RESULTS OF 2011
WEST KETTLE RIVER, KETTLE RIVER AND GRANBY RIVER FLOW, TEMPERATURE, USEABLE FISH HABITAT & SNORKEL ENUMERATION SURVEY

FOR

KETTLE RIVER FISH PROTECTION PLANNING

Prepared
by

Phil Epp, BSc(Ag), MSc, P.Ag.
Trout Creek Hydrology & Soils
Summerland, BC

&

Greg Andrusak, BSc., R.P.Bio.
Redfish Consulting Ltd.
Nelson, BC

February 2012

Prepared for the Ministry of Natural Resource Operations
Penticton, B.C.

ACKNOWLEDGEMENTS

The work in this report was funded by the Habitat Conservation Trust Foundation, with in-kind support from the Ministry of Forests Lands and Natural Resource Operations (MFLNRO). Tara White (senior fish biologist MFLNRO, Penticton) is the project manager, and Lisa Tedesco and Kristen Murphy (Ecosystem Officers) from the Nelson MFLNRO office conducted the majority of the flow habitat monitoring field work and field data input. Thank you to Ron Ptolemy (Rivers Biologist/Instream Flow Specialist) for editorial review and technical advice.

Snorkel surveys were conducted and lead by Tara White (Penticton MFLNRO Senior fisheries biologist). As well, Christian St. Pierre (MFLNRO biologist), Al Calverly (MFLNRO biologist), Dean Watts (Department of Fisheries and Oceans Canada), Kristen Murphy (MFLNRO biologist), Stefan Himmer (contractor) and, Gary Pavan (contractor) are acknowledged for their assistance on the snorkel team.

Fly-fishing clubs from Penticton, Kelowna and Castlegar are thank for their contribution during the mark-recapture experiment on the West Kettle River.

EXECUTIVE SUMMARY

The Kettle River Watershed supports several wild fish stocks, including rainbow trout (*Oncorhynchus mykiss*), whitefish (*Prosopium williamsoni*) and 2 identified Species at Risk. It has a history of severe low flows and high water temperatures, ranging in the sub-lethal to lethal limits for salmonids (19-26 °C) More than 6 fish kills involving trout and whitefish have been recorded in the watershed over the past 2 decades. These kills occurred during summer conditions when flows were very low and water temperatures exceeded 20 C° (MoE Files 2009).

During the last two decades the quality of the Kettle River rainbow trout fishery has deteriorated due to low abundance and small size. A number of fisheries assessments have identified issues such as water and land practices, available habitat, recruitment, over-fishing, low seasonal flows and high seasonal temperatures as having severely limited rainbow trout abundance. .Consequently, today this population appears depressed (Sebastian 1989; Oliver 2001, Oliver 2002, Andrusak 2007).

The Kettle River watershed is considered to be a high priority for fish protection planning given the deteriorating fishery. This 2011 flow and habitat monitoring program continues and expands the existing information sources for fish protection planning as follows: eight continuous seasonal flow measurements sites have been established in the Kettle River watershed to supplement the information available through Water Survey of Canada (WSC) and the US Geological Service (USGS) to determine if there are changes in flow patterns along the rivers that could be attributed to localized water use. The flow measurement sites incorporate temperature monitoring to determine how river temperature varies with flow and air temperature. Useable fish habitat width at varying flows was also determined for each new site to demonstrate how useable fish habitat varies as flows generally diminish during the summer and fall months. Lastly, additional information from annual fish index monitoring and habitat suitability information collected on target species is provided. The report summarizes results of the annual snorkel surveys for rainbow trout and whitefish conducted on the Kettle and West Kettle Rivers since 2001, providing an overview of trends from index sites. In addition, habitat use and preference criteria for speckled dace were used to provide habitat-flow information for this SARA listed species.

The results and observations from the 2011 Kettle River flow / temperature / habitat and snorkel enumeration can be summarized as follows:

Flows

- Flows are highly synchronized within sub-basins (West Kettle, Upper Kettle, Lower Kettle and Granby), with patterns of storm peaks and periods of low flows well replicated throughout the watershed.
- River flows were very high (1 in 10 year return frequency) at or above mean flows in July, but diminished to median flow levels by late August and continued to decline to low flows with a 1 in 4 year return frequency by late September.
- The lowest flows ranged from 5 to 6% Long Term mean annual discharge (LTmad) in the upper West Kettle and Granby Rivers and from 7 to 9%LTmad in the lower West Kettle and Kettle Rivers.
- The flow patterns among stations in the Granby and Lower Kettle sub-basins indicate periods at downstream sites that are lower than flows upstream. This is interpreted as evidence that downstream flows are being reduced by upstream water use.

Temperatures

- River temperatures were lower than in 2010, only reaching as high as 22 ^{o}C maximum daily temperature in August. River temperatures vary by site in each river, with a differences of 2 to 3 ^{o}C in August between the upstream and downstream sites.
- River temperatures are well correlated with mean air temperature, with the highest river temperatures measured on the days when mean air temperature exceeds 22 ^{o}C.
- River temperatures are also highly synchronized within and among sub-basins, with periods of high and low water temperatures well replicated throughout the watershed.
- River temperatures show up to 6 ^{o}C in diurnal fluctuation, with the highest water temperatures in later afternoon and lowest temperatures at about 7:00 A.M. to 9:00 A.M.
- Temperature and higher flow correlation data is available for the WSC station near Westbridge in 2011. This data does appear to indicate that higher flows do

result in somewhat lower river temperatures on high air temperature days, but only when the flow was higher than 12 m^3/sec.

- Consistent with 2010, there appears to be little if any correlation between river temperature and flow at the moderate to low flows that are common from mid July into September. Higher river temperatures commonly occur at low flows during this period, but this is mostly coincidental as periods of lower flows are associated with hot and dry weather conditions.

Useable Habit Width / Flow

- Useable habitat width vs. flow analyses show that for rainbow trout parr, useable habitat width is optimized or close to optimized values when flows are at 20%LTmad.
- Useable habitat width is significantly lower at flows of 10%LTmad, but riffle velocities still tend to be satisfactory at these flows.
- Useable habitat width declines rapidly as flows decrease further below 10% mad, with both riffle velocities and riffle depths declining rapidly.

Rainbow trout issues

- Lack of deep, fast water habitat (especially pools) limits rainbow trout abundance
- Late summer water temperatures can become lethal to rainbow trout
- Flows < 10%LTmad combined with high summer temperatures are problematic for trout and whitefish and mortalities can be expected at temperatures > 24°C if prolonged.
- Snorkel survey data provides population trend data but is of little use for interpreting fish flow requirements.
- Low flows and high temperatures most likely influence trout growth and survival but there are a number of other factors related to habitat such as pool limitation that also influence growth and survival.

.

Annual snorkel counts

- The Kettle River demonstrated considerable increases in rainbow trout numbers based on snorkel surveys at annual index sites
- The West Kettle River numbers declined substantially in both index sites

- Granby River counts demonstrated a slight decline in overall fish numbers in 2011 compared to 2010.
- Mark –recapture data collected on snorkel efficiencies in the West Kettle River for deriving abundance estimates may be biased as a result of high flow conditions in the summer of 2011.
- It is unsure whether trends in fish populations from snorkel surveys are a result of flow related issues on these systems. Nevertheless, data does support the fact that flows below < 10%LTmad, combined with high temperatures are problematic for fish in these systems.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RESULTS OF 2011
WEST KETTLE RIVER, KETTLE RIVER AND GRANBY RIVER
FLOW, TEMPERATURE, USEABLE FISH HABITAT &
SNORKEL ENUMERATION SURVEY
FOR
KETTLE RIVER FISH PROTECTION PLANNING

P. Epp and G. Andrusak
February 2012

1. INTRODUCTION AND BACKGOUND

This report presents the results of the 2011West Kettle River, Kettle River and Granby River flow, temperature, useable fish habitat and snorkel enumeration survey as an update of the 2011 report (Epp & Andrusak, 2011) which reported on the 2010 results. There is reference to and some comparisons to the 2010 results in this report, but the reader is referred to the 2011 report for further details of the 2010 results.

The Kettle River Watershed supports several wild fish stocks, including rainbow trout (*Oncorhynchus mykiss*), whitefish (*Prosopium williamsoni*) and 2 identified Species at Risk. It has a history of severe low flows and high water temperatures, ranging in the sub-lethal to lethal limits for salmonids (19-26 °C) (Oliver, 2002). More than 6 fish kills involving trout and whitefish have been recorded in the watershed over the past 2 decades which can be directly attributed to environmental and anthropogenic (water user) factors (MoE Files 2009). These kills occurred during summer conditions when flows were very low and water temperatures exceeding 20 C°.

Currently Kettle River rainbow trout and speckled dace (*Rhinichthys osculus*) are of conservation concern with the latter species listed in 2009 under the Federal Species at Risk Act (SARA) as endangered. During the last two decades the quality of the Kettle River rainbow fishery has deteriorated due to low abundance and small size. Issues such as: water and land practices, available habitat, recruitment, over-fishing, low seasonal flows and high seasonal temperatures have severely limited rainbow trout abundance and today this population appears depressed (Sebastian 1989; Oliver 2001, Oliver 2002, Andrusak 2007). A key bottleneck to rainbow trout production is a lack of deep water habitats that in turn affect thermal refuge habitat for sub-adult and adult fish during low flow periods.

A significant contributor to the problem of low flows and high water temperatures is believed to be water use including both surface and ground water sources (Aqua Factor Consulting Inc. 2002). There are 275 irrigation licenses on the Kettle River and its tributaries upstream of the USA border at Midway with a total licenced withdrawal volume of about 23,500 Acre Feet per season. This equates to 3.4 m^3/s of flow reduction in the Kettle River at Midway at peak irrigation in July and August (assumed to be 1% of total allocation) if all water licences are fully utilized. Very few of these licences are backed by water storage to supplement base flows, so the volume of licensed water can exceed water availability during dry years and result in unsatisfactory residual flows for ecosystem health. The water use is essentially run-of-river diversion which is most damaging in drought years and in smaller streams. Small streams such as July Creek (LT mad = 253 L/s) near Grand Forks has a 1 in 2 yr summer baseflow (residual) of only 7% LT mad and ranges from 4% in a drought to 19% LT mad in a wet summer.

Water Survey of Canada (WSC) currently operates seven active stream flow gauging stations in the Kettle River watershed. Active stations include 1 on the mainstem Kettle River, 2 on the West Kettle River, 1 on the Granby River, and 1 tributary to each of the Kettle, West Kettle and Granby Rivers. The US Geological Service (USGS) also operates two gauging stations on the Kettle River mainstem near the BC border in Washington State. In addition, there are numerous discontinued WSC stations with archived flow records within the Kettle River network and within the landscape unit called Northern Okanagan Highland EcoSection. Active and discontinued stations are listed in Table 1 and Table 2 respectively below.

Table 1. Kettle River Watershed Active Hydrometric Stations

River	Station ID	Length/Duration of Record
West Kettle River at Westbridge	08NN003	1914-1921, 1975-2011
West Kettle River near McCulloch	08NN015	1949-1957, 1964-2010
Kettle River near Westbridge	08NN026	1975-2011
Kettle River near Ferry (USGS)	08NN013	1928-2011
Kettle River near Laurier (USGS)	08NN012	1929-2011
Granby River at Grand Forks	08NN002	1814-1915, 1926-1931, 1966-2011
Trapping Creek near the Mouth	08NN019	1965-2010
Lost Horse Creek near Christian Valley	08NN028	1998 - 2010
Burrell Creek above Gloucester	08NN023	1973 - 2010

Analysis of the active WSC station data since 1965 shows increasing trends in monthly flows from November to April - May, with a strongly increasing trend in April, followed by decreasing flows from May - June to October with the greatest rate of decrease occurring in June. The strong increase in April flows suggests an earlier freshet. This could be the result of forest harvesting but warmer spring temperatures in recent years leading to earlier snow melt could also account for the earlier melt. The increasing winter flows also suggest warmer temperatures possibly due to climate change could be modifying flow timing. Lower summer flows would be expected from the earlier onset of base flows following earlier freshets. Water use could also have increased over time as more water licences have been issued.

Table 2. Kettle River Watershed Inactive Hydrometric Stations

River	Station ID	Length/Duration of Record
West Kettle River below Carmi Creek	08NN022	1973-1996
West Kettle River at Beaverdell	08NN025	1974-1976
Kettle River at Kettle Valley	08NN004	1914-1922
Kettle River at Carson	08NN005	1913-1922
Kettle River near Grand Forks	08NN024	1974-1991
Kettle River at Cascade	08NN006	1916-1934
Stirling Creek Diversion to McCulloch Reservoir	08NM212	1977-1984
Trapping Creek at 1220 M Contour	08NN020	1970-1981
Beaverdell Creek near Beaverdell	08NN027	1976-1984
Rock Creek near Rock Creek	08NN007	1921, 1971-1984
Myers Creek at International Boundary	08NN010	1923-1950, 1968-1977
Boundary Creek at Greenwood	08NN001	1913-1918, 1960-1980
Boundary Creek near Midway	08NN011	1929-1932, 1943-1953, 1971-1977
July Creek near Grand Forks	08NN018	1965-1974
Pass Creek near Grand Forks	08NN008	1921
Dan O'Rea Creek near Grand Forks	08NN009	1921
Moody Creek near Christina	08NN021	1971-1984
Sutherland Creek near Fife	08NN016	1960-1970, 1973
Christina Creek at Outlet of Christina Lake	08NN014	1944-1946

Further analysis of the WSC flow data shows substantial year to year variability in the flows. On an annual runoff basis, flows in the West Kettle River at McCulloch have varied from lows of 54% of the 45 year average in 1987 to a high of 169% of the average in 1997. Year to year monthly flows vary even more widely. July flows, for example, range from a low of 15% of average in 1985 to a high of 312% of July average in 1982. Similarly, August flows range from a low of 14% of the August average to a high of 638%, and September flows range from 11% to 548% of September average. Winter flows are generally less variable, but January flows also range from 30% to 562% of average because of unusually high flows in January of 2005.

Winter base flows are even lower than those experienced in the late summer therefore potential fish mortality is also possible with lower flows and freezing temperatures. For example on the West Kettle River at McCulloch, the 30-day 1 in 2 yr winter base flow is 8% LT mad and ranges from 4 to 18% LT mad.

2011 MONITORING OBJECTIVES

The 2011 flow and habitat monitoring program continues and somewhat expands the work that MOE (now) initiated in 2009 and expanded in 2010.

1. The first objective of the 2011 monitoring program was to again provide continuous seasonal flow measurements at seven 2010 sites in the Kettle River watershed to supplement the information available through WSC and the USGS. This included the Kettle River near Midway site established in 2009, plus two new sites in each of the West Kettle, Kettle and Granby Rivers. The goal of adding the additional monitoring sites was to be able to determine if there are changes in flow patterns along the rivers that could be attributed to localized water use. For 2011 an 8th flow monitoring site was added on the Granby River to try to answer questions about flow anomalies noted in 2010.

2. The second objective of the 2011 monitoring program was to again provide continuous seasonal river temperature measurements at the flow monitoring sites as well as at the three real time WSC sites in these rivers. The goal of the temperature monitoring was to determine how river temperature varies with flow and air temperature.

3. The third objective of the 2011 monitoring program was to continue the flow / habitat monitoring in the Kettle River watershed to quantify how the useable fish habitat width varies with flow over the range of flows experienced in late summer and fall. One more habitat site was added in the Granby River to supplement the

previously established two in the West Kettle River, three in the Kettle River and two in the Granby River. The flow / habitat data is combined with the flow data from WSC and the flow data from the new flow monitoring sites to demonstrate how useable fish habitat varies as flows generally diminish during the summer and fall months.

4. Lastly, additional information from annual fish index monitoring and habitat suitability information collected on target species is provided. The report summarizes results of the annual snorkel surveys for rainbow trout and whitefish conducted on the Kettle and West Kettle Rivers since 2001, providing an overview of trends from index sites. In addition, habitat use and preference criteria for speckled dace were used to provide habitat-flow information for this SARA listed species.

2. METHODS / MEASUREMENTS

Seasonal Flow Measurements

A total of eight seasonal flow monitoring sites are now established in the W. Kettle, Kettle and Granby Rivers (Figure 1). One site in each river was upstream of most of the licensed water use, with additional sites downstream spaced to provide data at 15 to 20 km intervals. Ideally there would have been two transects at each site - one in laminar flow such as in a glide or pool tailout to provide unbiased flow volume measuring conditions, and a second in a riffle for the useable width analyses. Due to time availability constraints, only 1 transect in a riffle location was measured at each site.

There is an associated lack of precision in the flow measurements in the transects in the smaller rivers like West Kettle at Carmi that have greater bed roughness (bias source due to turbulence) as reflected in the lower r^2 values in the 2010 rating curves. The Carmi transect was moved upstream of the Hwy 33 bridge for 2011 to reduce stream bed roughness and bias.

Each site consisted of a staff gauge and a Global Water WL16 UT water level recorder set to record water level and temperature at 30 minute intervals. The recorders and staff gauges were all installed on July 27 and 28, but flows were still to high to allow for the rivers to be waded to conduct the depth and velocity transects necessary to establish water level rating curves and the flow / habitat relationships. The installations at Kettle

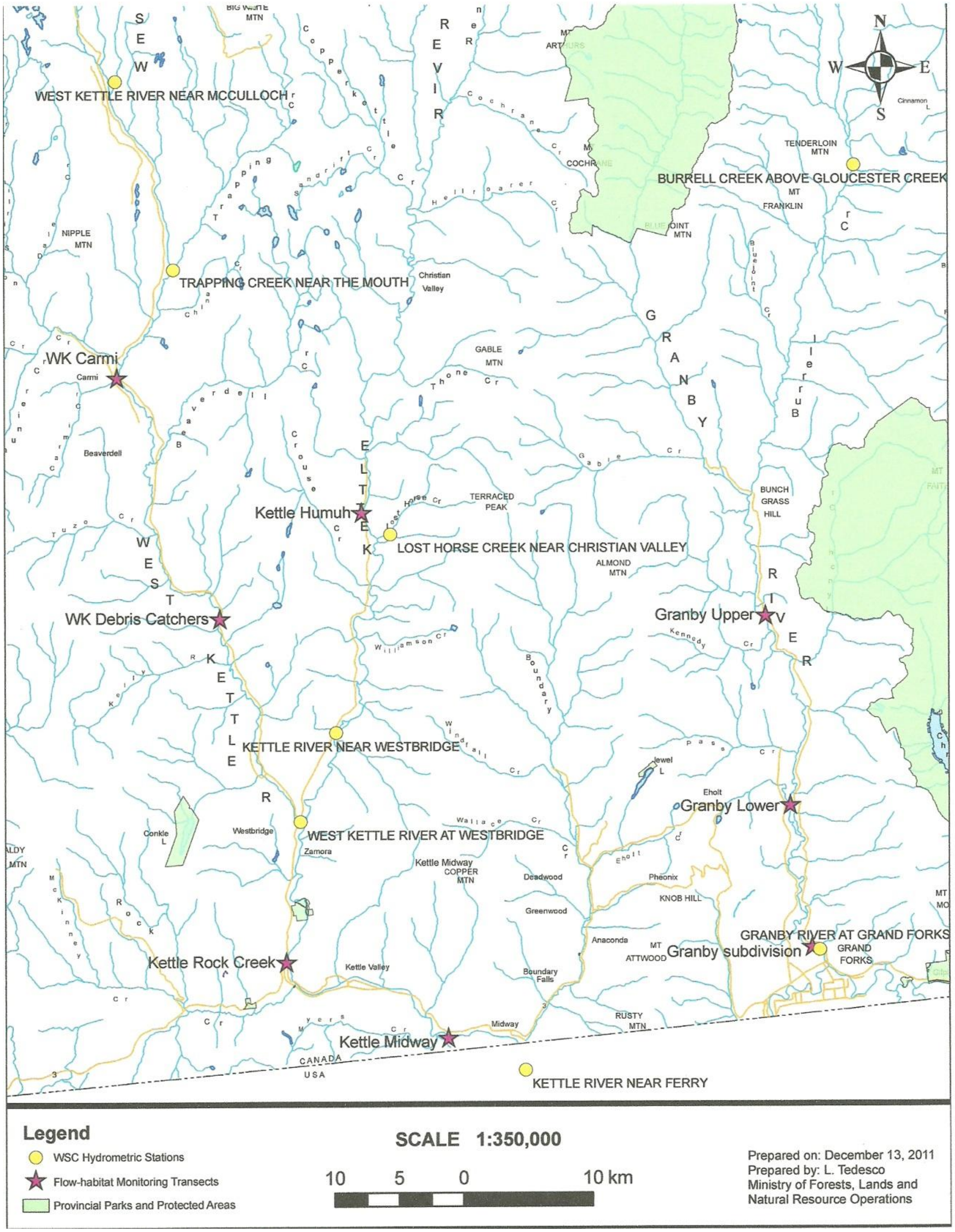


Figure 1. Location Map for the Flow / Temperature / Habitat Monitoring Sites and WSC / USGS Hydrometric Stations.

Humuh, Kettle Rock Creek, Kettle Midway and Granby Upper all required new T-posts to attach the equipment to as the 2010 T-posts at these sites were lost in the high freshet flows of 2011.

Transect measurements started on the West Kettle on August 3 and at the Kettle and Granby River sites on August 10 as flows diminished enough for wading to be feasible. Depth and velocity measurements on each transect were carried out weekly until late September with a final set of measurements in early October. All transects had approximately 20 to 25 verticals across the river channel where distance from bank, depth and velocity were recorded. Velocities were measured with a Marsh McBirney portable flow meter and the staff gauge level was noted at the start of each set of measurements.

The water level recorder data was also downloaded with a laptop computer after each set of measurements. After the final transect measurements in early October, bi-weekly data downloads continued until the end of October when the water level recorders were removed for the winter. There were several equipment / data interruptions in 2011 that shortened two of the water level data records and required adjustments to two sets of the data records. First, the water level recorder at the Kettle Humuh site turned off shortly after initial activation and was not reactivated until August 12, so the Kettle Humuh data set starts on August 12 rather than July 27. Second, the Kettle Humuh and Kettle Midway installations had to be shifted several meter to move them into deeper waters as the initial 2011 installation sites were close to de-watering. Staff gauge levels were noted before and after the re-location and the rating curves and water level records were adjusted accordingly. Finally, the W. Kettle Carmi water level experienced battery failure near the end of September which prematurely ended that data set.

Recorded values were entered into Excel spreadsheets to calculate flow values based on the depths and velocities at the verticals. The flow values and corresponding staff gauge levels were then used to construct a discharge curve for each site. There are 8 or 9 transects for each site that are used to construct the discharge curve. Power curves were generated and the data fit was generally satisfactory with r^2 values ranging from 0.97 to 0.99, except for Kettle Humuh with a lower r^2 value of 0.95 due to a poorer point to curve fit at the lowest flows.

Water levels recorded by the water level recorders were corrected to correspond to the staff gauge levels as the two values were different, but the difference remains relatively constant over the fluctuating water levels. The rating curves for each site were then applied to the 30 minute interval water levels to generate continuous flows for the July to October period. The 30 minute flows were also averaged for each day to provide daily flows for summary and comparison purposes.

Transect data, discharge curves, and water level downloads are stored in Excel format on the accompanying CD.

Temperature Measurements

Each of the Global Water WL16 UT units (except for the new Granby Subdivision site) recorded temperature as well as water level at the 30 minute intervals. Water temperatures were also recorded at the W Kettle and Kettle WSC sites, plus W. Kettle Carmi, W. Kettle Midway, Granby Upper and Granby Subdivision with Hobo temperature loggers that were also set to record temperatures at 30 minute intervals. These units were installed on July 27 & 28 when the level recorders were installed and removed and read when the water level recorders were removed in late in late October. Temperatures were also measured at each site with a handheld thermometer at the time of each transect measurement.

The temperature sensors in the Global Water units were re-calibrated after experiencing the inaccurate temperature readings in 2011. The temperatures recorded by these units in 2011 were closer to the handheld thermometer measurements, but still tended to be lower by a degree or two, and also were lower than the Hobo units when both recorded temperatures at the same location. The Hobo temperatures also did not exactly match the handheld temperatures. Hobo temperatures were generally within 1 degree C of the handheld thermometer readings, but were also consistently lower than the handheld temperatures. Minor difference between the Hobo and handheld temperatures is not surprising. The handheld thermometer was read to the nearest 0.5 degrees, the thermometer temperatures are measured in shallow water at the shoreline compared to the Hobo unit which is up to 1 meter deep (depending on water level) at the bottom of the staff gauge, and the timing of measurements (the Hobo units record temperature every 30 minutes while the handheld measurement is random) which be up to 15 minutes different between the two.

As in 2010, an initial attempt was made to correct the Global Water unit temperatures through correlation with the hand held thermometer temperatures. This resulted in a relatively good fit of corrected temperatures to the measured temperatures, but there were still differences between the corrected Global temperatures and the Hobo temperatures at the locations that had both units. The likely reasons are the generally higher readings from the handheld units than the Hobo units which bias the correction to higher temperatures, and perhaps more importantly the measured temperatures cover less than half of the range in actual temperatures so the correlation can be significantly off at the lower and higher temperatures.

A more definitive correlation was then achieved by synchronising the time on 7 Global Water Units with temperature loggers, setting the logging time to 15 minute intervals and placing all of them in a bucket of water which was then moved outdoors into freezing temperatures which gradually reduced the water temperature to 0 degrees C, and then bringing the bucket back indoors where temperatures gradually increased to room temperature (21 degrees C) and then were raised even further (25 degrees C) with hot water additions. Matching temperatures were also recorded at a number of times over the temperature range providing a better data set for correlation and temperature correction. The trend lines for the correlations had r^2 values ranging from 0.9963 to 0.9985 indicating a very good fit and the trendline formulas were then used to correct the Global Water unit temperatures.

The re-corrected temperatures fit well with the Hobo temperatures where they are duplicated and also match the field hand held temperature readings quite well suggesting that they can be used with a high degree of confidence.

Temperature downloads and the temperature correction calculations are stored in Excel format on the accompanying CD.

Weighted Useable Width

The depth and velocity data from the flow transects was also transferred to a series of Excel spreadsheets that calculate weighted useable width for rainbow trout fry and parr on each of the measurement dates. The useable width is weighted from the probability of use in each cell based on habitat suitability indices (HSI) look up tables provided by R. Ptolemy (MOE Fisheries Biologist Victoria BC pers. comm.), multiplied by the cell widths and then summed for a total weighted useable width for that transect at that flow. Informal validation of the parr HSI curves was based on direct snorkel observation of fish in context to meso-habitat conditions over several years of reach-level surveys. Numerous years of snorkel observations indicate that rainbow parr and adults tend to orientate in or near fast-water habitats that positions them in close proximity to drifting insects originating from riffles, rapids or cascades. The useable widths for each date were then plotted against the flows to generate a chart of how useable width varies with flow. The relationships are often complex, with a 3rd order polynomial trend line generally providing the best fit to the data.

The weighted useable width calculations are stored in Excel format on the accompanying CD.

WSC and USGS Real time and Provisional Flow Data

Flow data for the West Kettle River at Westbridge, the Kettle River near Westbridge and the Granby River at Grand Forks were downloaded from the WSC Real time hydrometric data site. Flow data for the Kettle River at Ferry and the Kettle River at Laurier were downloaded from USGS real time hydrometric data site. Provisional data for the non real time WSC hydrometric sites (West Kettle River near McCulloch, Trapping Creek near the Mouth, Lost Horse Creek near Christian Valley and Burrell Creek above Gloucester Creek) for 2011 were also requested and received from WSC. These data sets are all provisional and subject to change when the annual data validation and correction takes place. Past experience suggests that while minor changes in data values are likely on some dates, the overall data is quite useable for flow comparisons with the seasonal flow data from this study.

Snorkel Enumeration Surveys

Mark-Recapture & Snorkel Efficiency

In 2011, a mark–recapture experiment was conducted on the West Kettle within the; control and treatment snorkel survey sites. Angling captured rainbow trout were externally marked by inserting a highly visible Floy® FD-68B FF Anchor Tags with 3/8¨ monofilament using a Floy® Mark II Fine Fabric gun. Fish were captured during angling and were held for 5-10 minutes before they were tagged and released. Floy tags were inserted just below and in front of the anterior insertion of the dorsal fin. Following tagging, fish were checked to ensure tag was inserted and that no harmful effects from tagging were observed before fish was released.

Obtaining annual estimates of fish abundance using snorkel survey counts relies on the ability of surveyors to accurately observe fish numbers and size. Understanding observer efficiency is crucial in deriving fish abundance from fish counts using snorkel surveys. However, variable flows, visibility, visual obstructions (logs, debris, boulders), size of fish and inter-annual variability in individual surveyors are factors which effect the variability in obtaining estimates of observer efficiency.

Use of mark-recapture during snorkel surveys counts are often used to assess observer efficiency and derive estimates from fish counts. In many cases they are often simple in concept to implement but must ensure that certain assumptions are met. In general, estimated abundance is derived from counts over the discreet period, N_i, is found using the simple equation (Haddon 2001);

$$\hat{N}_i = \frac{M_i C_i}{R_i} \qquad (1)$$

Bias in this estimate can be reduced using the Peterson mark-recapture equation;

$$\hat{N}_i = \left[\frac{(M_i + 1)(C_i + 1)}{(R_i + 1)}\right] - 1 \qquad (2)$$

Where

M_i = Number of fish marked and released during discreet period *i*,
C_i = Number of unmarked fish sighted during discreet period *i*, and
R_i = Number of marked fish re-sighted during discreet period *i*.

The variance, $V(N_i)$, of the Peterson estimate can be calculated using;

$$V(\hat{N}_i) = \hat{N}_i^2 \frac{(C_i - R_i)}{[(C_i + 1)(R_i + 2)]} \qquad (3)$$

The 95% confidence interval (CI) is ± 1.96(sd).

Kettle and West Kettle rivers

Seven snorkel survey index sites have been established throughout the Kettle valley (Figure 2). Except for 2002, snorkel surveys have been conducted on the Kettle River since 2001 in July and September. Index sites, for monitoring trends in fish populations, were established by Oliver (2002) from the upper Kettle River extending down to the lower Kettle River. More specifically, index sites include KR 1 in the upper river reach through to KR 7 in the lower river below Grand Forks, BC (Fig. 1). Snorkel surveys have been conducted using a combination of 2-5 divers covering equidistant lanes spanning the entire wetted width of the river. Swimmers remained in standardized counting lanes as described in Slaney and Martin (1987). Since 2001, replicating individual sites has varied along with the number of divers and distances in some years. As a result, the mean of these counts represent indices of abundance that are informative in monitoring population trends. During the surveys fish counts were focused on enumerating salmonids in four size categories; 0-10 cm, 10-20 cm, 20-30 cm and >40 cm.

In 2004, catch and release regulations were implemented on portions of the Kettle River including index sites KR 2, KR3 and KR 7 while remaining index sites KR 1, KR4-KR 6 retained catch and harvest opportunities. In 2008, KR5 was added as a monitoring site to collect information on fish abundance prior to placement of LWD habitat structures. As well, a large complex side channel ~600 m in length was surveyed within the KR5 site in 2008 by two divers.

Similarly, snorkel surveys have been conducted on the West Kettle River since 1997 to measure the response of rainbow trout and whitefish abundance to in-stream restoration, primarily the response to additions of large woody debris (LWD). Annual surveys are conducted on index sites within a control section and a treatment section. Details of work and early responses are summarized by Slaney et al. (2001). Counts were focused on enumerating salmonids in four size categories; 0-10 cm, 10-20 cm, 20-30 cm and >40 cm.

Granby River

In 2010, similar to previous years (2007-2009), summer snorkel surveys were conducted to ascertain the effect of the 2003 regulation changes to harvest (Oliver 2002; Askey 2009).

Three snorkel sites (GR 2, GR 3, GR 6), from Oliver (2002), were selected for re-assessment beginning in 2007. The reaches used in 2007-2009 are believed to overlap substantially with the reaches in Oliver (2002), but the exact put-in and take-out areas may be different as no UTMs were provided in the first report (See map for reach locations). GR 2 was selected based on the extremely low abundance estimates for this reach in 2001 (despite apparently good habitat), and the other sites were selected as areas representing good fish abundance and fishing access/opportunities. Snorkel counts were conducted during midday hours (9am to 5pm) and done with crews of four people spread evenly into discrete lanes across the river. Counts were focused on enumerating salmonids in four size categories; 0-10 cm, 10-20 cm, 20-30 cm and >40 cm.

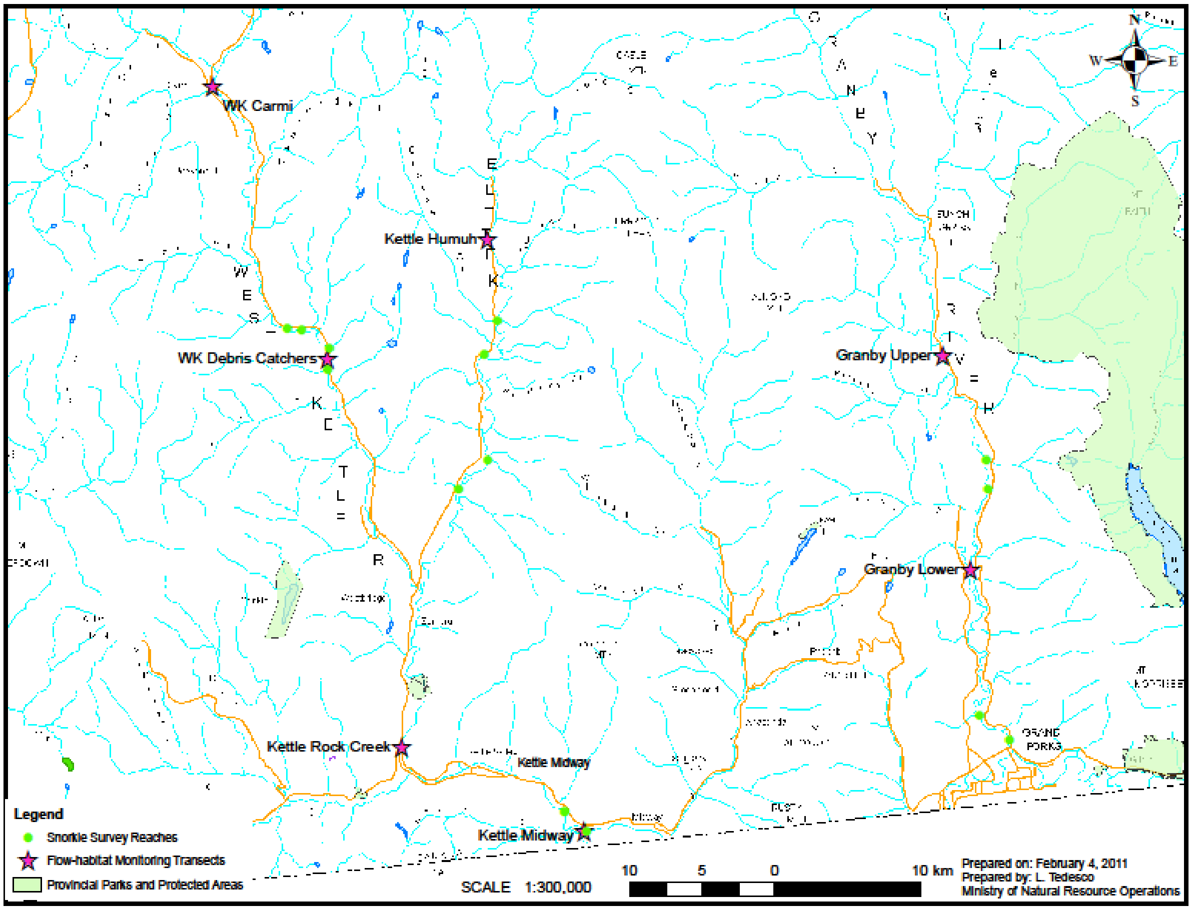


Figure 2. Location Map for the Snorkel Survey Reaches.

3. RESULTS & DISCUSSION

Seasonal Flow Measurements

West Kettle River

Flow data from 2011 is available for 4 sites on the W. Kettle River - the WSC real-time site at Westbridge, preliminary data from the WSC non real-time site at West Kettle River near McCulloch, and the Carmi and Debris Catchers seasonal sites from this project, plus preliminary flow data for Trapping Creek (a large tributary between the McCulloch and Carmi sites) from WSC.

Figure 3 shows the relationships among the available flow data for the W. Kettle River from near McCulloch (upstream of the agricultural and domestic water use), down through the Carmi site and the debris catchers site (below Beaverdell and midway between Carmi and Westbridge), and at Westbridge (where it joins the Kettle River) as well as Trapping Creek (tributary upstream of Carmi) for the period from July 15, 2010 to October 31, 2010. The flow values are shown in log scale to emphasize relative differences and focus on the lower flows.

As in 2010 there are several strong relationships among the flows at these 5 sites over the summer and fall time frame in 2011:

- The overall flow trend is identical or highly synchronous, with low flows and storm related flow peaks replicated at each site. Flows increase in a downstream direction as the watershed size increases and more tributaries join the river, and storm peaks often are delayed a day at the downstream locations as the increased flows move downstream.

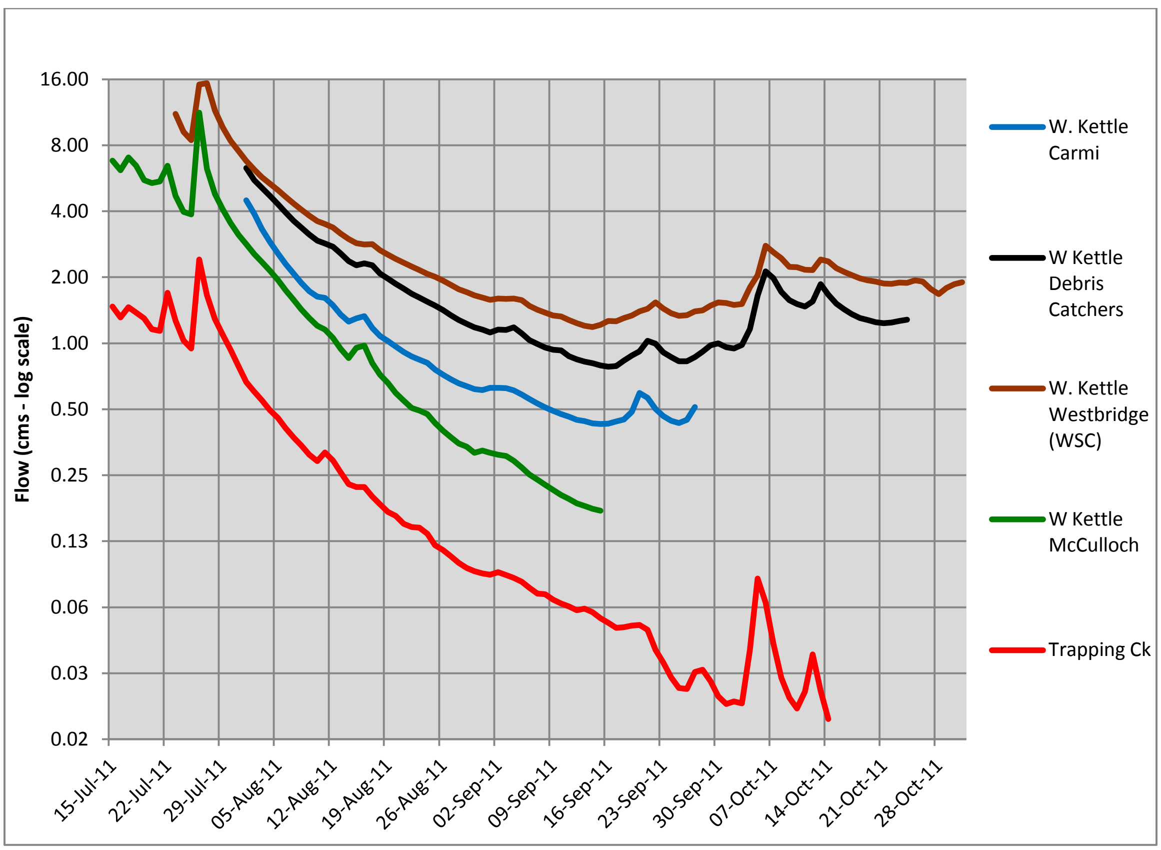


Figure 3. West Kettle River Daily Flows - July 15 to October 31, 2011

- It was also apparent in 2010 that there was a much greater storm response at the Carmi site with storm peak flows matching or even exceeding the downstream storm peak flows before receding faster between peaks. This implies that there is a strong surface flow / groundwater connection at the downstream sites where summer storm peaks are buffered by groundwater recharge. This is also seen in the Trapping Creek results for 2011, but no for Carmi as there were no storms during the period for which the Carmi has data in 2011.
- A similar pattern of upstream storm responses relative to W Kettle at Westbridge site are also seen in the historical WSC data for W Kettle near Carmi (to 1996) and the W. Kettle at McCulloch and Trapping Creek WSC stations.

It was anticipated in 2010 that water extractions from both surface and groundwater sources would show up in the flow patterns among the sites with flows diminishing faster at the downstream sites than at Carmi and McCulloch which are above most (Carmi) and all (McCulloch) of the summer and fall water use. As in 2010, the expected trend does not stand out in the chart in Figure 3. Several reasons were suggested in 2010 as to why the expected trend was not apparent:

- The buffering in the downstream flow patterns from the surface / groundwater pattern may be masking other changes in flows,
- Preliminary data for Westbridge site may be in error - WSC measured deviations from the rating curve vary from 2% to 20% during summer / fall 2010,
- Measured flows at Carmi in August 2010 were exceptionally low relative to the historical data for the discontinued WSC W Kettle at Carmi site. This could have been an artefact of transect characteristics which made low flow measurements difficult.

The published WSC data for 2010 changed marginally from the real-time values, so preliminary data error for the Westbridge site was not a significant factor in the trends. Also, the 2011 flow data using a new transect site to improve flow measurement accuracy is still very low relative to historic Carmi flow data in September, suggesting that 2010 Carmi flow records were in fact reasonably accurate. The recent flow data in fact suggest that a more likely rationale for the low flows relative to historic may be due to differences in the site location, and/or ongoing changes in flow regimes due to factors such as climate change.

A fourth reason for the expected trends not showing up in the charts is that smaller, headwater streams in general have lower groundwater influence due to bedrock geology and high basin slope and so they may be poor proxies for natural baseflows on downstream, larger streams. This becomes very evident in Table 3 with the preliminary WSC data for W. Kettle at McCulloch and Trapping Creek included. Trapping Creek flows in particular plummet as a percentage of Long Term Mean Annual Discharge (LTmad) in late September and October relative to the larger river sites.

Trapping Creek has an area of 145 km^2 and West Kettle near McCulloch has an area of 233 km^2 as compared to the larger West Kettle River at Westbridge site with an area of 1890 km^2 and both show much larger flow reductions as a percentage of Long Term MAD by mid September. This becomes even more evident in the Trapping Creek site where preliminary flow data is available through October. As such it becomes apparent that the natural differences in flow patterns among the monitoring sites are sufficient to mask the flow reductions due to water use among these sites.

Table 3. Flow summary for W. Kettle River sites plus Trapping Creek in 2011.

Date	**W Kettle McCulloch %LTmad**	**Trapping Creek %LTmad**	**W Kettle Carmi %LTmad**	**W Kettle Debris Catchers %LTmad**	**W Kettle Westbridge %LTmad**
1-Aug-11	84%	47%	48%	59%	51%
8-Aug-11	42%	24%	20%	31%	31%
15-Aug-11	28%	15%	14%	21%	22%
22-Aug-11	15%	10%	9%	16%	17%
1-Sep-1	10%	6%	7%	9%	12%
8-Sep-1	7%	5%	5%	7%	10%
15-Sep-11	5%	4%	5%	6%	9%
22-Sep-11		3%	5%	8%	12%
1-Oct-11		2%		7%	11%
8-Oct-11		2%		13%	18%
15-Oct-11		1%		12%	17%
LT mad	**3.360**	**1,430**	**9,400**	**10,750**	**13.300**

Kettle River

Flow data from 2011 is available for 6 sites on the Kettle River - the WSC real-time site at above Westbridge, the Humuh, Rock Creek and Midway seasonal sites from this study and the USGS sites near Ferry and Laurier, plus preliminary flow data for Lost Horse Creek (a small Kettle tributary near the Humuh site) from WSC.

Figure 4 shows the relationships among flows in the Kettle River at the Humuh bridge (upstream of most of the agricultural and domestic water use, near Westbridge (above the W. Kettle confluence), above Rock Creek (below the W. Kettle confluence), at Midway (upstream of the USA border), and at Ferry (on the USA side of the border) for the period from July 15, 2010 to October 31, 2010. The flow values are shown in log scale to emphasize relative differences and focus on the lower flows.

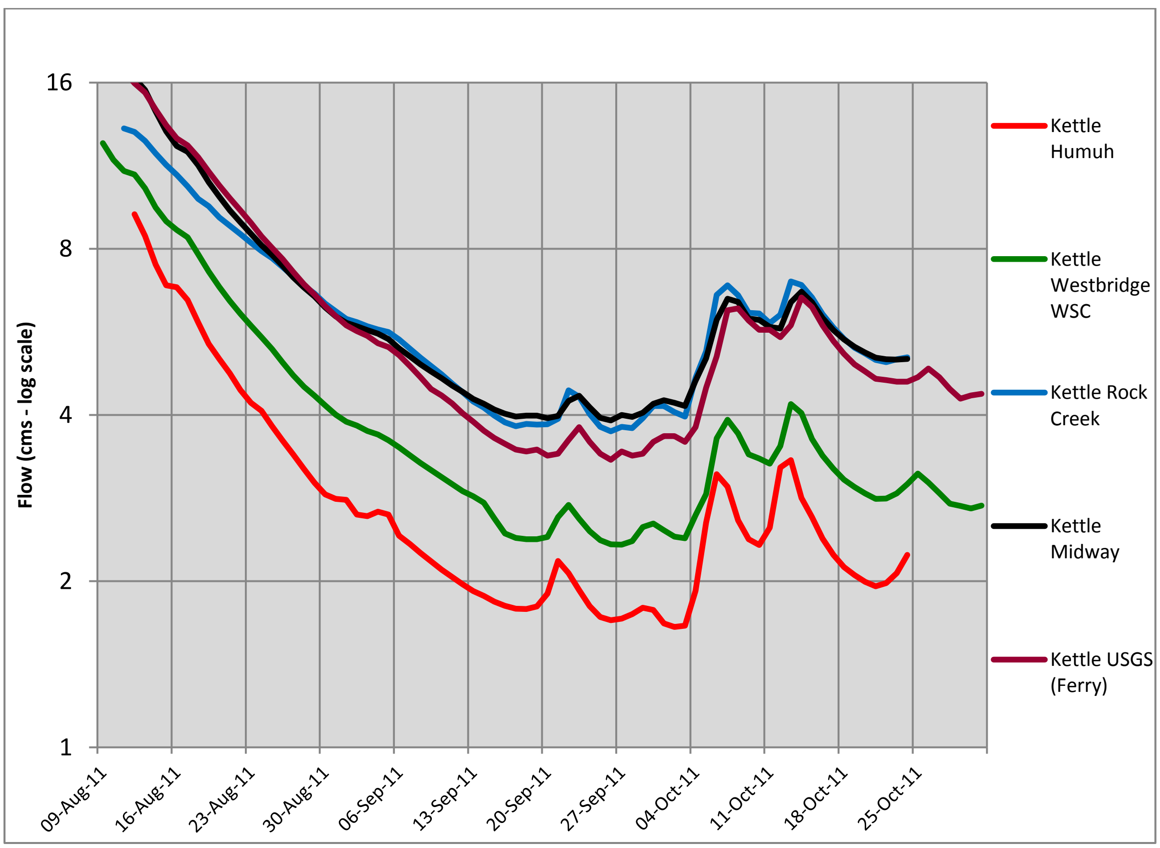


Figure 4. Kettle River Daily Flows - August 9 to October 31, 2011

As in 2010, there are several strong or highly synchronous relationships among the flows at these 5 sites over the 2011 summer and fall time frame:

- The overall flow trend is similar, with low flows and storm related flow peaks replicated at each site. Flows generally increase in a downstream direction as the watershed size increases and more tributaries join the river, and storm peaks can be delayed a day at the downstream locations as the increased flows move downstream.
- There is a very noticeable shift in the relative volumes of flow at the Rock Creek, Midway and Ferry sites over the course of the summer. By mid to late August, flows at Rock Creek, Midway and Ferry are all very similar in volume, and by early September flows are noticeably lower at Ferry than at Rock Creek and Midway. After the October 7 storm peak, flows are higher but flow at Ferry remains below Midway and Rock Creek.

The change in the Rock Creek / Midway / Ferry relative flow volumes occurs later in 2011 than in 2010 due to higher flows, but in both years the flow relationship changes as flows drop below about 8 m^3/sec, with very noticeable reductions in downstream flows at 4 m^3/sec. Downstream flows recover with fall storms. Flows at Ferry recovered to exceed upstream flows in 2010 after reached 14 m^3/sec on Sep 22. In 2011, flows at Ferry moved closer to upstream flow volumes flows reached 7 m^3/sec on Oct 7, but that wasn't enough to fully restore downstream flows to higher levels than at Midway and Rock Creek.

The changes in flow patterns appear to indicate that water extraction from both surface and groundwater noticeably reduces flows in the Kettle River in late summer and early fall. The timing of the change back to higher downstream flows coincides with both the end of the irrigation season and fall storms, so groundwater / surface water relationships are also likely part of the explanation of the flow patterns. It is interesting to note that the transition to lower flows at the downstream sites occurred at similar flows in both years, and that there is less downstream recovery in 2011 when storm flows remained below the 8 m^3/sec level at which the downstream flow reduction became noticeable. This suggests that flow volume is a factor in the relative flow pattern among the sites. However, Figure 4 also shows that while flows are still diminishing at the upstream Humuh site in late September and early October prior to the early October storm, flows at the downstream sites were already increasing, supporting the suggestion that water use is certainly a significant factor in the flow patterns.

Granby River

Flow data from 2011 is currently available for 5 sites on the Granby River - the WSC real-time site at Grand Forks and the Upper Granby, Lower Granby and Granby Subdivision seasonal sites from this study, plus preliminary flow data for Burrell Creek above Gloucester Creek (a large tributary above the Granby Upper site) from WSC.
Figure 5 shows the relationships among flows at Burrell Creek (multiplied by 6 to reach same order of magnitude for display), Upper Granby (upstream of most of the agricultural and domestic water use), Lower Granby (midway between Upper Granby and Grand Forks), Granby Subdivision (above Grand Forks) and Granby WSC at Grand Forks for the period from August 1, 2011 to October 31, 2011. The flow values are shown in log scale to emphasize relative differences and focus on the lower flows.

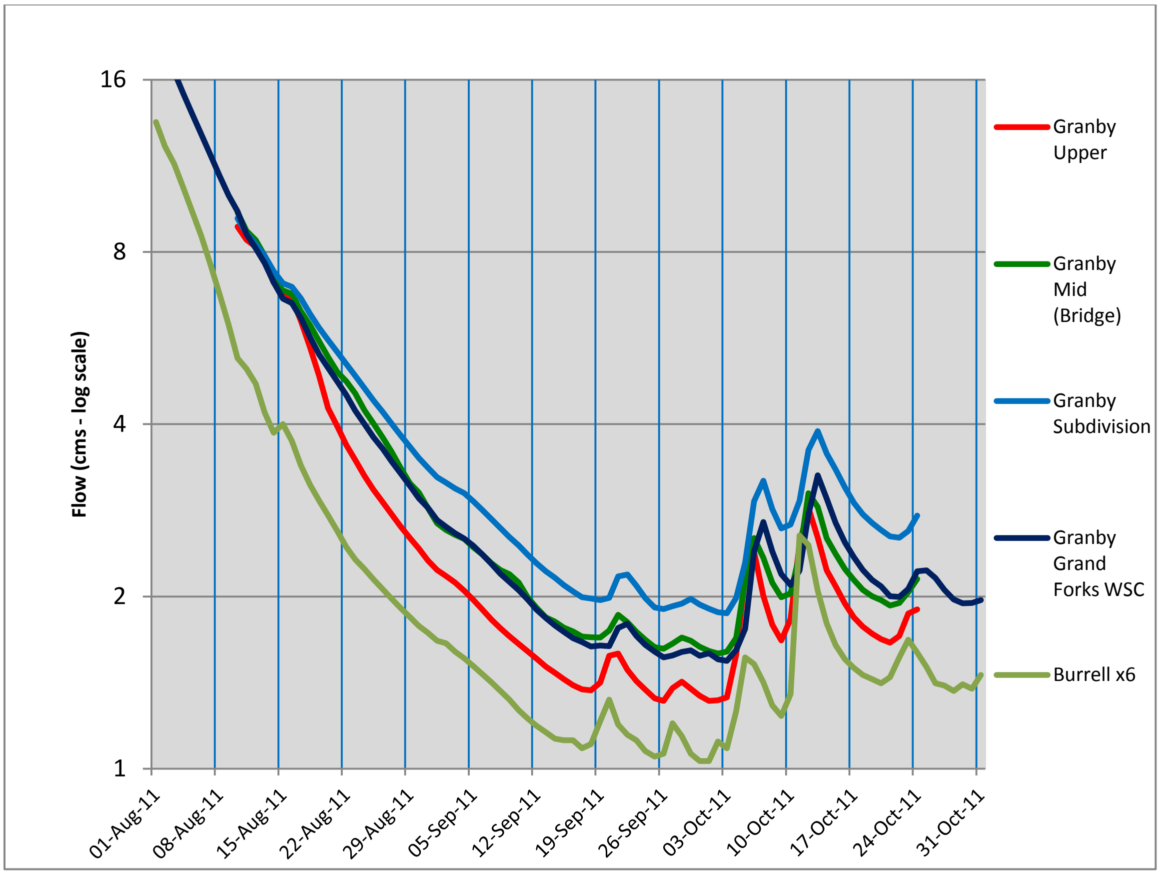


Figure 5. Granby River Daily Flows - August 1 to October 31, 2011

As in 2010, there are several strong or highly synchronous relationships among the flows at these sites over the summer and fall time frame in 2011:

- The overall flow trends are similar, with low flows and storm related flow peaks replicated at each site.
- Flows increase in a downstream direction as the watershed size increases and more tributaries join the river, and storm peaks can be delayed a day or more at the downstream locations as the increased flows move downstream.
- There is an unexpected similar volume of flow among the 4 Granby River sites when flow measurements at the seasonal sites start on August 10. Flows begin to separate within a few days and the flow relationships among between Granby River and Burrell Creek sites remain relatively constant over the summer and fall.

The Granby Subdivision site was added for 2011 due to unexpected flow pattern differences between flows at Granby Lower and Granby Grand Forks WSC. In 2010 the differences were suggested as being attributable to City of Grand Forks water diversions, but it has since been learned that Grand Forks does relies on wells and does not use the licenced surface water from the Granby River.

As seen in 2010, there are periods where the flow from the Grand Forks WSC site matches the flow from the upstream Granby Lower site and sometimes even exhibits less flow than the upstream site, until the early October storms after which flow increases at the Grand Forks WSC site relative to Granby Lower. The Granby Subdivision site on the other hand consistently records higher flows than both the Granby Lower site and the Grand Forks WSC site, and has a very similar flow pattern to the Granby Lower site. This suggests that unless there is a recording error at Grand Forks WSC (unlikely), there must be a loss in flow between the Granby Subdivision site and Grand Forks WSC. There are no actively used surface water diversion licences between the 2 sites that could account for the magnitude of the reduction (average of 500 L/sec), so loss of flow to groundwater to recharge to supply one or more large capacity groundwater wells is suggested as a possible explanation for the observed flow patterns.

2011 Flow Summary

Reference to the WSC / USGS realtime and provisional hydrometric data for 2011 in relation to historical data indicates that the W. Kettle River, Kettle River and Granby River had very high daily flows in July (75th to 90th percentile). Flows began to recede more quickly in August with dry weather, but flows remained above mean (50th percentile) daily flows for the date until mid to late August. Flows receded further in

September, reaching low flows that typically matched the 25th percentile flows in mid to late September. Flows increased back towards mean flows in early October after several storm events.

The mid to late September 2011 low flows compared to long term mean annual flows are shown in Table 4. The lowest flows as %LTmad occur in the Upper West Kettle River and the Granby River. This is similar to 2010 for the West Kettle River, but flows in the Granby River were proportionally lower relative to the Kettle River than in 2010.

Table 4. September 2011 Low Flows as Percentage of Long Term Mean Annual Discharge

Site	Sept 2011 Low Flow (cms)	Mean Annual Discharge (cms)	% Mean Annual Discharge
W. Kettle McCulloch	0.172	3.36	5%
W. Kettle Carmi	0.428	9.4	5%
W Kettle Debris Catchers	0.782	10.8	7%
W Kettle at Westbridge	1.187	13.3	9%
Kettle Humuh	1.701	23.0	7%
Kettle near Westbridge	2.329	26.5	9%
Kettle Rock Creek	3.736	40.6	9%
Kettle above Midway	3.911	43.0	9%
Kettle near Ferry	3.320	44.1	8%
Upper Granby	1.315	23.0	6%
Lower Granby	1.621	28.0	6%
Granby Subdivision	1.900	30.1	6%
Granby at Grand Forks	1.565	30.1	5%

Temperature Measurements

West Kettle River

Seasonal temperature data from 2011 is available for 3 sites on the W. Kettle River - the WSC real-time site at Westbridge and the Carmi seasonal site (measured with Hobo temperature loggers), and the Debris Catchers site where temperature were recorded with the Global Water water level / temperature recorders and corrected as described in Section III.

Figure 6 shows the relationships among daily maximum temperatures in the W. Kettle River at Carmi (upstream of most of the agricultural and domestic water use), at the debris catchers (below Beaverdell and midway between Carmi and Westbridge), and at Westbridge (where it joins the Kettle River) for the period from July 27, 2011 to October 24, 2011.

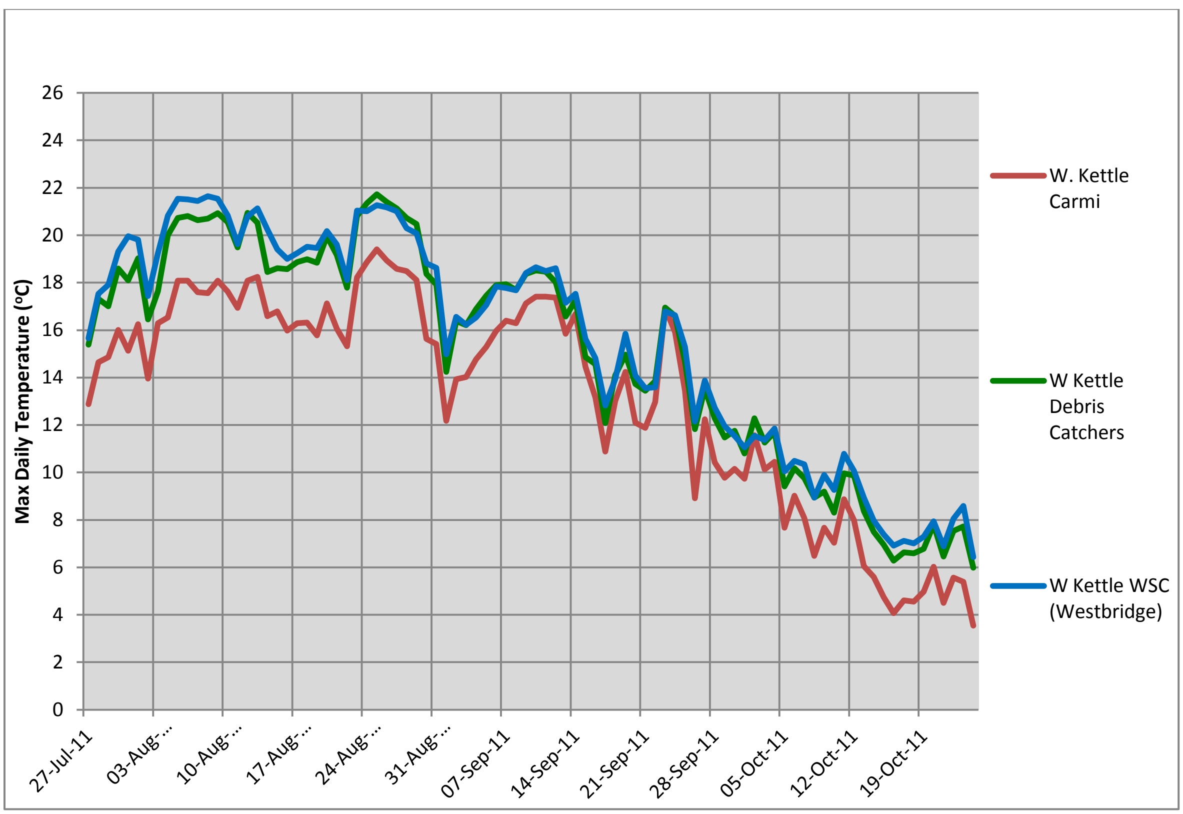


Figure 6. West Kettle River Daily Max Temperatures - July 27 to Oct 24, 2011

Similar to 2010, there are several temperature trends that are apparent at these 3 sites over the summer and fall time frame in 2011:

- The overall temperature trend is relatively high daily maximum temperatures until late August, after which the daily maximum temperature trends steadily downwards towards the end of October.
- Daily maximum temperatures fluctuate by as much as 6 to 8 ^{o}C over several days in response to weather conditions which alter air temperature and precipitation which in turn alters flow.
- Temperatures at the Carmi site are consistently lower than at the downstream sites, with a maximum daily temperature of 19.4 ^{o}C on August 25.
- Temperatures at the West Kettle at Debris Catchers and Westbridge sites are often (but not always) 2 ^{o}C higher than at Carmi, with a very similar pattern in the daily fluctuation and a maximum temperature of 21.7 ^{o}C on July 29.
- Maximum W. Kettle River temperatures in 2011 were approximately 2 ^{o}C lower than in 2010.

Kettle River

Seasonal temperature data from 2011 is available for 4 sites on the Kettle River - the WSC real-time site above Westbridge and the seasonal Midway site (recorded with Hobo temperature loggers), and the Humuh and Rock Creek sites where temperature were recorded with the Global Water water level / temperature recorders and corrected as described in Section III.

Figure 7 illustrates the relationships among daily maximum temperatures in the Kettle River at Humuh bridge (upstream of most of the agricultural and domestic water use), near Westbridge (above the W. Kettle confluence), above Rock Creek (below the W. Kettle confluence) and at Midway (upstream of the USA border) for the period from July 27, 2011 to October 24, 2011.

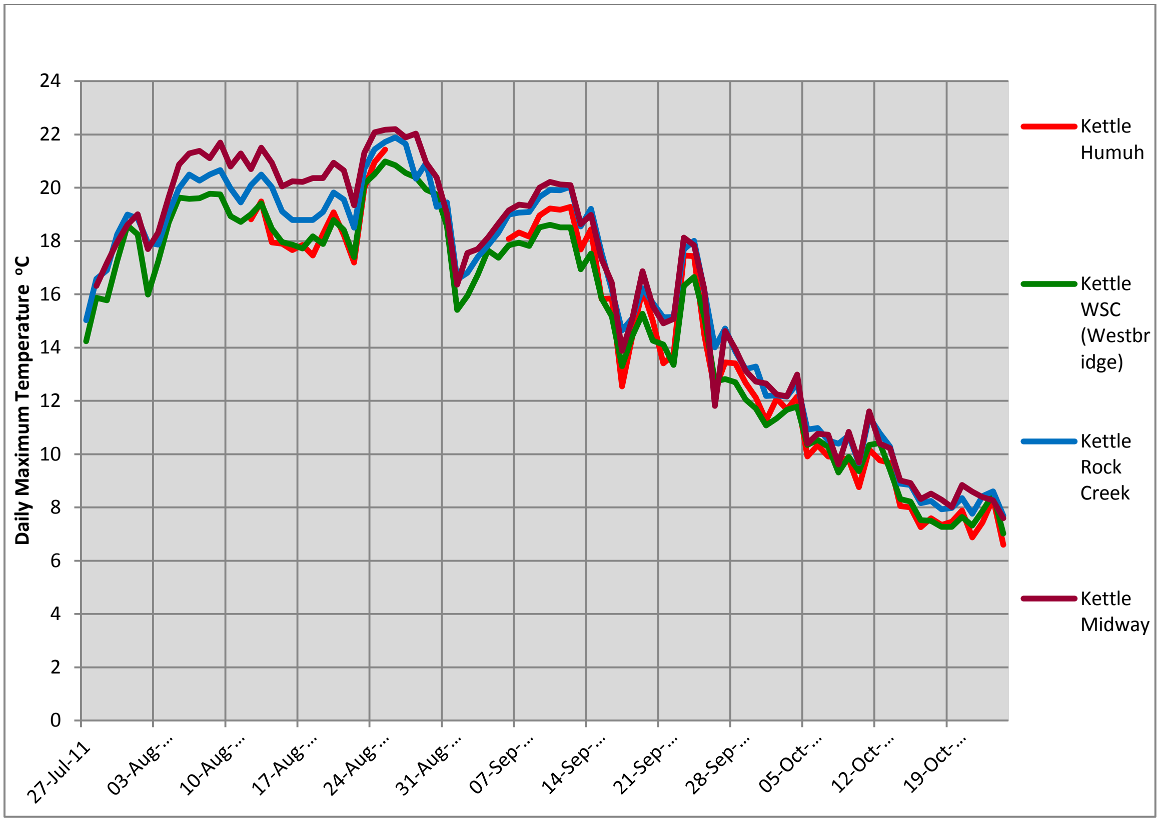


Figure 7. Kettle River Daily Max Temperatures - July 27 to Oct 24, 2011

As in 2010. there are several temperature trends that are apparent at these 4 sites over the summer and fall time frame in 2011 which are quite similar to the West Kettle River temperature trends:

- The overall temperature trend is relatively high daily maximum temperatures until late August, after which the daily maximum temperature trends steadily downwards towards the end of October.
- Daily maximum temperatures fluctuate by as much as 5 to 6 °C over several days in response to weather conditions which alter air temperature and precipitation which in turn alters flow.
- Temperatures at the upstream Humuh and WSC sites are consistently lower than at the downstream sites, with a maximum daily temperature of about 21 °C on August 24 & 25.
- Temperatures at the Rock Creek and Midway sites are up to 2 °C higher than at Humuh and WSC, with a very similar patterns in the daily fluctuation and maximum temperatures of about 22 °C on August 24 to 28.

- The daily maximum temperature patterns are very similar at all 4 sites with the greatest temperature differences between the upstream and downstream sites when temperatures are the highest in summer, and diminishing differences as temperatures decrease in September and October.
- As in the West Kettle River, maximum temperatures in 2011 are approximately 2°C lower than in 2010.

Granby River

Seasonal temperature data from 2011 is available for 3 sites on the Granby River - the Granby Subdivision at Grand Forks and the Upper Granby seasonal sites (recorded with Hobo temperature loggers), and the Lower Granby sites where temperature were recorded with the Global Water water level / temperature recorder and corrected as described in Section III.

Figure 8 shows the relationships among daily maximum temperatures at Upper Granby (upstream of most of the agricultural and domestic water use), Lower Granby (midway between Upper Granby and Grand Forks) and Granby Subdivision at Grand Forks for the period from July 28, 2011 to October 24, 2011.

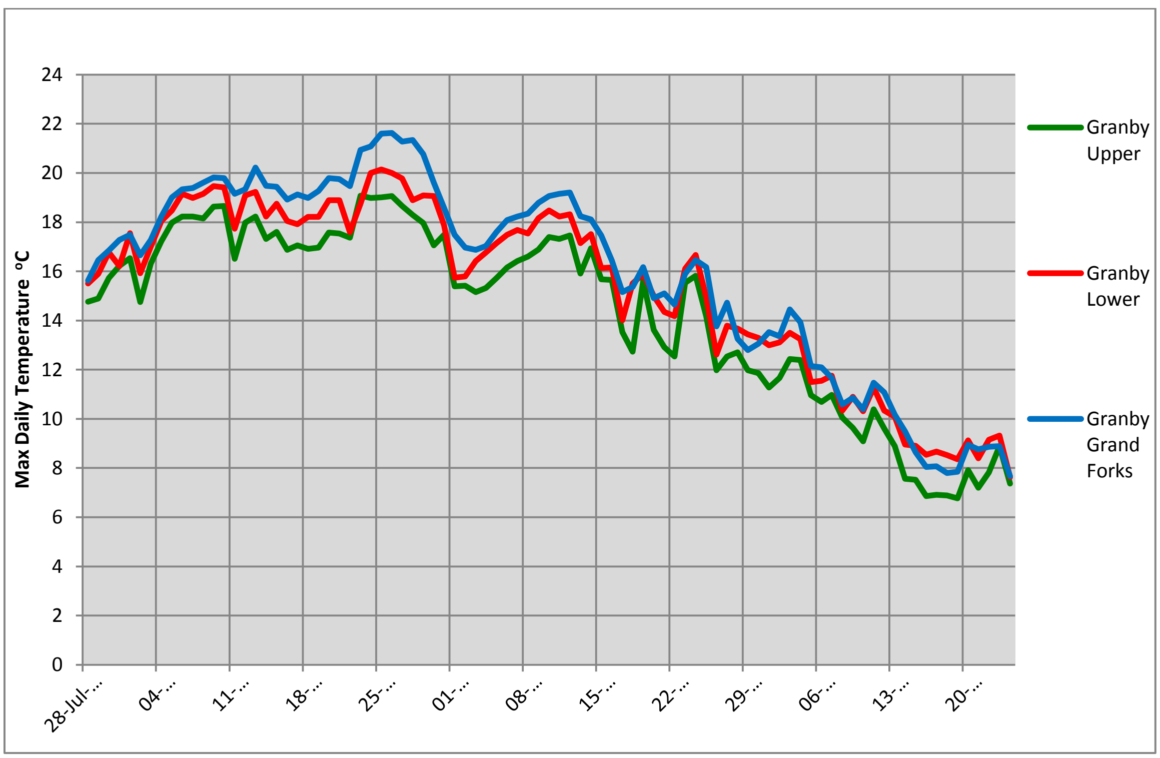


Figure 8. Granby River Daily Max Temperatures - July 128 to Oct 24, 2011.

As in 2010, there are several temperature trends that are apparent at these 3 sites over the summer and fall time frame in 2011 which are also quite similar to the West Kettle River and Kettle River temperature trends:

- The overall temperature trend is relatively high daily maximum temperatures until late August, after which the daily maximum temperature trends steadily downwards towards the end of October.
- Daily maximum temperatures fluctuate by as much as 4 ^{o}C over several days in response to weather conditions which alter air temperature and precipitation which in turn alters flow.
- Temperatures at the Upper Granby site are consistently lower than at the downstream sites, with a maximum daily temperature of about 19 ^{o}C on August 24 to 26.
- Temperatures at the Lower Granby site are generally about 1 ^{o}C higher than at Upper Granby, with a very similar patterns in the daily fluctuation and maximum temperatures of about 20 ^{o}C on August 25.
- Temperatures at the Grand Forks are higher again by about 1 ^{o}C than at Lower Granby until mid September, with a very similar patterns in the daily fluctuation and maximum temperatures of close to 22 ^{o}C on August 26. After mid September, temperatures are relatively similar between the Lower Granby and Grand Forks sites.
- The daily maximum temperature patterns are very similar at all 3 sites with the greatest temperature differences between the upstream and downstream sites when temperatures are the highest in summer, and diminishing differences as temperatures decrease in September and October.
- As in the West Kettle and Kettle Rivers, maximum temperatures in 2011 are lower than in 2010, but only by about 1 ^{o}C, rather than 2 ^{o}C in the other rivers.

River Temperature / Air Temperature / Flow Relationships

The Kettle River has a history of high water temperatures in mid to late summer, with temperatures sometimes reaching lethal levels for both trout and mountain whitefish. High water temperatures and fish kills appear to coincide with low flows, so there is a perception that river temperature increases because of diminished flows. Daily air temperature data is available for the Environment Canada climate station located at Midway, several kilometres from the flow and water temperature data collected in this project upstream of Midway. Comparison of river the temperatures to air temperatures also indicates a high correlation of water temperature to air temperature. The following analyses considers the fluctuation in river temperatures, air temperatures and flow changes.

Figure 9 shows the daily fluctuation in river temperature at the flow / temperature monitoring site above Midway from the start of recording on August 15, 2011 to August 31, 2011. The chart shows a very distinct pattern of diurnal fluctuation, with minimum daily temperatures occurring between 7:00 and 9:00 A.M following nightime cooling and maximum daily temperatures at around 5:00 P.M. following the daytime heating. The highest recorded river temperatures at this site were 22.2 ^{o}C, and the typical daily fluctuation is around 5 ^{o}C in August, with lesser daily fluctuation when river temperatures decrease.

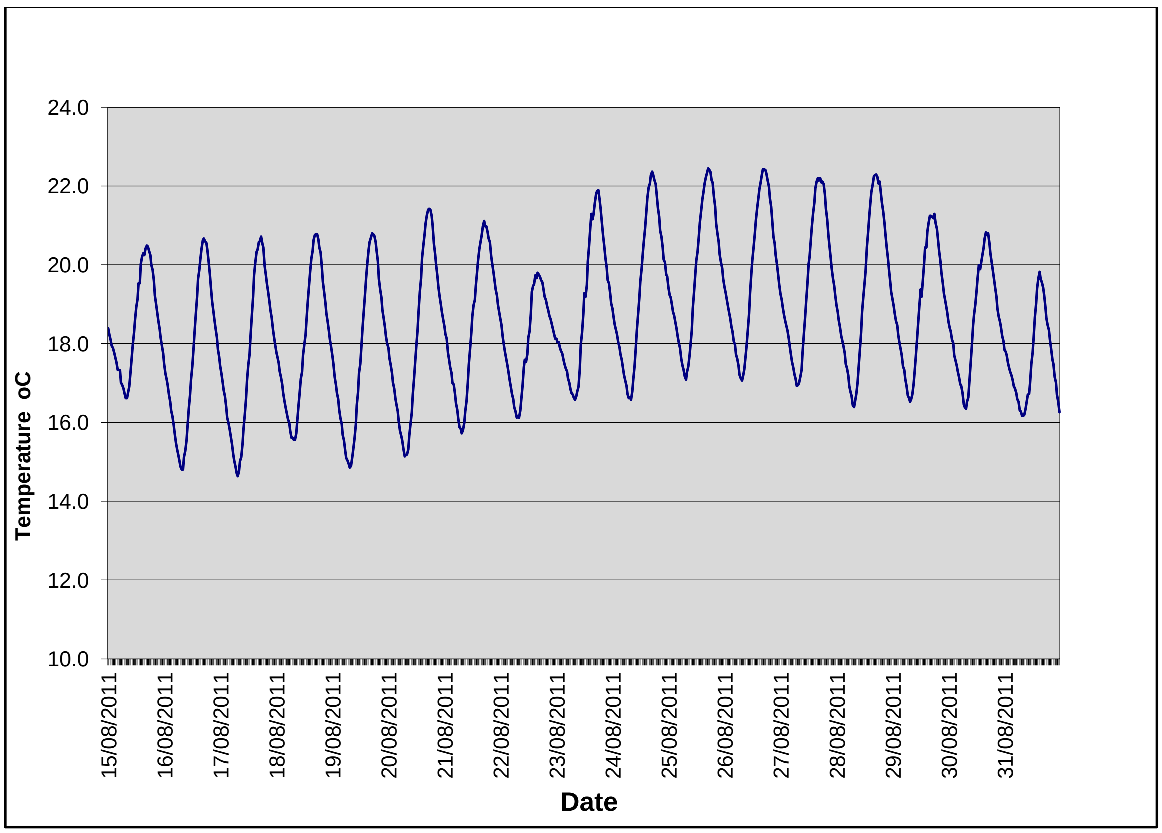


Figure 9. Kettle River near Midway Daily Temperature Fluctuation - August 15 to August 31, 2011

Figure 10 compares maximum daily water temperature and the mean daily flow at the flow / temperature monitoring site above Midway with the mean daily air temperature at the Environment Canada climate station at Midway. As in 2010, it is apparent that there is a strong relationship between mean air temperature and river temperature, as the daily maximum river temperature fluctuates in concert with the daily mean air temperature with the highest river temperatures of 22 ^{o}C coinciding with the highest mean daily air temperatures of 22 to 23^{o}C from in late August. Unlike 2010 however, temperature monitoring was initiated before the flows receded enough to begin flow monitoring at this site. It is apparent in Figure 10 that river temperatures are lower relative to mean air temperatures from the start of temperature monitoring on July 28 (when flows were likely around 50 m^3/sec based on flows at Ferry) until near the start of flow monitoring on August 11 by which time the flows had receded to below 18 m^3/sec. River temperature does not appear to continue to increase further at similar air temperatures as flows continue to drop to 6 m^3/sec at the end of August.

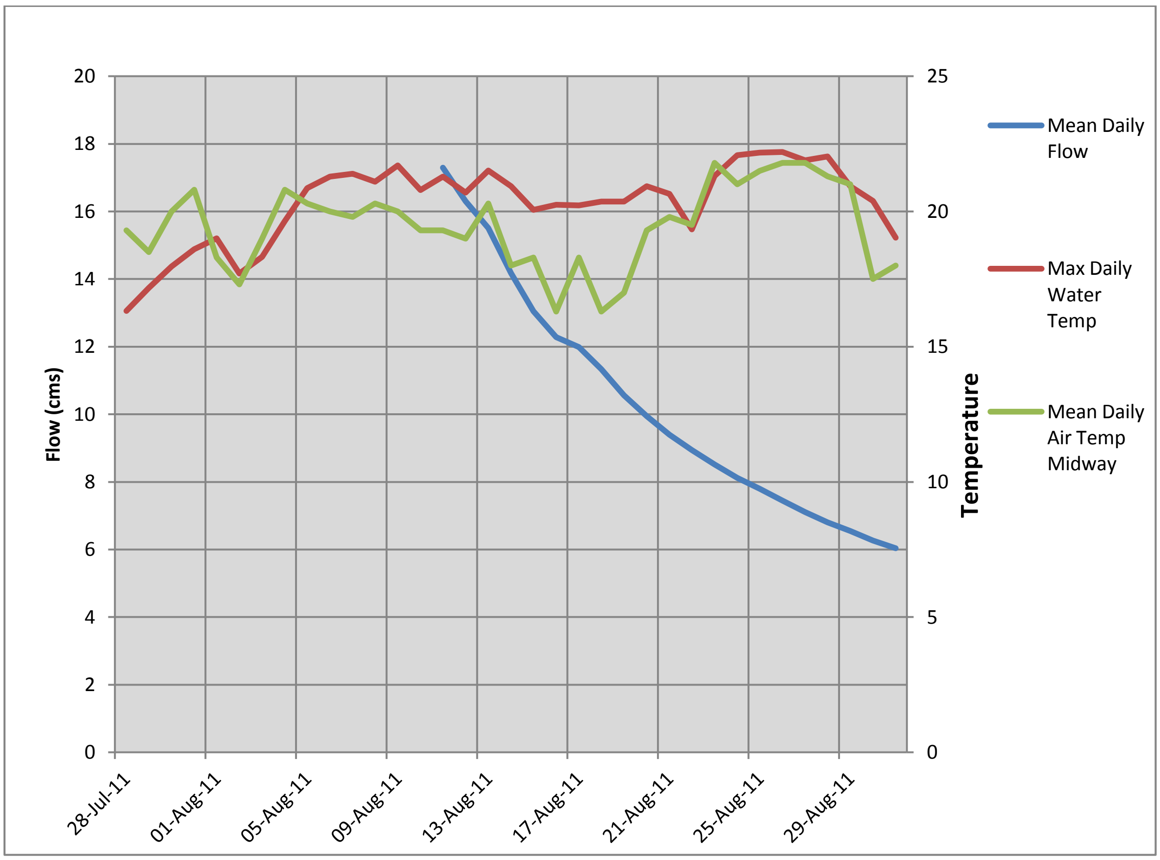


Figure 10. Kettle River near Midway Daily Flow, Daily Max Temperature & Midway Mean Air Temperature - July 28 to August 31, 2011.

Figure 11 shows the correlation between daily maximum river temperature at the flow / temperature monitoring site above Midway with the mean daily temperature at Midway from July 30 to August 31, 2010 and August 12 to August 31, 2012. This chart confirms that maximum daily river temperature is well coordinated with mean air temperature in August, with a polynomial trendline providing the best fit to the data. There is significant data scatter around the trendline, likely due in part to lag time in river temperature response to changes in air temperature, and also likely due in part to the temperature relationship changing in response to shorter days towards the end of August.

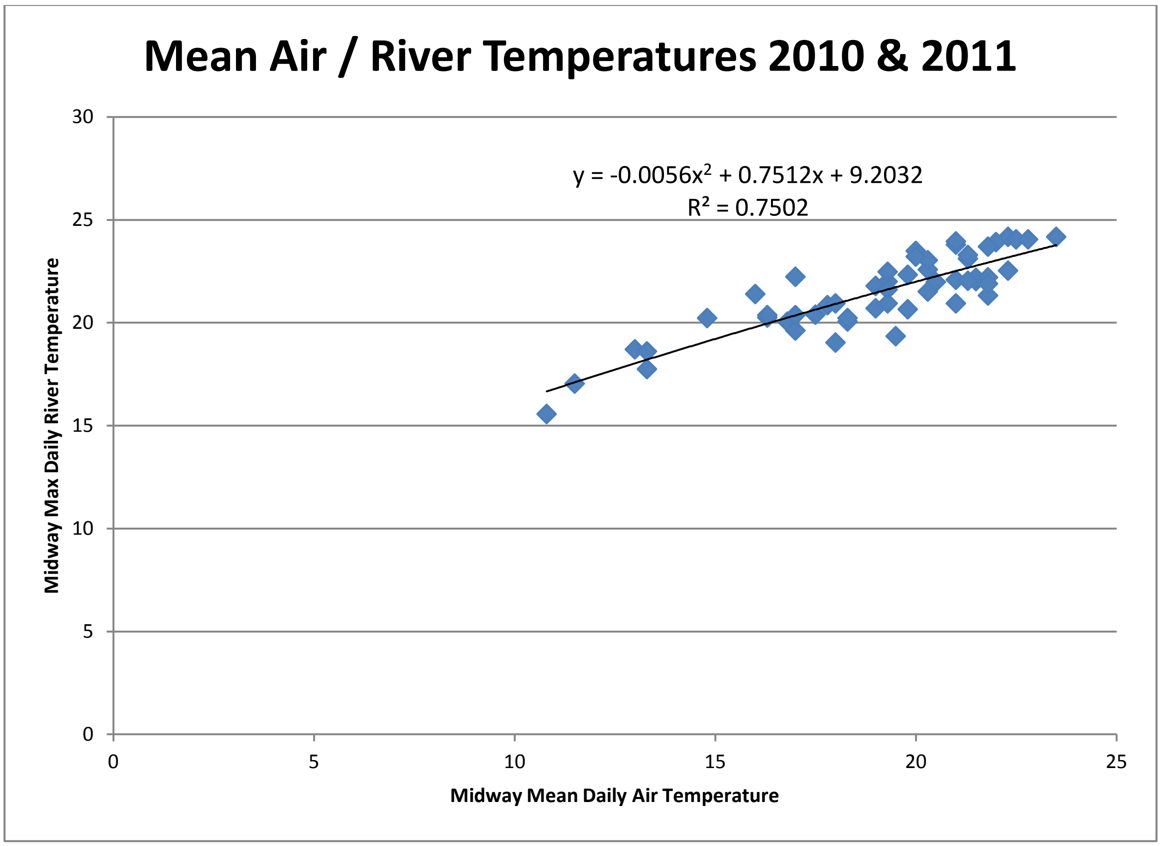


Figure 11. Kettle River near Midway Daily Max River Temperature vs. Midway Mean Air Temperature - July 30 to August 31, 2010

Figure 12 and Figure 13 show the correlation between daily maximum river temperature above Midway and above Westbridge with flow for the days when mean air temperature is between 19 and 22.9 °C. The data used for the correlations is shown in series of 1 degree air temperature increments to also display the influence of varying air temperature on the river temperatures.

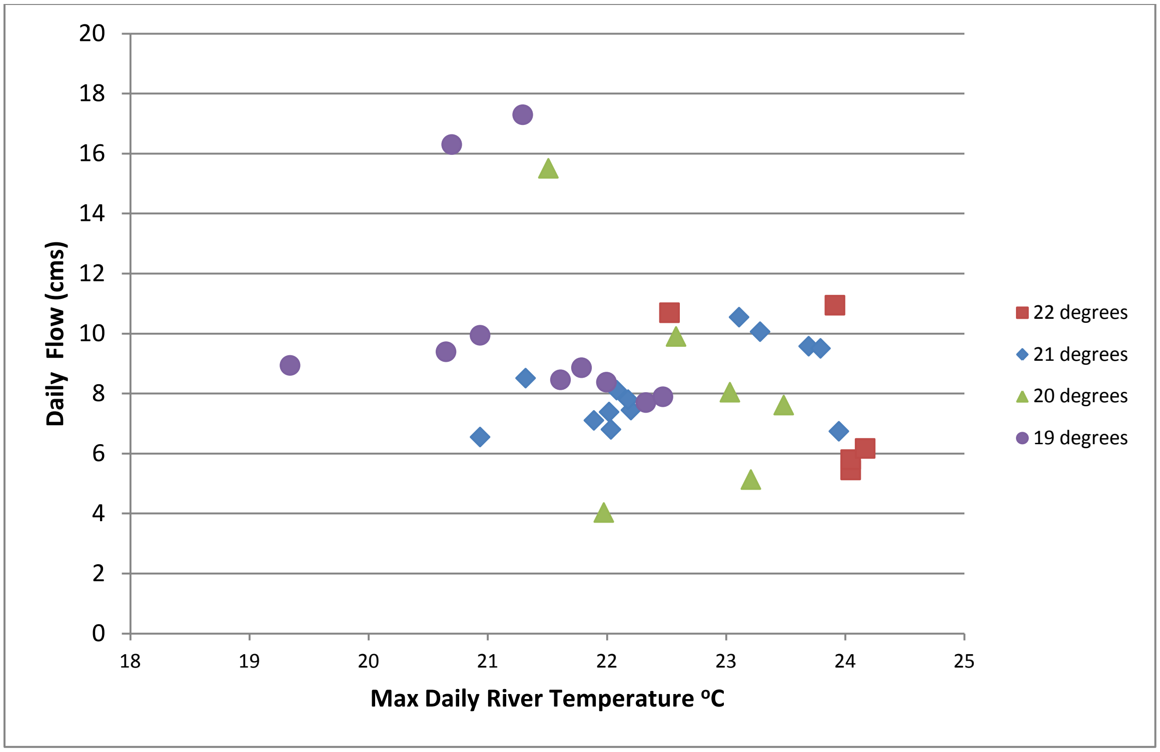


Figure 12. Kettle River near Midway Daily Max River Temperature vs. Flow at Mean Daily Air Temperatures of 19 to 22.9 ^{o}C - Jul & Aug, 2010 & 2011.

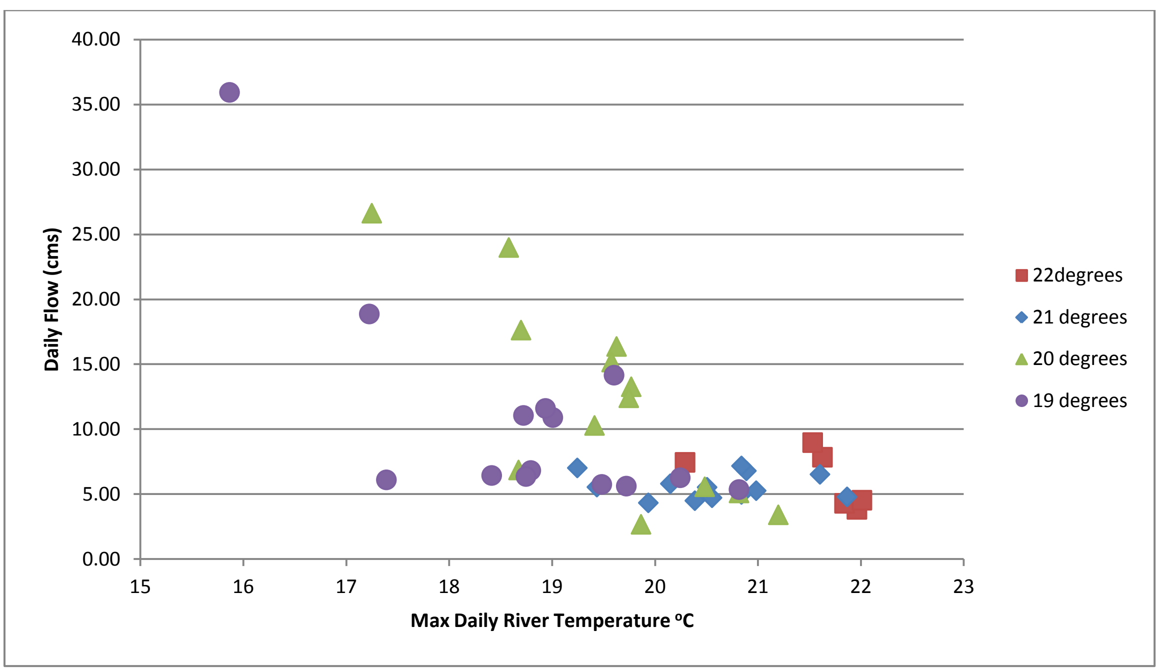


Figure 13. Kettle River above Westbridge Daily Max River Temperature vs. Flow at Mean Daily Air Temperatures of 19 to 22.9 ^{o}C - Jul & Aug, 2010 & 2011.

There is a suggestion of increasing river temperatures with flow in the Midway data, but the three highest flows occur on days with lower mean air temperatures in the 19 to 20 degree range, and at flows of less than 12 m^3/sec when the full range of temperatures is reached, there is no apparent increase in river temperature with decreasing flows.

Higher volume flow data is available from the WSC flow monitoring site above Westbridge, and this data set shown in Figure 13 does show a trend to increasing river temperatures at lower flows. As with the Midway data, the highest flows are also recorded when temperatures are in the lower part of the correlation range, but the trend appears to be strong enough to indicate that lower river temperature will occur at high flows. Similar to the Midway data though, there does not appear to be any trend to increasing temperature with flow when the daily flow is below 12 m^3/sec.

Given the above analyses, it appears that river temperature is highly correlated to air temperature, and while there is some evidence of lower river temperatures at high flows, there is little change in temperature with flow at lower flows when air and river temperatures are highest.

Weighted Useable Widths

West Kettle River

Useable width analyses for rainbow trout are available for 2 transect sites in 2011 - West Kettle Carmi and West Kettle Debris Catchers, 2 transect sites in 2010 - West Kettle Carmi and West Kettle Debris Catchers and 2 transect sites in 2009 - West Kettle Debris Catchers and West Kettle Rest Area (Rhone). Each of the transects at Debris Catchers and at Carmi were moved somewhat from the previous year, so while they are in the same general location, they each reflect slightly different riffle characteristics. Figure 14 shows the useable habitat width vs. flow relationships for the 2009 to 2011 transect sites in the West Kettle River and transect photos for 2011 are shown in Appendix A.

The 2009 transect measurements were initiated in August when flows were already less than 10% of long term Mean Annual Discharge (LT MAD), so while measurements were taken on 6 different dates, the range in flows is too low to establish much of a trend other than to state that useable habitat width is low at flows of about 1,000 L/sec (10% MAD) and diminish further as flow reduces.

For 2010, the Debris Catchers riffle site was re-located approximately 150 m downstream, and the Rhone Rest area transect was replaced with the one at Carmi to coincide with the water level (flow measurement) recording station. Both stations have 10 sets of transect measurements which cover a much greater range in flows (up to about 50% of MAD) than 2009. The Debris Catchers and the Carmi riffle sites were locations were moved again for 2011, with 9 sets of transects for each site.

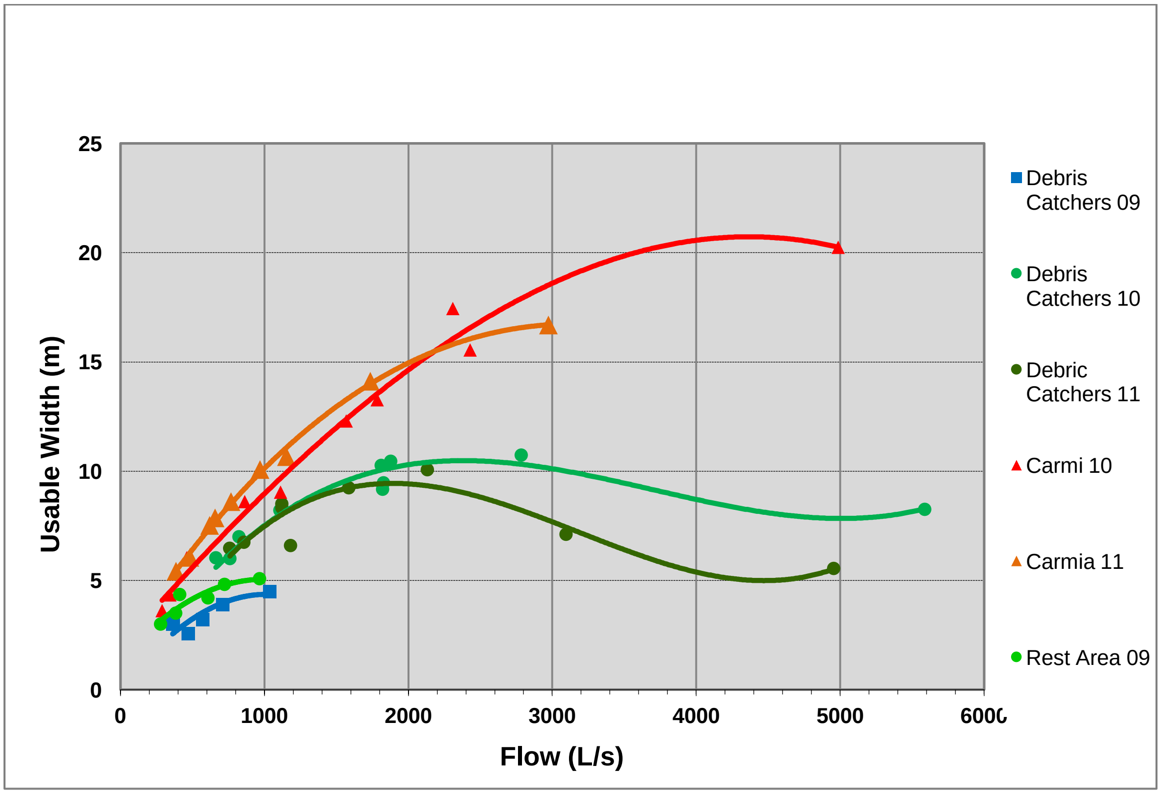


Figure 14. West Kettle River rainbow parr useable width with flow trends for 2009, 2010 and 2011 transect sites.

Discussion below includes comments by Ron Ptolemy (MOE Rivers Biologist/Instream Flow Specialist pers. comm. and Ptolemy (2011) which were provided when reviewing the 2010 data and report.

The trend for the Debris Catchers site is very close to what would be expected from the "Tennant" method of evaluating PHabSim results with % LT mad. The generic response of many BC streams whose channels are unconfined and with flows of 20% LT mad, is for the creation of optimal riffle conditions and near maximum usable parr width (Ptolemy 2011). However there is a trend to lower usable parr widths in smaller streams

due to the coupling of mean depth and discharge through downstream hydraulic geometry (Leopold 1994). The power exponent for depth is typically 0.40. Less than ideal parr depths (<30 cm) are common to small streams so that parr reside in pools. With a generic riffle protection flow of 20% LT mad, the result is 2150 L/s. The results for 2009 are limited by low flow range from 3 to 9% LT mad, but results for 2010 and 2011 suggest flows that nearly maximize usable parr width (90-100%) occur near 2,000 L/s. Ideal riffle velocities for benthic insects and food delivery (“drift”) are created at flows near 20% LT mad. It is noteworthy that even at 10% LT mad, streamflow produces mean riffle velocities that are satisfactory or OK (>30 cm/s) (Reiser and Bjornn 1979) as is seen in all three years of results.
The trend at the Carmi site shows both higher values of useable width and maximum useable width at higher flows (35% to 45%LTmad) in 2010 and 2011. However, near maximum usable parr space (% max usable width) is attained near 25%LTmad or 2300 L/s, and lower flows of 16%LTmad achieve a target mean riffle velocity of 30 cm/s (Reiser and Bjornn 1979).

As seen in these sets of transect results, useable width results do vary with the specific characteristics of each transect. The Debris Catchers site is narrower or confined with higher velocities and with less exposed stones and boulders at low flows when compared to the Carmi site. The lower velocities in the wider channel at Carmi result in more useable width at higher flows, but useable width diminishes to similar levels when lows are reduced to less than 1,000 L/sec. It is important to recognize the useable width results as relative rather than absolute, with the most important feature being that useable width declines rapidly with diminishing flow, particularly when flows are less than 10%LTmad.

Kettle River

Useable width analyses for rainbow trout are available for 3 transect sites in 2011 - Kettle Humuh, Kettle Rock Creek and Kettle Midway Upper, 3 transect sites in 2010 - Kettle Humuh, Kettle Rock Creek and Kettle Midway Upper as well as 2 transect sites in 2009 - Kettle Midway Upper and Kettle Midway Lower. The Kettle Midway Upper site uses the same transect in both 2009 and 2010

Figure 15 shows the useable habitat width vs. flow relationships for the 2009, 2010 and 2011 transect sites in the Kettle River and transect photos for 2011 are shown in Appendix A. The 2009 transect sites were located approximately 300 m apart at the flow measurement site upstream of Midway. There are differences between the two (the upstream site is wider and shallower, but the results were relatively similar between the two, so only the upper site was retained for 2010 and 2011). New sites were also added above Rock Creek and at the Humuh bridge to coincide with the flow measuring stations there. Discussion below includes comments by Ron Ptolemy (MOE Rivers Biologist/Instream Flow Specialist pers. comm. and Ptolemy (2011).

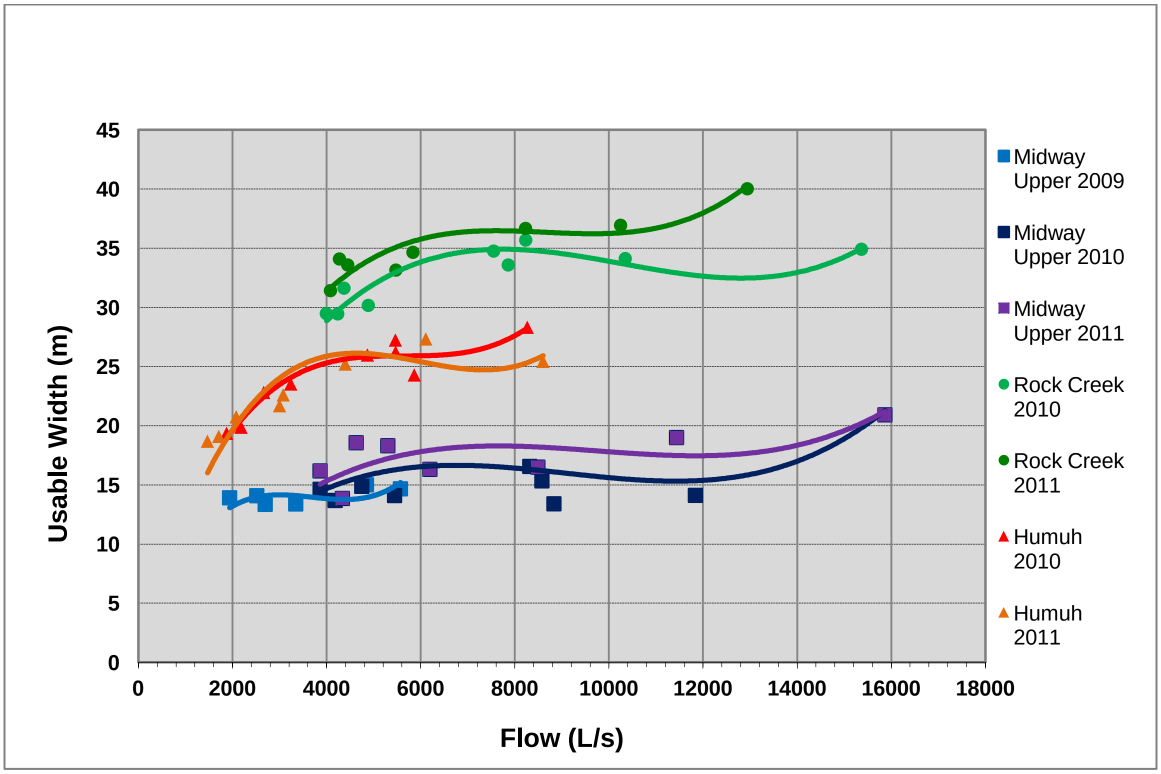


Figure 15. Kettle River rainbow parr useable width with flow trends for 2009, 2010 and 2011 transect sites.

The Kettle River is a larger river than the West Kettle River, and the useable width results reflect the larger river characteristics, particularly as the river increases in size at the downstream sites. Kettle Humuh has a LT mad of about 23,000 L/sec (about twice the flow at W. Kettle sites) and much of the potential maximum usable parr width was achieved at 20% LT mad or 4,600 L/s. Useable width does begin to drop off sharply below 3,500 L/sec (about 15% LT mad, and the mean riffle velocity drops below target riffle velocity of 30 cm/sec below 10%LTmad.

At Rock Creek, the LT mad is up to about 40,600 L/sec due to the large inflow from the West Kettle River at Westbridge. The useable width trend here is shallow, but does show a decrease below 7,500 L/sec (18% LT mad). Even at the lowest flows measured of

4,000 L/sec (10% LT mad), the useable width is still more than 80% of maximum due to maintenance of good velocities (> 30 cm / sec) and depths in the large river context. At the Midway sites, the LT mad is not much higher (43,000 L/sec), but the wetted width is narrower for comparable low flows leading to similar depths, but significantly higher velocities. This leads to an even flatter useable width curve with less overall useable width than at Rock Creek, but useable width starts to diminish noticeably below 6,500 L/sec (15%LTmad). Good riffle velocities and depths are still maintained though at the lowest measured flows of 2,200 L/sec (5%LT mad) due to the narrowing of this riffle with diminishing flows. As with the Rock Creek site, substrates are relatively uniform and the bed profile is quite smooth due to the larger river context.

Granby River

Useable width analyses for rainbow trout are available for 2 transect sites in 2010 - Granby Upper and Granby Lower and 3 transect sites in 2011 - Granby Upper, Granby Lower and the new Granby Subdivision site.. Figure 16 shows the useable habitat width vs. flow relationships for the 2010 and 2011 transect sites in the Granby River, and transect photos for 2011 are shown in Appendix A. Discussion below includes comments by Ron Ptolemy (MOE Rivers Biologist/Instream Flow Specialist pers. comm. and Ptolemy (2011).

Like the Kettle River, the Granby is larger than the West Kettle, with comparable flows at the Upper Granby site (LTmad of 23,000 L/sec) to those at the Kettle Humuh site on the Kettle. The suitability trend patterns are also very similar between these 2 sites. There is a relatively rapid rise in useable parr width with flow to optimal width near 15 to 20%Tmad or 3,500 to 4,500L/s. The main difference compared to the Humuh site on the Kettle is in the absolute amount of useable habitat width. The Upper Granby wetted channel width is narrower, and parr suitability in the Upper Granby is constrained by naturally low depths and higher velocities in the riffles.

Relatively similar results also occur in the Lower Granby site in 2011 although the 2010 trend line had more scatter and less obvious optimum. Maximum useable width appears to be met at about 3,200 L/sec in 2011 (<15%LT mad).

The new Granby Subdivision site does not show an optimal value for rainbow parr useable width in 2011, but it does appear that the trend in useable width flattens at about 4,500 L/sec (about 15%LTmad).

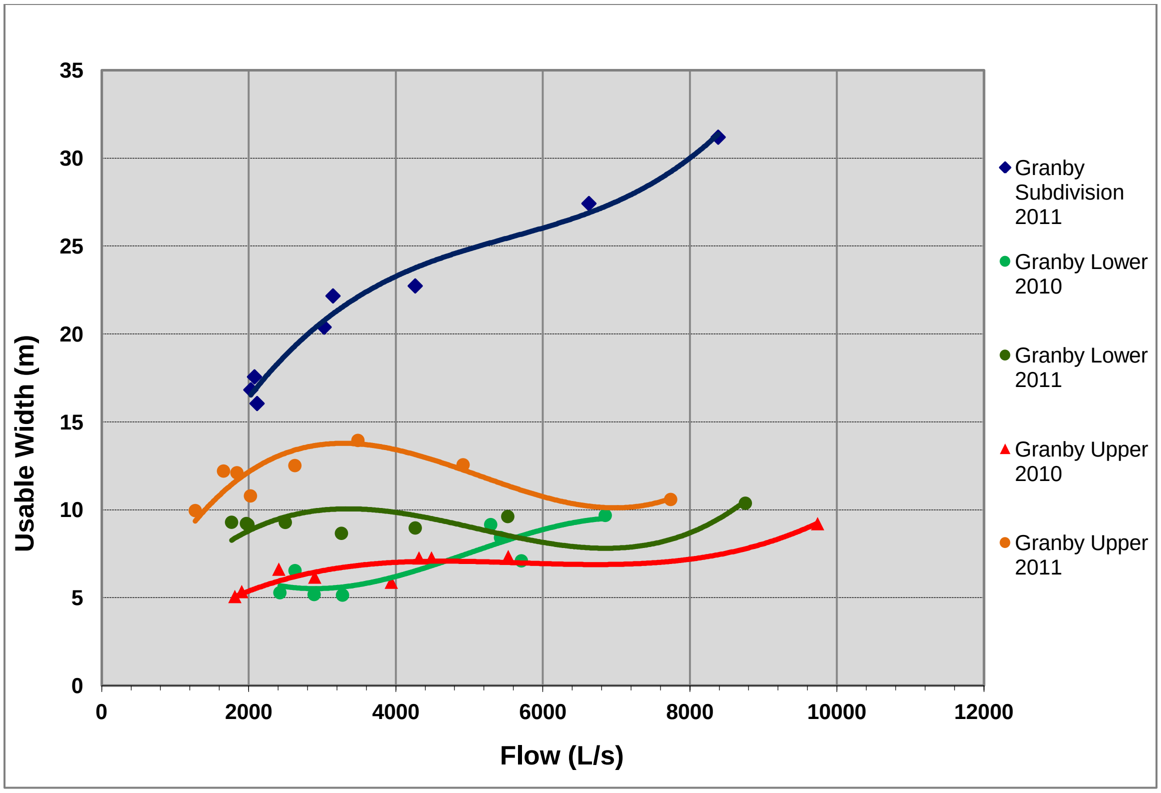


Figure 16. Granby River rainbow parr useable width with flow trends for 2010 and 2011 transect sites.

Useable Width Summary

Figure 17 shows the Kettle River useable width curves charted with flow as % LT mad, rather than absolute flow as in Figure 14 in the Kettle River discussion above. This standardizes the representation of flow among the sites and highlights the observation that useable width for rainbow parr is generally optimized at or even below 20%LTmad in the Kettle River.

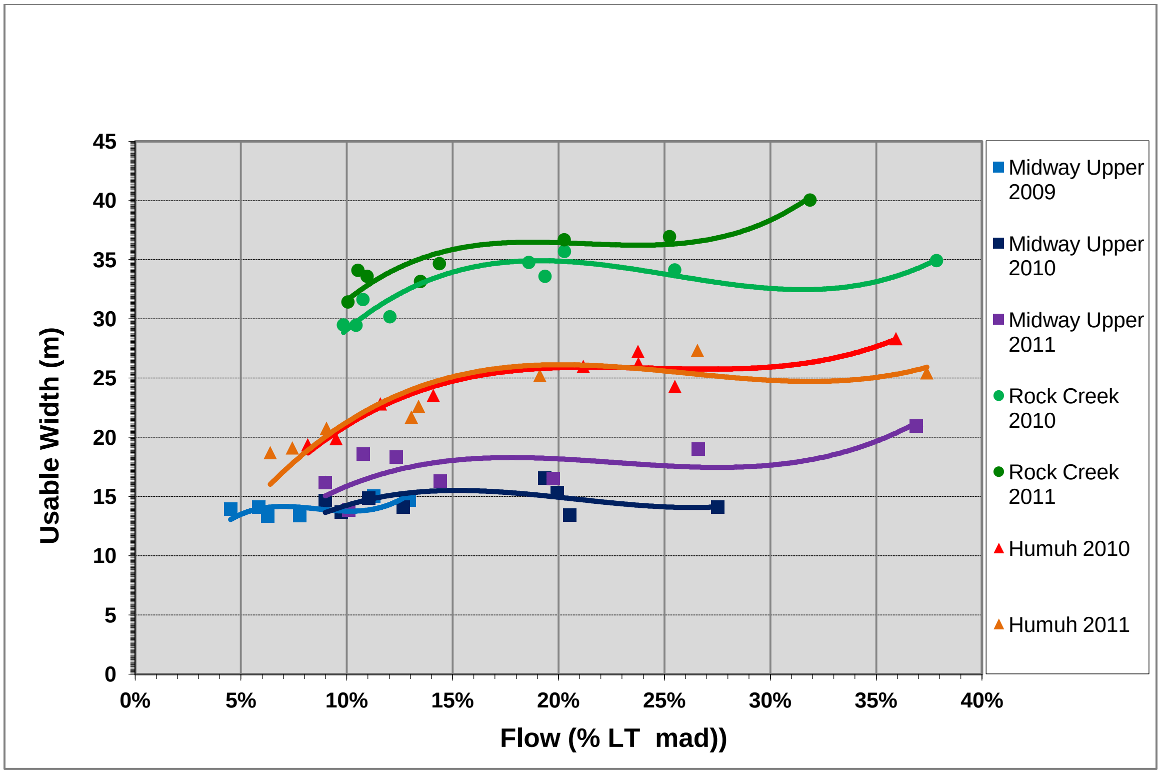


Figure 17. Kettle River rainbow parr useable width with flow (shown as %LTmad) trends for 2009, 2010 and 2011 transect sites.

Some of the differences in the weighted useable width curves for the West Kettle, Kettle and Granby Rivers relate to physical changes in the riffles as river size increases. Mean depths by meso-habitat class are highly correlated to LT mad or some standard large flow (hydraulic geometry in Leopold 1994); riffle depths in streams of 40 L/s may be 3 cm while a river with LT mad of 40,000 L/s may be 30 cm on average at the same relative flow of 20% LT mad. This is illustrated below in Figure 18, using the 3 cm depth at 40 L/s from Leopold and 2010 and 2011 results from this study. Even though the large flow sites are considered to be riffles, substrates are more uniform (cobble dominated) and the bed profiles are quite smooth. Extrapolation of the trend suggests though that useable habitat width will decline rapidly as flows decrease to less than 10% LT mad due to limited riffle depths at the lower flows

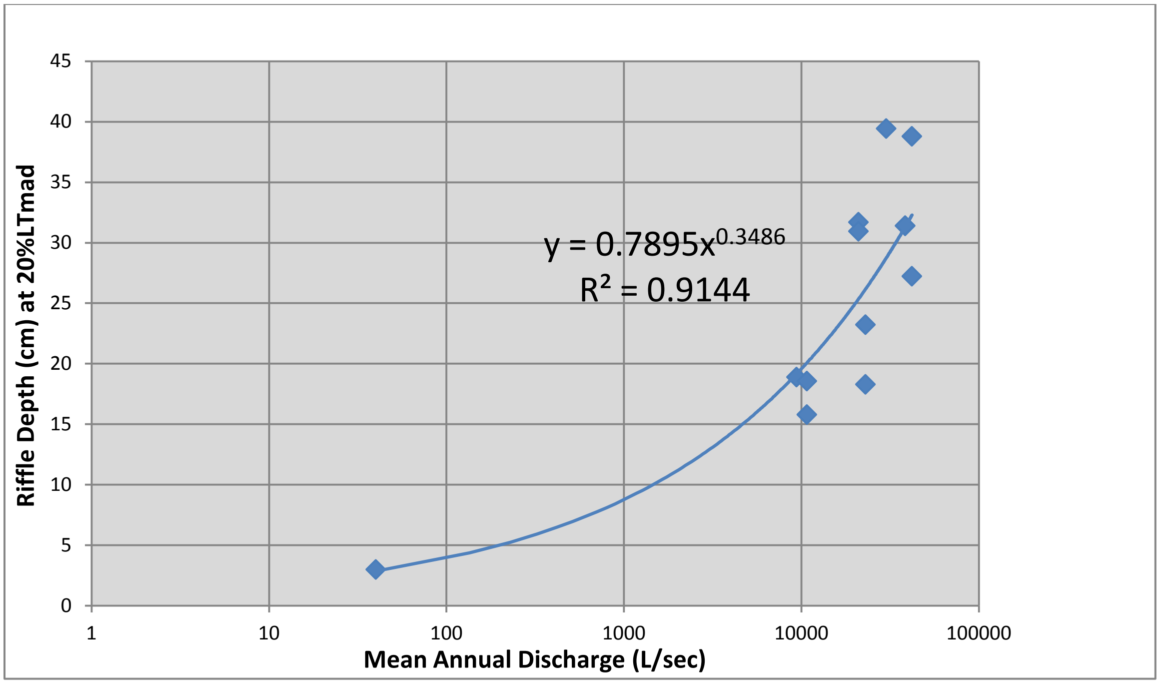


Figure 18. Scatterplot and curve for mean riffle depth (cm) dependence on stream size (LT mad in L/s) at standard relative flow of 20%LTmad for 2010 and 2011.

It also needs to be emphasized the weighted useable width results in this project focus on rainbow parr rearing. Binns (1982) of the Wyoming Game and Fish Department modelled summer baseflow influences on resident trout abundance using % LT mad as an indicator of habitat quality. Since the Kettle River has a significant large resident trout fishery and has a similar hydrograph to Wyoming streams, it is important to put into context the preliminary results of this Kettle River study. This study's results demonstrate that flows in the magnitude of 20% LT mad are satisfactory for the creation of optimal conditions for small trout or parr-sized rainbow trout (10-20 cm FL). However the Binns Habitat Quality Index Procedures manual (page 19) suggests that flows of 20% LT mad are rated as "2" with limited trout capacity; summer baseflows or CPSF may severely limit trout stocks every few years. Future riffle transect findings may refine a different usable width relation with flow had HSI curves for larger trout been applied. It is possible that flows of >55% LT mad are indeed more suitable for sustaining a larger stock of trout if "feeding station" criteria were used (Shirvell 1976).

Binns also characterizes flows less than 10% LT mad as inadequate to support large resident trout. Long-term flow records for much of the Kettle River indicate "regulated" summer baseflows in a drought are now less than 10% LT mad.

2011 Snorkel Enumeration Surveys

Mark-Recapture & Snorkel Efficiency

In 2011, the marking of fish by angling for estimating observer efficiency was conducted from July 13-15 on the West Kettle River. Local fly-fishing clubs from Penticton, Kelowna and Castlegar assisted with the capture of fish within the control and treatment sections of the West Kettle River that are enumerated annually using snorkel surveys. A total of 18 and 60 rainbow trout were marked within the control and treatment sections, respectively.

Subsequent to the marking of fish, snorkel surveys were conducted on July 27 within the control and treatment sections on the West Kettle River. The snorkel surveys were the continuance of surveys conducted annually as part of the fish population monitoring lead by MFLNRO since 2001. A total of 3 and 10 rainbow trout were re-sighted within the control and treatment sections during the snorkel surveys, respectively. Both sections indicated an efficiency of 16% (R/M).

Table 5. Number of marked fish from angling in July 13-15 and re-sighted fish during annual snorkel surveys in July 27 in 2011.

Location	Marked (M)	Re-sighted (R)	Estimated Snorkel Efficiency
Control	18	3	0.16
Treatment	60	10	0.16

While efficiencies appear to be lower than expected, it should be noted that flows were considered higher than normal for this time of year for the West Kettle River, near 15 cm/s (Table 6). These flows are considered to be 2 times higher than the average flows for this time of year (Environment Canada on file). Similarly, surveys conducted on the Kettle River experienced similar high flows, well above the average for annual floats (Table 7). As well, visibility was less than ideal and may have affected counting conditions (Slaney and Martin 19987; Hagen and Baxter. 2005)). Under the high flows experienced snorkel crews indicated that turbidity was limiting their range of visibility (Hagen and Baxter. 2005). Visibility was determined to be 2 m using a underwater Secchi disc. Use of the mark-recapture data and the utility of the information collected in 2011 based on the aforementioned issues around higher flow and reduced visibility will be discussed.

Table 6. Mean daily discharge on surveys conducted from 1997-2011 on the West Kettle River. Daily discharge data from Environment Canada WSC station at Westbridge (08NN003).

Year	Survey Date	Mean Daily Discharge (m^3/s)
1997	Aug-28	3.29
1998	Jul-07	16
1999	Jul-27	8.09
2000	Jul-19	5.03
2001	Jul-14	4.48
2002	Aug-02	1.44
2003	Jul-09	3.5
2004	Jul-07	10.5
2005	Jul-18	5.55
2006	Jul-26	2.09
2007	Jul-25	3.48
2008	Jul-23	1.91
2009	Jul-27	2.18
2010	Jul-21	3.97
2011	Jul-27	15
	Avg.	5.77

Table 7. Mean daily discharge on surveys conducted from 2001-2011 on the Kettle River. Daily discharge data from Environment Canada WSC station at Westbridge (08NN026).

Year	Survey Date	Mean Daily Discharge (m^3/s)
2001	Jul-23	12.6
2003	Jul-11	11.8
2004	Jul-06	8.5
2005	Jul-12	*
2006	Jul-27	*
2007	Jul-26	7.32
2008	Jul-24	7.26
2009	Jul-27	8.31
2010	Jul-22	12.5
2011	Aug-09	13.1
	Avg.	10.2

*No survey data available

Kettle River

Single pass, non-replicated, snorkel surveys were conducted on the Kettle River at three key index sites (KR2, KR3 and KR5) during July 22-23, 2010. Counts were focused on enumerating salmonids in four size categories; 0-10 cm, 10-20 cm, 20-30 cm and >40 cm.

The surveys on the three key index sites indicate that adult and sub-adult numbers in 2011 increased from estimates in 2010 (Figure 19). Average trout density (trout per km) were considerably higher at 62 trout per km in 2011 compared to 40 trout per km in 2010 (Figure 20). Density of rainbow trout at the catch and release sites KR2 and KR3 increased in 2011 at 71 and 83 trout per km, respectively (Table 8). As well, the catch and harvest site KR5 indicated trout densities were higher at 34 trout per km in 2011 compared to 21 trout per km in 2010 within the mainstem (Table 8). However, results in the ~600 m side channel within KR5 comprised of highly complex habitat (LWD and deep pool), indicated a substantial decline in 2011 compared to 2010, with observed densities that were only 2 times higher than the mainstem (Table 8).

As previously indicated, flows of 13 m^3/s were considered to be above the average of 10.2 m^3/s despite the survey timing extending into August (Table 7).

Table 8. Mean rainbow trout per kilometre at key index sites under regulations (catch and release) imposed in 2004 on the Kettle River.

	Catch and Release Section		**Catch and Harvest Section**	
Year	**KR2**	**KR3**	**KR5**	**KR5 side channel**
2001	54	49	n/a	n/a
2003	55	n/a	n/a	n/a
2004	17	n/a	n/a	n/a
2005	8	19	n/a	n/a
2006	36	60	n/a	n/a
2007	40	40	20	93
2008	30	46	29	80
2009	59	97	16	36
2010	45	54	21	118
2011	71	83	34	68

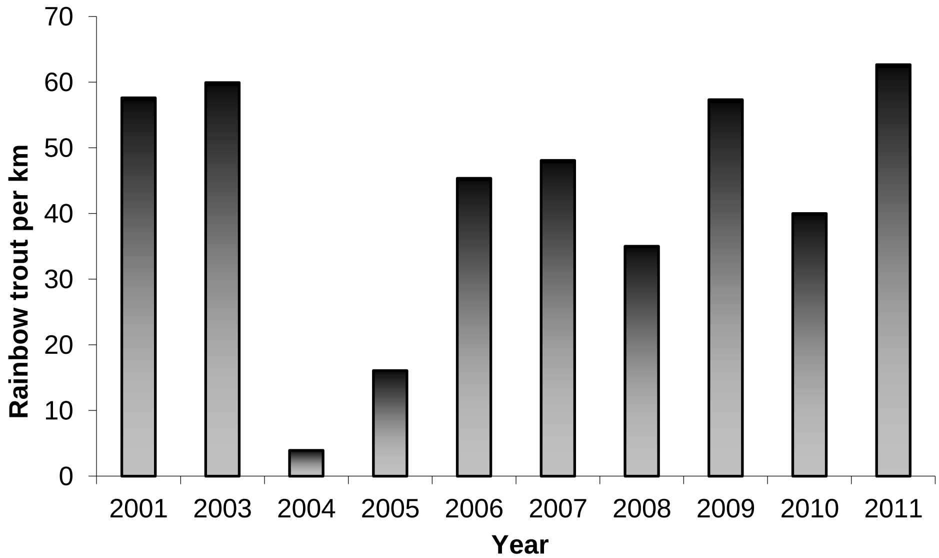


Figure 19. Mean rainbow trout per kilometre based on index sites (KR2, KR3, and KR5) for mainstem Kettle River from 2001 and 2003-2011.

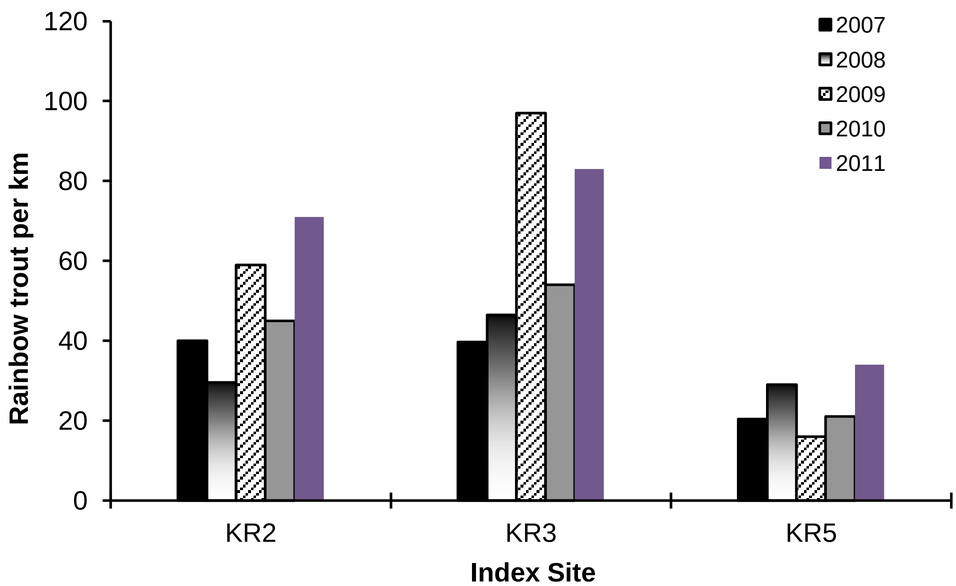


Figure 20. Mean rainbow trout per kilometre at key index sites under the catch and release (KR2 and KR3) and catch and harvest (KR5) regulations from 2007-2011.

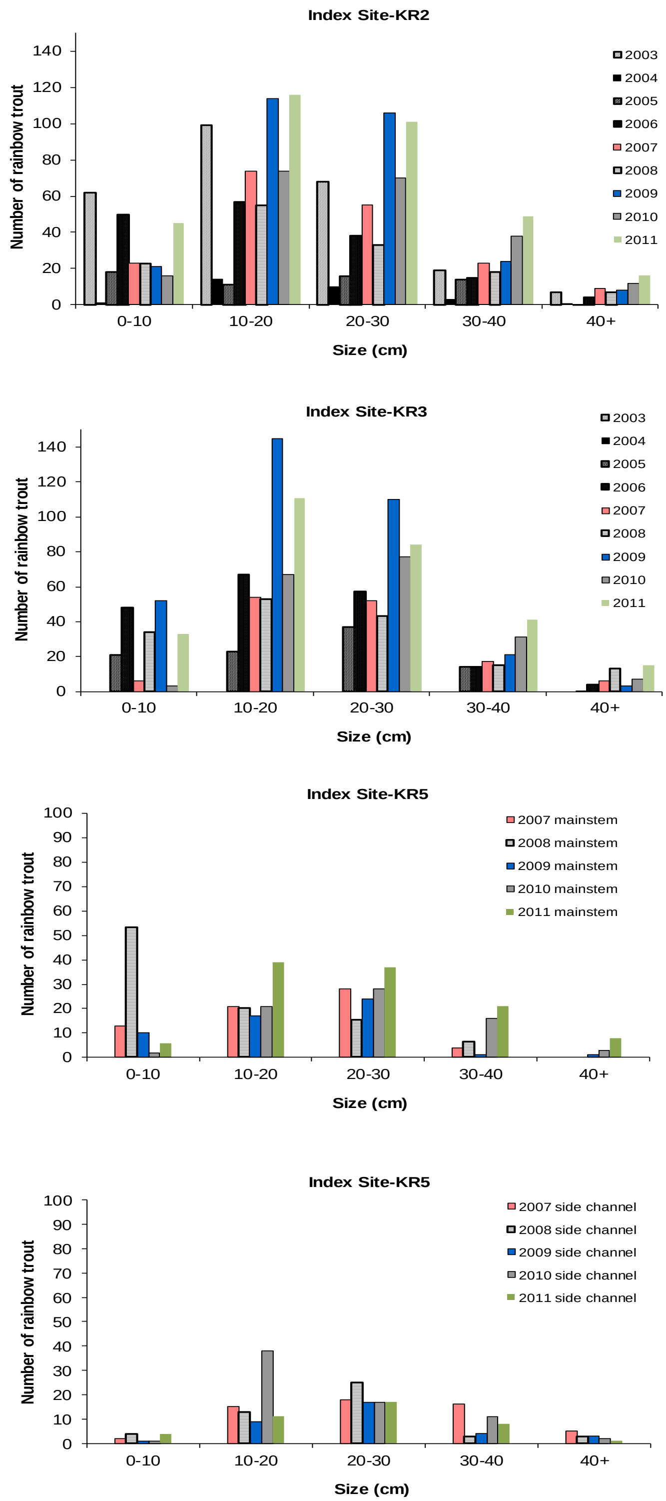


Figure 21. Rainbow trout abundance by size class at key index sites (2007-2011) before and after catch and release (KR2 and KR7) and catch and harvest (KR3) regulations were imposed in 2004**.**

West Kettle River

Single pass, non-repeatable, snorkel surveys were conducted within the 2.3 km treatment and 1 km control sections in the West Kettle River on July 21, 2010. Counts were focused on enumerating salmonids in four size categories; 0-10 cm, 10-20 cm, 20-30 cm and >40 cm, similar to that on the Kettle River.

Rainbow trout abundance within the treatment section showed a substantial decline from 398 trout per km in 2009 and 132 trout per km in 2010 to 66 trout per km in 2011 (Figure 21). Moreover, catchable trout numbers (> 20 cm) have also declined precipitously with declining abundance in 2011 (Figure 22). The control section also demonstrated a substantial decline in rainbow trout densities from 224 trout per km in 2009 and 220 trout per km in 2010 to 18 trout per km in 2011. While these results demonstrate substantial declines in both sections, as previously mentioned, flows were considered to be 2 times higher than the average flows for this time of year (Table 6; Environment Canada on file). Flows for the West Kettle River were ~ 15 cm/s and are normally conducted between 3-7 cm/s since 2001 (Table 6).

Whitefish abundance increased slightly to 18 fish per km within the treatment section in 2011 compared to 11 fish per km in 2010 (Figure 23). Similar to rainbow trout in the control section, whitefish densities declined substantially in 2011, with densities the lowest on record since 1998 at 2 fish per km.

Utilizing the estimated snorkel efficiencies from the mark-recapture experiment in each section (treatment and control), a total estimate of abundance can be calculated. An estimate of 108 (95% CI 77-139) rainbow trout were estimated in the control section of the West Kettle River (Table 9). Likewise, an estimate of 912 (95% CI 650-1173) rainbow trout were estimated in the treatment section of the West Kettle River (Table 9). However, sample size of marked fish (n=18) during the mark-recapture experiment in the control section was well below the minimum expected (n=50). Estimates by size class was not calculated due to the low recapture rates within each section.

Table 9. Mark-recapture estimates and 95% confidence intervals for control and treatment section of West Kettle River in 2011.

Location	Estimate	95% LCL	95% UCL
Control	109	77	139
Treatment	912	650	1173

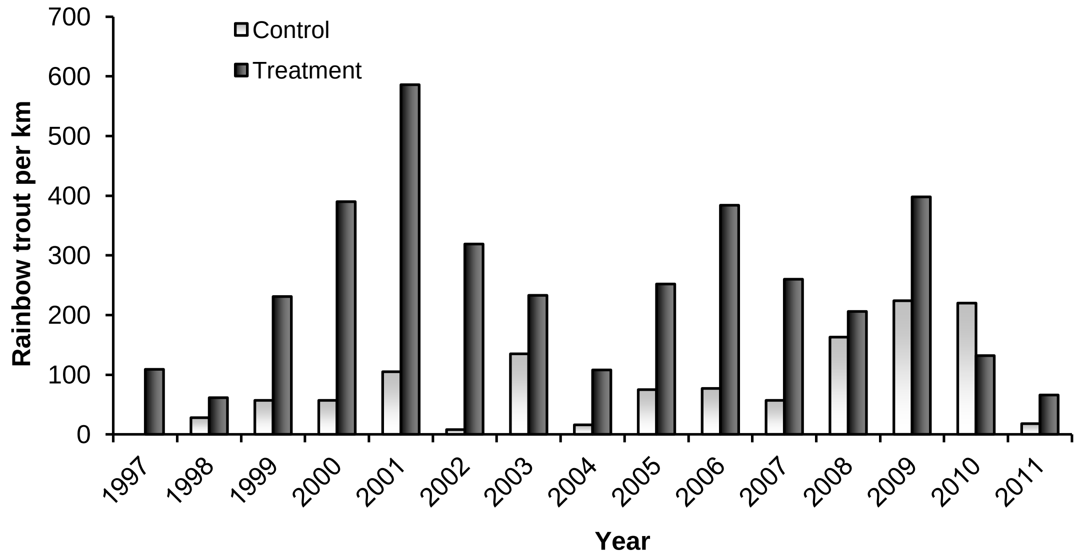


Figure 22. Rainbow trout per km in response to in-stream restoration on the West Kettle River, 1997 to 2011.

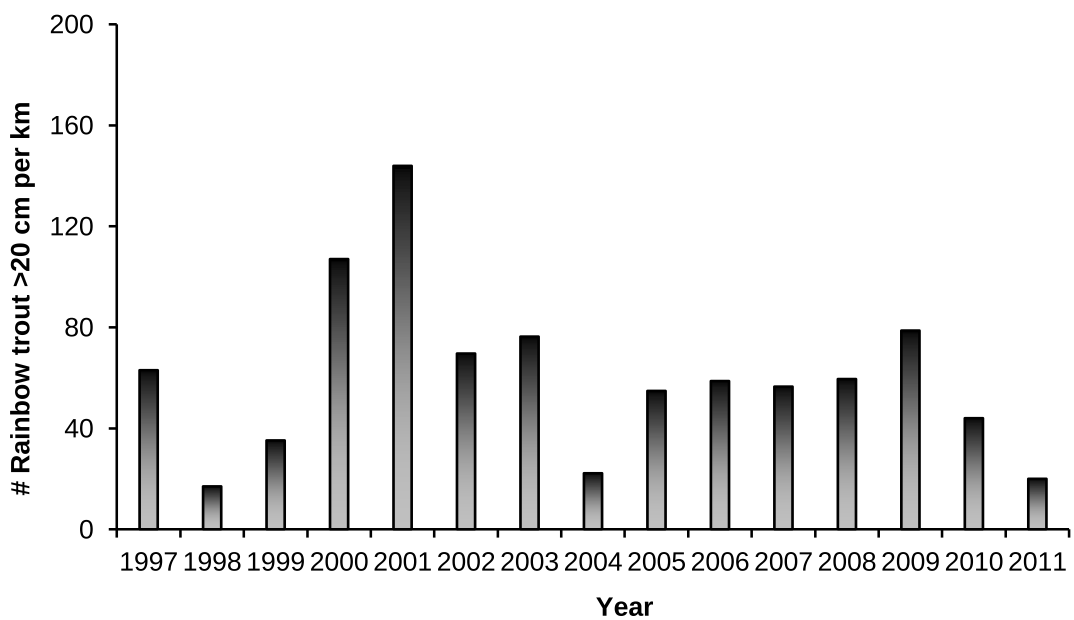


Figure 23. Catchable (> 20 cm) rainbow trout per km in response to in-stream restoration (treatment section) on the West Kettle River, 1997 to 2011.

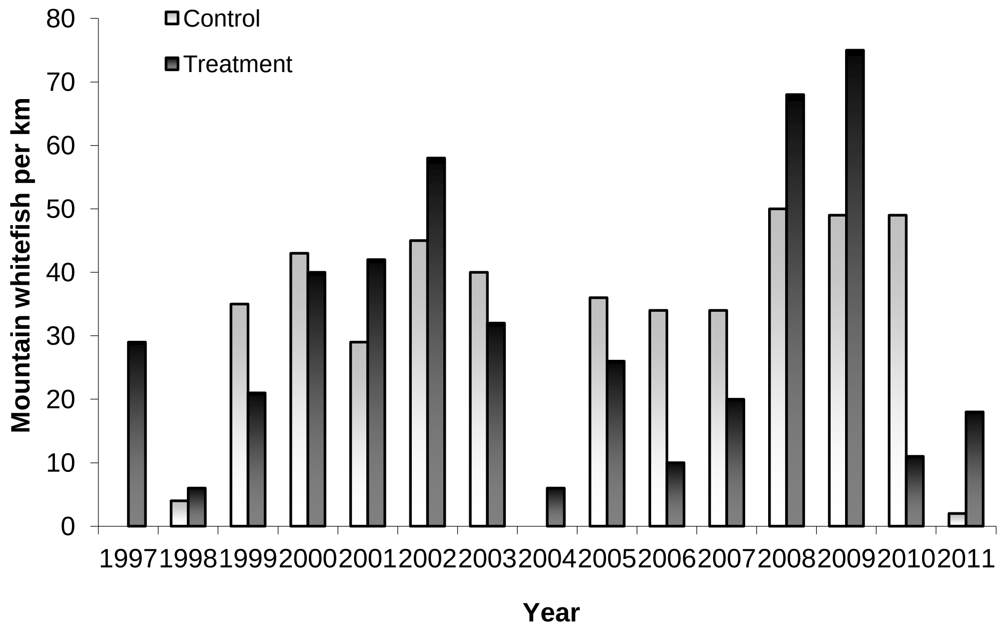


Figure 24. Whitefish per km in response to in-stream restoration (treatment section) on the West Kettle River, 1997 to 2011.

Granby River

In general, rainbow trout abundance, based on monitoring conducted since 2007, has increased following harvest regulations that were implemented in 2003 (Figure 24). Overall the abundance of rainbow trout had increased from ~50 rainbow trout per km in 2001 to > 80 rainbow trout per km in 2007-2011, based on the index site surveys However, the overlap in confidence intervals from pre harvest surveys (2001) indicates an inability to detect a significant change in abundance. Similarly, catchable rainbow trout (> 20 cm) demonstrated a slight increase in abundance following implementation of regulations, supporting the 2003 regulation change (Figure 25). However, despite the overlap in confidence intervals with pre harvest surveys (2001), the upward trend is not considered significantly different. Nonetheless, the information does support the importance of the regulation change to improve overall fishing conditions.

Comparison of the size class information suggests substantial changes in the proportion of small rainbow trout (< 20 cm) in the post regulation era (2007-2011) compared to the pre-regulation era (2001; Figure 26). Both the GR3 and GR6 site indicate comparably higher numbers of catchable trout (> 20 cm) following the regulation change in 2003. Both GR3 and GR6 demonstrate considerable increase in fish > 40 cm following the 2011 surveys. Once again, these observations support the change in regulation, which by not allowing a harvest has demonstrated an increase in catchable fish. Despite the increase in catchable trout in the post regulation era, total numbers of fish observed are lower in 2011 compared to 2010.

Surveys were conducted on the Granby River in 2011 indicated flows were slightly above the average from 2001 and 2007-2011 (Table 10). Nevertheless, survey timing in August made for good counting conditions with a range in visibility > 3 m.

Table 10. Mean daily discharge on surveys conducted from 2001-2011 on the Granby River. Daily discharge data from Environment Canada WSC station at Westbridge (08NN002).

Year	Survey Date	Mean Daily Discharge
2001	Jul-31	7.18
2007	Jul-25	5.43
2008	Aug-01	3.94
2009	Jul-28	6.85
2010	Jul-23	11.2
2011	Aug-10	9.6
	Avg.	7.4

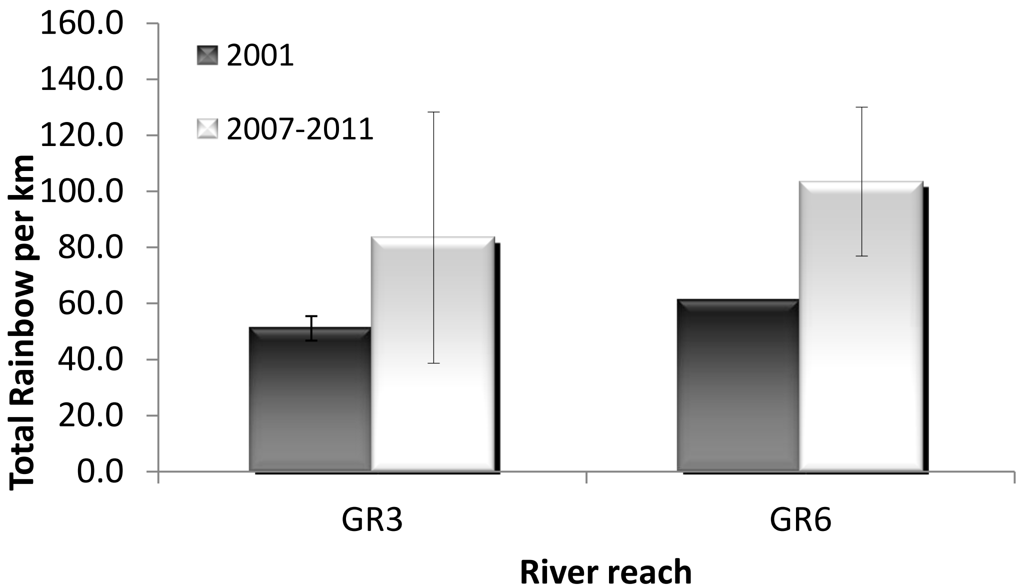


Figure 25. Total Rainbow Trout per km observed in snorkel surveys pre (2001) and post (2007-2011) harvest closure. Error bars on 2007-2011 data indicate 95% C.I.s where as the error bars for GR3 in 2001 indicate the range observed from two replicate counts.

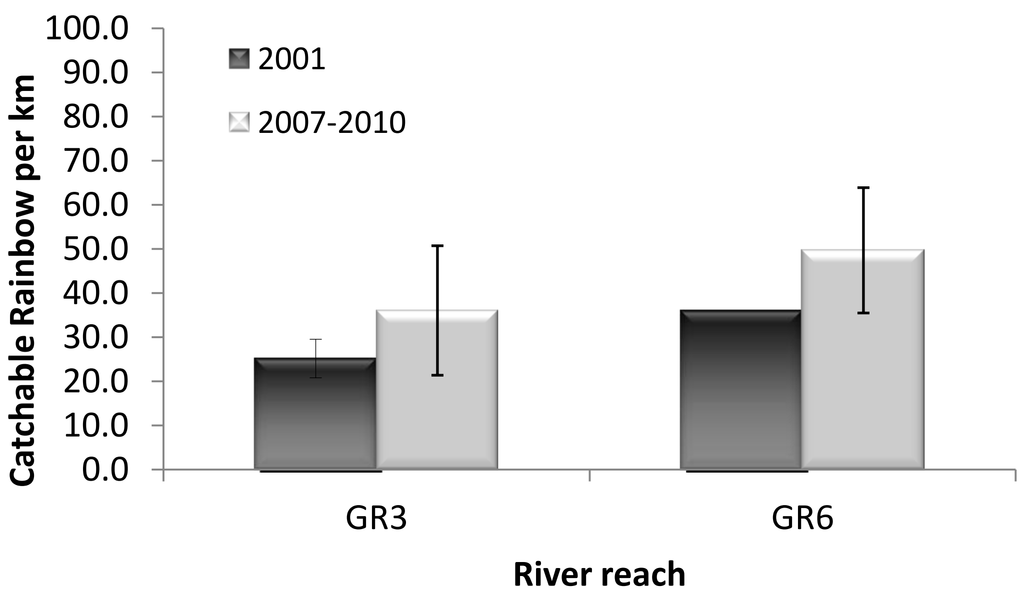


Figure 26. Catchable rainbow trout per km observed in snorkel surveys pre (2001) and post (2007-2011) harvest closure. Error bars on 2007-2011 data indicate 95% C.I.s where as the error bars for GR3 in 2001 indicate the range observed from two replicate counts

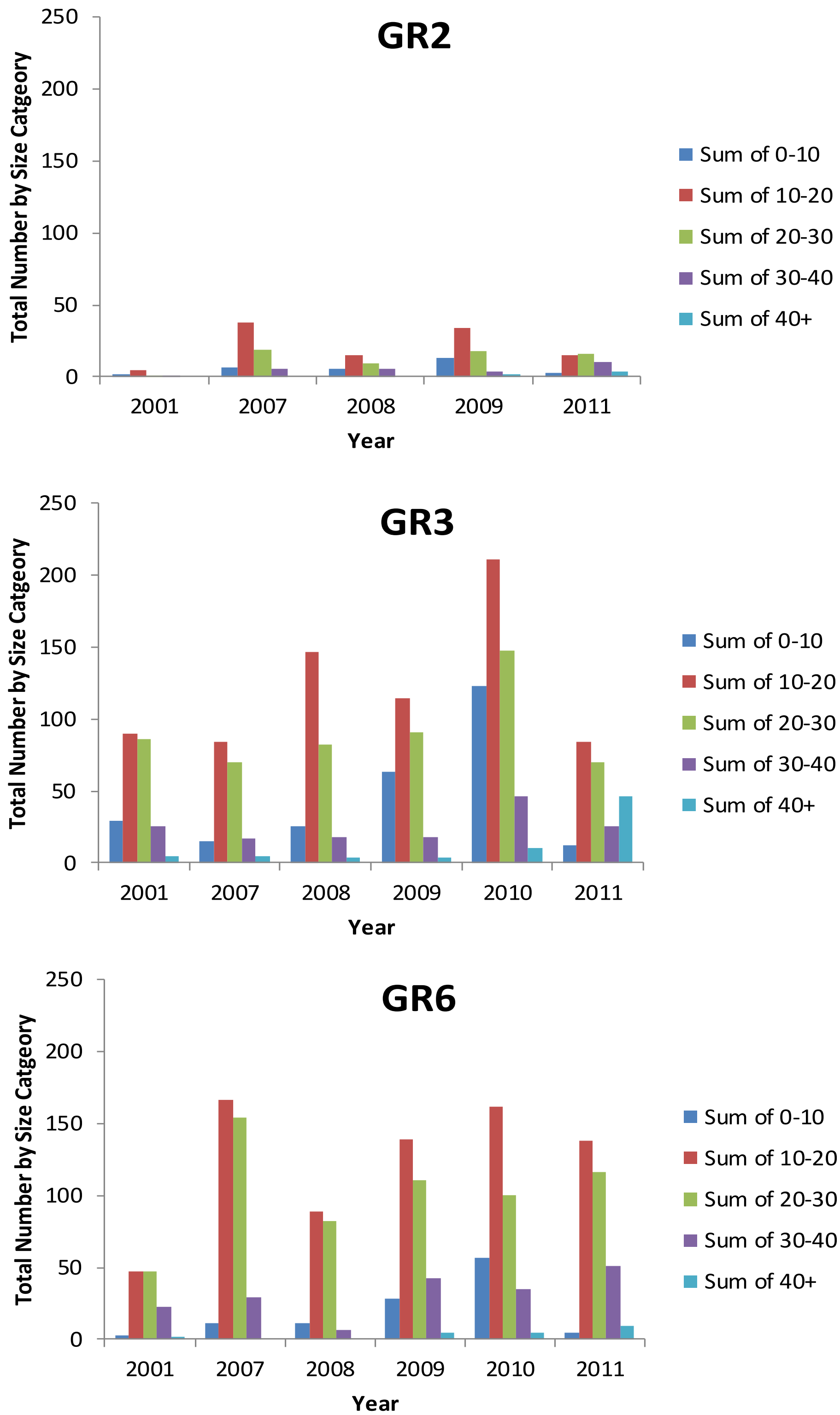


Figure 27. Rainbow trout abundance by size class surveys pre (2001) and post (2007-2011) harvest closure at key index sites.

4. SUMMARY AND CONCLUSIONS

The results and observations from the 2010 and 2011Kettle River flow / temperature / habitat and snorkel enumeration can be summarized as follows:

Seasonal Flow Information

- Flows are highly synchronized within sub-basins (West Kettle, Upper Kettle, Lower Kettle and Granby), with patterns of storm peaks and periods of low flows well replicated throughout the watershed.
- Annual flow patterns relative to long term averages can change significantly over the summer and fall. River flows in 2011 were very high in July at a 1 in 10 year return period (90th percentile), but diminished to median (50th percentile) flows by mid to late August and continued to diminish to 1 in 4 year (25th percentile) low flows by mid to late September.
- Similar to 2010, lowest flows in 2011 ranged from 5 to 9 % of long term mean annual discharge (LTmad) among the flow monitoring stations. The upper West Kettle River continued to have some of the lowest flows in the watershed, but in 2011 the Granby River also had lower flows relative to the larger Kettle River.
- The flow patterns among stations in the Lower Kettle sub-basins indicate periods at downstream sites that are lower than flows upstream. This is interpreted as evidence that downstream flows are being reduced by upstream water use. Flows at the Granby WSC station at Grand Forks are also lower than upstream stations, suggesting a possible loss to groundwater as influenced by withdrawals from nearby wells.

Temperature Information

- River temperatures were high at times in August, reaching 22 ^{o}C in the West Kettle and Kettle River both in early and late August and 22 ^{o}C in the lower Granby River in late August. Highest temperatures are recorded at the most downstream sites with a 2 to 3 ^{o}C difference between the most upstream and most downstream sites.
- River temperatures are well correlated with mean air temperature, with the highest river temperatures measured on the days when mean air temperature approached

22 ^{o}C. Maximum river temperatures were lower than in 2010 when river temperatures reached 24 ^{o}C.

- River temperatures are also highly synchronized within and among sub-basins, with periods of high and low water temperatures well replicated throughout the watershed.
- River temperatures show up to 6 ^{o}C in diurnal fluctuation, with the highest water temperatures in later afternoon and lowest temperatures at about 7:00 A.M. to 9:00 A.M.
- The 2011 results again show little if any correlation between river temperature and flow at flows of less than about 20 m^3/sec, but there were indications of lower river temperatures relative to air temperature in late July and early August when the Kettle River flows at Ferry were receding from above 50 m^3/sec. High river temperatures do commonly occur at low flows, but this is mostly coincidental as periods of low flows are typically associated with hot and dry weather conditions in late July and August.

Weighted Useable Widths in Relation to Flows

- Useable habitat width vs. flow analyses show that for rainbow trout parr, useable habitat width is optimized or close to optimized values when flows are close to 20%LTmad. While 20%LTmad is a good generalization for the watershed, sites with lower annual discharge like the Upper West Kettle optimize at values on the upper side of 20%LT mad, while sites with higher annual discharges like the Kettle River below Westbridge optimize a little below 20% LTmad.
- Useable habit width is significantly lower at all sites at flows of 10%LTmad due to low riffle depth, but riffle velocities still tend to be satisfactory at these flows.
- Useable habitat width declines rapidly as flows decrease further below 10% mad, with both riffle velocities and riffle depths declining rapidly.

Weighted Useable Widths in Relation to Rainbow Trout

- Deep, fast water habitat (especially pools) limits rainbow trout abundance
- Late summer water temperatures can become lethal to rainbow trout

- Flows < 10%LTmad combined with high summer temperatures are problematic for trout and whitefish and mortalities can be expected at temperatures > 24°C if prolonged.
- Snorkel survey data provides population trend data but is of little use for interpreting fish flow requirements.
- Low flows and high temperatures most likely influence trout growth and survival but there are a number of other factors related to habitat such as pool limitation that also influence growth and survival.

Snorkel Survey Information

- Mark –recapture data collected on snorkel efficiencies in the West Kettle River for deriving abundance estimates may be biased as a result of high flow conditions in the summer of 2011 (Slaney and Martin 19987; Hagen and Baxter. 2005).
- Derived snorkel efficiencies may need further years of data collection. Estimates should incorporate visibility and flow information into a model before deriving abundance estimates.
- While the Kettle River demonstrated considerable increases in rainbow trout numbers based on snorkel surveys at annual index sites, the West Kettle River numbers declined substantially in both index sites
- West Kettle snorkel surveys were conducted under abnormally high flows for this time of year, biasing fish counts. Increased turbidity reduced visibility to ~ 2m, near the limit for conducting snorkel surveys (Slaney and Martin 19987; Hagen and Baxter. 2005).
- Granby River counts demonstrated a slight decline in overall fish numbers in 2011 compared to 2010. Survey timing was delayed until August which allowed for ideal counting conditions. Nevertheless, numbers of catchable fish and overall abundance has increased since 2003 when regulations were imposed.
- It is unsure whether trends in fish populations from snorkel surveys are a result of flow related issues on these systems. Nevertheless, data does support the fact that flows below < 10%LTmad, combined with high temperatures are problematic for fish in these systems.

5. REFERNCES

Andrusak, G. 2006. Kettle River, West Kettle River and Tributary Rainbow Trout Assessment 2006. Prepared for the Ministry of Environment, Penticton and the Habitat Conservation Trust Fund.

Andrusak, G.F. 2007. Kettle River Restoration and Assessment - 2007. Prepared for the Ministry of Environment, Penticton and the Habitat Conservation Trust Fund.

Andrusak, G.F. 2009. Kettle River Rainbow Trout Assessment and Habitat Restoration 2009. Contract report by Redfish Consulting Ltd. written for the Ministry of Environment Penticton BC.

Andrusak, G.F. and H. Andrusak. 2011. Identification of Habitat Use and Preferences of Speckled Dace within the Kettle River Watershed. Redfish Consulting Contract Report prepared for the Department of Fisheries and Oceans (DFO) Vancouver BC.

Aqua Factor Consulting. 2004. Potential Effects of the Cascade Heritage Power Project on the Allocation of Water in the Kettle River Basin. Aqua Factor Consulting Inc., Victoria, BC

Askey, P. 2009. Granby River Snorkel Assessment 2007-2009. Prepared for Ministry of Environment, internal files.

Binns, N.A. 1982. Habitat quality index: procedure manual. Wyoming Fish and Game Department. Cheyenne, Wyoming. 209 pages

Epp, P.F. 2010. 2009 Flow & Habitat Monitoring Kettle and West Kettle Rivers. BC Ministry of Environment, Penticton, BC.

Haddon, M. 2001. Modeling and Quantitative Methods in Fisheries. Chapman and Hall/CRC, Florida.

Hagen, J, and Baxter, J.S. 2005. Accuracy of diver counts for fluvial rainbow trout relative to underwater horizontal visibility. North American Journal of Fisheries Management **25**:1367-1377

Jowett, I,G. 1992. Models of the abundance of large brown trout in New Zealand rivers. North American Journal of Fisheries Management 12: 417-432.Leopold, Luna B., 1994, A View of the River, Harvard University Press, 290p.

Oliver, G.G. 2001. Towards a fisheries management strategy for the Kettle River basin in south central British Columbia. Fisheries Renewal BC Project Report Prepared for the Ministry of Environment Lands and Parks, Penticton.

Oliver, G.G. 2002. Kettle River basin study phase II: Rainbow trout status and water temperature characteristics at selected sites. Fisheries Renewal BC Project Report Prepared for the Ministry of Environment Lands and Parks, Penticton.

Ptolemy, R. 2011. Personal communication - e-mails dated 05/01/2011 & 13/01/2011.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat Requirements of Anadromous Salmonids. General Technical Report PNW-96. Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Portland Oregon.

Sebastion, D. 1989. An Analysis of Rainbow Trout (Onchorynchus mykis) Production in the Kettle River System in South Central BC. Fisheries Project Report NO. FAIU - 13, Fisheries Assessment and Improvement Unit, Recreational Fisheries Branch, Victoria, BC.

Shirvell, C. S., and R. G. Dungey. 1983. Microhabitats chosen by brown trout for feeding and spawning in rivers. Transactions of the American Fisheries Society 112: 355-367.

Slaney, P.A. and A.D. Martin. 1987. Accuracy of underwater census of trout populations in a large stream in British Columbia. N. Am. J. Fish. Mgmt. 7: 91-105.

Slaney, P.A., W. Koning, S. D'Aoust and R. Millar. 2001. Increased Abundance of Rainbow Trout in Response to Large Woody Debris Rehabilitation at the West Kettle River. Streamline Vol. 5 No. 4.

6. APPENDIX-A-Photographs of Riffle Transects

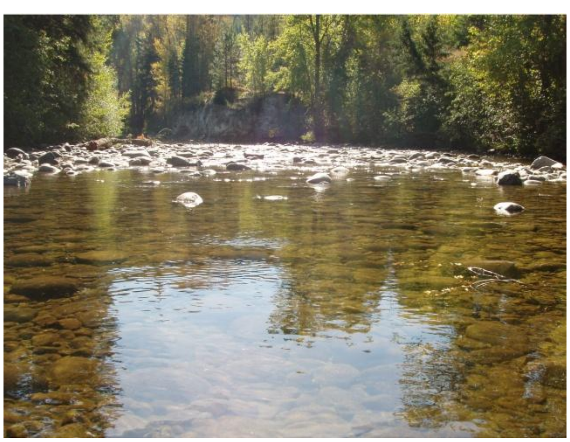
West Kettle River at Carmi

2,974 L/sec 32%LTmad

1,736 L/sec 18% LTmad

970 L/sec 10%LTmad

607 L/sec 7% LTmad



483 L/sec 5%LTmad

385 L/sec 4% LTmad

West Kettle River at Debris Catchers

4,960 L/sec 46%LTmad

3,093 L/sec 29% LTmad

2,133 L/sec 20%LTmad

1,586 L/sec 15% LTmad

1,182 L/sec 11%LTmad

760 L/sec 7% LTmad

Kettle River at Humuh Bridge

8,474 L/sec 37%LTmad

6,100 L/sec 27% LTmad

4,390 L/sec 19%LTmad

3,065 L/sec 13% LTmad

2,068 L/sec 9%LTmad

1,448 L/sec 6% LTmad

Kettle River near Rock Creek

12,944 L/sec   32%LTmad

10,251 L/sec   25% LTmad

8,226 L/sec   20%LTmad

5,838 L/sec   14% LTmad

4,452 L/sec   11%LTmad

4,085 L/sec   10% LTmad

Kettle River near Midway

15,816 L/sec 37%LTmad

11,437 L/sec 27% LTmad

8,480 L/sec 20%LTmad

6,183 L/sec 14% LTmad

4,338 L/sec 10%LTmad

3,859 L/sec 9% LTmad

Granby R. Upper (near Almond Ck)

7,739 L/sec 34%LTmad

4,916 L/sec 21% LTmad

3,485 L/sec 15%LTmad

2,628 L/sec 11% LTmad

2,024 L/sec 9%LTmad

1,273 L/sec 6% LTmad

Granby River Mid near Bridge

8,747 L/sec   31%LTmad

5,531 L/sec   20% LTmad

4,262 L/sec   15%LTmad

3,260 L/sec   12% LTmad

2,498 L/sec   9%LTmad

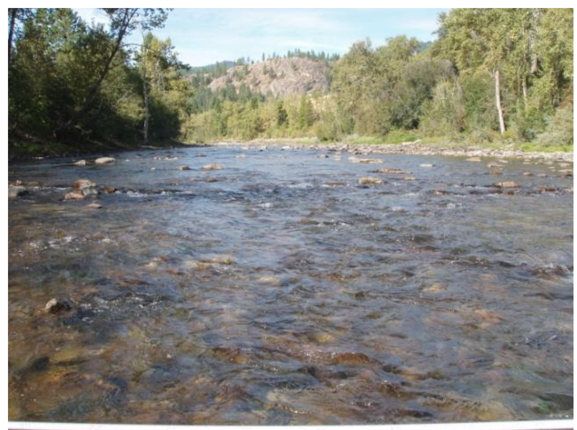
1,767 L/sec   6% LTmad

Granby River Subdivision

6.628 L/sec 22%LTmad

4.189 L/sec 14% LTmad

3,025 L/sec 10%LTmad



2,108 L/sec 7% LTmad

1,955 L/sec 6%LTmad