

Kimberley Water Study

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Introduction

The aim of this report is to gather together the available data for water flows in Mark and Matthew Creeks, as well as for water consumption in the City of Kimberley, and estimates of minimum flow requirements for aquatic life in those creeks. The goal is to determine the compatibility of current and future water consumption with the health of aquatic ecosystems, and in particular, Westslope cutthroat trout, a the provincially listed species at risk, in Mark and Matthew Creeks.

Specifically, this report provides a brief overview of the Mark and Matthew Creek community watersheds above their respective water intakes and of the City of Kimberley's water supply system. We provide some detail on water consumption (both overall and industrial use) in Kimberley and Marysville and on the flow requirements for aquatic life below the Mark Creek intake, where a significant portion of the creek's flow is diverted. Finally, we conduct an analysis of limiting low-flow cases to determine the restrictions on water consumption and downstream flows. We finish by discussing possible future trends in and actions affecting water supply and consumption.

This report has been prepared by the Kimberley Water Project, Wildsight Kimberley/Cranbrook's water sustainability project which includes the well known Mark Creek Recovery Program, as part of its mandate to maintain healthy ecosystems in Kimberley watersheds.

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Our Sources of Water

The City of Kimberley has two separate water systems, one drawing water from Mark Creek to supply Kimberley proper, and the other drawing water from Matthew Creek to supply Marysville.

Geography

Kimberley's water is supplied from a reservoir located on Mark Creek 5km northwest of downtown Kimberley at an elevation of approximately 1340m. The watershed above the dam rises to 2670m with an area of about 107km²⁽¹⁾.

Marysville's water supply comes from an intake on Matthew Creek, an adjacent drainage, located 7km west of downtown Marysville at 1030m. The Matthew Creek watershed above the intake is about 148km²⁽²⁾, with a maximum elevation of 2730m.

Hydrometrics

Flow has been monitored continuously at Mark Creek Above Diversions, located 1km north of the reservoir since 1989, with the exception of about 2.5 missing years between 1996 and 2002. There is also a flow monitoring station near downtown Kimberley, Mark Creek at Kimberley, that operated from 1996-1998 and has operated continuously since 2001.

At Matthew Creek Above Diversions, located directly above the intake, flow was monitored continuously from 1989 to 2003 and has been monitored from April to September annually since the fall of 2004.

Nanrich Water Management Consultants currently operate all three hydrometric stations: one for the City of Kimberley (Mark Creek above diversions), one for TeckCominco (Mark Creek at Kimberley), and one for Tembec (Matthew Creek above diversions).

Mark Creek has mean annual flow of 1.2 m³/s and Matthew Creek has a mean annual flow of 2.8 m³/s. Both Mark and Matthew Creeks have spring freshets with high flows driven by snowmelt that decline over the summer. The lowest annual flows are recorded during the winter months, from December to March. The lowest recorded flow for Mark Creek was 0.107m³/s on March 24th, 1989 and the lowest recorded flow for Matthew Creek was 0.125 m³/s March 8th, 2003.

Figures 1 and 2 show the average daily flow from all available data for Mark and Matthew Creeks above diversions.

Mark Creek Above Diversions Average Flow 1989-2007

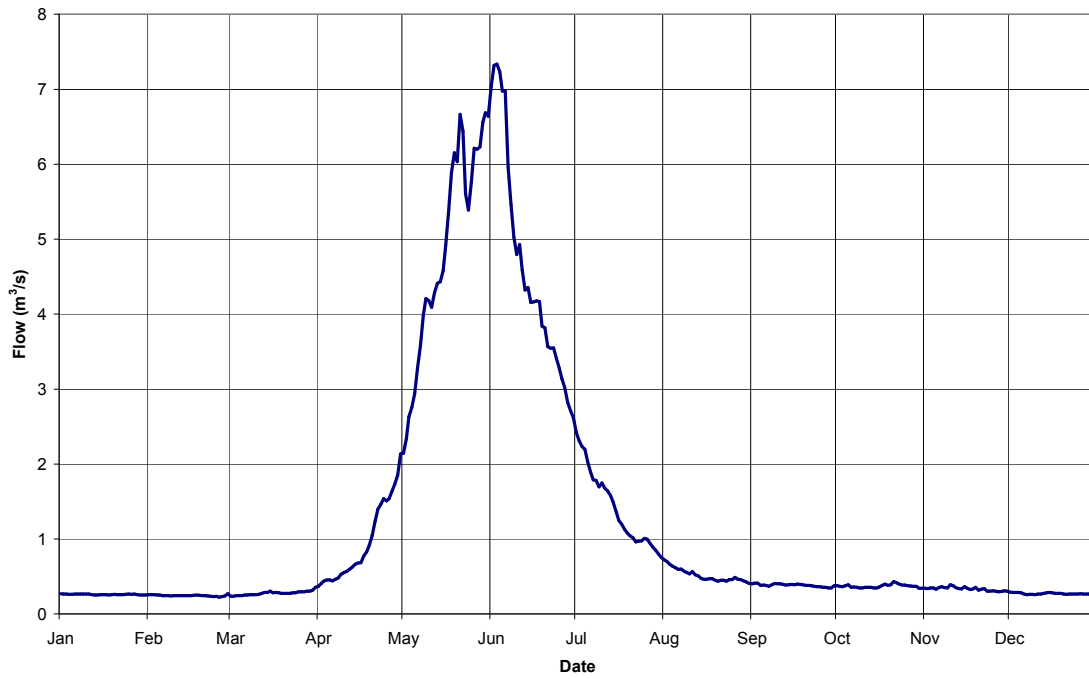


Figure 1

Matthew Creek Above Diversions Average Flow 1989-2007

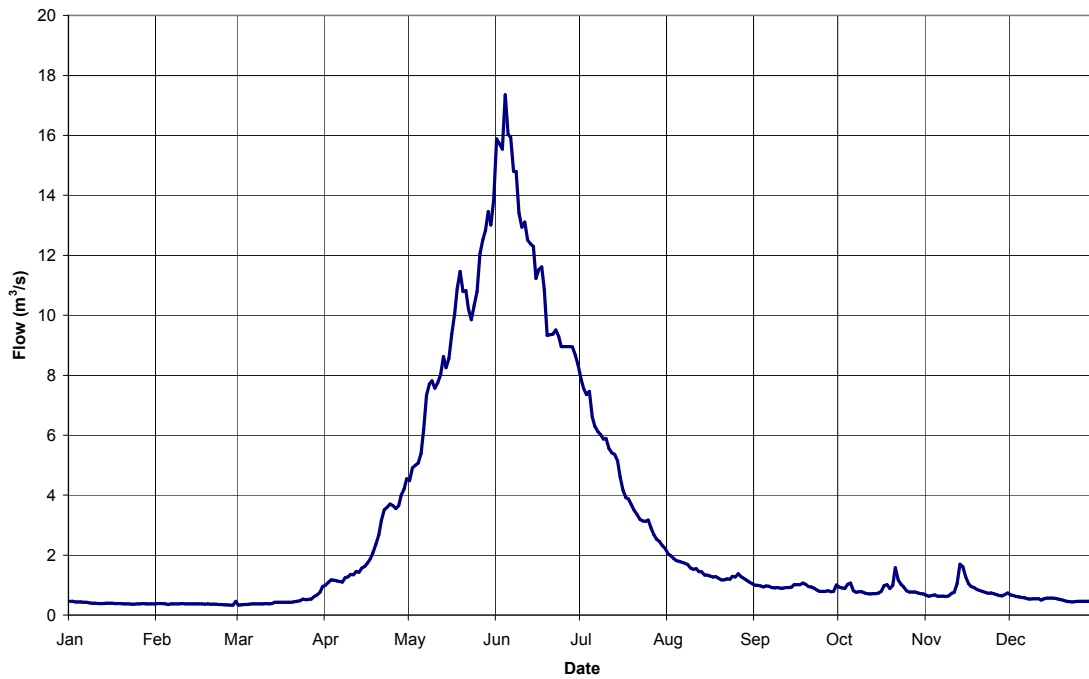


Figure 2

The City of Kimberley Water System

Kimberley

The Mark Creek system currently serves an estimated population of 5112 in Kimberley⁽³⁾, plus numerous vacation homes, condos, and hotels, commercial users, and three industrial users: the Trickle Creek golf course, Kimberley Alpine Resort, and TeckCominco. Forest Crowne, a subdivision located between Kimberley and Marysville is currently served by the Mark Creek system, but the City plans to connect it to the Matthew Creek system once the number of houses in the subdivision reaches 375⁽⁶⁾. This connection will also be designed to allow the use of Mark Creek water in Marysville during freshet, when it is of better quality (lower turbidity) than Matthew Creek water.

The city has water licenses allowing it to divert a total of 12 million m³ per year from Mark Creek⁽⁵⁾ or an average of 0.39 m³/s, which exceeds the average flow above the reservoir 200 days of the year. The Kimberley water system as a whole has a design capacity of 45 000 m³ per day⁽⁴⁾ (0.52 m³/s). The municipal reservoir on Mark Creek has a capacity of 272 000 m³⁽⁴⁾. Once dead storage and seepage are accounted for⁽¹⁵⁾, the reservoir has enough water to supply approximately 21 days of current August water use or 37 days of current December water use. From the intake, water passes through a chlorination plant and is distributed directly to water users in the downtown area and to other users via five small reservoirs totaling 4767 m³⁽⁷⁾. These reservoirs are automatically re-filled once their levels drop to approximately 7/8^{ths} of their capacity⁽⁶⁾.

Except in extreme conditions, flow is maintained over the top of the dam to maintain high water quality⁽⁶⁾. In addition, there is a flow valve on the dam that is left open year round to provide a minimum flow of approximately 0.02 m³/s⁽⁶⁾ for aquatic life. The city has no written or otherwise available policy or plan that covers reservoir drawdown in low flow conditions.⁽⁶⁾

Marysville

The Matthew Creek water system serves an estimated population of 1350, a small number of commercial users, and TeckCominco in Marysville. The system draws from a small settling pond located beside Matthew Creek. The city has water licenses totaling 2.3 million m³ per year⁽⁵⁾ or an average of 0.07 m³/s, which is less than the lowest recorded flow. The Matthew Creek system has a design capacity of 9000 m³ per day⁽⁴⁾ (0.10m³/s) with a chlorination plant and two small reservoirs above Marysville with a total capacity of 2270 m³⁽⁷⁾.

Our Water Use

Measurement

Water consumption is monitored by daily totalizer readings for the Mark Creek and Matthew Creek systems, but electronic versions of this data are only available from 2003 to present. Water consumption is also monitored at several substations by weekly totalizer readings, but these measurements are considered to be less accurate than the main totalizer measurements⁽⁶⁾. Industrial users are metered; TeckCominco reports their water usage monthly, while the Trickle Creek golf course and Kimberley Alpine Resort (ski hill portion) usage is currently recorded quarterly, but was recorded less frequently in the past.

Total Water Consumption

Figures 3 and 4 show average daily and maximum daily water consumption for Kimberley and Marysville from 2003-2007. It is worth noting that the totalizer readings that these figures are based on are recorded manually on a daily basis, so it is possible that some days' measurements represent somewhat more or less than 24 hours of water consumption.

Kimberley - Average and Maximum Daily Water Use 2003-2007

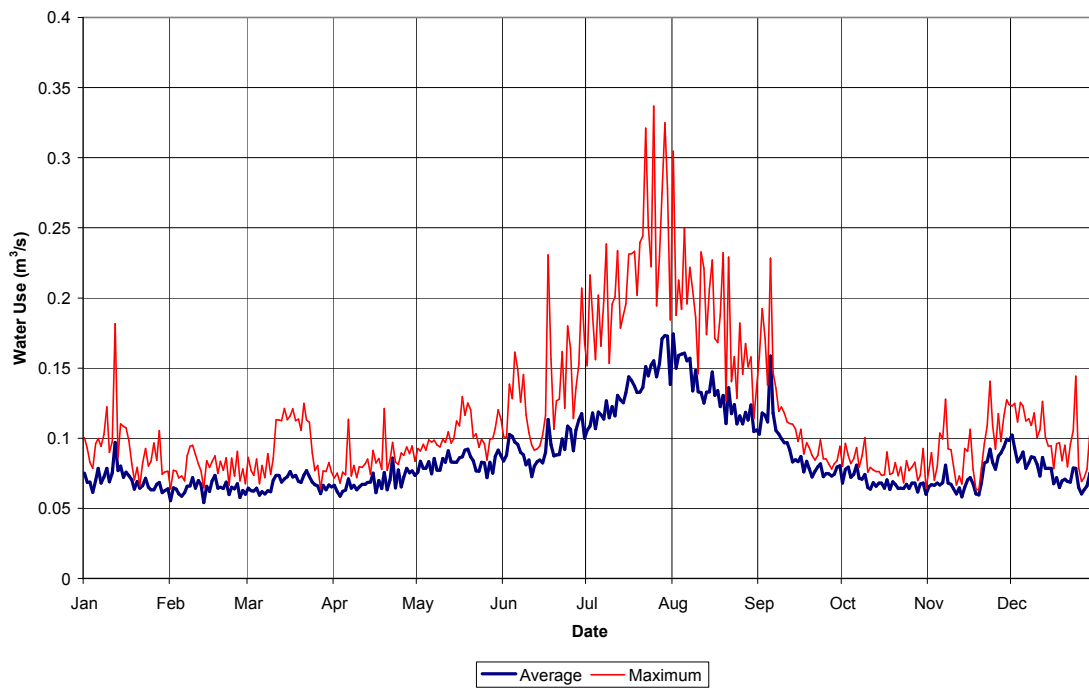


Figure 3

Marysville - Average and Maximum Daily Water Use 2003-2007

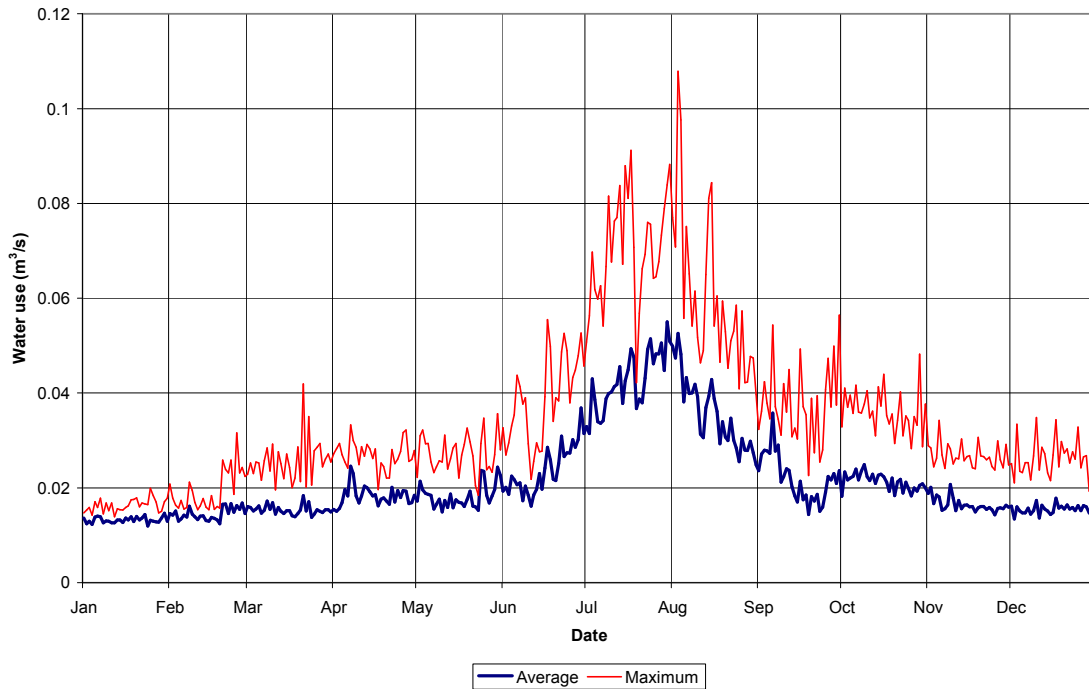


Figure 4

Industrial Use

The **Kimberley Alpine Resort** uses municipal water for snow making when weather conditions are favourable, typically on some days from late November to early January. Average seasonal consumption since fall 2000 has been approximately 104000 m³ and the maximum seasonal consumption has been 170000 m³⁽³⁾. Assuming 30 days of snow making, this is a daily consumption of 3500 m³ (or averaged over a day, 0.04 m³/s) in an average year and a daily consumption of 5700m³ (or 0.07 m³/s) in the highest consumption season on record 2002/2003. As overall water consumption in Kimberley is fairly constant over the winter, with the exception of days when snow making takes place, we can also estimate daily consumption by comparing average February water consumption to high consumption days during the snow making season. Taking the ten highest days of water consumption during the snow-making season, but before the opening of the resort so that tourist water use is minimal, from 2003 to 2007, we estimate that snow making consumes a maximum of 5300 m³ per day (or 0.07 m³/s). If daily consumption data were available for late 2002 to cover the high consumption 2002/2003 season, this number would likely be higher.

The **Trickle Creek golf course** stores water from Trickle Creek and uses it for irrigation during the early part of the summer but switches to municipal water in the late summer when their storage ponds have been drawn down. It is difficult to determine the typical daily water usage for irrigation of the golf course, but the average annual consumption since 2000 has been approximately 74 000 m³ and the maximum annual consumption has been 107 000 m³⁽³⁾. Assuming 50 days of irrigation, this is a daily consumption of 1500 m³ (or averaged over a day, 0.017 m³/s) in an average year and a daily consumption of 2100m³ (or 0.025 m³/s) in the highest consumption year on record, 2003. Given that irrigation needs will vary depending on the weather, we can assume that peak daily water consumption for the golf course is significantly higher.

We have asked Resorts of the Canadian Rockies to answer a set of questions about their water use at the golf course and alpine resort that would allow us to improve our estimates and to discuss the possibility of future changes in industrial water use, but we have not received any response at the time of writing to our questions from July, 2008.

TeckCominco uses a relatively insignificant quantity of water from Matthew Creek and has not used any water for industrial purposes from Mark Creek since 2004.

Per Capita Consumption

Average total daily consumption per capita for the 2003-2007 period was 1450 L in Kimberley and 1380 L in Marysville. Average daily consumption per capita, after subtracting metered industrial use[†], was 1360 L in both Kimberley and Marysville. This figure also includes water used by non-resident homeowners and tourists. For comparison, in 2004 the average daily consumption per capita in BC municipalities was 649 L⁽⁸⁾, inclusive of industrial use, leakage, etc.

[†] and substituting early 2008 data from the ski hill for the early 2003 data, as the latter is not available. The net result of this change is very small.

Leakage

It is possible that our high per capita water consumption is due to leakage in our relatively old distribution system. For the period 2003-2007, the lowest 7-day average per person water usage was 847 L. Assuming that leakage rates are constant throughout the year, and that Kimberley water consumption is always at least half of the provincial average consumption, we can conclude that leakage accounts for, at the most, about 500 L per person per day or 36% of total water consumption. This estimate is only an upper bound for leakage and actual leakage is likely much lower.

In order to maintain required chlorine concentrations in the water distribution system, the city maintains flows out of the water system at the bottom of Forest Crowne and at the bottom of Rotary Drive. We can estimate that the flow at the Forest Crowne site is between 0.001 m³/s and 0.002 m³/s given distribution system flow records for the area. The magnitude of the flow at the Rotary Drive site is not known, but it is likely less than the flow at the Forest Crowne site.

Flow Requirements for Aquatic Life

The creek reach of concern for minimum flow requirements for aquatic life in Mark Creek begins below the dam and extends to just above the TeckCominco flume. This reach of the creek begins at the dam with 2.5km of mixed riffle, cascade, pool, and glide channel, including a 35m waterfall, followed by a short channelized section through the former city reservoir and a 1km long section of steep-walled canyon both primarily featuring riffles and cascades with some glides. The reach ends at the concrete TeckCominco mine flume, 1.5km upstream of downtown Kimberley.⁽¹⁰⁾

Westslope Cutthroat Trout

The main fish species in this reach is the Westslope cutthroat trout, a provincially listed species at risk, which can be observed throughout the reach. Low flows in the reach are of greater threat to Westslope cutthroat trout than to any other aquatic species so discussion of minimum flow requirements focuses on the cutthroat trout population exclusively.

Wildsight completed a genetic sampling survey in 2007 of the Westslope cutthroat trout in Mark Creek and determined that the population above Marysville Falls are genetically pure and have not been hybridized with rainbow trout. Throughout the East Kootenays, Westslope cutthroat trout are often hybridized with rainbow trout, an introduced species, and only 1/5th of populations are free of hybrids.⁽¹¹⁾ Mark Creek is also populated by eastern brook trout, another introduced species that competes with the cutthroat trout and is often found in area rivers. Brook trout have not been found upstream of the city flume, a barrier to upstream migration, and are not found in the reach in question. Thus, much of the reach is valuable habitat for a relatively rare non-hybridized population of Westslope cutthroat trout that are unhindered by a competing population of brook trout. More concretely, a single pool near the dam was observed to contain 110-120 cutthroat trout.⁽¹⁰⁾

Limiting Habitat

The limiting factor for fish survival during low-flow periods is the availability of pool habitat. When flows are low, especially in the winter, trout may not be able to survive in shallower sections of the creek, so they tend to stay in deep pools. In order to accurately determine which flow-levels are or are not a threat to trout, a detailed study of the habitat and its relation to flow levels should be undertaken. The *Mark Creek Fish, Fish Habitat and Impact Assessment* recommends that such a study be undertaken with respect to over-wintering habitat in particular, citing a concern about minimum water depths during the winter "bordering on resulting in fish mortality". Until such a study has been completed, we must rely on more general guidelines for minimum flows to protect Westslope cutthroat trout.

Minimum Flows

The *Integrated Watershed Management Plan* for Mark Creek contains the following objectives for minimum flows downstream of the dam: a minimum flow of 0.09 m³/s to be maintained unless the "reservoir is unable to provide the minimum water necessary for the City of Kimberley industrial, commercial, and domestic use" and an optimum minimum flow of 0.15 m³/s to be maintained "when available".

Flows into the Reach

For the purposes of this report, we will ignore potential flows into the creek via surface or ground water and flows out via ground water, as we do not have any data to quantify those flows. Comparison of the flows below the dam and the flows at the station Mark Creek at Kimberley (located near the upstream edge of downtown Kimberley at the Gerry Sorenson Way bridge) shows that on days with a mean flow of less than 0.25m³/s, the flow at the lower gauging station is greater than the flow directly below the reservoir, which is calculated by subtracting water consumption from the flow above the reservoir. On average, the flow is 0.09 m³/s greater, with a standard deviation 0.03 m³/s, at the lower station. Clearly, there are flows entering Mark Creek between the reservoir and downtown Kimberley, including a small surface water flow into Mark Creek 400m below the dam, but it is not known how much effect these flows have on the limiting pool habitat. Without detailed information about these flows into the reach and how they affect limiting habitat, we must not rely on flows into the reach to meet the minimum flow requirements.

Matthew Creek

We are not aware of any guidelines pertaining to minimum flows for Matthew Creek, but concerns are limited at this point given the relatively low volume of water being diverted from the creek.

Low-flow Analysis

Figures 5 and 6 show maximum daily mean water consumption for Kimberley and Marysville and both the mean and range of creek flows for Mark and Matthew Creeks. High flows during spring freshet are not shown in the figures to allow low-flow periods to be shown more clearly. To minimize the large variability in recorded use from day to day that results from the varied manual reading of the flow meters, the Mark Creek figure shows water consumption averaged over three days.

Two periods present concerns for the maintenance of minimum flows in Mark Creek: 1) early winter, when peak consumption including snow making is only slightly less than the low winter flows, and 2) late summer, when peak consumption during the tail end of the summer irrigation season is relatively close to low late summer flows. Note that the period of high consumption shown in mid-March is not typical for the period and therefore doesn't merit particular concern for a long-term analysis. There are also reasonable concerns about the later winter period, but this study focuses on the early winter period because there is a greater threat of high water consumption during that period.

There is no immediate concern about Matthew Creek.

Frequency Analysis

In order to analyze the water availability for both municipal use and minimum flows for aquatic life during low-flow periods, we conducted a frequency analysis of annual low-flow events using the Log-Pearson III method for mean daily low flows during two periods: from August 1st to September 15th and from November 15th to January 15th. In the interest of completeness, we have done the same for Matthew Creek for daily average flows. The results are summarized in Table 1.

	Low Flow Return Period (years)	Daily Average Flow (m ³ /s)	Monthly Average Flow (m ³ /s)
Mark Creek (Winter)			
	2	0.20	0.24
	10	0.13	0.17
	25	0.11	0.15
Mark Creek (Summer)			
	2	0.28	0.38
	10	0.21	0.25
	25	0.19	0.22
Matthew Creek (Winter)			
	2	0.29	
	10	0.16	
	25	0.13	
Matthew Creek (Summer)			
	2	0.6	
	10	0.31	
	25	0.23	

Table 1: Mark and Matthew Creek low flow frequency analysis

Mark Creek Above Diversions Mean Flow, Range of Flows, and Maximum Water Use

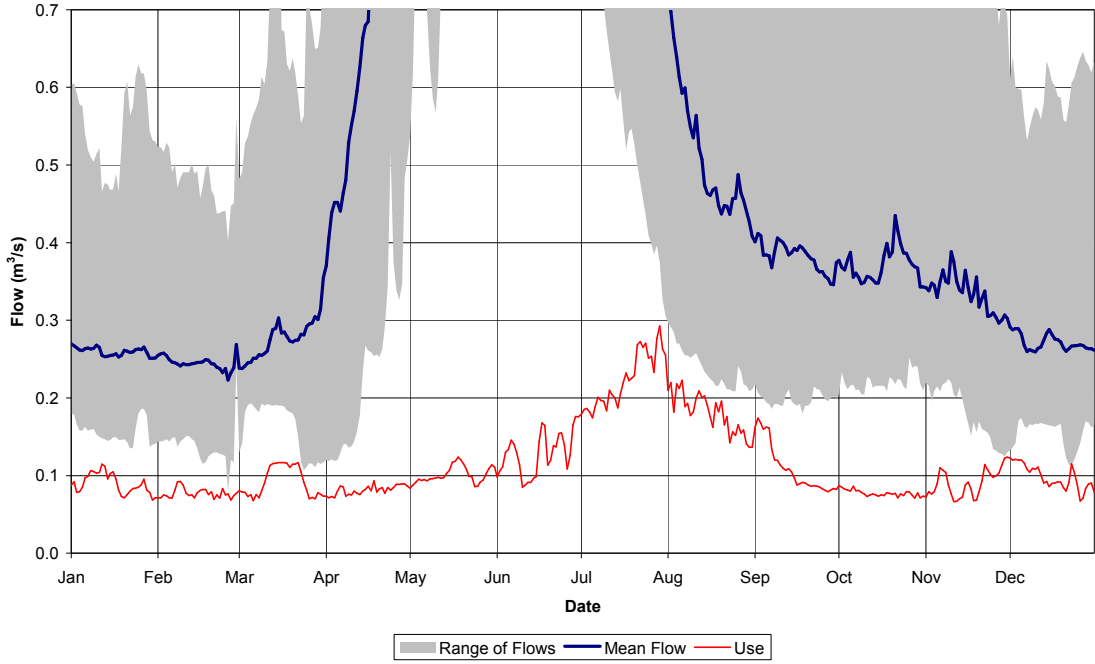


Figure 5

Matthew Creek Above Diversions Average Flow and Maximum Water Use

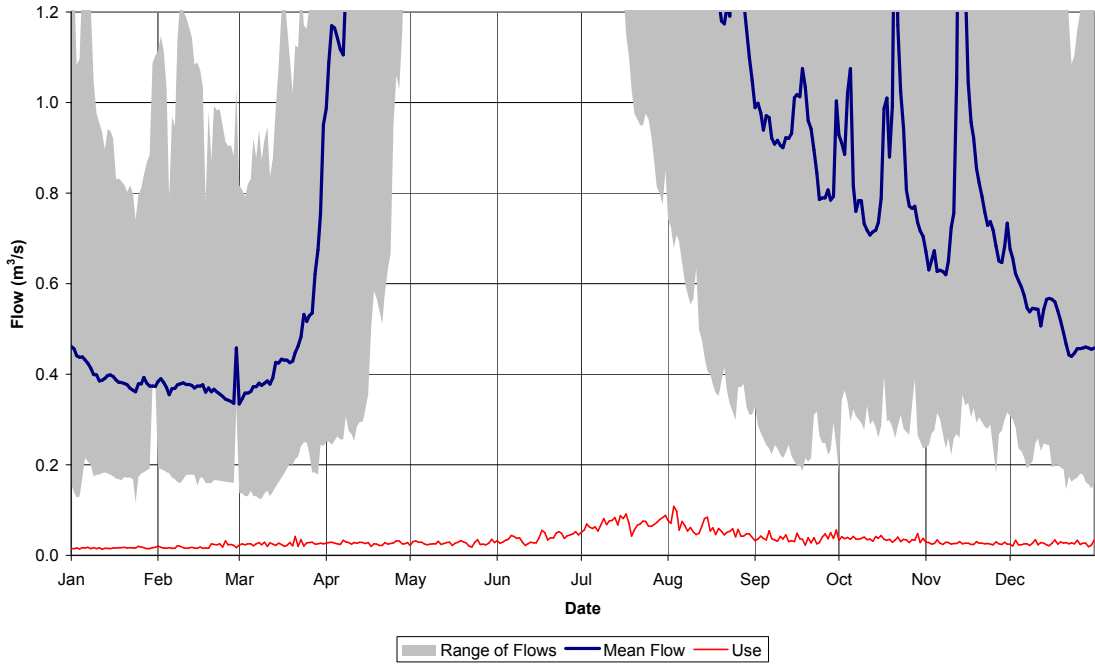


Figure 6

Limiting cases

Daily Mean Flows

By comparing the calculated low-flow values for the appropriate return period and the recorded water consumption data to the minimum flow limits outlined above, we can determine if the limits will be met, assuming water consumption remains constant in the future. For the first case, we will assume that the reservoir will not be drawn down at all, i.e. that all water consumption must be compensated for by water flowing into the reservoir. Figure 7 shows the calculated flows directly below the reservoir (the predicted flow above the reservoir for the return period minus the average consumption over the period, $0.08 \text{ m}^3/\text{s}$ and the predicted flow minus the maximum recorded 3-day average consumption) versus the minimum flow requirements set out above for Mark Creek during the winter period.

As one can see in figure 7, for low flows with a return period of greater than approximately 3.5 years, the flow below the reservoir will be less than the minimum requirement. In this case, the reservoir must be drawn down. Given the large variability in snow-making water use from year to year and day to day, there is a reasonable potential that all of the water flowing into the reservoir will be used on a heavy snow-making day with total consumption exceeding $0.10 \text{ m}^3/\text{s}$.

For the summer low-flow period, shown in figure 8, with average consumption of $0.12 \text{ m}^3/\text{s}$, the reservoir must be drawn down for low flows with return periods greater than approximately 9 years.

Additionally, we expect that water consumption and low-flows will be somewhat coupled in the summer. Hot, dry summers will have low creek flows and also higher than average water demand for irrigation. In other words, water consumption is likely to be higher than the average when flows are lower than average. The end result will be that drawing down the reservoir will be more likely than predicted above and that the shortfall will be greater. With only five years of available water consumption records, we cannot determine the degree to which consumption and flows are coupled.

**Mark Creek Winter Flows:
Calculated Flow versus Minimum Required Flow Directly Below the Reservoir**

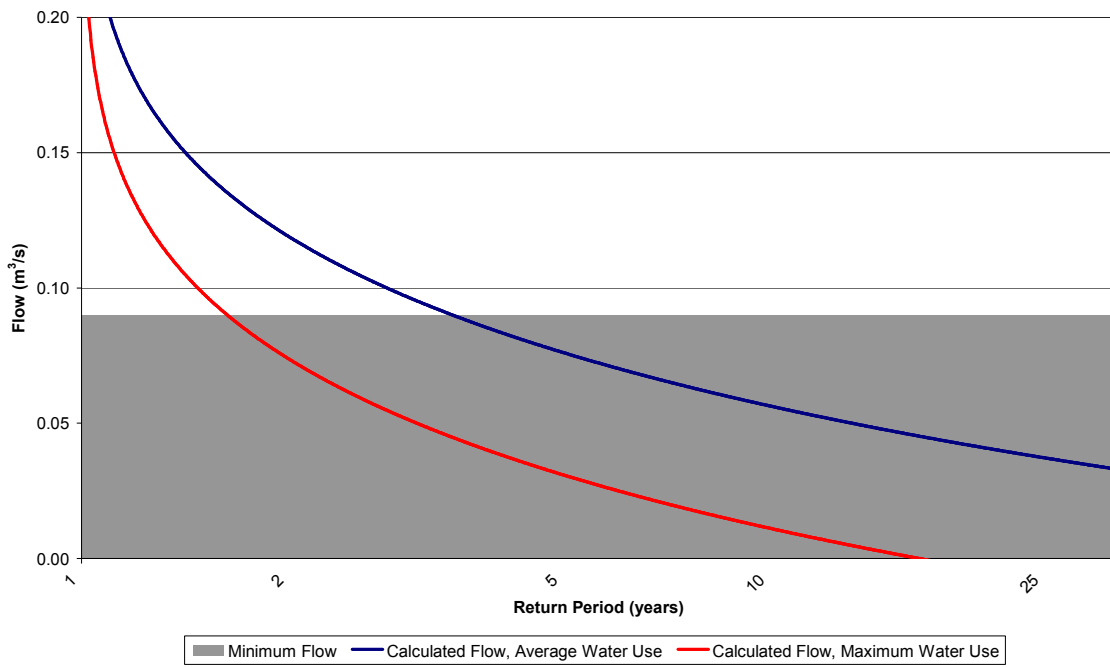


Figure 7

**Mark Creek Summer Flows:
Calculated Flow versus Minimum Required Flow Directly Below the Reservoir**

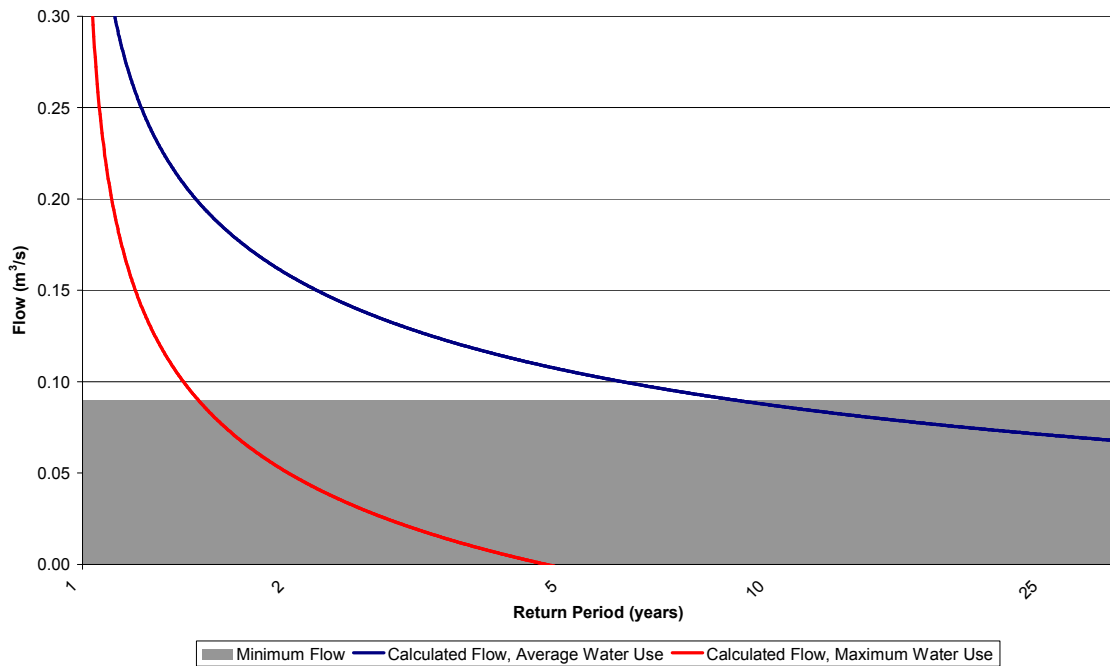


Figure 8

Intra-Day Flows

While intra-day variation in flow above the reservoir is fairly low during low-flow periods, water demand, especially in the summer, may vary significantly throughout the day, with the potential to affect downstream flows. However, the complicated interactions of water demand, the small reservoirs in the city, and the main reservoir are beyond the scope of this study and prevent us from determining if variations in intra-day flow are a potential fish stressor.

Monthly Mean Flows

While the city's preference is to maintain flow over the top of the reservoir to maintain water quality⁽⁶⁾, we have seen that this is not possible in low flow years without falling below the minimum flow requirements downstream of the reservoir.

Figure 9 shows the calculated flows directly below the reservoir versus the minimum flow requirements set out above for Mark Creek during the winter period for four different cases: average consumption with fluctuating reservoir levels, monthly average consumption for the highest year on record with fluctuating reservoir levels, average consumption with complete drawdown of the reservoir, and monthly average consumption for the highest year on record with complete drawdown of the reservoir. In this case, "fluctuating reservoir levels" means that the net flow into and out of the reservoir is zero, but that the reservoir level will fluctuate over the month, while "complete drawdown" means that at the end of the month the reservoir level will be at its lowest possible level (approximately 10% of its nominal size), allowing for seepage and dead storage⁽¹⁵⁾.

Figure 10 shows the same calculated flows for the summer period.

There is insufficient water in Mark Creek available to meet average monthly consumption in the winter period without drawing down the reservoir for a 11-year return period low flow. For high monthly winter consumption, there is insufficient water for a 6-year return period low flow. For the summer period, there is insufficient water to meet high monthly consumption without drawing down the reservoir in low flow year with a 7 year return period. It is worth noting that a complete emptying of the reservoir over one month is not desirable because low flow conditions and high demand may continue beyond one month.

On the other hand, there is more than sufficient water available in Mark Creek, including complete drawdown of the reservoir, for all cases including low flow return periods up to 30 years.

It is beyond the scope of this study to analyze the effect of reservoir drawdown on the quality of water supplied to Kimberley residents. However, we understand that the effects are significant even in cases where the water level drops a relatively small distance below the top of the dam⁽⁶⁾. In order to determine acceptable reservoir levels in low flow conditions, and thus be able to develop a plan to manage those levels, the effect on water quality of low reservoir levels over time must be determined.

**Mark Creek Winter Monthly Average Flows:
Calculated Flow Directly Below the Reservoir**

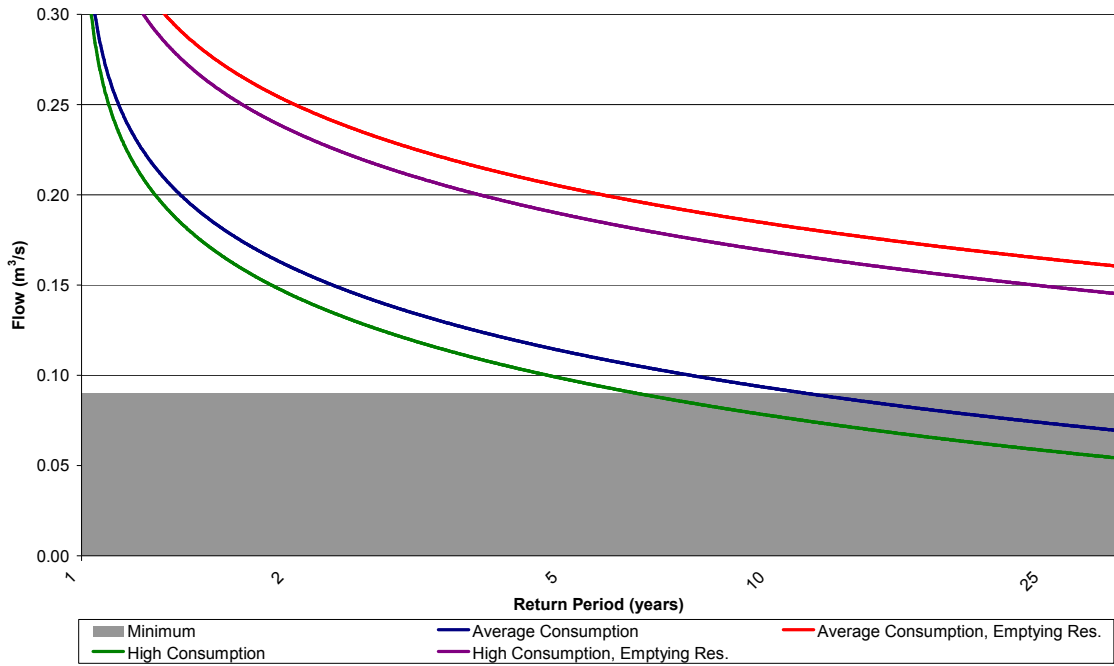


Figure 9

**Mark Creek Summer Monthly Mean Flows:
Calculated Flow Directly Below the Reservoir**

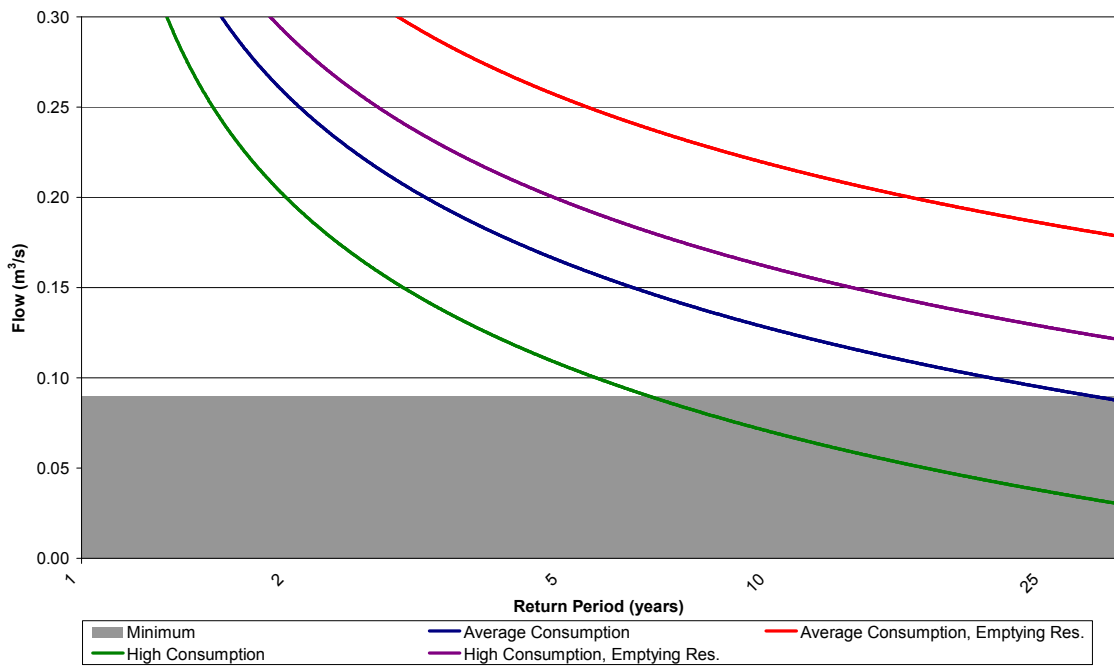


Figure 10

Water Conservation Measures

Residential

The City of Kimberley has a water conservation program to encourage residents to conserve water. The program focuses on educating residents. In 2004, the City of Kimberley instituted recommended outdoor sprinkling restrictions in an effort to reduce consumption. These voluntary restrictions limit residents to outdoor sprinkling every second day, before 10am or after 6pm.⁽¹²⁾

While July-August water consumption for 2004 through 2007 is approximately 40% lower than consumption over the same period in 2003, it is difficult to draw any conclusions about the success of the conservation program. Not only is 2003 the only year with available data before the water conservation program began, making it difficult to establish a baseline, but 2003 was a particularly dry and hot year with precipitation 73% lower, and average daily maximum temperatures 2.5C warmer, than the average for 2004-2007. Additionally, Trickle Creek golf course used 47% less water per year for 2004-2007 compared to 2003.

In any case, given the relatively high per person consumption, there is certainly room for reductions in water use in Kimberley. There are many options that other municipalities have used to reduce water consumption: watering restriction bylaws, metering, fixture retrofit programs, etc. Anything that can be done to reduce outdoor water use during August and September will reduce the chance of having to draw down the reservoir.

Industrial

However, in Kimberley, the greatest period of concern is the snow-making season. If the ski hill did not use municipal water for their snowmaking operations, average consumption during the period from November 15th to January 15th would be reduced by about 17% and peak consumption during the period would be reduced by about 50%. Since the water used for snow making need not be potable, there are a number of opportunities to reduce the peak or average demand on Mark Creek, including water storage, or pumping from Matthew Creek or the St. Mary's River. Additionally, efficiency can be improved by replacing older snow guns. Mandated or voluntary reductions in consumption during extreme low-flow periods could also help reduce the drawdown of the reservoir.

Growth, Future Concerns, and Plans

Potential Population Growth

While the resident population of Kimberley has been declining slightly over the past decade⁽¹³⁾, many condos and houses have been built and continue to be built in the Kimberley Alpine Resort area. There is also the potential for new home construction in other areas, with a number of upcoming proposed developments, both inside the current city boundary and on land currently being considered as part of a boundary expansion. Wildsight has estimated that the zoning designations in the Official Community Plan allow for construction of at least 3000 units⁽⁴⁾, which would nearly double the number of dwellings in the city. Many of these dwellings would be in the Forest Crowne, which will ultimately draw water from Matthew Creek, but developments in the Lois Creek area, densification and infill in currently developed areas, continuing development in the alpine resort area, and possible developments in the boundary expansion areas could increase the demand on the Mark Creek water system significantly. The proposed developments in the boundary expansion areas alone could increase the population in the Mark Creek water supply area by approximately 40%⁽¹⁶⁾. Increases in the number of visitors staying in Kimberley during the ski season, especially over the Christmas season, could increase demand during the winter low flow period of concern.

Water System Upgrades

Fortunately, we live in an area with a relative abundance of surface water. In the long term, the City of Kimberley could draw additional water to supply Kimberley proper from Matthew Creek or even the St. Mary's River. Unfortunately, such changes in water supply would be costly, in both capital and pumping costs.

Future Flow Trends

There is the potential for shifts to lower flows in Mark Creek due to pine beetle infestation and logging in the watershed. Pine beetle infestation levels in the Mark Creek watershed are a concern and logging operations are now affecting a significant part of the watershed. Briefly, when significant numbers of trees are removed or die, the watershed has less capacity to hold and slowly release moisture from precipitation or snowmelt and is more susceptible to evaporation, resulting in lower low flows during dry periods, especially during the summer. Pine beetle and logging are not likely to have as much effect on Matthew Creek flows because of the continuous history of logging and past forest fires in the watershed. Wildsight is currently involved in a UBC study that will attempt to quantify the changes in flows due to pine beetle tree mortality and pine beetle motivated logging in both Mark and Matthew Creeks.

Another possible long-term factor is climate change, which may result in two changes of potential significance: lower late summer flows due to warmer summer temperatures and higher winter flows due to warmer and possibly wetter winters⁽¹⁴⁾. The former is potentially problematic, especially if irrigation demand increases due to higher temperatures, while the latter is likely positive, unless there is a concurrent increase in snow-making demand. However, these changes are likely to take place over decades and are likely to be lower in magnitude than potential changes in demand due to population growth, so they are less pressing than other issues.

Recommendations

Wildsight Kimberley/Cranbrook recommends that the City of Kimberley:

- 1) Monitor and manage flows downstream of the Mark Creek reservoir to meet the minimum flow requirements in the *Integrated Watershed Management Plan*.
- 2) Conduct an assessment of fish habitat downstream of the reservoir to develop more detailed minimum flow requirements for the protection of aquatic life.
- 3) Develop a written policy to manage reservoir levels in low flow conditions while maintaining acceptable water quality.
- 4) Implement more aggressive water conservation measures in order to be able to meet the minimum flow requirements with minimal drawdown of the reservoir.
- 5) Develop and publish a long-term plan for water supply in Kimberley that lays out the advantages and disadvantages (including estimated costs) of future changes in water supply that may be brought about by growth, to help inform the public debate about future population growth and boundary expansions.
- 6) Begin discussions with Resorts of the Canadian Rockies to reduce the high water demand placed on the Mark Creek system by the Kimberley Alpine Resort during low flow periods.

References and Data Sources

Citations:

- (1) Mark Creek Water Resource Inventory, 2007, Nanrich Water Management Consultants
- (2) Matthew Creek Water Resource Inventory, 2007, Nanrich Water Management Consultants
- (3) Figures provided by the City of Kimberley
- (4) Kimberley Official Community Plan, 2005
- (5) BC Water Licenses Online Lookup
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- (6) Conversation with Bob Smith, City of Kimberley Operations Manager
- (7) Mark Creek Integrated Watershed Management Plan, 1999
- (8) Environmental Trends in British Columbia 2007: Fresh Water, BC Ministry of Environment
- (9) Historical Weather, Cranbrook Airport
<http://www.climate.weatheroffice.ec.gc.ca/climateData/>
- (10) Lower Mark Creek Fish, Fish Habitat and Impact Assessment, 2001, Interior Reforestation
- (11) An analysis of spatial and environmental factors influencing hybridization between native Westslope cutthroat trout (*Oncorhynchus clarkii lewisi*) and introduced rainbow trout (*O. mykiss*) in the upper Kootenay River drainage, British Columbia
- (12) City of Kimberley website,
<http://www.city.kimberley.bc.ca/siteengine/activepage.asp?PageID=253>
- (13) 2001 and 2006 Census, StatsCan
- (14) Preliminary Analysis of Climate Variability and Change in the Canadian Columbia River Basin: Focus on Water Resources, 2006, Columbia Basin Trust
- (15) Mark Creek Water Supply Study, 1992, Dayton & Knight
- (16) Water Supply Study – Mark Creek Supply, Technical Memorandum No. 1, 2008, Dayton & Knight

Data Sources:

Water Survey of Canada –

- Matthew Creek Above Diversions, 1989-1999
 - Mark Creek Above Diversions, 1989-1998
 - Mark Creek At Kimberley, 1996-1998
- Mark Creek Water Resource Inventory, 1998-2000, 2002-2007, Nanrich Water Management Consultants on behalf of the City of Kimberley
- Matthew Creek Water Resource Inventory, 1998-2007, Nanrich Water Management Consultants on behalf of Tembec
- Mark Creek at Kimberley (MY-16) 2001-2007, Nanrich Water Management Consultants on behalf of TeckCominco
- Total Kimberley and Marysville water consumption (2003-present) and metered industrial water consumption (1998-present), City of Kimberley