Nicola Water Use Management Plan

Instream Flow Requirements for Anadromous and Resident Fish

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Prepared for:

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EXECUTIVE SUMMARY

The objective of the Nicola Water Use Management Plan (WUMP) is to strike a balance between instream (environmental) and out-of-stream (human) benefits of water allocation with the ultimate goal of providing a safe, reliable and equitable supply of water for generations to come. The intention is to incorporate instream flow requirements (needs) for fish and fish habitat into the Nicola WUMP, however, prior recommendations for the Nicola River watershed are now over 25 years old. It has therefore been recommended that fish flow requirements for the Nicola watershed be updated to: a) incorporate more recent transect data on stream flows in the Nicola watershed; b) reflect recent research and scientific understanding of instream flow requirements for fish and fish habitat; and c) determine optimum flow levels using a combination of empirical and meta-analysis data.

The historical transect data collected by Kosakoski and Hamilton (1982), and Ptolemy (1984), are generally in good alignment with the recent transect data collected by Ministry of Environment (2004-2007). However, the MOE data provide a finer level of detail on habitat suitability than the historical studies. For example, the historical transect data suggest an increase in habitat suitability for coho adults with increasing discharge in the N2 reach. However, while the MOE data indicate that habitat suitability increases up to approximately 6.4 cms (46% MAD), there is then a decline in habitat suitability at higher discharges. This decline in habitat suitability at high discharge rates is not evident from the historical data.

Kosakoski and Hamilton (1982) predicted optimal flows for various life-history stages in certain reaches of the Nicola and Coldwater rivers. These optimal flows were compared with those predicted from the life-stage specific criteria predicted from discharge and geographical location using the relationships given by Bruce and Hatfield (2003), as well as those derived from recent empirical data (MOE 2004-2007). There were a few instances where the optimal flows predicted by Kosakoski and Hamilton were lower than those determined more recently, either from empirical data or through calculation via a meta-analysis of instream flow studies. The most notable discrepancy was for adult chinook in the Nicola and Coldwater rivers.

Kosakoski and Hamilton identified N2 as the critical reach in the Nicola River, and spawning chinook as the critical life-history stage. Reach N2 contains 75% of chinook spawning habitat despite representing only 25% of the river's length downstream of Nicola Lake, while adult chinook have the highest flow requirements during a period of naturally low flow, with the peak of spawning occurring in September. The recent MOE data support the conclusion that chinook adults have the highest flow requirements at a critical time. Kosakoski and Hamilton list the optimum flow for spawning chinook in the N2 reach as 4.25 cms (31% MAD). However, this is lower than the optimal flow predicted by relationships in Bruce and Hatfield (6.8 cms, or 49% MAD), and that suggested from recent empirical data (11.0 cms, or 80% MAD).

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Kosakoski and Hamilton recommended an instream flow minimum of 3.12 cms (23% MAD) for chinook spawning in the N2 reach, which is well below the predicted optimal flow. Increasing the recommended instream flow minimum in N2 during the spawning/rearing period (Aug-Nov) based on adult chinook requirements would also increase habitat suitability for coho adults, but it would decrease the habitat suitability for rearing chinook, coho and steelhead fry, as well as chinook parr. However, if additional water were available it would be beneficial to release this during the month of September, which is the peak spawning period for adult chinook in the Nicola River. In August, and October through December, flows should be maintained at the current recommended minimum instream flow for the N2 reach (3.12 cms, or 23% MAD), which is suitable for the rearing life-history stages of chinook, coho and steelhead.

The optimal flow for chinook adults in the N3 reach and Coldwater River also appear to have been underestimated by Kosakoski and Hamilton, although the recommended minimum instream flows in these reaches also appear valid for the rearing life-history stages of chinook, coho and steelhead.

This analysis suggests that any change being considered to the minimum instream flow recommendations made by Kosakoski and Hamilton should be an increase in the minimum instream flow in September, in order to support the critical life-history stage of spawning adult chinook. The current recommended instream flow minima remain valid for the other species and life-history stages, although coho adults would also benefit from increased flows in October and November. However, any increase in the minimum recommended instream flow during the fall would decrease the habitat suitability for rearing life-history stages. Given the current pressures on the available water supply, an increase in minimum instream flow may not be attainable, even if desired. Nevertheless, this analysis supports the general recommendation of Kosakoski and Hamilton that "to ensure that the salmonid production potential of the Nicola River system is maintained, it is recommended that there be no increase in water diversion from the Nicola mainstem, Spius Creek, and Coldwater River during low flow periods, and no new water diversion licences unless they are supported by storage."

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1. INTRODUCTION

1.1. Objective

Ecofish Research Ltd. (Ecofish) was retained by the Fraser River Basin Council to update the instream flow requirements for fish and fish habitat for the Nicola and Coldwater Rivers, a key input the Nicola Water Use Management Plan (WUMP). The WUMP was initiated in 2004 by residents of the Nicola watershed and others stakeholders to reduce future water use conflicts and address both existing and newly emerging water use issues. Conflicts are predicted to intensify with economic and population growth but most particularly with the current and impending problems associated with climate change (Nicola WUMP 2006). The objective of the Nicola WUMP is to strike a balance between instream (environmental) and out-of-stream (human) benefits of water allocation with the ultimate goal of providing a safe, reliable and equitable supply of water for generations to come (Nicola WUMP 2006).

The Nicola River and tributaries are important producers of salmon and other fish species, all of which depend on an adequate supply of streamflow to survive. There is a long history of fisheries assessment in the basin, and instream flow requirements (needs) for fish have been well studied, supporting instream flow requirements that provide targets for water allocation in the Nicola River and tributary streams. The key study, a detailed instream flow field investigation published by Gordon Kosakoski and Roy Hamilton of the Department of Fisheries and Oceans, was prepared over 25 years old in 1982. Since that time there have been substantial changes in water use and streamflow in the Nicola basin, as well as in the way instream flows are evaluated and set (Hatfield *et al.* 2003, Lewis *et al.* 2004). Changing environmental conditions and a new understanding of water use issues has lead WUMP stakeholders to recommend that the fish flow requirements for the Nicola watershed be updated to reflect current conditions (Roseneau and Angelo 2003, Hatfield 2007, Water Management Consultants 2008). The work presented in this report meets one of the WUMP recommendations to undertake detailed instream flow needs assessment in key areas (Nicola WUMP Multi-Stakeholder Committee 2009), thus providing key information for setting instream flow requirements for fish.

In this report instream flow requirements for the Nicola River and tributaries have been calculated using contemporary techniques (Lewis *et al.* 2004) that analyze the historic transect data (Kosakoski and Hamilton 1982) and incorporate transect data recently collected by the Ministry of Environment. The analysis integrates stream transect data with hydrology, fish distribution and habitat use timing (fish periodicity) to construct habitat-flow relationships that can be used to set instream flows. However, the present analysis does not include preparation of a habitat time series, nor do we assess habitat losses from a particular flow regime, a key part of the flow assessment methodology described in the BC Flow Assessment Methods. That approach is appropriate when evaluating the effects of a proposed flow withdrawal on fish

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habitat. However, the NWUMP Multi-Stakeholder Committee will be evaluating alternative operating regimes using a multiple performance measures, some reflecting instream flow needs for fish, others reflecting stream health and water temperature, and others reflecting non-fisheries interests measures such as downstream flooding risk and beach availability. In the context of the Nicola WUMP, the habitat flow relationships calculated here are one of many inputs that will help guide decision making an iterative process lead a by third-party facilitator.

The following tasks were completed as part of this work:

1. Update the Kosakoski and Hamilton (1982) Instream Flow Requirement (IFR) analysis, results and recommendations using the most recent habitat suitability index data (including, if suitable, recent data on chinook collected for WUMP (Triton 2009));
2. Analyse recent MOE/DFO/SNHC habitat transects for the Nicola and Coldwater Rivers, providing these data are suitable;
3. Include updated fish periodicity tables prepared by Hatfield (2009), synthetic daily hydrograph data, and optimum IFR recommendations based on meta-analysis;
4. Present data in tabular and graphical summaries; and
5. Evaluate original IFR's recommended in Kosakoski and Hamilton (1982) for Nicola and Coldwater Rivers in units of cms and %MAD;

1.2. Background

The Nicola River (WC 120-246600) is a 6th order stream and one of the biggest tributaries to the Thompson River, occupying a 7,280 km^2 watershed in the Thompson River basin in south-central British Columbia. From the headwaters in the high country of the Douglas Plateau, the river meanders 150 km to meet the Thompson River at the town of Spences Bridge (Figure 1). The largest tributary to the Nicola River is the Coldwater River (120-246600-33700), a 5th order stream (FISS 2009) (Figure 1). Nicola Lake, the largest lake in the watershed, situated approximately 20 km north of the Merritt, plays a critical role in regulating flows for human and environmental uses. A dam was constructed at the outlet of Nicola Lake in 1927 and rebuilt in 1985, when new operating rules and flow release levels were instated for manage irrigation storage, flood protection, and fisheries flows (Roseneau and Angelo 2003).

As early as 1871, water flow was diverted and withdrawn from the Nicola River and its tributaries for agricultural, domestic, and industrial uses (Starr 1977). Irrigation is the most extensive and intensive user of water in the arid Nicola River basin, and agricultural withdrawals have substantive effects on fish habitat in the watershed (Roseneau and Angelo 2003).

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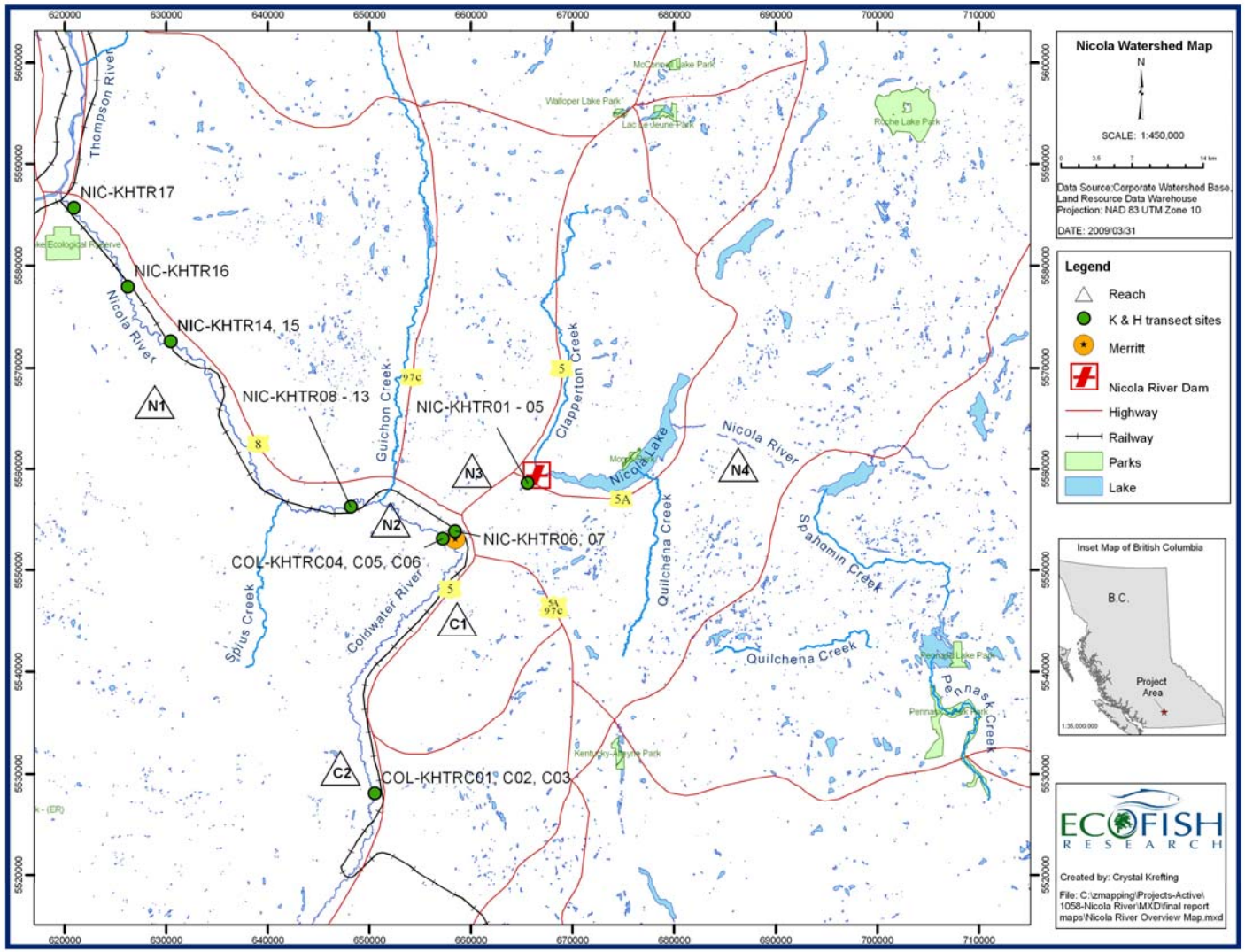
Figure 1 **Map of the Nicola River watershed with the Kosakoski and Hamilton (1982) study transect and reach locations.**



Although there is sufficient water supply on an annual basis to supply both environmental and human needs, most of the water flow in the Nicola River occurs during the spring runoff period and there are occasional years where large late-autumn/early winter floods occur. Despite these periods of high flow, water supply does not match water use within years, resulting in water deficits during the low flow months of July through September (Water Management Consultants 2008). This time period coincides with the most critical time for salmon reproduction and rearing. As a result, conflicts between water extraction for agriculture and fisheries values have been taking place for decades (Starr 1977, Fleming and Nathan 1985, Petrie 1986, Roseneau and Angelo 2003).

The Nicola River watershed supports many species of resident fish and four species of anadromous salmonids, providing critical habitat for stocks of upper Fraser River chinook salmon (*Oncorhynchus tshawytscha*) (Roseneau and Angelo 2003) and populations of interior Fraser River coho salmon (*O. kisutch*), which were listed as endangered by the Committee on the Status of Endangered Wildlife in Canada in 2002 (COSEWIC 2002). The Nicola River watershed also supports a population of the exceptionally large Thompson River steelhead (*O. mykiss*), as well as other populations of steelhead (Roseneau and Angelo 2003). The lower Nicola River, near the confluence with the Thompson River, also hosts a small but significant population of odd-year pink salmon (*O. gorbuscha*) (Kosakoski and Hamilton 1982).

The health and survival of the freshwater life history stages of all species of salmon depends in part upon the magnitude and seasonal timing of stream flow (Roseneau and Angelo 2003, Hatfield 2007, Nelitz *et al.* 2007). Stream flow is a master variable that forms fish habitat by controlling the key attributes physical space, water temperature, water chemistry, and dissolved oxygen. Water withdrawals can negatively impact fish habitat directly, by reducing living space, and indirectly, by reducing habitat quality. To address this problem on the Nicola River, Kosakoski and Hamilton (1982) defined the amount of flow required to maintain fisheries production potential – the 'fisheries resource maintenance flows' (today know as instream flow requirements or IFR's) – for the Nicola River and its principal tributaries. Kosakoski and Hamilton (1982) considered the habitat requirements for each species and life history stage in the context of the hydrology of the system, identifying August through November as the salmon spawning and rearing period, and December through April as the incubation and juvenile overwintering period. They set minimum flow levels for these two periods for four reaches of the Nicola River (from Douglas Lake to the Thompson River) and for the Coldwater River (Table 1). Kosakoski and Hamilton (1982) made a number of additional recommendations to protect fish and fish habitat from the effects of excessive water use including that "there be no increase in water diversion from the Nicola mainstem, Spius Creek, and Coldwater River during low flow periods, and no new water diversion licences unless they are supported by storage". However, within the Nicola River basin, intense pressure persists to allocate additional water for both agricultural and development objectives (Roseneau and Angelo 2003).

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Table 1 Fisheries resource maintenance flows recommended by Kosakoski and Hamilton (1982).

Stream	Reach	MAD	Fisheries Resource Maintenance Flows					
			Aug-Nov			Dec-Apr		
		cms	cfs	cms	%MAD	cfs	cms	%MAD
Nicola River	N1 - Thompson River to Spius Creek	26.9	200 [1]	5.66	21%	200 [1]	5.66	21%
	N2 - Spius Creek to Coldwater River	13.8	110 [1]	3.12	23%	110 [1]	3.12	23%
	N3 - Coldwater River to Nicola Lake	5.1	60 [1]	1.69	33%	40 [1]	1.13	22%
	N4 - Nicola Lake to Douglas Lake	4.4	28 [2]	0.78	18%	28 [2]	0.78	18%
Coldwater River	Brodie to Merrit	8.7	50 [1]	1.42	16%	50 [1]	1.42	16%

[1] Recommended minimum flows

[2] Estimate based on 20% of mean annual discharge

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2. METHODS

2.1. Instream Flow Study

2.1.1. Data

Instream flow data collected by Kosakoski and Hamilton in 1981, Ron Ptolemy from the BC Ministry of Environment (MOE) in 1984, and by MOE in 2004 to 2007 were utilized to develop revised instream flow guidelines for the Nicola and Coldwater Rivers.

Kosakoski and Hamilton (1982) collected data along 17 transects on the Nicola River and 6 transects on the Coldwater River (Figure 2, Table 2). These data are hereafter referenced as the K & H dataset. Transects were selected to adequately represent all habitat types (i.e. pools, riffles and runs). Depth and velocity (at 0.6 of depth) measurements were taken along whole-river transects at intervals ranging from 4 to 8 ft (Kosakoski and Hamilton 1982). Measurements were repeated at different flow periods. Dominant and sub-dominant substrate type was also recorded using a modified Wentworth particle size scale.

Instream flow data were also provided by Ron Ptolemy from MOE. These data represent a one-time measurement of flow over whole-river transects collected during an electrofishing study conducted by MOE in 1984. As such, depth and velocity measurements were only taken along whole-river transects at one flow level. Substrate data was not collected for the whole-river transects. These data are hereafter referenced as the Ptolemy dataset.

Instream flow data collected by MOE in 2004-2007 followed the methods outlined in the BC Instream Flow Methodology (BCIFM) (Lewis *et al.* 2004). Depth and velocity data were collected following protocol standards (Lewis *et al.* 2004). MOE collected instream flow data at multiple whole-river transects at different flow periods within the Nicola watershed and beyond. Only transects within the Nicola River and the Coldwater River were selected for analysis (Appendix 3). MOE, however, did not collect substrate and cover data at each transect, as stipulated in the guidelines. These data are hereafter referenced as the MOE dataset.

In the Kosakoski and Hamilton (1982) study, transects were clumped into distinct reaches along the Nicola River and tributaries for recommending fisheries resource maintenance flow requirements (FRMF) (Table 1). These distinct reaches were retained for the current instream flow analysis (Figure 2 to 7). A total of 54 transects were analyzed to develop instream flow guidelines (Table 2). Further details on these transects are provided in Appendix A. This assessment relies on these data collected by other individuals and organizations.

Water Survey Canada (WSC) hydrometric data were utilized for the instream flow study. We used the same WSC gauge data as Kosakoski and Hamilton (1982) (Table 2, Figure 2). However, in 1981, hydrometric data for reach three, N3, was unavailable. Hydrometric data for

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this reach was estimated by using data from the Nicola River near Merritt Gauge (08LG007) and removing inflow from the Coldwater River measured at the Coldwater at Merritt Gauge (08LG010). As of 1983, WSC installed a gauge on the Nicola River at the outlet of Nicola Lake (08LG065). This gauge was utilized for the Ptolemy and MOE transects in reach N3 (Table 2).

Table 2 List of transect data from Kosakoski and Hamilton (1982), Ron Ptolemy (1984) and MOE (2004-07) used to update the instream flow requirements for the Nicola and Coldwater Rivers.

River	Reach	Number of Transects Assessed			Total Number of Transects per Reach
		Kosakoski & Hamilton 1982	Ptolemy 1984	MOE 2004-2007	
Nicola	N1 - Thompson River to Spius Creek	4	4		8
	N2 - Spius Creek to Coldwater River	6	4	3	13
	N3 - Coldwater River to Nicola Lake	7	1		8
	N4 - Nicola Lake to Douglas Lake			3	3
Coldwater	C1 - Brodie to Merrit	6		3	9
	C2 - Mine Creek to Brodie	3	5	5	13
Total Number of Transects per Study		26	14	14	54

Table 3 Water Survey Canada stations used to estimate flow for each reach on the Nicola and Coldwater Rivers.

River	Reach	WSC Hydrometric Station		
		Kosakoski & Hamilton 1982	Ptolemy 1984	MOE 2004-2007
Nicola	N1 - Thompson River to Spius Creek	8LG006		8LG006
	N2 - Spius Creek to Coldwater River	8LG007	8LG007	8LG007
	N3 - Coldwater River to Nicola Lake	8LG007 & 8LG010	8LG065	
	N4 - Nicola Lake to Douglas Lake			08LG049
Coldwater	C1 - Brodie to Merrit	8LG010		8LG010
	C2 - Mine Creek to Brodie	08LG048	08LG048	08LG048

Figure 2 **Map of the Nicola River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 1.**

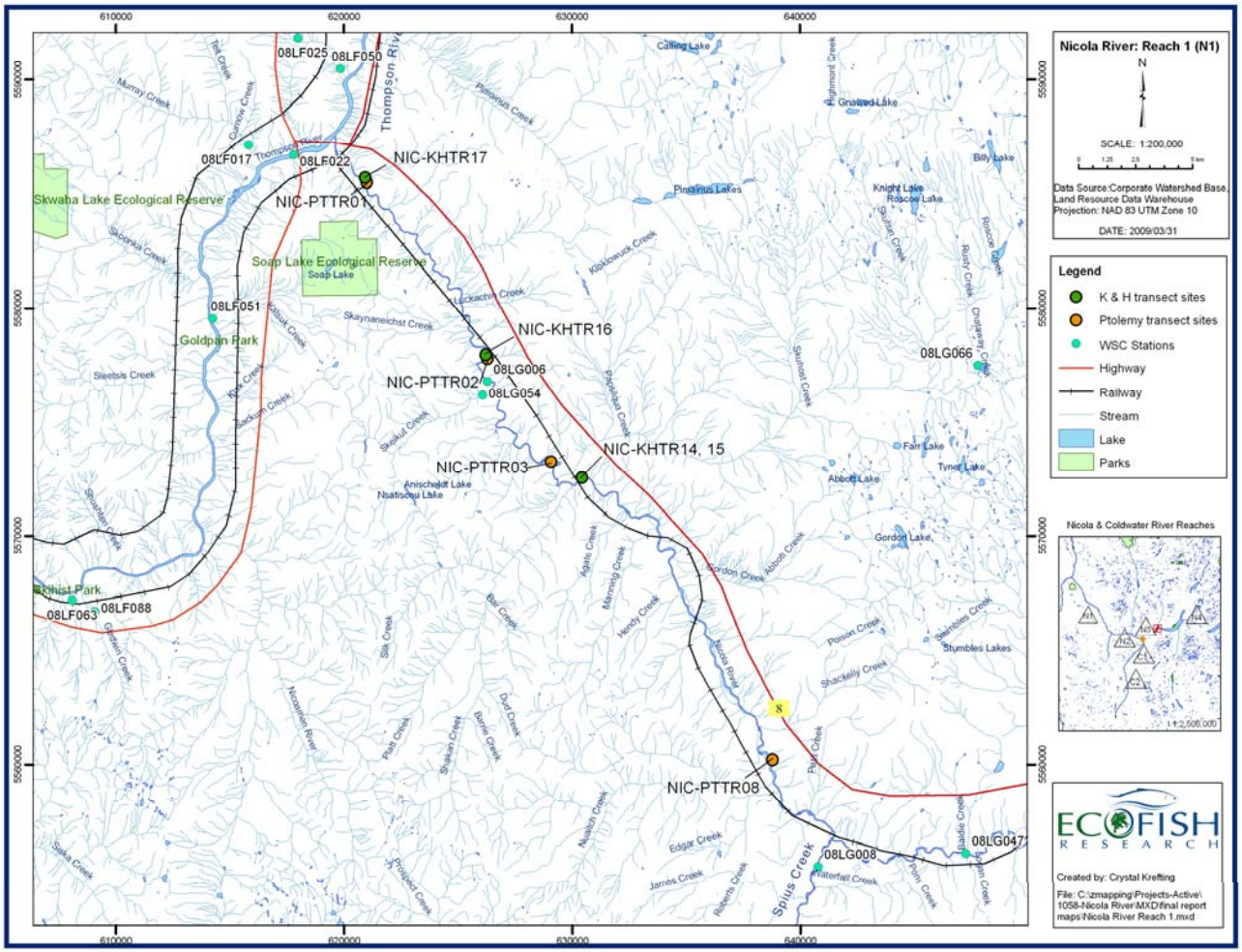

Figure 3 **Map of the Nicola River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 2.**

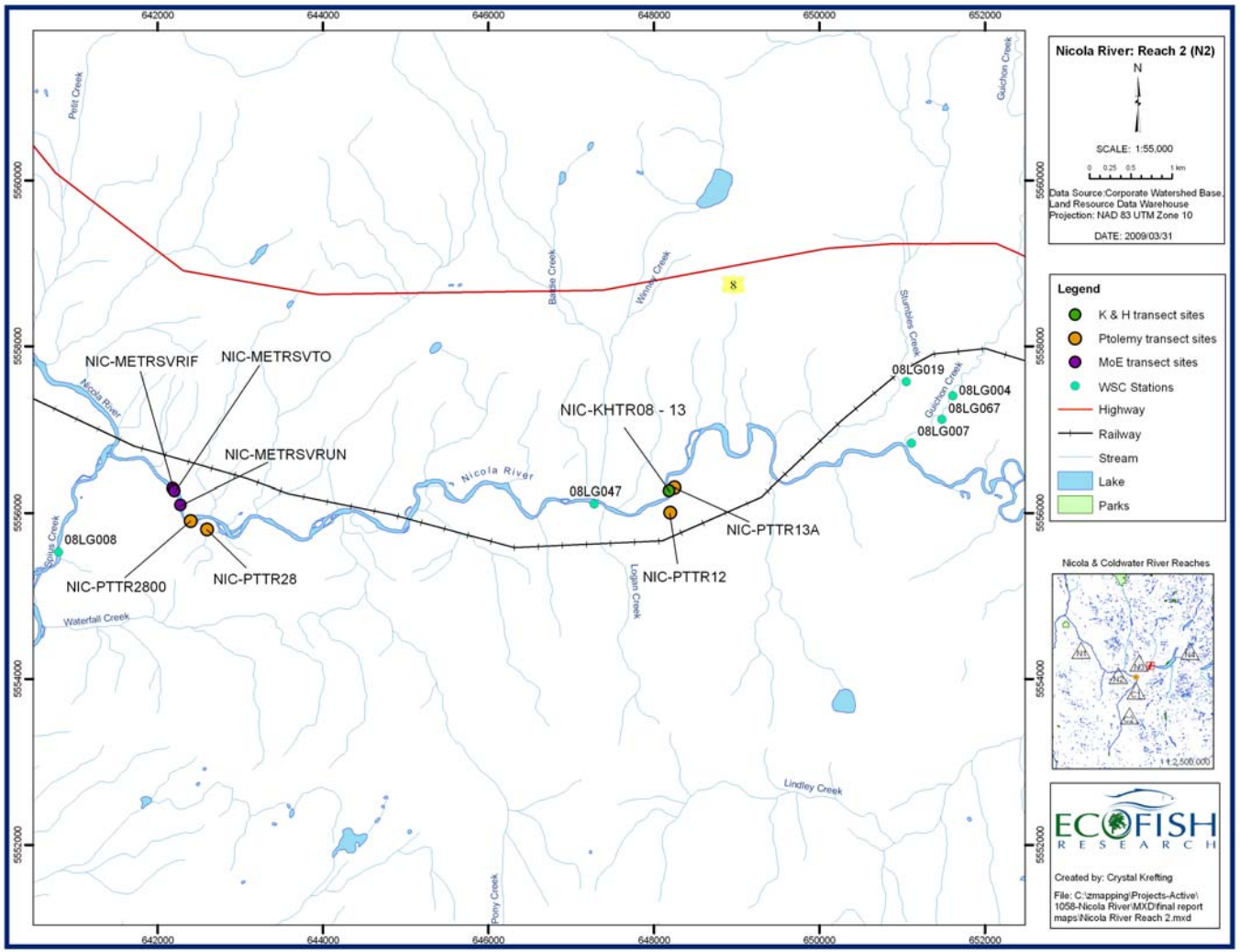

Figure 4 **Map of the Nicola River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 3.**

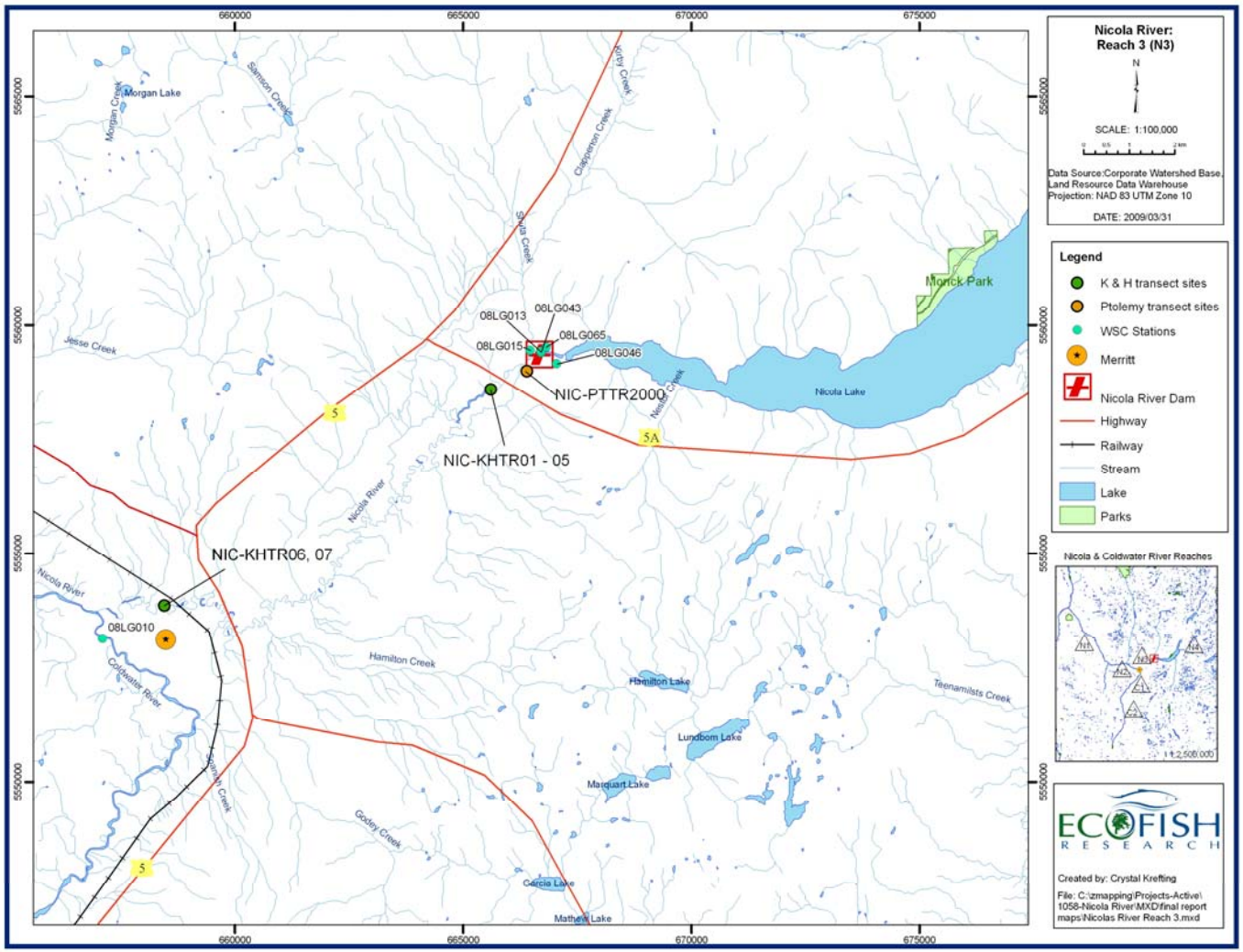

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Figure 5 **Map of the Nicola River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 4.**

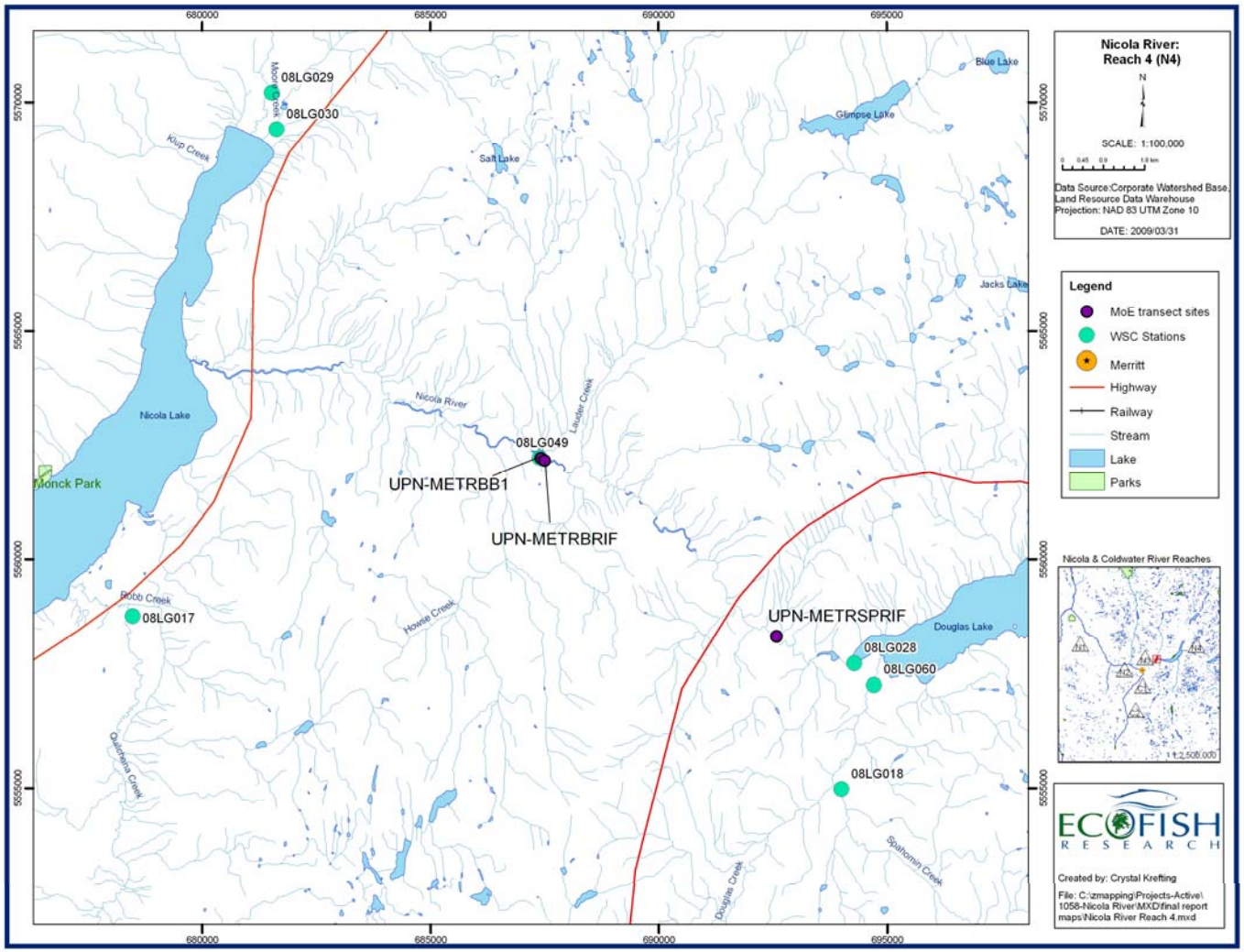


Figure 6 **Map of the Coldwater River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 1.**

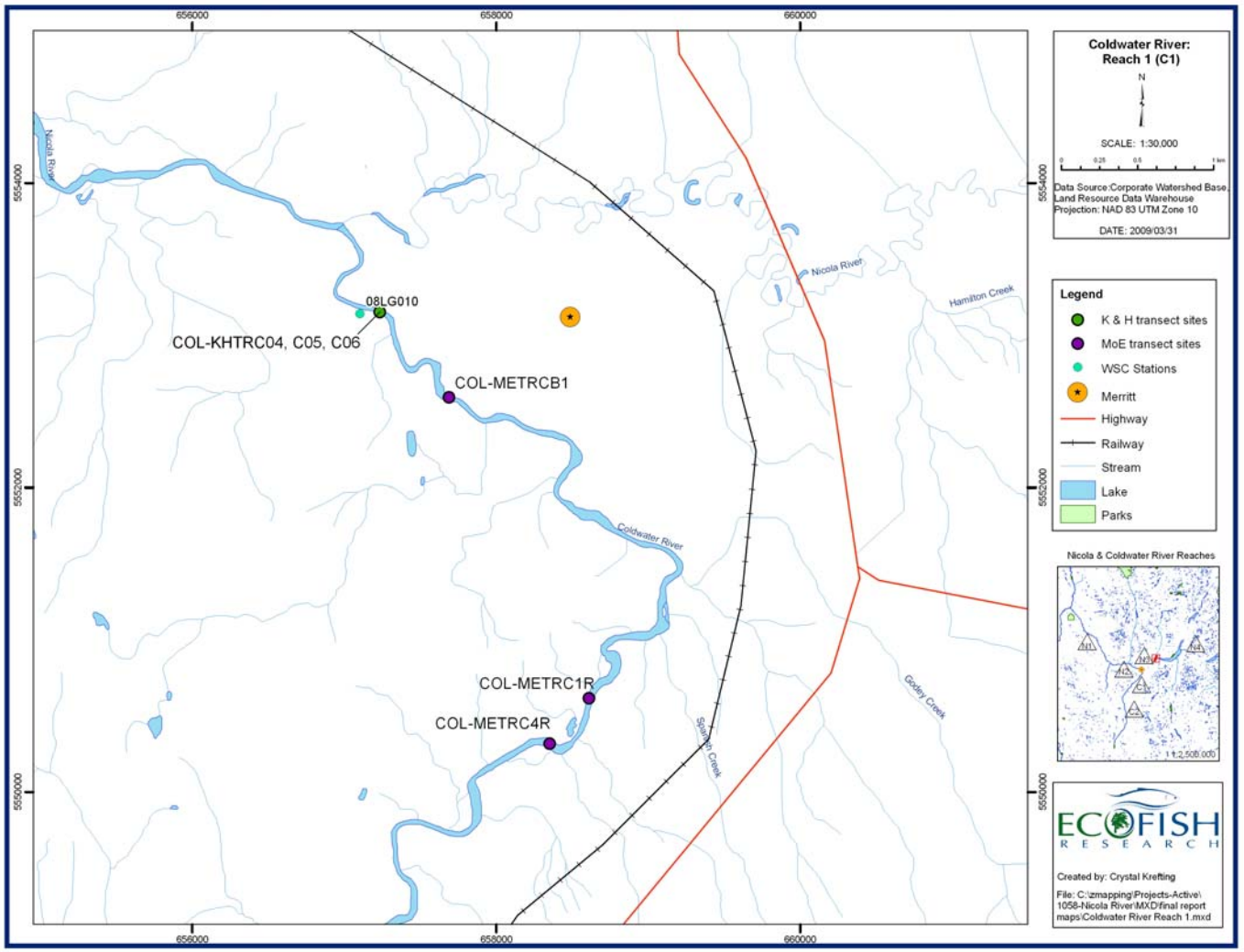
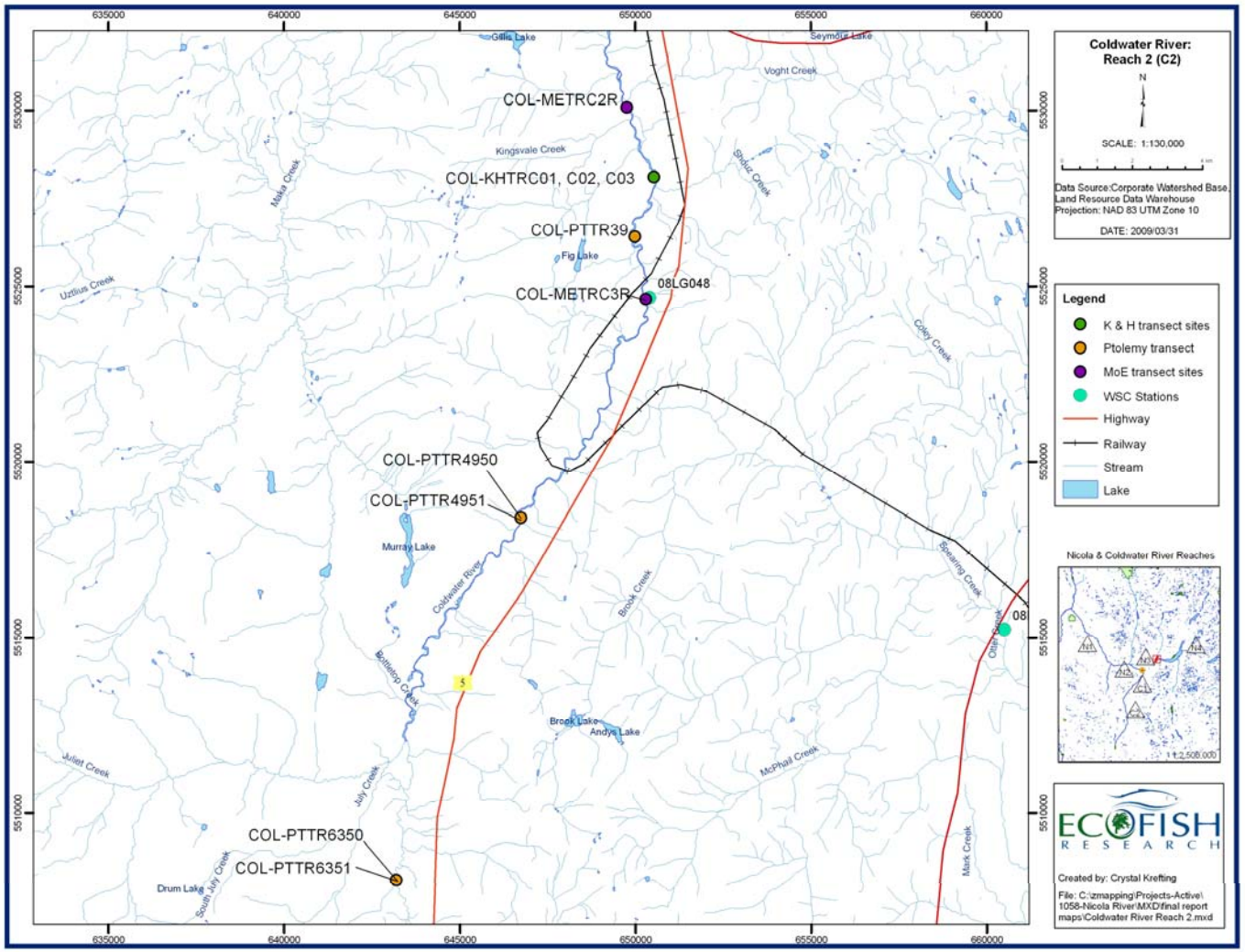


Figure 7 **Map of the Coldwater River displaying the geographic locations of the Kosakoski and Hamilton (1982), Ptolemy (1984) and MOE (2004-2007) transects in reach 2.**



2.1.2. Habitat Suitability Indices

Table 4 lists the habitat suitability criteria used to calculate habitat suitability for chinook, coho and steelhead in this study. The criteria used varied with life history stage. The recent data collected for small-bodied chinook in the Thompson-Nicola watershed (Triton 2009) could not be used in this study as they represent habitat use, rather than habitat preference curves.

Table 4 Source of habitat suitability criteria for fry, parr and adult chinook, coho and steelhead.

	Fry	Parr	Adult
Chinook	CH - WUP Delphi 2001	CH - Raleigh et al 1986	CH - WUP Delphi 2001
Coho	CO - WUP Delphi 2001	CO - Envirocon 1984	CO - WUP Delphi 2001
Steelhead	SH - WUP Delphi 2001	SH - WUP Delphi 2001	SH - WUP Delphi 2001

2.1.3. Habitat Modeling

The suitability of habitat at each flow was estimated by weighting the area around each station (cell) by the suitability of each habitat parameter based on the relevant habitat suitability criteria. This habitat-based method is similar to the PHABSIM component of the Instream Flow Incremental Methodology (IFIM, Bovee 1982) in that stations along whole channel transects were weighted by fish preferences for depth and velocity. Unlike PHABSIM however, physical characteristics at a station were not extrapolated upstream for a distance half-way to the next transect. We calculated wetted usable width at each transect and expanded this to area by averaging the transect values for each hydraulic unit type, and multiplying these values by the total length of a hydraulic unit type.

Weighted usable width (WUW) was calculated at each station by applying habitat suitability index values for depth and mean velocity (at 0.6 of depth). Suitability variables were applied in the depth and velocity models as follows:

$$WUW_{dvs} = \Sigma_{in} (W_i * D_i * V_i)$$

where W_i is the width of cell *i* on the transect, D*i* is the suitability of depth at cell *i*, and V_i is the suitability of velocity at cell *i*.

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Habitat measurements taken at an individual station were assumed to apply from the station to a point intermediate to the adjacent station. Thus cell width was the sum of the distances to the intermediate points on each side of the station. Along the margin, the cell from the wetted edge to a point halfway to the first station was weighted by the habitat characteristics at the first station. In this manner, habitat adjacent to the wetted edge was included in the calculation of weighted usable width.

2.1.4. Habitat Flow Relationships

The habitat model was run in calibration mode to obtain weighted usable widths (WUWs) based on depth and velocity for each set of transect data and set of criteria for fry, parr, and adult life-history stages (Table 4). Flows in the reaches corresponding to each transect were obtained from Water Survey of Canada (Table 3).

Predicted WUW were derived by fitting a lognormal relationship between WUW and flow (Bruce and Hatfield 2003) for each MOE transect location. This was completed for each species and life history stage. We investigated the relationship for fry, parr and adults of chinook, coho and steelhead due to their importance in the Nicola watershed. There was insufficient data to fit this type of relationship to the K&H and Ptolemy transect data, as there were a maximum of only two flow regimes sampled for each transect site. Therefore, we calculated the mean, minimum and maximum WUWs for each flow regime for these transects.

For each river reach, a habitat-flow relationship for each species and life history stage was estimated by fitting a lognormal relationship between predicted WUW and flow. As previously mentioned, the predicted WUW were derived from individual MOE transects. Overall habitat-flow relationships for each river and life history stage were estimated by fitting a lognormal relationship to the predicted WUWs for all MOE transects in that river.

Optimal flows for each reach and life history stage were estimated based on mean annual discharge and geographical location using the relationships given by Bruce and Hatfield (2003).

3. RESULTS

3.1. Fish Resources

As previously mentioned, the various habitat requirements for specific fish species and life history stages are considered to determine instream flow requirements. Thus, it is important to identify the fisheries resources in the Nicola River watershed.

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3.1.1. Distribution

The Nicola River watershed has numerous anadromous and resident fish species. Fish distribution information was obtained directly from Hatfield's report entitled "Nicola Water Use Management Plan: Instream Flow Needs For Fish" (2008). More detailed fish distribution information is provided in Appendix B.

The Nicola watershed supports four species of anadromous salmon: chinook, coho, pink and steelhead trout. There are also records of anadromous Pacific lamprey (*Lampetra tridentata*) and river lamprey (*Lampetra ayresii*) in the lower Nicola River. Pink salmon use the lower reaches (~25 km) of the Nicola River mainstem and spawn as an odd year run (Kosakoski and Hamilton 1982, Sebastian and Yaworski 1984). When pink salmon run size in the Thompson River is very high, small numbers spawn in the lower Coldwater River. Chinook, coho and steelhead are widely distributed throughout the watershed, but are most abundant downstream of Nicola Lake, in the Nicola and Coldwater rivers.

Resident fish are present throughout the Nicola watershed. Burbot (*Lota lota*) occur in Nicola and Douglas lakes, and the Nicola River between these lakes. Rainbow trout (*O. mykiss*) are widely distributed in the numerous small lakes in the Nicola watershed, and throughout almost all streams large enough to support fish. Mountain whitefish (*Prosopium williamsoni*) occur in Nicola and Douglas Lakes and several of the larger streams, such as Coldwater River. Large adfluvial bull trout (*Salvelinus confluentus*) use the mainstem Thompson River for rearing, and the headwaters of Coldwater River for spawning and juvenile rearing. Bull trout often use areas upstream used of those used by chinook and coho (Decker 2007). The lower Nicola River is thus an essential migration corridor for bull trout.

3.1.2. Life Histories

Life history or "species periodicity" tables have been prepared for species of primary management concern in the Nicola mainstem, defined for this purpose as downstream of Nicola Lake to the confluence with the Thompson River, as well as the Coldwater River. The life history tables can be used to compare flow needs for different species and across multiple locations in the Nicola watershed as part of the Nicola WUMP.

<u>Nicola Mainstem</u>

The Nicola River mainstem and its tributaries provide important fish habitat. Early spring to fall, from March through to October, coincides with the peak rearing period for steelhead, rainbow trout, chinook and coho salmon (Table 5). The fall period coincides with peak spawning activity for chinook, coho, pink salmon and mountain whitefish (Table 5). Chinook peak spawning occurs the earliest, occurring from late August to early September. This is

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followed by pink salmon spawning, which primarily occurs from mid-September into early October. Coho typically spawn later, from late September through to October. The mountain whitefish peak spawning period begins in October and extends into November. Steelhead and rainbow trout spawn and lay eggs in the spring (April and May). These hatch within the same year. In contrast, anadromous salmon eggs incubate over winter and hatch the following spring. Once hatched, the young fry emerge in spring and rear within the stream system for varying amounts of time depending on the species.

Upper Nicola

The mid-Nicola River section, located between Nicola and Douglas Lake, has the same periodicity for chinook and coho spawning and incubation as the lower section (Hatfield 2009). Pink salmon are not known to venture into the upstream waters of the mid-Nicola River. Mountain whitefish and kokanee (*O. nerka*) have peak spawning activity in the late summer/fall months between August and November. The summer months hold peak activity of incubation and rearing for rainbow trout.

Coldwater River

The Coldwater River is an important tributary to the Nicola River. The Coldwater River provides habitat for the following salmonids: chinook, coho and steelhead. The annual activities for these and other fish present in the Coldwater River are similar to the activities found within the Nicola River mainstem. Table 6 also indicates the presence of bull trout and mountain whitefish within the Coldwater River, which is also used occasionally by pink salmon. All the species present, except rainbow trout/steelhead, spawn in the late summer/early fall (Table 6). In regards to important migration periods, bull trout peak migration takes place in the spring, between April and May. Meanwhile, the peak of chinook migration occurs in the middle of the summer, from June to July (Table 6). As previously mentioned, these fish species utilize freshwater habitat for various lengths of time depending on the species.

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Table 5 **Periodicity information for anadromous chinook, coho, pink and steelhead and resident mountain whitefish in the Nicola mainstem, defined here as downstream of Nicola Lake.**

Species	Event	Life History Stage: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Coho	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Pink	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Rainbow / Steelhead	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Mountain Whitefish	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												

Indicates peak period
Indicates active period

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ECOFISH RESEARCH

Table 6 Periodicity information for anadromous chinook, coho, pink and steelhead and resident mountain whitefish and bull trout in the Coldwater River

Species	Event	Life History Stage: Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chinook	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Coho	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Pink (occassionally present in lower reaches)	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Bull Trout (in headwaters)	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Rainbow / Steelhead	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												
Mountain Whitefish	Adult migration												
	Spawning												
	Incubation												
	Rearing												
	Juvenile migration												

Indicates peak period
Indicates active period

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ECOFISH RESEARCH

3.2. Habitat Flow Relationships

The following plots present the relationship between weighted usable width (WUW) and flow for the three different species and life-history stages. As previously mentioned, only the MOE transect data was used to fit curves. The data used to estimate these relationships are represented by red circles. The K & H and Ptolemy transect data are presented as the mean WUWs calculated for each flow regime, including the minimum and maximum WUW. The optimal flow derived from relationships in Bruce and Hatfield (2003) is provided above each plot and illustrated as a dark blue line.

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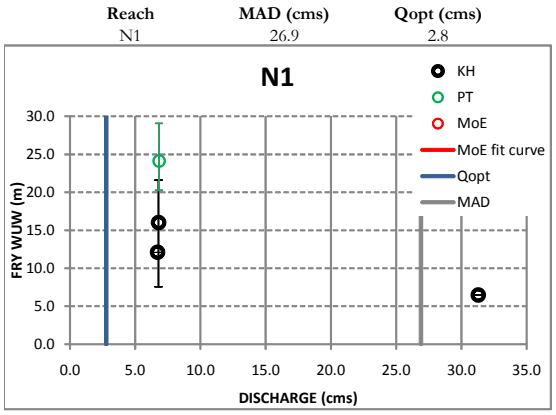
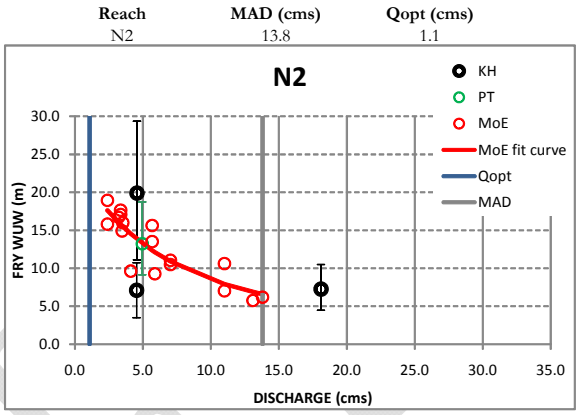
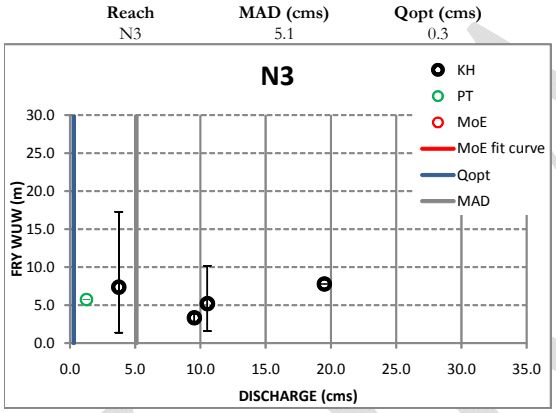
Figure 8 **Relationship between weighted usable width (WUW) and flow for chinook fry at specific reaches and for the entire Nicola River.**

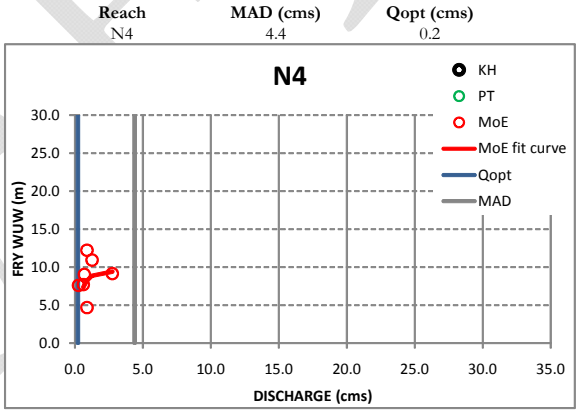
River: **Nicola River**
Criteria: **CH - WUP Delphi 2001**

Life History: **Chinook Fry**
Date Created: **4/1/2009**









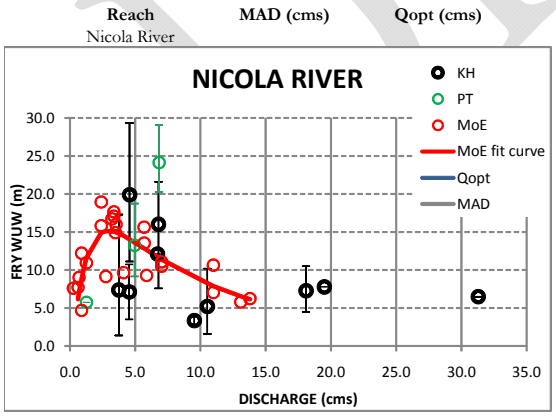


Figure 9 **Relationship between weighted usable width (WUW) and flow for chinook parr at specific reaches and for the entire Nicola River.**

River: **Nicola River** Life History: **Chinook Parr**
Criteria: **CH - Raleigh et al. 1986** Date Created: **4/1/2009**

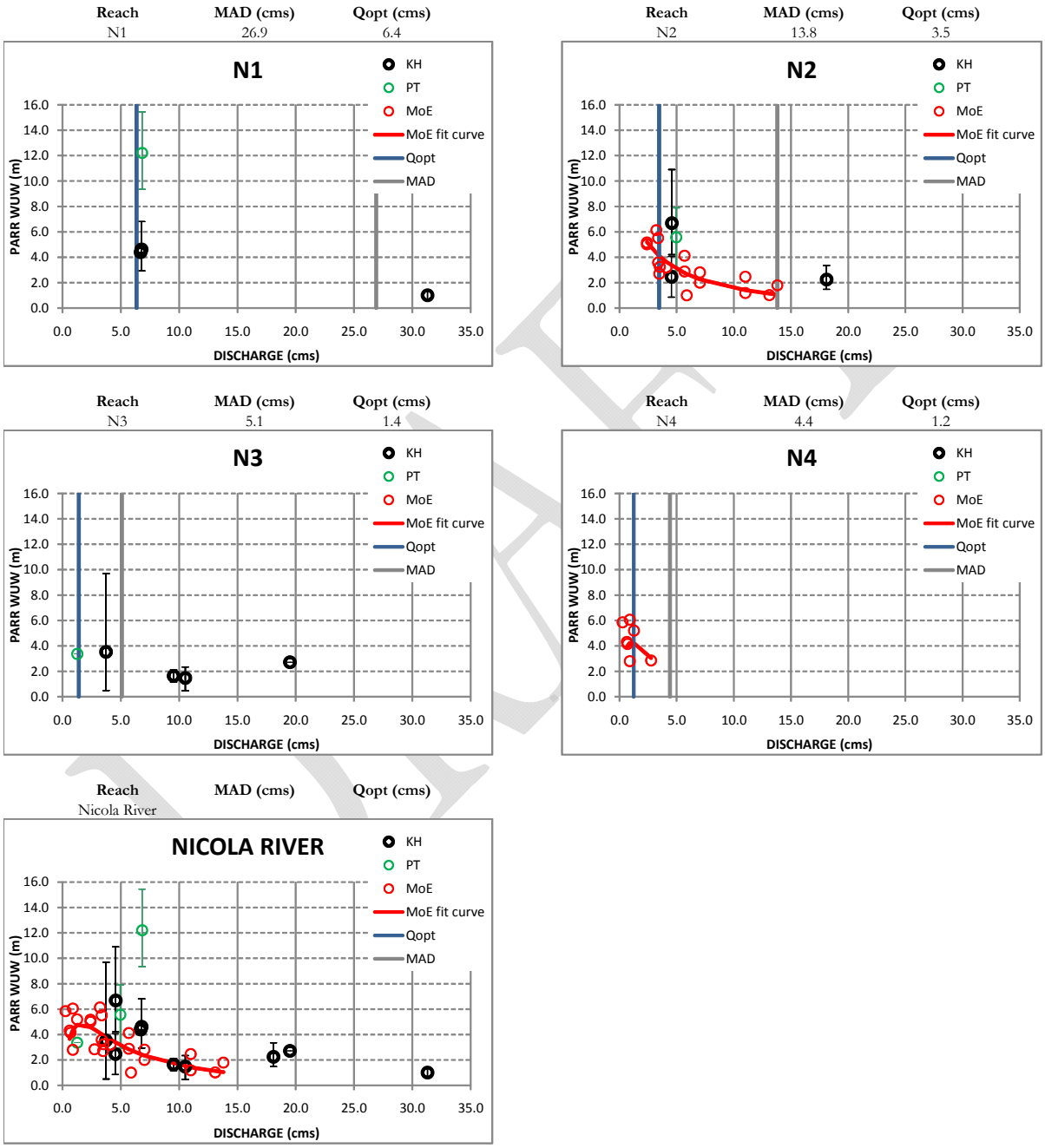


Figure 10 Relationship between weighted usable width (WUW) and flow for adult chinook at specific reaches and for the entire Nicola River.

River: **Nicola River**
Criteria: **CH - WUP Delphi 2001**

Life History: **Chinook Adult**
Date Created: **4/1/2009**

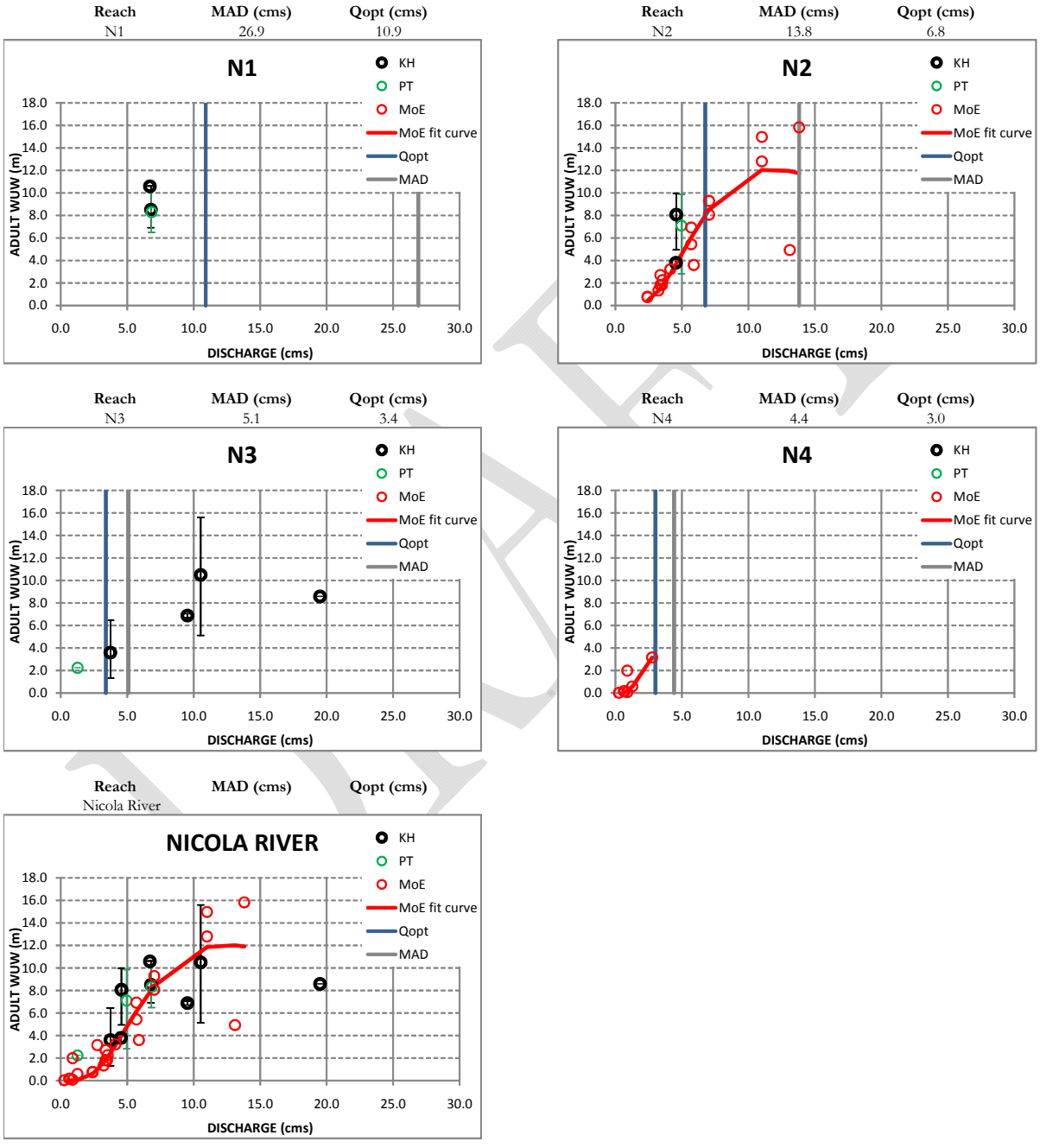
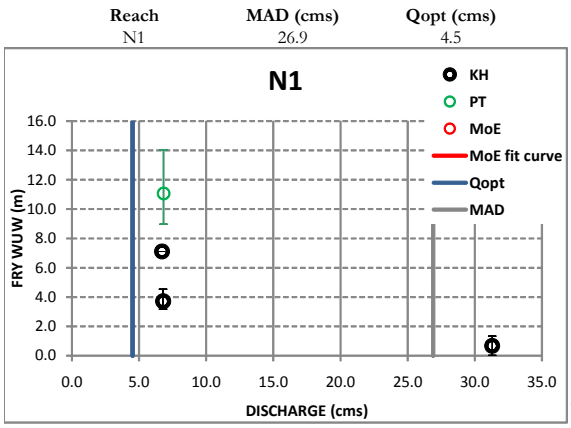
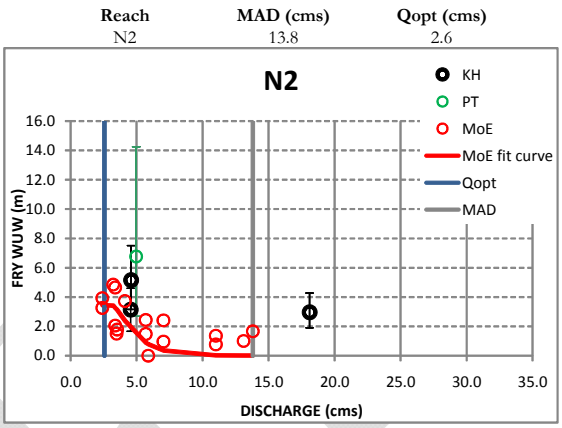
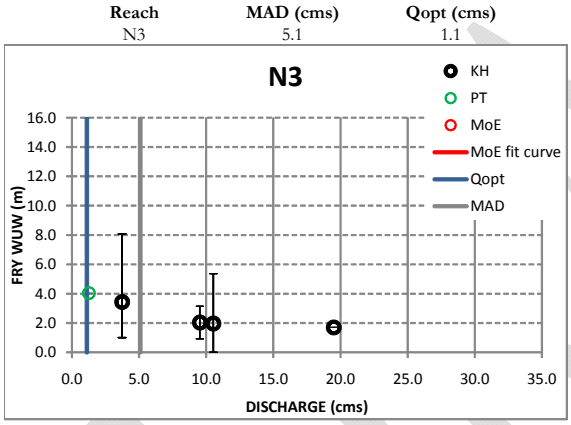


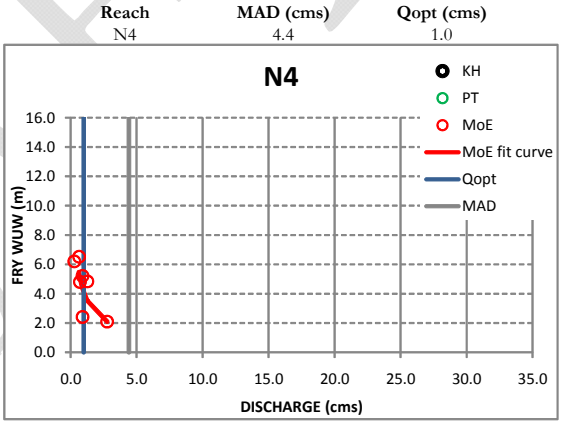
Figure 11 **Relationship between weighted usable width (WUW) and flow for coho fry at specific reaches and for the entire Nicola River.**

River: **Nicola River** Life History: **Coho Fry**
Criteria: **CO - WUP Delphi 2001** Date Created: **4/1/2009**









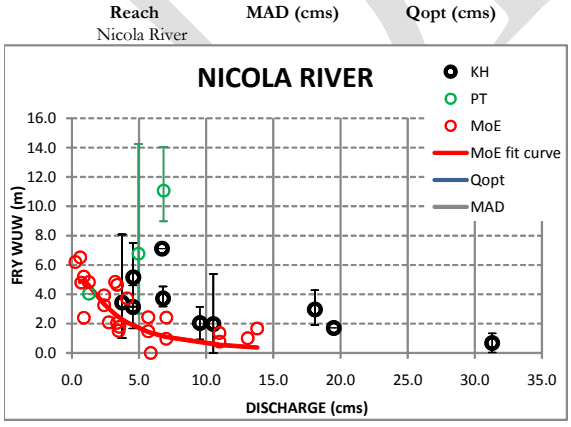


Figure 12 **Relationship between weighted usable width (WUW) and flow for coho parr at specific reaches and for the entire Nicola River.**

River: **Nicola River**
Criteria: **CO - Envirocon 1984**

Life History: **Coho Parr**
Date Created: **4/1/2009**

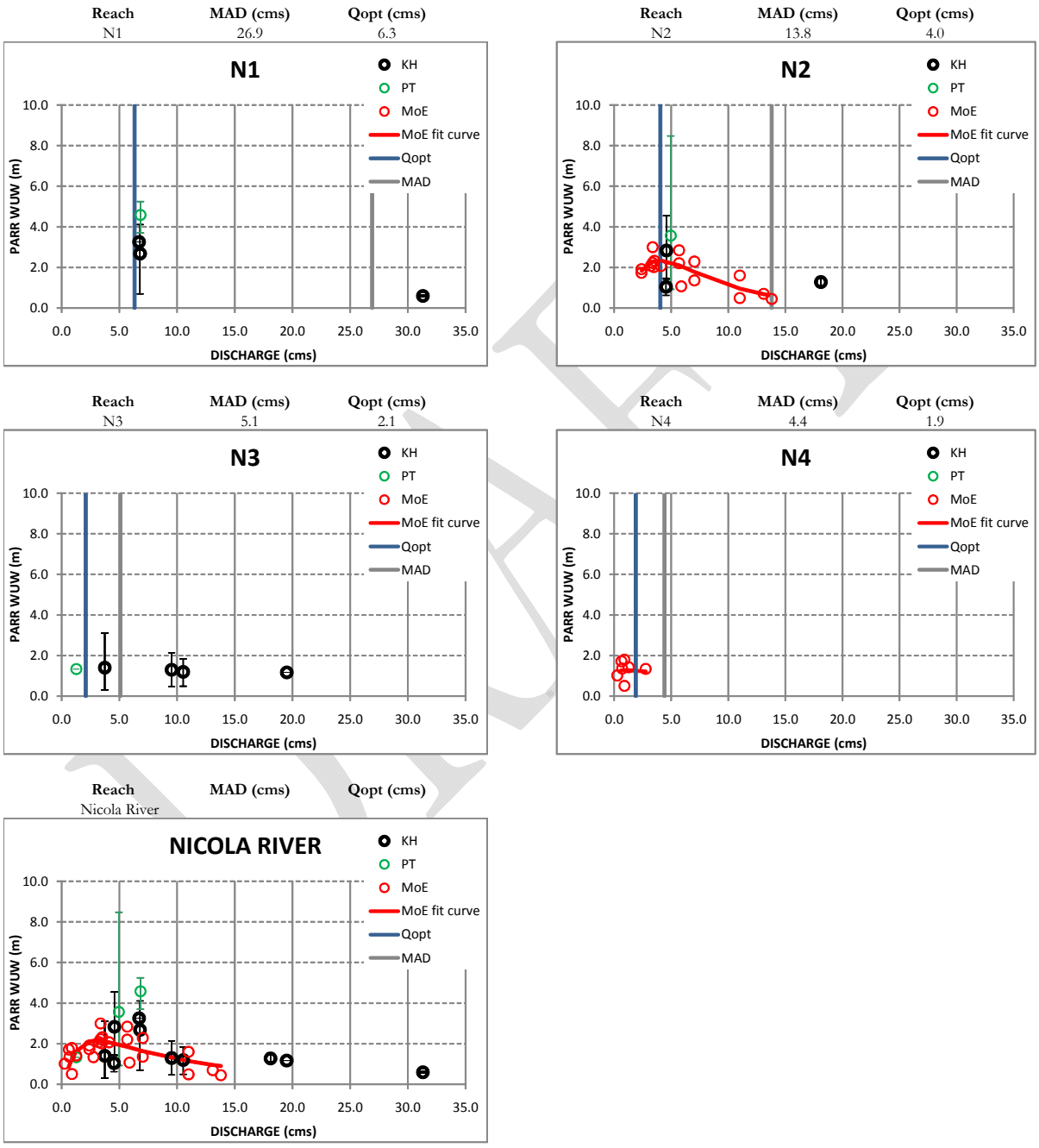
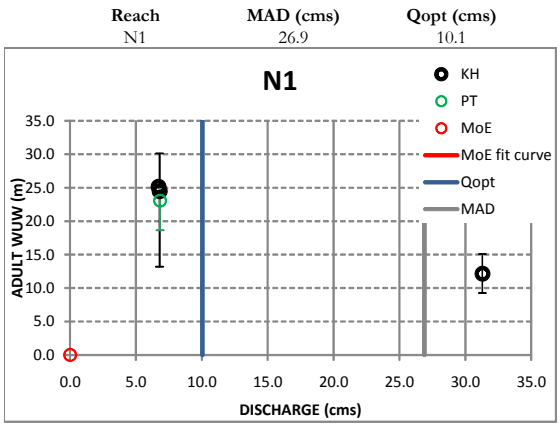
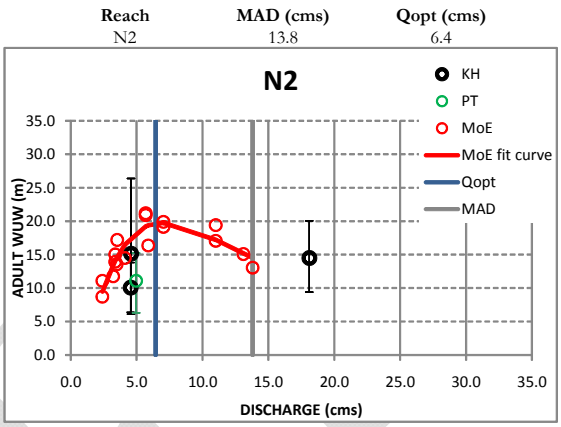
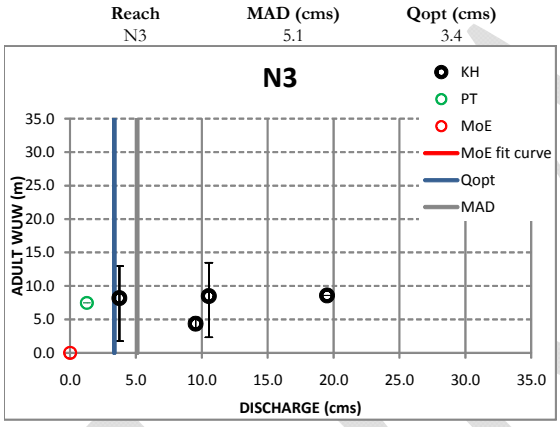


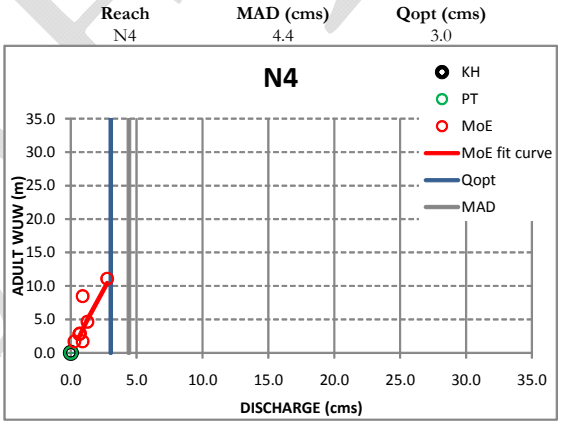
Figure 13 **Relationship between weighted usable width (WUW) and flow for adult coho at specific reaches and for the entire Nicola River.**

River: **Nicola River** Life History: **Coho Adult**
Criteria: **CO - WUP Delphi 2001** Date Created: **4/1/2009**









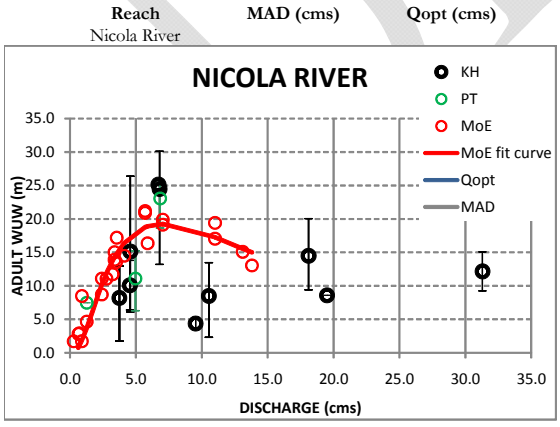
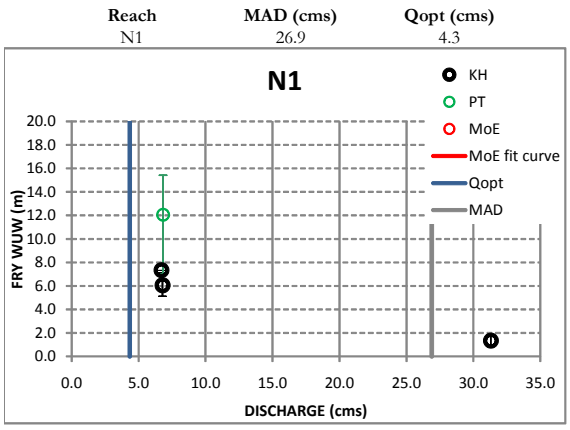
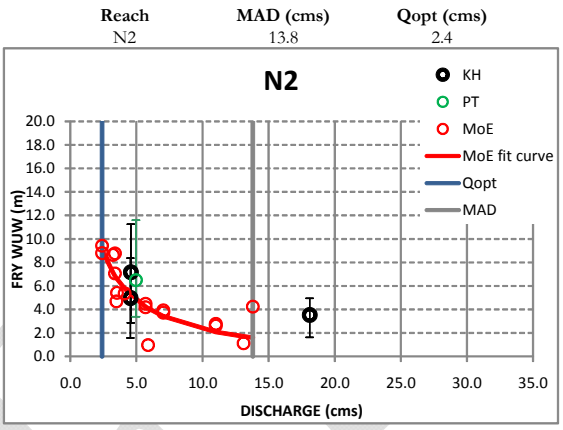


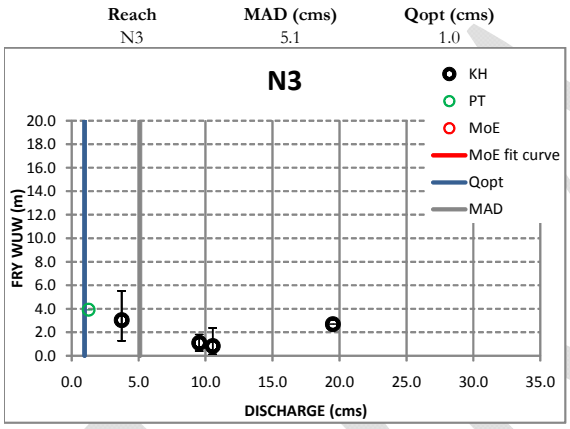
Figure 14 Relationship between weighted usable width (WUW) and flow for steelhead fry at specific reaches and for the entire Nicola River.

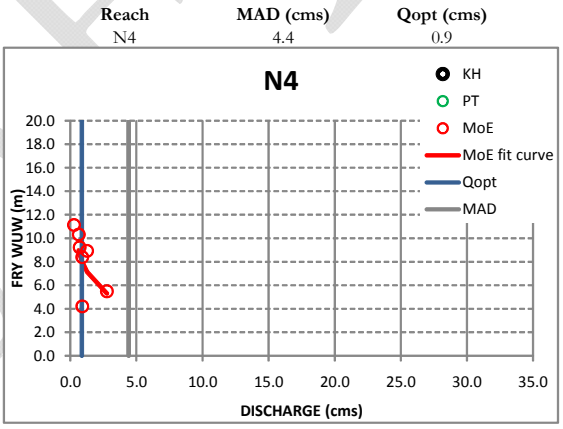
River: **Nicola River**
Criteria: **SH - WUP Delphi 2001**

Life History: **Steelhead Fry**
Date Created: **4/1/2009**









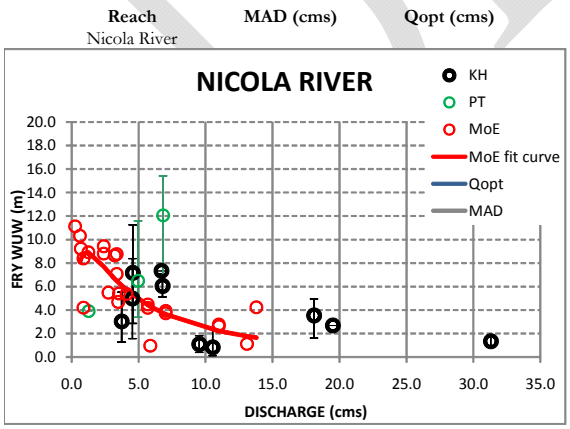
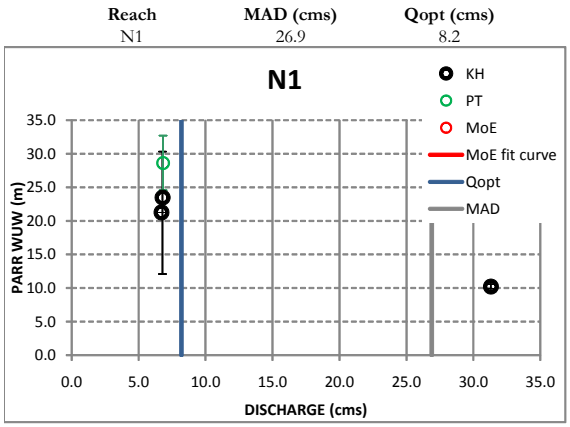
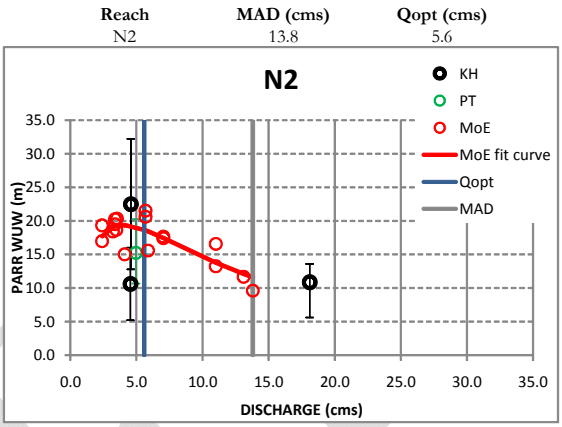


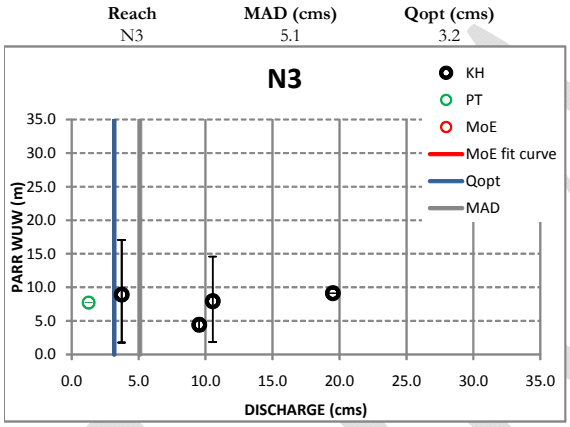
Figure 15 Relationship between weighted usable width (WUW) and flow for steelhead parr at specific reaches and for the entire Nicola River.

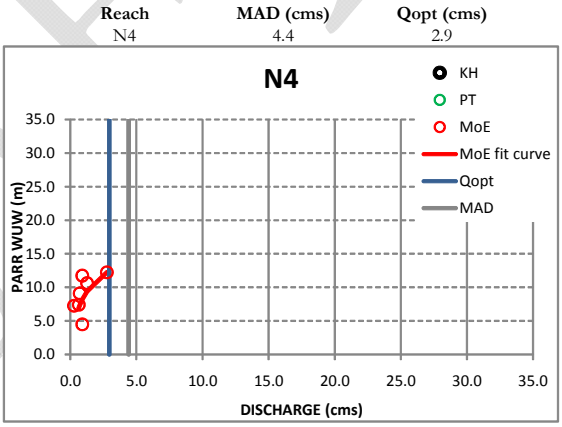
River: **Nicola River**
Criteria: **SH - WUP Delphi 2001**

Life History: **Steelhead Parr**
Date Created: **4/1/2009**









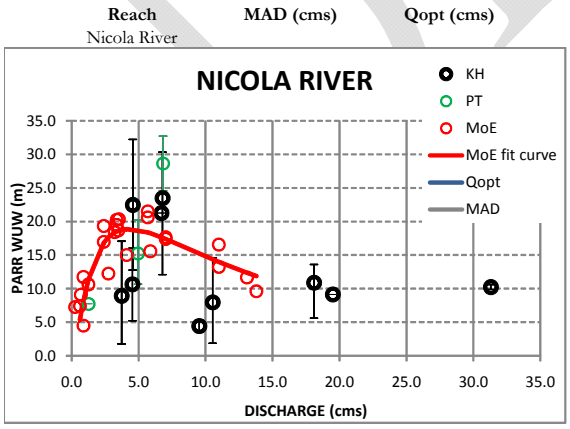
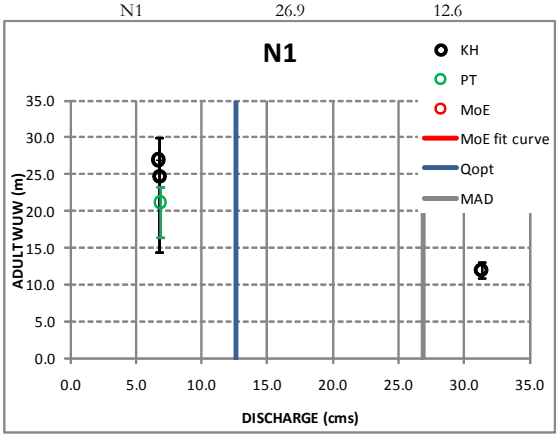


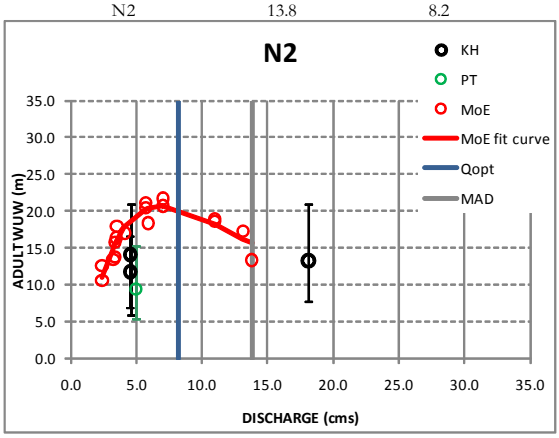
Figure 16 Relationship between weighted usable width (WUW) and flow for adult steelhead at specific reaches and for the entire Nicola River.

River: **Nicola River** Life History: **Steelhead Adult**
Criteria: **SH - WUP Delphi 2001** Date Created: **4/1/2009**

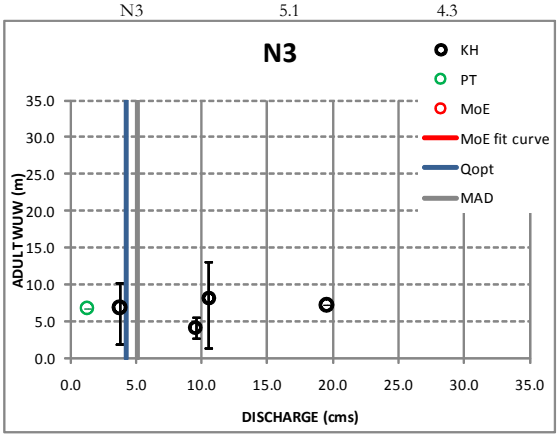
Reach	MAD (cms)	Qopt (cms)
N1	26.9	12.6



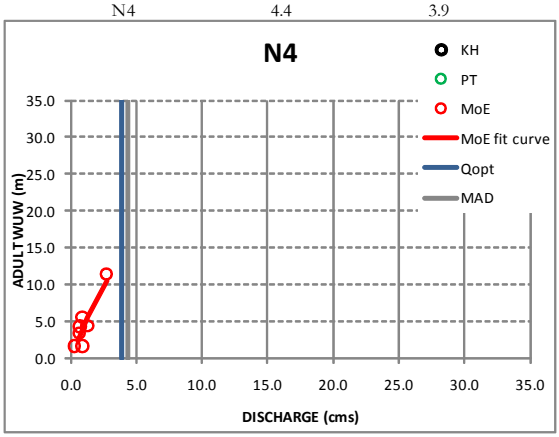
Reach	MAD (cms)	Qopt (cms)
N2	13.8	8.2



Reach	MAD (cms)	Qopt (cms)
N3	5.1	4.3



Reach	MAD (cms)	Qopt (cms)
N4	4.4	3.9



Reach	MAD (cms)	Qopt (cms)
Nicola River		

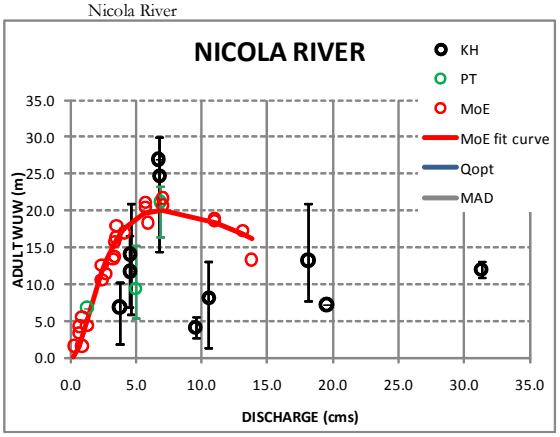
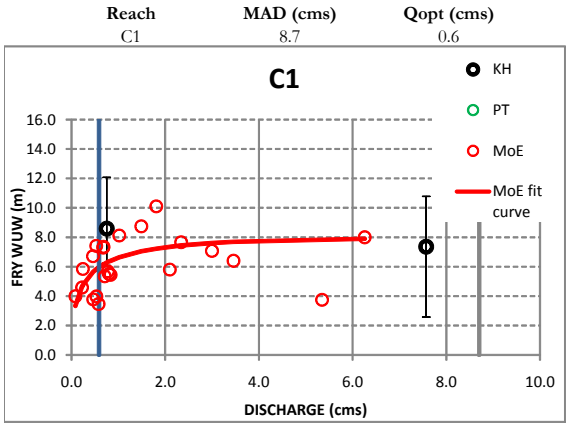
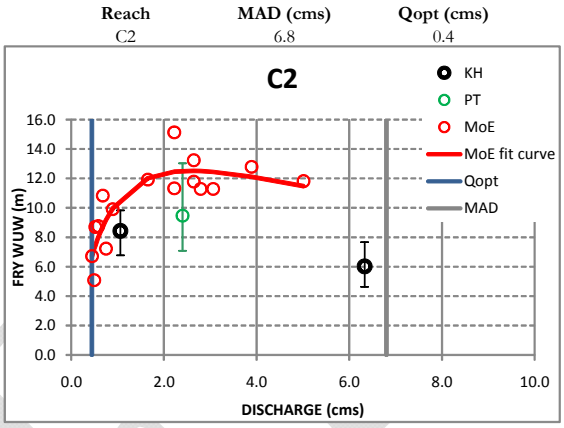


Figure 17 **Relationship between weighted usable width (WUW) and flow for chinook fry at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **CH - WUP Delphi 2001**

Life History: **Chinook Fry**
Date Created: **4/1/2009**





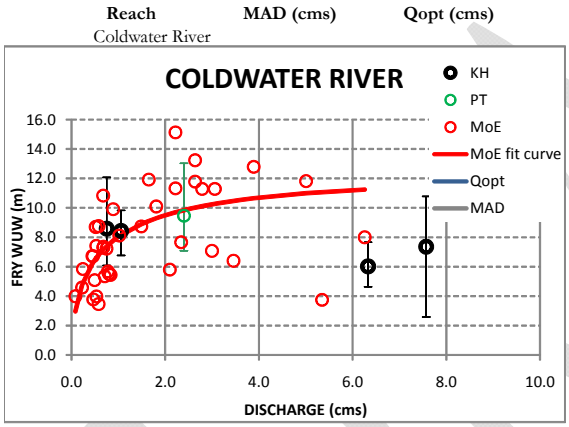


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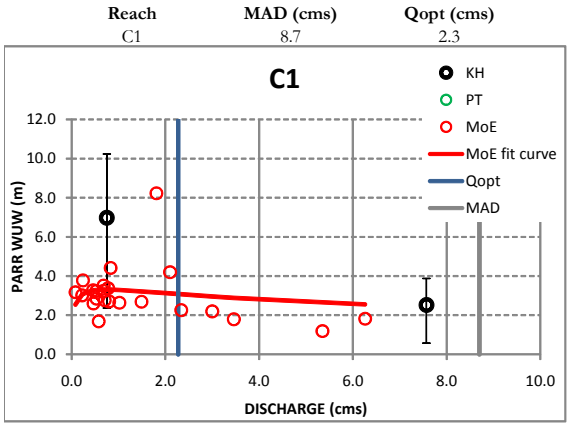
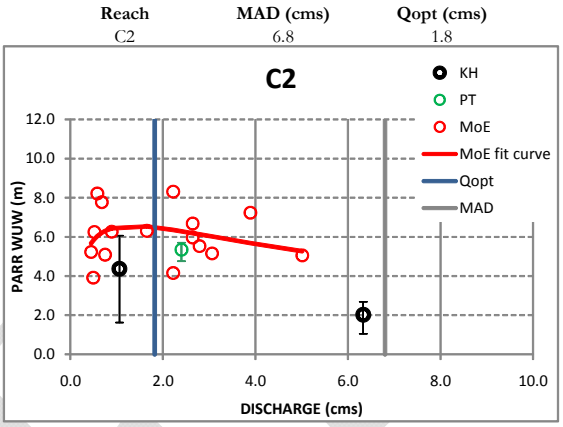
Figure 18 **Relationship between weighted usable width (WUW) and flow for chinook parr at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **CH - Raleigh et al. 1986**

Life History: **Chinook Parr**
Date Created: **4/1/2009**





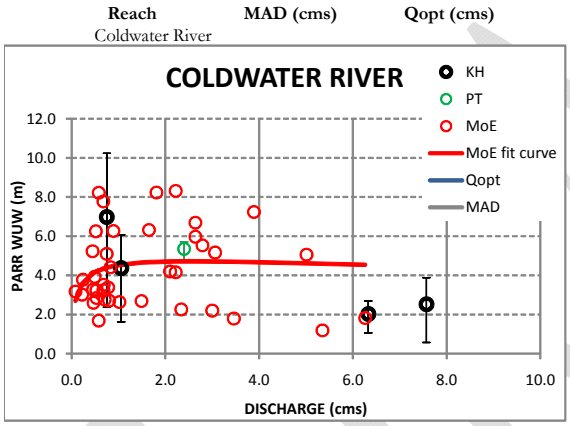
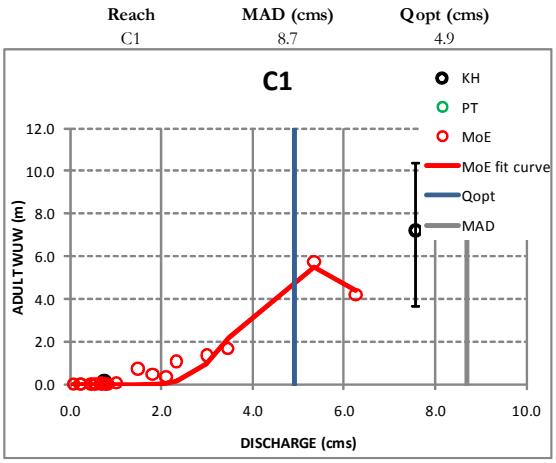
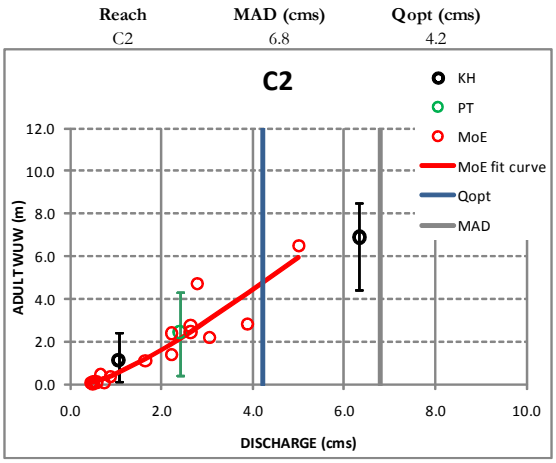


Figure 19 **Relationship between weighted usable width (WUW) and flow for adult chinook at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **CH - WUP Delphi 2001**

Life History: **Chinook Adult**
Date Created: **4/1/2009**





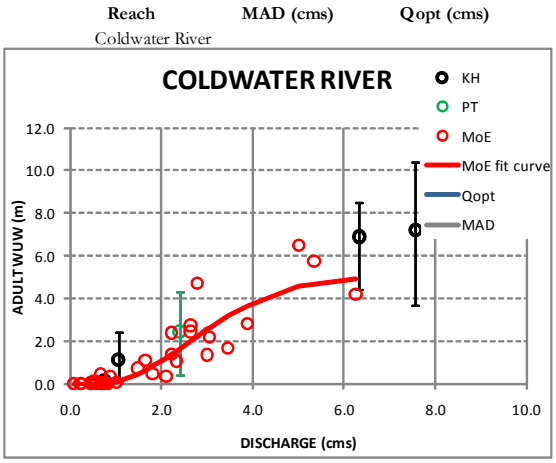
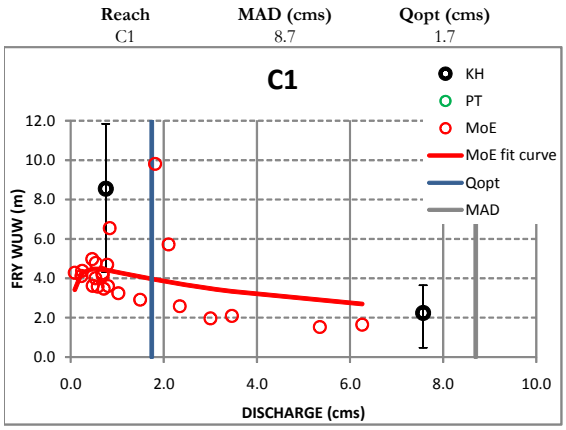
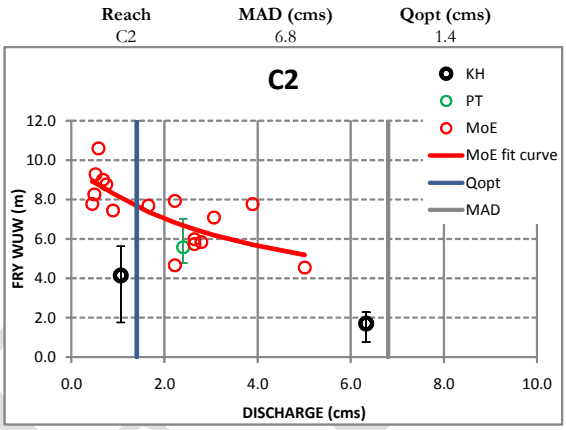


Figure 20 **Relationship between weighted usable width (WUW) and flow for coho fry at specific reaches and for the entire Coldwater River.**

River: **Coldwater River** Life History: **Coho Fry**
Criteria **CO - WUP Delphi 2001** Date Created: **4/1/2009**





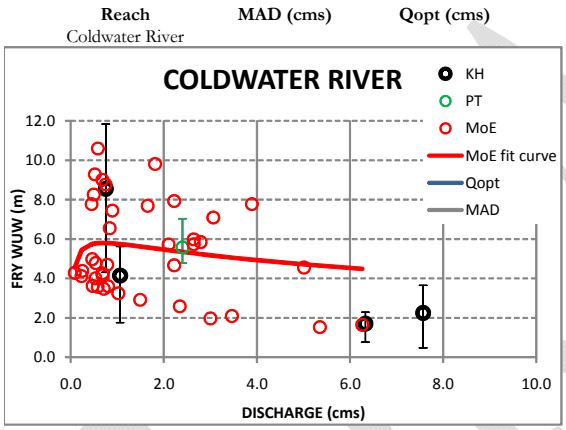
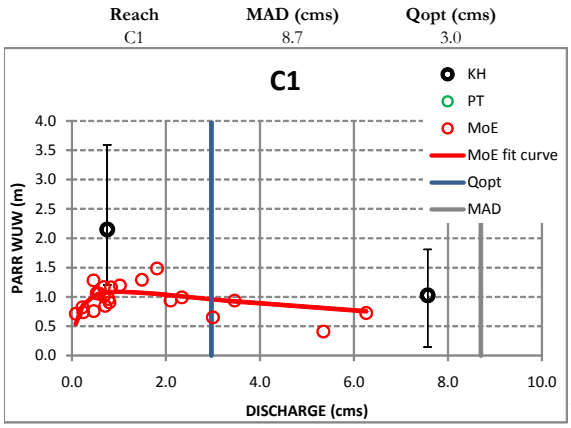
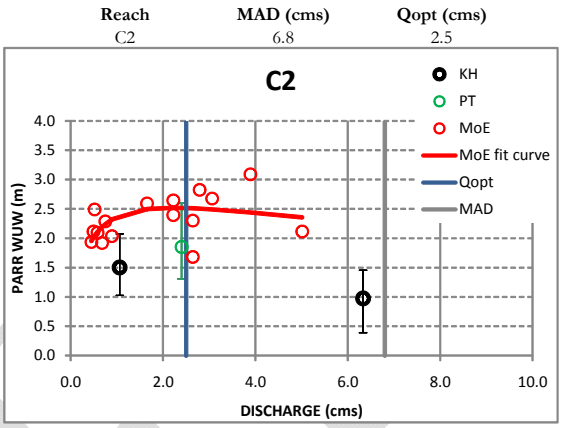


Figure 21 **Relationship between weighted usable width (WUW) and flow for coho parr at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **CO - Envirocon 1984**

Life History: **Coho Parr**
Date Created: **4/1/2009**





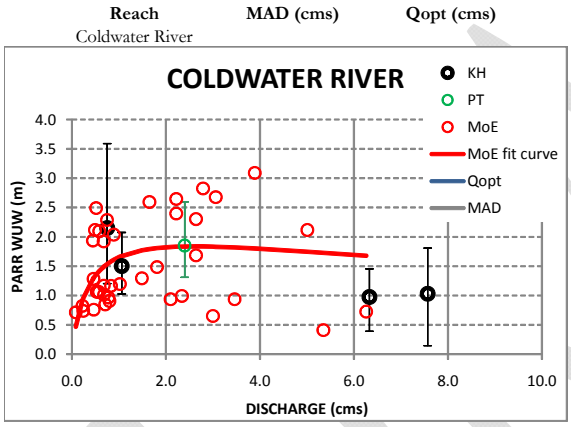
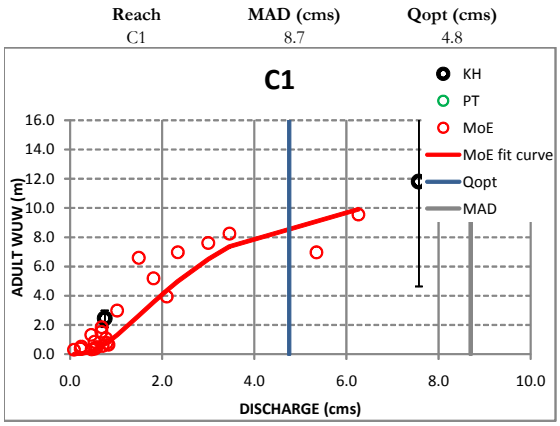
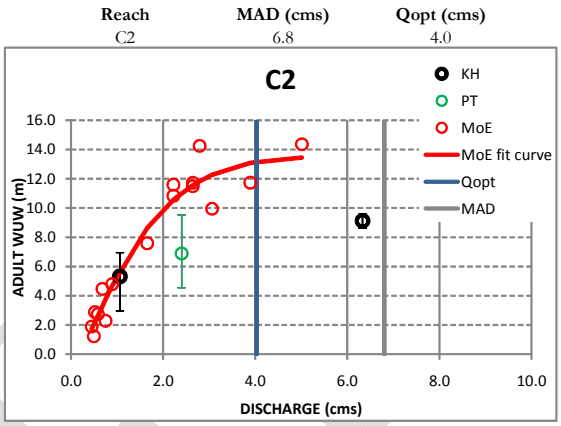


Figure 22 **Relationship between weighted usable width (WUW) and flow for adult coho at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **CO - WUP Delphi 2001**

Life History: **Coho Adult**
Date Created: **4/1/2009**





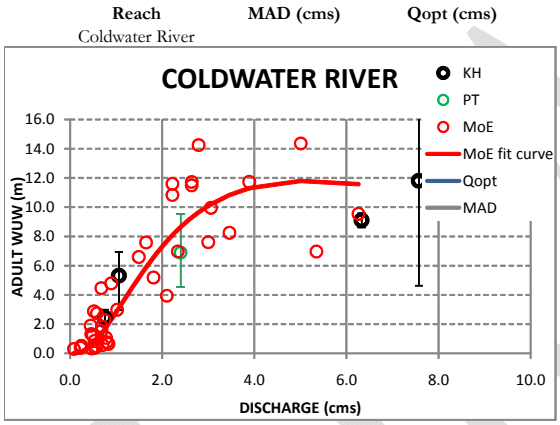


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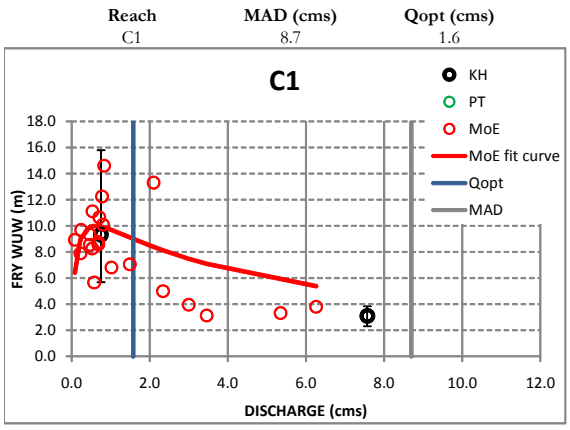
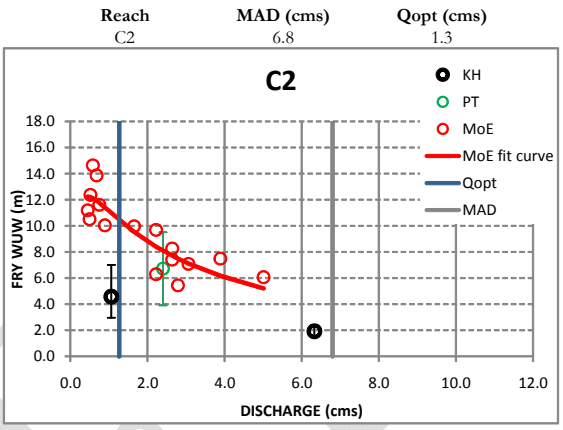
Figure 23 **Relationship between weighted usable width (WUW) and flow for steelhead fry at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **SH - WUP Delphi 2001**

Life History: **Steelhead Fry**
Date Created: **4/1/2009**





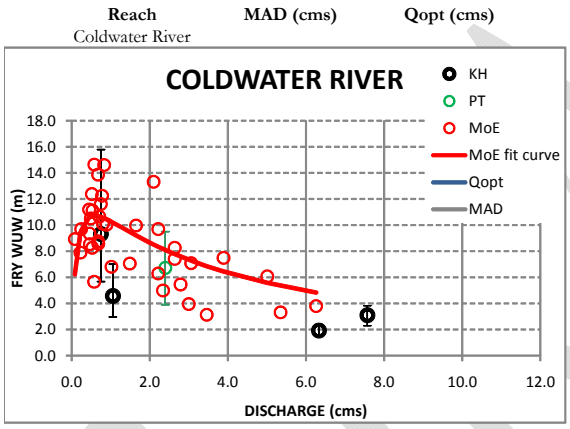


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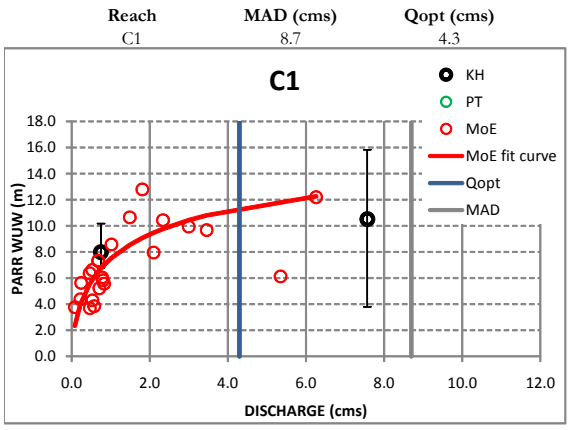
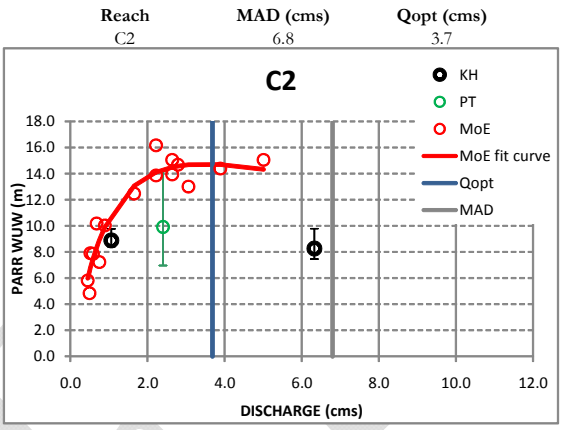
Figure 24 Relationship between weighted usable width (WUW) and flow for steelhead parr at specific reaches and for the entire Coldwater River.

River: **Coldwater River**
Criteria: **SH - WUP Delphi 2001**

Life History: **Steelhead Parr**
Date Created: **4/1/2009**





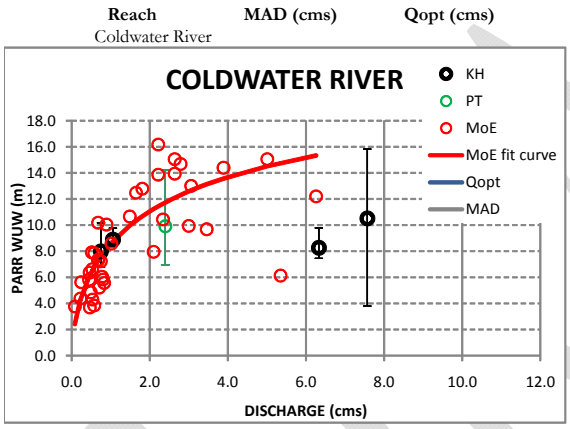
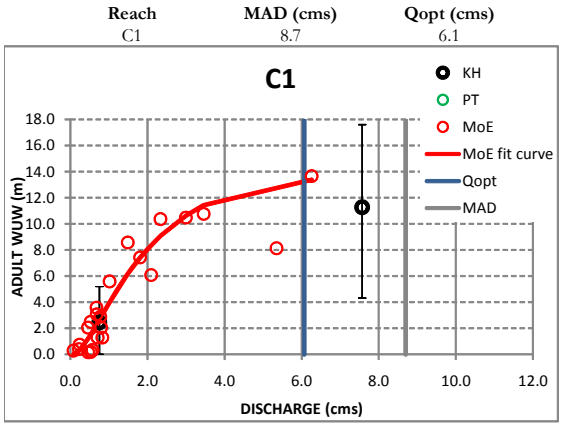
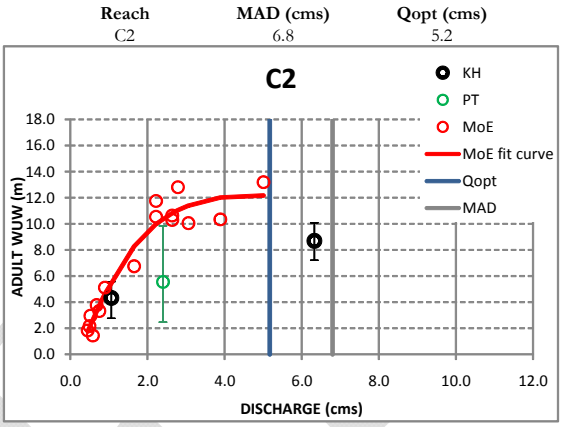


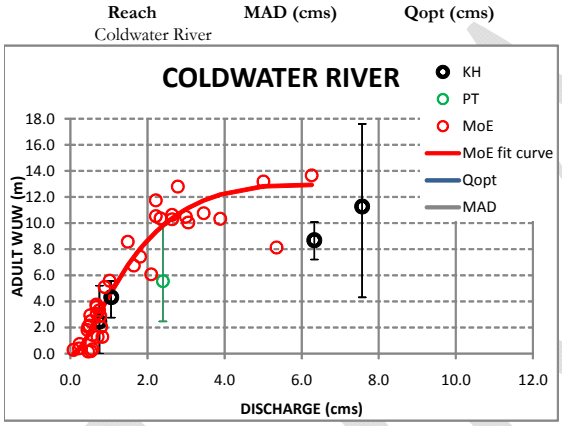
Figure 25 **Relationship between weighted usable width (WUW) and flow for adult steelhead at specific reaches and for the entire Coldwater River.**

River: **Coldwater River**
Criteria: **SH - WUP Delphi 2001**

Life History:**Steelhead Adult**
Date Created: **4/1/2009**







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4. DISCUSSION & RECOMMENDATIONS

The objective of the Nicola WUMP is to strike a balance between instream (environmental) and out-of-stream (human) benefits of water allocation with the ultimate goal of providing a safe, reliable and equitable supply of water for generations to come (Nicola WUMP 2006). The Nicola WUMP will incorporate instream flow requirements for fish and fish habitat; however, the recommendations made by Kosakoski and Hamilton (1982) are over 25 years old. It has therefore been strongly recommended that fish flow requirements for the Nicola watershed be updated to reflect recent research and scientific understanding of instream flow requirements for fish and fish habitat (Roseneau and Angelo 2003, Hatfield 2007, Water Management Consultants 2008). It has also been recommended that recent data on stream flows in the Nicola watershed be incorporated into the determination of fish flow requirements (Water Management Consultants 2008), and compared with optimum flow levels derived using a meta-analysis of numerous IFR studies (Bruce and Hatfield 2003).

The weighted usable width versus flow curves presented above (Figure 8 to 25) were constructed using the most recent HSI curves, and combine transect data from Kosakoski and Hamilton (1982), and Ptolemy (1984), with all suitable recent data from MOE (2004-2007). This discussion first describes how the recent transect data align with the historical data collected by Kosakoski and Hamilton (1982), and Ptolemy (1984), before comparing optimum flow values derived by an IFR meta-analysis (Bruce and Hatfield 2003) with empirical values based on recent MOE transect data and the latest HSI curves. Finally, the continued validity of Kosakoski and Hamilton's recommendations in maintaining fish capacity in the Nicola River watershed are discussed in light of these analyses.

4.1. Comparison of Historical and Recent Transect Data

The historical transect data collected by Kosakoski and Hamilton (1982) and Ptolemy (1984) are generally in good alignment with the recent transect data collected by MOE. However, the MOE data provide a finer level of detail on habitat suitability than the Kosakoski and Hamilton study, particularly at low discharge rates. For example, in the Coldwater River, in many cases a flat or decreasing trend in habitat suitability with increasing discharge is apparent from the Kosakoski and Hamilton data, but there is often an increase in habitat suitability at low discharge rates that is not evident in the historical data (e.g., habitat suitability for chinook (Figure 17) and steelhead (Figure 23) fry in C1).

In the Nicola River, the finer level of detail on habitat suitability at low discharge rates is largely driven by data collected from N4, which was not surveyed by Kosakoski and Hamilton. However, MOE also collected data at more discharge rates than Kosakoski and Hamilton in the critical N2 reach, including some lower discharge rates. An example of the finer detail provided by the greater number of discharges sampled by MOE is evident in the graph for coho adults in

N2 (Figure 13). The Kosakoski and Hamilton and Ptolemy transect data suggest an increase in habitat suitability for coho adults with increasing discharge in N2. However, while the MOE data indicate that habitat suitability increases up to approximately 6.4 cms (46% MAD), there is then a decline in habitat suitability at higher discharges. This decline in habitat suitability at high discharge rates is not evident from the historical data.

Despite the general agreement between the historical transect data and that collected by MOE, there are several other occasions where recent data reveal interesting differences or relationships not evident from the historical data. These are discussed briefly below for the Nicola and Coldwater rivers. For the Nicola River this discussion focuses on reach N2, from which data exist from Kosakoski and Hamilton (1982), Ptolemy (1984), and MOE (2004-2007). No recent data were collected from reaches N1 and N3, whereas only recent data exist for N4.

4.1.1. Nicola River

Kosakoski and Hamilton (1982) identified N2 as the critical reach in the Nicola River as it represents only 25% of the river length downstream of Nicola Lake, but contains 75% of chinook spawning habitat and 40% of chinook rearing habitat. The recent transect data from MOE, combined with the latest habitat suitability criteria, fall within the range of habitat suitability that would be predicted from the Kosakoski and Hamilton data for chinook fry and parr. For chinook adults, the recent data provide a far better indication of habitat suitability than the historical data as a result of more discharge rates being surveyed. The recent data indicate that habitat suitability for chinook adults increases up to approximately 11.0 cms (80% MAD) in the N2 reach.

Recent transect data suggest that habitat suitability for coho parr in reach N2 is similar to that predicted from Kosakoski and Hamilton data. However, suitability values derived from historical transects are likely to have overestimated habitat suitability for coho fry in reach N2, particularly for discharge rates greater than 5 cms (36% MAD). Also, as previously mentioned, there was a decline in habitat suitability for coho adults at discharges greater than 6.4 cms (46% MAD), which was not evident from the historical data. The decline in habitat suitability for coho adults is in contrast to the relationship for chinook adults, which reached a plateau at 11.0 cms (80% MAD) but did not decline with further increases in discharge.

The historical and recent habitat suitability data for steelhead fry and parr in reach N2 are similar. However, as was the case for coho adults, the fact that more discharge rates were sampled by MOE than Kosakoski and Hamilton, means that recent data provide a finer level of detail of habitat suitability for steelhead adults between 3 cms (22% MAD) and 13.8 cms (100% MAD). As was the case for coho adults, habitat suitability increased with increasing discharge to approximately 7 cms (51% MAD), before declining with additional increases in discharge. This relationship was not evident from the limited historical data.

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4.1.2. Coldwater River

The habitat suitability for chinook fry in reach C1 is within the range of that derived from the Kosakoski and Hamilton data, although the recent data show an initial increase in habitat suitability from very low discharges (near zero) to those around 0.6 cms (7% MAD) that is not evident from the Kosakoski and Hamilton data. Meanwhile, recent transect data suggest that habitat suitability for chinook fry in reach C2 is higher than would be predicted from the Kosakoski and Hamilton data at discharges greater than 1.5 cms (22% MAD).

The recent MOE transect data and latest habitat suitability criteria suggest that there is a fairly constant relationship between wetted usable width and discharge for chinook parr in the Coldwater River. However, habitat suitability at low discharge rates (<1.5 cms, 22% MAD) appears to be lower than would be predicted from the Kosakoski and Hamilton data in reach C1. Recent and historical data for chinook adults in the Coldwater River is very similar, with habitat suitability increasing with increasing discharge.

There was a clear difference in habitat suitability for coho fry in the two Coldwater River reaches at low discharge rates. This distinction was not accurately shown by the Kosakoski and Hamilton data. In reach C1, habitat suitability for fry was less than would be predicted from the Kosakoski and Hamilton data at discharges ≤1 cms (11% MAD), but in reach C2, habitat suitability was greater than would be predicted at discharges ≤1 cms (15% MAD). A similar pattern was observed in the habitat suitability curves for coho parr. Kosakoski and Hamilton and MOE data for coho adults in the Coldwater River were similar in reach C1, and at low discharge rates in reach C2. However, habitat suitability for adults in reach C2 was higher than predicted from historical data at discharges greater than 2 cms (29% MAD).

For steelhead fry and parr, habitat suitability derived from the Kosakoski and Hamilton and MOE values are similar in reach C1, although the recent data provide a greater level of detail of habitat suitability at discharges <1 cms (11% MAD). However in C2, habitat suitability for steelhead fry is greater than predicted by the historical data at discharge rates less than 1.5 cms (22% MAD). Meanwhile, habitat suitability for steelhead parr in C2 is also greater than predicted from the historical data, but only at discharge rates greater than 2 cms (29% MAD). Results from Kosakoski and Hamilton and MOE are similar for steelhead adults in reach C1. In C2, however, habitat suitability is greater than would be predicted from the historical data at discharges greater than 2 cms (29% MAD).

4.2. Comparison of Optimum Flows Derived Empirically and by Meta-Analysis

Kosakoski and Hamilton (1982) predicted optimal flows for various life-history stages in certain reaches of the Nicola and Coldwater rivers. The following section discusses how these optimal values compare with those predicted from the life-stage specific criteria predicted from discharge and geographical location using the relationships given by Bruce and Hatfield (2003). In

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addition to identifying where the Bruce and Hatfield optimal values differ from those predicted by Kosakoski and Hamilton, those instances where the recent transect data from MOE, combined with the modern habitat suitability criteria, do not match with optimal flows predicted by Bruce and Hatfield are also described (i.e. discrepancies between optimal flows derived from empirical data and from meta-analysis). These comparisons are based on a visual analysis of the weighted usable width versus flow curves presented above (Figure 8 to 25), rather than any formal tests. Although there was reasonable agreement between the Bruce and Hatfield and empirical results, there were certain instances where empirically derived optimal flows were higher or lower than those derived from the relationships in Bruce and Hatfield (2003).

4.2.1. Nicola River

Kosakoski and Hamilton list the optimum flow for spawning chinook in N2 as 4.25 cms (31% MAD). This is lower than the optimal flow derived from the relationships in Bruce and Hatfield, which is 6.8 cms (49% MAD). Recent MOE transect data and the habitat suitability criteria used in this study suggest that the optimal flow for chinook spawning in N2 may be even higher than the 6.8 cms predicted from Bruce and Hatfield. Empirical data presented in Figure 10 suggest that the optimal flow for adult chinook in reach N2 is approximately 11.0 cms (80% MAD).

In terms of chinook rearing in the N2 reach, Kosakoski and Hamilton list the optimum flow as 1.42 cms (10% MAD), with a fairly rapid decrease in suitability at discharges greater than 4.25 cms (31% MAD). The Bruce and Hatfield derived optimal values for chinook rearing in N2 are 1.1 cms (8% MAD) for fry and 3.5 cms (25% MAD) for parr. Thus, the optimal flow predicted by Kosakoski and Hamilton may be an underestimate of the optimal flow for chinook parr in N2, although there are no empirical data below 3.0 cms to assess whether this is the case (Figure 9).

Kosakoski and Hamilton list the optimum flow for steelhead fry and parr in N2 as 2.83 cms (21% MAD). This is similar to the optimal flow predicted by Bruce and Hatfield for fry (2.4 cms, 17% MAD), but lower than that predicted for parr (5.6 cms, 41% MAD). Once again, therefore, the value presented by Kosakoski and Hamilton may underestimate the optimal flow for parr.

Kosakoski and Hamilton also report that N3 is a productive chinook spawning area, although its use appears to be limited by high water temperatures in summer. Kosakoski and Hamilton list optimum spawning flow for chinook in N3 as 1.70 cms (33% MAD), while the optimal flow based on relationships in Bruce and Hatfield is 3.40 cms (67% MAD). There are no recent MOE transect data from N3 against which to compare these optimal flows; however, applying modern habitat suitability criteria to the Kosakoski and Hamilton data suggest that both optimal flows are underestimates for chinook adults in N3 (Figure 10).

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4.2.2. Coldwater River

For the Coldwater River, the only discrepancies between the optimal flows derived from relationships in Bruce and Hatfield and optimal flows based on empirical data were for fry. In reach C2, the recent MOE data suggest that habitat suitability for chinook fry increases with increasing discharge to approximately 2.5 cms (37% MAD), which is not accurately reflected in the Bruce and Hatfield calculated optimum flow of 0.4 cms (6% MAD) (Figure 17). While not as clear as for reach C2, there is also a discrepancy for reach C1, with the optimal flow derived from relationships in Bruce and Hatfield being 0.6 cms (9% MAD), whereas recent empirical data suggest that optimal flow in reach C1 is approximately 2.0 cms (29% MAD).

In contrast to chinook fry, the optimal flows derived from Bruce and Hatfield for coho fry in C1 and C2 may be slightly high (Figure 20). The optimal flow for reach C2 was calculated as 1.4 cms (21% MAD), while recent empirical data suggest that the optimal flow is likely to be approximately 1.0 cms (15% MAD). Likewise, in C1 the calculated optimal flow is 1.7 cms (25% MAD), while empirical data suggest it is likely to be 0.6 cms (9% MAD). The Bruce and Hatfield derived optimal flows for steelhead fry in C1 and C2 were also slightly high when compared with the empirical data (Figure 23), with steelhead fry habitat suitability in these reaches appearing similar to that of coho fry.

4.3. Validity of Kosakoski and Hamilton Recommendations

In general, the habitat suitability data from Kosakoski and Hamilton are similar to those from MOE, although the recent data provide a finer level of detail on habitat suitability having been collected at a greater number of discharge rates. This would suggest that the recommendations made by Kosakoski and Hamilton for minimum instream flow requirements are still valid today. However, the Kosakoski and Hamilton data presented in the above graphs (Figures 8 to 25) were calculated using recent habitat suitability criteria, not the criteria originally used by Kosakoski and Hamilton. Therefore, it is necessary to re-examine the Kosakoski and Hamilton recommendations in light of the new habitat suitability criteria and empirical data.

4.3.1. Nicola River

Kosakoski and Hamilton identified N2 as the critical reach in the Nicola River, and spawning chinook as the critical life-history stage. Reach N2 contains 75% of chinook spawning habitat despite representing only 25% of the river's length downstream of Nicola Lake, while adult chinook have the highest flow requirements during a period of naturally low flow, with the peak of spawning occurring in September. The recent MOE data support the conclusion that chinook adults have the highest flow requirements at a critical time, for while adult steelhead also require high flows, this requirement occurs in April when flows are naturally much higher than in September.

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Kosakoski and Hamilton list the optimum flow for spawning chinook in the N2 reach as 4.25 cms (31% MAD). However, as discussed above, this is lower than the optimal flow predicted by relationships in Bruce and Hatfield (6.8 cms, or 49% MAD), and that predicted from recent empirical data (11.0 cms, or 80% MAD). Kosakoski and Hamilton recommended an instream flow minimum of 3.12 cms (23% MAD) for chinook spawning in the N2 reach, which is well below the predicted optimal flow. Increasing the recommended instream flow minimum in N2 during the spawning/rearing period (Aug-Nov) based on adult chinook requirements would also increase habitat suitability for coho adults, but it would decrease the habitat suitability for rearing chinook, coho and steelhead fry, as well as chinook parr. However, if additional water were available it would be beneficial to release this during the month of September, which is the peak spawning period for adult chinook in the Nicola River. In August, and October through December, flows should be maintained at the current recommended minimum instream flow for the N2 reach (3.12 cms, or 23% MAD), which is suitable for chinook, coho and steelhead fry and parr. This flow regime would maximize the habitat suitability for chinook adults while minimizing the decrease in habitat suitability experienced by rearing life-history stages.

Based on the data that are currently available for the N3 reach, the Kosakoski and Hamilton recommended minimum instream flows appear valid for the rearing life-history stages of chinook, coho and steelhead.

This analysis suggests that any change being considered to the minimum instream flow recommendations made by Kosakoski and Hamilton should be an increase in the minimum instream flow in September, in order to support the critical life-history stage of spawning adult chinook. The current recommended instream flow minima remain valid for the other species and life-history stages, although coho adults would also benefit from increased flows in October and November. However, any increase in the minimum recommended instream flow during the fall would decrease the habitat suitability for rearing life-history stages. Given the current pressures on the available water supply (Water Management Consultants 2008), an increase in minimum instream flow may not be attainable, even if desired. Nevertheless, this analysis supports the general recommendation of Kosakoski and Hamilton that "to ensure that the salmonid production potential of the Nicola River system is maintained, it is recommended that there be no increase in water diversion from the Nicola mainstem, Spius Creek, and Coldwater River during low flow periods, and no new water diversion licences unless they are supported by storage."

4.3.2. Coldwater River

Kosakoski and Hamilton list optimum spawning conditions for chinook in the Coldwater River as 3.40 cms (39% MAD), with the recommended minimum instream flow set at 1.42 cms (16% MAD). Optimal flows for chinook adults derived from Bruce and Hatfield data are 4.2 cms in C2 (62% MAD), and 4.9 cms in C1 (56% MAD), with recent empirical data supporting these calculated optimal flows. Therefore, as was the case in the Nicola River, current instream flow

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recommendations do not represent optimal flow conditions for adult chinook. However, in contrast to the N2 reach, where increasing the recommended instream flow minimum would decrease habitat suitability for rearing life-history stages, in C1 and C2 increasing the recommended instream minimum would not impact habitat suitability for chinook and coho parr, and may slightly increase the habitat suitability for chinook fry and steelhead parr. Conversely, coho and steelhead fry may benefit from lower flows during August to December than the current recommended level of 1.42 cms (16% MAD). In light of these differences between species and life-history stages, the minimum instream flow recommended by Kosakoski and Hamilton seems a reasonable target for fish productivity in the Coldwater River. However, natural water availability in the Coldwater River is consistently below this current target flow threshold (Hatfield 2009).

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5. REFERENCES

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Paper 12. U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS-82/86.

Bruce, J. and T. Hatfield. 2003. Predicting salmonid habitat-flow relationships for streams from western North America. II. Prediction of whole curves. Draft manuscript.

COSEWIC 2002. COSEWIC assessment and status report on the coho salmon *Oncorhynchus kisutch* (Interior Fraser population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 34 pp.

Decker, S. 2007. Distribution and abundance of anadromous salmonids and migratory bull trout in headwater reaches of Nicola River Watershed in 2006. Report for Ministry of Environment, Kamloops, BC.

FISS (Fisheries Information Summary System). 2009. Fisheries inventory database managed by the BC Ministry of Environment. Available at: http://a100.gov.bc.ca/pub/fidq/fissReport.do

Fleming, J. O., and J. S. Nathan. 1985. A field survey and review of fisheries/agriculture conflicts with regard to gravity-fed irrigation ditches in the Nicola and Coldwater River Valleys. Canada Works. 67 pp.

Hatfield, T. 2007. Nicola River Watershed – Water Use Management Plan. Instream flow needs for fish. Consultants report prepared for the Pacific Salmon Foundation.

Hatfield, T. 2008. Nicola Water Use Management Plan: Instream flow needs for fish. Consultants report prepared for the Fraser Basin Council.

Hatfield, T. 2009. Nicola Watershed and Water Use Management Plan: Overview of Instream Flow Requirements. Consultant's report prepared by Solander Ecological Research for the Fraser Basin Council. August 2009.

Hatfield, T., A. Lewis, D. Ohlson and M. Bradford. 2003. Development of instream flow thresholds as guidelines for reviewing proposed water uses. Prepared for BC Ministry of Sustainable Resource Management and BC Ministry of Water, Land and Air Protection. Victoria, BC.

Hatfield, T., A.F. Lewis and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia. Prepared by Solander Ecological Research Ltd. and Ecofish Research Ltd. for the BC Ministry of Environment, Surrey, BC.

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Kosakoski, G.T., and R.E. Hamilton. 1982. Water requirements for the fisheries resource of the Nicola River, B.C. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1680. 127 pp.

Lewis, A.F., Hatfield, T., Chilibeck, B., and C. B. Robert. 2004. Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia. Available on the internet: http://wlapwww.gov.bc.ca/wld/documents/bmp/assessment_methods_instreamflow_in_bc.pdf

Nelitz, M., C.A.D. Alexander and K. Wieckowski. 2007. Helping Pacific salmon survive the impact of climate change on freshwater habitats: case studies. Perspectives from the Okanagan, Quesnel, Nicola, Cowichan, Nass, and Englishman River watersheds. Pacific Fisheries Resource Conservation Council. Vancouver, BC.

Nicola WUMP Multi-Stakeholder Committee. 2009. Nicola Water Use Management Plan. Draft Report. Prepared on behalf of the Citizens of the Nicola Watershed with support from Compass Resource Management Ltd.

Nicola WUMP. 2006. Nicola Water Use Management Plan website. Available on the internet: http://www.nicolawump.ca/index.htm

Petrie, R. J. 1986. Partial inventory and preliminary evaluation of ditch irrigation systems in the Nicola Valley. Ministry of Environment and Parks. 16 pp.

Roseneau, M. L. and M. Angelo 2003. Conflicts between People and Fish for Water: Two British Columbia Salmon and Steelhead Rearing Streams in Need of Flows. Report prepared for Pacific Fisheries Resource Conservation Council.

Sebastien, D. C. and B.A. Yaworksi. 1984. Summary of Nicola Fisheries Assessment, 1980-83. Fisheries Branch, BC Ministry of Environment.

Starr, P. 1977. Nicola River folio: Nicola River watershed—review of fisheries related demands. Department of Fisheries and Oceans internal report. 25 pp. & appendices.

Triton. 2009. Habitat suitability for small bodied chinook in the Thompson Nicola Watershed. Consultant's report prepared by Triton Environmental Consultants Ltd. for the Fraser Basin Council. January 2009.

Water Management Consultants. 2008. Nicola watershed water budget analysis. Consultant's report prepared for the Nicola Watershed Community Round Table.

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