SUSTAINING THE FLOW: MANAGING WATER SUPPLY AND DEMAND TO SUPPORT ECOSYSTEM HEALTH AND COMMUNITY NEEDS

DISCUSSION PAPER THREE – JULY 23, 2014

Regional District of Kootenay Boundary

Kettle River Watershed Management Plan

The Kettle River Starts Here

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1 Introduction

The Regional District of Kootenay Boundary (RDKB) is developing a watershed management plan for the Kettle River in British Columbia. The Kettle River Watershed Management Plan (KRWMP) is a collaborative initiative supported by a Stakeholder Advisory Group (Advisory Group) with participation from local and provincial governments and representatives from multiple sectors and organizations from across the region.

This discussion paper is the third of five papers presenting strategies and actions to be included in the Watershed Management Plan, which will be finalized in the summer of 2014. The Advisory Group invites a broader network of stakeholders and public to consider the issues, strategies and actions presented in these discussion papers and provide feedback towards the Watershed Management Plan.

Discussion Paper 1 proposed three overall goals with nine sub-goals in support of aquatic ecosystems, healthy communities, and sustainable economy and food system. It proposed several strategies to be developed in the KRWMP [38], one of which is to "Improve the quality, reliability and security of water supplies through sustainable management of water resources." Water supplies are also tightly linked to the integrity of riparian, wetland and upland systems (Discussion Paper 5, forthcoming) and the capacity of the community to plan for and adapt to watershed issues (Discussion Paper 2 [41]).

Conserving water to sustain human needs and ensure the health of fish and aquatic ecosystems is a central challenge in the Kettle River watershed. By carefully managing water quantity, our communities will be able to improve water security during drought, reduce infrastructure and water treatment costs, and improve overall stewardship of the watershed. Learning how to conserve water and adopting appropriate strategies will build our ability to reduce greenhouse gas emissions and adapt to the impacts of climate change.

Some people in our communities have identified the need to increase water security by developing water storage. This could be in the form of large or small dams, groundwater storage, or soil improvement, depending on the site. But each option is not without costs or risks, and we will need to carefully evaluate needs and options for water storage before expanding.

This discussion paper identifies issues related to surface water quantity and water use. It provides preliminary analyses of low flow trends and scenarios of future water use (Appendix A); reviews the "water soft path" approach to water supply (Section 3.2); and proposes strategies and actions related to water conservation, water storage and environmental water needs (Section 4).

These strategies and actions are to be considered *draft* until the Advisory Group reviews and incorporates feedback from involved stakeholder groups. The final plan will be reviewed and endorsed by the Advisory Group as recommendations to the RDKB, other authorities having jurisdiction over land and water, and individual businesses, landowners and residents.

2 KEY CHALLENGES

Access to water and the services it provides is vital for people and for nature, particularly in basins with insufficient or unreliable water supplies. However, water is often undervalued and perceived as limitless. This poses particular challenges in areas that experience drought or have strong environmental limitations on water withdrawals. Within these constraints, our communities face risks to drinking water, increasing conflicts among water users, diminishing economic opportunities, and declining aquatic ecosystem health.

The Advisory Group and members of the public have identified a number of challenges to meeting water supply and environmental needs in the Kettle River, including high water use, climate change, lack of effective regulation and governance, and land management practices. Central challenges related to water supply and demand and impacts on aquatic ecosystems are discussed below.

2.1 Water use, groundwater, and climate change

Communities in the Boundary Region have high water use relative to other communities in the region and province [6]. Excessive water consumption was identified as a top priority by respondents in a survey across the watershed in 2012, and people are highly concerned that there is not enough water to support current and future uses [40].

The effect of water use on river flows can be reported as the difference between *net flows* (the amount of water measured in the river) and *naturalized flows* (estimates of the amount of water that would be in the river without diversions, storage, and water use)[30]. Currently, average annual net flow in the Kettle River main stem at Laurier, Washington is 2% less than annual naturalized flow. In the highest demand months in average years, net flows are 16-17% lower than naturalized flows.

In dry years, net flows are 76-90% lower than the monthly naturalized flow, and estimated water use is greater than the monthly net low flow [30]. This means that during late summer in dry years water use can substantially reduce water flowing in the Kettle River (Figure 1).

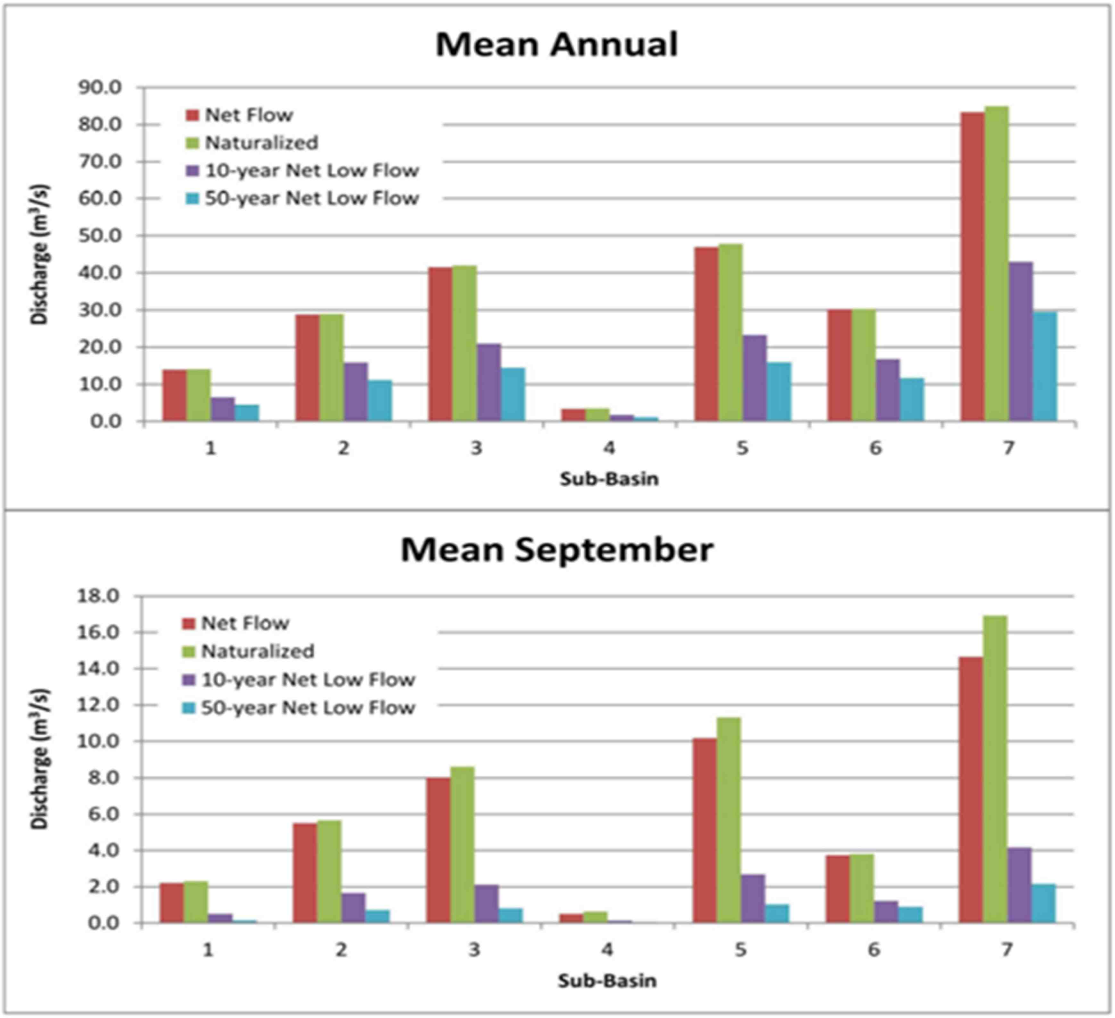

Figure 1. Mean annual and mean September net flow and naturalized flow across sub-basins of the Kettle River watershed (1. West Kettle, 2. Kettle River to Westbridge, 3. Kettle River to Midway, 4. Boundary Creek, 5. Kettle River to Carson, 6. Granby River, 7. Kettle River to Cascade). The amount of water flowing in a 1:50 year net low flow (2 m^3/s) is similar to the difference between net flow and naturalized flow (Figure 2-1 from Phase 1 Report [30]).

Because much of the water use is from aquifers, low river flows may be buffered from groundwater extraction depending on well depth, aquifer material, and distance to the river [30,42]. However, the region’s high-demand aquifers are closely connected to surface water, which means that high groundwater withdrawals worsen low flow conditions (Figure 2).

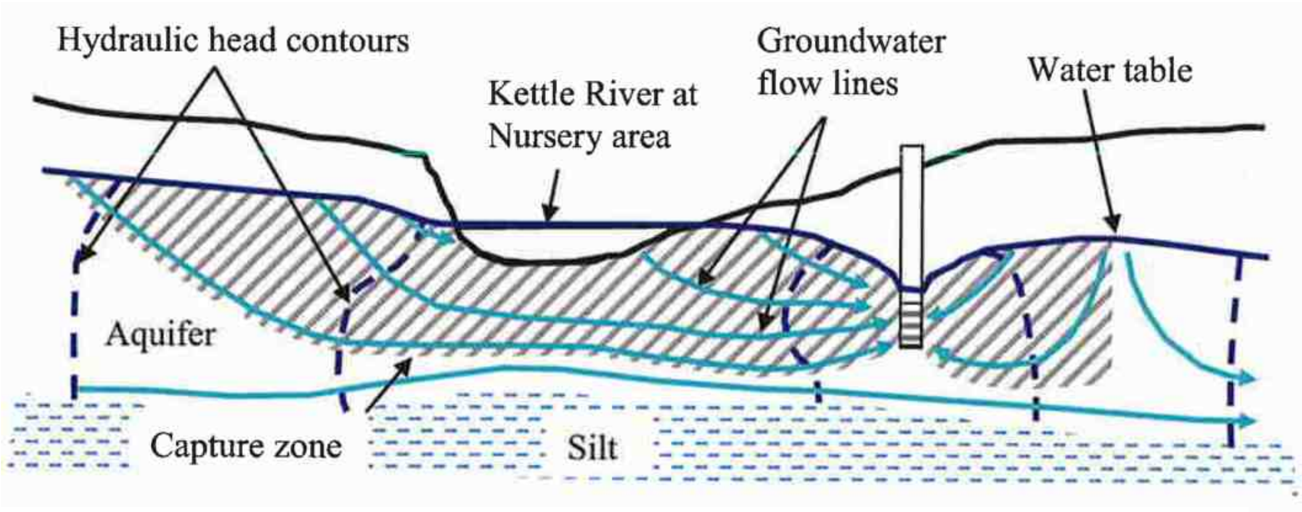

Figure 2. Schematic cross-section (looking north) at the Nursery area, showing the Grand Forks Irrigation District Nursery well pumping and capturing water from the Kettle River and some groundwater from the other side of the Kettle River (from Wei and others [42]).

The aquifers in the Kettle River watershed are recharged in various ways. The most important is infiltration from streams and rivers where they flow across sand and gravel deposits. The aquifers are connected to the Kettle River, as shown by the matching rise and fall of river and groundwater levels. During spring freshet, between 11-20% of flow in the Kettle River is transferred to groundwater in the Grand Forks Aquifer, some of which returns to the river later in the season as baseflow and some of which is lost to surface uses. However, there is no significantly decreasing or increasing trend over the monitoring period at observation wells in Grand Forks or Beaverdell [30].

Currently, water users may be able to switch to groundwater when surface water becomes unreliable or unavailable [30], making effective regulation of surface and groundwater difficult until effective, meaningful, and locally-informed legislation and policies are in place. Groundwater regulations under the new Water Sustainability Act are expected to enable groundwater in the same manner as surface water, but it may take considerable time and study to determine how to implement regulations on an aquifer by aquifer basis.

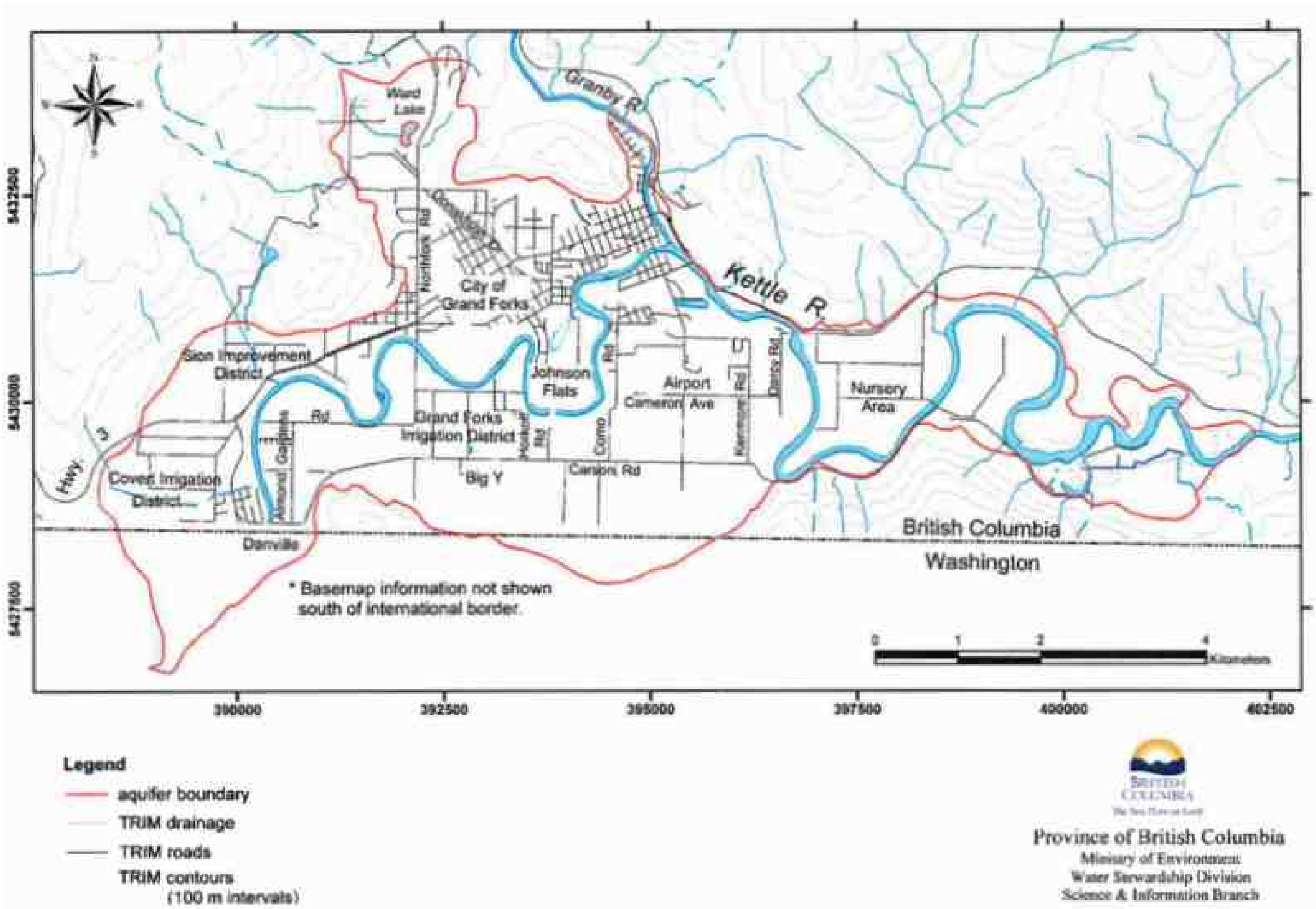

Figure 3. Extent of the Grand Forks Aquifer. Reproduced from Figure 2 in Wei and others [42].

Historical low flow trends. The Phase 1 Report evaluated hydrometric records for trends in river discharge over time using monthly means. It found no statistically significant trend from 1929-2010, and a slight downward trend from 1981-2010 [30]. However, shorter periods of low flow (i.e. 3 or 7 days) are much more meaningful to floaters, fish, and the aquatic ecosystem, and are useful indicators of changes in streamflow due to climate change, water use, or dam and reservoir development [22,27].

A new analysis of flow data for Laurier, Washington showed a small but meaningful downward trend in the volume of water flowing during three day and seven day low flows for the entire period of record (1929-2012) and from 1980-2012 (Appendix A.1).

2.2 Impacts on fisheries & aquatic ecosystems

Low river flows affect many aspects of life in the Boundary, including the aquatic ecosystem, recreation, and water quality and availability. Dry periods are especially challenging for fish. The decline towards low flows in the late summer can happen very quickly. In 2003, for instance, Kettle River flows at Laurier, Washington were above normal in the spring. Then flows declined within a few weeks to well below normal, low enough to cause significant harm to fish and fish habitat [44].

A recent government study found that the greatest constraint for trout in the Kettle River is the lack of refuge habitat during high temperatures and low flows in mid- to late-summer [8,44]. Fish habitat availability and quality are good at 20% of the mean annual discharge (MAD) but decline rapidly below 10%, with serious harm to fish populations occurring at 5% of MAD (Figure 4). Furthermore, water temperatures of 19-26°C can also harm or kill trout – during low flows from late July into August the Kettle River frequently gets above 22°C and occasionally above 25°C [30].

Human impacts on fish and aquatic ecosystems go beyond water use and low flows. Damage to riparian areas directly impacts fish habitat, and indirectly impacts flows by decreasing water storage in banks and floodplains [18]. Disturbance such as roads, forest harvesting and agriculture can decrease natural water storage, increase flooding, and increase erosion and sedimentation. This impacts fish habitat and causes streams and rivers to further erode their banks [21]. Related issues and strategies related to water quality issues are discussed in Discussion Paper 4, and riparian areas, wetlands and floodplain management are developed further in Discussion Paper 5 (forthcoming).

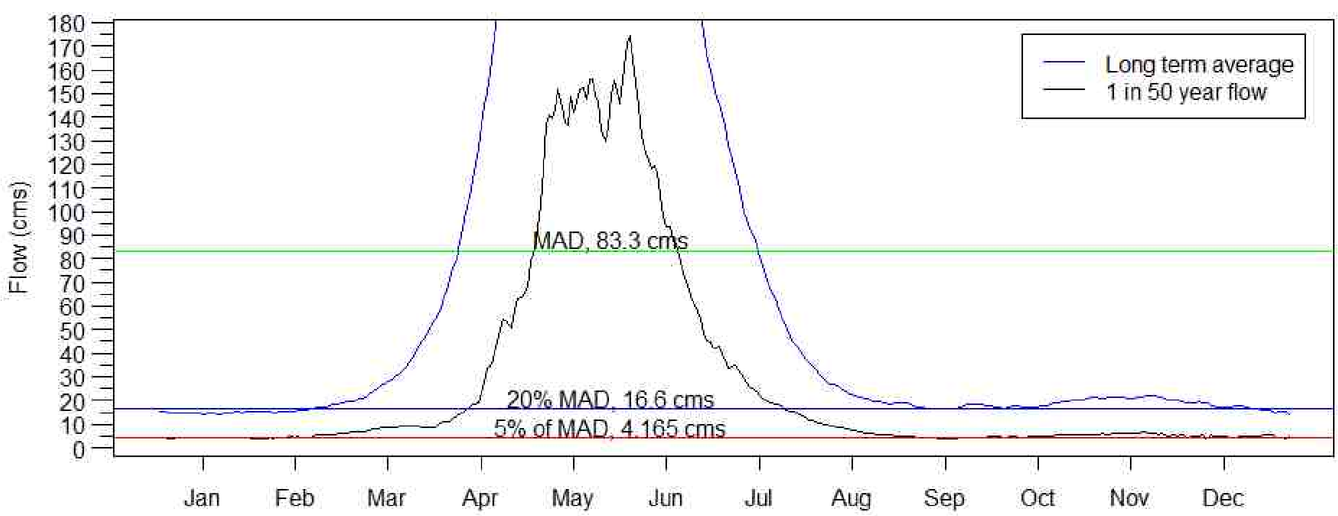

Figure 4. Mean and 1 in 50 year daily flows (cubic metres/second) for the Kettle River at Laurier, Wa, with Mean Annual Discharge, 20% and 5% MAD referenced.[1] Graph truncated to focus on low flows.

[1] Caution should be used when extrapolating findings from the FLNRO fish habitat study about effects at different % MAD as they may not be applicable to all sections of the Kettle River and tributaries [30].

2.3 Future Water Demand

Climate change is expected to place further pressure on water resources due to higher temperatures, earlier spring freshets and longer growing seasons with less precipitation [19,30]. According to a report about climate change effects on agricultural water use in the region, there could be at least 10-25% increased water demand from agriculture by 2050 due in part to greater evapotranspiration and longer growing seasons [9].

Future water use scenarios. Based on an agricultural water demand model developed for the region [9] and population trends [2], we developed scenarios of the potential effect of water use on flows in the Kettle River in future (40 year) scenarios of agricultural expansion, population growth, and economic development (full details in Appendix A.2). We calculated coarse estimates of water demand by agriculture, water works, and other uses based on current water licence and use information, then evaluated scenarios based on the following potential future conditions:

- Increased agricultural water demand associated with two agricultural land use (current and build-out) and climate change (average 2050s dry year and extreme 2050s dry year)
- Annual population growth of 0%, 0.34%, 0.68%, and 1.68%
- Other water demand (i.e. mining) increase of 1% and 2%

On an annual basis, if population growth is low, agricultural growth is limited and water conservation is widespread in agriculture, there could be a relatively low increase in water demand (4%). Moderate growth with increasing agriculture could expand water demand by 67%, and extreme climate change and rapid growth could increase water demand by 116%, up to about 4% of the annual flow.

Because irrigation use (including garden and landscaping) occurs in summer, increases in future water demand will have a stronger effect on river flows in summer months, when flows are naturally less. Under moderate and extreme growth scenarios, summer water use could rapidly reduce water in the Kettle River to critically low levels in 1 in 10 and 1 and 50 year low flows (Figure 5 and Appendix A.2). Even in average flow years there could be over 16 days with poor flow conditions (5-10 m^3/s) in an extreme growth & climate scenario.

These scenarios provide an illustration of what could happen if water demands grow in the coming decades without implementing effective water conservation, water regulations, or storage strategies. Impacts on fish (i.e. Section 2.2), aquatic ecosystems, water quality, water supply and quality of life would be unacceptable. The key challenge is to design and implement strategies to sustain the flow of water in the Kettle River using a balance of conservation, regulations and/or storage that avoids unacceptable tradeoffs and provides a range of benefits for human and natural communities in the region (Section 3).

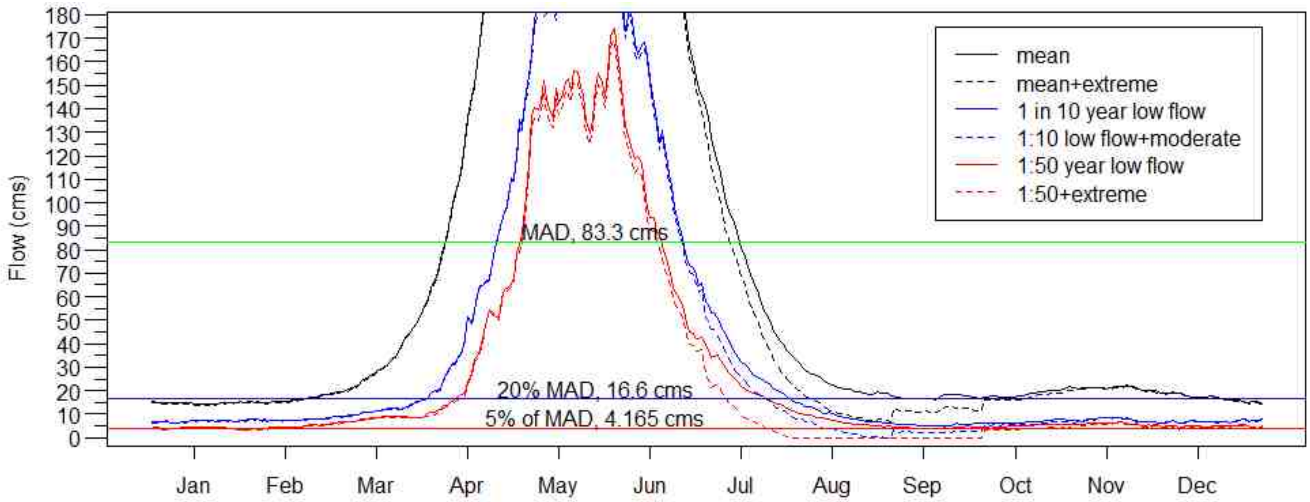

Figure 5. Potential impact of water use scenarios on low flows. Daily mean flow, 1:10 year low flows and 1:50 year low flows reduced by monthly-adjusted water use from extreme, moderate and extreme scenarios, respectively. Graph truncated to focus on low flows.

3 Priorities and Strategies to Sustain the Flow

3.1 Priority uses of water

Discussion Paper 1 introduced several goals and sub-goals that directly relate to water quantity and water conservation. In addition, goals for capacity and understanding, watershed function, and recreation & cultural values also affect water supplies, and will need to be considered in strategies to conserve water and protect aquatic ecosystems.

Participants at a special meeting of the Advisory Group in March, 2014 identified priority uses of water as part of a larger discussion about how to 'sustain the flow':

1. Ecosystem health[2]
2. Agriculture & food production
3. Household & domestic
4. Industry, mining and forestry
5. Recreation & amenity values

[2] Healthy ecosystems provide benefits (goods and services) to people, which support all the uses of water listed here as well as wild foods, water purification, flood control and other benefits [29].

Participants also emphasized other considerations, including: finding ways to encourage 'wise management' of water resources; that the use of water does not compromise quality; that there are no further inter-basin transfers or diversions; that water licensing encourages and prioritizes efficient uses of water; and that a local authority in water management should set the overall priorities.

Determining how much water is needed in the river to sustain fish and aquatic ecosystems, or environmental flow needs (EFN), is recognized as the foundation of sustainable water management [10,15]. Environmental Flow Needs are a set of quantitative measures describing the quantity, timing, and quality of water flows or levels required to sustain the aquatic ecosystem and human communities that depend on these ecosystems.

The functions and benefits of healthy rivers also include aquifer recharge, sufficient water to cover water intakes and outfalls, waste assimilation from point source and non-point source pollution,[3] hydropower requirements, and navigation and recreation (including tubing) [14]. Thus analysing environmental flow needs goes beyond minimum flows to include the natural patterns in magnitude, timing, frequency, duration, variability, and rate of change.

A multi-year study by the BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO) aimed to identify the flow needs for rainbow trout in the Kettle River in order to: a) set thresholds for regulation and closure of the fishery; b) determine minimum stream flow requirements and targets for protection of fish stocks; and c) specify management strategies to protect fish and fish habitat during critical low flow periods [8,44]. Proposed management strategies are discussed further in Section 3.3.2.

3.2 A Softer Path to Sustaining Flows[4]

Typical responses to water supply challenges fall into two broad categories. "Supply-side" management seeks to improve reliability by storing water and improving conveyance and treatment infrastructure to meet water demand. The emphasis is on centralized decision-making, building dams, reservoirs, and treatment plants, with potable water delivered and wastewater treatment taken away for treatment. "Demand-side" water management seeks to help communities lower their water needs and relieve pressure on water supplies by promoting conservation through tools such as marketing, education, pricing and incentives.

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[3] Point source pollution comes from a discrete location such as a wastewater outfall. Non-point source pollution comes from many diffuse sources and enters water bodies via runoff and infiltration or atmospheric deposition [35].

[4] Adapted from November 2013 Kettle River Q&A column, "Thinking outside the box" [37].

These approaches tend to focus on *how* we deliver more clean water or improve conservation to get more out of each drop. However, a third approach, known as the "water soft path," focuses more on *why,* blending appropriate tools from demand-side and supply-side water management [3].

For instance, a demand-side approach to wastewater could be to reduce consumption by switching to low-flow toilets. The soft path approach would look first at the service need, and then ask why we use water to carry away our waste then put partly treated water back to surface water, when there are viable alternatives such as composting toilets, waterless systems, or on-site treatment.

Or it might go beyond promoting efficient landscape irrigation to develop policy and plumbing and health codes to enable recycling bathtub and washing machine water, bringing in localized supply-side tools. This approach addresses the soft path principle of matching the quality of water delivered to that needed by the end use. For instance, the Town of Oliver improved the quality of water for rural domestic uses by installing a new well, reservoir and parallel delivery system, which avoided treatment costs for water that was unsafe for drinking water but good enough for most agricultural uses [32].

Another principle of the soft path is that more good quality water needs to be left in streams and aquifers to provide for aquatic ecosystems and provide resilience to future drought – ecosystems are seen as legitimate users of freshwater and as the foundation of our economy. This principle is related to the established practices of setting objectives for environmental water requirements or conditions on the quality of water returned to nature [5].

The key to the water soft path is the integration of existing tools from supply and demand-side management with new, holistic thinking about watersheds and ecosystems. Sometimes the ideas may challenge current policies, as with greywater systems, but the new approaches often provide resilient solutions for the new challenges of climate change mitigation and adaptation alongside existing challenges of water security and the expense of infrastructure.

3.3 Key Strategies

Achieving these goals will require considerable effort and collaboration by local governments, residents and stakeholders of the Kettle River watershed who use and value these waters, and the senior levels of government who are responsible for water allocation, licensing, fisheries, and resource management [41]. It will also require careful consideration of a range of strategies, with further studies required to establish the suitability, risks, and feasibility of major projects before proceeding.

Building on Discussion Papers 1 [38] and 2 [41], this section discusses three major strategies and identifies objectives, management directions and actions to improve the reliability of water supplies in the Kettle River watershed. The first strategy is to **build support, understanding and capacity** through public engagement, policy development, scientific studies, education and capacity-building. The second strategy is **to reduce water demand through broad scale water conservation and soft path approaches** (Appendix B), and to prepare for droughts with **comprehensive drought management planning**. The third strategy is to examine and implement methods to **increase water storage capacity,** through traditional approaches of small dams or larger reservoirs, as well as approaches that restore and improve watershed health and function using permanent vegetation cover, soil organic matter, natural water storage, and riparian and wetland ecosystems.

These strategies are itemized with suggested actions for discussion in Section 4.4. Three aspects will have special consideration here to reflect discussions of the Advisory Group: 1) means of moving towards a culture of water conservation; 2) measures under consideration by FLNRO to protect fish stocks in the Kettle River; and 3) purposes and limitations on water storage.

3.3.1 Develop a culture of water conservation

High levels of water use per capita and perceptions that the water supply is limitless or 'ours to use' are major barriers to improving water conservation [39]. The Advisory Group and participants at the March 2014 Special Meeting discussed several ways to shift attitudes about water use, embrace innovations in water conservation, and achieve better community stewardship of water supplies.

Participants identified the need to **increase public awareness of water issues** through educational programs that help make the connection between high water use and low river levels. For instance, a regular water use advisory could be published in the summer, and the ongoing column on water issues (Kettle River Q&A) could highlight water use priorities and conservation needs.

Research on environmental attitudes, belief and behaviour supports identifying and removing barriers to behaviour change rather than simply increasing awareness. For instance, Doug McKenzie-Mohr and others have established methods for *community-based social marketing* that motivate social change towards sustainable behaviour [16]. Typical strategies include: a) inviting a commitment to try an action or behaviour; b) prompting to keeping the commitment; c) developing and reinforcing cultural norms about sustainable behaviour; d) diffusing norms and behaviours through social networks; e) deploying effective communication methods; f) providing incentives or disincentives (rewards and prices); and g) increasing the convenience of the desired behaviour by removing barriers.

Participants at the special meeting also recommended **promoting practical measures to conserve water** for households, farms, and other users through workshops, tools, incentives, and supporting policies to increase adoption of methods such as rain barrels, drip irrigation, xeriscaping (dryland landscaping) and building soil organic matter.

Water conservation and more efficient water use could provide significant savings. For instance, the agricultural water demand model estimated an 11% reduction in demand with a) conversion of sprinkler systems to drip systems for horticultural crops and b) conversion of larger forage fields to pivot systems [9]. Additional savings could be achieved by targeting irrigation efficiency on smaller farms and promoting the adoption of dryland agriculture strategies.

Water conservation planning in urban areas could create even more significant savings. BC's 'Living Water Smart' plan identified targets for 50% of new water needs met by conservation and 33% increase in water use efficiency [23]. The water conservation plan for the City of Grand Forks adopted this target as a 33% reduction in residential water demand [13], and has assumed a 20% 'water conservation reduction factor' in their long-term water supply planning [34]. Simply limiting lawn watering in summer months would have a major impact on water demand.

Stakeholders and participants have identified the need to **more consistently regulate water use** across the watershed to reduce water consumption and help communities prepare to respond to drought and low river flows. Participants recommended further work on the regulation of surface and ground water licences, metering and pricing water, and celebrating effective water conservation by individuals and communities. Planning for and responding to droughts was also emphasized.

BC's Water Sustainability Act received Royal Assent on May 29, 2014 and is expected to come into force in spring of 2015 once supporting regulations are completed [24,25]. Among other things, the new Act enables groundwater licensing and protection of environmental flows, which could foster real advances in water conservation.

The Phase 1 Report recommended that detailed hydrogeological analyses be carried out on any new large capacity wells to delineate the capture zone, determine effects on other wells, and evaluate impacts on surface flow [30]. Under current regulations under the *Water Act* and the B.C. *Environmental Assessment Act*, an authorization or review is only triggered for wells drawing greater than 75 litres / second (4.5 m^3/minute). However, this threshold should be re-examined for aquifers in the Kettle River watershed with regard to seasonal low river flows and cumulative effects of groundwater withdrawals.

3.3.2 Implement measures to protect fish

Because of the impacts of low flows to fish, FLRNO is considering changes to fisheries, water use and forestry regulations [8,20,44]. Some of the ideas have included supporting water conservation measures, restricting water use during low flows, developing off-stream storage, regulating groundwater use, and changing fisheries regulations to include in-season closures and 'catch and release' only. Several of these ideas were presented to the Advisory Group in November, 2013 [44] and are summarized and discussed below.

- Designate watershed as fully recorded. This means that there would be no further licences for surface water, except where supported by storage from spring freshet. It is difficult to determine the effects on groundwater licencing until new regulations are developed and implemented.
- Regulate water use (unstaged and staged). During low flows, a staged (i.e. tiered) or unstaged (abrupt) approach would be considered.
    - The unstaged approach simply means cutting off junior licences or lower priority uses at 5% of Mean Annual Discharge, where there is expected to be serious harm to fish and fish habitat.
    - The staged approach starts awareness campaigns at 30-40% of MAD, then notifies water users to prepare to cut back at 20% of MAD. Water users would then be required to start reducing water use by 25% at 10% and 7.5%, respectively, and 50% at 5% of MAD.
    - The staged approach would have significant resource requirements to implement (3-5 mail outs), and would need to consider the timing & stage in growing season, the impact on water users, and the behaviour of water users in response. Collaboration with community-based groups and water suppliers would be required for success.
- Regulate Groundwater Use. Currently, groundwater is not regulated (aside from water suppliers) and is not managed jointly with surface water. When the new Water Sustainability Act is implemented in 2015, groundwater will be regulated and licenced in a similar manner to surface water. Key considerations:

- Regulating groundwater use would impact irrigation and other uses during droughts, requiring collaborative water conservation and drought management planning
- While the Grand Forks Aquifer is very well studied, other aquifers in the watershed have had little study or monitoring. Further site-specific studies will be needed to support licencing and would be needed to determine aquifer priority, capture zones and the contribution of individual wells to water shortages in surface water bodies.

- Designate Kettle as Environmentally Sensitive Watershed under the Fish Protection Act. If enacted, this designation could entail certain provisions on government officials issuing licences and approvals under the Water Act. These conditions mean new or amended licences or approvals must be consistent with the Sensitive Streams Designation and Licensing, and result in a) no significant adverse impacts on the protected fish population; b) mitigation measures that avoid significant impacts, or c) if mitigation cannot address the problem, compensation measures elsewhere that compensate for adverse impacts. This designation also means that legally binding recovery plans may be developed by cabinet, and that local governments can be directed to protect streamside environments [43]. Additional changes could be required to forest stewardship plans by BC Timber Sales and Tree Farm Licence holders to protect stream temperature and hydrological response.
- Develop Off-Stream Storage to Support Water Use. This would require new surface licences to be supported by storage from spring freshet if the Kettle River is designated fully recorded (licenced). In addition, there needs to be technical work to identify potential off-stream storage to buffer extreme low flows and warm water temperatures during critical periods [30]. For instance, in 2003 the Kettle River at Laurier spent up to 10 days at or below 5% of Mean Annual Discharge. Over 800,000 cubic metres of water would be required over that period to buffer flows by 1 cubic meter per second. This is more than the volume carried by a super tanker and almost three times the size of the newer reservoir (Paul Lake) at Big White [11].
- Change fishing regulations. Potential changes to protect stocks and breeding adult trout. Further discussions by FLRNO are proceeding with recreational fishing organizations and other stakeholders. Options include: a full closure of the river from July 15 for four to six weeks, when flows are the lowest and temperatures are the highest; moving the river to full catch and release only for rainbow trout; mixture of catch and release and closure. Stakeholders have voiced the need for simplified, easy to understand fishing regulations that are applied uniformly to the rivers instead of piecemeal reaches.

3.3.3 Identify purposes and limitations of water storage

The Advisory Group and participants at the March 2014 Special Meeting discussed various purposes for future water storage by dams and other means, as well as constraints and limitations that need to be understood before proceeding with developing storage (Table 1). They also discussed 'smart' water storage strategies for the Kettle River watershed, in order of increasing cost and complexity:

- Increase retention of organic matter and improve soil health in forestry, range, urban and agricultural land uses.
- Develop a network of small storage sites, including dams, natural landscape storage, gabion / sand dams, beaver dams, and weirs in suitable streams, uplands and stable slopes. Provide support and resources for landowners to install and maintain structures.
- Investigate suitability and feasibility of larger dams on Kettle River or large tributaries.

Table 1. Purposes, limitations and site selection factors for water storage projects

Purpose	Negatives to avoid	Site selection factors
Augmenting flow for environmental water needs	Evaporation losses	height of dam
Limiting temperatures with releases with water	Affecting natural flows	Slope stability
Recreation, navigation & quality of life purposes	Disrupting habitat connectivity and routes for migratory species	Land value / land use
Aquifer recharge	Affecting species/ecosystems at risk	Multi-resource values
Agricultural water needs	Loss of farmland and communities	Recreational uses
Domestic (including drinking water), human health	Impacts on groundwater recharge and late-season flows	Capacity needs
Fire protection	Cost, liability, misuse	Assess each stream
Other habitat considerations	Temperature increases	
	Sedimentation of reservoirs	

4 Draft strategies, management directions and actions

This section summarizes the strategies, management directions and actions related to flow and water conservation under consideration by the Advisory Group. Strategies and Management Directions were first outlined in Discussion Paper 1 [38]. Here they are expanded on with additional strategies and specific actions to be undertaken by specific agencies or organizations, and timelines over the first phase of implementation (2014-2017).[5]

Strategy 1. Increase community understanding, support and capacity for stewardship of the Kettle River Watershed.

Direction 1.1. Build public and institutional support for improved watershed management, including the development, implementation, and continued support of policies and regulations that safeguard watershed health.

Action 1.1.1 Improve the consistency, alignment and application of policies and regulations for water allocation, licensing, water conservation, and protection of environmental flow needs. Consider designating the Kettle River as an Environmentally Sensitive Watershed under the Fish Protection Act (Provincial government, federal government, with support and monitoring by local government and non-governmental organizations; ongoing)

Action 1.1.2 Prioritise the high-demand aquifers of the Kettle River watershed for groundwater licensing and regulation in support of stream health (provincial government)

Action 1.1.3 Develop and implement water conservation programs to motivate changing practices toward water conservation (Implementation team, water suppliers; by end of 2014 and ongoing).

Outcomes

- All water suppliers have water conservation strategies developed and adopted by 2017
- At least 50% of new water demands met by water conservation by 2020 [23]
- Determine operable storage capacity required for augmenting low flows of at least 1 cubic meter per second for 10 days in each of the West Kettle, Kettle, and Granby Rivers

[5] The *Implementation Team* was identified in Discussion Paper 2 [41] as the partnership of RDKB, other government agencies, local organizations and individuals who lead the first phase of implementation. It is expected to evolve into a more formal organization or partnership following a governance study by the implementation team.

Action 1.1.4 Give consideration to source water protection, water conservation and aquifer recharge protection in local government planning documents (RDKB, municipalities, with support of Implementation Team; ongoing).

Direction 1.2. Improve understanding of watershed function, integrity, resilience, and sustainability. Fill gaps in understanding through scientific studies and ongoing monitoring.

Action 1.2.1 Implement monitoring and central reporting of a) water use and b) flow and water levels in tributaries and aquifers connected to the Kettle River. Report regularly on meeting flow requirements or any alterations to flow regimes that could affect aquatic ecosystems or human uses (Provincial government, implementation team, water suppliers and local organizations; by 2015 and ongoing).

Action 1.2.2 Complete a comprehensive Environmental Flow Needs assessment[6] of the Kettle River and major tributaries that addresses groundwater connections and establishes objectives for flow and water conservation. (Provincial government, with support from implementation team; by 2016).

Action 1.2.3 Manage the water allocation, licencing and approval process (including groundwater) to support environmental flow requirements (Provincial government)

Direction 1.3. Improve capacity for watershed stewardship

Action 1.3.1 Align and target financial and technical support of beneficial management practices and ecosystem restoration by landowners, local governments, resource industries and the public in support of water conservation and protection of stream health (Provincial government, implementation team; ongoing).

Strategy 2. Improve the quality, reliability and security of water supplies through sustainable management of water resources

Direction 2.1. Improve water conservation and increase efficiency and productivity of water use in all sectors

Action 2.1.1 Identify, implement and report on water conservation goals and measures in water conservation plans (water suppliers, municipalities; by 2017).

Direction 2.2. Improve water security by developing and implementing drought management plans

[6] Including flow objectives for fish, aquatic ecosystem, water quality, infrastructure and recreation

Action 2.2.1 Establish and implement drought management strategies that identify land and water management responses during periods of extreme low flows (water suppliers, implementation team; by 2017)

Direction 2.3. Improve water supply reliability by evaluating water storage needs and implementing, where appropriate, water storage strategies for surface and ground water

Action 2.3.1 Identify water storage needs based on projections of future supply, demand, conservation and environmental flow needs (implementation team; by 2015)

Action 2.3.2 Identify potential water storage sites, prioritize sites for further study, and calculate water storage potential and high priority sites (Implementation team, Provincial government; 2017)

Action 2.3.3 Develop water storage sites where community deems essential and appropriate (lead as appropriate; ongoing)

Strategy 3. Improve watershed health and function in the Kettle River Watershed

Direction 3.1. Maintain or increase the extent and cover of permanent vegetation, including forests, in uplands, stream corridors and on floodplains

Action 3.1.1 Implement or extend incentives for retaining or increasing native tree, shrub and grassland cover (provincial government, implementation team)

Action 3.1.2 Design and implement urban & rural tree programs to maintain or increase tree cover (local municipalities, RDKB; by 2017)

Direction 3.2. Protect soil and improve soil health to improve water retention and decrease erosion

Action 3.2.1 Implement and align agricultural stewardship incentives for crop management & soil conservation (provincial government, implementation team)

Direction 3.3. Maintain or increase the areal extent and function of wetlands and riparian areas across the watershed[7]

Direction 3.4. Develop long term management plans to achieve the above in a timely manner

Direction 3.5. Encourage shoreline and bank protection measures that protect aquatic and riparian habitat

Strategy 4. Maintain or enhance recreational, cultural and amenity values

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[7]Actions for Strategies 3.4 and 3.5 to be developed in Discussion Paper 5

Direction 4.1. Maintain a healthy sport fishery through habitat protection and restoration, continued stocking of recreational lakes and the protection of native fish populations in tributaries and rivers.

Action 4.1.1 Identify the source, transport and fate of sediment currently affecting fish habitat and investigate the aggradation (widening) of the Kettle and Granby Rivers (Provincial government, university researchers, implementation team; by 2017).

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Appendix A: Supporting Technical Analyses

A.1: Trends in annual minimum flows

As a preliminary analysis to evaluate trends in low flows on the Kettle River, the Nature Conservancy's Indicators of Hydrologic Alteration program [31] was used to extract 3-day and 7-day minimum flow summaries (i.e. the smallest values of average streamflow over any consecutive 3 or 7 days during the year [28]) from the US Geological Survey data for Laurier, Washington [33]. The Mann-Kendall test for trends over time was then performed with Sen's slope estimator using the R statistical program and trend analysis packages [4,17,26].

Visual examination of the distribution of 7-day minimum flows over the period of record shows a slight increase in low flow volume between the 1930s and 1950s and a gradual decline since the 1950s (Figure 6).

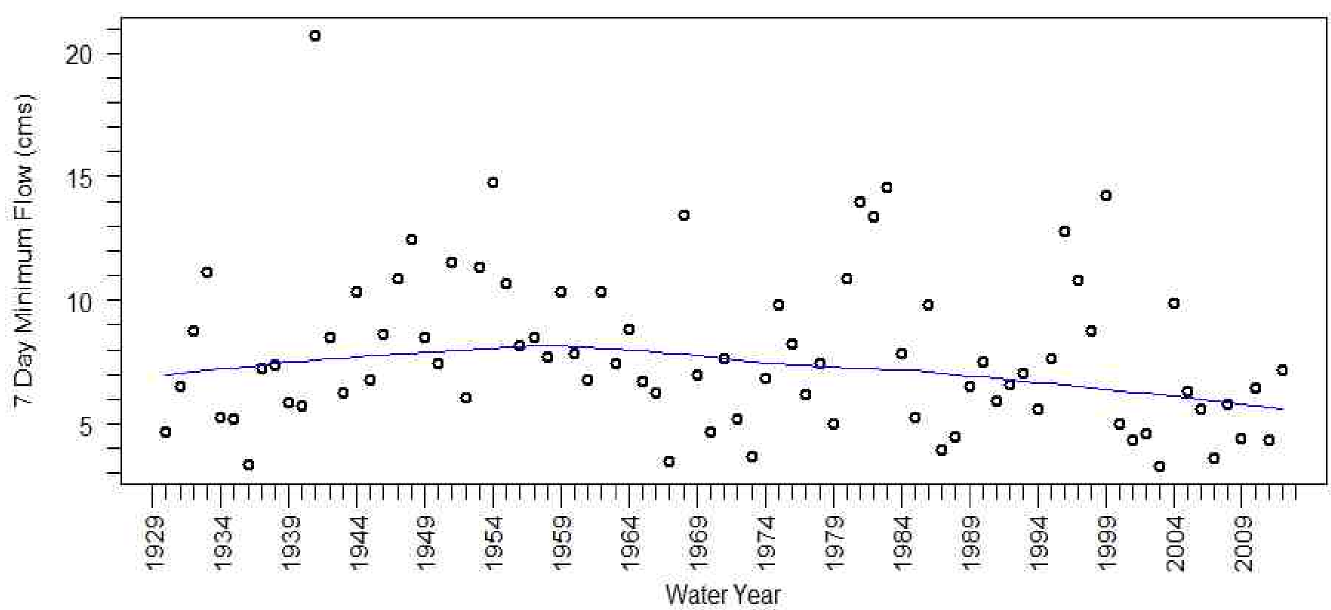

Figure 6. Seven-day minimum flows for Laurier, WA, 1929-2012, fitted with a LOWESS local trend.

There were small downward trends in both 7-day and 3-day minimum flows for both 1931-2012 and 1981-2012 periods (Table 2). The overall strength of the trend is relatively low, likely because of the wide variation from year to year. Because of this variation, the estimated trend in flow (Sen's slope) over shorter time periods (i.e. 30 years) is very sensitive to low or high flows, as shown by the decline in flow of -0.223 cms/year for 1931-2012 and -0.124 cms/year for the recent period.

To obtain a more nuanced understanding of changes to low and high flows, a greater number of the indicators of hydrological alteration (i.e. timing, maximum flows) should be examined at all available hydrometric stations in the watershed [22,31].

Table 2. River discharge trend statistics - Kettle River at Laurier.

Period	Minimum flow period	Mann-Kendall Statistic	2-sided P-Value	Sen's slope (cms/year)*	Kendall Tau Statistic**	Is there a significant trend?***
1929-2012	7 day	-484	0.057	-0.265	-0.164	No
1980-2012	3 day	-688	0.006	-0.031	-0.142	Yes
	7 day	-135	0.030	-0.124	-0.272	Yes
	3 day	-131	0.035	-0.087	-0.264	Yes

*****Estimates the linear trend in a time series of data – cms per year; A measure of the strength of the rank correlation, ranges from -1 to 1; ***Considered significant where p≤0.05.

A.2: Future Water Use Scenarios

The Phase 1 Technical Report [30] recommended that the Watershed Plan should evaluate the effect of population and economic growth scenarios on water demand. However, there are currently no detailed sector-by-sector data on actual use of surface and groundwater that would be required for systematic scenarios (i.e. AMEC [1]). In the future, actual water use will depend on changes in legislation, technology, practices, and the ups and downs of resource and agricultural industries. Therefore, only certain aspects of future water demand may plausibly be projected.

With regards to current water allocations, agricultural water licences (irrigation) account for by far the greatest licenced water use volumes, followed by domestic licences (waterworks, which includes domestic, commercial and industrial uses - Appendix B1 in the Phase 1 Report [30]). Assuming that these proportions are reasonable and remain constant, they can be used in building simplistic, watershed-wide projections of future water demand based on projections of agricultural build-out, climate change scenarios of precipitation and evapotranspiration, and forecasts of population growth.

Agriculture & Climate Scenarios

The BC Ministry of Agriculture has developed an agricultural water demand model for the Kettle River Watershed that estimates current and future agricultural water demands using data about crops, irrigation systems, soil texture and climate [9]. The water demand model was used to evaluate demand for specific dry years in the 2050s, using three climate models with different assumptions about global population growth and emissions. Averaging the three models, the model projects an overall increase in annual water demand of 7.5% by the 2050s. In an extreme climate scenario but with good water conservation, there could be an annual water demand that is 25% higher than 2003 by the year 2059 with current crop types (**Table 3**).

If all agricultural land was 'built out' (used to its full agricultural potential and irrigated with suitable methods and good management for each crop type),[8] the near-doubling of agricultural land use by the 2050s could result in a 75% increase in annual water demand, or a 116% increase under an extreme climate scenario [9].

[8] The report only gave results from model runs under 'good irrigation management' for future water demands under climate change scenarios. Future model runs for longer time trends could, for example, evaluate business-as-usual water management or shifts towards dryland agricultural practices.

Table 3. Modeled current and future agricultural water demand (Ml = 1000 m^3) for current and built-out agricultural land use for the Kettle River watershed. Compiled from Appendix Tables F, K, L and M from van der Gulik and others [9].

Scenario	irrigate-ed land (ha)	2003 demand (Ml) with average management	Average dry 2050s demand (Ml) with good management	% rise over 2003	extreme dry 2059 demand (Ml) with good management	% rise over 2003
2003 land use	3,988	43,106	43,794	2%	53,894	25%
agricultural build-out	7,829	72,375	75,612	4%	92,953	28%
% increase w/ build-out	96%	68%	75%	75%	116%	116%

Of course, future climate scenarios will likely bring very different patterns of vegetation, land use, agricultural practices, and regulatory constraints on stream and aquifer use [36]. In the model results, improvements in irrigation efficiency and management alone mostly offset increased water demand due to climate change in the 2050s for average dry years (**Table 3**). It should also be noted that irrigation demand can be much lower in wetter years; modeled water use in 1997, for instance, was only 51% of water demand of the hot, dry year of 2003.

Additionally, future developments in water governance could mean that a greater proportion of water users will be served by centralized waterworks or municipal utilities and subject to conservation measures (water metering, pricing and incentives).

Population scenarios

Population trends in the Boundary tend to reflect changes in resource extraction industries such as forestry and mining [7]. Currently, population in the area has leveled off compared to the gradual growth from the 1960s to early 2000s. BC Stats is currently projecting small population increases for the Boundary over the next 20 years, with an average annual rate of about 0.34% [2].

Future demand for wood products or mineral resources, interest in the area’s potential for retirement housing and recreation amenities, costs of living compared to other areas, and decentralization of workplaces could increase future growth beyond current trends [7]. In addition, migration associated with climate change disruptions (sea level rise, dust-bowl droughts) could increase migration to inland areas with moderate climate and adequate water supply, though most such increases would concentrate in large urban centres [12].

Population projections and growth scenarios for the whole region are provided in **Table 4**, showing 0% growth, double growth (0.68% annual), and the much higher growth rate (1.68% annual) experienced by the Okanagan Valley between 2006 and 2011. While the latter is highly unlikely for the Boundary, it allows us to envision the 'perfect storm' if several of the above factors coincide.

Table 4. Population projections and scenarios for 2015, 2025, 2035 and 2055 for Grand Forks and Kettle Valley Local Health Areas. (Projected data to 2035 from BCStats [2] 2055 projected based on calculated growth rate (0.34% annually). 1.68% growth based on 2006-2011 Okanagan Valley average growth).

	Projections (0.34% annual growth)			Scenarios		
Year	Grand Forks	Kettle Valley	Total	0% growth	.68% growth	1.68% annual growth
2015	8,802	3,728	12,530	12,530	12,530	12,530
2025	9,145	3,815	12,960	12,530	13,409	14,802
2035	9,466	3,940	13,406	12,530	14,349	17,485
2055	10,131	4,217	14,345	12,530	16,432	24,399

Agricultural and population scenario impact on water use and availability

Estimating Annual Demand. Based on the relative proportion of licenced volume and groundwater use for Grand Forks-Christina Lake (Sub-basin 7),[9] irrigation demand was assigned 80% of water use and waterworks was assigned 15%, with the remaining 5% for all other uses.[10] Current water use was assumed to be the sum of the estimated actual annual off-stream use (Table 4-12 in the Phase 1 Report [30]), not accounting for return flows from wastewater treatment or groundwater recharge from irrigation (**Table 5**).

Future irrigation water use for 2025, 2035 and the 2050s was projected from Table 3 using the simple compound annual growth rate for average dry and extreme dry conditions with current land use and agricultural build-out scenarios.[11] Future waterworks water use was projected by applying compound

[9] Reported in Appendix B1 of the Phase 1 Report [30], excluding power reserve, storage and conservation uses.

[10] Note that licensed volume does not equal total water use – actual use for surface water licences may be around 50% of licensed in a normal year, and groundwater estimates do not account for domestic and private wells. Calculated agricultural water use is markedly higher than the Agricultural Water Demand Model. Proportions of domestic (waterworks) use are lower across the entire watershed than in sub-basin 7. Estimated actual use may be higher than real water use based on assumptions used in calculations in the Phase 1 report. Future forecasts of water demand should incorporate better water use data to overcome these errors.

[11] This assumes current water use for dry years reflects 2003 water demand as calculated in the Ag. Demand Model [9].

annual growth rates calculated from **Table 3** and **Table 4** on water use values for **Table 5** for 2025, 2035 and 2050s, respectively. The remaining 5% of water use (currently 4905.4 Ml) was projected to grow at a conservative 1% annual growth and a higher 2% growth, reflecting different possible futures for economic and resource development in the region.

Table 5. Estimated current water use as flow (cubic metres per second) and total annual volume (megalitres [1000 cubic metres]) for total 'actual' water use, irrigation water use, waterworks use. The 50 year annual net low flow is provided for comparison.

Sub-basin	Total water use (m^3/s)	annual (Ml)	irrigation (m^3/s)	irrigation annual (Ml)	waterworks (m^3/s)	w.works annual (Ml)	50 year annual net low flow (m^3/s)
1	0.137	4,320	0.11	3,456	0.02	648	4.28
2	0.097	3,059	0.08	2,447	0.01	459	11.2
3	0.43	13,560	0.34	10,848	0.06	2,034	14.5
4	0.094	2,964	0.08	2,372	0.01	445	1.17
5	0.825	26,017	0.66	20,814	0.12	3,903	16
6	0.048	1,514	0.04	1,211	0.01	227	11.7
7	1.48	46,673	1.18	37,339	0.22	7,001	29.6
total	3.111	98,108	2.49	78,487	0.47	14,716	12.63 (mean)

On an annual basis, low growth rates with current land use and future water conservation in agriculture provide a relatively low increase in water use of 3,664 Ml (4%) by 2055 (Table 8). Moderate growth rates with built-out agriculture could expand overall water use by over 65,649 Ml (67%), and extreme growth and agricultural build-out with extremely dry conditions could expand annual water use by 114,003 Ml (116%). Given that about 2% of the annual naturalized flow (about 3.1 cms) is currently used [30], these scenarios suggest that just over 2% to over 4% of annual flow (about 6.7 cms) will be used by the 2050s.

Seasonal use & impacts on flow. Because irrigation use (including garden and landscaping) occurs mostly from May-September, increases in future water demand will have an amplified effect on river flows in later summer, increasing the impacts discussed in Section 2.2. For instance, late summer use could rise from the current use of 16% to over 36% of monthly naturalized flow.

To explore potential impacts of projected water use on future water flows, the average monthly volume of water use (m^3/s) was approximated using the seasonal distribution of water use for sub-basin 7 (Appendix C7 in the Phase 1 report [30]). This estimate was converted to a multiplication factor as the ratio of the monthly flow to the average flow (Table 6). Each scenario's increase in annual use (calculated from Table 8) was multiplied by this factor to estimate future monthly use (m^3/s). Future monthly use was then subtracted from historical daily mean, median, 1:10 and 1:50 year low flows. Negative flows were set to 0 m^3/s.

No attempt was made to incorporate other climate change impacts, such as seasonal changes in flow patterns due to earlier freshet or lower summer precipitation. Additionally, no attempt was made to evaluate the potential effects of water conservation planning by waterworks and other water uses, nor the effects of drought-response measures such as irrigation and watering restrictions.

Table 6. Monthly distribution of water use (Appendix C7, [30]) and multiplication factors for monthly-adjusted flows.

month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
use (cms)	0.19	0.2	0.19	0.4	1.9	2.15	5.04	4.55	2.2	0.55	0.17	0.17
multiplication factor	0.13	0.13	0.13	0.27	1.29	1.46	3.41	3.08	1.49	0.37	0.12	0.12

When potential future monthly water use is subtracted from flows in the historical record, most of winter and spring have a similar pattern to the historical hydrograph (Figure 5). However, starting in the late spring and early summer, estimated future flows under moderate and extreme growth scenarios rapidly fall to extremely low flows, with mean flows falling below 10% cms for a short period.

The potential impact on flow and the aquatic ecosystem can also be visualized as the number of days in a year that the flow falls below thresholds identified by FLNRO studies [8,44] (Figure 7). Current mean flows have roughly equal number of days in good (>20 cms) and satisfactory (10-20 cms) flow conditions. However, even average dry years in the 2050s could have a number of days below 10 cms, when trout habitat starts to decline rapidly. With moderate and extreme growth and climate scenarios for 1 in 10 and 1 in 50 year dry flows, the river spends up to three months in poor to very poor flow condition and up to 60 days at “zero” flow.

It is very unlikely that society would allow flow conditions to regularly decline to very poor and zero flows, so Figure 7 and Table 7 could alternately be read as the period when conservation measures, water regulations, and/or releases from water storage are used to prevent extreme low flows and protect in-stream environmental flow needs.

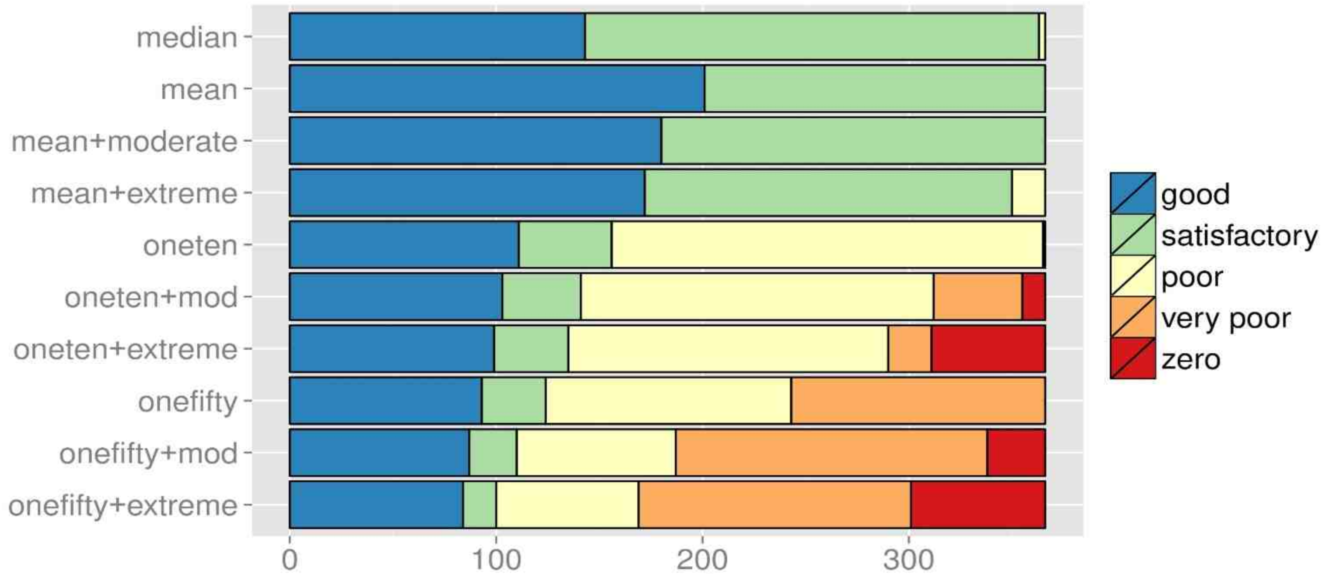

Figure 7. Potential days of the year with different categories of river flow in moderate and extreme future water use scenarios for median, mean, 1 in 10 and 1 in 50 year low flows. Categories are good=>20 cms; satisfactory=10-20 cms; poor=5-10 cms; very poor=0.1-5 cms, and zero=0 cms (based on FLRNO analysis [44]).

Table 7. Number of days in flow condition categories as displayed in Figure 7.

Scenario	good	satisfactory	poor	very poor	zero flow
historical median	143	220	3		
historical mean	201	165			
mean moderate	180	186			
mean extreme	172	178	16		
historical 1:10 year low flow	111	45	209	1	
1:10 moderate	103	38	171	43	11
1:10 extreme	99	36	155	21	55
historical 1:50 year low flow	93	31	119	123	
1:50 moderate	87	23	77	151	28
1:50 extreme	84	16	69	132	65

Table 8. Water use projections from growth scenarios for agriculture, waterworks, and other water uses.[12] Estimated annual water use is reported in megalitres (Ml = 1 million liters or 1000 cubic metres) and summarized with both Ml and m^3/second.

	Agriculture (growth in irrigation demand)			Waterworks (population growth rates)				other growth rate		minimum (a+d+h)		moderate (b+e+h)		maximum (c+g+i)	
Year	a - Current land use	b - Ag. build out	c –ext. climate+ ag build out	d - 0%	e - 0.34%	f - 0.68%	g - 1.68%	h - 1%	i -2%	Ml	**m^3/s**	Ml	**m^3/s**	Ml	**m^3/s**
current	78,487	78,487	78,487	14,716	14,716	14,716	14,716	4,905	4,905	98,108	3.11	98,108	3.11	98,108	3.11
2025	78,801	90,639	95,581	14,716	15,224	15,747	17,383	5,418	5,979	98,936	3.14	111,282	3.53	118,944	3.77
2035	79,117	104,673	116,399	14,716	15,749	16,852	20,535	5,985	7,289	99,818	3.17	126,409	4.01	144,223	4.57
2055	79,752	139,598	172,624	14,716	16,855	19,298	28,655	7,303	10,831	101,772	3.23	163,757	5.19	212,111	6.73
volume change	1,265	61,111	94,137	-	2,139	4,582	13,939	2,398	5,926	3,664	0.12	65,649	2.08	114,003	3.62
% change	2%	78%	120%	0%	15%	31%	95%	49%	121%	4%	4%	67%	67%	116%	116%

[12] Current water use data calculated from Appendix C, Table 7 of the Phase 1 Report