watershed have generally been lower on average than the previous decades (Figure 4-1). Rivers in semi-arid regions (like the Kettle River watershed) can be sensitive to changes in rainfall; therefore, the low flows in the Kettle River watershed are likely influenced more noticeably by the climatic variability of the watershed. These results are similar to the Okanagan Basin (located to the west of the Kettle River watershed), where the variation in low flows has been attributed to both water use and climate influence. For example, the net inflows into Okanagan Lake are approximately 40% of the mean annual net inflow under the 1-in-10 year return period and 14% of the mean annual under the 1-in-50 year return period (AECOM, Associated Engineering Ltd. & Kerr Wood Leidel Associates Ltd. 2012).

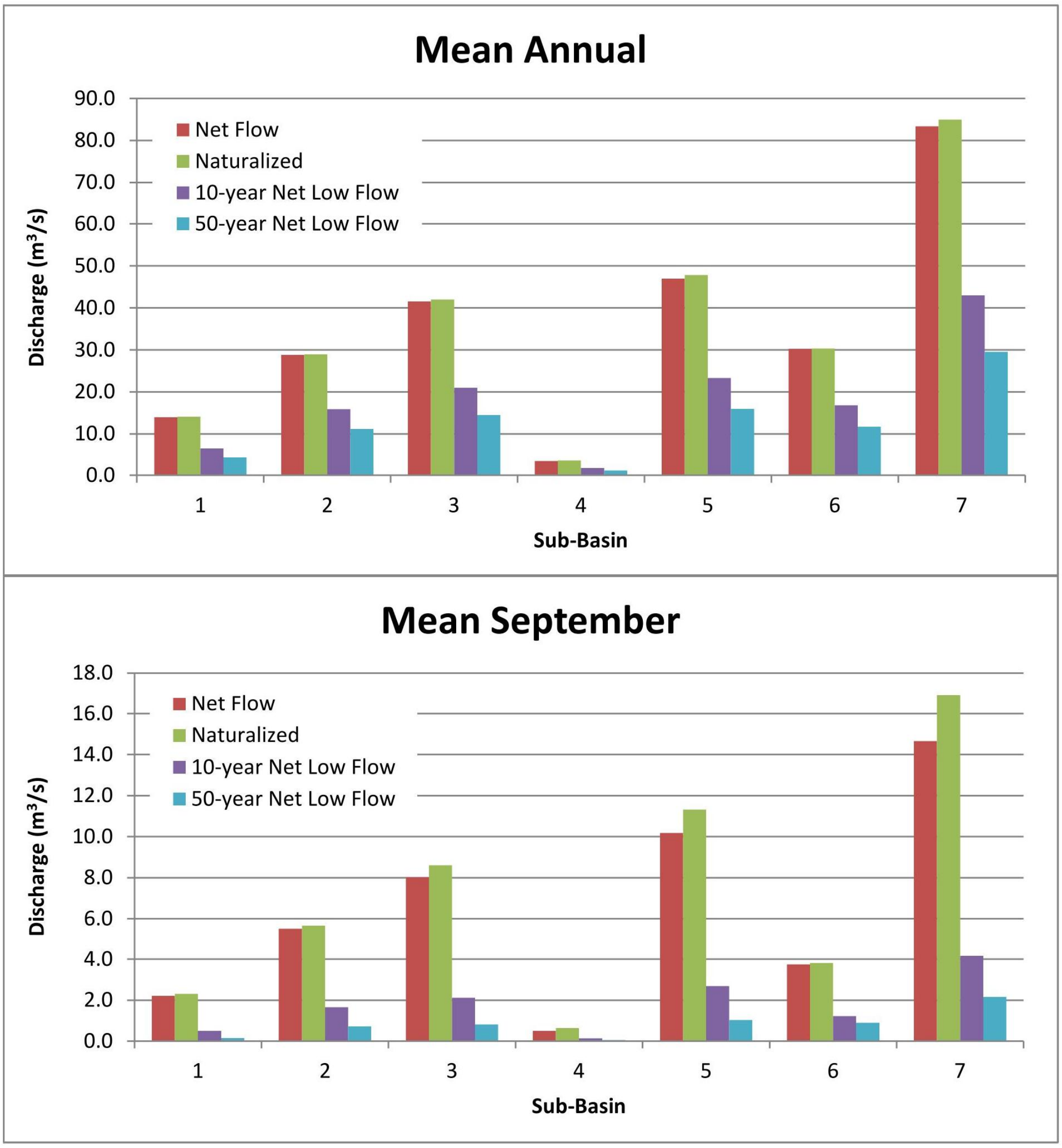

Figure 4-3
Comparison of mean annual and September net and naturalized flows to 10-year and 50-year net flows for the Kettle River watershed points-of-interest

4.3.5 Sub-basin Water Balances

The water balance calculations for each POI are provided in the tables in Appendix C. For each of the sub-basins contributing flow to the POI, an approximate annual water balance, based on the available climate data and naturalized flow estimates, is provided in Table 4-11. The results indicate that surface water runoff accounts for between 28% and 58% of the total precipitation volume, while the remaining water is associated to both groundwater recharge and evapotranspiration. At the time of this investigation, potential evapotranspiration estimates from the climate model were only available for 2003 (Section 3.4.2); therefore, actual evapotranspiration estimates for the standard period are not yet available. The results of the water balance support other studies (e.g. Allen *et al.* 2004, Scibek 2005) that indicate that a portion of the Kettle River runoff contributes to groundwater recharge.

Detailed estimates of actual evapotranspiration (AET) from land surfaces are not widely available for the Kettle River watershed. AET is less than PET when the demand exerted by PET exceeds the available water supply, and most of the Kettle is characterized by significant summer soil moisture deficits (Table 4-11). First approximation estimates have been generated using the "bookkeeping" water budget approach that considers the available soil water content. The approach was first outlined in Thornthwaite and Mather (1955). For valley bottom sites, AET ranges between about 50% and 70% of PET depending on soil texture (i.e. for coarser textured soils the AET is less because more of the precipitation that enters the soil in the surplus months (when P>PET) drains through the soil to recharge groundwater, and is not available to plants when demand is high in the summer). At higher elevation where it is cooler and wetter, AET approaches about 90% of PET. More robust sub-basin scale estimates of AET would need to consider the variation in soil depth, soil texture, and vegetation cover in the watershed.

For the residual values in Table 4-11, most is likely accounted for by AET and only a small part directly re-charges groundwater, mostly in the latter stages of spring snowmelt and from rain in the late fall. The valley-bottom aquifers are mostly re-charged from streams losing flow to ground in the locations where they flow over alluvial sediments. For tributaries this is on alluvial fans where the streams emerge from the forested uplands. For the mainstem of the Kettle, West Kettle and Granby Rivers there is evidence to indicate that flow is "lost" to groundwater along portions of their length during freshet (Allen *et al.* 2004; Scibek 2005; Wei et al. 2010), with a portion returning as baseflow. Outside of the Grand Forks area there is little detailed information on the spatial and temporal variability of this process in the watershed.

Table 4-11
Water balance summary above the 7 points-of-interest in the Kettle River watershed for the standard period.

Point-of-Interest	Precipitation[1] (mm)	Annual Naturalized Runoff (mm)	Residual - Evapotranspiration plus Groundwater Recharge[2] (mm)
West Kettle River at Mouth (Sub-basin #1)	682	235	447
Kettle River above West Kettle Confluence (Sub-basin #2)	835	423	412
Kettle River at the Midway International Boundary (Sub-Basin #3)	614	262	352
Boundary Creek at Mouth (Sub-basin #4)	664	188	476
Kettle River at the Grand Forks International Boundary (Sub-basin #5)	582	189	393
Granby River at Mouth (Sub-basin #6)	801	465	336
Kettle River at the Cascade International Boundary (Sub-basin #7)	602	270	332

Note:

1. Precipitation is estimated based on the 1981-2010 mean annual precipitation measured by the Meteorological Service of Canada climate station “Grand Forks” (Station No. 1133270; Elevation = 531.9 m). The mean annual precipitation was scaled for each sub-basin based on the 2003 precipitation information provided by Environment Canada (section 3.4.2); and
2. Evaporation and groundwater recharge is calculated as the difference between the estimated precipitation and runoff.

4.3.6 Effects of Water Use on Surface Flow

This section summarizes the current hydrologic conditions at the seven POIs for the standard period (refer to Appendix C for detailed tabular summaries). A summary of 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-in-10 year and 1-in-50 year return period net low flows are presented in Table 4-12.

Table 4-12
Annual average naturalized flow, total licences, actual offstream use, and annual net low flows at the 7 point-of-interest in the Kettle River watershed for the 1981-2010 standard period

Point-of-Interest	Annual Naturalized Flow (m^3/s)	Total Annual Licences for Offstream Use (m^3/s)	Estimated Actual Annual Offstream Use[1] (m^3/s)	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]
West Kettle River at Mouth (Sub-basin #1)	14.1	0.455	0.137	14.0 [99.3%]	6.53 [46.3%]	4.28 [30.4%]
Kettle River above West Kettle Confluence (Sub-basin #2)	28.9	0.198	0.097	28.8 [99.6%]	15.9 [55.0%]	11.2 [38.8%]
Kettle River at the Midway International Boundary (Sub-Basin #3)	42.1	1.53	0.430	41.5 [98.6%]	21.0 [49.9%]	14.5 [34.4%]
Boundary Creek at Mouth (Sub-basin #4)	3.54	0.141	0.094	3.44 [97.1%]	1.76 [49.7%]	1.17 [33.1%]
Kettle River at the Grand Forks International Boundary (Sub-basin #5)	47.8	2.11	0.825	47.0 [98.3%]	23.3 [48.7%]	16.0 [33.4%]
Granby River at Mouth (Sub-basin #6)	30.3	0.157	0.048	30.3 [99.9%]	16.8 [55.4%]	11.7 [38.6%]
Kettle River at the Cascade International Boundary (Sub-basin #7)	84.9	2.62	1.48	83.3 [98.1%]	43.0 [50.6%]	29.6 [34.9%]

Note:
1. Estimated actual annual offstream water use includes both individual surface water licensed use and average groundwater use (unlicensed) by major purveyors. The small amount of groundwater use by individuals is not included.

West Kettle River at Mouth (Sub-basin #1)

- Currently, the net flows range from 2.21 m^3/s in September to 60.5 m^3/s in May under mean monthly conditions, while the annual net flow is estimated to be 14.0 m^3/s. Under 10-year return period conditions, the monthly net low flows range from 0.501 m^3/s in September to 38.0 m^3/s in May, while the monthly net low flows range from 0.155 m^3/s in September to 28.7 m^3/s in May under a 50-year return period conditions;

- On an annual basis, net flow is 1% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0.5% to 6.0% (i.e. flows in the highest demand month are 94% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 37% to 80% and 53% to 93%, respectively;
- On an annual basis, there is an estimated maximum of 13.6 m^3/s that is not currently licensed. On an annual basis, this ranges from 1.90 m^3/s in September to 60.0 m^3/s in May;
- On an annual basis, 3% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 1.4% to 28% of the naturalized flow;
- On an annual basis, 1% of the naturalized flow is actually used offstream. On a monthly basis, actual offstream use varies from 0.2% to 6% of the naturalized flow;
- On an annual basis, there is 0.308 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.041 m^3/s in January to 0.736 m^3/s in May; and
- On an annual basis, there is 0.1% of the naturalized flow held for “conservation – stored water” purposes.

Kettle River above West Kettle Confluence (Sub-basin #2)

- Currently, net flows range from 4.44 m^3/s in January to 120 m^3/s in May, while the annual net flow is estimated to be 28.8 m^3/s. Under the 10-year return period conditions, the monthly net low flows range from 1.65 m^3/s in September to 94.6 m^3/s in May, while the monthly net low flows range from 0.725 m^3/s in September to 87.1 m^3/s in May under 50-year return period conditions;
- On an annual basis, net flow is 0.3% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately <0.1% to 4% (i.e. flows in the highest demand month are 96% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 21% to 71% and 28% to 89%, respectively;
- On an annual basis, there is an estimated maximum of 28.7 m^3/s that is not currently licensed. On an annual basis, this ranges from 4.44 m^3/s in January to 120 m^3/s in May;
- On an annual basis, 0.7% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for <0.1% to 9% of the naturalized flow;
- On an annual basis, 0.3% of the naturalized flow is actually used offstream. On a monthly basis, actual offstream use varies from <0.1% to 4% of the naturalized flow;
- On an annual basis, there is 0.101 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.0 m^3/s in the winter months to 0.383 m^3/s in May; and
- On an annual basis, there is <0.1% of the naturalized flow held for “conservation – stored water” and 3% of the naturalized flow held for “power – residential” purposes.

Kettle River at Midway International Boundary (Sub-basin #3, including Sub-basin #'s 1-2)

- Currently, net flows at the POI range from 6.87 m^3/s in January to 171 m^3/s in May, while the annual net flow is estimated to be 41.5 m^3/s. Under 10-year return period conditions, the monthly net low flows range from 2.12 m^3/s in September to 121 m^3/s in May, while the monthly net low flows range from 0.810 m^3/s in September to 125 m^3/s in May under a 50 year return period conditions;
- On an annual basis, net flow is 1% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0.2% to 11% (i.e. flows in the highest demand month are 89% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 30% to 76% and 41% to 91%, respectively;
- On an annual basis, there is an estimated maximum of 40.5 m^3/s that is not currently licensed. On an annual basis, this ranges from 6.69 m^3/s in January to 168 m^3/s in May;
- On an annual basis, 4% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 2% to 27% of the naturalized flow;
- On an annual basis, 1% of the naturalized flow is actually used offstream (including groundwater use by major water purveyors). On a monthly basis, actual offstream use varies from 0.1% to 11% of the naturalized flow;
- On an annual basis, there is 1.12 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.182 m^3/s in December to 2.98 m^3/s in May; and
- On an annual basis, there is <0.1% of the naturalized flow held for "conservation – stored water" and 2% of the naturalized flow held for "power – residential" purposes.

Boundary Creek at Mouth (Sub-basin #4)

- Currently, net flows at the POI are estimated to range from 0.502 m^3/s in September to 14.8 m^3/s in May, while the annual net flow is estimated to be 3.44 m^3/s. Under the 10-year return period conditions, the monthly net low flows range from 0.133 m^3/s in September to 10.4 m^3/s in May, while the monthly net low flows range from 0.051 m^3/s in September to 8.84 m^3/s in May under 50-year return period conditions;
- On an annual basis, net flow is 3% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0.3% to 26% (i.e. flows in the highest demand month are 74% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 30% to 79% and 41% to 92%, respectively;
- On an annual basis, there is an estimated maximum of 3.37 m^3/s that is not currently licensed. On an annual basis, this ranges from 0.431 m^3/s in September to 14.6 m^3/s in May;
- On an annual basis, 4% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 0.3% to 43% of the naturalized flow;

- On an annual basis, 3% of the naturalized flow is actually used offstream (including groundwater use by major water purveyors). On a monthly basis, actual offstream use varies from 0.3% to 27% of the naturalized flow;
- On an annual basis, there is 0.066 m^3/s not being utilized under existing licences (this does not include groundwater use by major purveyors). On a monthly basis, flow available for use without further licensing ranges from 0.0 m^3/s in the winter months to 0.245 m^3/s in July; and
- On an annual basis, there is 0.6% of the naturalized flow held for “conservation – stored water” purposes.

Kettle River at Grand Forks International Boundary (Sub-basin #5, including Sub-basin #’s 1-4)

- Currently, net flows at the POI are estimated to range from 6.46 m^3/s in October to 179 m^3/s in May, while the annual net flow is estimated to be 47.0 m^3/s. Under the 10-year return period conditions, the monthly net low flows range from 2.15 m^3/s in October to 126 m^3/s in May, while the monthly net low flows range from 1.02 m^3/s in September to 107 m^3/s in May under a 50-year return period;
- On an annual basis, net flow is 2% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0.3% to 14% annually (i.e. flows in the highest demand month are 86% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 30% to 76% and 41% to 91%, respectively;
- On an annual basis, there is an estimated maximum of 45.6 m^3/s that is not currently licensed. On an annual basis, this ranges from 6.10 m^3/s in October to 175 m^3/s in May;
- On an annual basis, 4% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 2% to 30% of the naturalized flow;
- On an annual basis, 2% of the naturalized flow is actually used offstream (including groundwater use by major water purveyors). On a monthly basis, actual offstream use varies from 0.3% to 14% of the naturalized flow;
- On an annual basis, there is 1.40 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.181 m^3/s in December to 3.35 m^3/s in May; and
- On an annual basis, there is 1% of the naturalized flow held for “conservation – stored water” and <0.1% of the naturalized flow held for “power – residential” purposes.

Granby River at Mouth (Sub-basin #6)

- Currently, net flows range from 3.74 m^3/s in September to 123 m^3/s in May, while the annual net flow is estimated to be 30.3 m^3/s. Under the 10-year return period conditions, the monthly net low flows range from 1.22 m^3/s in September to 91.9 m^3/s in May, while the monthly net low flows range from 0.744 m^3/s in November to 82.5 m^3/s in May under a 50-year return period conditions;
- On an annual basis, net flow is 0.2% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0% to 3% annually (i.e. flows in the highest demand month are 97% of normalized flow). However, under 10-year and 50-year monthly low

flow return period conditions, the net flows are less than the mean monthly naturalized flows by 25% to 74% and 33% to 94%, respectively;

- On an annual basis, there is an estimated maximum of 30.2 m^3/s that is not currently licensed. On an annual basis, this ranges from 3.58 m^3/s in September to 123 m^3/s in May;
- On an annual basis, 0.5% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 0.1% to 8% of the naturalized flow;
- On an annual basis, 0.2% of the naturalized flow is actually used offstream. On a monthly basis, actual offstream use varies from 0% to 3% of the naturalized flow; and
- On an annual basis, there is 0.109 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.014 m^3/s in November to 0.365 m^3/s in July.

Kettle River at Cascade International Boundary (Sub-basin #7, including Sub-basin #'s 1-6)

- Currently, net flows at the POI are estimated to range from 14.7 m^3/s in September to 329 m^3/s in May, while the annual net flow is estimated to be 83.3 m^3/s. Under 10-year return period conditions, the monthly net low flows range from 4.16 m^3/s in September to 237 m^3/s in May, while the monthly net low flows range from 2.15 m^3/s in September to 2.05 m^3/s in May under a 50-year return period conditions;
- On an annual basis, net flow is 2% smaller than naturalized flow. On a monthly basis, net flows are smaller than naturalized flows by approximately 0.6% to 16% annually (i.e. flows in the highest demand month are 84% of normalized flow). However, under 10-year and 50-year monthly low flow return period conditions, the net flows are less than the mean monthly naturalized flows by 29% to 75% and 38% to 90%, respectively;
- On an annual basis, there is an estimated maximum of 74.7 m^3/s that is not currently licensed. On an annual basis, this ranges from 12.1 m^3/s in September to 297 m^3/s in May;
- On an annual basis, 3.1% of the naturalized flow is licensed for offstream use. On a monthly basis, offstream licences account for 1% to 26% of the naturalized flow;
- On an annual basis, 2% of the naturalized flow is actually used offstream (including groundwater use by major water purveyors). On a monthly basis, actual offstream use varies from 0.2% to 17% of the naturalized flow;
- On an annual basis, there is 1.51 m^3/s not being utilized under existing licences. On a monthly basis, flow available for use without further licensing ranges from 0.197 m^3/s in December to 3.56 m^3/s in July; and
- On an annual basis, there is <0.1% of the naturalized flow held for "conservation – stored water" and 9% of the naturalized flow held for instream purposes.

4.3.7 Summary

The following points summarize the hydrology of the Kettle River watershed presented in the preceding parts of Section 4.3:

- Flows in all major sub-basins of the Kettle River watershed, except the Granby River, are considered "regulated". Accordingly, naturalized flows were estimated at seven POIs based on water licensing and water use information and available hydrometric records;
- On an annual basis, net flows are estimated to be 2% smaller than naturalized flows for the Kettle River watershed above the Cascade International Boundary. The estimated naturalized and net annual flows at the seven POIs in the Kettle River watershed for the 1981-2010 standard period are:

	Naturalized	Net
o West Kettle River at Mouth	14.1 m^3/s	14.0 m^3/s
o Kettle River above West Kettle Confluence	28.9 m^3/s	28.8 m^3/s
o Kettle River at Midway International Boundary	42.1 m^3/s	41.5 m^3/s
o Boundary Creek at Mouth	3.54 m^3/s	3.44 m^3/s
o Kettle River at Grand Forks International Boundary	47.8 m^3/s	46.8 m^3/s
o Granby River at Mouth	30.3 m^3/s	30.3 m^3/s
o Kettle River at Cascade International Boundary	84.9 m^3/s	83.4 m^3/s

- For the Kettle River watershed above the Cascade International Boundary, the lowest monthly flow generally occurs during September. The estimated naturalized and net flows at the seven POIs in the Kettle River watershed for the 10-year and 50-year return period September net low flows are:

	Naturalized	10-year	50-year
o West Kettle River at Mouth	2.30 m^3/s	0.501 m^3/s	0.155 m^3/s
o Kettle River above West Kettle Confluence	5.66 m^3/s	1.65 m^3/s	0.725 m^3/s
o Kettle River at Midway International Boundary	8.68 m^3/s	2.12 m^3/s	0.810 m^3/s
o Boundary Creek at Mouth	0.642 m^3/s	0.133 m^3/s	0.051 m^3/s
o Kettle River at Grand Forks International Boundary	11.2 m^3/s	2.66 m^3/s	1.02 m^3/s
o Granby River at Mouth	3.82 m^3/s	1.22 m^3/s	0.895 m^3/s
o Kettle River at Cascade International Boundary	16.8 m^3/s	4.16 m^3/s	2.15 m^3/s

- Offstream licences account for 3.1% of the average annual naturalized flow for the Kettle River watershed above the Cascade International Boundary (including estimates of surface water rights within the portions of the watershed located in the United States). The percentage of naturalized annual flow represented by both water licences for offstream use and actual use for the seven POIs are:

	Licensed	Actual
o West Kettle River at Mouth	3.3 %	1.0 %
o Kettle River above West Kettle Confluence	0.7 %	0.3 %
o Kettle River at Midway International Boundary	3.6 %	1.0 %
o Boundary Creek at Mouth	4.0 %	2.7 %
o Kettle River at Grand Forks International Boundary	4.4 %	1.7 %
o Granby River at Mouth	0.5 %	0.2 %
o Kettle River at Cascade International Boundary	3.1 %	1.7 %

- On an annual basis, approximately 74.7 m^3/s of flow is not presently licensed for offstream or instream use for the Kettle River watershed above the Cascade International Boundary (including estimates of surface water rights within the portions of the watershed located in the United States). The flows not presently licensed for offstream or instream use are as follows:

	Annual Flow Not Currently Licensed
West Kettle River at Mouth	13.6 m^3/s
Kettle River above West Kettle Confluence	28.7 m^3/s
Kettle River at Midway International Boundary	40.5 m^3/s
Boundary Creek at Mouth	3.37 m^3/s
Kettle River at Grand Forks International Boundary	45.6 m^3/s
Granby River at Mouth	30.2 m^3/s
Kettle River at Cascade International Boundary	74.7 m^3/s

The term “not licensed” means that this is remaining naturalized flow under average conditions that is not held under a water licence. As described earlier, in late summer, especially under below-average flow conditions, the streamflows are significantly reduced and any further surface withdrawals in the summer would likely have a detrimental effect on water supply and flows that support aquatic life. Instream flow needs for aquatic life are discussed in the next section.

4.4 In-Stream Flow Needs Overview

4.4.1 Provincial Government Studies

The provincial government has conducted a progression of studies of the Kettle River watershed since Sebastian (1989) identified that the river was well below its carrying capacity for adult trout and identified streamflow as one of the key potential limiting factors, along with high summer water temperatures and low availability of deep pools for adult holding during summer and winter.

Oliver (2001) analyzed water quantity and quality in the Kettle River basin and corroborated the earlier assessment, noting that periodic extreme low flows likely contribute to the observed imbalance in the age structure of the fish population. Oliver (2001) also implicated fish harvesting, and land and water use as contributing factors in the low abundance and small size of rainbow trout in the fishery.

Epp and Andrusak (2011, 2012) summarized available water quantity, quality, and fish population information for key locations in the watershed; building on the recommendations outlined in Oliver (2001). The Epp and Andrusak (2011, 2012) reports include an evaluation of fish population responses to habitat restoration efforts, including the creation of deep pool habitat and an evaluation of parr habitat availability over a range of low to moderate flows. The report suggests that the relatively lower flows observed further downstream in the watershed reflect water use. As reported in Section 4.3 above, the average natural flows in the lower reach near Grand Forks are reduced by about 17% by off-stream withdrawals, even in the months with the highest demand.

During years with below-average flows, however, the percentage of flow that is reduced by off-stream withdrawals is greater.

As discussed previously, parr habitat at all sites is optimal at flows of about 20% MAD and still satisfactory at flows of 10% MAD, but declines rapidly in both availability and quality at lower flows.

4.4.2 Potential Implications for Fish Habitat

Low flows during summer have consistently been identified as one of the key factors limiting fish production in the Kettle River watershed, along with over fishing, the low abundance of deep pools and high summer water temperatures.

The rainbow trout parr habitat modeling by Epp and Andrusak (2011, 2012) indicates that physical living space for trout parr is not the critical factor; however, the growth and productivity implications of the current low flows warrant further investigation, especially at flows less than 10% MAD.

The relative lack of deep pools and habitat diversity may cause a significant limitation to the fish population, especially since it may encourage adult fish to depart for more desirable habitat elsewhere or may reduce their growth and survival; however, this issue is not attributed to water use, rather to land use, especially riparian tree removal. In natural conditions, riparian trees contribute large woody debris (LWD) when they fall down. Tree stems in the streams create the habitat complexity that benefits fish.

High summer water temperatures have been implicated in several fish kills in the Kettle River; however, Epp and Andrusak (2011, 2012) indicate that during low flow periods water volume is not correlated with water temperatures, which rather reflect air temperatures. However, earlier in the summer when there is more water, water temperatures are less affected by air temperature. It may be worthwhile to calculate how much flow would be required to significantly influence water temperatures, both the mean and range of daily water temperatures[10]. The flows to be considered could include a comparison between current and naturalized flows, as well as potential continuous and pulse supplementation from existing and potential headwater reservoirs.

Table 4-13 presents the estimates of 10% MAD and 20% MAD for each POI in September (generally the lowest flow month of the year) based on the naturalized flow estimates generated in this report. These values are compared to average, 10-year low, and 50-year low flow estimates. The average monthly net flows for September are between 12% and 21% MAD. While care should be exercised in extrapolating the optimal (20% MAD) and reasonable (10% MAD) flows from Epp and Andrusak (2011) to other locations, this preliminary characterizaton indicates that under average flow conditions during the lowest flow month much of the parr rearing habitat is still available and of reasonable quality. However, low flows drop off sharply from the average

[10] As a "first cut" indication, the average Kettle River flow at Laurier in late summer is about 20 m^3/s. Assuming a water temperature of 22°C, if flow could be augmented by 10% (2 m^3/s) at a temperature of 10°C, the resulting mixed flow would have a temperature of about 20.9°C.

condition, such that **the 1-in-10 year return period monthly net low flows for September are between 3.6% and 5.7% MAD and between 1.1% and 3.0% MAD for the 1-in-50 year return period**. Based on this analysis, the most severe low flow conditions for the standard period are observed in the West Kettle River and Boundary Creek, whereas conditions in the Granby River are less restrictive. These data support the hypothesis that parr rearing habitat is likely greatly reduced under low flow conditions.

It should also be noted at this time that the 2003 low flows, that are a common reference for discussions of extreme low flows in the Kettle River watershed, represent an 82-year return period low flow. In addition, the naturalized MADs for the POIs in this study are based on available hydrometric information, available water use information, and some assumptions on water use patterns.

The 10% MAD and 20% MAD values in Table 4-13 are derived from the naturalized flow estimates. Therefore it is valuable to consider the sensitivity of the percent MAD estimates to the assumptions that were employed when naturalizing flows. For example, if the naturalized flows were either higher or lower than the true natural value, then the 10% and 20% MAD values would also be proportionally higher or lower. Under average conditions, this means that the September flows would still be mostly within the 10 to 20% MAD range. Under the 10- and 50-year low flow conditions the current estimates are all under 10% MAD and this would not change even if the naturalized flow estimates were out by as much as 50%.

Table 4-13
Summary of Mean Annual and Mean Monthly September Discharge statistics for each point-of-interest in the Kettle River Watershed

Point-of-Interest	Mean Annual Naturalized Flow (m^3/s)	20% MAD (m^3/s)	10% MAD (m^3/s)	Mean Monthly September Net Flow (m^3/s)	Mean Monthly September Net Flow as % MAD	10-year Return Period Net Low Flow for September (m^3/s)	10-year Net Low Flow for September as % MAD	50-year Return Period Net Low Flow for September (m^3/s)	50-year Net Low Flow for September as % MAD
1	14.1	2.82	1.41	2.21	16%	0.501	3.6%	0.155	1.1%
2	28.9	5.78	2.89	5.51	19%	1.65	5.7%	0.725	2.6%
3	42.1	8.42	4.21	8.02	19%	2.12	5.0%	0.810	1.9%
4	3.54	0.708	0.354	0.502	14%	0.133	3.8%	0.051	1.4%
5	47.8	9.56	4.78	10.1	21%	2.66	5.6%	1.02	2.1%
6	30.3	6.06	3.03	3.74	12%	1.22	4.0%	0.895	3.0%
7	84.9	17.0	8.49	14.7	17%	4.16	4.9%	2.15	2.5%

Note:
a. All naturalized and net flow information is from Appendix C for the 1981-2010 standard period.

4.5 Climate Change and Surface Water Resources

4.5.1 Climate Change Projections

The University of Victoria's Pacific Climate Impacts Consortium (PCIC) 'Plan2Adapt' tool provides outputs for the Kootenay-Boundary and other regions in B.C. (website address: (http://plan2adapt.ca/plan2adapt.php). Table 4-14 lists the median and ranges of values expected for the 2020s, 2050s and 2080s as compared to the baseline period of 1961-90 for the Kootenay-Boundary. These values are derived from a 15 General Circulation Model (GCM) ensemble, under two of the most likely CO_2 emission scenarios.

The model shows the mean annual air temperature increasing by about 1°C by the 2020s, about 2°C by the 2050s, and 3°C by the 2080s. There is a small increase in average annual precipitation but this is biased by more rain (not more snow) in the winter. Less rainfall is projected in summer; about 6% less in the 2020s up to 16% less in the 2080s. Snowfall, especially in the spring, is projected to steadily decrease as more of the winter and spring precipitation falls as rain.

In response to the projected increased temperatures and lower summer rainfall, both residential and agricultural water demand will likely increase in the future. In the agricultural sector, the increased demand will be driven by these factors: the warmer temperatures (which increase evapotranspiration); by the increase in the frost-free period by up to 38 days by 2080; and by reduced precipitation during the growing season. The warmer temperatures and longer growing season would increase the crop options available for farmers, but could mean that irrigation begins earlier and extends later than at present. The implications of these projected climate changes are outlined in Section 4.5.2.

Table 4-14
Climate change projections for the Regional District of Kootenay Boundary

Climate Change for Kootenay-Boundary Region in 2020s Period

Climate Variable	Time of Year	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range
Mean Temperature (°C)	Annual	+1.1 °C	+0.7 °C to +1.4 °C
Precipitation (%)	Annual Summer Winter	+4% -6% +3%	-0% to +7% -16% to +8% -1% to +11%
Snowfall* (%)	Winter Spring	-7% -32%	-15% to -0% -58% to -3%
Growing Degree Days* (degree days)	Annual	+210 degree days	+105 to +321 degree days
Heating Degree Days* (degree days)	Annual	-383 degree days	-514 to -253 degree days
Frost-Free Days* (days)	Annual	+14 days	+9 to +20 days

Climate Change for Kootenay-Boundary Region in 2050s Period

Climate Variable	Time of Year	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range
Mean Temperature (°C)	Annual	+1.9 °C	+1.2 °C to +2.8 °C
Precipitation (%)	Annual Summer Winter	+6% -13% +6%	-2% to +9% -28% to -2% -3% to +16%
Snowfall* (%)	Winter Spring	-16% -57%	-26% to -4% -75% to -19%
Growing Degree Days* (degree days)	Annual	+419 degree days	+253 to +593 degree days
Heating Degree Days* (degree days)	Annual	-688 degree days	-964 to -433 degree days
Frost-Free Days* (days)	Annual	+24 days	+13 to +36 days

Climate Change for Kootenay-Boundary Region in 2080s Period

Climate Variable	Time of Year	Projected Change from 1961-1990 Baseline	
		Ensemble Median	Range
Mean Temperature (°C)	Annual	+3.0 °C	+1.7 °C to +4.4 °C
Precipitation (%)	Annual Summer Winter	+6% -16% +11%	+2% to +13% -36% to -0% +2% to +23%
Snowfall* (%)	Winter Spring	-25% -78%	-43% to -9% -89% to -19%
Growing Degree Days* (degree days)	Annual	+626 degree days	+413 to +1060 degree days
Heating Degree Days* (degree days)	Annual	-1022 degree days	-1489 to -628 degree days
Frost-Free Days* (days)	Annual	+38 days	+22 to +60 days

Source: Pacific Climate Impacts Consortium (2010). http://www.pacificclimate.org/tools-and-data/plan2adapt

4.5.2 Climate Change Implications for Streamflows

A warming climate has implications for stream flow and other hydrologic processes. The University of Washington's Climate Impacts Group[11] provides information for three sites in the Kettle River watershed – the Kettle River at Westbridge, the West Kettle River at Westbridge, and the Granby River near Grand Forks. The work is reported in Hamlet *et al.* (2010), which includes graphical and tabular output for the following four parameters: streamflow (m^3/s), peak flows (m^3/s), low flows (m^3/s), and snow water equivalent (mm). These outputs are derived from a 10 GCM model ensemble, under the two likely emission scenarios (i.e. A1B and B1) for the periods centering on the 2020s, 2040s and 2080s and compared to the modeled baseline period of 1970-1999. The general future trends for each modeled variable are summarized as follows:

Streamflow

- Late fall, winter and early spring flows are forecast to be greater; while late spring, summer and early fall flows will be smaller;
- A general shift in the hydrograph to an earlier spring melt period; and
- Total flows for the year increase

Daily Peak Flows:

- Average peak flows increase under both scenarios

Low Flows:

- Late summer/early fall low flows decrease, while winter low flows increase

Snow Water Equivalent (SWE):

- Average SWE predicted to decrease in all periods under both scenarios due to warming;
- A general shift to a transition watershed (between a rain and snow dominant behaviour)

In addition to the work completed by the University of Washington's Climate Impacts Group, the Pacific Climate Impacts Consortium (PCIC) has been conducting climate change modeling of flows in a number of locations in B.C., but not yet for the Kettle River. The closest watershed that has been modeled by this program is the Whatshan River watershed (within the Upper Columbia River watershed), located northeast of the Kettle River watershed (Schnorbus *et al.* 2011; Zwiers *et al.* 2011). The modeling conducted by PCIC has been aimed at assessing the impacts of projected temperatures and precipitation changes on streamflow over the 2041-2070 period (i.e. the 2050s), using a 23 GCM ensemble and three emission scenarios (B1, A1B, and A2).

The results of the climate change modeling for the Whatshan River suggest a 3% increase in median annual discharge for the 2050s, while median annual discharges for the entire Upper Columbia River watershed are reported to range between an increase of 3% to 19% for the 2050s depending on location

[11] Website address: http://www.hydro.washington.edu/2860/products/sites/)

(Zwiers *et al.* 2011). In addition, consistent with the University of Washington results for the Kettle River watershed, PCIC indicates that for the Upper Columbia River watershed, monthly discharges will increase in the late fall and early winter period and the spring melt will occur sooner with higher discharges during the spring and early summer. PCIC also suggests that monthly flows in the late summer and early fall will be lower than in the past. Figure 4-4 (upper graph) shows how the projected changes from the model (coloured lines) for the Whatshan River compare to the historical average (black line). The lower graph shows the range of departures from the historical. April average flow is projected to be about 5 m^3/s higher than the historical average, June is about 7 m^3/s lower, and September is about 1 m^3/s lower.

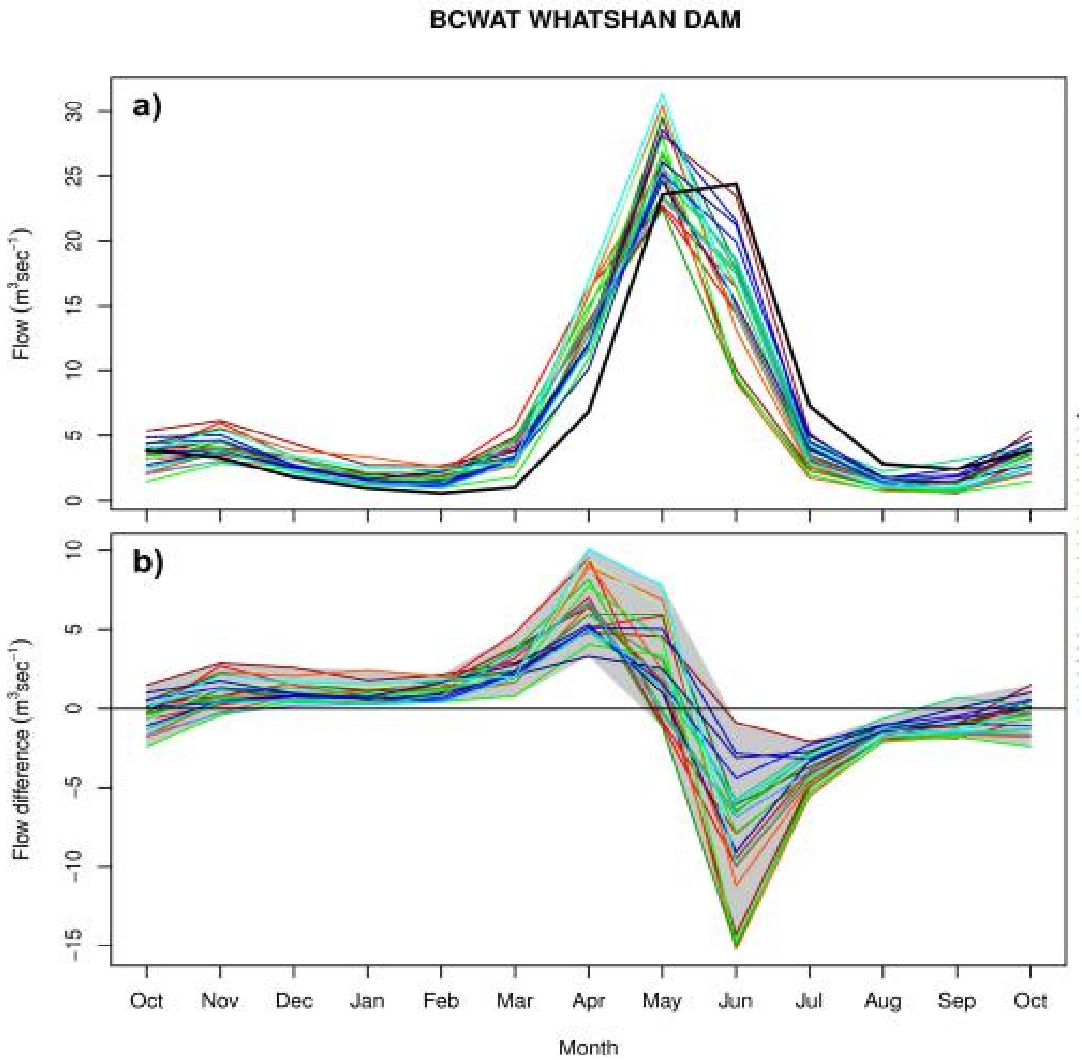

Figure 4-4
Projected changes in Whatshan River flows due to climate change

Upper graph (a) shows historical average flow (thick black line) compared to model projections (each line represents a different model). Lower graph shows the range of projected monthly differences from the historical.
Source: Schnorbus et al. (2011)

4.6 DAMS AND WATER STORAGE

There are no major dams in the Kettle River watershed, although a number of older dams have been removed over the years, notably from Boundary Creek between Greenwood and Midway, Cascade Falls, and Burrell Creek, a major tributary to the Granby River. A search of the provincial dam database by Mr. Michael Noseworthy, P.Eng., Senior Regional Dam Safety Officer with MFLNRO, found that there are 47 dams on record in the watershed. Of these, only 12 are classified as a “regulated” dam, which is:

a) a dam 1 metre or more in height that is capable of impounding a volume of water greater than 1,000,000 m^3
b) a dam 2.5 metres or more in height that is capable of impounding a volume of water greater than 30,000 m^3
c) a dam 7.5 metres or more in height
d) a dam that does not meet the criteria under paragraph (a), (b) or (c) but has a safety risk classification of significant, high, very high or extreme.

The remaining dams do not meet these criteria and are considered “unregulated”. Table 4-15 lists the dams on file with MFLNRA. Additional information on these dams is available from MFLNRO.

In 2007 the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada completed a preliminary review of the Granby River watershed to assess the feasibility of one or more dams in the watershed to reduce flood risk and add storage for beneficial use of water during low flow periods (PFRA 2007). PFRA focussed their attention on two sites: Site #1 is the site of the previous dam on Burrell Creek that was operated by the City of Grand Forks, and Site #2 is located on the Granby River main stem just south of the confluence with Howe Creek. The analysis showed that even very large structures would not be effective as flood control structures because the volume of water they would retain would not be significant compared to the freshet flows. Additional analysis and public consultation was recommended to assess the costs and benefits of dams at these sites to manage flows in the watershed (PFRA 2007).

Table 4-15
Dams in the Kettle River watershed

Dam Site - Reference Name	*Owner*	*PD No.*	*Height (ft)*	*Crest Length (ft)*	*Crest Width (ft)*
REGULATED DAMS					
MOODY CREEK POND	Private	PD54869	13	262	13
SADDLE LAKE	Private	PD55455	14	25	2.7
JEWEL LAKE	MoE - Fisheries	PD55817	6	105	5.9
PROVIDENCE (MARSHALL) LAKE	MoE - Fisheries	PD55854	33.5	160	10
BAKER CREEK #1 (H)	Private	PD55875	15	320	-
BAKER CREEK #2 (Q)	Fossen Air Ltd.	PD55870	17	110	13
ED JAMES LAKE	Private	PD55891	7	190	15
HOODOO LAKE - CONTROL	Private	PD56247	9	66	4
HOODOO LAKE - SADDLE	Private	PD56248	11	140	100
RHONDA LAKE	Big White Utilities	PD55974	70	1140	40
TAURUS (BULL) LAKE	MoE - Fisheries	PD56219	-	-	-
WOLFF CREEK	Private	PD65000 & PD73522	-	-	-
NON-REGULATED DAMS					
ANGELO CREEK	Sandner Bros.	n/a	-	-	-
CASCADE POWER	Powerhouse Dev.	PD54848	-	-	-
KETTLE RIVER MARSH (BOOTHMAN OXBOW)	DU - Habitat	PD55581	3	-	-
NEFF CREEK (H)	Private	PD55726	0	-	-
NEFF CREEK (J)	Private	PD55725	0	-	-
CARON POND	Private	PD55733	-	-	-
CASTLEMAN CREEK	Private	PD55708	-	-	-
EAST CASTLEMAN CREEK	Private	PD55710	-	-	-
EHOLT CREEK INTAKE	Private	PD55822	-	-	-
BAKER CREEK #3 (J)	Private	PD55876	6	-	-
BAKER CREEK EAST (Dugout)	Private	PD55880	0	-	-
BALLO CREEK	Private	PD55856	-	-	-
HANSON LAKE	Private	PD56093	-	-	-
JOHNSTONE LAKE	Private	PD56079	4	-	-
MATTHEWS LAKE	No Licensee	none	-	-	-
MOUNT BALDY - McKINNEY CREEK	Mt Baldy Strata Corp	PD54397	-	-	-

- no data. Private – Indicates a private individual. Owner's name is available from MFLNRO.

Table 4-15 (continued)

Dam Site - Reference Name	***Owner***	***PD No.***	***Height (ft)***	***Crest Length (ft)***	***Crest Width (ft)***
MOUNT BALDY (MCKINNEY) LOWER BALANCING	Mt Baldy Strata Corp	PD54401	-	-	-
MOUNT BALDY (MCKINNEY) UPPER BALANCING (WEST FORK)	Mt Baldy Strata Corp	PD54402	-	-	-
MYERS CREEK @ LOT 170	M & J Orchards Ltd	PD55992	-	-	-
MYERS MARSH	Ducks Unlimited	PD56056	-	-	-
MYERS WETLANDS	Ducks Unlimited	PD56056	-	-	-
NATHAN CREEK @ LOT @2514	Private	PD56089	4.7	-	-
SIDES CREEK	Private	PD56072	0	-	-
SIDLEY MEADOW	MoF - Grand Forks	PD54386	-	-	-
CARL CREEK - S/W DUGOUT	MoF - Grand Forks	PD65111	-	-	-
CARL SPRING S/W DUGOUT	MoF - Grand Forks	PD72351	-	-	-
CLARK CREEK (BIG WHITE PONDS)	MoF - Penticton Dist.	PD71711	-	-	-
CLARK LAKE	Private	PD55954	-	-	-
DAVID CREEK POND	Private	PD56169	-	-	-
ELKE'S BROOK (#1)	Private	PD56303	8		
ELKE'S BROOK (#2)	Private	PD56303	11		
LILY PAD LAKE	MoE - Fisheries	PD55905	-	-	-
MCINTYRE LAKE	MoE - Fisheries	PD55906	-	-	-
RENDELL CREEK POND	Private	PD55958	-	-	-
SAUNIER LAKE	MoE - Fisheries	PD56243	-	-	-

- no data. Private – Indicates a private individual. Owner's name is available from MFLNRO.

4.7 FLOODPLAINS AND FLOOD RISK

4.7.1 Kettle and Granby Rivers Floodplain Mapping

The Canada – B.C. floodplain mapping program (Canada *et al*. 1991; Ministry of Environment, Lands and Parks 1996) was completed in the 1990s, and the following floodplain maps were prepared for the Kettle River watershed:

- Lower West Kettle and Kettle Rivers, from Conkle Creek to Midway (8 maps)
- Kettle River in vicinity of Grand Forks (2 maps)
- Kettle River from Morrissey Creek to US Border including Christina Creek (4 maps)
- Granby River from Niagara to Grand Forks including confluence with the Kettle River (3 maps)
- Christina Lake (5 maps)

The maps can be downloaded from the MOE web site found at:
http://www.env.gov.bc.ca/wsd/data_searches/fpm/reports/region3.html

The maps show the “designated floodplain limit”, which is defined as the estimated limit of the 1 in 200-year flood (i.e. the peak flow that would probably occur once in every 200 years, or 0.5% chance every year). They also show the 20-year flood elevation for selected river valley cross-sections (5% chance of occurrence each year). It is important to note that the relationship between frequency and flood elevation is not linear. For example, just below Rock Creek the 20-year Kettle River flood elevation is 599.7 m and the 200-year elevation is 600.0 m, just 30 cm higher, and the two limits map very close together. At Gilpin, the 20-year and 200-year flood elevations are 500.6 m and 501.0 m, respectively, or 40 cm different.

Background hydrologic studies were completed for these watershed areas to develop the maps. The analyses used the flood records from stream gauging stations in the watershed as input to a computer model of flood backwater elevations to delineate areas lower than the 200-year flood elevation. The local flood elevation includes an allowance (0.6 m) for freeboard (i.e. the elevation to which impacting waves or wind-influenced water may rise).

The 200-year flood elevations may change over time with:

- New development in the floodplain;
- The presence of dikes, bridges and abutments, highway embankments in the floodplain;
- Improved survey control; and
- Climate change (Section 4.7.2).

Historical floods occurred in May 1894, May 1942, May 1948, on the Kettle River and May 1948, May 1956, May 1983, and May 1986 on the Granby River. Since these original reports, flooding has occurred on the Granby River in 2006 and on both the Kettle and Granby Rivers in 2011.

No flood records for the period since about 1990 were used for the Kettle River – Granby floodplain mapping, or since about 1995 for the Kettle River – Midway – Rock Creek – Westbridge section. With recent weather and flood patterns, the current 200-year flood elevations may be somewhat different than originally calculated. Also, although the current maps cover areas with most of the watershed's population, floodplain mapping has not been completed for the watershed upstream of Westbridge.

4.7.2 Potential Climate Change effects on Flood Hazard

Regional climate change modelling for the period 2010 to 2100 suggests that while the average annual precipitation may not change significantly, the average air temperatures will be warmer, and more winter precipitation will arrive as rain and not snow (Rodenhuis et al. 2007; Hamlet *et al.* 2010). The maximum snow depth may decrease and the high elevation snowpack may also melt by up to three weeks sooner in spring. The regional studies by Hamlet *et al.* (2010) and Schnorbus *et al.* (2011) indicate that the Kettle River watershed could see larger average peak flows in the spring and the peak would occur earlier (Section 4.5). However, there is still uncertainty about how much winter precipitation would fall as snow or rain, and any projection indicating higher peak flows is still preliminary for the Kettle River.

The existing floodplain mapping is based on data from before 1996, and there would be value in updating it for developed areas to include streamflow data collected since then (i.e. to include the 2006 and 2011 peaks) and to consider the effects of climate change.

5 WATER QUANTITY - GROUNDWATER

5.1 INTRODUCTION

Groundwater extraction is not regulated in B.C. and therefore only limited, mostly voluntarily collected information about private wells and groundwater extraction rates is available at present. The provincial government maintains a database of reported wells that is available to the public online through the B.C. Water Resources Atlas. In addition, information on groundwater wells (the WELLS database), aquifers (the aquifer mapping database), and groundwater and aquifer properties (the iMAPBC application) are available on-line[12].

Since 2005, the Groundwater Protection Regulation has required all wells (except dug wells less than 15 m deep) to be installed by qualified drillers who report the well properties, so the completeness of the database is improving. This database of well borehole information is used to create the provincial aquifer database in B.C. Therefore, aquifer mapping is only available in places with an appreciable number of reported wells present, which is a small percentage and currently insufficient to develop accurate estimates of available groundwater supply and use for the Kettle River watershed. Groundwater use records are more readily available in the Grand Forks area than in the rest of the watershed due to the relative concentration of population and because the aquifer is used for both irrigation and drinking water. A detailed investigation of the Grand Forks aquifer making use of the available data was recently completed by the Ministry of Environment with Simon Fraser University (Wei et al. 2010). The findings are summarized in Section 5.6.

As reported in Section 4.2.1, the major community water suppliers that extract groundwater have reasonably good records of how much water is pumped from the aquifers, notably City of Grand Forks, Grand Forks Irrigation District, SION Improvement District, and Covert Irrigation District. For the remainder of the watershed, groundwater use is generally not monitored or reported. Basic well data including number of wells, their location, and production is available from permitted community water systems.

Lastly, historic groundwater information collected by the province has mainly been in the form of basic data such as well records, water chemistry, water levels, or site-specific investigations.

5.2 AQUIFERS

The B.C. Ministry of Environment identifies and maps groundwater aquifers in the province. The goal of the aquifer classification system is “to inventory and prioritize aquifers for planning, management and protection of the Province's ground water resource” (MOE web site). A total of 15 aquifers in the Kettle River Watershed have been mapped and characterized by MOE, comprising only 1% of the total area on the Canadian side of the watershed (presented on Map 2). However, despite this limited coverage, the

[12] See http://www.env.gov.bc.ca/wsd/data_searches/

mapped aquifers encompass the major population centres in valley bottoms in the southern part of the watershed near the international border, where groundwater use is concentrated.

Table 5-1 summarizes the aquifer information available from the provincial database. At 39 km^2, the Grand Forks Aquifer (158 IA) is the largest mapped aquifer in the Kettle River watershed. Through the provincial aquifer classification system, the demand on the aquifer is classified as high and highly vulnerable to contamination because it is naturally unconfined and shallow. The aquifers near other population centres in the Kettle River watershed include:

- Aquifer 482 IIIA (11) – Kettle River Valley near Beaverdell (15.9 km^2). Rated as moderate productivity, low demand and high vulnerability;
- Aquifer 481 IIIB (11) – Kettle River Valley at Westbridge (6.1 km^2). Rated as high productivity, low demand and moderate vulnerability;
- Aquifer 478 IIA (13) – Midway (3.6 km^2). Rated as high productivity, high demand and high vulnerability;
- There are four aquifers mapped near Rock Creek; three in sand and gravel and one in bedrock (Table 5-1). The demand rating either matches or is one category less than the productivity rating. Two of the aquifers in the Kettle Valley bottom are rated as high vulnerability, while the other two are low vulnerability;
- There are two aquifers near Christina Lake (Table 5-1). Both are sand and gravel aquifers with low demand. The larger of the two (9.7 km^2) has moderate productivity and moderate vulnerability; and
- In addition to the main Grand Forks aquifer, there are five other aquifers on record located north of town, totally 9 km^2 in area. Three are in bedrock with low-moderate productivity, low demand, and moderate vulnerability, while the other two are in sand and gravel with high productivity and moderate demand. One (815) has high vulnerability and one (812) has moderate vulnerability.

Aquifer properties such as transmissivity and long-term sustainable water yield have only been studied in a systematic way in the Grand Forks Aquifer system (summarized by Wei *et al.* 2010). Less is known about the physical properties and capacity of other aquifers in the watershed. However, water demand is highest in the Grand Forks area and before 2011, when the current watershed planning process was initiated; there has arguably been less need for detailed studies in areas with low population densities. As aquifers are used and recharged locally, there has previously been little interest in determining average values of aquifer properties for the entire watershed or at the scale of the sub-basins delineated in this report. Moving forward into the next phases of the Kettle Watershed Management Plan, the demand ratings of the mapped aquifers should be reviewed based on existing and projected demand, considering projected changes in population and agricultural activity, and the factors that may increase the demand on groundwater including maintaining flows for fish and climate change. Where the projected future demand is high, additional technical assessment may be needed to characterize aquifer properties and obtain a better understanding of groundwater-surface water interactions. This could include installation of additional long-term monitoring wells, measurements of river discharge at the aquifer boundaries, plus additional aquifer-specific investigations (see Section 9.0 Recommendations).

Table 5-1 Summary of Aquifer Information in the Kettle River Watershed

Name	Type	Productivity	Vulnerability	Demand	Location	Size (km^2)	Sub-basin
158 IA (17)	Sand and Gravel	High	High	High	Grand Forks	38.8	6, 7
474 IIIA (11)	Sand and Gravel	High	High	Low	Kettle Valley - Rock Creek	0.7	3
475 IIIC (7)	Bedrock	Moderate	Low	Low	Bedrock slope north of Rock Creek	0.7	3
476 IIC (8)	Sand and Gravel	Moderate	Low	Moderate	Low lying area northeast of Rock Creek	0.4	3
477 IIA (13)	Sand and Gravel	High	High	Moderate	Kettle R., eastward from Rock Creek	5.8	3
478 IIA (13)	Sand and Gravel	High	High	High	Midway	3.6	3, 4
479 IIIB (9)	Sand and Gravel	Moderate	Moderate	Low	Kettle River Valley near Christina Lake	9.7	7, 8
480 IIIA (11)	Sand and Gravel	High	High	Low	South end of Christina Lake.	0.9	7
481 IIIB (11)	Sand and Gravel	High	Moderate	Low	Kettle River Valley at Westbridge	6.1	1, 2, 3
482 IIIA (11)	Sand and Gravel	Moderate	High	Low	Kettle River Valley near Beaverdell	15.9	1
811 IIB (11)	Sand and Gravel	High	Moderate	Moderate	North of Grand Forks	2	6
812 IIB (9)	Bedrock	Moderate	Moderate	Low	North of Grand Forks	1.7	6
e813 IIIB (8)	Bedrock	Moderate	Moderate	Low	North of Grand Forks	1.5	6
814 IIB (7)	Bedrock	Low	Moderate	Low	North of Grand Forks	0.8	6
815 IIIA (12)	Sand and Gravel	High	High	Moderate	North of Grand Forks	3	6

5.3 GROUNDWATER WELLS

There are 1,425 wells registered with the BC Ministry of Environment in the Kettle River watershed as of 2011. As noted earlier, registration of all wells is not currently mandatory (although reporting has improved significantly since 2005) and abandonment or closure of wells also commonly went unreported before the Groundwater Protection Regulation (GWPR) came fully into effect in 2005. Now drilled wells greater than 4.6 m depth or excavated wells deeper than 15 m must be closed by a qualified well driller or a qualified professional, and the closure report submitted to the Comptroller of Water Rights within 90 days.

While parts of the database may therefore not be complete, there are enough data from the 1,425 wells that it can be used as a representative sample of existing wells. Table 5-2 presents a summary of the database divided by sub-basin, while Figure 5-1 presents the distribution of wells across the eight sub-basins. Sub-basin 7, which includes the Grand Forks Aquifer, contains about half of all registered wells in the Kettle River watershed (686 wells or 48% of the total). The number of wells correlates with the “high” water demand from the aquifer (Table 5-1) indicating that groundwater demand in the watershed is greatest in the Grand Forks area. Sub-basin 3, which includes Midway, Rock Creek, and Bridesville, has the next highest concentration of wells at 20% of the total.

With respect to water withdrawal from wells, the majority of wells have a low or no reported well yield, while only a small number of wells have reported well yields larger than 500 US gpm (Figure 5-2). Of the wells with a reported yield, more than 85% have yields of 100 US gpm or less. The wells with the largest yields are commonly used as irrigation wells or for community water supply. Table B-2 of Appendix B provides a summary of the actual annual water use from major water purveyors; the majority of the data is from the Grand Forks Aquifer system

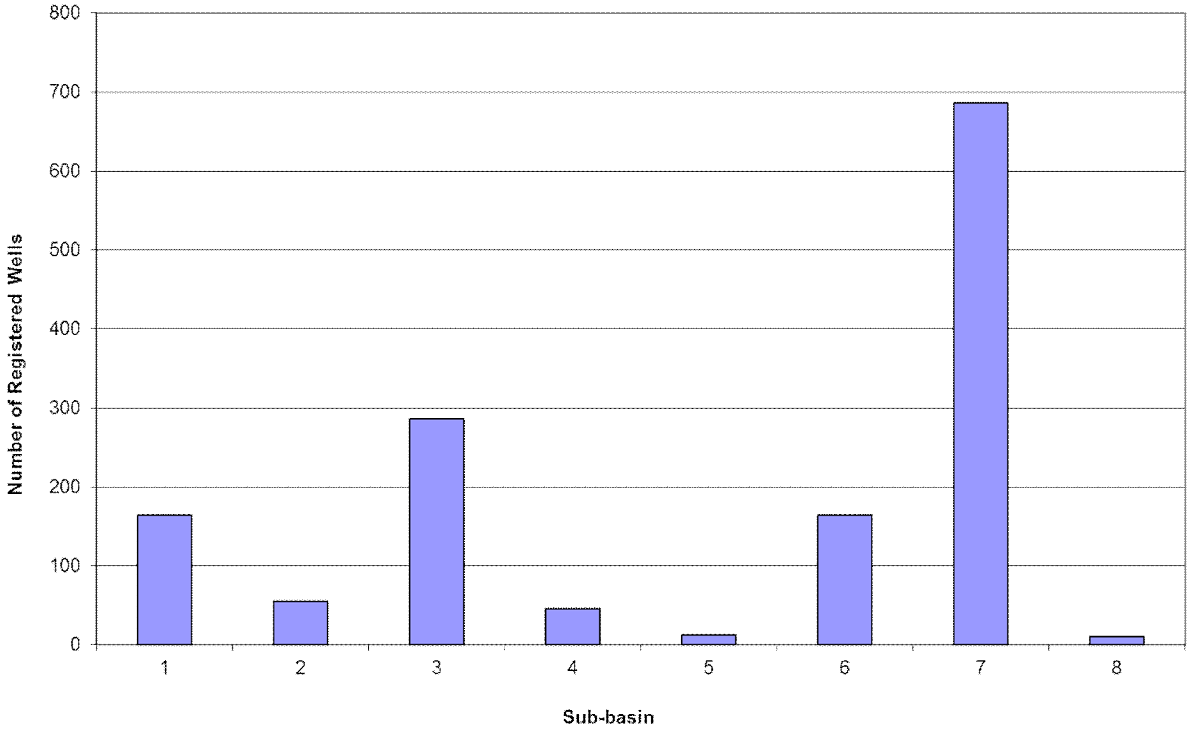

Figure 5-1
Distribution of wells across the eight sub-basins.

Table 5-2 Summary of Ministry of Environment Registered Wells by Sub-basin in the Kettle River Watershed

Sub-basin	Total Number of Wells	%	Purpose												Areas
			Private Domestic	%	Irrigation	%	Water Suppliers	%	Observation Wells (MFLNRO)	%	Commercial & Industrial	%	Other/ Unknown	%	
1	164	11.5	107	13.2	6	8.5	8	21.1	2	50.0	5	19.2	36	7.6	Westbridge, Beaverdell, West Kettle River
2	55	3.9	40	4.9	1	1.4	1	2.6	0	0.0	0	0.0	13	2.7	Christian Valley, Kettle River, Rendell Creek
3	286	20.1	92	11.4	13	18.3	9	23.7	1	25.0	5	19.2	166	34.9	Midway, Rock Creek, Bridesville, Mt Baldy
4	46	3.2	22	2.7	0	0.0	0	0.0	0	0.0	4	15.4	20	4.2	Greenwood Anaconda, Boundary Falls
5	13	0.9	7	0.9	1	1.4	1	2.6	0	0.0	3	1.2	1	0.2	July Creek Watershed
6	164	11.5	128	15.8	3	4.2	2	5.3	0	0.0	4	15.4	27	5.7	Niagara, Granby River
7	686	48.1	406	50.1	47	66.2	17	44.7	1	25.0	4	15.4	211	44.3	Grand Forks, Christina Lake
8	11	0.8	8	1.0	0	0.0	0	0.0	0	0.0	1	3.8	2	0.4	Southeast
Total	1,425	100	810	100	71	100	38	100	4	100	26	100	476	100	

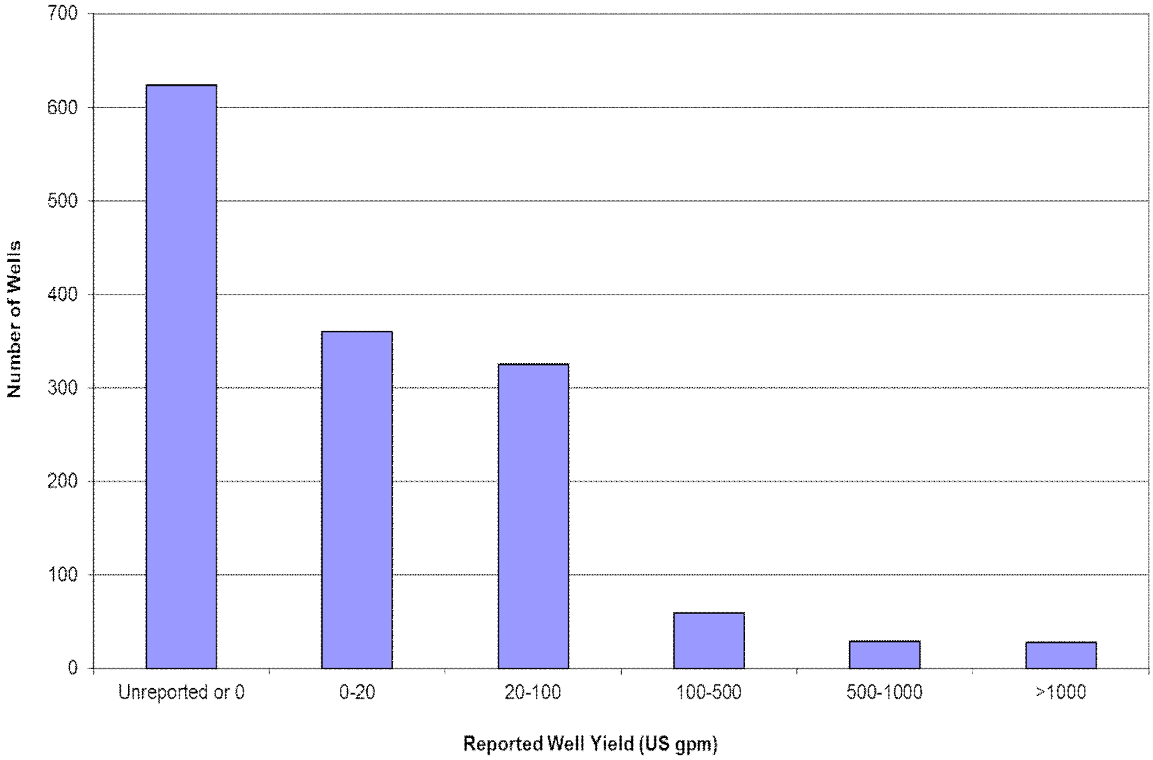

Figure 5-2
Frequency distribution of Well Yields in the Kettle Watershed

5.4 GROUNDWATER RE-CHARGE AND DISCHARGE

In the Kettle River watershed, groundwater recharge and discharge processes have been studied in some detail by the MoE and Simon Fraser University for the Grand Forks Aquifer (Wei et al. 2010). Previously, Scibek (2005) identified that approximately 11 – 20% of the spring freshet flow of the Kettle River is transferred into storage in the Grand Forks valley aquifer and releases the stored water back to the river as baseflow within 30-60 days. In addition, Aqua Factor Consulting Inc. (2004) suggested that surface-groundwater interactions could occur in the aquifers near Midway, Kettle Valley, Beaverdell, and Westbridge. However, these aquifers have not been studied in detail and the current level of understanding is limited by a lack of data (e.g. long-term pumping tests), which may partly relate to historically lower demand (Note: other than the Grand Forks aquifer only the Midway aquifer is currently rated as having high demand).

To date, there is only limited information on the role of bedrock aquifers and upland surficial aquifers in the recharge of the aquifers at lower elevations that are the main source of the valley's groundwater supply. Wei et al. (2010) indicate that groundwater flow from upland areas to the valley bottom (known as mountain block recharge) may be important, but assessment of this process was not within the scope of the Grand Forks aquifer study. The recent Okanagan Water Supply and Demand Project included development of a conceptual groundwater flow model (Summit 2010; Golder/Summit 2009) that is may generally be applied to the Kettle River watershed based on its similar topography, geology and climate.

Two upland groundwater flow systems exist within the conceptual model: 1) a shallow upland flow system comprised of relatively thin and localized surface deposits overlying weathered bedrock formations; and 2) flow through deeper-seated bedrock fractures. Precipitation and snowmelt in upland areas mainly supplies the shallow upland aquifer zone, and only a small volume makes its way through to the deeper zone. Groundwater within the shallow zone stays within the boundaries of the overlying surface catchment area, and is stored and eventually discharged to lower-lying unconsolidated aquifers and streams on a timeframe from years to decades. The proportion of recharge that goes to the deep fracture-flow system is likely small as a percentage of total groundwater recharge, but occurs over a large area and a much longer timeframe of hundreds to thousands of years. The mechanisms by which this deeper groundwater moves towards the low elevation unconsolidated aquifers are variable, depending on the nature of bedrock fractures and the presence or absence of faults. However, the annual contribution to the lower aquifers is relatively constant and relatively small, while the recharge from the shallow zone is seasonally variable and proportional to surface water runoff, with most of the flow happening not too long after the snowmelt-generated streamflow peaks in the spring.

Groundwater recharge and discharge in the Grand Forks aquifer is discussed in more detail in Section 5.6. The lack of information from other lower elevation areas is a data gap that could constrain water resources management decisions (see Section 8.0).

5.5 TEMPORAL VARIATION IN GROUNDWATER LEVELS

Long-term groundwater level monitoring data in the Kettle River watershed is available from provincially-operated observation wells Number 217 in Grand Forks (1977 – ongoing) and Number 306 in Beaverdell (1989 – ongoing). Figures 5-3 and 5-4 plot the water level data from Wells 217 and 306 respectively. Note that water level measurements in these two observation wells occurred approximately monthly until 2004 when automated pressure transducer systems were installed. Continuous daily data are available from then on (Note: This is why the plot appears to thicken towards the right side of the charts).

In the Grand Forks well (#217), the annual variation is the groundwater level is about 1.2 m. The annual rise and fall is linked to the water level in the Kettle River. The maximum groundwater level corresponds to the maximum river level, but lags by a few weeks (Wei et al. 2010). Also, the annual cycle is dampened in groundwater compared to the river and decreases the farther away a well is from the river.

From a visual review of observation well 217, it appears that there is no observable long-term trend of aquifer depletion or replenishment. The presence or absence of a statistically significant trend was examined in the 1977 to 2003 data when groundwater level was measured about monthly[13], using the Mann-Kendall test for trend (Systat 2010). The results indicate that neither an upward or downward trend were significant over this 26 year period at the $p \leq 0.05$ level. This observation correlates with the findings in Wei et al. (2010), which indicates that the shallow aquifer is connected to the Kettle River and that temporal variations in river flow are reflected in the groundwater elevation. The decreasing trend identified for August Kettle River flows over 1981-2010 in Section 4.3.3 of this report does not appear to translate into a trend in groundwater levels.

Figure 5-5 further examines the data from observation well 217. It shows the monthly average, maximum, minimum, and 10th and 90th percentile values. There is somewhat more year-to year variability during freshet. The water levels in the well for each year were plotted on the same graph to assess if there was any shift in the annual pattern (not shown). The analysis indicated that maximum water levels in the aquifer occur in early to late June every year with no apparent shift in either peak water level or timing of that peak over the period of record. However, very detailed water level data collection (i.e. hourly) has only occurred since 2004 and temporal changes reflecting climate effects may become more apparent with time.

At Beaverdell (Well #306) the groundwater level shows the same annual cycle as at Grand Forks (Figure 5-4), but the annual change is only about 1 m on average. The presence of the annual cycle mirroring the West Kettle River hydrograph confirms that the river-aquifer hydraulic connection is present here as well. The assessment of trend using the Mann-Kendall test found

[13] One of the assumptions in statistical trend analyses is that the data are evenly spaced in time, which is why the more frequent post-2003 data were not included. Initial screening with the full data set suggest a very slight decreasing trend, but the Sen's slope value is sufficiently low (<0.001) that it is not considered reliable given the precision of the measurement instruments. The Grand Forks and Beaverdell data should be assessed for trend again in 2014 when there are 10 years of automated data (a statistical guideline for minimum sample size for trends).

that there is a very slight (Sen's slope <0.001) but statistically significant ($p<0.05$) downward trend in groundwater level over both the full 1989-2010 data set and the period when measurements were taken manually (1989-2003).

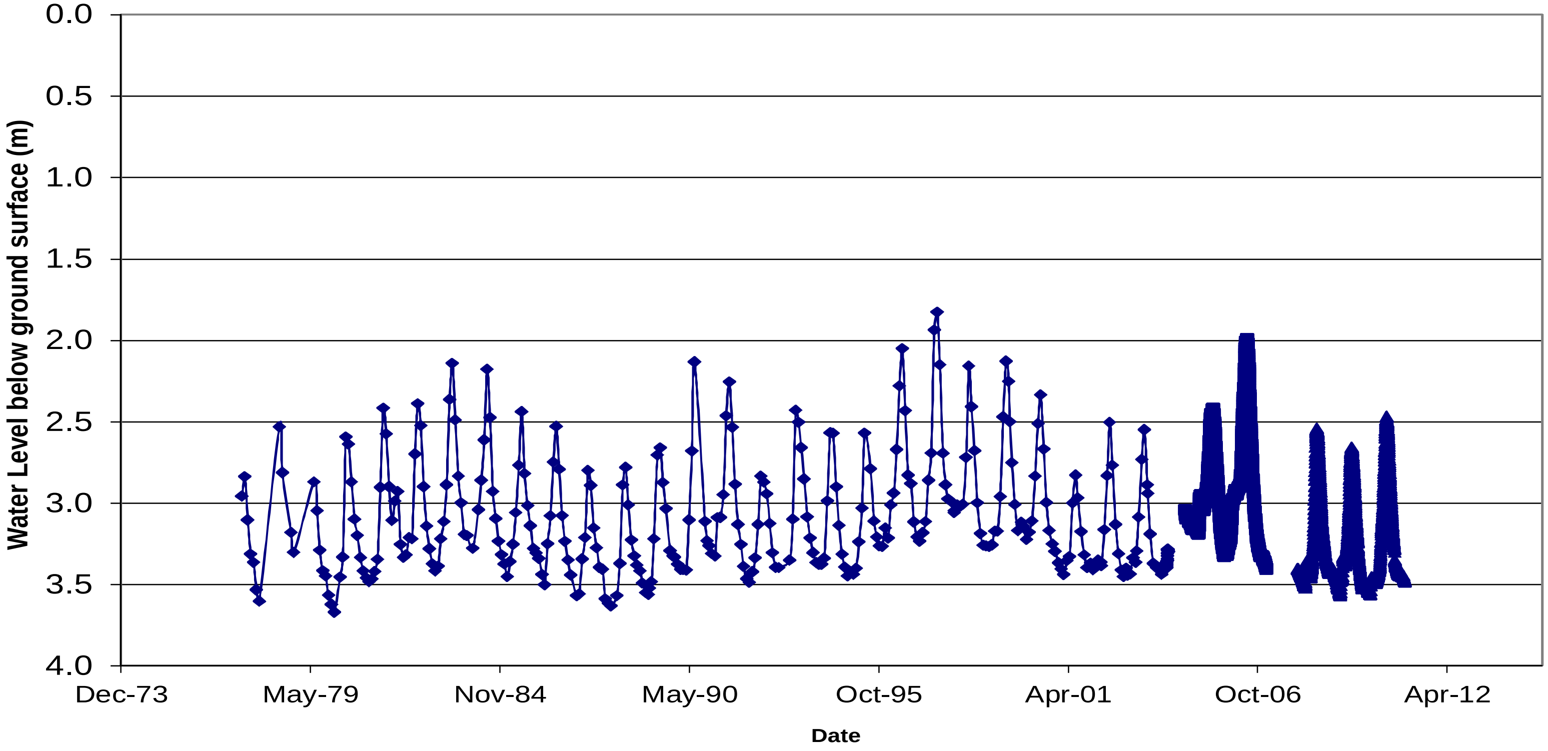

Figure 5-3
Water level data from Observation Well 217 in Grand Forks (1977 – 2011)

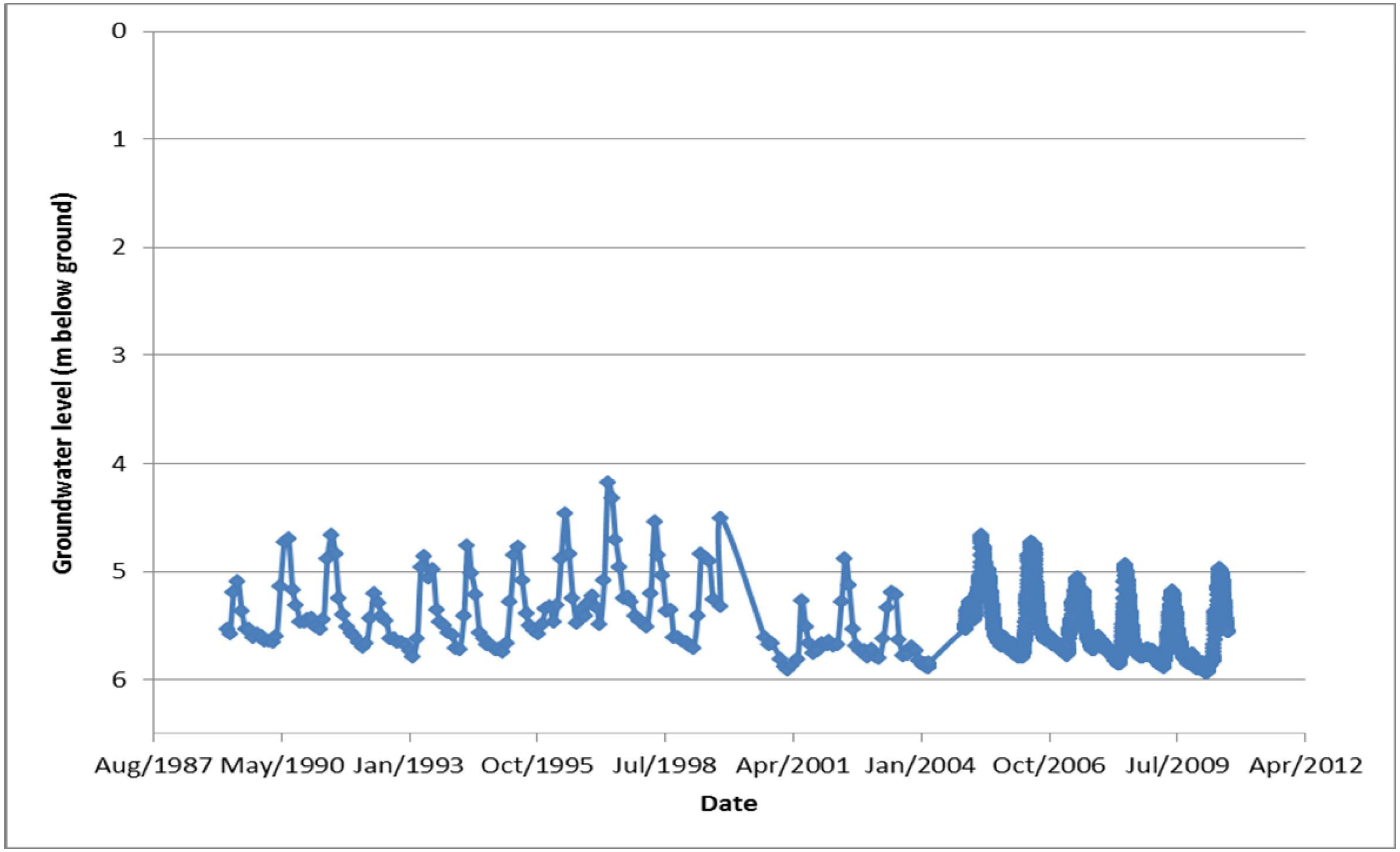

Figure 5-4
Water level data from observation well 306 in Beaverdell (1989-2011)

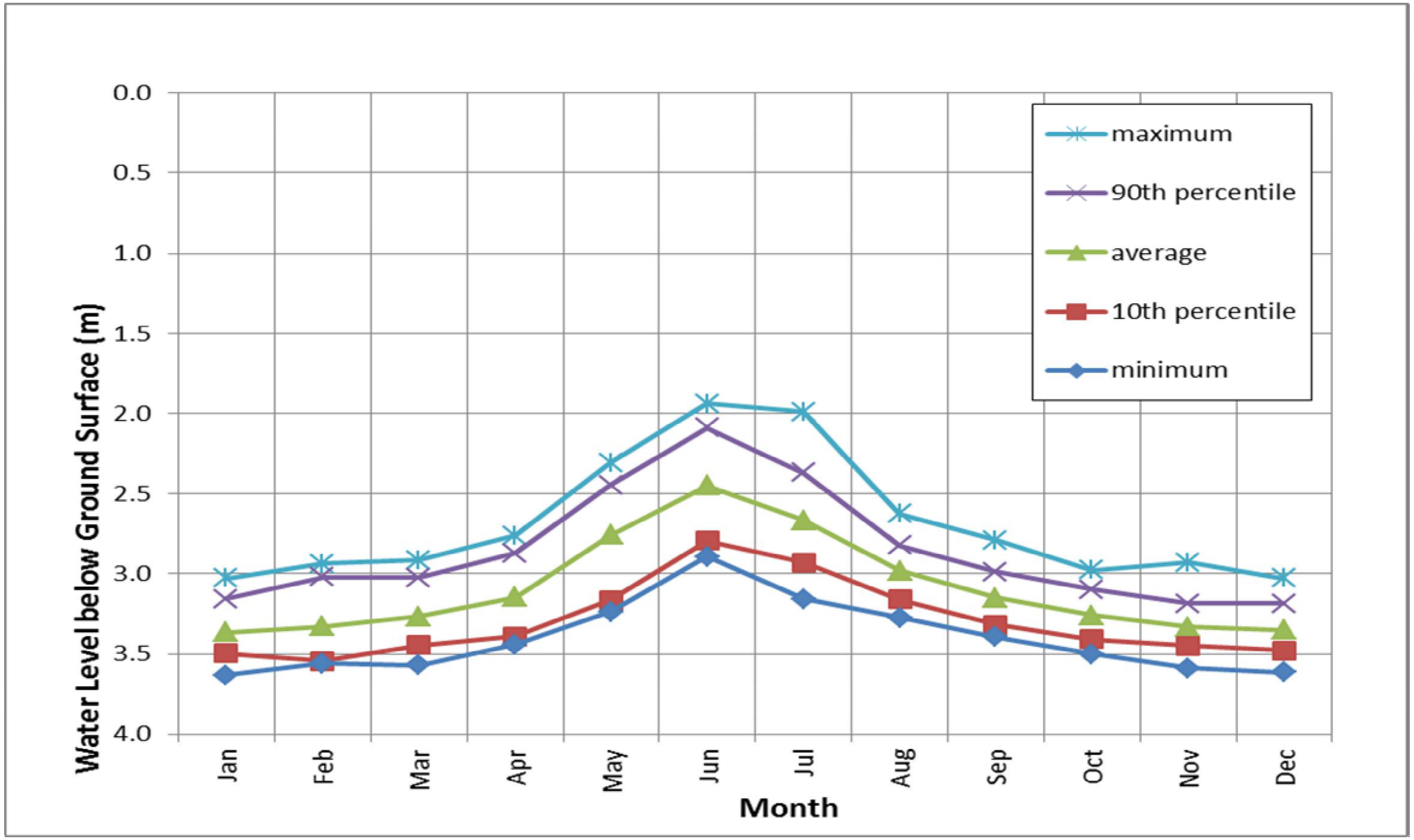

Figure 5-5
Water level data from Observation Well 217 in Grand Forks for years 1981 – 2010

5.6 DOES GROUNDWATER EXTRACTION INFLUENCE SURFACE WATER?

5.6.1 Grand Forks Aquifer Hydrogeology Study (2010)

A detailed study of groundwater in the Kettle River watershed by the Ministry of Environment and Simon Fraser University (Wei *et al.* 2010) has examined the physical and chemical hydrogeology of the Grand Forks aquifer system in detail. The report includes a good summary of the relatively numerous number of studies on local groundwater resources that extend back to the 1960s. The key findings of the Wei *et al.* (2010) investigation are summarized below. The full report can be obtained from the MOE web site.[14]

The Wei *et al.* (2010) groundwater review confirmed that the Grand Forks aquifer and the Kettle River are hydraulically connected. This was based on the combination of evidence from the surficial geology, surface and groundwater elevation measurements, pumping tests, numerical groundwater modeling, and groundwater chemistry studies that have been conducted. Pumping from a well induces groundwater from the surrounding area to flow towards that well. The area from which groundwater is drawn to a well depends on aquifer properties and pumping rates and is called the capture zone. Hydrogeologic modelling of the groundwater capture zones of high-yielding wells from SION Improvement District, the Grand Forks Irrigation District, Covert Irrigation District, and the City of Grand Forks, indicate that the capture zones of most of the wells that are located within one kilometre of the Kettle River intersect or extend past the Kettle River. These wells are mostly located in the western part of the aquifer, which suggests that there is a high probability that pumping from the wells enhances the natural recharge of the aquifer from the Kettle River, thereby reducing flow in the Kettle River to a not fully defined extent. As described in Section 4 of this report, the overall annual effect is small on average if it is assumed that all groundwater is actually derived from surface (2% reduction), but the reduction is up to 17% in August (on average) at the POI located downstream of Grand Forks. That estimate is conservative since it assumed that all groundwater pumping at that time is pulling water from the river. In reality it is likely less and the average net river flows in August are probably about 90% of natural flows. In years with below average flow, however, the percentage reduction is greater (see Section 4.3.5 for details).

Pumping tests conducted on some wells indicate that after a period of pumping, the drawdown in the tested wells stopped and the water level in the well remained steady even with continued pumping. This indicated a close connection to a surface water body and corroborates the findings of the capture zone modelling.

Further and more detailed computer modelling of the aquifer and the high-flow wells in the Grand Forks area showed that pumping from wells during baseflow periods in August may lead to a steady-state decrease of flow in the Kettle River in the western part of the aquifer ranging from slight (2% increase) in Zone 3 up to 41% in Zone 2 (Wei *et al.* 2010; pgs. 42-45, 97). The model included river stage, groundwater depth, porosity, and hydraulic conductivity for the Grand Forks Aquifer and assumed the maximum possible extraction rates from the pumping wells. However, computer modelling relies on a number of assumptions

[14] At http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/library/aquifers/gf_report_feb_5-10.pdf

and professional judgment, and therefore there is some uncertainty. Nevertheless, the results showed that flows in the Kettle River could be potentially affected by pumping from the surrounding wells. It is important to remember; however, that most water suppliers do not make use of their current surface water licensed allocations. They selectively use groundwater instead and the overall effect on Kettle River flows is less than if the surface licences were actually used.

5.6.2 Preliminary Water Balance Estimate of Recharge from Kettle River

Groundwater extraction from the Grand Forks aquifer by the major water purveyors reported in this study (Section 4.2.1) provides an updated estimate of groundwater extraction compared to the conservative (i.e. high) pumping estimates used by other studies (e.g. Wei *et al.* 2010). Accordingly, a simple water balance model was developed for this study to examine if water use from wells in the area exceeds the local recharge to the aquifer (Table 5-3) and that if any shortfall in recharge will be met by recharge from the Kettle and Granby Rivers, and consequently lower the volume of flow in these rivers. Therefore, to capture the inherent variability in the system, we included low and high estimates of recharge, varying the estimated area over which recharge to the aquifer occurs and the percentage (as fraction) of precipitation that enters the aquifer as recharge. It was also assumed that there is no change in water levels in the aquifer, consistent with the limited multi-year trend observed in observation well 217 (Section 5.5). In addition, the model did not take into account any irrigated water returning to the aquifer, and it was assumed that irrigation return flow is equal to zero. This is unlikely to be the case (see next paragraph).

The results suggest that an annual average of 0.128 to 0.280 m^3/s of water is drawn from the river system to replenish the aquifer (Table 5-3). By comparison, the net inflow value given by Wei et al. (2010) for Zone 2 is equal to 0.27 m^3/s (23,578 m^3/day – Figure 22), comparable to the upper limit of the range in Table 5-3. However, water demand is generally highest in July and August, when flows in the Kettle River are low. Accordingly, this suggests that flow in the Kettle River may be affected by current levels of groundwater extraction and any concerns with low flows in the river are likely to manifest themselves in drier years and in the months of August and September. However, any future modeling efforts should include an estimate of irrigation return flow to the aquifer based on scientifically sound estimates. The Grand Forks aquifer is an unconfined aquifer with significant sand and gravel (Wei et al. 2010), and some portion of the irrigation water returns to groundwater. Estimates of actual irrigation effects on the aquifer would be improved if irrigation return is factored in (see Section 8.2 – Data Gaps).

The results of the simple water balance supports the recommendation made by Wei *et al.* (2010) that any new large water supply well in the Grand Forks Aquifer should be subject to a detailed hydrogeological study. Currently there are limited options to regulate the development of such a new water supply based on quantity of extraction. The need for a Kettle watershed-specific regulation, which is possible under Section 4 of the B.C. *Water Act*, can be considered during Part 2 of the Watershed Management Plan

Table 5-3
Water Balance Model for the Grand Forks Aquifer

Variable	Units	Low Recharge Estimate	High Recharge Estimate
Max Annual Water Use[1]	m^3	9,132,000	9,132,000
Estimated Area of Aquifer Recharge[2]	km^2	44	100
	m^2	44,000,000	100,000,000
Mean Annual Precipitation[3]	mm	510	510
Estimated Fraction of Precipitation Recharging Aquifer[4]		0.02	0.10
Mean Annual Recharge	mm	10.2	51
	m	0.0102	0.051
Mean Annual Recharge Volume	m^3	306,000	5,100,000
Deficit not provided by precipitation	m^3/year	8,826,000	4,032,000
	m^3/s	0.280	0.128

Note:

1. Total combined maximum actual water use by SION Improvement District, Grand Forks Irrigation District, City of Grand Forks, and Covert Irrigation District from 2003-2010;
2. Low estimate is the area of direct recharge (i.e. Kettle River valley), while the high estimate includes the surrounding mountains;
3. 1971-2000 climate normals for the Meteorological Service of Canada climate station “Grand Forks” (Station No. 1133270; Elevation = 531.9 m); and
4. Source: MOE (2011)

5.7 WATER ALLOCATION IN THE FUTURE

As described in Section 4.1, there are currently 994 water licences on the Canadian side of the Kettle River watershed at 826 points of diversion. The licensed off-stream volume from the licences is 57,765 ML/year and 16,849 ML/yr is licensed for storage. In addition, surface water rights in the United States in the watershed upstream of Grand Forks total about 24,800 ML/yr. On average, the off-stream licences from both sides of the border account for 3.5% of the average naturalized flow for the Kettle River watershed above the Cascade international boundary. Actual use is estimated to be 1.8% of the naturalized flow, and about half of what the licenses permit. Demand is highest when river flows are near their annual lows, but even in August water withdrawals account for no more than 17% of the average flow at Cascade. As described in Section 4.0, this is an intentionally conservative (i.e. high) estimate and the actual flow reduction is possibly less. For allocation planning purposes, however, it is reasonable to utilize this conservative estimate of the effect of current withdrawals on river flow since a number of assumptions were employed concerning groundwater-surface water interaction and actual water use in the U.S. Allocation must also consider instream flow needs during drier than average years. As presented in Section 4.2.2, late summer flows fall below 10% MAD during the 10-year return interval low flows.

With respect to future demand, the draft results of the Kettle Agriculture Demand Model are for 2003, the warmest and driest year on record, and therefore provide an indication of demand under the influence of climate change. As the model is refined it can be used to estimate demand under a range of climate scenarios as well as scenarios that consider either expansions or contractions of agricultural activity. These projections can then be compared against the existing licence volumes and river flow statistics to assess to what degree the existing licence capacity (Section 4.3.5) would potentially be used.

Any consideration of future applications for off-stream **surface water** use or storage should consider 1) the location of the proposed point of diversion and cumulative impact downstream, and 2) the timing of the proposed withdrawals with respect to the current licensed use. With respect to location, the licensed volumes in the Kettle River above Westbridge and the Granby River are less than 1% of the annual flow, while at other points-of-interest the licensed volume exceeds 5% of the flow (Section 4.3.5); however, any new point of diversion should consider impacts downstream. With respect to timing, withdrawals or storage from spring freshet would tend to have only a slight effect on flow, whereas a new application for an irrigation licence could have a potentially biologically-significant effect in late summer depending on location.

For **groundwater**, licences are not currently needed for withdrawals, although a new water utility must obtain a Certificate of Public Convenience and Necessity (CPCN). Other groundwater users only need authorization in most cases if the pumping rate exceeds 75 L/s, which is a very large rate (equal to 4.5 m^3/minute), and if the pumping will occur continuously or intermittently for a year or more. A pumping rate of 75 L/s is also the threshold for a new or expanded groundwater extraction facility that normally triggers a formal environmental review under the Reviewable Projects Regulation of the B.C. *Environmental Assessment Act* (e.g. if a mine proposed to pump at this rate for pit de-watering).

Wei et al. (2010) recommended that before any new large capacity water well was brought into production in the Grand Forks aquifer, an assessment should be completed to delineate the capture zone, determine effects on other wells, and evaluate impacts on the Kettle and Granby Rivers. This is a valid recommendation and would be in the proponent's best interest, but it is not a legal requirement at present except where noted above. The recommendations that a detail groundwater resources assessment be completed to support new large capacity wells also holds true for other valley-bottom aquifers in the watershed since the hydraulic connectivity between river and aquifer documented at Grand Forks is present to varying degrees throughout the valley.

In future, the modernization of the B.C. *Water Act* is likely to lead to a requirement to do a hydrogeological assessment to support an application for any new water well over some pumping threshold, to demonstrate capacity and to determine if there is potential for a detrimental impact on nearby wells. RDKB and the other local governments should look for ways to also require an assessment of effects on streamflows in the groundwater use authorization process, if it is not included in the provincial legislation. This could be a component of the planned Watershed Management Plan if it is made legally binding under Section 4 of the *Water Act*.

6 WATER QUALITY

6.1 SURFACE WATER QUALITY

6.1.1 Water Quality Monitoring Locations

A search of the B.C. Environmental Monitoring System (EMS) database was completed to determine how much water quality data are in the public record. The search was completed for the Kettle River main stem, the named tributaries on the NTS 1:50,000 scale maps, and for any other streams or lakes where land use activities suggest that monitoring may have occurred. The monitoring sites with data from nine or more sampling dates are listed in **Appendix E** and shown on Map 1. Other sites are listed in the databases, but typically have only a few samples and have limited value for assessing water quality conditions.

Included in the list of sites are two active long-term water quality monitoring sites that are part of the Canada - British Columbia Water Quality Monitoring Agreement:

- Kettle River at Midway (#BC08NN0011); and
- Kettle River at the Carson Road Bridge (#BC08NN0021).

Both of these sites were established in 1979 and have about 22 years of data. In addition to these two active stations, a former Canada-B.C. station on the Kettle River at Gilpin (downstream of Grand Forks) has about 16 years of data (#BC08NN0022) and a former station on Myers Creek at the U.S. border has six years. The Canada-British Columbia Water Quality Monitoring Network is a system of about 45 sites throughout B.C. where data are collected frequently (i.e. every 2 weeks) in order to allow assessment of trends (changes over time) and detailed comparisons of the results to water quality guidelines and objectives. Large areas of B.C. such as the northeast have no long-term sites, so more is known about water quality trends in the Kettle River watershed than in many other areas of B.C. However, the long-term data are concentrated in the lower Kettle watershed near the Canada-US border and less is known about tributaries, headwater streams, and small lakes.

The other sites with EMS data that have multi-year (>5 years), shorter but relatively frequent, or ongoing sampling data include:

- “Upstream-downstream” monitoring sites above and below the wastewater treatment outfall to Boundary Creek at Greenwood (1975 - ongoing).
- A “downstream” monitoring site on the Kettle River below the Midway wastewater treatment plant (1997 – ongoing).
- Christina Lake in the deep centre of the North Basin (1991 – ongoing).
- Three additional sites in shallow parts of Christina Lake (2000-2006).

- “Upstream-downstream” sites on the West Kettle River at the location of a former tailings pond (1980-1994).
- Burrell Creek at 19.5 km of the Burrell Creek forestry road (1988-1997).
- Snowshoe Creek upstream of the July Creek confluence (2000 – 2009).
- Sutherland and Moody Creeks (1998-2001). These streams were sampled over three years as part of a Kootenay region water quality inventory program funded by Forest Renewal B.C. The intent was to set Water Quality Objectives and draft reports were prepared, but the provincial program to set objectives in watersheds with forest harvest activity was not widely implemented.

WSC used to collect suspended sediment data at selected streamflow monitoring stations across Canada. However, a search of the WSC archived sediment data found that none of the Kettle watershed hydrometric sites have associated suspended sediment data.

6.1.2 Canada – British Columbia Water Quality Monitoring Program

As noted above, there are two active Canada-BC stations and two discontinued stations. Table 6-1 shows the median, 10th percentile, and 90th percentile values for a selected number of water quality variables at the two active Canada-B.C. sites. The data in Table 6-1 cover the period from October 1979 to December 2005 (the data collected since the end of 2005 are not yet available in EMS).

Environment Canada and B.C. MOE periodically calculate a Water Quality Index (WQI) from the data at the Canada-BC sites. This was last done in 2007 using 2000-2004 data (Environment Canada et al. 2007). For Kettle River at Midway the water quality was rated as “fair” with a score of 76.7 out of 100 (the possible ratings are poor, marginal, fair, good, and excellent); meaning “measurements sometimes exceed water quality guidelines and, possibly by a wide margin. Aquatic life is protected, but may at times be threatened or impaired”. No significant trends (i.e. increases or decreases over time) were noted for the 1972-2000 period (see below). In the previous index report this site was also rated as fair with a score of 71.1, suggesting that water quality improved slightly between 2001-2003 and 2002-2004. Environment Canada’s web site provides the WQI score for 2004-2006, which is 76, indicating that the “fair” rating was maintained. The “fair” rating is attributed to common exceedances of the water quality guidelines for water temperature and total cadmium, and less frequent exceedances of guidelines for fluoride, lead and phosphorus.

At the Carson Road site the rating is “good to fair” based on a 2002-2004 WQI score of 71 and a 2001-2003 score of 82.6 (a “good” rating means “measurements rarely exceed water quality guidelines and, usually, by a narrow margin. Aquatic life is protected with only a minor degree of threat or impairment”). The most recently available WQI score for Environment Canada is 65 for 2004-2006, which is the low end of the “fair” range (65-79). As with the Midway site, water temperature, fluoride, phosphorus, and cadmium were the parameters that limit water quality.

In 2009 the Canada-B.C. program published an assessment of water quality trends (i.e. changes over time) at the two active sites based on 18 years (1990-2007) of data (Dessouki, 2009). The key findings of the assessment were:

- Water quality at both sites was very similar and “generally good”.
- Summer peak water temperatures exceeded B.C. aquatic life (19ºC) and drinking water (15ºC) guidelines.
- Statistically significant increasing trends were found at one or both sites for turbidity, total hardness, total phosphorus, total molybdenum, dissolved chloride, dissolved fluoride, and fecal coliforms.
- Statistically significant decreasing trends were found at one or both sites for total colour, specific conductivity, several total metals (aluminum, chromium, copper, iron, lead, lithium, manganese, nickel, and zinc), and several extractable metals (gallium, lanthanum, and potassium).
- The concentrations of a number of total metals exceeded water quality guidelines, but the concentrations were strongly correlated with turbidity and thus likely bound to suspended sediments and organic matter. As such these metals are not available for uptake by biota.
- As reported in earlier publications, dissolved fluoride often exceeds the aquatic life guidelines.
- There was a statistically significant decrease in flow (discharge) in the Kettle River at Midway as measured on the bi-weekly sampling dates. This is consistent with the flow trend analysis completed for this report (Section 4.3.3).

Based on the assessment, the author recommended changes to the monitoring program including measuring dissolved metals in addition to total metals, lower detection limits for some metals, and sampling at the two sites on the same day (Dessouki, 2009). Field filtering and analyses for dissolved metals is expected to begin shortly, but coordinating sampling to the same date may not always be operationally feasible (Dessouki, pers. comm. 2012).

Table 6-1
Water quality statistical summary – Kettle River at Midway and Carson Road

Parameter	Units	B.C. Aquatic Life Guideline	Canadian Drinking Water Guideline	Kettle River at Midway (Oct. 1979 – Dec. 2006)		Kettle River at Carson Road (Oct. 1979 – Dec. 2006)	
				Median (n)	10^{th} & 90^{th} percentile	Median (n)	10^{th} & 90^{th} percentile
pH	pH units	6.5 – 9.0	6.5 – 8.5	7.9 (677)	7.4 – 8.1	8.0 (569)	7.5 – 8.2
Alkalinity, total	mg/L	ng	ng	58.1 (535)	24.9 - 84.4	74.2 (410)	30.9 - 104
Hardness, total	mg/L	ng	200*	57.7 (239)	24.8 – 80.5	69.2 (125)	31.7 - 98.5
Specific conductance	µS/cm	ng	ng	135 (756)	59 - 192	172 (637)	71 - 234
Turbidity***	NTU	8	ng	0.5 (744)	0.2 – 3.94	0.60 (611)	0.21 – 4.7
TSS***	mg/L	25	ng	10 (266)	5 – 32.5	10 (244)	5 - 38
Chloride, dissolved	mg/L	600	250	1 (535)	0.5 – 1.9	1.4 (409 0)	0.6 - 2.3
Sulphate, dissolved	mg/L	100	500	6.8 (534)	2.8 – 11.1	9.9 (410)	4.10 – 15.8
Dissolved Oxygen	mg/L	8	ng	10 (1)	10 -10	-	-
Total P	mg/L	ng	ng	0.009 (512)	0.004 – 0.051	0.013 (383)	0.005 – 0.065
Total dissolved P	mg/L	ng	ng	0.004 (176)	0.002 - 0.012	0.004 (179)	0.002 - 0.012
Ammonia-N	mg/L	5.86 (pH 8, t 10°)	ng	.001 (5)	0.001 – 0.004	0.004 (4)	0.001 – 0.014
Nitrate + nitrite-N	mg/L	3.0	10	0.037 (410)	0.007 - 0.141	0.039 (288)	0.01 – 0.154
Total aluminum	µg/L	100 (dissolved)	100**	31 (437)	6 - 497	44 (419)	8 - 646

Table 6-1 Continued

Parameter	Units	B.C. Aquatic Life Guideline	Canadian Drinking Water Guideline	Kettle River at Midway (Oct. 1979 – Dec. 2006)		Kettle River at Carson Road (Oct. 1979 – Dec. 2006)	
				Median (n)	**10th & 90th percentile**	**Median (n)**	**10th & 90th percentile**
Total arsenic	µg/L	5	10	0.4 (541)	0.2 – 0.62	0.50 (496)	0.2 – 0.8
Total cadmium	µg/L	0.03	5	0.1 (456)	0.008 – 0.25	0.1 (413)	0.01 – 0.1
Total copper****	µg/L	3.0	500	0.48 (457)	0.2 - 2	0.8 (409)	0.4 – 2.4
Total lead****	µg/L	5.5	10	0.2 (458)	0.026 - 1	0.2 (409)	0.03 – 0.9
Total iron	µg/L	1,000	≤300*	45.9 (586)	15.7 – **517.5**	64 (537)	19 - **659**
Total manganese****	µg/L	800	50*	5.6 (586)	2.4 – 20.8	5.0 (537)	2 - 22
Total mercury	µg/L	ng	1.0	-	-	-	-
Total uranium	µg/L	ng	20	0.99 (96)	0.49 – 1.64	1.17 (93)	0.49 – 1.64
Total zinc****	µg/L	7.5	≤5,000*	0.5 (452)	0.2 – 2.99	1 (405)	0.2 - 4.36
Total cyanide	µg/L	10	200	<0.5 (247)	<0.5 – 1.1	<0.5 (371)	<0.5 – 1.3
Fecal coliforms	CFU/ 100 mL	ng	0	**8** (172)	<1 - **37**	**5** (162)	<1 - **24**

n – Sample size; < indicates less than detection limit shown
ng – no guideline
*Aesthetic guideline. Other drinking water guidelines are health-based
** Operational guideline for water treatment plants only
*** Turbidity and TSS guidelines are increases above background. Values shown are for “clear flow” period.
**** Aquatic life guideline varies with hardness. Value is approximate based on site water hardness.
Bold – exceeds Drinking Water Guideline
Underlined – exceeds Aquatic Life Guideline

Monitoring at the Gilpin Canada-B.C. site ceased in 1995. The last water quality summary report for that site concluded that water quality there "was generally excellent during 1980 to 1994" (Webber and Pommen 1996). Fluoride was noted to be naturally high and the report suggested that local fish populations were adapted to fluoride above-guideline concentrations. Based on the excellent rating, the report recommended that monitoring at Gilpin was no longer needed.

6.1.3 Monitoring of Point-Source Discharges and other Permits

The EMS data set includes water quality data from Boundary Creek from sites located upstream and downstream of the wastewater treatment plant. Table 6-2 shows the average concentrations of a select number of parameters that are potentially indicative of a municipal wastewater discharge, including total suspended solids, chloride, ammonia-N, nitrate-N, total phosphorus, and fecal coliform bacteria. The differences in the averages between the two sites were tested to see if they were statistically significant using the Mann-Whitney U test (Systat 2010). The results show no significant difference (at $p \leq 0.05$) between the upstream and downstream sites, indicating that the wastewater is not having a detectable effect on the creek. All of the parameters in Table 6-2 met the applicable water quality guidelines for aquatic life protection in the downstream sample.

There are "downstream" data for the wastewater facility at Midway (EMS # E228518) but no parallel "upstream" monitoring. Table 6-3 shows the median, maximum and minimum values for that site. The Canada-B.C. station on the Kettle River at Midway is located downstream of the main community, and is sampled much more frequently. In the most-recent water quality assessment report (Dessouki 2009), several variables were found to have increased slightly at this site over 1990-2007 that may be indicative of wastewater inputs, including fecal coliforms, total phosphorus (but not dissolved P), and dissolved chloride.

The City of Grand Forks WWTP discharges to the Kettle River. The Canada-B.C. station at Carson Road is located upstream of the discharge point, and therefore does not provide information on potential effects from discharges in the City. Monitoring at the former Canada-BC site at Gilpin, downstream of Grand Forks, ceased in 1994 because the water quality over the 1980-1994 period was good and monitoring resources were needed elsewhere.

As noted in Section 6.1, EMS includes data from "upstream-downstream" monitoring that took place on the West Kettle River upstream and downstream of a Teck Corporation tailings pond location from 1980 to 1994. This tailings pond was part of the Highland Bell Mine that operated with a number of owners from 1913 to 1989. The tailings pond discharged to an exfiltration ditch rather than directly to the river (Ministry of Environment, 1977). Monitoring took place at this site before 1980, but the data were not captured in a digital format until 1980 (see Section 6.1.4).

Table 6-2
Boundary Creek water quality upstream and downstream of the Greenwood wastewater treatment plant

Parameter	Boundary Creek Upstream STP	Boundary Creek Downstream STP	Difference in averages significant at p≤0.05?
	Average (range)	Average (range)	
Total suspended* solids	1.5 (1-11)	2 (1-11)	no
Chloride, dissolved	1.26 (0.6-2.2)	2.94 (0.5-25.4)	no
Fecal coliforms	56 (5-540)	67 (<1-310)	no
Nitrate + Nitrite-N	0.12 (0.02-0.27)	0.20 (0.02-0.99)	no
Ammonia-N	0.011 (0.005-0.064)	0.009 (0.005-0.029)	no
Total N	0.09 (0.02-0.22)	0.11 (0.02-0.24)	no
Total dissolved P	0.007 (0.003-0.015)	0.007 (0.003-0.015)	no
Total P	0.013 (003-0.089)	0.013 (0.003-0.099)	no
Dissolved oxygen	11.2 (9.3-14.0)	11.4 (9.5-13.7)	no

Units are mg/L except for fecal coliforms (MPN/100 mL).
*TSS is sometimes referred to as non-filterable residue (NFR)

Table 6-3
Water quality data summary, selected parameters: Kettle River downstream Midway STP

Variable	Median	Maximum	Minimum
pH	7.7	8.1	7.2
Total Suspended Solids (mg/L)	1	17	<1
Ammonia Dissolved (mg/L)	0.02	1.07	<0.005
Nitrate+Nitrite-Nitrogen (mg/L)	0.02	1.8	<0.005
Total Nitrogen (mg/L)	0.22	2.06	0.09
Ortho-Phosphate Dissolved (mg/L)	0.005	0.19	<0.005
Phosphorus, Total Dissolved (mg/L)	0.02	0.36	<0.005
Total Phosphorus (mg/L)	0.03	0.39	<0.005
Fecal coliforms (MPN/100 mL)	23	43	<3
E. coli (MPN/100 mL)	9.1	23	<3
Chloride, dissolved (mg/L)	1.3	31.8	0.95

Source: EMS database. EMS No. E228518

6.1.4 BC Government Water Quality Reports

The Ministry of Environment (1977) completed a water quality study of the Kettle River watershed based on data collected up to 1975. This was before the start of the Canada-B.C. program and the report emphasizes the monitoring data collected at the industrial and municipal point sources. At that time these were:

- two active mines - Granby Mining Corporation Phoenix Mine at Greenwood and the Teck Highland Bell Mine at Beaverdell. There were also numerous small inactive mines, some of which were noted to be discharging untreated effluent to streams;
- two sawmill-planer mills - Midway and Grand Forks;
- a sawmill on Christina Lake;
- a slag handling plant that manufactured abrasives at Grand Forks;
- municipal sewage treatment facilities at Grand Forks, Midway and Greenwood; and
- eight municipal landfills.

The report found that water quality was generally good throughout the watershed, with only occasional exceedances of the water quality guidelines. Some degradation of water quality was noted in the south end of Christina Lake (see Section 6.1.5). The report also summarizes the first survey of invasive aquatic plants that was completed in the lake in 1974.

6.1.5 Christina Lake

Following up from the 1977 water quality study, MOE began annual monitoring of Christina Lake. In 1994 an assessment report was completed and Water Quality Objectives (WQO) were set for the lake (Cavanagh et al. 1994). The report indicates that Christina Lake was in an oligotrophic state and the overall water quality was considered "very good". WQO were set for nutrients (total phosphorus and nitrogen), turbidity, dissolved oxygen, Secchi depth, and several biological indicators – pelagic phytoplankton, zooplankton, periphyton and chlorophyll *a*. Subsequent monitoring assesses the results against the WQO, which are periodically reported on by MOE in provincial Objectives Attainment reports[15]. The most recent addresses 2006 data (Phippen 2008). The WQO were met 97% of the time that attainment could be determined, with minor excursions noted for dissolved oxygen and Secchi depth. The water quality rating score was 85 out of 100, giving a water quality ranking of "good".

Table 6-4 provides a summary of the water quality data available from the EMS at the "North Basin Deep Centre" monitoring site (EMS #E215758) that has been sampled since 1979.

In 2010 McGregor (2010) completed a Master of Science thesis that used periphyton abundance and phytoplankton assemblage as biological indicators of productivity to examine the change in water quality in Christina Lake over time. The research included nutrient sampling and water clarity measurements in addition to the biological sampling. The results suggested a change in the abundance of algae and in the species of phytoplankton that were present between 1992 and 2006. This thesis is available through the Christina Lake Stewardship Society web site[16].

[15] Available at http://www.env.gov.bc.ca/wat/wq/wq_sediment.html#kootenay
[16] Available at http://lakesteward.ca

Table 6-4
Christina Lake water quality summary – North Basin Deep Centre site (1979-2006).

Parameter	Units	B.C. Aquatic Life Guideline	Canadian Drinking Water Guideline	Christina Lake Christina Lake North Basin Deep Centre (E215758) **(Oct. 1979 – Dec. 2006)**	
				Median (n)	**10th & 90th percentile**
pH	pH units	6.5 – 9.0	6.5 – 8.5	7.1 (311)	**6.4** – 7.7
Alkalinity, total	mg/L	ng	ng	33.2 (22)	31.1 – 34.1
Hardness, total	mg/L	ng	200*	30.4 (4)	29.8 – 32.5
Specific conductance	µS/cm	ng	ng	77 (38)	73 - 82
Turbidity***	NTU	8	ng	0.3 (30)	0.2 – 0.5
Chloride, dissolved	mg/L	600	250	1.7 (20)	1.2 – 1.9
Sulphate, dissolved	mg/L	100	500	3.8 (11)	3.6 -4.3
Dissolved Oxygen	mg/L	8	ng	11.0 (618)	8.8 – 13.0
Total P	mg/L	ng	ng	0.004 (136)	<0.003 – 0.012
Total dissolved P	mg/L	ng	ng	<0.003 (126)	<0.002 – 0.008
Ammonia-N	mg/L	5.86 (pH 8, t 10°)	ng	<0.005 (86)	<0.005 – 0.007
Nitrate + nitrite-N	mg/L	3.0	10	0.007 (160)	<0.002 – 0.020
Chlorophyll a				0.0011 (90)	<0.0005 – 0.0024
Total aluminum	µg/L	100 (dissolved)	100**	<0.02 (12)	<0.02 - <0.06

Continued.

Table 6-4 (continued).

Parameter	Units	B.C. Aquatic Life Guideline	Canadian Drinking Water Guideline	Christina Lake	
				Median (n)	10th & 90th percentile
Total arsenic	µg/L	5	10	<0.04 (11)	<0.0001 - <0.04
Total cadmium	µg/L	0.03	5	<0.002 (12)	<0.00001 – 0.002
Total copper****	µg/L	3.0	500	0.0015 (12)	0.0003 – 0.0040
Total lead****	µg/L	5.5	10	<0.02 (12)	0.00003 - <0.02
Total iron	µg/L	1,000	≤300*	0.017 (10)	0.006 – 0.026
Total manganese	mg/L	0.8	0.05	<0.002 (12)	0.0007 – 0.005
Total uranium	µg/L	ng	20	0.00018 (4)	0.00016 – 0.0002
Total zinc****	µg/L	7.5	≤5,000*	0.005 (11)	0.0004 – 0.012
Fecal coliforms	CFU/ 100 mL	ng	0	<2 (24)	<1 - <2

n – Sample size; < indicates less than detection limit shown
ng – no guideline
*Aesthetic guideline. Other drinking water guidelines are health-based
** Operational guideline for water treatment plants only
*** Turbidity and TSS guidelines are increases above background. Values shown are for "clear flow" period.
**** Aquatic life guideline varies with hardness. Value is approximate based on site water hardness.
Bold – exceeds Drinking Water Guideline
Underlined – exceeds Aquatic Life Guideline

6.1.6 Monitoring by Community Groups

Boundary Environmental Alliance - Uranium in Freshwater Mussel Tissue

In 2009 a group coordinated by Mr. Al Grant of the Boundary Environmental Alliance (BEA) collected tissue specimens of the Western pearlshell mussel (*Margaritifera falcata*) and had the tissue analyzed for total uranium at a certified environmental laboratory (Grant et al. 2009). The mussels were collected at two sites in the Kettle River; at Cox's Bridge in the Christian Valley and at Spraggett Bridge at Grand Forks. The sampling was completed as an initial step in assessing baseline bioaccumulation of uranium in mussel tissue. The measured concentrations were 0.17 µg/g at Cox's Bridge and 0.18 µg/g at Spraggett Bridge.

In 2010 MOE provided funding that allowed the 2009 samples to be tested for a complete scan of metals and for further sampling and analysis in 2010. The results are provided in a report that is posted on the BEA web site (Grant 2012). Five locations were sampled in August 2010 and three more in October 2010 (total of 8). Table 6-5 provides the average, minimum and maximum values for arsenic, cadmium, chromium, selenium, and uranium as well as the average from the Canada-B.C. site at Midway, as reported in Grant (2012). The report also includes a discussion of bioaccumulation of these metals in the mussel tissue.

Table 6-5
Average, minimum and maximum concentrations of selected metals in freshwater mussel tissue at eight Kettle Watershed sites (2009-2010)

Metal	Mean tissue concentration – all samples (g/kg)	Minimum tissue concentration – all samples (g/kg)	Maximum tissue concentration – all samples (g/kg)	Mean Water Concentration at Midway (µg/L)
Arsenic	1.15	0.98	1.4	0.00048
Cadmium	0.54	0.48	0.65	0.00001
Chromium	1.08	0.62	1.9	0.0003
Selenium	0.98	0.8	1.2	0.00014
Uranium	0.24	0.17	0.4	0.001

Adapted from Grant (2012).

Boundary Environmental Alliance – Coliform Bacteria in Range Area streams
The Boundary Environmental Alliance has carried out sampling for total coliform and *E. coli* bacteria in four streams in the vicinity of Rock Creek. A report published on the Alliance's web site provides the results for 2007, 2008 and 2009. The results suggest that there are higher bacteria counts when range cattle are present in the watersheds then when they are not present. In the author's view, the dry climate of their study area makes the streams more likely to exhibit high bacteria counts because range cattle are more likely to congregate in riparian areas for longer periods. In some streams the *E. coli* counts are reported to have been in the 2,200 to 3,400 CFU/100 mL range when cattle were present, compared to <10 CFU 100/mL when they were not.

Christina Lake Stewardship Society
The Christina Lake Stewardship Society has carried out water quality monitoring of the lake under guidance from MoE. The data are included in the provincial EMS database (Sections 6.1.1 and 6.1.5).

6.2 GROUNDWATER QUALITY

6.2.1 Summary of Existing Information

Groundwater quality information that has been collected by or made available to the province of B.C. is available online through the B.C. Environmental Monitoring System. Outside of Grand Forks, groundwater data in EMS is limited to a few monitoring wells where data are captured as part of permitting requirements. There are not enough of these sites to draw conclusions about either natural groundwater quality or potential contamination at a broader spatial scale. Groundwater quality data and water quality testing results from currently existing public water systems is available from the Interior Health Authority, but is not generally collected centrally and therefore not easily available. Newly constructed wells for community water systems are also tested and the data provided to IHA. Private well owners in B.C. rarely test their well water and do not generally report the results to local government, MoE, or IHA, as there are no regulations in place regarding the reporting of such data.

A relatively large set of historical groundwater quality data is available from a number of wells in the Grand Forks Aquifer, as the aquifer has been subject to water quality concerns for several decades. In particular, stakeholders in this study are interested in historical nitrate trends in the Grand Forks area and this information is presented in the following subsection.

6.2.2 Groundwater Quality – Land Use Effects and Trends at Grand Forks

The 2010 MOE/SFU hydrogeology report on the Grand Forks aquifer contains a detailed summary of water quality monitoring results from the Grand Forks area (Wei et al. 2010). The major findings are:

- Nitrate-nitrogen has been the groundwater contaminant of greatest concern. Nitrate-N in groundwater in the aquifer ranges from a reported low of <0.01 mg/L to >30 mg/L, with a median nitrate-nitrogen concentration of 3.4 mg/L (the Canadian Drink Water Guideline is 10 mg/L nitrate-N). Natural background concentrations of nitrate-N are typically low (<1 mg/L) and concentrations greater than 3 mg/L usually reflect human activities (MOE 2007).
- Comparisons to well depth showed that nitrate-N was generally highest in shallower wells, and that concentration generally decreases with well depth.
- Sources of nitrate include agricultural fertilizers, septic systems, and sites with concentrated livestock wastes. Nitrogen isotopes studies have shown that fertilizers are the largest source.
- On average, groundwater in the aquifer is rated as “very hard” (about 300 mg/L average), indicating relatively high concentrations of calcium, magnesium, and iron. Hardness values range from <50 mg/L (“soft”) to >500 mg/L (“very hard”).
- Total dissolved solids (TDS) concentration is also relatively high on average but with a wide observed range. At the higher end, the TDS values are interpreted by the authors as being indicative of land use effects. This is related to leaching of calcium, magnesium, nitrate, chloride to the groundwater from chemical fertilizers and lime applied to the soil, thereby increasing the total amount of dissolved minerals in these locally affected areas.
- Dissolved chloride is also high in some areas, generally the same areas where nitrate-N and TDS are elevated.
- The report includes maps showing the interpolated concentrations of nitrate, chloride, TDS, hardness, alkalinity and specific conductance across the aquifer. The highest concentrations of nitrate, TDS, chloride and nitrate are found in the southeast corner of the aquifer near the US border.
- The MOE/SFU team found only limited data for coliform bacteria or other pathogens, but suggest that any contamination would likely be spatially limited.

A concentration of nitrate-N of more than 10 mg/L exceeds the Guideline for Canadian Drinking Water Quality and is not recommended for human consumption. As noted above, the MOE/SFU report (p. 56) maps nitrate-N concentrations, showing concentrations above the 10 mg/L drinking water guideline extrapolated to a significant portion of the aquifer southwest of Grand Forks. However, there is a fair amount of both temporal and spatial variability. This is likely because the concentrations of nitrate vary locally with land use, farming practices on individual fields, and recharge of the aquifer from the Kettle River. Overall, most wells display concentrations of nitrate-N above 0.4 mg/L, indicating some level of human-caused impacts. Exceptions are the wells Grand Forks No 3 and Grand Forks No 5, which have historically shown low or no concentrations of nitrate-N. Several wells have exceeded the guideline value in the past (at Horkoff Road, Como & Carson Roads, Cameron Road, and Grand Forks No. 7), although concentrations generally remained below this value between 2006 and 2009. This suggests the possibility of an improving trend[17].

The nitrate-N concentrations measured in this aquifer were high enough to require continued monitoring of the groundwater. The elevated concentrations are likely mostly due to overwatering of fields and application of excess fertilizer (Wei et al. 2010) and could be lowered by optimizing farming practices. The groundwater quality monitoring network is very useful in determining overall trends in the aquifer and a data review every three years is recommended to aid public officials in determining public policy regarding mitigation of high nitrate concentrations in the aquifer and the public water supply derived from the aquifer.

In response to observed above-background nitrate concentrations in groundwater in the 1990s, policies in the Official Community Plan in both the City of Grand Forks and RDKB Area D have limited residential development that would rely on on-site septic systems. In addition, public education programs have been implemented on best management practices for agriculture and for on-site sewage disposal. Since the loadings of nitrate and other contaminants are from multiple small sources rather than a few major sources, continuing education and policies to support the adoption of BMPs are recommended.

6.2.3 Drinking Water Source Protection Plans

Some communities in the Kettle River watershed have taken initial measures to develop Source Water Protection Plans. These plans seek to identify the threats to the quality and quantity of surface or groundwater. In 2008, Golder Associates Ltd. completed Phase I of a groundwater protection plan for the Village of Midway. At the end of 2009, further funding from the Province of B.C. was granted to the Village of Midway for Phase II of the plan. In the Grand Forks area, groundwater well protection plans were initially developed in the 1990s but have not been updated since the recent groundwater studies expanded the local understanding of surface water – groundwater connection (i.e. Wei et al. 2010).

The Christina Lake Stewardship Society has implemented a Watershed Management Plan that includes participation from Local, Provincial, and Federal Government Agencies, in addition to non-profit organizations, businesses and local residents. The plan includes activities and initiatives involving water quality monitoring, fisheries and ecosystem management, noxious and invasive plant programs, working with timber operations, and other environmental concerns.

[17] A statistical test for a significant trend could not be completed because the sampling data are not spaced evenly in time (see Section 5.5).

7 FISHERIES, AQUATIC HABITAT AND RIPARIAN AREAS

7.1 HISTORICAL EFFECTS OF LAND USE ACTIVITY ON FISH HABITAT

7.1.1 Overview: Fisheries Management Issues

The Kettle River is a popular recreational fishery for both local residents and visitors. Oliver (2001) summarized fisheries management issues, namely the perceived deterioration of stream angling in the Kettle basin related to the low abundance and small size of rainbow trout in the fishery. The population of adult rainbow trout was calculated to be well below carrying capacity, which was attributed to low summer flows, low habitat diversity, especially adult holding habitat, low productive capacity, high summer water temperatures and high fishing pressure. In addition, land and water use were implicated in the habitat conditions, but their influence was not quantified.

Epp and Andrusak (2011, 2012) have confirmed that there are substantial reductions in rainbow trout parr rearing habitat under low flow conditions and suggest that these flow conditions in the lower portions of the watershed are significantly exacerbated by water withdrawals. In addition they have examined the relationship between high water temperatures, flow, and air temperature during these low flow periods and note that during low flow periods there is no correlation between flow and water temperature, but that earlier in the summer when there is more flow and water temperatures are less influenced by air temperature (Epp and Andrusak, 2012).

Epp and Andrusak (2011, 2012) have begun to evaluate the effectiveness of pool and cover habitat creation and catch and release fishing regulations for rainbow trout implemented for portions of the watershed, but have yet to draw definitive conclusions about either.

Speckled dace are abundant in the Kettle River watershed, but there are no assessments of population trends (Batty 2010). This species is less affected by water temperature than are the salmonids present in the watershed and appear to prefer shallow, slow water over deeper fast water so may also be less affected by low flows in the lower reaches than are rainbow trout.

Rainbow trout in particular have been stocked in the watershed many times and over many years, primarily with stocks from elsewhere in BC. The effects of this stocking program on the robustness of the native stocks have not been assessed.

7.1.2 Riparian and Stream Channel Habitat

Riparian habitats are the areas that are immediately adjacent to streams, lakes, and wetlands. They represent the transition from terrestrial to aquatic landscapes, and typically include plants that are adapted to moist or wet conditions. If intact, the riparian zone provides a number of key functions for the adjacent aquatic habitat including shade cover, bank strength, sources of food for fish, water quality protection (e.g. filtration of sediment and plant uptake of nutrients), and the source of large woody debris.

Forest and Range Areas

The clearing of riparian areas for logging and agricultural uses has reportedly decreased the large woody debris accumulations within the Kettle River basin, resulting in adverse effects on fish habitat complexity in the watercourses (Slaney et al. 2001). Large woody debris can generate scour, which creates pool habitats and increases pool depths; can supply bank armor and divert flows away from banks to prevent erosion; and provide instream cover and refugia. In addition, dense riparian vegetation can influence the range of variability in daily water temperatures. Numerous LWD structures have been constructed, especially in the West Kettle River, to restore habitat and permit evaluation of the habitat by fish. The results of the effectiveness monitoring on these structures has been reported regularly since the late 1990s (e.g. Koning and Slaney 1998, Slaney et al. 2001, and Andrusak 2009). Structures have also been constructed in Boundary Creek (Zimmer 2002).

The various reports that discuss the large woody debris rehabilitation programs are based on the understanding that those reaches of the streams were affected by riparian harvest prior to the implementation of the Forest Practices Code in 1994. A series of watershed and fish habitat assessments were completed in the watershed over the period from about 1995 to 2003 when the Forest Renewal B.C. program was underway and watershed assessments (WAPs) were required to support forest development plans. Typically the restoration-focussed assessments documented the degree of riparian disturbance and made recommendations for restoration if warranted. The WAPs documented riparian disturbance as one of the factors is assessing the risks of planned forest development. Since riparian buffers were a requirement of the Code, both types of assessment usually reinforced the need to meet or exceed Code minimums, but some led to the channel structures in the West Kettle and elsewhere. In 2006 Slaney (2006) completed a Fish Habitat Assessment Procedure (FHAP) of selected reaches of Lower Rock Creek, Lower Myers Creek, Lower Conkle Creek, and the Kettle River near Creek. Some of the reaches assessed were still showing the residual effects of riparian clearing for placer mining that likely pre-dates the Code.

Since the Code was replaced by the *Forest and Range Practices Act* (FRPA) in 2002 and the Watershed Restoration program wound down, there have been fewer assessments of riparian function or related habitat effects in forested areas. It has been 18 years since the riparian protection requirements of the Code (which were retained by FRPA)[18] came into effect, which is long enough for natural riparian restoration processes to have had some positive influence on the key riparian functions of providing stream bank and channel stability, shade, and litter. However it is not long enough to have restored natural LWD recruitment processes, as noted by Slaney (2006) in some sites near Rock Creek.

[18] A reserve (no harvest) zone is not required for smaller streams (<1.5 m wide with fish, <3 m wide if no fish) under FRPA. A riparian management zone with retention of at least 10% of the tree basal area is required except for non-fish streams that are <3 m wide. In all management zones harvesting must not significantly affect bank or channel stability.

Although forest harvest in riparian areas has been significantly reduced since 1994 and many impacted areas are recovering, there is concern among watershed residents that range use is having an effect on riparian function in some areas. Complaints to the Forest Practices Board (FPB) have led to investigations of the effects of range livestock on riparian areas. In 2002 the Ministry of Forests found that of 23 stream reaches in the Ingram-Boundary Range Unit, 16 were rated as being either “non-functional” or “highly at risk” (Miller and Fraser 2003). A 2009 assessment of the Overton-Moody Range Unit by the FPB found evidence of damage to Gilpin Creek from range cattle, which the licensee reportedly addressed (Forest Practices Board 2009).

Based on the review of available documents for this study, it does not appear that any systematic assessments of riparian function or health have been completed in the forested or open range parts of the Kettle River watershed for some time. Overall, there is reason to believe that riparian areas in forests are in better shape than they were before the Code came into effect, but this has not been quantified. Concerns over the role of water temperatures on fisheries and water quality (Section 6.1.6) suggest that there would be value in completing an overview-level assessment, potentially leading to recommendations for more detailed assessment in high-value sub-basins.

Land Use Effects on Riparian Habitat in Agricultural Areas

Mr. Fred Marshall of Midway, B.C. guided a member of the consulting team on a half-day field tour of selected riparian areas along Boundary Creek on December 5, 2011. The tour highlighted the sensitivity of alluvial streams to instability if the stream lacks a functioning riparian zone. The sites that were viewed are generally representative of low elevation streams in agricultural areas within the watershed. In general, sections of the stream that had no or negligible tree and shrub cover in the riparian zone were more likely to show signs of bank erosion and channel migration. At one site, for example, a bridge appears to be somewhat undersized and the resulting back-watering effect has resulted in channel widening and sedimentation because the banks are less stable due to the absence of trees. Mr. Marshall also pointed out several sites where fencing has been installed to reduce cattle access and tree and shrub cover is becoming re-established.

Mr. Marshall and riparian consultant Lee Hesketh completed a survey of Boundary Creek in 2005 and developed a list of sites that are a priority for restoration works. This work was completed under the Farmland - Riparian Interface Stewardship Program (FRISP) of the B.C. Cattlemen's Association. The field documentation, photographs, and restoration prescriptions are available from Mr. Hesketh[19]. Some of the recommendations were apparently implemented by private landowners. Mr. Hesketh has also completed some riparian restoration works for private landowners elsewhere in the watershed.

The Environmental Farm Plan (EFP) program in British Columbia includes a funding program for farmers and ranchers to implement Beneficial Management Practices on farms that have an EFP in

[19] Lee Hesketh may be contacted at silverhillsranch@aol.com.

place. As of March 31, 2012, 38 BMP projects had been implemented in the Kootenay Boundary Regional District; including 13 riparian management projects (see Section 7.2.2).

The Canadian Wildlife Service (CWS) of Environment Canada is currently carrying out a project to create a spatially explicit list and map of priority riparian sites along the Kettle and Granby Rivers and recommend conservation tools required to protect or restore these sites (Luszcz, pers. comm. 2012). The results of this work are intended to direct on-the-ground conservation work of riparian habitats. The project area extends from Kettle River Provincial Park south and east along the Kettle River to RDKB Electoral Area D boundary east of Grand Forks, and the reach of the Granby River from Grand Forks to the 10 Mile Bridge. The assessment is being completed by a local consultant and includes consultation with local and provincial government staff and stakeholders. The report is expected by the end of March 31, 2012.

Since the CWS work is not yet complete, a preliminary, high-level review was completed for this study using the aerial photography imagery on Google Earth, which is dated 2010. Riparian cover was categorized using a simple 0 to 3 scoring system:

0 - No riparian cover visible or negligible (<2 m wide) on either bank
1 – From 2 to 15 m on one bank only
2 – From 2 to 15 m on both banks
3 – At least 2-15 m on one bank and >15 m on the other.

Categories 0 and 1 are most likely to have reduced riparian function, while Categories 2 and 3 are more likely to have adequate riparian function. However, it is not possible to tell what proportion of the riparian cover includes mature trees that best contribute to channel and bank stability, LWD recruitment, and shade. The results are summarized in Table 7-1. The stream sections with potentially reduced riparian function (i.e. ≥30% Categories 0 and 1) are Boundary Creek, Beaverdell Creek, Kettle River within Sub-basin 2, and Kettle River between Westbridge and Rock Creek. Overall, the agricultural areas viewable on Google Earth were 13%, 11%, 21% and 55% in categories 0, 1, 2 and 3 respectively. The forthcoming CWS study may help to refine this overview-level characterization of riparian function, although its emphasis is on riparian zones as wildlife habitat. Depending on the outcome, there may be benefit in augmenting the study with follow-up work to determine if the priorities for wildlife habitat restoration would also provide value for the aquatic habitats.

Other Wetlands

The terms of reference for this Phase I Assessment included a summary of riparian habitat information. Although some riparian areas would be classified as wetland (e.g. swamp, marsh, fen, bog, or wet meadow), there are other wetland ecosystems in the Kettle River watershed that provide a range of ecological and hydrological functions. To date, it does not appear that there has been an inventory of wetlands in the watershed or an assessment of wetland function.

Table 7-1
Aerial photo overview of riparian cover in agricultural areas of the Kettle River watershed

Sub-basin	Stream reaches predominantly in agricultural valley bottoms	Stream Name	Approximate Total Length of Stream (km)	Riparian Category (%)			
				0	1	2	3
#1	Carmi to Beaverdell	West Kettle	8	0	0	20	80
	Beaverdell to Rhone		30	5	20	0	75
	Rhone to Westbridge		8	0	5	75	20
	Start of agricultural lands to mouth	Beaverdell Creek	9	30	5	40	25
#2	Start of agricultural lands to mouth	Kettle River	44	25	10	5	60
#3	Westbridge to Rock Creek	Kettle River	15	10	25	45	20
	Rock Creek to Midway		21	5	20	50	25
#4	Start of agricultural lands to mouth	Boundary Creek	28	25	10	10	55
#5	Start of agricultural lands to mouth	July Creek	7	15	15	40	30
#6	Start of agricultural lands to mouth	Burrell Creek	9	0	10	10	80
	From confluence of Burrell Creek to Grand Forks	Granby River	51	10	10	10	70
#7	Kettle River from the US border to confluence with the Granby River	Kettle River	12	15	5	65	15
	From confluence of Granby River to US border south of Christina Lake		30	5	5	25	65

7.1.3 Flow Fluctuations and Instream Flow Needs

Oliver (2001) identified summer low flows as a potential key limiting factor in the production of sport fish in the lower reaches of the Kettle River and its major tributaries. Epp and Andrusak (2011) provide an analysis of Kettle basin hydrology, especially low flows, at selected sites throughout the basin and note that the availability and quality of rainbow trout parr rearing habitat declines rapidly at flow below 10% long term MAD. As noted in Section 3.8.3, under average summer conditions habitat for rearing salmonids parr appears to be of reasonable quality and quantity; however, this condition drops sharply under drier conditions such that habitat limitations are likely to be severe under dry conditions.

In addition, Epp and Andrusak (2011) note that forest harvesting activity may have influenced the timing and magnitude of freshet flows, but did not investigate this potential influence in detail.

7.1.4 Water Quality Potential Effects on Aquatic Life

High summer water temperatures have long been implicated as a potential limiting factor for fish production in the Kettle River basin, with Epp and Andrusak (2011) noting that there have been at least six summer fish kills reported that were likely caused by high water temperatures. In addition, there has been concern about summer water withdrawals exacerbating naturally high water temperatures at this time of year; although, Epp and Andrusak (2011) found no correlation between river flows and water temperature, with water temperature merely reflecting air temperature.

With the exception of water temperature, the water quality monitoring data that are available for the Kettle River, the major tributaries, and Christina Lake indicate that the water quality is very good for aquatic life (Section 6.1). Aquatic life guidelines for some metals, phosphorus, and fluoride are occasionally exceeded, but most exceedances are linked to periods with high turbidity (i.e. freshet) when most of the metals are tied up with sediment and not bio-available.

7.2 WATERSHED, CHANNEL, AND RIPARIAN RESTORATION

7.2.1 Summary of Efforts to Date

A summary of restoration activities in the Kettle River watershed is presented in Andrusak (2009). It is summarized below along with summaries of additional reports that have been prepared subsequently.

During the 1970s the Fish and Wildlife Branch performed a formal assessment of the Kettle River and West Kettle River fisheries. This included the identification of important spawning streams, the observation of low flows, and collection of a small amount of creel census data for selected areas.

In the late 1980s Sebastian (1989) quantified the abundance of juvenile and adult trout; estimating that adult fish were at less than 20% of theoretical capacity. The key constraints were identified as low flows, lack of cover, and over fishing (Sebastian 1989). In response to these findings, adult fish were twice released into the Kettle River on an experimental basis (Godin et al. 1994); however assessments following these releases concluded that the initial increase in fishing opportunities was offset by higher occurrences of winter mortalities in native trout. All stocking of the river eventually ceased due to concerns about potential detrimental effects to wild fish populations.

In 2001, a review of available hydrological and temperature data for the Kettle basin was prepared by Oliver (2001). This review supported Sebastian's (1989) findings that trout populations were below the expected carrying capacity. The study attributed the lack of adult fish to over-fishing and habitat limitations. Oliver recommended that large woody debris be placed in the river to increase adult trout habitat, and advised that further water allocation should be restricted until the effects of flow fluctuations could be determined (Oliver 2001).

In 1994 catch-and-release regulations were implemented for certain sections of the Kettle River as a means of studying the effects of over-fishing. However, snorkel surveys done in 2003 and 2004 recorded further declines in the adult trout populations. The conclusion from this was that over-fishing was not the sole cause of the deterioration of adult trout populations (Wilson et al. 2002).

In 2001, an experiment to test the ability of coarse woody debris to increase adult trout habitat was completed. The abundance of trout greater than 10cm were measured before, and after the installation of 19 large woody debris structures along a 4 km section of the West Kettle River. The post-construction count was 10 times that of the pre-construction count (Slaney et al. 2001). While there was a similar magnitude (10x) response in control sites, the absolute numbers of fish in the restored area were two to three times higher than those in the control area (Andrusak 2009).

Restoration works conducted in the West Kettle River in 1999 and 1998 have been monitored every year since. The most recent fish survey numbers indicate that there has been a recent substantial decline to near or even below pre-treatment levels in the density of rainbow trout (all sizes combined and catchable) and whitefish in the treatment sections of the river, but that in the control sections the numbers are about as high as they have ever been in the 13 year monitoring period, and much higher than prior to the treatments.

In 2006 a juvenile production survey (Andrusak 2006) determined that the density of juvenile trout was consistently high throughout the Kettle Valley watershed, and that habitat restoration for adult trout would be highly beneficial for increasing the number of adult trout in the mainstem of the Kettle River (Slaney et al. 2006).

In 2003 fishing regulations were changed in the Granby River to reduce harvest of large rainbow trout. Subsequent monitoring (2007 to 2010) indicates that there has not been a statistically significant increase in fish abundance and the age structure of the population is similar to the pre-treatment period (Epp and Andrusak 2011).

Flow and temperature data were collected at selected sites throughout the watershed in 2010 and 2011. These data were then used to determine the effects of these variables on the availability of fish habitat (Epp and Andrusak 2011, 2012). It was determined that flow during the latter part of the summer season causes substantial reductions in parr rearing habitat, and that high water temperatures during the same period (up to 24°C) can cause sub-lethal and lethal effects in some fish. Water temperatures during low flow periods were determined to be a function of the daily mean air temperature, not flow volumes as was often assumed in earlier reports (Epp and Andrusak 2011), but that at substantially higher flow volumes water temperatures are suppressed below the levels that would be predicted based purely on air temperature (Epp and Andrusak 2012).

7.2.2 Recent and On-going Restoration Programs

There is ongoing evaluation of fish populations in the Kettle River basin, including the area in which numerous large woody debris structures were installed in the West Kettle River; however, there are no ongoing instream restoration programs for the forested parts of the watershed. While it is likely that there has been some local riparian restoration in the forested areas of the watershed in recent years, we did not find documentation of the works.

As noted earlier, the Environmental Farm Plan program has funded 13 riparian Beneficial Management Practices (BMP) projects in the Kootenay Boundary - nine in Riparian Area Management totalling $69,445 and four in Erosion Control Structures in riparian zones totalling $57,027. This is a cost share program, so the total expenditure on riparian restoration in the agricultural areas of the watershed under the BMP program is actually greater. Information on the EFP BMP program is available at http://www.bcefp.ca/. In addition to the $126,452 spent on riparian programs, an additional $81,000 was spent on other BMPs, including 14 projects that either reduce risk of water contamination or contribute to water conservation.

7.2.3 Areas where additional Restoration is Warranted

Following a thorough evaluation of the restoration works that have been completed to date and filling of some of the identified gaps, it may be warranted to conduct further riparian and/or instream habitat restoration works. In addition, it may be worthwhile to consider water storage and flow augmentation, either continuously or in pulses during low flow periods.

7.3 CLIMATE CHANGE IMPLICATIONS FOR FISH HABITAT

The climate change models indicate annual average air temperature increases of 1.1°C, 1.9°C and 3.0°C by 2020, 2050 and 2080 respectively in RDKB. These average air temperature increases (Table 3-2) may result in increased water temperatures during the summer. To date, the effects of the combination of reduced summer flows and increased air temperatures have not been quantified through water temperature modelling.

Climate change projections suggest that summer low flows will be lower and will persist for a longer period, both of which may further reduce rainbow trout and whitefish production in the watershed. Spring and fall flows may be slightly higher as there is projected to be more rain (and less snow) during these periods. Freshet is projected to arrive slightly earlier, potentially altering the timing or success of spawning by spring/early-summer spawners (e.g. rainbow trout and speckled dace).

8 INFORMATION SUMMARY AND DATA GAPS

8.1 SUMMARY OF KEY FINDINGS

8.1.1 Data Availability and Spatial Coverage

Despite the relatively low population of the Kettle River watershed compared to other parts of southern B.C., the watershed has a solid information base on which water resource management decisions can be made. This is because of its status as an international river where certain treaty obligations exist, and because of the long history of agriculture in the watershed that depends on irrigation. The numbers of streamflow monitoring (hydrometric) and long-term water quality monitoring stations are above average for B.C. because the Kettle River flows into the United States, but those stations are concentrated in the southern part of the basin near the border. Relatively little surface water quality data is in the public domain for the northern two-thirds of the watershed.

The number of on-going climate monitoring stations is somewhat limited. At present, there are only two Environment Canada stations, both in the valley bottom, and no Farmwest stations. The recent development of a climate model by Agriculture Canada enables a better understanding of climate variation in the watershed, but a mid- or high elevation monitoring station would be of benefit to confirm the model estimates (Note: RDKB has budgeted for a station, but Environment Canada has yet to proceed to installation). There is just one snow pillow in the watershed in addition to four snowcourses, although there are several others nearby in adjacent watersheds. Building on the climate model, the Ministry of Agriculture's irrigation demand model and the water use records obtained for this study have improved the understanding of actual water use compared to a few years ago.

With respect to groundwater, there is very good data coverage for the Grand Forks aquifer, and the analysis of river flows for this study has built on that to advance understanding of surface water-groundwater interaction. Less is known upstream from Grand Forks, which is a key data gap that should be addressed (see below – Section 8.2). The information base for fisheries is also reasonably good, augmented over the past three years by a focussed MFLNR study on low flows and water temperatures and by monitoring of the effectiveness of LWD structures. Although it is generally understood that riparian function has and continues to be affected by land use practices, only selected areas of the watershed have been studied, limiting the ability to set priorities for management or restoration. Sensitive Ecosystem Inventory mapping has not been completed but a CWS funded study of riparian wildlife function is in progress.

8.1.2 Surface Water Flow

The current hydrologic regime is similar to other parts of the B.C. Southern Interior, dominated by snowmelt processes that create very large differences between high flows in the spring and early summer and low flows from mid-summer through winter. Climate change projections for the RDKB indicate warmer annual average temperatures (1°C by the 2020s to 3°C by the 2080s), less rainfall in summer (about 6% less in the 2020s to 16% less in the 2080s), and a steady decrease in snowfall as more of the winter and spring precipitation falls as rain. The implications for streamflow are that flows from late fall to early spring will be greater, while flows in late spring, summer and early fall will be less, thus adding to the current constraints on fish and surface water supply in late summer. Spring runoff will occur sooner on average and water yield (total flow) will increase.

There are 994 current licences (at 826 points-of-diversion) for surface water in the Canadian portion of the watershed (with an additional 1,100+ is the U.S.), with irrigation confirmed as the largest licensed volume. After irrigation, domestic use accounts for the next highest licensed volume. Stock watering is not a significant use. Off-stream licenses account for 54,199 ML/yr, storage is 7,351 ML/yr, and conservation is 1,352 ML/yr.

The water licences tell us the volume of water that licence holders could use. For this study estimates of actual use have been developed by obtaining the records from the community water utilities in the watershed and from the Ministry of Agriculture's recent irrigation demand model. The major finding from the analysis of the use records is that even though the major water suppliers have surface water licenses, they mostly use groundwater and many of the largest licenses have not been used for many years. Of the water suppliers that do use surface water; those that are able to store water during high flows (e.g. Big White) avoid off-stream surface water withdrawals during low flow periods.

The data records from water suppliers were used to estimate the natural flows at selected points where flow data are available. The results indicate that on an annual basis the average flow is only slightly less than the natural (pre-development) flows. However, in August (the highest demand month) the flows in the study sub-basins range from 74% to 96% of the naturalized flows. Near the final crossing of the Kettle River into the U.S. at Cascade, the average August net flow is estimated to be 83% of the naturalized flow. This is a conservative estimate, assuming the groundwater withdrawals near Grand Forks essentially use river water. In an average year the net flow is likely closer to 90% of natural flow, but in drier years or at specific locations the net flow would be less. The surface water hydrology data indicate that the mainstem of the Kettle and larger tributaries are "losing streams", where a portion of the flow infiltrates to ground.

In 2007 Powerhouse Developments Inc. was granted a water license for a total of 2,838 ML for the purpose of power generation on the Kettle River near Cascade. Following government, First Nations and stakeholder review, a bulk water reserve was created for the Kettle River and its tributaries. The reserve ensure that the water rights of the power licence holder are always subordinate to the rights of any water licences for purposes other than power production that may be acquired in the future on the Kettle River or its tributaries.

There are relatively few active dams in the watershed, and none would be considered major structures. A PFRA (2007) study of the Granby watershed indicated that constructing dams there would offer little potential for flood control. PFRA indicated than although there may be potential for flow augmentation by building a dam, more analyses were needed to assess effectiveness. This finding also would apply to the rest of the watershed since storage potential has not been investigated in any detail.

8.1.3 Groundwater Quantity and Quality

Relative to other watersheds in southern B.C., groundwater makes up a significant proportion of agricultural and domestic water use in the Kettle River watershed. MOE has mapped a total of 15 aquifers in the watershed, all located along or in proximity to the valley bottoms where agricultural activities and communities are concentrated. Most of the mapped aquifers are in sand and gravel deposits and are ranked as having moderate to high productivity and moderate to high vulnerability to contamination from surface activities. The demand on these aquifers is either low or moderate, with the exception of the Grand Forks aquifer where demand is high. As a direct outcome of this high demand, the Grand Forks aquifer has been studied in detail over the past 20 years (e.g. Wei et al. 2010), and there is a very good base of information for the aquifer. Less is known about other parts of the watershed.

A search of the provincial water well database found over 1,400 wells. Registration of drilled wells is not mandatory, so there may be 2,000 wells or more in the watershed, although it isn't known how many are not in use or have been closed. About half of all known wells are in Sub-Basin 6, which includes the Grand Forks aquifer. Of the well records with reported yields, more than 85% report yields of 100 USgpm or less. There are two operating groundwater observation wells in the watershed, at Beaverdell (#306) and Grand Forks (#217), and the data are available on-line.

The aquifers in the Kettle River watershed are re-charged by a number of processes, the most significant being infiltration from streams and rivers where they flow across sand and gravel alluvial deposits. For the Grand Forks aquifer, it has been estimated that 11-20% of flow in the Kettle River is transferred to groundwater during freshet. Some of that water moves back to the river as baseflow from mid-autumn through the winter. There is some indication that this pattern is repeated at Beaverdell, Westbridge, and Midway, but it has not been documented to the same level of detail as at Grand Forks. The groundwater aquifers are hydraulically connected to the Kettle River, evidenced by the matching rise and fall of river and groundwater levels. Trends in groundwater level therefore mirror trends in river flow. At Grand Forks and Beaverdell water level data have been collected since 1977 and 1989 respectively. Water levels have varied over this period, but no statistically significant trend is apparent (neither decreasing nor increasing).

Although the Grand Forks aquifer is re-charged by the Kettle River during freshet, there is evidence that groundwater pumping in the latter part of the summer begin to induce additional re-charge from the river and reduce flows compared to natural (pre-development) conditions. Over an annual cycle this makes negligible difference to river flow, but in August the average flow is less than the estimated natural flow. Note, however, that the water suppliers in the area do not use their water licence(s), and the reduction in flow from groundwater use is less than if they did.

Similar to much of B.C., there is relatively little information on groundwater quality in the public domain, again with Grand Forks being an exception. Nitrate has been the contaminant of greatest interest because of potential human health effects, but also because it is mobile in groundwater and therefore an indicator of the potential presence of other contaminants that originate on the surface. Concentrations of nitrate-N have exceeded the 10 mg/L drinking water guideline, especially in the southeast part of the aquifer. Regular monitoring would be of value to determine if there are any changes in nitrate concentrations in response to improved awareness of this issue.

8.1.4 Water Quality – Surface Water

Surface water quality in the Kettle River is sampled every two weeks at two stations that are run by the Canada-B.C. water quality monitoring program; downstream of Midway before the river crosses into the U.S. for the first time and upstream of Grand Forks after it crosses into Canada from the U.S. A recent (2009) summary report concluded that water quality at both sites was very similar and "generally good". The parameters that regularly exceed water quality guidelines at these sites are water temperature (for both aquatic life and drinking water), fluoride (aquatic life), and some metals (aquatic life). With metals, the concentrations of the metals that exceed guidelines were strongly correlated with turbidity and thus likely bound to suspended sediments and organic matter. As such, these metals are not available for uptake by biota. Statistically significant increasing trends were found at one or both sites for turbidity, total hardness, total phosphorus, total molybdenum, dissolved chloride, dissolved fluoride, and fecal coliforms. Statistically significant decreasing trends were found at one or both sites for total colour, specific conductivity, and several metals (notably aluminum, chromium, copper, iron, lead, manganese, nickel, and zinc).

There are relatively few point discharges (i.e. end-of-pipe) in the Kettle River watershed. Treated effluent from the Greenwood wastewater treatment plant is discharged to ground close to Boundary Creek. Statistical analysis of "upstream-downstream" data found no significant difference ($p \leq 0.05$) between the upstream and downstream sites, indicating that the wastewater is not having a detectable effect on the creek. All of the parameters assessed met the applicable water quality guidelines for aquatic life protection in the downstream sample. The wastewater facility at Midway discharges treated effluent to the Kettle River. In the most-recent Canada-B.C. water quality assessment report, several variables were found to have increased slightly at this site over 1990-2007 that may be indicative of wastewater inputs, including fecal coliforms, total phosphorus, and dissolved chloride.

Water quality in Christina Lake is regularly monitored because of its value for both aquatic life and recreation, and site-specific Water Quality Objectives (WQO) have been set to guide management. The most recent WQO attainment report (2006 data) found that the WQO were met 97% of the time, with minor excursions for dissolved oxygen and Secchi depth. The water quality rating score was 85%, giving a water quality ranking of “good”. A recent thesis on Christina Lake suggested that between 1992 and 2006 there were changes in algae abundance and in the species of phytoplankton that are present.

In addition to water quality sampling by government and dischargers, several community groups have been active. The Boundary Environmental Alliance has measured several metals, including uranium, in the tissue of a freshwater mussel. This provides useful baseline data in the event of future mine development. The Christina Lake Stewardship Society carries out Secchi depth and water quality sampling in the lake.

Although our understanding of water quality in the basin is well served by regular monitoring at the Canada-B.C. sites, Christina Lake, and near the WWTPs; most of the data are concentrated in the lower third of the watershed. Less is known about water quality in tributaries, although there are data from the West Kettle River and other locations from when mines were operating.

8.1.5 Fisheries and Aquatic Habitat

The Kettle River supports several fish species, with most of the management effort focussed on rainbow trout and whitefish, with a more recent additional focus on speckled dace due to its endangered status under the *Species at Risk Act*. Of the 39 fish species present in the Kettle River Watershed, two are provincially red-listed (speckled dace and Umatilla dace) and five are provincially blue-listed (westslope cutthroat trout, cutthroat trout, bull trout, chiselmouth and shorthead sculpin) (CDC 2008). Westslope cutthroat trout and shorthead sculpin are both listed as “Special Concern” under Schedule 1 of the federal *Species at Risk Act*, while speckled dace are federally listed as “Endangered”.

There is a century-long history of fish stocking in the watershed, reflecting the potential importance of the sport fishery and possibly a long-standing recognition of low sport fish abundance. The population of adult rainbow trout is estimated to be well below carrying capacity. In recent decades a progressive deterioration of the Kettle River sport fish fishery has been identified, indicated by decreasing abundance and size of sport fish present (Oliver, 2001; Andrusak 2009). These declines have been attributed to interactions between natural and anthropogenic factors; chiefly seasonal low flow, high water temperatures, decreased habitat availability (due to land use), and over fishing. No single factor appears to be driving the decline in fish numbers and size, rather their combined effect on adult recruitment and survival.

Epp and Andrusak (2011, 2012) have confirmed that there are substantial reductions in rainbow trout parr rearing habitat under low flow conditions and suggest that these flow conditions in the lower portions of the watershed are significantly exacerbated by water withdrawals; however, the work conducted for the current report indicates that current water usage is not as influential as expected. In addition, Epp and Andrusak (2011, 2012) examined the relationship between high water temperatures, flow, and air temperature during these low flow periods and note that during low flow periods there is no correlation between flow and water temperature. Earlier in the summer, when there is more flow, the water temperatures are less influenced by air temperature (Epp and Andrusak, 2012).

Epp and Andrusak (2011, 2012) have begun to evaluate the effectiveness of pool and cover habitat creation and catch and release fishing regulations for rainbow trout implemented for portions of the watershed, but have yet to draw definitive conclusions about either.

Speckled dace are abundant in the Kettle River watershed, but there are no assessments of population trends (Batty 2010). This species is less affected by water temperature than are the salmonids present in the watershed and appear to prefer shallow, slow water over deeper fast water so may also be less affected by current and predicted low flows in the lower reaches than are rainbow trout.

Rainbow trout in particular have been stocked in the watershed many times and over many years, primarily with stocks from elsewhere in BC. The effects of this stocking program on the robustness of the native stocks have not been assessed.

8.1.6 Riparian Habitat

Riparian habitats are the areas that are immediately adjacent to streams, lakes, and wetlands. They represent the transition from terrestrial to aquatic landscapes, and typically include plants that are adapted to moist or wet conditions. If intact, the riparian zone provides a number of key functions for the adjacent aquatic habitat including shade cover, bank strength, sources of food for fish, and the source of large woody debris. The current understanding of riparian health in the Kettle River watershed can be divided into forested and open range (mostly Crown Land) areas and low elevation, mostly private lands. In Crown forests, loss of riparian habitat was a serious concern before the B.C. Forest Practices Code came into effect in 1994. Since then, riparian management zones have been required on all streams and riparian reserve zones are required on all but the smallest streams. In the 18 years since then, some riparian functions have gradually been restored, but there are still some residual effects; notably LWD recruitment has not returned to natural levels. Detrimental effects of range use on streams and wetlands have been documented in some areas in the watershed.

In the agricultural valley bottoms, the loss of riparian habitat is considered a concern, but recent assessments of riparian function have been limited to a number of select areas such as Boundary Creek. The Canadian Wildlife Service is currently completing an assessment of riparian areas along the Kettle and Granby Rivers that will be available by April 2012. For the current study, a reconnaissance-level review of aerial photographs was completed for the riparian zones of streams in agricultural areas using Google Earth. Overall, the results indicate that about half the riparian areas have good coverage by trees and shrubs on both sides of the channel, about a quarter has good coverage on one side and limited but adequate coverage on the other, and about a quarter has limited or no riparian cover on both sides. Depending on the results of the CWS funded study, which places emphasis on wildlife, additional field assessment may be of value to set priorities for riparian restoration for water quality and fish habitat improvement. Once the CWS study is complete, it would be beneficial to convene a workshop of riparian stakeholders to update what is known about riparian function in the watershed and set priorities for further action.

8.1.7 Water Allocation in the Future

Consideration of future applications for off-stream **surface water** use or storage should consider 1) the location of the proposed point of diversion, and 2) the timing of the proposed withdrawals with respect to the current licensed use. With respect to location, the licensed volumes in the Kettle River above Westbridge and the Granby River are less than 1% of the <u>average</u> annual flow, while at other points-of-interest the licensed volume exceeds 5% of the average flow. In the lowest flow month, on average, the licensed volumes range from less than 5% to close to 30%.

There is sufficient evidence of late summer constraints on fish during below-average flow conditions to indicate that further surface withdrawals should not be considered without a detailed assessment of effects on fish. With respect to timing, withdrawals or storage from spring freshet would tend to have only a slight effect on flow, whereas a new application for an irrigation licence could have a potentially biologically-significant effect in late summer depending on location.

Given the constraints on future surface withdrawals, **groundwater** is likely to be the preferred source for new developments in the valley bottoms. For groundwater, licenses are not currently needed for withdrawals, except for large pumping volumes (≥75 L/second). Wei et al. (2010) recommended that before any new large capacity water well was brought into production in the Grand Forks aquifer, an assessment should be completed to delineate the capture zone, determine effects on other wells, and evaluate impacts on the Kettle and Granby Rivers. This is a valid recommendation and would be in the proponent's best interest, but it is not a legal requirement at present except where noted above. This is also true for other valley-bottom aquifers in the watershed since the hydraulic connectivity between river and aquifer documented at Grand Forks is present to varying degrees through the valley. If the projected cone of depression from pumping intersects a surface water body, the effect on streamflows could approach that for a surface withdrawal and should be evaluated with a similar level of caution.

8.2 DATA GAPS

There are enough available water resources data, analyses and reports to move into Phase 2 of the Kettle watershed management plan without undue delay. However, there are several information gaps should be addressed in 2012 to support plan development. The first group listed below are directly related to the watershed plan, while the second group are longer-term initiatives that will help address expected on-going water management information needs.

8.2.1 Information need to Support the Watershed Management Plan

- To date, investigations of surface water-groundwater interaction have focussed on the Grand Forks aquifer and the Kettle and Granby Rivers in the Grand Forks area. Less is known about these processes elsewhere in the watershed. In addition, no estimates on the contribution of groundwater flows from upper elevation areas to the lower elevation aquifers are available.
- Previous studies have suggested that there is a loss of river flow to groundwater in some sections of the Kettle River and tributaries. An assessment of gaining and losing stream processes will help determine which sections of river are sensitive to water withdrawals (Note: The recent in-fill flow monitoring by MOE has enabled initial analyses of these processes).
- There is limited information on how much irrigation water returns to underlying aquifers or to nearby streams. This may be significant in some areas (e.g. with sandy soils), and estimates of actual water use by irrigation would be improved by better estimates of return flow.
- The Ministry of Agriculture's agricultural demand model estimates irrigation and stockwatering use under a "worst case" scenario (i.e. 2003), but irrigation use estimates for a range of climate scenarios are not yet available and the model has not yet been checked against actual use in the Kettle watershed, as has been done elsewhere in B.C. The checking of actual water use against the model predictions should begin with a number of the larger individual irrigation licenses, but also include some assessment of users across the range of licensed volumes.
- There is insufficient detailed creel survey information with which to estimate the potential impacts of fishing on sport fish populations. A 2012 creel survey will help clarify some issues while Part 2 of the watershed plan is in development.
- Confirmation of the fate of adult fish through the summer period, including whether they depart the river or die in response to conditions. This assessment would likely take more than one year to complete, but should be initiated in 2012.
- Information on riparian health and riparian restoration is scattered among a variety of agencies and private individuals, with little in the public domain.

8.2.2 Longer-term Assessment, Monitoring and Adaptive Management

- The existing spatial coverage by climate monitoring stations is limited by a lack of mid- to high elevation data.
- The aquifers mapped to date by MOE cover the most populated and agriculturally intensive parts of the watershed where groundwater was being utilized at the time when the mapping program was active. A review of the existing geologic and aquifer mapping should be completed to set priorities for delineating and characterizing aquifers outside the boundaries of the provincially mapped aquifers.
- There is not an existing hydrometric monitoring station Boundary Creek. Therefore the flow estimates in this report relied on older data or inferences from other stations.
- There are only two active groundwater Observation Wells (Beaverdell and Grand Forks), and large areas of the watershed lack information on variations in groundwater levels.
- Although there are some data, information on water quality from sites located away from the lower Kettle River and the major communities is limited. Proponents of major new projects such as mines typically are required to carry out baseline monitoring as part of the environmental assessment process, but a basic monitoring program in areas currently lacking data would be of benefit to assess the sensitivity of the upper watershed to development.
- Water quality monitoring on the Kettle River downstream of Grand Forks has not been conducted since 1994. At that time, the water quality was rated as good, which is why monitoring ceased. A basic monitoring program at the former Gilpin site would be of benefit to allow comparison to the historic (1980-1994) data and to data from the Carson Canada-BC site located upstream of Grand Forks. A basic yet cost-effective water quality program would consist of sampling every other month for three years, for a core list of parameters that are indicative of stormwater and treated wastewater inputs (e.g. pH, TDS, TSS, turbidity, nutrients, chloride, hardness, and sulphate).
- Oliver (2001) made a number of recommendations for fish and fish habitat studies. The recent MFLNRO-sponsored studies have addressed several of those recommendations. Information needs that remain include:
    - River-specific habitat use and preference data with which to model the availability and quality of habitats for key species (e.g. rainbow trout, mountain whitefish and speckled dace) and life stages during summer and winter;
    - Determination of fish growth and productivity responses to a range of flow, temperature and habitat conditions;
    - Inventory of the current abundance of deep pools and LWD in the rivers and the estimation of the potential abundance assuming undisturbed or restored riparian conditions;
    - Evaluation of the competitive interactions between sport fish and less temperature-sensitive species such as speckled dace; and
    - Consideration of whether stocking programs may have reduced the vigour of the native stocks to naturally occurring high water temperatures and low flows.

9 RECOMMENDATIONS

9.1 TECHNICAL STUDIES AND MONITORING TO ADDRESS DATA GAPS

The following recommendations for additional technical studies to support water resources planning in the Kettle River watershed are provided in two categories. The first (Section 9.1.1) are specific studies that would be completed as soon as feasible to address information gaps identified in this Part 1 technical report. The second category (Section 9.1.2) is recommended additions to on-going water and climate monitoring in the watershed that would support decision making in the future.

9.1.1 Technical Assessments to Address Information Gaps and Support Part 2

Groundwater - Surface Water Interaction

Groundwater level monitoring in provincial observation wells and the recent detailed groundwater study of the Grand Forks aquifer have confirmed that the Kettle River is hydraulically connected to the valley bottom aquifers. Late summer flows are a concern for fish habitat despite actual surface water use being less than the existing licensed allocations. This is especially a concern during years with below average late summer flows. Therefore it is likely that any new water demands in the watershed downstream of Westbridge would look to groundwater as the source before considering surface water. Outside of the Grand Forks aquifer there is not enough information on groundwater resources and interaction with surface water to plan effectively for future demand.

Before moving directly to installing additional observation wells or pumping tests, the existing hydrometric and groundwater data should be analyzed to expand current understanding of the spatial and temporal variation in groundwater discharge and re-charge from rivers and streams. If the evidence points towards significant effects on surface flows from groundwater pumping, then a groundwater study can be designed to assess surface water-groundwater interaction in more detail. The initial assessment using existing data would include:

- The B.C. aquifer database rates only the Grand Forks aquifer as having high demand. The remainder are rated as either low or moderate demand. These ratings are now more than 10 years old and should be reviewed by the TAC and RDKB planning staff to determine whether the demand ratings would still apply in 2012 and in the future.
- In addition to the WSC data used in this report, compile other hydrometric data from several key locations along the river (e.g. non-active WSC stations and data collected recently by MFLNR).
- Compare the groundwater level data to precipitation and potential evapotranspiration data to assess the presence of climate-related trends [e.g. to the El Nino cycle and the Pacific Decadal Oscillation (PDO)]. Depending on the findings, the hydrometric data would be standardized the data to a common time period to eliminate variability due to these climate trends;

- Compute the runoff (i.e. discharge per unit area) at each of the key locations on a monthly basis, both for 2003 (“worst case”) and for an average year. Analyze downstream changes in runoff along the river to identify any anomalies;
- Develop estimates of aquifer recharge from upland areas based on existing information;
- Obtain the observation well water level data from the inactive observation well at Midway and determine if the well can be re-activated. If not, determine if there are other wells in the area that could be used.
- Plot the existing observation well groundwater level data against the WSC water level data from the nearest stations to see if there is a similar linkage as observed at Grand Forks and Greenwood, and to determine the nature of the linkage (e.g. inflowing, out-flowing, or varying throughout the year); and
- If there are sections with apparent net outflow, determine whether there are any nearby shallow groundwater wells that could be affecting surface water flow. Compare any available groundwater and surface water quality data to assess similarity.

After this review is complete, it will be possible to design a site-specific study for cases where the data suggests the potential for a surface/groundwater interaction that could be significantly reducing surface flow.

Surface Water and Water Use

The Ministry of Agriculture irrigation demand model should be run for a normal year (30 year average) to augment the recent modelling of 2003, the warmest and driest year on record. The model results should be calibrated by interviews with a number of individual license holders (the water utilities were surveyed for this report). The checking of actual water use against the model predictions should begin with a number of the larger individual irrigation licenses, but also include some assessment of users across the range of licensed volumes.

Water and Sediment Quality

Conduct a reconnaissance-level water and sediment quality monitoring program to characterize current conditions in the major tributaries where mining or other major developments could occur. Sites of interest include the West Kettle and Kettle Rivers before their confluence at Westbridge, Boundary Creek, and Rock Creek. Parameters would include routine variable (conductivity, temperature, pH, alkalinity, etc.), suspended sediment, nutrients, and total and dissolved metals. Quarterly water sampling over two years would be adequate since there are some historical data that can be built upon. The water sampling should be augmented by sampling the sediment in nearby pools once during low flow with analyses for total metals, grain size, and total organic carbon.

Fish and Fish Habitat

- Conduct creel surveys in 2012 to update current angler use and fishing effects for both summer and winter fisheries; and

- Initiate a radio-telemetry study of adult and sub-adult rainbow trout to identify critical habitats that support summer rearing, spawning, and overwintering; and to confirm the fate of adult fish through the summer period, including whether they depart the river or die in response to ambient conditions.

Riparian Function

The CWS riparian study of the Kettle watershed is expected to be complete by spring 2012. When it is available we recommend that a riparian working group be organized by the TAC to review the findings and recommendations, compare it against previous studies such as the 2005 inventory of Boundary Creek (Section 7.1.2), and determine whether further field work is needed to 1) assess how well the riparian zone functions with respect to aquatic habitat and water quality, and 2) set priorities for conservation and restoration.

Develop Future Demand Scenarios

Part 2 of the Watershed Management Plan should include development by the TAC and SAC of a number of population and economic growth scenarios to then be assessed for effects on water demand (e.g. no growth, the best estimate of growth from BC Stats, and double the best estimate). The most recent projections from BC Stats indicate an annual average population growth rate of about 0.5%, much of it coming from retirees (Section 3.9.5). This suggests negligible increase in residential water demand, which can be easily off-set from low cost water conservation measures. The potential for changes (increase or decrease) in demand from agriculture and industry is less easy to forecast, and would benefit from specialist input from the SAC. Once scenarios are in place it will be possible to estimate water demand and compare the demand to what is known about water supply.

9.1.2 Monitoring and Longer-Term Studies

Climate

An additional climate station would be of benefit at mid- to high elevation to augment the existing valley-bottom Environment Canada stations and serve to calibrate the recently-developed climate and irrigation demand models. A Farmwest site in Grand Forks would also be of benefit to assist farmers and ranchers with irrigation decisions for water conservation, and is therefore recommended[20].

Hydrometric and Water Quality Monitoring

Establishment of a hydrometric monitoring station on Boundary Creek would be of value for assessing the influence of the creek on flows in the Kettle River and on groundwater re-charge. Although a year-round station would be best, a seasonal station that covers freshet to late autumn

[20] See http://www.farmwest.com/index.cfm?method=pages.showPage&pageid=48

(e.g. March to November) would be adequate. Re-establishment of the former station near Midway (08NN011) would be preferred since there are about 49 years of data.

If a hydrometric station is re-established, there would be value in installing automated turbidity, water temperature, and conductivity measurement instruments at the site to assess variations in water quality (utilizing the same instrument housing). This addresses the on-going gap in water quality monitoring in tributary streams, but also provides a means to assess the effectiveness of recent and future riparian conservation and restoration actions. The automated measurements should be supported by manual sampling for calibration and to determine the relationship between turbidity and suspended sediment concentrations.

Re-establishment of the former Gilpin (downstream of Grand Forks) water quality monitoring station for two years (6 samples/year) would be of benefit to assess changes since it was monitored in 1980 to 1994, and for comparison to the active Carson site upstream of Grand Forks (see Section 8.2.2).

Groundwater Level

On-going groundwater level measurements are currently only made at Grand Forks and Beaverdell. Additional wells would be of value to provide information on variability, long term trends, and groundwater-surface water interaction in the watershed between these two sites. The specific number and location of new observation wells should be determined from the Groundwater-Surface Water interaction studies recommended above in Section 9.1.1.

Fish and Fish Habitat

- For selected species and life stages; develop river-specific habitat use and preference data then model the availability and quality of a range of habitats during summer and winter;
- Assess the growth and productivity of sport fish and potential competitors over a range of summer flow, temperature and habitat conditions to determine whether interspecific competition is a key driver of low sport fish productivity;
- Quantify rearing habitat availability under current and naturalized flow regimes to determine the scale of influence of water withdrawals;
- Estimate the current abundance of deep pools and LWD in the rivers and their potential abundance assuming a range of potential riparian conditions in the watershed; and,
- Conduct a review of stocking records and literature to determine the potential magnitude of influence of fish stocking on the vigour of native stocks in the watershed and whether such effects could be mitigated.

These studies will contribute to decisions on management strategies, which could include changes in local sportfishing regulations and further riparian and channel habitat restoration. The data would also be used to assess the effectiveness of any strategies that are implemented.

9.2 LINKAGES TO WATERSHED MANAGEMENT PLANNING

This Part 1 Technical Assessment represents the first step in development of the Kettle River Watershed Management Plan. There is a solid existing information base and a number of soon to be completed studies that provides a good foundation for water management planning, but the recommended technical studies will move RDKB and other water stakeholders closer to being able to plan for sustainability by providing the water resource information needed to make land use and economic development decisions and set policy. Decisions that depend on good water supply, water demand, water quality, and aquatic life information include:

- Environmental assessments of proposed waste discharges, both industrial (e.g. mines) and municipal (e.g. Liquid Waste Management Planning);
- Environmental assessments of projects that would include groundwater extraction (e.g. food processing, wineries, breweries, or mining);
- Applications for new surface water licenses and, in the future, for groundwater licenses if the B.C. government implements groundwater licensing;
- Setting priorities for fish and riparian habitat restoration;
- Hydro-power proposals;
- Reviews of future land development applications such a residential sub-divisions, golf courses, and recreational vehicle parks; and
- Assessments of costs and benefits of creating water storage in the upper watershed to mitigate late summer low flow.

It is important to note that completing the watershed-scale technical studies recommended by this report will better enable consideration of these types of proposed developments, but site-specific information would also be needed.

To help facilitate stakeholder and public engagement in the watershed planning process, RDKB should consider the implementing the following communication tools:

1. On-line Information Database. This study has compiled the key water resources reports that are available for the Kettle River watershed into a database using the EndNote software program. It would be beneficial to put the database into a format that would be made available in a searchable format that is on the Internet. This was done for the Okanagan Water Supply and Demand Project[21] and has proven to be a valuable and popular tool for technical specialists, stakeholders, and decision-makers. It could be accessed through the RDKB web site, since the community is already familiar with that site as a source of information.

2. Water "Backgrounder" Reports. There would appear to be value in developing a series of short summary reports that are accessible to the informed public and community stakeholders. These

[21] It is called the Okanagan Basin Water Resource Information Database. See http://www.obwb.ca/obwrid/

would be prepared with input from the technical and stakeholder advisory committees and would not exceed about six to 10 pages in length, include illustrations, and provide references for more detailed information. They could be published in a series based on what is priority for supporting the plan development process, and to spread the cost out. These reports would include references and linkages to information on best management practices for water conservation, groundwater quality protection, riparian management, and other water management strategies that can be implemented by individuals and landowners.

10 REFERENCES

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A Appendix A – Phase 1 Terms of Reference

Regional District of Kootenay Boundary

Phase 1 - Technical Assessment
Kettle River Watershed Management Plan

Request for Proposals

Closing date and time: 4:00 PM, January 28, 2011 Pacific Standard Time

Location of proposal closing:

Regional District of Kootenay Boundary, 202 - 843 Rossland Avenue, Trail B.C., V1R 4S8

Contact:

Mark Andison, Director of Planning and Development

250-368-9148

November 26, 2010

Phase 1 - Technical Assessment
Kettle River Watershed Management Plan

Request for Proposals

1.0 Purpose

The Regional District of Kootenay Boundary (RDKB) is issuing this Request for Proposals for the purpose of identifying a firm (consultant) interested and qualified in providing consulting services to the RDKB for the specific purpose of assisting with completing a technical assessment of the Kettle River watershed which will comprise Phase 1 of the Regional District of Kootenay Boundary's Kettle River Watershed Management Plan.

2.0 Background

Residents of the Regional District of Kootenay Boundary are concerned about the state of the Kettle River and its tributaries, primarily in terms of the diminishing flows during the summer months and the quality of both ground water and surface water due to land uses occurring along the river, its tributaries, and above aquifers in the watershed. The state of the watershed has attracted the attention of those outside the basin, with the Outdoor Recreation Council of B.C. recently ranking the Kettle River the most endangered river in B.C. due to concurrent seasonal low flows and new and existing water extraction proposals and licenses.

Within this context the Regional District of Kootenay Boundary is undertaking the development of a watershed management plan for the Kettle River basin with broad participation from other agencies and stakeholders. A watershed management plan, when completed, will provide a strategic vision for the watershed with concrete actions to be undertaken by the various agencies and stakeholders who have a role in the management of water and land resources within the basin, including individual citizens.

The watershed management planning process will be conducted in two phases. The goal of Phase 1 of the project is to characterize the existing water and water-related resources in the Kettle River watershed by compiling available data from existing studies, various agencies and relevant technical reports. This technical assessment of the Kettle River watershed will be presented in a "State of the Kettle River Watershed" document.

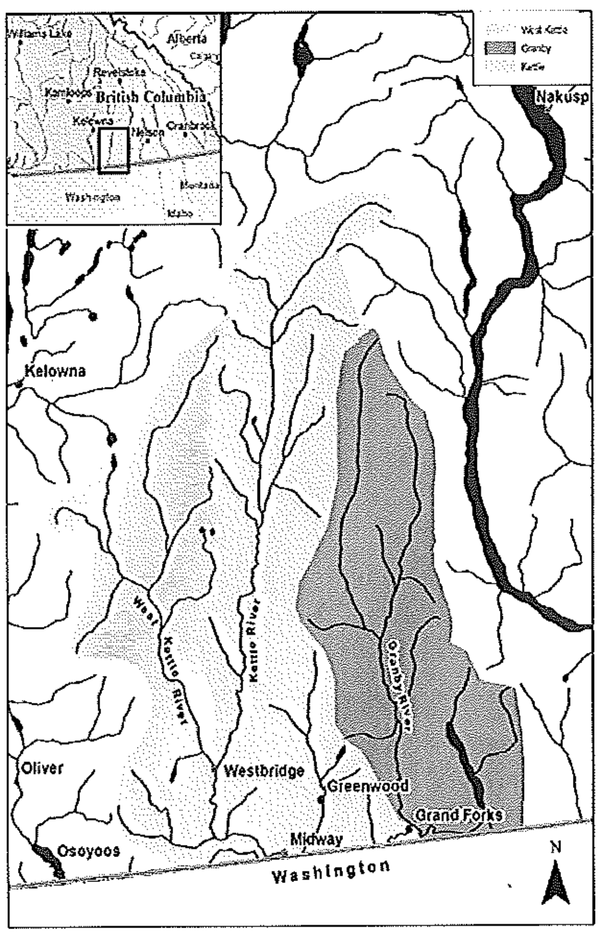
Phase 2 of the project will commence after Phase 1 The Technical Assessment has been completed. During Phase 2, the information gathered in Phase 1 will be utilized to establish planning goals, actions, and policy directions that may be pursued to improve the long-term health of the watershed.

3.0 Study Area

The Kettle River lies between the Okanagan and Columbia River valleys in the central part of southern British Columbia and northern Washington. The Kettle River is a 282 km (175 mile) tributary of the Columbia River located both in the southern interior of British Columbia and northeastern Washington State. Its drainage basin is 11,000 km^2 (4,200 $miles^2$), of which 8,230 km^2 (3,177 $miles^2$) are in Canada and 2,650 km^2 (1,023 $miles^2$) are in the United States.

In British Columbia, the Kettle River basin is divided into two large sub-basins by the Midway Range of the Monashee Mountains. The large western sub-basin is divided into two smaller sub-basins by the Beaverdell Range into the West Kettle River Valley and the Main Kettle River – the Christian Valley. From its source at the outlet of Holmes Lake in the Monashee Mountains, the Kettle River flows through the Christian Valley and joins the West Kettle River at Westbridge. The Kettle River continues to flow south and east until it crosses the Canada/U.S. border at Midway, BC and Ferry, Washington (see map below).

The eastern large sub-basin of the Kettle River is drained by the Granby River, also commonly known as the North Fork. This sub-basin is located between the Midway Range to the west and the Selkirk Trench, which holds the Columbia River, to the east. Below Midway, the river loops south into the United States, through Ferry County, Washington, before flowing north back into Canada, passing through Grand Forks, BC where the Granby River joins. After flowing east for approximately 18 kilometres , the river turns south again at its confluence with Christina Creek. From there, the river crosses the Canada/U.S. border for a third time near the Laurier, Washington border crossing on Highway 395. It then flows south, joining the Columbia River near Kettle Falls, Washington. The Columbia River at this point is a large reservoir referred to as Lake Roosevelt which is impounded by the Grand Coulee Dam.



The shaded areas comprise the Study Area.

The portion of the Kettle River watershed which is the subject of the watershed management plan is the area located within Canada. As the river crosses the border between B.C. and Washington in three locations, there are mutual interests and impacts to the two jurisdictions (Washington State and BC) relating to the management of the Kettle River watershed. A separate watershed planning process was undertaken for the US portion of the basin in the late 1990s under the provisions of the State of Washington's 1998 Watershed Planning Act (*Level I Technical Assessment Water Resource Inventory Area 60 Kettle River Watershed*; http://www.ecy.wa.gov/pubs/0406012.pdf). That multi-agency process, which was conducted with Ferry County acting as the lead agency, was discontinued after completion of Phase 2 of the process (Technical Assessment). Phase 3 (Planning) and Phase 4 (Implementation) were not undertaken.

4.0 Scope of Work

A Phase 1 "State of the Kettle River Watershed Report" will be provided which describes in detail the current status of the watershed in terms of water quantity, quality, and the state of the habitat/riparian areas. The data will be compiled from various sources, including existing studies and reports, local sources, and provincial, state, and federal agencies. This phase of the project will provide a sound scientific base for decision-making in the watershed.

This scope of work may be refined by the RDKB and/or the Technical Advisory Committee during the consultant selection process and/or in consultation with the selected consultant as part of contract negotiations.

From available data sources the report should contain, at a minimum:

Watershed Physical Description

An overview description of the watershed including: land use, climate, ecology, bedrock geology, surficial geology, regional hydrogeology, watershed hydrology, physiography, soils, and natural sub-regions.

Water Quantity

- An estimate of the surface and groundwater present in the plan area;
- An estimate of the water in the plan area that is allocated under a water license or any other form of water right;
- An estimate of the surface and groundwater actually being used in the plan area, broken down by user type (i.e. domestic, agricultural irrigation, municipal, industrial, hydroelectric generation, etc.);
- An estimate of the water needed in the future for use in the plan area;
- Minimum thresholds required for in-stream flows to maintain a healthy aquatic environment for fish and other aquatic organisms;
- Location and characterization of aquifers in the area;
- Identification of areas where aquifers are known to recharge surface bodies of water and areas where surface bodies of water are known to recharge aquifers, and where these processes are vulnerable to change over time based upon climate change and other influences;
- An estimate of the surface and groundwater available for further allocation, taking into account the minimum in-stream flows required for fish and other aquatic organisms;

- Flooding history and identification of the most vulnerable properties in the plan area;
- Projected impacts upon surface and groundwater supply, demand, temperatures for fish survival, flooding, and other factors resulting from climate change in the plan area;
- Development of a water balance model for the plan area which may be used to evaluate water resource allocations within the watershed and identify the impacts of potential changes to water balance components that may be considered during the next phase of watershed planning.

Water Quality

- An examination of the degree to which established surface and groundwater water quality standards are being met in the plan area , based upon existing studies conducted by provincial, state, and federal agencies, academic institutions, non-governmental organizations, and local sources;
- A similar examination of the causes of any surface and groundwater quality problems or regulatory violations in the plan area, including the provision of information regarding land uses, pollutants, point and non-point sources of pollution. This information should include an examination of the impacts of the major land uses occurring in the plan area, including urban and rural development, agriculture, and forestry.

Habitat/Riparian Areas

- The assessment shall take into consideration seasonal stream flow variations, natural events, and pollution from natural sources that occur independent of human activities;
- An examination of the established characteristic uses of the rivers and streams and adjacent riparian areas in the plan area and the impacts associated with those uses.

The report should include information documenting the data sources used to compile the above-noted information, as well as identification of data gaps with a presentation of technical information related to the watershed which is not readily available. The report should include recommendations regarding any data gaps which should be addressed prior to the RDKB undertaking Phase 2 of the watershed management planning process.

5.0 Committee Involvement

The successful consultant will work with a Technical Advisory Committee appointed by the RDKB to oversee the development of the Phase 1 Report. This committee consists of representatives from various agencies having responsibility for the management of water and terrestrial resources in the plan area. The successful consultant will meet with this committee regularly and provide regular updates and status reports to the committee as work unfolds.

The successful consultant will present the draft final report to the Public Advisory Committee which will be involved in the preparation of Phase 2 of the Kettle River Watershed Management Plan.

6.0 Deliverables

Deliverables for the project shall include:

- A technical assessment of the Kettle River watershed area which includes detailed data and mapping addressing each of the subject areas identified in the scope of work;
- GIS databases and mapping associated with the relevant subject areas identified under the scope of work, subject to the availability of that data (eg. location of aquifers and recharge areas, locations of areas vulnerable to flooding, locations of water licenses, etc.) ;
- Regular meetings and communication with the Technical Advisory Committee and RDKB staff;
- Presentation of a final draft to the RDKB Board of Directors;
- Presentation of a final draft to the Public Advisory Committee;
- Final report, as described above, presented as a "State of the Kettle River Watershed" document.

7.0 Consultant Expertise

The successful consultant shall have expertise and experience in undertaking projects of this nature and will submit evidence of same.

The ideal consulting team will exhibit the following:

- Strong technical expertise in water resource management including proven methodologies to assess the state of water resources at the watershed level;
- Experience in the development of technical watershed reports and, specifically, watershed management plans;
- Familiarity with the Kettle River and its sub-basins;
- A proven track record in preparing and presenting high quality technical analyses within a collaborative process.

8.0 Personnel

The proposal must specify the team members who would do the actual work, the estimated hours involved, charge-out rates, and qualifications of each of these individuals, including a summary of their experience with related work.

9.0 Timing and Budget

It is anticipated that the process will commence upon the awarding of the contract with a projected completion date within 12 months of award of contract. We anticipate the cost of this project will be no more than $100,000 including taxes, disbursements, printing and all other costs and charges. Our objective will be to obtain the valuable assistance we require at the lowest overall cost.

10.0 Submission Requirements

The following must be included in the proposal submission and will be used as the basis for evaluation of the successful proposal:

- Qualifications of the primary project consultant and other individuals who would be involved in the project. A clear indication of the role of the primary consultant and other individuals involved and both the percentage of time and the components of the project with which each would be involved.
- Experience with watershed management planning, and specifically the technical assessment of watersheds.
- Methodology – a work plan including the proposed method of accomplishing the tasks identified in the General Scope of Work section above with a timeline for the project.
- Assurance that the consultant is not in a position which may be perceived as a conflict of interest with respect to undertaking this project.
- The total cost to complete the work including all taxes and disbursements and any potential additional works.
- Examples and samples of other reports of a similar nature that have been prepared by the firm and experience that the team members have working together on other projects.
- At least three references outlining the services of a similar nature provided to other clients. Include the company/jurisdiction's name and address, contact person and telephone number, and a brief description of the service provided and the date of that work.

11.0 Evaluation Criteria

The following evaluation criteria will be used in the selection process:

- Proposed methodology (*on-going consultation with the Technical Advisory Committee is considered to be very important to the successful outcome of this project*);
- Consultant's understanding of the context, issues, and the ultimate objectives of the project;
- Experience and qualifications of those involved;
- Fees and disbursements;
- Schedule; and
- Reference checks.

12.0 General Instructions, Terms and Conditions

1. Proposals will be accepted in the following formats:

   courier mail, regular mail, email (PDF format only) until **4PM Pacific Standard Time** on **January 28, 2011** at the Regional District of Kootenay Boundary office, located at:

Regional District of Kootenay Boundary,
202 - 843 Rossland Avenue, Trail, BC V1R 4S8
Phone: 250-368-9148
Email: mandison@rdkb.com

2. The RDKB reserves the right to accept or reject any or all proposals and to accept the proposal that it deems most advantageous.

3. The RDKB will not be responsible for the costs of preparing proposals.

4. The successful consultant will be authorized to proceed only upon approval from the RDKB.

5. The budget for this study is up to a maximum of $100,000, including all fees, expenses and taxes. It is hoped that a lesser amount will be sufficient to accomplish the purpose of the study.

6. The RDKB is available to provide some of the base mapping which may be required for the project.

7. Invoices, no more frequently than monthly, will be required before the RDKB will make payments. Each invoice must be accompanied by a progress report. Each invoice must include a breakdown of staff, hours, rates, and expenses. The RDKB will hold back a maximum total of 10% of the entire agreed value of this project to be paid upon successful completion of the project. Determination of the successful completion of project deliverables, milestones and of this project as a whole is at the sole discretion of the RDKB.

8. The consultant selected to carry out the study will be required to enter into a contract with the RDKB respecting the conduct of the study.

9. If a contract cannot be negotiated within thirty days of notification of the successful consultant, the RDKB may, at its sole discretion at any time thereafter, terminate negotiations with that consultant and either negotiate a contract with the next qualified consultant or choose to terminate the RFP process and not enter into a contract with any of the consultants.

10. The consultant must commit to commencing work within 30 days of the signing of the contract and work diligently thereafter to ensure the stated timelines are met.

11. The draft Kettle River Watershed Technical Assessment Report will be submitted to the RDKB in three (3) copies and the final Kettle River Watershed Technical Assessment Report will be submitted in three (3) copies. The final Kettle River Watershed Technical Assessment Report will also be submitted digitally (text and mapping) in a format(s) satisfactory to the RDKB.

12. The consultant will be required to have in place a general liability insurance policy for not less than $2,000,000 during the study, naming the RDKB as an additional insured.

Inquiries

Inquiries during the proposal period should be directed to Mark Andison, Director of Planning and Development, Regional District of Kootenay Boundary.
Phone: 250-368-9148
Fax: 250-368-3990
E-mail: mandison@rdkb.com

B Appendix B - Water Licence Tables

Table B1 – Water Licence Summary: Kettle River Watershed Sub-basin

Sub-basin	License Type	Purpose	No. Water Licenses	Licensed Volume (ML)	Major license holder(s)
1	Agricultural	Irrigation	40	7596.1	Individuals (3,278.9 ML); Southeast Kelowna Irrigation District (SEKID) (4,317.2 ML)
		Stockwatering	2	3.3	Ministry of Forests and Range (MOFR)
	Domestic	Domestic	22	28.6	Individuals
		Waterworks	5	464.6	SEKID (414.8 ML); Big White Water Utility Ltd. (49.8 ML)
	Industrial and Commercial	Enterprise	2	10.0	Big White Water Utility Ltd. (8.3 ML); Individual (1.7 ML)
		Snowmaking	1	3.7	Big White Water Utility Ltd.
	Other	Storage	12	5,239.8 to support irrigation	SEKID (5,239.8 ML); Big White Water Utility Ltd. (597.0 ML); Individuals (160.4 ML)
				757.4 to support other purposes	
		Conservation	3	579.7	Ministry of Environment (MOE)
2	Agricultural	Irrigation	43	6,116	Individuals
		Stockwatering	5	7.5	MOFR (6.7 ML); Individuals (0.8 ML)
		Residential Lawn/Garden	1	6.2	Individual
	Domestic	Domestic	31	39.0	Individuals
	Industrial, Commercial, and Institutions (ICI)	Institutions	2	3.3	Individuals
		Enterprise	1	8.3	Individual
	Other	Camps	2	17.0	Individual
		Conservation	1	30.8	MOE
		Power	4	8.4	Individuals
		Ponds	1	3.6	Individual
		Storage	3	185.0 to support irrigation	MOFR (69.1 ML); Individuals (192.7 ML)
				76.8 to support other purposes	

Table B1 cont'd – Water Licence Summary: Kettle River Watershed Sub-basins

<table>
<tr><th>Sub-basin</th><th>License Type</th><th>Purpose</th><th>No. Water Licenses</th><th>Licensed Volume (ML)</th><th>Major license holder(s)</th></tr>
<tr><td rowspan="13">3</td><td rowspan="3">Agricultural</td><td>Irrigation</td><td>115</td><td>13,249.0</td><td>Individuals</td></tr>
<tr><td>Stockwatering</td><td>37</td><td>73.6</td><td>MOFR (45.6 ML); Individuals (28.0 ML)</td></tr>
<tr><td>Residential Lawn/Garden</td><td>1</td><td>6.2</td><td>Individual</td></tr>
<tr><td rowspan="2">Domestic</td><td>Domestic</td><td>103</td><td>172.6</td><td>MOFR (73.0 ML); Individuals (99.6 ML)</td></tr>
<tr><td>Waterworks</td><td>3</td><td>4,330.9</td><td>Village of Midway (4,314.2 ML); Mt. Baldy Waterworks Inc. (16.7 ML)</td></tr>
<tr><td rowspan="3">Industrial and Commercial</td><td>Enterprise</td><td>2</td><td>7.5</td><td>Individuals</td></tr>
<tr><td>Mining – Hydraulic</td><td>1</td><td>2.7</td><td>Individual</td></tr>
<tr><td>Mining - Placer</td><td>1</td><td>0.2</td><td>Individual</td></tr>
<tr><td rowspan="4">Other</td><td>Fire Protection</td><td>1</td><td>716.8</td><td>Individual</td></tr>
<tr><td>Ponds</td><td>1</td><td>8.6</td><td>Individual</td></tr>
<tr><td rowspan="2">Storage</td><td rowspan="2">13</td><td>474.8 to support irrigation</td><td rowspan="2">Mt. Baldy Waterworks Inc. (127.5 ML); Individuals (760.2 ML)</td></tr>
<tr><td>412.9 to support other purposes</td></tr>
<tr><td rowspan="9">4</td><td rowspan="3">Agricultural</td><td>Irrigation</td><td>69</td><td>3,920.4</td><td>Individuals</td></tr>
<tr><td>Stockwatering</td><td>8</td><td>11.2</td><td>Individuals</td></tr>
<tr><td>Watering</td><td>1</td><td>9.3</td><td>Individual</td></tr>
<tr><td>Domestic</td><td>Domestic</td><td>46</td><td>75.1</td><td>Individuals</td></tr>
<tr><td rowspan="2">Industrial and Commercial</td><td>Processing</td><td>1</td><td>16.6</td><td>Small Business</td></tr>
<tr><td>Mining – Processing Ore</td><td>1</td><td>331.9</td><td>Individual</td></tr>
<tr><td rowspan="3">Other</td><td>Conservation</td><td>5</td><td>697.0</td><td>MOE</td></tr>
<tr><td rowspan="2">Storage</td><td rowspan="2">5</td><td>87.6 to support irrigation</td><td rowspan="2">Individuals</td></tr>
<tr><td>37.0 to support other purposes</td></tr>
</table>

Table B1 cont'd – Water Licence Summary: Kettle River Watershed Sub-basins

Sub-basin	License Type	Purpose	No. Water Licenses	Licensed Volume (ML)	Major license holder(s)
5	Agricultural	Irrigation	6	394.7	Covert irrigation District (354.6 ML); Individuals (40.1 ML)
		Stockwatering	1	0.8	Individual
	Domestic	Domestic	10	11.6	Individuals
		Waterworks	1	33.2	SION Improvement District
6	Agricultural	Irrigation	36	3,396.0	Individuals (3,006.2 ML); SION Improvement District (389.8 ML)
		Stockwatering	1	3.3	Individual
	Domestic	Domestic	42	46.3	Individuals
		Waterworks	5	1,495.9	City of Grand Forks (1,493.4 ML); SION Improvement District (2.5 ML)
	Industrial and Commercial	Enterprise	1	3.3	Individual
		Processing	1	33.2	Small Business
	Other	Storage	1	3.7 to support irrigation	Individual

Table B1 cont'd – Water Licence Summary: Kettle River Watershed Sub-basins

Sub-basin	License Type	Purpose	No. Water Licenses	Licensed Volume (ML)	Major license holder(s)
7	Agricultural	Irrigation	120	9,415.5	City of Grand Forks (1.3 ML); Individuals (4,916.6 ML); Grand Forks Irrigation District (4260.6 ML); SION Improvement District (205.4 ML); Sutherland Creek Waterworks District (31.6 ML)
		Residential Lawn/Garden	2	23.1	Christina Waterworks District (21.8 ML); Individuals (1.3 ML)
		Stockwatering	2	2.1	Individuals
		Watering	2	223.9	Individuals
	Domestic	Domestic	131	139.0	Individuals
		Waterworks	13	1,690.8	City of Grand Forks (829.6 ML); Christina Waterworks District (599.0 ML); SION Improvement District (13.3 ML); Sutherland Creek Waterworks District (248.9 ML)
	Other	Conservation	3	44.1	MOE
		Power	2	2,838.1	Small Business
		Ponds	2	5.0	City of Grand Forks
		Storage	2	58.7 to support irrigation	Individuals
8	Agricultural	Irrigation	1	21.6	Individual
	Domestic	Domestic	10	12.4	Individuals

Table B2 – Water Use Summary: Major Water Suppliers in the Kettle River Watershed Sub-basins

Water Supplier	Source Type	Purpose	Actual Water Use		Notes
			Period of Record	Annual Range (ML)	
Big White Water Utility Ltd.	Surface Water	Domestic, Commercial	2004 - 2011	250.1	Annual volume is an average Breakdown between end uses not available Surface water usage only since 1963
Bridesville Waterworks District	Groundwater	Domestic	n/a	n/a	No recorded volumes available
City of Grand Forks	Groundwater	Metered (Industrial and Commercial), Domestic, Parks and open space, Losses	2006 - 2010	1765.0 - 3512.5	Metered (Industrial and Commercial): 20%, Domestic: 60%, Parks and open space: 10%, Losses: 10% City of Grand Forks has used strictly groundwater from 1995 - present. Prior to 1995, a combination of groundwater and surface water from Overton Creek was used. Main licences on Kettle and Granby Rivers not used since 1960's/early 1970's Pacific Abrasives uses 75.078m3 per/day from the Granby River (conditional water license from City of Grand Forks)
City of Greenwood	Groundwater	Domestic, Commercial	2009	635.95	Groundwater usage only since 1968 Volume is based on engineer's estimate Domestic (80%), Commercial (20%)
Christina Waterworks District	Surface Water	Domestic, Commercial	2007 - 2010	282.1 - 379.5	Breakdown between end uses not available Stopped using Moody Creek as a surface water source 5 years ago (2006); now Christina Lake is sole source.
Covert Irrigation District	Groundwater	Domestic, Agricultural	2006 - 2010	105.6 - 252.5	Groundwater usage only since 1980 Breakdown between end uses not available Nearby landowner used July Creek to irrigate 90 acres of land prior to 2009.
Grand Forks Irrigation District	Groundwater	Domestic, Agricultural	1995 - 2010	2206.9 - 3630.2	Domestic (1%), Agricultural (99%). Surface water licences not used since 1989.
Southeast Kelowna Irrgiation District (SEKID)	Surface Water	Domestic, Agricultural, and Storage	2004 - 2008	1461.7 – 3373.6	SEKID diverts surface water from Stirling Creek (Kettle River Basin) into Hydraulic Reservoir (Okanagan Basin)
Sion Irrigation District	Groundwater	Domestic, Agricultural	2006 - 2010	1227.4 - 1738.3	Groundwater usage only since 1967 Breakdown between end uses not available
Sutherland Creek Waterworks District	Surface Water/Groundwater	Domestic, Commercial, Industrial, Agricultural	2002 - 2010	221.8 - 298.7	Strictly surface water to 2007; Strictly groundwater 2007 to present. Breakdown between end uses not available
Village of Midway	Groundwater	Domestic, Commercial, Parks	1996 - 2010	391.0	Annual volume is an average Prior to 1995, the majority of water supply to Midway was provided by privately owned wells. Breakdown between end uses not available
	Surface Water	Agricultural	Prior to 2009	n/a	The Village of Midway has a annual water lease for 4313.4 ML/year used for agricultural lands around the airport.

C Appendix C - Streamflow Naturalization

The following provides a detailed description and the results of the streamflow naturalization process for the seven points-of-interest (POI) within the Kettle River watershed.

C.1 STREAMFLOW NATURALIZATION

On the basis of the evaluation of available hydrometric records and water use information, a standard period for the baseline analyses of 1981-2010 was adopted for this study. By adopting this standard period, the annual and monthly distribution of natural or naturalized and net flows were estimated at each of the POIs as follows:

Kettle River at Boundary Creek Confluence (Sub-basin #'s 1-4)

As the USGS hydrometric station "*Kettle River near Ferry*" (1928-2010) (Table 4-3) is situated approximately 2 km downstream of the Boundary Creek confluence, the hydrometric records at this station are representative of total streamflows from sub-basin #'s 1-4 (Map 1). The USGS refers to this station as representing "natural" flows; however, other hydrometric stations on the Kettle River upstream (e.g. *Kettle River near Westbridge* and *West Kettle River at Westbridge*) are referred to as "regulated" by the WSC due to water extractions in the watersheds above each station. Accordingly, for naturalization purposes in this study, as the "*Kettle River near Ferry*" hydrometric station is located downstream of the "regulated" stations, it is assumed to represent regulated records.

In order to provide naturalized streamflow estimates at the POIs in sub-basin #1-4, the following methodology was utilized:

1. For the West Kettle River at Mouth (sub-basin #1) and Kettle River above West Kettle Confluence (sub-basin #2), seasonal (April to September, 1981-2007) and continuous (January to December, 2008-2010) regulated records were available close to the POI's of each sub-basin by WSC stations "*West Kettle River at Westbridge*" and "*Kettle River near Westbridge*", respectively. The records of each station were scaled to the POI of each sub-basin assuming the same unit discharge as measured by each WSC station;
2. The seasonal records of both "*West Kettle River at Westbridge*" and "*Kettle River near Westbridge*" were transformed to continuous records assuming that the ratio of the total seasonal streamflow to the total annual streamflow measured by "*Kettle River near Ferry*" for each respective year was comparable at all locations of interest. This assumption was verified by comparison of the 2008-2010 seasonal-to-total streamflow ratio's for the continuous hydrometric records of all stations, which had an average annual standard deviation of 0.007 between the three datasets. Accordingly, the seasonal-to-total streamflow ratio's measured by "*Kettle River near Ferry*" were applied to the respective seasonal records of both "*West Kettle River at Westbridge*" and '*Kettle River near Westbridge"* for the standard period to estimate the total annual streamflows for each sub-basin. Once the total annual streamflows were calculated, missing months were estimated assuming the

same monthly distribution measured by "*Kettle River near Ferry*". The results of this step provided net flows for both the West Kettle River (sub-basin #1) and Kettle River at Westbridge (sub-basin #2);

3. For Boundary Creek (sub-basin #4), historic WSC hydrometric monitoring within the sub-basin included "*Boundary Creek at Greenwood*" (continuously from 1913-1918, 1960-1969, and 1971-1980) and "*Boundary Creek near Midway*" (seasonally from 1929-1932, 1943-1947, 1949-1953, and 1971-1977), both of which are considered "regulated" (Map 1 and Table 4-3). Due to the location of the "*Boundary Creek near Midway*" station, it was selected as representative of the net streamflow pattern and the seasonal records scaled to the POI of sub-basin #4. As the records for this station are generally out-of-date, the 1971-1977 period of record was assumed most representative of current water use. Following the same methodology as for the "*West Kettle River at Westbridge*" and "*Kettle River near Westbridge*" sub-basins, the missing months of the "*Boundary Creek near Midway*" seasonal records were estimated assuming the same monthly distribution measured by "*Kettle River near Ferry*" for the same time period. In addition, the "*Boundary Creek near Midway*" records were adjusted to the 1981-2010 standard period using the flow records of "*Kettle River near Ferry*". The results of this step provided net flows for Boundary Creek (sub-basin #4). Please note that due to the limited hydrometric information available for the Boundary Creek watershed, this methodology was selected as most appropriate since actual records close to the POI were utilized. However, as presented in Section 9.1.2 of the main report, it is recommended that the "*Boundary Creek near Midway*" hydrometric station be re-activated in order to improve streamflow estimates in this sub-basin;
4. For Residual Area #1 (sub-basin #3), net flows at the POI of the sub-basin were estimated as a function of the remainder of total net flow of "*Kettle River near Ferry*" and removing the net flow contributions from sub-basin #'s 1, 2, and 4. The remainder was then added to the combination of net flows of sub-basin #'s 1 and 2 to provide net flows at the end-point of Residual Area #1 (sub-basin #3). Please note that the remainder for sub-basin #3 is both positive and negative for the standard period, which reflects aquifer infiltration recharge and the dependence of the groundwater system on river-stage elevation both under baseflow and peak flow conditions in the Kettle River reported by Allen *et al.* (2004) and Scibek (2005); and
5. All net flows were transformed to naturalized flows by adding all water licensing information and water purveyor records.

Kettle River at Deep Creek Confluence (Sub-basin #'s 5-8)

As the USGS hydrometric station "*Kettle River near Laurier*" (1929-2010) (Table 4-3) is situated approximately 500 m downstream of the Deep Creek confluence, the hydrometric records at this station are representative of total streamflows from the entire Canadian and United States portions of the Kettle River watershed upstream of this point (i.e. sub-basin #'s 1-8) (Map 1). The USGS refers to this station as representing "natural" flows; however, due to the identified "regulated" stations on the Kettle River upstream, it is assumed that the "*Kettle River near Laurier*" represents "regulated" records.

As naturalized streamflow estimates were calculated for sub-basin #'s 1-4 (above), the following methodology was utilized to estimate naturalized streamflows for sub-basin #'s 5-8:

1. For the Granby River (sub-basin #6), continuous "natural" records (1914-1915, 1926-1931, and 1966-2010) were available close to the POI of the sub-basin by WSC station "*Granby River at Grand Forks*" (Map 1 and Table 4-2). The records of this station were scaled to the end point of the sub-basin assuming the same unit discharge as measured by the WSC station;
2. In order to estimate net and naturalized flows for Residual Area #3 (sub-basin #7), the net and naturalized flow contributions between the POIs of sub-basin #7 and the "*Kettle River near Laurier*" station (i.e. Residual Area #4 (sub-basin #8)) needed to be removed. Accordingly, the unit discharge measured by the WSC Station "*Sutherland Creek near Fife*" (seasonally from 1960-1970 and 1973) (Map 1 and Table 4-2) was assumed representative of the runoff from Residual Area #4. Following the same methodology as for the "*West Kettle River at Westbridge*" and "*Kettle River near Westbridge*" sub-basins (above), the missing months of the "*Sutherland Creek near Fife*" seasonal records were estimated assuming the same monthly distribution measured by "*Kettle River near Laurier*". In addition, the "*Sutherland Creek near Fifie*" records were adjusted to the 1981-2010 standard period using the flow records of "*Kettle River near Laurier*". The results of this step provided the natural unit discharge for Sutherland Creek; accordingly, natural flow estimates for Residual #4 (sub-basin #8) were calculated. Net flows for Residual Area #4 were estimated by removing the relevant water licensing information and water purveyor records. Once the Residual Area #4 values were determined, they were removed from the "*Kettle River near Laurier*" records in order to provide estimates at the POI of Residual Area #3 (sub-basin #7); and
3. For Residual Area #2 (sub-basin #5), naturalized flows at the POI of the sub-basin were estimated as a function of the remainder of total naturalized flow of the corrected "*Kettle River near Laurier*" records (see above) and removing the contributions from the Granby River (sub-basin #6) and Residual Area #3 (sub-basin #3). Using the "*Granby River at Grand Forks*" records, the percentage of monthly runoff of the "*Kettle River near Laurier*" records contributed by the Granby River was estimated for the standard period of record. In addition, using the difference in "natural" discharge contribution recorded by the WSC stations "*Kettle River at Carson*" and "*Kettle River at Cascade*" from 1917-1921 and assuming the same percentage of monthly runoff by the Granby River, the percentage of monthly runoff of Residual Area #3 (sub-basin #3) was estimated. Assuming the same Granby River and Residual Area #3 monthly runoff percentages for the standard period, naturalized flows at the POI of sub-basin #5 was estimated; and
4. All net flows were transformed to naturalized flows by adding all water licensing information and water purveyor records.

C.2 STREAMFLOW NATURALIZATION RESULTS

The following tables summarize the results of the streamflow naturalization process and include estimates of the following at each POI:

- Net flow;
- Naturalized flow;

- 1-in-10 year return period net flow
- 1-in-50 year return period net flow
- Total licensed quantity for both offstream and instream use;
- Licensed quantity for offstream use;
- Licensed quantity for instream use;
- Licensed quantity for conservation (storage);
- Estimated actual licensed offstream use (not including major purveyors); and
- Estimated actual water purveyor use (including groundwater).

Table C-1 - West Kettle River at Mouth

DATA:

Month	(1) Net Flow (m^3/s)	(2) Naturalized Flow (m^3/s)	(3) 10-yr Return Period - Monthly Net Low Flow (m^3/s)	(4) 50-yr Return Period - Monthly Net Low Flow (m^3/s)	(5) Total Licensed (Offstream and Instream) (m^3/s)	(8) Offstream Licences (m^3/s)	(9) Instream Licences (m^3/s)	(10) Conservation - Stored Water (m^3/s)	(11) Total Estimated Actual Offstream Use (m^3/s)	(12) Estimated Actual Licensed Offstream Use (m^3/s)	(13) SEKID Estimated Water Use (m^3/s)	(14) Big White Estimated Water Use (m^3/s)
Jan	2.31	2.32	0.958	0.564	0.046	0.046	0.000	-0.011	0.005	0.001	0.000	0.004
Feb	2.46	2.47	1.06	0.873	0.055	0.055	0.000	-0.010	0.005	0.001	0.000	0.004
Mar	5.46	5.46	1.48	0.731	0.128	0.128	0.000	-0.009	0.006	0.002	0.000	0.004
Apr	34.2	34.2	13.6	3.21	0.54	0.48	0.000	0.059	0.038	0.011	0.000	0.027
May	60.5	61.3	38.0	28.7	1.27	1.17	0.000	0.103	0.760	0.073	0.644	0.043
Jun	36.9	37.2	16.7	14.3	1.10	1.04	0.000	0.062	0.300	0.078	0.195	0.027
Jul	11.5	11.7	2.45	0.753	0.947	0.947	0.000	-0.070	0.228	0.182	0.046	0.000
Aug	2.86	3.04	0.610	0.252	0.862	0.862	0.000	-0.065	0.171	0.165	0.006	0.000
Sep	2.21	2.30	0.501	0.155	0.399	0.399	0.000	-0.031	0.088	0.076	0.012	0.000
Oct	3.07	3.11	1.00	0.698	0.107	0.107	0.000	-0.013	0.034	0.014	0.019	0.001
Nov	3.64	3.65	1.07	0.461	0.058	0.058	0.000	-0.008	0.003	0.001	0.000	0.002
Dec	2.58	2.58	0.988	0.687	0.049	0.049	0.000	-0.008	0.005	0.001	0.000	0.004
Annual	14.0	14.1	6.53	4.28	0.463	0.445	0.000	0.000	0.137	0.050	0.077	0.010

COMPARISONS (See text for descriptions):

Month	#1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#7: Actual Offstream Use vs Offstream Licences
Formula:	=(1)-(2)	=100*((1)-(2))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(8)/(2)	=100*(11)/(2)	=(4)-(11)
Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	-0.005	-0.2	-58.6	-75.6	2.27	2.0	0.2	0.041
Feb	-0.005	-0.2	-57.1	-64.6	2.41	2.2	0.2	0.050
Mar	-0.006	-0.1	-72.9	-86.6	5.33	2.3	0.1	0.122
Apr	-0.039	-0.1	-60.2	-90.6	33.7	1.4	0.1	0.444
May	-0.762	-1.2	-38.0	-53.2	60.0	1.9	1.2	0.406
Jun	-0.302	-0.8	-55.1	-61.5	36.1	2.8	0.8	0.736
Jul	-0.235	-2.0	-79.1	-93.6	10.8	8.1	1.9	0.719
Aug	-0.178	-5.9	-80.0	-91.7	2.18	28.3	5.6	0.691
Sep	-0.091	-4.0	-78.2	-93.3	1.90	17.3	3.8	0.311
Oct	-0.035	-1.1	-67.9	-77.5	3.00	3.4	1.1	0.073
Nov	-0.003	-0.1	-70.7	-87.4	3.59	1.6	0.1	0.055
Dec	-0.005	-0.2	-61.8	-73.4	2.53	1.9	0.2	0.044
Annual	-0.139	-1.0	-53.7	-69.6	13.6	3.3	1.0	0.308

Table C-2 - Kettle River above West Kettle Confluence

COMPARISONS (See text for descriptions):

DATA:													#1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#7: Actual Offstream Use vs Offstream Licences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	*Formula:*	=(2)-(1)	=100*((2)-(1))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(8)/(2)	=100*(9)/(2)	=(6)-(9)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	Net Flow	Naturalized Flow	10-yr Return Period - Monthly Net Low Flow	50-yr Return Period - Monthly Net Low Flow	Total Licensed (Offstream and Instream)	Offstream Licences	Instream Licences	Conservation - Stored Water	Total Estimated Actual Offstream Use	Estimated Actual Licensed Offstream Use	Estimated Actual Water Purveyor Use									
Month	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)		(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	4.44	4.44	2.18	1.28	0.005	0.002	0.003	-0.001	0.002	0.002	0.000		-0.002	-0.05	-50.9	-71.2	4.44	0.05	0.05	0.000
Feb	4.57	4.57	2.28	1.44	0.006	0.002	0.004	-0.001	0.002	0.002	0.000		-0.002	-0.04	-50.1	-68.5	4.56	0.04	0.04	0.000
Mar	10.5	10.5	3.28	1.18	0.012	0.004	0.008	-0.0005	0.004	0.004	0.000		-0.004	-0.04	-68.6	-88.7	10.4	0.04	0.04	0.000
Apr	44.9	44.9	19.7	7.87	0.069	0.032	0.035	0.002	0.021	0.021	0.000		-0.021	-0.05	-56.1	-82.5	44.8	0.1	0.05	0.011
May	120	120	94.6	87.1	0.367	0.269	0.093	0.005	0.138	0.138	0.000		-0.138	-0.1	-21.4	-27.6	120	0.2	0.1	0.131
Jun	97.8	98.0	47.6	24.4	0.373	0.293	0.075	0.004	0.148	0.148	0.000		-0.148	-0.2	-51.4	-75.1	97.6	0.3	0.2	0.145
Jul	30.5	30.9	9.07	3.81	0.759	0.735	0.024	-0.004	0.352	0.352	0.000		-0.352	-1.1	-70.6	-87.7	30.1	2.4	1.1	0.383
Aug	7.57	7.89	2.73	1.69	0.675	0.669	0.006	-0.003	0.320	0.320	0.000		-0.320	-4.1	-65.4	-78.6	7.21	8.5	4.1	0.349
Sep	5.51	5.66	1.65	0.725	0.313	0.309	0.004	-0.002	0.148	0.148	0.000		-0.148	-2.6	-70.8	-87.2	5.34	5.5	2.6	0.161
Oct	6.60	6.63	2.24	1.46	0.062	0.057	0.005	-0.001	0.028	0.028	0.000		-0.028	-0.4	-66.2	-78.0	6.57	0.9	0.4	0.029
Nov	7.86	7.86	2.67	1.22	0.008	0.002	0.006	-0.0004	0.002	0.002	0.000		-0.002	-0.03	-66.0	-84.5	7.85	0.03	0.03	0.000
Dec	5.50	5.50	2.29	1.65	0.006	0.002	0.004	-0.0004	0.002	0.002	0.000		-0.002	-0.04	-58.3	-70.0	5.49	0.04	0.04	0.000
Annual	28.8	28.9	15.9	11.2	0.221	0.198	0.022	0.000	0.097	0.097	0.000		-0.097	-0.3	-45.2	-61.4	28.7	0.7	0.3	0.101

Table C-3 - Kettle River at Midway International Boundary

DATA: / *COMPARISONS (See text for descriptions):*

Month	(1) Net Flow (m^3/s)	(2) Naturalized Flow (m^3/s)	(3) 10-yr Return Period - Monthly Net Low Flow (m^3/s)	(4) 50-yr Return Period - Monthly Net Low Flow (m^3/s)	(5) Total Licensed (Offstream and Instream) (m^3/s)	(6) Offstream Licences (m^3/s)	(7) Instream Licences (m^3/s)	(8) Conservation - Stored Water (m^3/s)	(9) Total Estimated Actual Offstream Use (m^3/s)	(10) Estimated Actual Licensed Offstream Use (m^3/s)	(11) Estimated Actual Water Purveyor Use (m^3/s)		#1: Naturalized flow vs Net flow (m^3/s)	#1: Naturalized flow vs Net flow (%)	#2: Naturalized flow vs 10-yr Monthly Low Flow (%)	#3: Naturalized flow vs 50-yr Monthly Low Flow (%)	#4: Total Licences vs Naturalized flow (m^3/s)	#5: Offstream Licences vs Naturalized flow (%)	#6: Actual Offstream Use vs Naturalized Flow (%)	#7: Actual Offstream Use vs Offstream Licences (m^3/s)
												Formula:	=(2)-(1)	=100*((2)-(1))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(6)/(2)	=100*(9)/(2)	=(6)-(9)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
Jan	6.87	6.89	3.11	1.83	0.197	0.194	0.003	-0.012	0.015	0.011	0.004		-0.020	-0.3	-54.8	-73.4	6.69	2.8	0.2	0.183
Feb	7.33	7.35	3.40	2.46	0.223	0.219	0.004	-0.011	0.015	0.011	0.004		-0.020	-0.3	-53.7	-66.6	7.13	3.0	0.2	0.208
Mar	16.0	16.1	4.70	1.99	0.417	0.409	0.008	-0.010	0.022	0.018	0.004		-0.030	-0.2	-70.8	-87.6	15.7	2.5	0.1	0.391
Apr	74.9	75.1	31.3	10.1	1.51	1.41	0.035	0.061	0.097	0.093	0.004		-0.130	-0.2	-58.3	-86.5	73.6	1.9	0.1	1.32
May	171	172	121	102	3.78	3.58	0.093	0.108	0.608	0.593	0.015		-1.300	-0.8	-29.8	-40.6	168	2.1	0.4	2.98
Jun	132	133	62.2	42.2	3.45	3.31	0.075	0.066	0.657	0.636	0.021		-0.890	-0.7	-53.3	-68.3	130	2.5	0.5	2.67
Jul	43.0	44.6	11.0	4.13	3.66	3.63	0.024	-0.077	1.538	1.50	0.036		-1.590	-3.6	-75.3	-90.7	41.0	8.1	3.4	2.13
Aug	11.1	12.5	3.18	1.73	3.32	3.31	0.006	-0.072	1.400	1.37	0.034		-1.410	-11	-74.5	-86.2	9.18	26.5	11.2	1.95
Sep	8.02	8.68	2.12	0.810	1.55	1.55	0.004	-0.034	0.652	0.633	0.020		-0.660	-7.6	-75.6	-90.7	7.13	17.8	7.5	0.914
Oct	9.27	9.42	3.09	2.08	0.418	0.413	0.005	-0.014	0.127	0.121	0.006		-0.150	-1.6	-67.2	-78.0	9.00	4.4	1.4	0.292
Nov	11.0	11.0	3.50	1.55	0.209	0.203	0.006	-0.009	0.014	0.011	0.003		-0.020	-0.2	-68.3	-85.9	10.8	1.8	0.1	0.192
Dec	7.67	7.69	3.07	2.17	0.196	0.192	0.004	-0.009	0.014	0.010	0.004		-0.020	-0.3	-60.1	-71.8	7.49	2.5	0.2	0.182
Annual	41.5	42.1	21.0	14.5	1.58	1.53	0.022	0.000	0.430	0.417	0.013		-0.520	-1.2	-50.2	-65.6	40.5	3.6	1.0	1.12

Table C-4 - Boundary Creek at Mouth

COMPARISONS (See text for descriptions):

	DATA:												#1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#6: Actual Offstream Use vs Offstream Licences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	*Formula:*	=(1)-(2)	=100*((1)-(2))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(6)/(2)	=100*(9)/(2)	=(6)-(10)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	Net Flow	Naturalized Flow	10-yr Return Period - Monthly Net Low Flow	50-yr Return Period - Monthly Net Low Flow	Total Licensed (Offstream and Instream)	Offstream Licences	Instream Licences	Conservation - Stored Water	Total Estimated Actual Offstream Use	Estimated Actual Licensed Offstream Use	Estimated Actual Water Purveyor Use									
Month	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)		(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	0.549	0.567	0.249	0.147	0.013	0.013	0.000	-0.013	0.018	0.013	0.005		-0.018	-3.2	-56.1	-74.2	0.554	2.3	3.1	0.000
Feb	0.581	0.599	0.270	0.195	0.013	0.013	0.000	-0.012	0.018	0.013	0.005		-0.018	-3.0	-55.0	-67.5	0.586	2.2	3.0	0.000
Mar	1.24	1.26	0.365	0.154	0.015	0.015	0.000	-0.010	0.018	0.013	0.005		-0.018	-1.4	-71.1	-87.8	1.25	1.2	1.4	0.002
Apr	10.7	10.7	4.45	1.44	0.121	0.035	0.000	0.086	0.029	0.023	0.006		-0.029	-0.3	-58.3	-86.5	10.6	0.3	0.3	0.012
May	14.8	14.9	10.4	8.84	0.311	0.191	0.000	0.120	0.121	0.098	0.023		-0.122	-0.8	-29.9	-40.6	14.6	1.3	0.8	0.093
Jun	7.58	7.72	3.56	2.42	0.268	0.206	0.000	0.062	0.140	0.106	0.034		-0.140	-1.8	-53.9	-68.7	7.45	2.7	1.8	0.100
Jul	2.54	2.85	0.651	0.244	0.487	0.487	0.000	-0.084	0.300	0.242	0.058		-0.300	-11	-77.1	-91.4	2.36	17	11	0.245
Aug	0.760	1.04	0.218	0.119	0.444	0.444	0.000	-0.078	0.276	0.221	0.055		-0.276	-27	-79.0	-88.6	0.592	43	27	0.223
Sep	0.502	0.642	0.133	0.051	0.211	0.211	0.000	-0.037	0.140	0.108	0.032		-0.140	-22	-79.4	-92.1	0.431	33	22	0.103
Oct	0.703	0.742	0.234	0.158	0.048	0.048	0.000	-0.016	0.039	0.030	0.009		-0.039	-5.2	-68.4	-78.8	0.694	6.5	5.3	0.018
Nov	0.836	0.854	0.266	0.118	0.013	0.013	0.000	-0.009	0.018	0.013	0.005		-0.018	-2.1	-68.9	-86.2	0.841	1.5	2.1	0.000
Dec	0.588	0.606	0.235	0.166	0.013	0.013	0.000	-0.010	0.018	0.013	0.005		-0.018	-3.0	-61.2	-72.5	0.593	2.1	2.9	0.000
Annual	3.44	3.54	1.76	1.17	0.163	0.141	0.000	0.000	0.094	0.074	0.020		-0.095	-2.7	-50.3	-66.9	3.37	4.0	2.7	0.066

Table C-5 - Kettle River at Grand Forks International Boundary

	DATA:												*COMPARISONS (See text for descriptions):* #1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#7: Actual Offstream Use vs Offstream Licences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	*Formula:*	=(1)-(2)	=100*((1)-(2))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(6)/(2)	=100*(9)/(2)	=(6)-(9)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	Net Flow	Naturalized Flow	10-yr Return Period - Monthly Net Low Flow	50-yr Return Period - Monthly Net Low Flow	Total Licensed (Offstream and Instream)	Offstream Licences	Instream Licences	Conservation - Stored Water	Total Estimated Actual Offstream Use	Estimated Actual Licensed Offstream Use	Estimated Actual Water Purveyor Use									
Month	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)		(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	9.38	9.45	4.25	2.50	0.230	0.227	0.003	-0.025	0.069	0.044	0.026		-0.069	-0.7	-55.0	-73.5	9.22	2.4	0.7	0.183
Feb	10.5	10.6	4.87	3.52	0.256	0.252	0.004	-0.022	0.073	0.044	0.029		-0.073	-0.7	-53.9	-66.7	10.3	2.4	0.7	0.208
Mar	21.8	21.9	6.40	2.71	0.451	0.443	0.008	-0.020	0.076	0.050	0.026		-0.076	-0.3	-70.8	-87.6	21.5	2.0	0.3	0.393
Apr	75.4	76.2	31.5	10.2	1.69	1.51	0.035	0.147	0.819	0.157	0.662		-0.819	-1.1	-58.6	-86.6	74.5	2.0	1.1	1.35
May	179	180	126	107	4.64	4.32	0.093	0.229	1.197	0.963	0.234		-1.197	-0.7	-29.8	-40.5	175	2.4	0.7	3.35
Jun	162	163	76.1	51.6	4.33	4.13	0.075	0.129	1.151	1.049	0.102		-1.151	-0.7	-53.3	-68.3	159	2.5	0.7	3.08
Jul	53.5	56.1	13.7	5.13	5.73	5.71	0.024	-0.158	2.613	2.51	0.101		-2.613	-4.7	-75.6	-90.8	50.3	10.2	4.7	3.20
Aug	15.2	17.6	4.36	2.37	5.21	5.21	0.006	-0.146	2.389	2.29	0.102		-2.389	-14	-75.2	-86.5	12.4	29.6	13.6	2.92
Sep	10.1	11.2	2.66	1.02	2.44	2.44	0.004	-0.070	1.144	1.073	0.071		-1.144	-10	-76.3	-90.9	8.80	21.7	10.2	1.36
Oct	6.46	6.70	2.15	1.45	0.604	0.599	0.005	-0.029	0.242	0.226	0.016		-0.242	-3.6	-67.9	-78.4	6.10	8.9	3.6	0.373
Nov	10.8	10.8	3.43	1.52	0.240	0.234	0.006	-0.017	0.059	0.042	0.017		-0.059	-0.5	-68.4	-86.0	10.6	2.2	0.5	0.192
Dec	9.90	9.96	3.96	2.80	0.227	0.223	0.004	-0.019	0.067	0.041	0.026		-0.067	-0.7	-60.3	-71.9	9.74	2.2	0.7	0.181
Annual	47.0	47.8	23.3	16.0	2.17	2.11	0.022	0.000	0.825	0.707	0.118		-0.825	-1.7	-51.2	-66.6	45.6	4.4	1.7	1.40

Table C-6 - Granby River at Mouth

	DATA:												***COMPARISONS (See text for descriptions):*** #1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#7: Actual Offstream Use vs Offstream Licences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	***Formula:***	=(1)-(2)	=100*((1)-(2))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(6)/(2)	=100*(9)/(2)	=(6)-(9)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	Net Flow	Naturalized Flow	10-yr Return Period - Monthly Net Low Flow	50-yr Return Period - Monthly Net Low Flow	Total Licensed (Offstream and Instream)	Offstream Licences	Instream Licences	Conservation - Stored Water	Total Estimated Actual Offstream Use	Estimated Actual Licensed Offstream Use	Estimated Actual Water Purveyor Use									
Month	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)		(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	5.04	5.04	1.84	1.36	0.022	0.022	0.000	0.000	0.002	0.002	0.000		-0.002	0.0	-63.5	-73.0	5.02	0.4	0.0	0.020
Feb	5.79	5.79	2.10	1.35	0.022	0.022	0.000	0.000	0.002	0.002	0.000		-0.002	0.0	-63.7	-76.7	5.77	0.4	0.0	0.020
Mar	17.5	17.5	4.63	0.984	0.018	0.018	0.000	0.000	0.002	0.002	0.000		-0.002	0.0	-73.5	-94.4	17.4	0.1	0.0	0.016
Apr	63.4	63.4	36.4	16.4	0.036	0.036	0.000	0.000	0.007	0.007	0.000		-0.007	0.0	-42.6	-74.1	63.3	0.1	0.0	0.029
May	123	123	91.9	82.5	0.191	0.191	0.000	0.000	0.061	0.061	0.000		-0.061	0.0	-25.4	-33.0	123	0.2	0.0	0.130
Jun	94.8	94.9	48.0	27.3	0.231	0.231	0.000	0.000	0.068	0.068	0.000		-0.068	-0.1	-49.4	-71.2	94.7	0.2	0.1	0.163
Jul	26.5	26.7	8.47	4.36	0.541	0.541	0.000	0.000	0.176	0.18	0.000		-0.176	-0.7	-68.3	-83.7	26.1	2.0	0.7	0.365
Aug	5.80	5.96	2.06	1.41	0.495	0.495	0.000	0.000	0.160	0.16	0.000		-0.160	-2.7	-65.5	-76.4	5.47	8.3	2.7	0.335
Sep	3.74	3.82	1.22	0.90	0.233	0.233	0.000	0.000	0.075	0.075	0.000		-0.075	-2.0	-68.0	-76.6	3.58	6.1	2.0	0.158
Oct	4.80	4.81	1.52	1.15	0.057	0.057	0.000	0.000	0.015	0.015	0.000		-0.015	-0.3	-68.4	-76.1	4.76	1.2	0.3	0.042
Nov	7.38	7.38	1.76	0.744	0.016	0.016	0.000	0.000	0.002	0.002	0.000		-0.002	0.0	-76.2	-89.9	7.37	0.2	0.0	0.014
Dec	5.62	5.63	2.10	1.73	0.017	0.017	0.000	0.000	0.002	0.002	0.000		-0.002	0.0	-62.7	-69.2	5.61	0.3	0.0	0.015
Annual	30.3	30.3	16.8	11.7	0.157	0.157	0.000	0.000	0.048	0.048	0.000		-0.048	-0.2	-44.5	-61.5	30.2	0.5	0.2	0.109

Table C-7 - Kettle River at Cascade International Boundary

COMPARISONS (See text for descriptions):

	DATA:												#1: Naturalized flow vs Net flow		#2: Naturalized flow vs 10-yr Monthly Low Flow	#3: Naturalized flow vs 50-yr Monthly Low Flow	#4: Total Licences vs Naturalized flow	#5: Offstream Licences vs Naturalized flow	#6: Actual Offstream Use vs Naturalized Flow	#7: Actual Offstream Use vs Offstream Licences
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	*Formula:*	=(1)-(2)	=100*((1)-(2))/(2)	=100*((3)-(2))/(2)	=100*((4)-(2))/(2)	=(2)-(5)	=100*(6)/(2)	=100*(9)/(2)	=(6)-(9)
												Remarks:	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = net flow is less than naturalized flow	neg = there is no additional surface water to licence	% of naturalized flow licensed to offstream use	% of naturalized flow actually withdrawn for use	neg = no additional room to remove water without additional licensing
	Net Flow	Naturalized Flow	10-yr Return Period - Monthly Net Low Flow	50-yr Return Period - Monthly Net Low Flow	Total Licensed (Offstream and Instream)	Other Offstream Licences	Instream Licences	Conservation - Stored Water	Total Estimated Actual Offstream Use	Estimated Actual Licensed Offstream Use	Estimated Actual Water Purveyor Use									
Month	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)		(m^3/s)	(%)	(%)	(%)	(m^3/s)	(%)	(%)	(m^3/s)
Jan	15.5	15.7	6.57	4.16	1.67	0.274	1.40	-0.025	0.191	0.071	0.120		-0.202	-1.3	-58.2	-73.5	14.1	1.7	1.2	0.203
Feb	17.7	17.9	7.61	5.33	1.89	0.299	1.59	-0.023	0.196	0.071	0.125		-0.209	-1.2	-57.5	-70.3	16.0	1.7	1.1	0.228
Mar	40.8	41.0	11.6	4.12	4.12	0.482	3.64	-0.020	0.191	0.073	0.118		-0.204	-0.5	-71.8	-90.0	36.9	1.2	0.5	0.409
Apr	162	162	76.1	28.5	16.2	1.61	14.5	0.150	0.404	0.229	0.175		-0.43	-0.3	-53.1	-82.4	146	1.0	0.2	1.38
May	329	332	237	205	34.6	4.97	29.4	0.235	1.902	1.48	0.420		-2.56	-0.8	-28.6	-38.2	297	1.5	0.6	3.49
Jun	258	260	124	79.7	28.1	4.89	23.1	0.134	2.149	1.65	0.503		-2.34	-0.9	-52.2	-69.4	232	1.9	0.8	3.24
Jul	84.7	89.7	23.5	9.99	15.5	7.55	7.97	-0.162	5.040	3.99	1.05		-4.99	-5.6	-73.8	-88.9	74.1	8.4	5.6	3.56
Aug	22.6	27.0	6.97	4.15	9.30	6.89	2.42	-0.150	4.552	3.63	0.918		-4.47	-16.5	-74.2	-84.6	17.7	25.5	16.8	3.25
Sep	14.7	16.8	4.16	2.15	4.72	3.22	1.50	-0.072	2.197	1.70	0.496		-2.18	-13.0	-75.3	-87.2	12.1	19.1	13.0	1.52
Oct	16.6	17.2	5.44	3.81	2.30	0.772	1.53	-0.030	0.553	0.357	0.196		-0.575	-3.3	-68.4	-77.9	14.9	4.5	3.2	0.415
Nov	21.7	21.9	6.32	2.76	2.21	0.268	1.95	-0.018	0.173	0.062	0.111		-0.186	-0.8	-71.1	-87.4	19.7	1.2	0.8	0.206
Dec	16.7	16.9	6.55	4.87	1.76	0.260	1.50	-0.019	0.173	0.063	0.110		-0.188	-1.1	-61.3	-71.2	15.2	1.5	1.0	0.197
Annual	83.3	84.9	43.0	29.6	10.2	2.62	7.54	0.000	1.48	1.11	0.362		-1.545	-1.8	-49.3	-65.2	74.7	3.1	1.7	1.51

D Appendix D - Fisheries Tables

Table D1 – Native and introduced fish species present in the Kettle River watershed

Common Fish Name	**Status**
Bass/Sunfish	Introduced
Black Catfish	Introduced
Bridgelip Sucker	Native
Brook Trout	Introduced
Brown Catfish	Introduced
Brown Trout	Introduced
Bull Trout	Native, Blue-listed
Burbot	Native
Carp	Introduced
Chiselmouth	Native, Blue-listed
Cutthroat Trout	Native, Blue-listed
Kokanee	Native
Lake Chub	Native
Lake Trout	Native
Largemouth Bass	Introduced
Largescale Sucker	Native
Leopard Dace	Native
Longnose Dace	Native
Longnose Sucker	Native
Mottled Sculpin	Native?
Mountain Whitefish	Native
Northern Pikeminnow	Native
Peamouth Chub	Native
Prickly Sculpin	Native
Pumpkinseed	Introduced
Rainbow Trout	Native
Redside Shiner	Native
Yellow Sculpin	Native
Shorthead Sculpin	Native, Blue-listed
Slimy Sculpin	Native
Smallmouth Bass	Introduced

Table D1 – continued.

Common Fish Name	Status
Speckled Dace	Native, Red-listed
Tench	Introduced
Torrent Sculpin	Native
Umatilla Dace	Native, Red-listed
Walleye	Native
Western Brook Lamprey	Native
Westslope (Yellowstone) Cutthroat Trout	Native, Blue-listed
Yellow Perch	Native

Table D2 – Fish Stocking History.

Watercourse	Date Range	No. of stocking events	Species
Arlington Lakes	1931-1951	11	Longnose sucker, Perch, Rainbow Trout, Redside Shiner
Bear Paw Lake	1985-2010	23	Rainbow Trout
Bisson Lake	1966-2010	23	Rainbow Trout
Boundary Creek	1932-1952	6	Rainbow Trout, Westslope (Yellowstone) Cutthroat Trout
Buck Lake	1939-2011	47	Rainbow Trout
Christina Lake	1901-1963	50	Bass/Sunfish, Kokanee, Rainbow Trout
Clark Lake	1939-1975	11	Rainbow Trout
Collier Lake	1935-1911	49	Rainbow Trout
Conkle Lake	1931-2011	52	Rainbow Trout
Copperkettle Lake	1963-1985	16	Rainbow Trout
Cup Lake	1971-2011	41	Rainbow Trout
Davis Lake	1930-1975	18	Rainbow Trout, Brook Trout
Fluorine Lake	1974-2010	26	Rainbow Trout
Granby River	1930-1952	15	Rainbow Trout
Hoodoo Lake	1962-2011	44	Rainbow Trout
Idabel Lake	1937-2011	32	Rainbow Trout, Brook Trout
Idleback Lake	1969-2011	43	Rainbow Trout

Table D2 – continued

Watercourse	Date Range	No. of stocking events	Species
Jewel Lake	1925-2011	123	Rainbow Trout, Brook Trout, Brown Trout
Kettle River	1914-2000	73	Rainbow Trout, Brook Trout
Lassie Lake	1952-2011	47	Rainbow Trout
Little Fish Lake	1953	1	Rainbow Trout
Little Sandrift Lake	1979-2001	3	Rainbow Trout
Loch Larsen	1977-2010	27	Rainbow Trout
Maloney Lake	1952-1954	3	Rainbow Trout
Martin Lake	1941-1975	21	Rainbow Trout, Brook Trout
Matthews Lake	1940-1989	24	Rainbow Trout, Brook Trout
McIntyre Lake	1976-2011	21	Brook Trout
Mc Rae Lake	1938-1939	2	Kokanee
Myers Lake	1940-1958	5	Rainbow Trout, Brook Trout
Nevertouch Lake	1962-2011	49	Rainbow Trout
Pass Creek	1951	14	Rainbow Trout, Brook Trout
Reith Lake	1994	1	Westslope Cutthroat Trout
Rock Creek	1938-1952	8	Rainbow Trout, Cutthroat Trout
Sandner Creek	1935-1939	4	Kokanee
Sandrift Lake	1973-2011	36	Rainbow Trout
South Sandrift Lake	1979-2011	32	Rainbow Trout

Table D2 – continued

Watercourse	Date Range	No. of stocking events	Species
State Lake	1936-1985	21	Rainbow Trout
Stump Lake	1963-1968	4	Rainbow Trout, Western Brook Lamprey
Taurus Lake	1980-2011	40	Rainbow Trout
Thone Lake	1967-2011	43	Rainbow Trout
Tuzo Lake	1994-2011	16	Rainbow Trout
Upper Collier Lake	1962-2011	39	Rainbow Trout
Wallace Lake	1932-1951	5	Rainbow Trout
West Kettle River	1994-2000	7	Rainbow Trout
Wilgress Lake	1935-2011	100	Rainbow Trout, Brook Trout
Wilkinson Lake	1947-1951	2	Rainbow Trout, lake Trout
Williamson Lake	1909-2011	53	Rainbow Trout
Wolff Creek	1939-1943	2	Rainbow Trout
Xenia Lake	1947-2011	56	Rainbow Trout

E

Appendix E - EMS Water Quality Sites

Table E1 - Water quality monitoring sites with more than 10 sampling dates.

EMS ID	NAME	DESCRIPTION	Number of samples	First collect. start date	Latest collect. start date	Latitude (deg-min-sec)	Longitude (deg-min-sec)
KETTLE RIVER							
920673	Kettle River; at Carson	Carson Road Bridge 5km SW of Grand Forks; NAQUADAT Station OOBC08NN0021	3,001	08-Jan-80	On-going	49.00.00	118.28.54
	Kettle River at Midway	Highway bridge 0.5 km north of U.S. border. Sampled from upstream side of bridge.BC08NN0011	>3,000	10 Sept-79	On-going	49.005	118.78
E228518	Kettle River D/S Midway Sewage Treatment Plant		20	29-Sep-97	29-Nov-10	49.00.01	118.46.13
BOUNDARY CREEK							
200501	Boundary C D/S Greenwood Stp (Pe04113)	Adjacent To Entrance To Provincial Campground Two Miles South Of Greenwood	128	23-Sep-75		49.0586	118.6933
200500	Boundary C U/S Greenwood Stp (Pe04113)	Upstream Bridge In Greenwood City Park	117	23-Sep-75		49.0956	118.6775
E219612	Boundary Hospital - 7649 - 22nd St. Grand For		10	26-Sep-95			
GRANBY RIVER							
200082	Granby R. Near Mouth @ Grand Forks	At Grand Forks Above BC Hwy 3 Bridge, 0.25 Mile Above Confluence With Kettle River, River Mile 0.3	9	12-Aug-92	12-Aug-92	49.0347	118.435

Table E1 cont'd - Water quality monitoring sites with more than 10 sampling dates.

EMS ID	NAME	DESCRIPTION	Number of samples	First collect. start date	Latest collect. start date	Latitude (deg-min-sec)	Longitude (deg-min-sec)
WEST KETTLE RIVER							
500777	West Kettle R U/S Teck Tailing Pond-Pe00444	On West Side About 20m U/S Of New Tailings Pond. Access From Road Between East Berm And River Bank.	49	30-Sep-80	25-May-94	49.4431	119.0906
500778	West Kettle R D/S Teck Tailing Pond-Pe00444	On West Side About 80m D/S New Tailings Pond And 200 M U/S Road Bridge.	22	27-Apr-81	14-Mar-88	49.435	119.0914
CHRISTINA LAKE							
E215758	Christina Lake North Basin Deep Centre	centre of north basin at deepest point	1,042	11-Apr-91	15-Jun-11	49.137133	118.260631
E246191	Christina Lake #16 @ Trapper Creek	Littoral zone used by Christina Lake Stewardship Society for periphyton and water chemistry	28	22-Aug-00	23-Aug-06	49.165916	118.269721
E215960	Christina Lake North Of D'appolonia's Dock	1634a West Lake Rd	23	20-Jun-91	28-Oct-92	49.043739	118.222402
E215959	Christina Lake North End Of Dr. Merry's Dock	1955 Tambellini	22	20-Jun-91	28-Oct-92	49.158045	118.221304
E246192	Christina Lake #17 @ Treadmill Creek	Littoral zone used by Christina Lake Stewardship Society for periphyton and water chemistry	18	22-Aug-00	23-Aug-06	49.156326	118.281588
E246186	Christina Lake #11 @ Tambellini Residence	Sample at West Lake drive, cove by Dupee (Clifton's pnt) Littoral zone used by Christina Lake Stewardship Society for periphyton and water chemistry	16	22-Aug-00	23-Aug-06	49.056696	118.234969

Table E1 cont'd - Water quality monitoring sites with more than 10 sampling dates.

EMS ID	NAME	DESCRIPTION	Number of samples	First collect. start date	Latest collect. start date	Latitude (deg-min-sec)	Longitude (deg-min-sec)
E246104	Christina Lake #5 @ South End Of English Cove	Sample between Howard and Kempston properties. Sample area along shoreline corner of Br. Rd. Littoral zone used by Christina Lake Stewardship Society for periphyton and water chemistry	16	22-Aug-00	23-Aug-06	49.097963	118.221424
E249792	Christina Lake @ Lyon's (Alpine Area)	shallow water chemistry and periphyton site sampled by stewardship society	11	21-Aug-02	21-Aug-02	49.0998	118.237
ROCK CREEK							
E246723	ROCK CREEK LANDFILL - BACKGROUND WELL - MW1		16	11-Jan-01		49.3864	119.0971
SUTHERLAND CREEK							
E232365	SUTHERLAND CREEK AT FIFE DIVERSION CWS	Christina Lk cws	117	11-Jun-98	18-Jul-01	49.0761	118.1664
E220681	SUTHERLAND CREEK AT SUTHERLAND INTAKE	just upstream of Sutherland waterworks intake	162	11-Jun-98	18-Jul-01	49.060467	118.207421
GOOSMUS CREEK							
E266384	GOOSMUS CREEK 100M DOWNSTREAM LEXINGTON PORTAL		56	26-Jul-06	01-Nov-09	49.008056	118.615008
E266382	GOOSMUS CREEK UPS LEXINGTON PORTAL	100 metres upstream Lexington Mine portal	24	26-Jul-06	09-Oct-07	49.0106	118.6158

Table E1 cont'd - Water quality monitoring sites with more than 10 sampling dates.

EMS ID	NAME	DESCRIPTION	Number of samples	First collect. start date	Latest collect. start date	Latitude (deg-min-sec)	Longitude (deg-min-sec)
E269143	GOOSMUS CREEK UPSTREAM#2 LEXINGTON PORTAL		34	21-Sep-07	01-Nov-09	49.01175	118.61572
JULY CREEK							
E240863	JULY CREEK DNS STACEY CREEK - KETTLE R DRAINAGE		32	08-Mar-00	02-Oct-01	49.0017	118.5375
E241165	JULY CREEK UPS SKEFF CREEK - KETTLE R DRAINAGE		26	11-Apr-00	02-Oct-01	49.0664	118.5486
MOODY CREEK							
E232323	MOODY CREEK AT UPPER SITE - KETTLE R DRAINAGE		102	11-Jun-98	18-Jul-01	49.0499	118.2707
E232324	MOODY CREEK AT DIVERSION CWS - KETTLE R DRAINAGE		166	11-Jun-98	18-Jul-01	49.0334	118.2217
BURRELL CREEK							
E207458	BURRELL CREEK D/S SUMAC GRAND FORKS	Sample Creek at 19.5 km on Burrell Creek Main Logging Road	14	27-Apr-88	18-Jun-97	49.4475	118.4131
FISHERMAN CREEK							
E241282	FISHERMAN CREEK AT LOWER CROSSING ON PHOENIX RD	800 metres west of Highway 3 - kettle r drainage	17	11-Apr-00	02-Oct-01	49.1071	118.5375

Table E1 cont'd - Water quality monitoring sites with more than 10 sampling dates.

EMS ID	NAME	DESCRIPTION	Number of samples	First collect. start date	Latest collect. start date	Latitude (deg-min-sec)	Longitude (deg-min-sec)
GIBBS CREEK							
E241166	GIBBS CREEK UPS JULY CREEK	Gibbs Creek at first road crossing upstream July Creek	20	11-Apr-00	02-Oct-01	49.0105	118.5503
MAY CREEK							
E241167	MAY CREEK U/S JULY CREEK		19	11-Apr-00	02-Oct-01	49.0211	118.5477
MYERS CREEK							
E236795	MYERS CREEK AT US BORDER - KETTLE R DRAINAGE	4 miles south from Rock Creek, B.C.; sampled 75 feet north from the US Border. This is a former federal-provincial station. Same location as ENVIRODAT station # BC08NN0030.	630	05-Feb-98	13-Sep-04	49.0003	119.0193
SKEFF CREEK							
E241168	SKEFF CREEK U/S JULY CREEK - KETTLE R DRAINAGE	Skeff Creek at first road crossing upstream July Creek	16	11-Apr-00	02-Oct-01	49.0559	118.5522
SNOWSHOE CREEK							
E241169	SNOWSHOE CREEK U/S JULY CREEK - KETTLE R DRAINAGE	Snowshoe Creek ups July Creek (ephemeral drainage?) and above marsh area along highway 3	43	11-Apr-00	01-Nov-09	49.0865	118.5481