Wigwam River
Water Quality and Quantity
Monitoring Program
2002 Data Report.

Funded by Tembec Industries Inc.
Activity No. 02-RIP-FIA-501

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Executive Summary

The upper Wigwam River water quality and quantity monitoring program is a Tembec Industries Inc. initiative that is funded by the Forest Investment Account (FIA) and the Ministry of Water Land and Air Protection (MWLAP). This program was commissioned in planning for fish habitat protection and forest development within the upper Wigwam River valley and complements initiatives taken by the Ministry of Water, Land, and Air Protection to develop a regional hydrometric network. Elements of this monitoring program were established in consultation with representatives from the former Ministry of Environment (MELP), Ministry of Forests (MOF), Department of Fisheries and Oceans (DFO), Ktunaxa-Kinbasket Tribal Council (KKTC), and the Montana Department of Fish, Wildlife, and Parks (MDFWP).

The broad intent of the program is to develop a better understanding of existing conditions for select parameters and the ongoing hydrologic and morphologic processes in the upper Wigwam River, especially as they relate to fish spawning habitat quality. These conditions may then be tracked over time as forest development progresses. The 2002-study period (01 January to 31 December 2002) represents the fourth year of a long-term trend monitoring program that includes specific elements designed to enable impact assessment at a site level. Logging in the Wigwam started in the winter of 2000/2001. In 2001, 36% of the allowable cut was harvested and by the end of 2002, 82% or 601.8 hectares had been logged.

Wigwam River flow, water temperature, water quality (TSS, turbidity), rainfall, and air temperature were monitored continuously from 26 April to 12 November 2002. Measurements of stage and discharge were collected to establish a rating curve. In addition, water temperature and water quality monitoring occurred on representative S4 and S6 tributaries traversing cut blocks, and at bridge crossings on Brewery and Desolation Creeks. Four tributary sites outside of cut blocks were also monitored for temperature and water quality and are intended to serve as controls.

All hydrometric data were collected and analyzed in accordance with the Resources Inventory Committee (RIC) approved standards for inventories in British Columbia. Discrete environmental water quality sampling and analysis was carried out in accordance with the technical standards set out by MWLAP.

The flow regime of the Wigwam River is comparable to most interior systems with a snowmelt dominated peak occurring in late spring (May-June). The error term associated with the stage – discharge relationship was less than +/- 7.0%; thus, the 2002 Wigwam River Water quality and quantity monitoring program has demonstrated the ability to meet Class A provincial standards for hydrometric surveys and data computation (Anon. 1998). In fact, all data points collected during four years of monitoring from the programs inception to date (1999-2002) are now able to be characterized by one of four polynomial equations or rating curves to Class A standards (+/-7%): one curve for dynamic flow conditions (ascending, peak, and descending) and three curves for steady flow conditions (Table 4.1.2). A shift in the stage-discharge relationship appears to occur at a stage of 4.7 to 4.9 m and characterizing the rating curve will require additional measurements at this point of inflection to better describe the transition; thus, it is recommended that these gauge levels be targeted in future years of metering.

While discharge followed a similar pattern between years, mean monthly discharge in 2002 was significantly higher from April to November than during any previously metered year (Kruskal-Walis, $P < 0.05$). Maximum instantaneous discharge was recorded on 31 May 2002 at 03:00 MST and measured 92.881 m^3/s, almost double that of the maximum flow recorded last year. The 2002 increase in discharge is most likely explained by the increase in snow pack. Both 2000 and 2001, were considered below average snow pack years in the Kootenays with 2001 being only 50-53% of normal levels (Environment Canada 2001).

The natural temperature cycle of the Wigwam River has not altered since harvesting (Kruskal-Wallis $P>0.05$) and is well within the provincial guideline of 15°C for streams frequented by bull trout. Peak mean weekly maximum water temperatures for the Wigwam River occurred during the week of 15-21 July and reached 12.64°C. This peak occurred a full three weeks earlier than last year and is believed to have resulted from the increase in groundwater recharge (note air temperatures did not significantly differ among years 1999-2002; Kruskal-Walis, $P>0.05$). Mean weekly maximum temperatures for the Wigwam River dropped below 9°C during the last week of September and remained so through November. Thus, the 2002 spawning population of bull trout experienced waters within the recommended upper temperature limit for reproduction.

All but one of the Wigwam's tributaries monitored for temperature in 2002 were also within provincial guidelines for trout streams (i.e. < 15°C). The exception hosts a resident population of Westslope cutthroat trout. While mean weekly maximum temperatures in the creek were within the temperature guidelines for a rearing cutthroat population (i.e. 16°C), they exceeded the upper temperature guideline for incubation by 1-2 °C for four weeks; however background levels indicate that this is often the case for this beaver impounded tributary. Last year water temperatures at this site increased significantly after logging; however, this year, the temperatures have returned to background levels. Thus, the natural temperature cycle of this creek appears not to have increased in amplitude from pre-harvest conditions.

To assure quality reporting in the water quality data for TSS, we examined the difference in measurements for samples analyzed within 72 hours and those that had exceeded the recommended time limits across both clear and turbid flow periods (Table 4.3.2). As in previous years, results of samples collected by the automated pump samplers did not differ from those collected manually and analyzed within the recommended 72 hr holding guideline (Wilcoxon, $P>0.05$). The ability to accurately measure suspended sediment after 72 hours is indicative of a low organic component to Wigwam River water. The high degree of correlation between TSS and turbidity (Spearman rank=0.953, $P<0.05$, $n=86$) further supports this hypothesis. Thus, TSS levels in the Wigwam River may be determined with a reasonable degree of precision without having to ship samples to a laboratory or increase the frequency of field visits to ensure analysis is conducted within holding times.

In 2002, the ambient water quality guidelines for turbidity and suspended sediment were updated to recognize that exposure duration plays a key role in the toxicity response (Anon. 2001). There are now distinct guidelines for periods of clear and turbid flow. The terms clear flow and turbid flow are used to describe the portion of the hydrograph when suspended sediment concentrations are low (i.e. less than 25 mg/L or less than 8 NTU) and relatively elevated (i.e. greater than or equal to 25 mg/L or greater than or equal to 8 NTU respectively). The suspended sediment/turbidity guidelines were adjusted upward for turbid flow periods in recognition of the extreme variability found in relationships between suspended sediment concentrations and discharge flows (Anon 2001).

The clear and turbid flow periods for the Wigwam River and its tributaries were defined using data on the background concentrations of suspended sediment at a site-specific level. Maximum TSS (148 mg/l) and turbidity concentrations (67.8 NTU) for the Wigwam River were measured on 31 May 2002, during peak discharge (Figure 4.3.2). Since flow is correlated with TSS in the Wigwam River, and flow was significantly greater this year than background, it was not surprising to measure TSS values that exceeded guidelines during turbid flow periods. In total, 5.7% of samples collected at the hydrometric station in 2002 exceeded the TSS guideline and 15.38% of samples exceeded the turbidity guideline during the turbid flow period. In contrast, neither TSS or turbidity guidelines were exceeded during the clear flow period. Given that the only Wigwam River samples to exceeded guidelines were collected during the turbid flow period, and the fact discharge was significantly greater in 2002 compared to background, the elevation in suspended sediment should not be attributed to forestry activities in the watershed but rather to natural processes resulting from the increased discharge. Thus, the current water quality of the Wigwam River and its tributaries appear to meet the updated standards for ambient water quality parameters of suspended sediment and turbidity.

The following recommendations are provided for the protection of the water resource based on inventory data collected. In addition, the recommendations are made to improve upon the program.

1. It is recommended that gauge levels between 4.7 and 4.9 m be targeted to better characterize the rating curve. This change in stage occurs rapidly in early May and would require several visits in one week. However, given the well defined relationship of the high flow curve, effort could be redirected to target the transitional portion of the Wigwam's hydrograph.
2. Reduce the data collected at the groundwater recharge monitoring station to provide information on temperature and water quality only. As expected, the dewatering phenomenon that occasionally occurs at this site in early August, appears to impact the distribution of young-of-the-year bull trout; but not their abundance (Cope 2003). Now that the juvenile bull trout population is no longer being monitored, collecting water level data at this station would appear to no longer be necessary.
3. Given the costs associated with accessing the watershed, and the demonstrated ability to accurately measure suspended sediment and turbidity levels even though recommended holding times have been exceeded, we recommend the automated pump sampler program continue. With the inclusion of solar panels to

operate the ISCO samplers, we could further reduce the number of site visits while increasing the number of samples collected on the Wigwam River as most missed samples were a result of power failures.

4. A temperature data logger should be added to the Rabbit Creek site. This site is the only Mainstem station above the bulk of forest development and therefore may serve as an indicator of watershed events (control). At a cost of $160.00 per temperature logger, this represents a minimal expenditure and would provide data on a parameter that has paramount significance to the fishery resource (i.e. bull trout are temperature sensitive).
5. If there is no longer any winter harvesting activities scheduled for the Wigwam (Don Jakobic, Tembec Roads Supervisor, personal communication 13 Nov 2002) then the winter sampling point may be eliminated from the current program.

Acknowledgements

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1 Introduction

In the spring of 1999, Crestbrook Forest Industries (CFI), now Tembec Industries Inc., initiated the upper Wigwam River water quality and quantity monitoring program with funding from Forest Renewal British Columbia (FRBC). The program was commissioned in planning for fish habitat protection and forest development within the upper Wigwam River valley and complements initiatives taken by the Ministry of Water Land and Air Protection (MWLAP) to develop a regional hydrometric network. Elements of this monitoring program were established in consultation with representatives from MWLAP, Ministry of Forests (MoF), Department of Fisheries (DFO), Ktunaxa-Kinbasket Tribal Council (KKTC), and the Montana Department of Fish, Wildlife, and Parks (MDFWP). The broad intent of the program is to develop a better understanding of existing conditions for select parameters and the ongoing hydrologic and morphologic processes in the upper Wigwam River, especially as they relate to fish spawning habitat quality, and to track any change in these conditions over time. The monitoring program is a measure that extends beyond requirements of the British Columbia Forest Practices Code (FPC), and is one component of a best management practices approach described in the silviculture prescription for the area. This report summarizes the results of the fourth year of data collection. The 2002 data represent the second year of measurements since harvesting began in the watershed (winter 2000-01). Attention has focused on quality control and quality assurance protocols, data collection, and recommendations to meet stated objectives.

1.1 Objectives

The purpose of this Water Resource Inventory is to enable short and long-term evaluation of the water resource. The monitoring program has been designed to achieve a better understanding of existing conditions for select parameters and the ongoing hydrologic and morphologic processes in the upper Wigwam River, especially as they relate to fish spawning habitat quality. These conditions may then be tracked over time as forest development progresses. Specific objectives were:

- Focus monitoring on forest development activities, including harvesting and stream crossings, to detect whether site-specific impacts are occurring with possible ramifications for fish habitat conditions; and
- Monitor conditions over time to provide a better understanding and characterization of the hydrology, morphology and select habitat parameters of the upper Wigwam River.

Referring to Resources Inventory Committee (RIC) documentation on water quality monitoring objectives, the Wigwam monitoring program represents a trend monitoring program that includes specific elements designed to enable impact assessment monitoring at a site level (Cavanagh *et. al*. 1998a). To achieve program objectives, the following program components were implemented:

- A Hydrometric station for continuous monitoring of upper Wigwam River streamflow, rainfall, air temperature, water temperature and development of a rating curve through correlation of manual stream discharge measurements and river stage;
- Continuous monitoring of water quality (total suspended solids (TSS), turbidity) at two mainstem locations above and below the focal forest development area;
- Continuous monitoring of water table fluctuations of the upper Wigwam River spawning grounds directly upstream of Brewery Creek
- Continuous water temperature monitoring of 4 representative S4 and S6 tributaries, above and below proposed harvest boundaries;
- Periodic sampling of water quality (TSS, turbidity, temperature) at proposed bridge crossing locations (Desolation Creek, Brewery Creek), representative S4 and S6 tributaries, and three mainstem river locations (grab sample locations n=10)

Annual channel bed and bank measurements including a standardized suite of habitat parameters are no longer a part of the water quality monitoring program. The regional Cranbrook MWLAP office is continuing to monitor the habitat component independently of Tembec Industries Inc.

2 Summary of Existing Information

2.1 Study Area

The Wigwam River is a fourth order tributary (83,500 ha) originating in the Rocky Mountains in the state of Montana (Table 2.1.1). The upper 10,500 ha are located in Montana. The Wigwam River then flows approximately 55 km north between the Galton and Macdonald Mountain Ranges of southeastern British Columbia, where it enters the Elk River, a tributary to Lake Koocanusa, the reservoir formed by Libby Dam in Montana on the upper Kootenay River

(Figure 2.1.1). The upper Wigwam River study area is bound by Bighorn Creek to the north, the British Columbia – Montana border to the south, and by height of land to the east and west (Figure 2.1.2). The valley is characterized by four biogeoclimatic zone variants; Kootenay dry mild interior Douglas-fir, dry cool montane spruce, Kootenay moist cool interior cedar hemlock, and dry cool Engelman spruce sub-alpine fir (Braumandl and Curran 1992). Within the study area, the mainstem Wigwam River begins at an elevation of 2,135 m and declines to 1,120 m.

Access to the study area is via Highway 3 to Morrisey and by a series of logging roads (Lodgepole to Ram Creek, Ram Creek to Wigwam mainline). The study area begins at km 45 on the Wigwam mainline. Sampling locations within the valley included four locations on the Wigwam River mainstem, two locations within Brewery and Desolation Creeks, two locations within each of one S4 and one S6 tributary (Figure 2.1.2). The precise locations of each sampling site along with MWLAP's identifying environmental monitoring site (EMS) number are summarized in Table 2.1.2.

Table 2.1.1 Summary of geographic information for the Wigwam River Watershed.

Geographic Information	
Stream Order	Fourth
Approximate Distance to Nearest Town	68 km to Fernie BC
MELP Region	Kootenay
MELP Management Unit	4-02
DFO District	Pacific
Ministry of Forests Region	Nelson
Ministry of Forests District	Cranbrook
NTS Map Reference	82G/03 and 82G/07
Water body Identifier	00000ELKR
Watershed Code	349-248100-04900
UTM (confluence)	11 638565 5456248

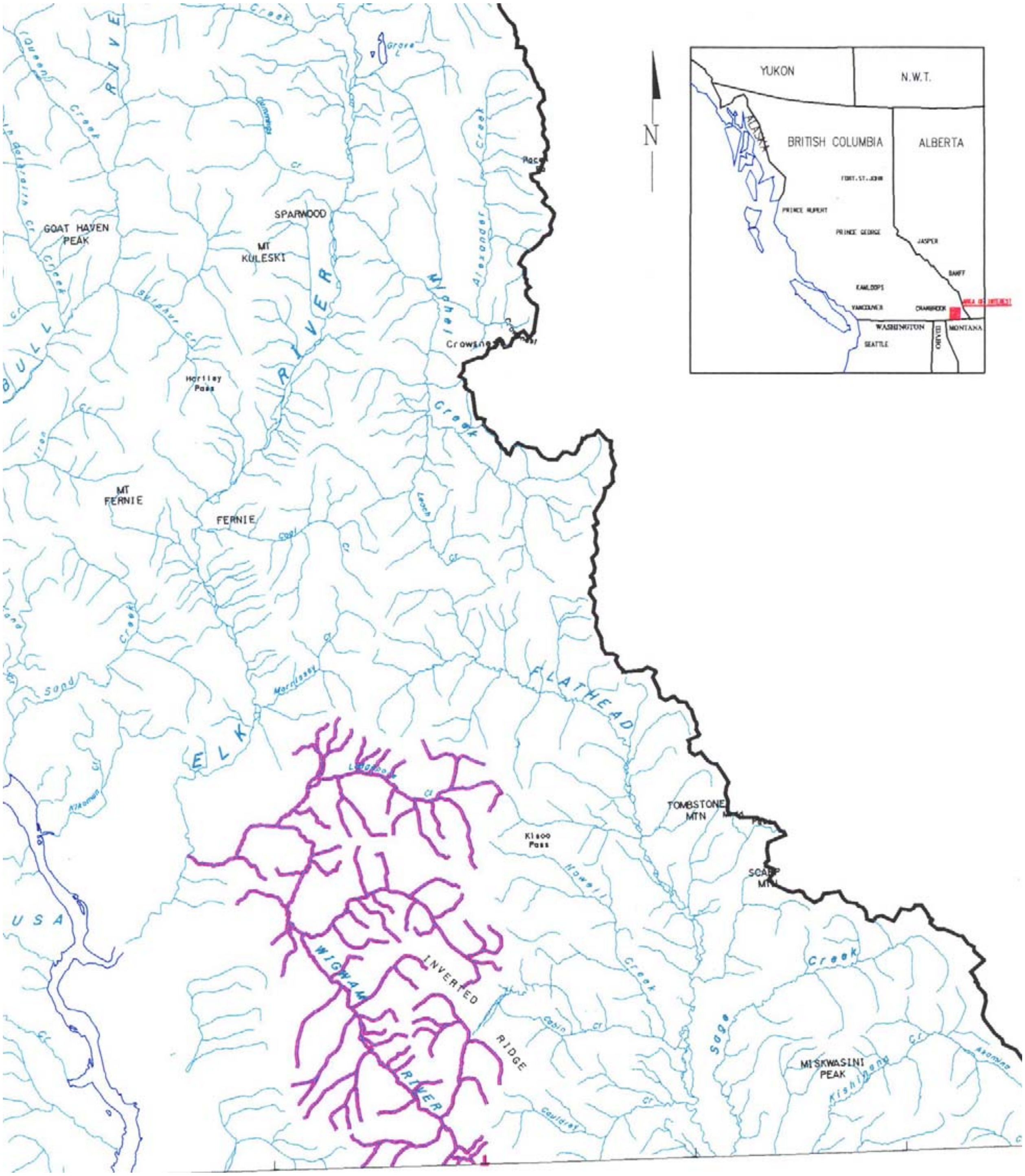


Figure 2.1.1 Wigwam River study area (not to scale).

Figure 2.1.2 Sampling locations for the Wigwam River Water Quantity/Quality Monitoring Program.

Table 2.1.2. Summary of sampling locations within the Wigwam River study area.

EMS Number	Site Name (s)	Location	Latitude/Longitude
E238242	Hydrometric Station	Wigwam River bridge above Bighorn Creek	N 49°10’35.7” W 114°57’36.2”
E238246	Groundwater station (WQGS1)	Wigwam River above Brewery Creek	N 49°04’57.8” W 114°52’24.4”
E238250	WQGS7	Wigwam River above Rabbit Creek	N 49°01’48.0” W 114°47’58.0”
E238248	T1 (WQGS4)	S6 upstream of W cutblock 168	N 49°03’45.8” W 114°51’44.2”
E238247	T2 (WQGS5)	S6 downstream of W cutblock 168	N 49°04’04.6” W 114°51’34.2”
E238253	T3 (WQGS8)	S4 upstream of E cutblock 172	N 49°02’57.3” W 114°48’57.6”
E238252	T4 (WQGS9)	S4 downstream of E cutblock 172	N 49°02’45.4” W 114°49’29.1”
E238245	WQGS2	Brewery Creek upstream of bridge	N 49°05’10.8” W 114°58’24.3”
E238244	WQGS3	Brewery Creek downstream of bridge	N 49°05’12.4” W 114°53’16.3”
E238249	WQGS6	Desolation Creek upstream of bridge	N 49°02’21.3” W 114°47’46.8”
E242997	WQGS10	Desolation Creek downstream of bridge	N 49°02’24.1” W 114°42’38.2”
E243974	T5	S6 upstream E control	N 49°04’27.1” W 114°51’04.01”
E243975	T6	S6 downstream E control	N 49°04’21.1” W 114°51’08.01”
E243972	T7	S5 upstream W control	N 49°02’49.2” W 114°50’11.01”
E243973	T8	S5 downstream W control	N 49°03’05.1” W 114°49’55.01”

2.2 Background

2.2.1 Land Use Designation

In 1980/81 the Wigwam River was nominated as a candidate for designation as a wilderness area; however, it failed to meet MoELPs criteria (G. Oliver, Cranbrook, B.C. *pers. comm.*). The importance of the Wigwam River was again addressed in the 1990's through the provincial Commission on Resources and Environment (CORE). The CORE process was designed to overcome land-use uncertainty, ensure community stability in industrial sectors (e.g. forestry and mining), and at the same time provide a sustainable environment. Although seven new protected areas were created through the CORE process, the Wigwam River was not selected. Instead, the Wigwam River Valley was designated as a Special Resource Management Zone (SRMZ) under the Kootenay-Boundary Land Use Plan (KBLUP). While the prime bull trout spawning reach between Brewery and Fenster Creeks is currently under consideration for designation as a bull trout Wildlife Habitat Area (WHA) under the Managing Identified Wildlife Strategy (B. Westover, MWLAP, Cranbrook, B.C. *pers. comm.*), the Wigwam remains Crown land with a forest license.

2.2.2 Forest Development

Forest harvesting and accompanying road development in the Wigwam basin to date have been undertaken primarily in Montana, where approximately 20% of the watershed was logged (with extensive road network) in the 1950's and 1960's with subsequent 'green-up' ongoing to the present day (Anon. 1999). In the Canadian portion of the watershed, logging has been limited to the Rabbit Creek sub-basin (< 100 ha), with some helicopter logging in the 1990's near the confluence of the Wigwam River with the Elk River. Conventional logging occurred approximately 20 years ago in the vicinity of the confluence with the Elk River, and in the Bighorn Creek sub-basin. Watershed Restoration Program activities have been on-going within the Bighorn Creek watershed since 1995 (Cope 2000).

The original Forest Development Plan (FDP; CFI 1999) has gone through several iterations in response to stakeholder concerns. The original plan (commonly referred to as amendment 5) called for logging a total of 657.3 ha (1.7% of the entire watershed) or 156,632 m^3 of harvest volume, over a three to four year period after which no further harvesting is planned for at least 20 years. Factors that give rise to reviews of harvesting plans in the watershed include forest health infestations (i.e. mountain pine beetle) or catastrophic events (i.e. wind throw or fire). Lodgepole pine is the predominant species to be harvested. All cutblocks are on glacial till terraces in the valley bottom and are to be clear-cut. Tembec's FDP meets or exceeds all current FPC rules and regulations, and the Ministry of Forests (MoF) District Manager approved amendment 5 in early 1999.

Logging in the Wigwam started in the winter of 2000/2001 and by the end of the first year, 36% of the allowable cut was harvested. Then, on 27 May 2002 there was a heavy snow that downed large tracts of forest in the Wigwam study area. As a result, allowances were made to the cutting permit to harvest the downed trees (Table 2.2.1). By December 2002, the majority of harvest activity had been completed and only block 175, which is accessed by another drainage (i.e. the Rabbit Creek Road), remains to be logged (Figure 2.2.1).

Table 2.2.1 Summary of forest development in the Wigwam River drainage, 2002. Data provided by Tembec Industries Inc.

BLOCK	Net Harvest Area (ha)	Total Appraisal Vol (cruise) (m^3)	2000-2001 Net Harvested Area (ha)	2000-2001 Total Harvested Vol (cruise) (m^3)	2001-2002 Net Harvested Area (ha)	2001-2002 Total Harvested Vol (cruise) (m^3)	Remaining Area (ha)	Remaining Volume (m^3)
130 - 1	26.1	4,056	25.3	4,056	0.8	-	-	-
130 - 2	16.5	2,235	16.5	2,235	-	-	-	-
138	31.7	6,275	-	-	31.7	6,275	-	-
153	20.7	4,653	-	-	20.7	4,653	-	-
155	23.0	5,046	-	-	23.0	5,046	-	-
165	8.2	1,957	-	-	8.2	1,957	-	-
168 - 1	134.8	36,219	35.2	9,444	99.6	26,775	-	-
168 - 2	15.6	7,486	15.6	7,486	-	-	-	-
170	27.9	4,329	-	-	27.9	4,329	-	-
171	39.2	5,811	-	-	39.2	5,811	-	-
172 - 1	137.0	32,542	135.7	32,542	1.3	-	-	-
172 - 2	3.2	897	3.2	897	-	-	-	-
175	110.7	31,455	-	-	-	-	110.7	31,455
176	66.5	13,672	-	-	66.5	13,672	-	-
001-1	35.2	6,794	-	-	15.1	2,915	20.1	3,879
001-2	21.6	4,061	-	-	21.6	4,061	-	-

002	3.2	378	-	-	-	-	3.2	378
003	4.5	909	-	-	4.5	909	-	-
004	1.8	364	-	-	1.8	364	-	-
005	2.0	404	-	-	2.0	404	-	-
006	6.4	1,069	-	-	6.4	1,069	-	-
TOTAL	**735.8**	**170,612**	**231.5**	**56,660**	**370.3**	**78,240**	**134.0**	**35,712**

In response to stakeholder concerns, recognition of the international significance of the Wigwam River fisheries resource, and the sensitivity of bull trout and Westslope cutthroat trout to overharvest and habitat degradation, Tembec has adopted a best management practices approach to forest development. This management approach incorporates measures extending beyond FPC requirements (CFI 1999, Oliver and Cope 1999). These best management practices include but are not limited to:

- Timing restrictions to winter harvest;
- Section 105 road closures;
- Buffer treatments to all tributary streams regardless of classification;
- Progressive harvest to stage degree of disturbance over time;
- Incorporation of a water quality/quantity monitoring program;
- Monitoring and maintenance of access roads.

The combination of a multi-year harvest strategy and a monitoring/impact assessment program incorporates an adaptive management approach that minimizes risk to the fisheries resource.

2.2.3 Fisheries Resource

The Wigwam River supports two distinct fisheries: Bull trout (*Salvelinus confluentus*) and Westslope cutthroat trout (*Oncorhynchus clarki lewisi*). Many anglers target Wigwam River bull trout on their spawning migration through the lower Elk and Wigwam Rivers. In addition, the Wigwam River supports some of the largest Westslope cutthroat trout in the Kootenay Region which, are highly sought after by anglers (Westover 1999a, 1999b).

2.2.3.1 Bull Trout

A lacustrine-adfluvial stock of adult bull trout resides in the mainstem Kootenay River and/or Lake Koocanusa and ascends the Wigwam River to spawn. These fish hold off the mouth of the Elk River between March and May, enter the lower Elk River and Wigwam drainage during June and July, and move onto their spawning grounds in the upper Wigwam River during August and September. Water temperature is reported to be a key indicator for the commencement of spawning in this species (McPhail and Baxter 1996). The juveniles rear within the Wigwam River for one to three years before returning to Lake Koocanusa (Oliver 1979, Cope 1998).

Bull trout are adapted to cold water temperatures and thrive in waters that are too cold, unproductive or too steep in gradient for other fish. They are not found in streams where maximum monthly water temperatures exceed 18^{o}C and are most abundant where water temperatures are 12^{o}C or less (Goetz 1989, Ford *et. al.* 1995, McPhail and Baxter 1996, Buchanan and Gregory 1997). This preference for cooler water manifests in the frequent association of bull trout with cold perennial springs (Oliver 1979, McPhail and Baxter 1996, Buchanan and Gregory 1997, Goetz 1989). In general, the species does not occur in high densities, a tendency that is partly due to the life-history strategy and the environment in which they live. Low population densities, slow growth, delayed maturation and high quality habitat requirements (water temperatures < 12 ^{o}C, spawning gravel with low % fines) make bull trout sensitive to habitat degradation and overharvesting (Goetz 1989, Fraley and Shepard 1989, Ratliff *et. al.*1996, Ford *et. al.* 1995, McPhail and Baxter 1996).

Bull trout are "blue-listed" or sensitive/vulnerable as defined by the British Columbia Conservation Data Center (Cannings 1993), and are a species of special concern within the Kootenay Region (Westover and Conroy 1997). In contrast to bull trout populations within the contiguous United States and Alberta, the Wigwam River contains a healthy, and increasing, population of bull trout. Juvenile densities are some of the highest densities reported within the literature (Cope 1998) and spawning escapements have more than doubled over the past 20 years (Baxter and Westover 1999). This population response has been attributed to special regulations restricting harvest and available habitat. These regulations will continue during forest harvesting (Anon. 1999).

2.2.3.2 Westslope Cutthroat Trout

Westslope cutthroat trout are also typical of cold, nutrient poor streams (Liknes and Graham 1988). Westslope cutthroat trout within the upper Wigwam River are considered to represent the fluvial life history strategy; however, due to the large size attained by this stock, it has been proposed that there may be a lacustrine-adfluvial component to their lifehistory (Oliver 1979). The Wigwam River population of Westslope cutthroat trout contains appreciable numbers of large individuals with adults attaining 450 mm fork length (Westover and Conroy 1997). Although the distribution and abundance of Westslope cutthroat trout have drastically declined from its historic range during the last 100 years, the abundance and size of the current Wigwam River population may be attributed to the combination of special regulations designed to limit harvest and available habitat.

2.2.4 Geomorphology

The flow regime of the Wigwam River is comparable to most interior systems with high spring run-off and winter low flows. Freeze-up generally occurs in late November. The surface geology in the area is such that portions of many watercourses, including the mainstem, have only subsurface flow during late summer. Due to the conflicting nature of anecdotal reports, the frequency and extent of this phenomenon remains uncertain (Anon. 1999).

The upper reaches of the Wigwam River occupy a glacial outwash channel that is bounded by glacial till terraces and silt seams. The occurrence of lacustrine silt deposits overlain by highly permeable glacial till within adjacent terraces has contributed to a predominance of sub-surface flow that reaches the mainstem as groundwater. The influence of groundwater has been a large factor in the maintenance of cool stream temperatures and annual low flows. A number of natural disturbance events over time appear to have contributed a substantial volume of coarse sediment to the river including: wildfires in the 1930’s, a slide in 1993, and the 1995 flood event thought to occur every 100 to 200 years. Sediment aggradation throughout a broad, alluvial floodplain is associated with channel-confining bedrock outcrops immediately downstream of Fenster Creek. The combination of frequent lateral migration and erosion of adjacent terraces and coarse sediment delivery to the mainstem river has created a braided channel comprised of sorted gravels and cobbles that provide prime spawning habitat for bull trout (Oliver and Cope 1999). The provision of suitably sized bed materials (<20 mm) in a low gradient, low water velocity location with associated groundwater have been identified as repeating patterns of preferred bull trout spawning habitat (McPhail and Baxter 1996). Demonstrated patterns of redd location fidelity over the last 20 years supports this hypothesis (Oliver 1979, Westover and Conroy 1997).

2.2.5 Review of Previous Water Resource Inventory Findings within the Study Area

In 1999, the program did not commence until July; therefore, development of a rating curve was limited to reflect only low flow conditions (Prince and Cope 2000). Deviations derived from the stage-discharge relationship were within the required provincial and national standards for Class A data. Maximum water temperatures in the Wigwam were below the thermal tolerance for bull trout. Background levels of TSS and turbidity were documented within the study area as provincial guidelines are in reference to background levels. TSS and turbidity were not correlated with precipitation in the mainstem Wigwam but were correlated with precipitation in S4/S6 tributaries. Pre-treatment analysis between monitoring sites located upstream and downstream of proposed cutblocks indicated significant variability; thus implementation of spatial controls was recommended.

In 2000, a high and low flow rating curve was developed for the Wigwam River and the data collected was again, representative of Class A standards (Prince and Cope 2001). A maximum discharge of 73.74 m3/s was recorded on 23 May and by 15 November, the Wigwam River above Brewery Creek had gone subsurface. As in 1999, the maximum water temperatures recorded were below the thermal tolerance for bull trout. Water temperatures among all monitoring locations showed temporal homogeneity but not spatial homogeneity; therefore, implementation of spatial controls was once again recommended. Maximum TSS and turbidity concentrations were measured on 22 May 2000 at 73 mg/L and 23 NTU respectively. TSS and turbidity were highly correlated in the Wigwam and indicative of a low organic component.

2001 represented the first year of harvesting activity in the study area and during that year, snowpack in the Kootenay region was 50-53% less than normal levels. Consequently, the maximum instantaneous discharge (recorded 26 May 2001 at 05:15 am MST) measured 48.322 m3/s, or 66% that of the previous years’ flow. As a result of the extreme low flows in 2001, the Wigwam River above Brewery Creek went subsurface on 24 August during the bull trout spawning migration and it was hypothesized that the low water yields may have negative implications for egg-to-fry survival of incubating bull trout due to the increased allowance for thermal conductance.

Indeed, the low water yields of 2001 did correspond with increased stream temperatures and variability during summer months. While water temperatures in the Wigwam River mainstem did not alter, one of the fish bearing tributaries to the Wigwam River (block 172) was significantly warmer in 2001 compared to background conditions (Kruskal-Walis $P > 0.05$). Block 172 was harvested in the winter of 2000/01 and since there was temporal homogeneity among all other temperature monitoring locations in the watershed, the increase appeared to be site specific. Furthermore, all monitoring locations except those in the tributary traversing block 172, were within the newly adopted 15 ^{o}C mean weekly maximum temperature guideline for streams frequented by bull trout (Oliver and Fidler 2001). The tributary traversing block 172 exceeded the upper temperature guideline for spawning and incubation of cutthroat trout by 4 degrees over a period of 5 weeks.

Unlike temperature, the water quality parameters of TSS and turbidity were within provincial guidelines in 2001 for all monitoring sites. Given that these parameters are correlated with discharge, and flow was significantly reduced, it was not surprising to have measured them at one third of background levels. Four monitoring sites for water quality were added in 2001 (T5-T8) and are intended to serve as indicators of watershed events.

3 Methods

To complement MWLAP initiatives, rigorous methods were employed in the monitoring program as the Wigwam River is viewed as a critical component in developing a regional hydrometric network. All hydrometric data was collected and analyzed to provincial standards recommended for hydrometric surveys (Anon. 1998) and mirrors the national standard followed by Water Survey of Canada (WSC). Discrete environmental water quality sampling and analysis was carried out in accordance with the technical standards set out by the Water Quality Branch of MWLAP (Cavanagh *et al.* 1998a, 1998b, Oliver and Fidler 2001, Anon. 2001). Project biologists Angela Prince M.Sc. RPBio and Kerry Morris B.Sc preformed all sampling, measurements, and analysis. Jon Bisset B.Sc., R.P. Bio provided technical support to biologists in the field. The monitoring program includes the following components, each of which is provided with a rationale and described more fully throughout this section (refer to Figure 1.2 for locations).

- Hydrometric station for continuous monitoring of streamflow and rainfall (mainstem)
- Automated monitoring of water quality (turbidity and TSS) (2 mainstem sites = hydrometric station and Rabbit Creek station)
- Periodic sampling of water quality (turbidity and TSS) (1 mainstem, 12 tributary sites)
- Continuous water temperature monitoring (2 mainstem, 8 tributary sites); and
- Continuous groundwater monitoring to track recharge (1 mainstem site)

3.1 Sampling Schedule

Winter grab samples and a discharge measurement at the km 45-bridge crossing were collected 04 & 05 February 2002 during logging. The hydrometric station was operational by 26 April 2002 and the groundwater station by 06 May 2002. Upon installation and throughout freshet, automated pump samplers collected Wigwam River water samples on a daily basis and were reprogrammed to sample every 72 hrs after freshet (i.e. July). Grab samples were collected from all locations in the study area every 4 weeks from March-November 2002. Discharge measurements were collected bi-weekly during freshet and once every month after June 2002. Below is a summary of activities and dates they occurred (Table 3.1.1).

Table 3.1.1. Schedule of program components for the Wigwam River water quality and quantity-monitoring program 2002.

EMS Number	Site Name (s)	Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
E238242	Hydrometric Station (HS)	Wigwam River bridge @ km 45		X D		X *C D	XXXX XXXX *C DDDD	XXX C DDD	XX C D	XX C D	X C D	XX C D	XXX C D	
E238246	Groundwater station (WQGS1)	Wigwam River above Brewery Creek		X		***	XXX C	X C	X C	X C	X C	X C		
E238250	WQGS7	Wigwam River above Rabbit Creek		X		X **C	XXXX **C	XX C	X C	X C	X C	X C	X C	
E238248	T1 (WQGS4)	S6 upstream of E cutblock 168		X		X C	XX C	X C	X C	X C	X C	X C	X C	
E238247	T2 (WQGS5)	S6 downstream of E cutblock 168		F		X C	XX C	X C	X C	X C	S	S	X	
E238253	T3 (WQGS8)	S4 upstream of W cutblock 172		X		X C	XX C	X C	X C	X C	X C	X C	X C	
E238252	T4 (WQGS9)	S4 downstream of W cutblock 172		X		X C	X C	X C	X C	X C	X C	X C	X C	
E243974	T5	S6 upstream E control		X		***	XXX C	X C	X C	X C	X C	X C	X C	
E243975	T6	S6 downstream E control		X		***	XXX C	X C	X C	X C	X C	X C	F C	
E243972	T7	S5 upstream W control		X		X C	XX C	X C	X C	X C	X C	X C	X C	
E243973	T8	S5 downstream W control		X		X C	XX C	X C	X C	X C	X C	X C	X C	

X Basic Grab Sample
C Automated monitoring
D Stage-Discharge measurement
F Frozen therefore no sample collected.
S Subsurface flow therefore no sample collected.
* Missing continuous data for pump sampler from 26 Apr-09 May
** Missing continuous data for pump sampler from 11 May to 02 June
*** No access to site available, road blocked therefore station installation delayed and grab sample not possible

Table 3.1.1 Schedule of program components con't.

EMS Number	Site Name (s)	Location	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
E238245	WQGS2	Brewery Creek upstream of bridge		X		X	XXX	X	X	X	X	X	X	
E238244	WQGS3	Brewery Creek downstream of bridge		X		X	XXX	X	X	X	X	X	X	
E238249	WQGS6	Desolation Creek upstream of bridge		X		X	XXX	X	X	X	X	X	X	
E242997	WQGS10	Desolation Creek downstream of bridge		X		X	XXX	X	X	X	X	X	X	

X Basic Grab Sample
C Automated monitoring
D Stage-Discharge measurement
F Frozen therefore no sample collected.
S Subsurface flow therefore no sample collected.
* Missing continuous data for pump sampler from 26 Apr-09 May
** Missing continuous data for pump sampler from 11 May to 02 June
*** No access to site available, road blocked therefore station installation delayed and grab sample not possible

3.2 Hydrology

The Wigwam River is viewed as a critical component in developing a regional hydrometric network and as such, data collection and computation have been conducted to provincial standards (Anon. 1998). A thorough understanding of the relationship between river stage (i.e. gauge height) and discharge is the foundation of hydrometric work. Daily or continuous discharge data cannot be practically obtained directly; however, it is possible to obtain daily or continuous stage data and from that, a continuous discharge record can be calculated based on the relationship between water level and flow. The following section details the methods utilized for converting periodic discharge measurements and continuous water level records to a continuous discharge record according to provincial standards.

Periodic discharge measurements were made in the Wigwam River mainstem at the bridge gauging station (also referred to as the hydrometric station) from February to November 2002. The corresponding gauge height was recorded to the nearest millimeter for each measured discharge to develop a stage-discharge rating curve. All flow measurements were collected using a Price AA model 1210 current meter. The meter was obtained from the National Calibration Institute for Environment Canada in Burlington Ontario and was calibrated for use with a 30 lb and 50 lb. sounding weight, and a top-set wading rod (Appendix C). The duty cycle (i.e. calibration schedule) for this instrument is six months after which time it was returned to the center for calibration. This type of instrument is used by Water Survey of Canada and is often recommended as it is accurate enough to produce a stage-discharge relationship within the recommended standard of ± 7% margin of error for Class A data (RIC standard) while being cost effective.

A cross channel transect was established perpendicular to the flow and divided into 20 to 30 increments for velocity and depth measurements. Beginning from the right bank (rb, looking upstream), the meter was placed at the first increment and lowered to 0.2, 0.6, or 0.8 of the total water depth. The total water depth as well as the number of revolutions in a 60 second period was then recorded. After which, the meter was raised and moved on to the next increment for another flow measurement. The procedure was repeated until the entire transect had been completed to the left bank (lb, looking upstream). The number of revolutions/second was then entered into a meter specific formula to convert revolutions to velocity (m/s). Depth and velocity measurements were recorded and later entered onto an Excel spreadsheet. Discharge was calculated using the mid-point method as per the RIC manual of standard operating procedures for hydrometric surveys in British Columbia (Anon. 1998).

When wading was not possible, the current meter was suspended from the downstream side of the bridge using a crane, Type A sounding reel, and a 30 lb. or 50 lb. sounding weight (depending on flows) with fins to allow for stabilization (Figure 3.2.1).

Figure 3.2.1 Bridge crane and sounding reel suspension used to raise and lower the Price AA velocity meter needed to calculate discharge for the Wigwam River.

The sounding reel measured the length of cable released and the weight allowed the meter to sit perpendicular to the flow. At low flows, the meter was attached to a top-set wading rod and measurements were taken 10m upstream of the bridge as the channel is more uniform in this location. A mid-channel bar, which functions as a stage control, makes it difficult to accurately measure low flows downstream of the bridge.

To measure river stage, a permanent reference point was established 10 m downstream from the bridge from which gauge height was recorded using a level and staff gauge. The level was extended from a reference point and with the staff gauge held on the waters' surface, a reading was taken where the level intersected the gauge. Periodically, the position of the reference point was surveyed and checked against two permanent benchmarks, one of which was the bridge abutment, to determine whether or not the reference point had not shifted and the correction factor (if any) that need be applied. In addition to manual stage measurements, a pressure transducer was installed at the same location (i.e. reference point) to record water depth. An established datum conversion was used to convert continuous water depth to a continuous stage data set (gauge height). A polynomial equation was fit to the measured discharge and the corresponding river stage to represent the stage – discharge rating curve. As per provincial and national standards, the deviations derived from the calculated discharge was not to exceed +/- 7% for class A data (RIC Hydrometric standards Anon 1998b). This stage – discharge relationship was subsequently used to convert the continuous gauge height data to a continuous discharge data set.

3.2.1 Hydrometric and Groundwater Stations

The hydrometric station located at the Wigwam River bridge was programmed to automatically record measurements of water level, water temperature, precipitation and air temperature every 15 minutes. To measure water level and temperature, a submersible pressure transducer (model # PS9800) manufactured by Instrumentation Northwest Inc. was connected to a RX-4 Ultra-Logger with 64K memory by Lakewood Systems Ltd. A high accuracy level option was added to the transducer to ensure factory calibration with 0.1% accuracy (*i.e*. ±0.3 mm)(Appendix C). Factory calibration of the transducers is recommended every 6 months or if problems develop with sensor stability. The 6 month duty cycle is a guideline that may be doubled (one year) as long as there is no evidence of drift (Frank van der Have, Hoskin Scientific Ltd. Vancouver, B.C. *pers. comm.*). To ensure the transducer did not move in the current, several pieces of T-bar were driven into the river bottom and bank. The transducer, contained within perforated PVC pipe, was secured to the bar with pipe clamps and cable ties. The PVC also served as conduit for the transducer cable and was buried beneath ground and extended from the bank up to the metal housing that contained the data logger (Figure 3.2.2).

A TP-X temperature probe (Lakewood Systems Ltd.) and an 8” tipping bucket precipitation gauge (Jarek manufacturing Ltd.) were also connected to the data logger. Calibration of the tipping bucket is recommended at least once per year using a graduated cylinder to equate one tip with 0.25 mm of precipitation (Appendix C). The tipping bucket was located 5 m away from the logger station, as it is required to be in an open area. The air temperature probe was mounted 2m from the ground on top of the wooden data logger housing supports.

Figure 3.2.2 Hydrometric station located at the Wigwam River Bridge. Metal housing was used to protect the data logger that recorded water level, temperature, air temperature, and precipitation every 15 minutes.

The groundwater station located above the Brewery Creek confluence utilized the same data logger and transducer models as described above. In addition, the same construction techniques and housing materials were used at this location. Like the hydrometric station, water level and temperature were recorded every 15 minutes; however, air temperature and precipitation were not recorded at the groundwater station.

3.2.1.1 Data Censoring and Compression

The LS4 Lakewood logger software allowed sensor output (voltage) to be easily converted to an ASCII file format. Viewing the data on site was conducted in order to detect data drift or anomalies that would indicate a sensor malfunction or the need for re-calibration. ASCII files were converted to Excel 7.0 formats and imported into Systat 5.0 for statistical analysis. Daily and monthly summary statistics calculated included mean, min, max, standard deviation for water and air temperatures, and water levels (Appendix A, Tables A1 and A2). Precipitation was summed to yield cumulative daily and monthly totals. All raw data collected by the logger units is presented in Table A7 (hydrometric station output) and A8 (groundwater station output),

Appendix A. Due to the sheer volume of raw output generated by the loggers, only the first page of each table is presented in a printed format and is intended to serve as an example that the data is formatted and ready for upload to EMS. The remainder of the data (i.e. the raw tables in their entirety) is available in digital format (Appendix A, Tables A7-A16).

Several correction factors were first applied to the raw data before analysis. These correction factors arose from changes in position of the transducer as well as the staff gauge. For example, structural modifications were required to the groundwater station on 21 August and 24 September due to rapidly declining water levels. A correction factor was calculated based on the difference between depth readings immediately prior to and after transducer movement (Table 3.2.1). This number was then added to all values prior to the modification.

Another correction factor that was applied to continuous water level data resulted from shifts in the staff gauge. Staff gauges are subject to many extreme conditions and are often displaced by the action of frost and ice. In addition, high flows during freshet often result in stream bank instability and streambed erosion that may affect gauges. Consequently, staff gauges are surveyed several times throughout the year (Appendix A on Form AQU-04 History of Gauge Level Checks). However, since the Wigwam River Hydrometric station's gauge is surveyed only periodically, the exact date of the shift is not known. Therefore, when a shift was detected, it was assumed that the change occurred uniformly and the correction factor was determined by dividing the change in the correction by the number of days to find the change per day (Table 3.2.1)(RIC Hydrometric manual Anon. 1998).

Table 3.2.1 Summary of data correction factors for automated water level data collected in 2002.

Date	Location	Correction	Reason
06 May to 21 August	E238246	+0.114m	Repositioned transducer due to rapidly declining water levels.
06 May to 24 September	E238246	+0.165	Repositioned transducer due to rapidly declining water levels.
03 May to 19 August	E238242	+ 0.000218182	Freeze-thaw shift in staff gauge
20 August to 12 November	E238242	-0.000023255	Freshet shift in staff gauge

In addition to corrections factors, some of the continuous data was deleted prior to analysis. The data deletions were necessary when the transducer position was modified. There also arose gaps in the continuous data record when the data loggers were offline for downloading. Below is a summary of all data gaps and deletions for the automated data collected at the Hydrometric and Groundwater stations. Each gap listed in the table is inclusive of all parameters monitored at that station. For example, the missing data on 09 May from 11:15-12:00 at the Hydrometric station means that all records of water level, air temperature, water temperature, and precipitation are missing for that time period.

Table 3.2.2 Summary of data gaps and deletions for automated stations in the Wigwam River for 2002

Date	Location	Gap or Deletion	Reason
09 May 11:15-12:00	E238242	Gap	Station offline while downloading
21 May 12:46-13:00	E238242	Gap	Station offline while downloading
04 June 12:36-13:00	E238242	Gap	Station offline while downloading
01 July 12:45-14:00	E238242	Gap	Station offline while downloading
08 August 15:10	E238242	Gap	Station offline while downloading
21 August 13:30	E238246	Gap	Station offline during transducer shift
25 Oct to 14 Nov	E238246	Deletion	Station dry therefore values indicate air temp rather than water temp.

3.3 Temperature

Water temperatures in the Wigwam River were collected using pressure transducers outfitted with thermistor sensors calibrated to 0.01% accuracy (Appendix C). Both data loggers recorded water temperature every 15 minutes. Stowaway® TidbiT® temperature loggers manufactured by the Onset Computer Corporation were used to record temperatures in the tributaries. These small thermistor units were factory calibrated to yield an error of 0.1 °C to 0.2 °C, have a battery life of 5 years and store up to 32K of data. These loggers were chosen to remain immersed in streams that often have only a few centimeters of available depth.

Thermistors were placed in tributaries traversing proposed cutblocks 168 and 172 and in two control tributaries located outside cutblocks (Figure 2.1.2). The site locations within the control tributaries were selected on their geographic position relative to the upstream and downstream locations of creeks crossing cutblocks 172 and 168 (Figure 2.1.2). Each thermistor was contained within a protective piece of PVC, which in turn was fastened to a short length of rebar that was secured into the streambed.

The thermistor units were downloaded after removal for winter storage and all data were converted to Excel 7.0 and imported to Systat 5.0 for statistical summaries. Daily and monthly summary statistics calculated included mean, min, max, and standard deviation (Appendix A, Tables A1-A6). The raw data is presented in Appendix A Tables A7-A16. As with the raw data output for the hydrometric and groundwater stations, only the first page of the tables is presented in printed format. The tables in their entirety are available in digital format (Appendix A, Tables A9-A10). Water levels at two tributary sites, one in cutblock 168 (T2), the other the East control tributary (T6), went subsurface during monitoring. Data collected during this time was not included in analysis as it represents air temperatures (Table 3.2.3).

Table 3.2.3 Summary of data gaps and deletions for temperature stations in tributaries of the Wigwam River for 2002.

Date	Location	Gap or Deletion	Reason
28 May 13:13:46	E238248	Deletion	Station offline while downloading
01-25 September	E238247	Deletion	Streambed dry
10-20 September	E243975	Deletion	Streambed dry

3.4 Water Quality

Two types of water samples were collected from the Wigwam mainstem, automated water samples and grab samples. All samples were analyzed for turbidity and total suspended sediment (TSS). Automated samples were collected at the Hydrometric Station and at the Rabbit Creek station using ISCO 3700 portable samplers.

Pump samples were collected every 24 hours during freshet and every 72 hrs afterwards as per provincial standards. The ISCO unit was programmed to collect a sample at 16:00 hrs each day to capture peak flows during snowmelt in the spring. Length of the suction line extending from pump intake to the water was 5.3 m. Each sample contained 900 ml of water that was drawn through a suction head positioned mid way in the water column. The suction head was attached vertically to the PVC conduit that contained the pressure transducer, which in turn was fastened to T-bar driven deep into the adjacent bank and river bottom. The ISCO samples were decanted on site into pre-sterilized Cantest bottles. Each ISCO bottle was then rinsed with distilled water prior to being returned to the sampler. During site visits, the position of the suction head was often adjusted with declining water levels such that intake remained mid depth in the water column.

Grab samples were collected at several locations throughout the Wigwam mainstem as well as several tributaries (Figure 2.1.2) and were always conducted prior to any discharge measurements or other program activities. The sampler waded mid channel, removed the cap of the pre-sterilized Cantest Ltd. bottle, and collected a one-litre sample from mid column before replacing the cap. All water samples were immediately placed in a cooler and returned to the lab for analysis of turbidity and TSS.

Turbidity was also analyzed in the field using a Lamotte 2020 turbid meter as laboratory results are not guaranteed accurate if more than 72 hours has passed since sample collection. Detection limits of the Lamotte meter are 0.05 NTU (nephalometric turbidity units) with an accuracy of ± 2% below 100 NTU. Detection limits of Cantest Ltd. analysis were reported at 0.1 NTU for turbidity and 1 mg/L for TSS. For the purpose of analysis, measurements of TSS and turbidity at or below detection limits were recorded as ½ of detection limit. This was done since log transformations do not accept zero, and values of zero can skew descriptive statistics.

Due to the remoteness of the study area, the pump samplers were only checked periodically. As a result, when a power failure or mechanical problem occurred, several samples were often missed before the problem was detected and repaired. For example, soon after installation (26 April 2002), the pump sampler at the hydrometric station experienced a mechanical failure that required servicing by the manufacturer in Mississauga Ontario. The time required to ship and repair the unit meant that several paired samples (i.e. upper and lower mainstem) were missed (Table 3.2.4). Since the hydrometric station is the fulcrum of the program, the ISCO unit from Rabbit Creek (control) site was relocated to the hydrometric station during this time. In addition, there was one occasion during which battery power failed some and two occasions where freezing of the water intake resulted in missed samples (Table 3.2.4).

Table 3.2.4 Summary of data gaps for automated pump samplers and manual grab samples in 2002

Date	Location	Gap or Deletion	Reason
27 April – 08 May	E238242	Gap	Mechanical Failure
10 May – 02 June	E238250	Gap	Unit moved to Hydrometric Station during repairs
23 April	E238246, E243974, E243975.	Gap	No access, Henry's road blocked
24 July – 16 August	E238242	Gap	Power failure
08-19 & 29 October, 01 & 04 November	E238242	Gap	No liquid detected, water frozen
29 October, 01 & 04 November	E238250	Gap	No liquid detected, water frozen

3.5 Quality Assurance

The field quality assurance program was a systematic procedure that, together with laboratory quality assurance ensured confidence in the data acquired. In addition to the many quality control measures already described in methods (e.g. viewing data on site for anomalies at each visit, and rinsing automated pump sample bottles with distilled water after decanting etc…), the following section outlines additional procedures followed to assure quality data. The results of these measures are presented throughout the text in relation to the particular parameter being examined (e.g. turbidity). Where consistent differences exists between field and laboratory measurements, differences in measuring technologies accounted for the discrepancy rather than actual sampling error.

Quality assurance for the continuous data is slightly problematic. While operating manuals for monitors exist, there are no standards for ensuring the accuracy of sensor, data standards, software and hardware. Because duplicate automated samplers or probes would be economically unfeasible, the most reasonable approach to this problem is regular maintenance and review of the data.

To ensure proper function prior to installation, all equipment was bench tested. Bench testing included checking all probes while monitoring real-time output from the loggers as well as checking the stored data. The pressure transducer was checked by immersing it in a bucket of water and checking output against measured depth. Similarly, temperature was checked by immersing the transducer in both an ice bath and a hot bath to ensure proper read out at both temperature extremes. The tipping bucket was checked using a graduated cylinder to ensure that each tip corresponded to 0.25 mm or 8.11 ml of water. The air temperature probe was checked by blowing on it and holding in the hand to ensure an immediate response to change. Each Tidbit® was also checked by breathing on the unit to raise the temperature above the alarm threshold. Data output was checked for each unit prior to installation to ensure each was recording properly.

The automated ISCO pump sampler was tested in a tub and run through an entire sequence of 24 bottles to ensure that the intake was positioning itself correctly, the appropriate sample volume was being collected, and that the purge cycle was being completed for each sample. Several combinations of date and time were tested to ensure proper clock function. All units were bench tested using the auxiliary power source and a 12-volt battery to mimic field-operating conditions. Similarly, all data was downloaded using the laptop computer that was operated off battery power.

During each site visit, all parameters were checked against calibrated standards while observing the real-time output of the sensors. Pressure transducer readings were manually checked against staff gauge measurements. Water and air temperatures were checked with a digital thermometer that had been calibrated against an alcohol thermometer prior to each visit. The tipping bucket was checked with a level and water run through the funnel to ensure all precipitation drained in spite of an accumulation of debris. The results of these measures have been reported monthly to MWLAP with each submission of the WQDMS automated data forms.

Quality assurance of water samples employed several measures. Field quality control requires the submission of blank and replicate samples at least twice during the yearly sampling program (Anon 1998). In 2002, one blank and two replicate samples were submitted from each of the clear and turbid flow periods. A quality control inspection by MLWAP (Nov 2002) confirmed that field personnel were collecting samples properly. Turbidity for all samples (N=312) was analyzed both in the field using a Lamotte turbidity meter and by Cantest Ltd. in Vancouver BC. The Lamotte meter was calibrated using factory specific solutions of 1.0 and 10.0 NTU's and distilled water before processing each set of samples. Cantest laboratories conducted their own quality control procedures each time samples were analyzed and were included with the results. In addition, Cantest is a member of the CAEL (Canadian Association of Eligible Laboratories) and submits regularly to government testing and audits. The TSS data collected from 20 samples that had exceeded the 3-day recommended holding time (i.e. automated pump samples) was compared with samples collected and analyzed within 72 hours (grab samples). In addition, the results of 5 samples collected by the different methods (i.e. pump vs. manual grab) but analyzed within recommended holding times were compared. Finally, the data presented in this report have been subject to a third party review by Summit Environmental Consultants Ltd.

4 Results

4.1 Hydrology

4.1.1 Stage-Discharge

4.1.1.1 Rating Curve Development

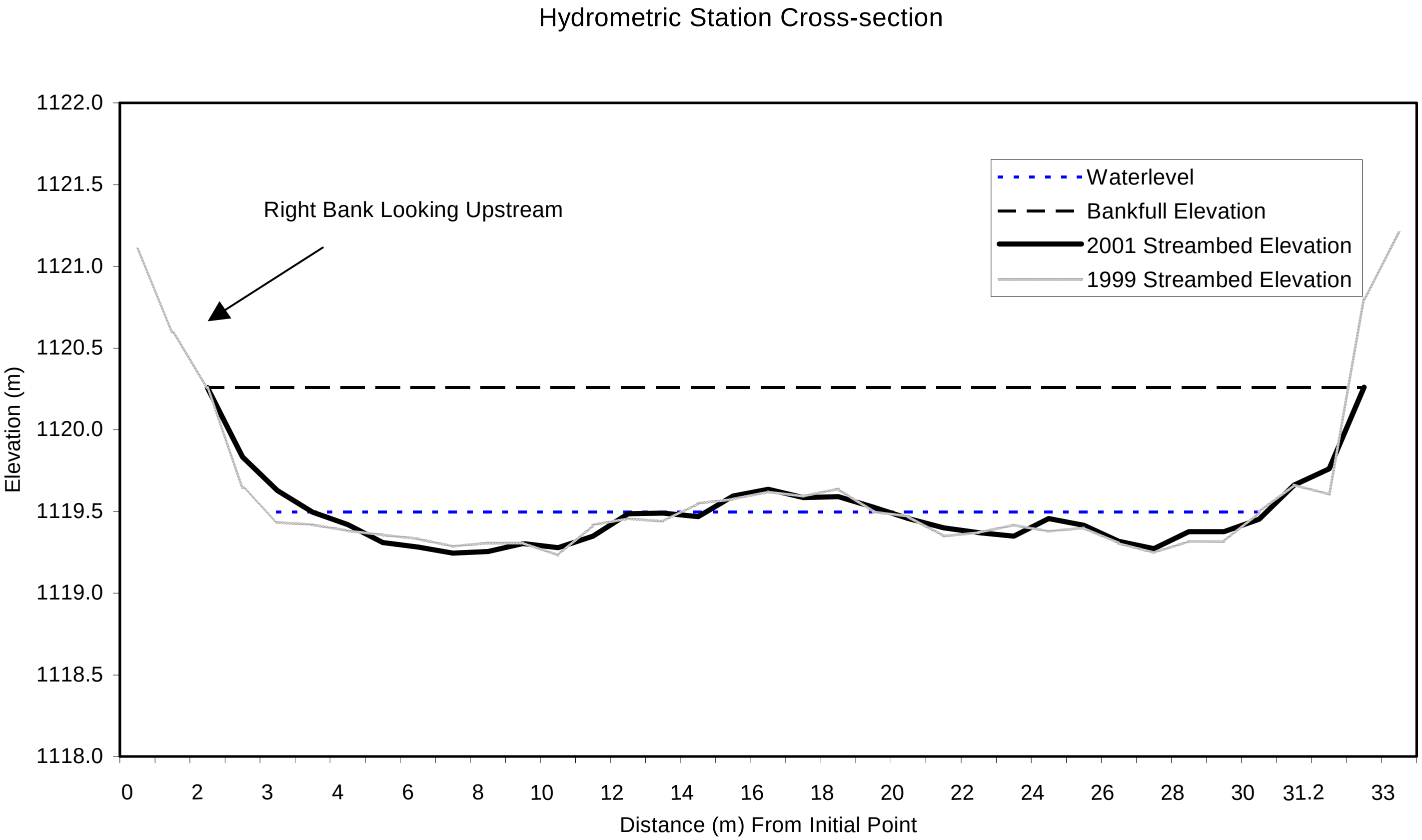
In total, fourteen discharge measurements were obtained at the gauging station in 2002 (Wigwam River bridge hydrometric station). Measured discharge ranged from 67.59 m^3/s on 18 June to 2.73 m^3/s on 04 February 2002 (Table 4.1.1).

Table 4.1.1. Summary of discharge measurements and deviations from the stage-discharge relationship for the Wigwam River as recorded from February to November 2002 at the km 45-bridge station (RIC Form AQUA-05).

Date	Metered by	Meter Type	Unit #	Water Temp °C	Width (m)	Mean Velocity (m/s)	Gauge Height (m)	Measured Discharge (m^3/s)	Calculated Discharge (m^3/s)	Difference	% Difference
04-Feb-02	KM/AP	Price AA	1-242	3.0	26.8	0.436	4.646	2.728	2.727	0.001	0.02
26-Apr-02	KM/JB	Price AA	1-242	4.5	29.1	0.806	4.882	8.489	8.638	-0.148	-1.72
09-May-02	KM/JB	Price AA	1-242	4.4	29.4	0.871	4.896	9.131	8.969	0.162	1.81
14-May-02	KM/JB	Price AA	1-242	4.2	30.2	1.076	5.066	15.754	16.362	-0.608	-3.72
21-May-02	KM/AP	Price AA	1.242*	3.5	31.0	2.384	5.500	64.827	63.500	1.327	2.09
29-May-02	KM/JB	Price AA	1-826	4.4	31.3	2.344	5.497	62.385	63.035	-0.649	-1.03
03-Jun-02	KM/JB	Price AA	1-826	5.7	31.6	2.123	5.473	55.503	59.383	-3.879	-6.53
10-Jun-02	KM/JB	Price AA	1-826	4.0	30.8	1.854	5.297	36.672	36.396	0.276	0.76
18-Jun-02	KM/JB	Price AA	1-826	4.7	31.8	2.251	5.514	67.592	65.697	1.895	2.88
01-Jul-02	KM/JB	Price AA	1-826	6.7	30.5	1.803	5.323	37.677	39.371	-1.693	-4.30
19-Aug-02	KM/AP	Price AA	1-826	10.5	29.1	0.619	4.789	7.447	7.511	-0.064	-0.85
23-Sep-02	AP/JB	Price AA	1-826	9.0	25.4	0.522	4.695	4.121	4.024	0.097	2.40
22-Oct-02	KM/JB	Price AA	1-826	3.4	23.5	0.476	4.657	3.249	3.152	0.097	3.07
12-Nov-02	KM/AP	Price AA	1-826	4.1	27.2	0.415	4.638	3.282	3.185	0.097	3.04

* meter damaged during measurement, discharge calculated with recalibrated repair equation

Under ideal conditions, a single polynomial plot would be fit to the measured discharge and the corresponding river stage to represent the stage – discharge-rating curve. However, the channel geometry at the bridge is such that at low flows (i.e. < 6.0 m^3/s), the mid-channel bar significantly influences the stage-discharge relationship (i.e. stream geometry changes with depth (Figure 4.1.1).



N.B. Site surveyed on October 10, 2001
N.B. Elevations referenced to local datum established in field
Vertical exageration 1:4

Figure 4.1.1 Cross-sectional profile of the Wigwam River stream channel at the hydrometric station (i.e. km 45 bridge crossing).

Consequently, the deviations derived from a single curve exceeded that recommended for standard computation procedures for Class A data (RIC standard +/- 7%). In this case, two stage discharge relationships were derived; one encompassing high flow conditions (i.e. ascending, peak, and descending flows from 26 April to 19 August) and one describing stable flow conditions (23 September to 12 November). The deviations derived from these relationships were less than +/- 7.0% (Class A data) for all measurements (Table 4.1.1).

The 2002 dynamic and steady flow curves represent curves 7 & 8 in the rating curve development for the Wigwam River as curve numbers always increase in chronological order of when the curve is derived. Curves 1 & 2 were developed during low flow conditions in 1999, as the hydrometric station was not established until July 1999. In September 1999 the channel morphometry around the transducer was changed which necessitated the development of a second curve. (Cope and Prince 2000). Curves 3 & 4 characterized low and high flow measurements for the year 2000. By 2001, sufficient measurements had been obtained to better define the Wigwam's rating curve and the two years were able to be combined to develop curves 5 & 6 for low and high flow conditions respectively (Prince and Morris 2002). The years 2000 & 2001 represent two consecutive low snow pack years (i.e. < 50% normal snow pack)(Prince and Morris 2001). Since the hydrograph of the Wigwam River is predominantly determined by snow pack, when snow pack conditions returned to "normal" in 2002, the relationship between stage and discharge was further clarified.

With the additional measurements obtained in 2002, we were better able to describe the high end of the rating curve. A single polynomial equation can now predict discharge for all stages greater than 5.0 m in elevation from 1999-2002 to within +/- 7% of actual measured discharge (Table 4.1.2). However, the influence of the mid-channel bar, the slope of the stream, and the course substrate of the Wigwam River, all contribute to subsurface flow which makes it difficult to accurately measure discharge at low flows; thus, the stage-discharge relationship is more difficult to characterize under these conditions.

To date, we have 3 low flow rating curves we may use to describe the relationship between stage and discharge for points measured below 5.0 m in stream elevation (1999-2002): Curve 2 developed during low flow in 1999, Curve 5 based on all low flow measurements from 2000 & 2001, and Curve 8 from low flow measurements in 2002. The 04 February 2002 data point was best described by the low flow equation developed two months earlier in 2000&2001 rather than by curves developed after the high discharge experienced in 2002 (Table 4.1.2).

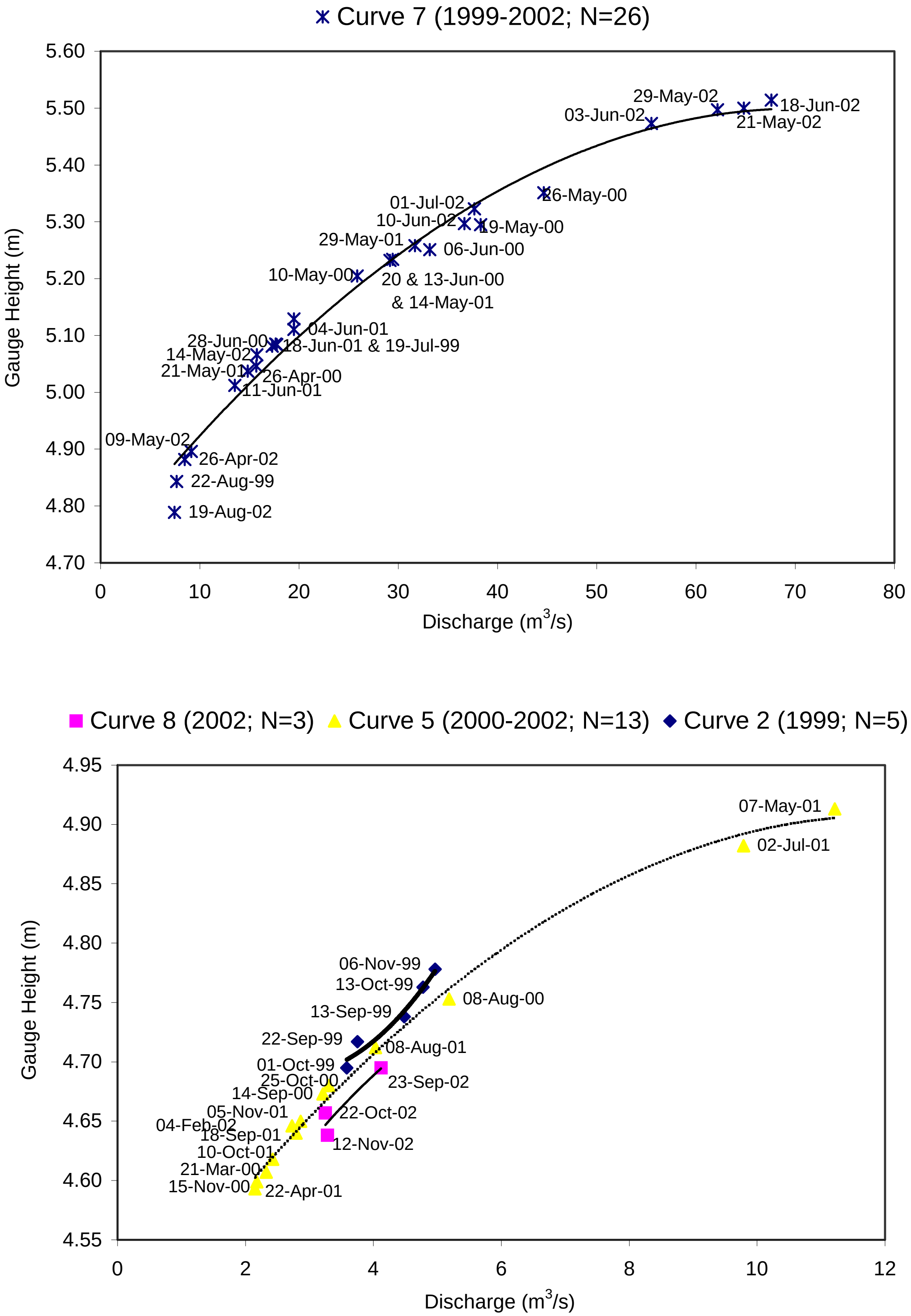


Figure 4.1.2. Stage–Discharge rating curves for the Wigwam River gauging station. (Curve 7 characterizes dynamic flow conditions; Curves 2, 5, & 8 describe steady flow conditions).

Table 4.1.2. Summary of discharge measurements and their deviations from the stage-discharge rating curves developed for the Wigwam River.

Date	Gauge Height (m)	Measured Discharge (m^3/s)	Calculated Discharge (m^3/s)	Percent Difference (%)	Rating Curve (1-8)
01-Oct-99	4.695	3.58438	3.64955	-1.79	2.00
22-Sep-99	4.717	3.75011	3.93000	-4.58	2.00
13-Sep-99	4.738	4.48250	4.27290	4.91	2.00
13-Oct-99	4.763	4.77487	4.77687	-0.04	2.00
06-Nov-99	4.778	4.96401	5.12921	-3.22	2.00
22-Apr-01	4.593	2.14656	2.15777	-0.52	5.00
15-Nov-00	4.599	2.17934	2.20102	-0.99	5.00
21-Mar-00	4.607	2.32566	2.26713	2.58	5.00
10-Oct-01	4.618	2.42783	2.37375	2.28	5.00
18-Sep-01	4.640	2.79333	2.64163	5.74	5.00
04-Feb-02	4.646	2.72785	2.72733	0.02	5.00
05-Nov-01	4.650	2.86294	2.78747	2.71	5.00
14-Sep-00	4.673	3.21394	3.18004	1.07	5.00
25-Oct-00	4.68	3.30458	3.31533	-0.32	5.00
08-Aug-01	4.712	4.03116	4.02769	0.09	5.00
08-Aug-00	4.753	5.18464	5.16566	0.37	5.00
02-Jul-01	4.882	9.78770	10.39657	-5.86	5.00
07-May-01	4.913	11.21169	12.02691	-6.78	5.00
19-Aug-02	4.789	7.44709	7.51116	-0.85	7.00
22-Aug-99	4.843	7.66099	7.93825	-3.49	7.00
26-Apr-02	4.882	8.48931	8.63776	-1.72	7.00
09-May-02	4.896	9.13106	8.96887	1.81	7.00
11-Jun-01	5.012	13.51247	13.33827	1.31	7.00
21-May-01	5.037	14.81877	14.66001	1.08	7.00
26-Apr-00	5.046	15.69574	15.16883	3.47	7.00
14-May-02	5.066	15.75400	16.36208	-3.72	7.00
18-Jun-01	5.081	17.30144	17.31362	-0.07	7.00
19-Jul-99	5.084	17.76159	17.50975	1.44	7.00
28-Jun-00	5.085	17.65440	17.57556	0.45	7.00
04-Jun-01	5.111	19.49187	19.36226	0.67	7.00
10-May-00	5.129	19.47951	20.68460	-5.83	7.00
20-Jun-00	5.205	25.86467	27.03807	-4.34	7.00
13-Jun-00	5.232	29.16015	29.59507	-1.47	7.00
14-May-01	5.234	29.43458	29.79073	-1.20	7.00
06-Jun-00	5.251	33.15986	31.48868	5.31	7.00
29-May-01	5.258	31.67907	32.20595	-1.64	7.00
19-May-00	5.295	38.29579	36.17275	5.87	7.00
10-Jun-02	5.297	36.67155	36.39558	0.76	7.00
01-Jul-02	5.323	37.67749	39.37088	-4.30	7.00
26-May-00	5.351	44.66989	42.73808	4.52	7.00
03-Jun-02	5.473	55.50331	59.38253	-6.53	7.00
29-May-02	5.497	62.17967	63.03465	-1.36	7.00
21-May-02	5.5	64.82715	63.49990	2.09	7.00
18-Jun-02	5.514	67.59156	65.69672	2.88	7.00
23-Sep-02	4.695	4.12087	4.02422	2.40	8.00
22-Oct-02	4.657	3.24903	3.15229	3.07	8.00
12-Nov-02	4.638	3.28183	3.18504	3.04	8.00

Also of note, Curve 2 was able predict the October and November measurements of 2002 within +/- 7%; but, the development of Curve 8 (curve development requires a minimum of 3 points) was necessary to incorporate the 23 September 2002 measurement.

In summary, all data points collected during four years of monitoring from the programs' inception to date (1999-2002) are now able to be characterized by one of four polynomial equations or rating curves to Class A RIC standards (+/-7%): one curve for dynamic or high flow conditions (ascending, peak, and descending) and three curves for steady or low flow conditions (Table 4.1.2). A shift in the stage-discharge relationship appears to occur at a stage of 4.7 to 4.9 m and characterizing the rating curve will require additional measurements at points of inflection to better describe this transition; thus, it is recommended these gauge levels be targeted in future years of metering.

4.1.1.2 Data Summaries

The continuous water level readings obtained every 15 minutes from the hydrometric station; the data were compressed to provide daily summaries of water level (Appendix A, Table A1). The mean daily water level was then converted to gauge height (i.e. water elevation) using the established datum conversion:

Reference point elevation – (distance from reference point to transducer) + water level. ***Equation (1)***

However, since the staff gauge was subject to many extreme conditions and was displaced by the action of frost and high flows, the reference point elevation first required the application of two correction factors (Table 3.2.1). Recall that the Wigwam River Hydrometric station's gauge was surveyed only periodically; thus, the exact date of the shifts was not known. Therefore, when a shift was detected, it was assumed that the change occurred uniformly and the correction factor was determined by dividing the change in the correction by the number of days to find the change per day (Table 3.2.1)(RIC Hydrometric manual Anon. 1998).

After having corrected for the shifting reference point, we noticed that the distance from the reference point to the transducer was not consistent which indicated a shift in the transducer position. Again, this observation was not unexpected given the high discharges experienced in 2002. Thus, a correction factor was also applied to the distance from the reference point to the transducer by dividing the difference by the number of days, and applying that factor incrementally to each day between readings. The corrected reference point elevation, distance from the reference point to the water's surface, and summarized water level data was then used to calculate mean daily gauge height as per Equation 1 above (Table 4.1.3).

Mean daily discharge was calculated by applying the equations derived from the rating curves of the Wigwam River (Figure 4.1.2) to the mean daily gauge height data from Table 4.1.3. The equation characterizing Curve 7 for dynamic flow conditions (Equation 2) was applied to gauge height data from 26 April to 22 September, while the equation characterizing Curve 8 (Equation 3) for steady flow conditions was applied to gauge height data from 23 September to 12 November 2002 (Table 4.1.3).

Curve 7: $y = 107.8196x^2-1030.6094x+2470.3087$ **Equation (2)**
Curve 8: $y = 432.8x^2-4024.6x+9359.3$ **Equation (3)**

Where y represents discharge (m^3/s) and x represents stage (m)

Maximum instantaneous discharge occurred on 31 May 2002 at 03:00 MST and measured 92.881 m^3/s, which represents an increase of 92% compared with the maximum flow of last year (48.32 m^3/s). Minimum daily discharge occurred 30 October at 9:00 MST and measured 3.704m^3/s (Table 4.1.3).

In addition to daily summaries, the stage and discharge calculations for the Wigwam River were summarized by month for inter-annual comparison (Table 4.1.5). As in previous years, mean daily discharge declined rapidly from June 21 to August 15 following the snowmelt controlled hydrograph peak (Figure 4.1.3). While the Wigwam River discharge followed a similar pattern between years, mean daily discharge in 2002 was significantly greater from April to November than during the same period in any other monitoring year (Kruskal-Walis $P<0.05$, Table 4.1.5). The 2002 increase in discharge is most likely explained by the increase in snow pack. Both 2000 and 2001, were considered below average in the Kootenays with 2001 having only 50-53% of normal snow pack levels (Environment Canada 2001).

Table 4.1.3. Annual summary of mean daily gauge height as measured at the Wigwam River hydrometric station. Data is recorded every 15 minutes and averaged to provide mean daily summaries.

Gauge Height Data Westslope Fisheries
Stn Name: Wigwam River at Bridge Computed by: Kerry Morris Date: November 23
Year: 2002 Stn. E238242 Checked by: Angela Prince Date: January 15

	January	February	March	April	May	June	July	August	September	October	November	December	
	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	G.HT	
1					4.928	5.563	5.329	4.883	4.742	4.706	4.628		1
2					4.977	5.511	5.272	4.873	4.740	4.696	4.625		2
3					5.031	5.461	5.240	4.865	4.735	4.691	4.623		3
4					5.031	5.454	5.218	4.861	4.733	4.688	4.622		4
5					5.011	5.481	5.196	4.868	4.760	4.684	4.620		5
6					4.989	5.487	5.175	4.858	4.765	4.681	4.619		6
7					4.962	5.420	5.163	4.849	4.771	4.678	4.619		7
8					4.934	5.369	5.178	4.840	4.759	4.676	4.632		8
9					4.914	5.325	5.180	4.832	4.745	4.672	4.637		9
10					4.897	5.295	5.154	4.826	4.736	4.672	4.629		10
11					4.887	5.267	5.134	4.821	4.729	4.673	4.627		11
12					4.890	5.265	5.117	4.816	4.723	4.669	4.628		12
13					4.935	5.302	5.100	4.810	4.718	4.666			13
14					5.043	5.370	5.084	4.804	4.714	4.663			14
15					5.076	5.433	5.066	4.801	4.711	4.661			15
16					5.059	5.488	5.048	4.806	4.708	4.659			16
17					5.052	5.526	5.029	4.800	4.716	4.657			17
18					5.054	5.517	5.014	4.792	4.716	4.655			18
19					5.089	5.505	4.999	4.787	4.708	4.653			19
20					5.326	5.423	4.985	4.782	4.703	4.651			20
21					5.495	5.395	4.971	4.779	4.700	4.649			21
22					5.503	5.412	4.960	4.774	4.698	4.648			22
23					5.372	5.496	4.950	4.769	4.695	4.646			23
24					5.284	5.507	4.941	4.764	4.692	4.644			24
25					5.244	5.467	4.931	4.761	4.690	4.642			25
26				4.877	5.265	5.437	4.923	4.765	4.687	4.641			26
27				4.868	5.315	5.415	4.945	4.763	4.683	4.640			27
28				4.855	5.400	5.411	4.919	4.756	4.681	4.639			28
29				4.854	5.496	5.398	4.904	4.752	4.688	4.636			29
30				4.887	5.565	5.371	4.896	4.750	4.711	4.629			30
31					5.601		4.895	4.745		4.630			31
Total				24.341	159.626	162.772	156.916	148.950	141.559	144.495	55.508		Total
Max.				4.887	5.601	5.563	5.329	4.883	4.771	4.706	4.637		Max.
Min.				4.854	4.887	5.265	4.895	4.745	4.681	4.629	4.619		Min.
Avg.				4.868	5.149	5.426	5.062	4.805	4.719	4.661	4.626		Avg.

Max. Inst. Gauge Height:	5.670 on May 31, 2002 @ 03:00AM	B Ice Conditions
Max. Daily Gauge Height:	5.601 on May 31, 2002	A Manual Gauge
Min. Inst. Gauge Height:	4.613 on Oct. 30, 2002 @ 09:00AM	E Estimated
Min. Daily Gauge Height	4.619 on Nov. 6, 2002	

Table 4.1.4. Annual summary of calculated mean daily discharge as measured at the Wigwam River hydrometric station. Data is recorded every 15 minutes and averaged to provide mean daily summaries.

Discharge Data Westslope Fisheries
Stn Name: Wigwam River at Bridge Computed by: Kerry Morris Date:November 26
Year: 2002 Stn. E238242 Checked by: Angela Prince Date: January 15

	April Discharge		May Discharge		June Discharge		July Discharge		August Discharge		September Discharge		October Discharge		November Discharge		December	
	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3	m^3/s	m^3		
1			9.871	852811.260	73.730	6370300.881	40.053	3460536.290	8.663	748484.465	7.652	661145.458	4.490	387909.918	3.335	288141.494		1
2			11.727	1013217.945	65.225	5635473.573	33.680	2909936.633	8.445	729627.021	7.671	662740.736	4.080	352526.038	3.383	292276.118		2
3			14.355	1240252.744	57.588	4975574.872	30.370	2623998.574	8.290	716283.490	7.710	666129.654	3.871	334426.296	3.423	295760.686		3
4			14.356	1240324.602	56.550	4885961.742	28.230	2439059.247	8.226	710759.166	7.735	668299.426	3.777	326299.404	3.464	299272.686		4
5			13.298	1148966.002	60.629	5238346.657	26.204	2264045.759	8.349	721315.451	7.540	651429.408	3.656	315860.219	3.508	303124.181		5
6			12.223	1056042.463	61.471	5311058.149	24.410	2109013.708	8.171	705994.473	7.525	650118.848	3.561	307676.795	3.532	305139.082		6
7			11.088	958022.824	51.702	4467080.412	23.338	2016372.715	8.020	692946.581	7.509	648737.075	3.484	300990.354	3.528	304800.396		7
8			10.075	870489.298	45.028	3890456.251	24.660	2130624.451	7.894	682012.766	7.547	652029.777	3.431	296414.014	3.254	281136.419		8
9			9.460	817355.587	39.663	3426903.208	24.776	2140681.294	7.798	673732.608	7.625	658802.112	3.355	289863.602	3.197	276237.002		9
10			8.986	776431.270	36.154	3123721.716	22.635	1955685.327	7.736	668353.880	7.700	665279.383	3.351	289516.652	3.314	286325.676		10
11			8.754	756385.040	33.110	2860729.426	21.048	1818538.476	7.689	664355.370	7.770	671338.357	3.360	290289.368	3.355	289858.031		11
12			8.811	761271.474	32.966	2848256.753	19.815	1712027.283	7.643	660339.965	7.839	677291.198	3.296	284808.508	3.333	287978.733		12
13			10.118	874227.757	37.011	3197755.806	18.560	1603566.134	7.600	656600.699	7.901	682625.532	3.248	280591.501				13
14			14.994	1295465.635	45.121	3898481.084	17.488	1510934.664	7.567	653766.804	7.962	687877.761	3.212	277548.018				14
15			17.019	1470474.916	53.616	4632451.391	16.385	1415698.672	7.551	652404.807	8.005	691670.903	3.187	275338.786				15
16			15.933	1376634.631	61.659	5327301.729	15.297	1321629.116	7.580	654901.763	8.048	695305.934	3.168	273737.128				16
17			15.526	1341425.952	67.623	5842589.045	14.226	1229146.191	7.545	651892.956	7.934	685510.427	3.151	272245.572				17
18			15.654	1352490.312	66.181	5718079.690	13.431	1160469.873	7.518	649570.606	7.928	684962.170	3.140	271291.896				18
19			17.837	1541143.849	64.281	5553891.620	12.706	1097819.569	7.507	648635.594	8.050	695539.525	3.133	270696.818				19
20			39.683	3428650.318	52.185	4508791.149	12.058	1041806.590	7.502	648161.856	8.137	702996.740	3.129	270340.448				20
21			62.682	5415692.684	48.376	4179649.463	11.475	991463.494	7.501	648094.200	8.174	706273.854	3.128	270276.719				21
22			64.015	5530887.853	50.618	4373403.570	11.016	951758.963	7.504	648373.835	8.219	710088.472	3.129	270328.589				22
23			45.431	3925258.299	62.914	5435785.858	10.657	920748.739	7.512	649024.356	4.006	346125.211	3.133	270658.850				23
24			34.991	3023217.256	64.587	5580319.634	10.319	891596.520	7.526	650225.250	3.925	339160.926	3.142	271433.341				24
25			30.813	2662237.328	58.526	5056649.861	9.992	863327.376	7.538	651323.801	3.852	332773.685	3.151	272270.668				25
26	8.531	737119.003	32.916	2843903.985	54.156	4679121.506	9.725	840264.954	7.524	650031.973	3.734	322614.820	3.162	273219.212				26
27	8.349	721372.687	38.403	3318060.243	51.015	4407735.427	10.468	904458.238	7.529	650480.888	3.628	313469.806	3.169	273831.257				27
28	8.111	700790.370	49.069	4239558.658	50.510	4364032.487	9.603	829668.183	7.560	653181.772	3.564	307972.142	3.175	274309.270				28
29	8.105	700257.810	62.811	5426912.515	48.732	4210425.615	9.177	792891.556	7.580	654940.388	3.762	325011.841	3.211	277473.416				29
30	8.749	755931.088	74.029	6396098.024	45.268	3911169.464	8.970	774972.449	7.596	656336.736	4.776	412677.839	3.308	285783.434				30
31			80.367	6943700.563			8.948	773121.440	7.627	659010.684			3.296	284753.650				31
Total	41.846	3615470.958	855.296	73897611.287	1596.198	137911498.038	549.721	47495862.477	240.291	20761164.209	203.426	17575999.021	104.082	8992709.741	40.626	3510050.504		Total
Max.	8.749	755931.088	80.367	6943700.563	73.730	6370300.881	40.053	3460536.290	8.663	748484.465	8.219	710088.472	4.490	387909.918	3.532	305139.082		Max.
Min.	8.105	700257.810	8.754	756385.040	32.966	2848256.753	8.948	773121.440	7.501	648094.200	3.564	307972.142	3.128	270276.719	3.197	276237.002		Min.
Avg.	8.369	723094.192	27.590	2383793.912	53.207	4597049.935	17.733	1532124.596	7.751	669714.974	6.781	585866.634	3.357	290087.411	3.385	292504.209		Avg.

Max. Inst. Discharge:	92.881 on May 31, 2002 @ 03:00AM		B Ice Conditions
Max. Daily Discharge:	80.367 on May 31, 2002		A Manual Gauge
Min. Inst. Discharge:	3.704 on Oct. 30, 2002 @ 09:00AM		E Estimated
Min. Daily Discharge:	3.128 on Oct 21, 2002		

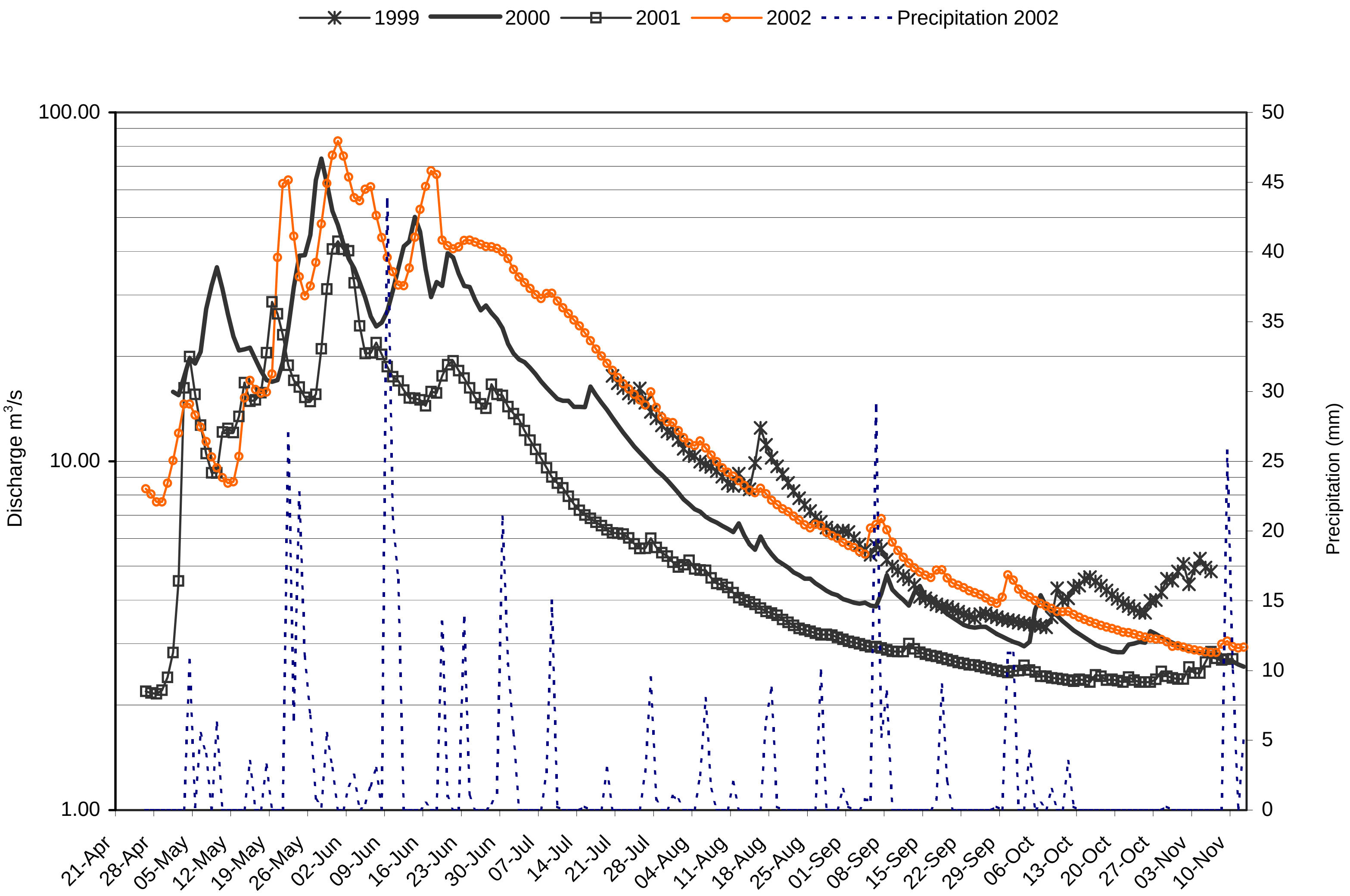


Figure 4.1.3. Inter-annual comparison of mean daily discharges for the Wigwam River from 1999-2002.

Table 4.1.5 Inter-annual comparison of mean daily discharges for the Wigwam River. Calculated discharge in 2002 was significantly higher than previous years (Kruskal-Walis <0.05)

Month	Calculated Discharge (m^3/s)											
	Hydrometric Station 1999			Hydrometric Station 2000			Hydrometric Station 2001			Hydrometric Station 2002		
	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Mar				2.33	2.33	2.33						
April				17.51	15.48	19.72	7.02	2.16	19.96	8.37	8.11	8.75
May				33.01	16.89	73.74	20.77	9.26	42.70	27.59	8.75	80.37
June				30.45	18.54	50.17	16.24	11.49	21.88	53.21	32.97	73.73
July	14.64	12.00	17.08	12.26	7.17	17.76	6.68	4.87	10.82	17.73	8.95	40.05
August	8.87	6.21	12.46	5.16	3.86	6.93	3.61	2.94	4.86	7.75	7.50	8.66
September	4.42	3.51	6.27	3.65	2.95	4.72	2.69	2.48	3.00	6.78	3.56	8.22
October	4.01	3.34	4.83	3.13	2.79	4.13	2.40	2.33	2.66	3.36	3.13	4.49
November	4.92	4.44	5.26	2.55	2.38	2.76	2.74	2.69	2.84	3.39	3.20	3.53

4.1.2 Water Level and Groundwater Recharge

Water levels in the upper Wigwam River followed a similar pattern at both the groundwater and hydrometric stations (Figure 4.1.4). Water levels showed seasonal variability, the highest during spring freshet in May and June, again reflecting the snowmelt dominated peak of the Wigwam River hydrograph (Table 4.1.5). In 1999, 2000, and again this year in 2002, the water in the Wigwam River just above Brewery Creek went subsurface in late fall (05 October). However, last year, the channel at the groundwater station was dry by 24 August 2001. This natural phenomenon has previously been reported in low yield years and there was some concern that this event may have negative implications for egg-fry survival of incubating bull trout. The dewatering event of 2001 appeared to impact the distribution of young-of-the-year bull trout; but not their abundance (Cope 2003).

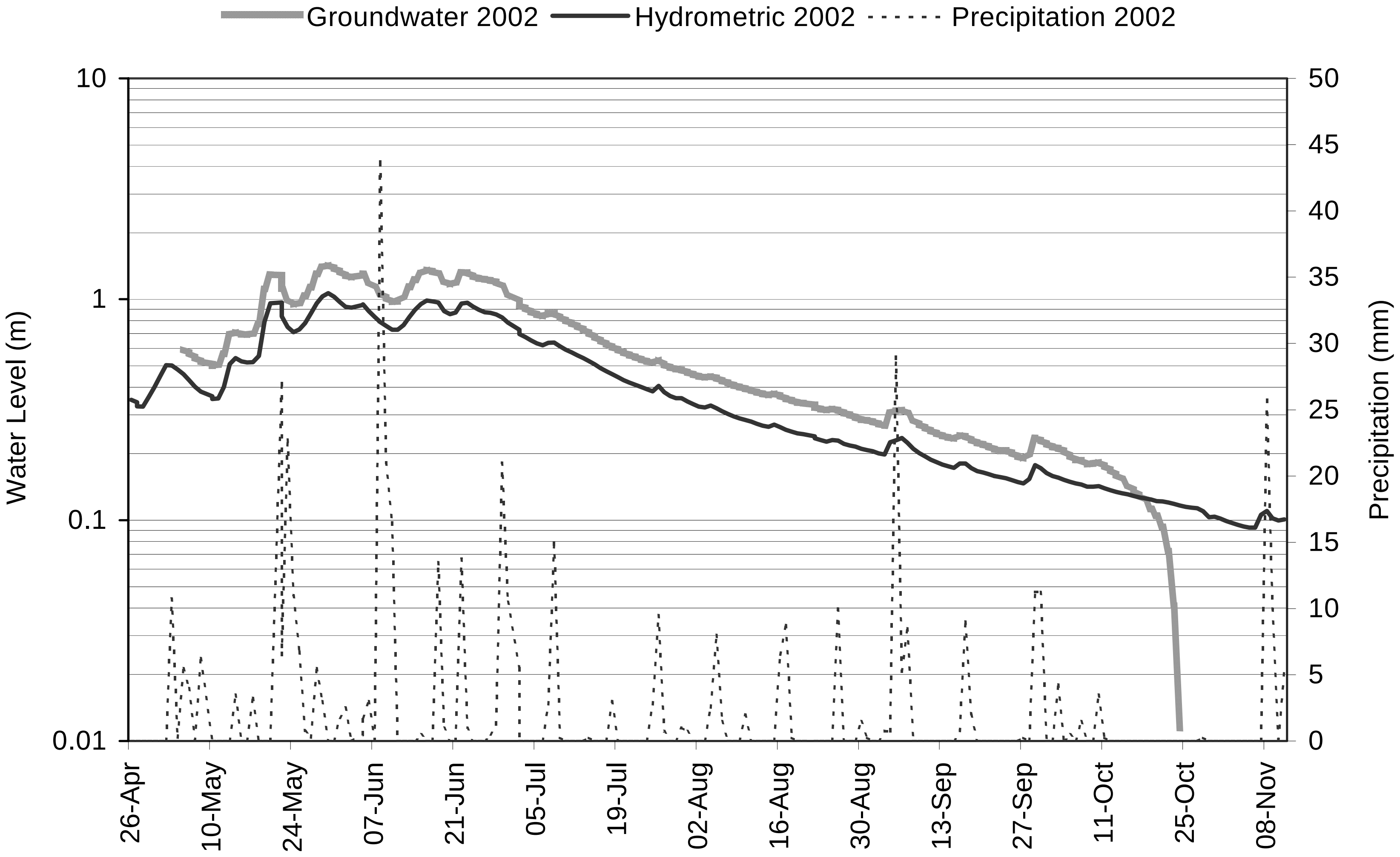


Figure 4.1.4. Mean daily water levels recorded at the hydrometric (Wigwam River above Bighorn Creek) and groundwater recharge (above Brewery Creek) monitoring stations, April to November 2002.

4.2 Temperature

4.2.1 Wigwam River Mainstem

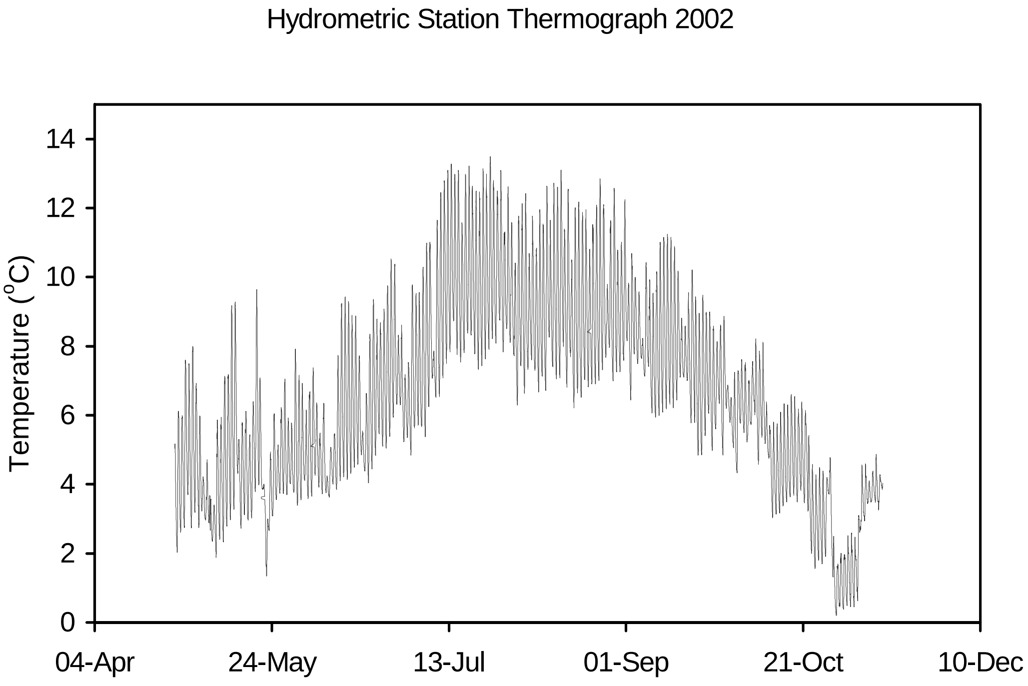
Table 4.2.1 summarizes the water quality guidelines for temperature that apply to the Wigwam River (Oliver and Fidler 2001). The guidelines refer to optimum temperature ranges for the various life-history stages of salmonids and other coldwater species. All guidelines are based on mean weekly maximum temperatures, which is defined as "the average of the warmest daily maximum temperatures for seven consecutive days" (Oliver and Fidler 2001). The guidelines also state that the natural temperature cycle for the site should not be altered in amplitude or frequency by human activities.

Table 4.2.1 Summary of provincial water quality guidelines for temperature relevant to the Wigwam River. Guidelines refer to mean weekly maximum temperature ranges.

Species	Incubation	Rearing	Migration	Spawning
Cutthroat Trout	9-12	7-16	---	9-12
Bull Trout	2-6	6-14	---	5-9

Figure 4.2.1 illustrates the thermograph of the Wigwam River at the hydrometric station (15-min. interval) from 26 April to 12 November 2002. Also presented is the thermograph (15 min interval) from 06 May to 25 October 2002 for the groundwater station (located approximately 10 km upstream of the hydrometric station). The groundwater station was dry by 25 October 2001 and remained so throughout the winter of 2002/03. Since the groundwater recharge monitoring station was not decommissioned until 14 November 2002, those temperatures collected after 25 October 2002 when the river flowed subsurface were omitted from analysis but have been provided in the raw data (Table A6 and A7 Appendix A).

After freshet (May & June), temperatures at the groundwater recharge station decreased indicating an increase in groundwater recharge. This is the first year since monitoring began that this phenomenon has been recorded. In past years (2000 & 2001), water temperatures at the groundwater station had increased post freshet reflecting the increased thermal conductance of



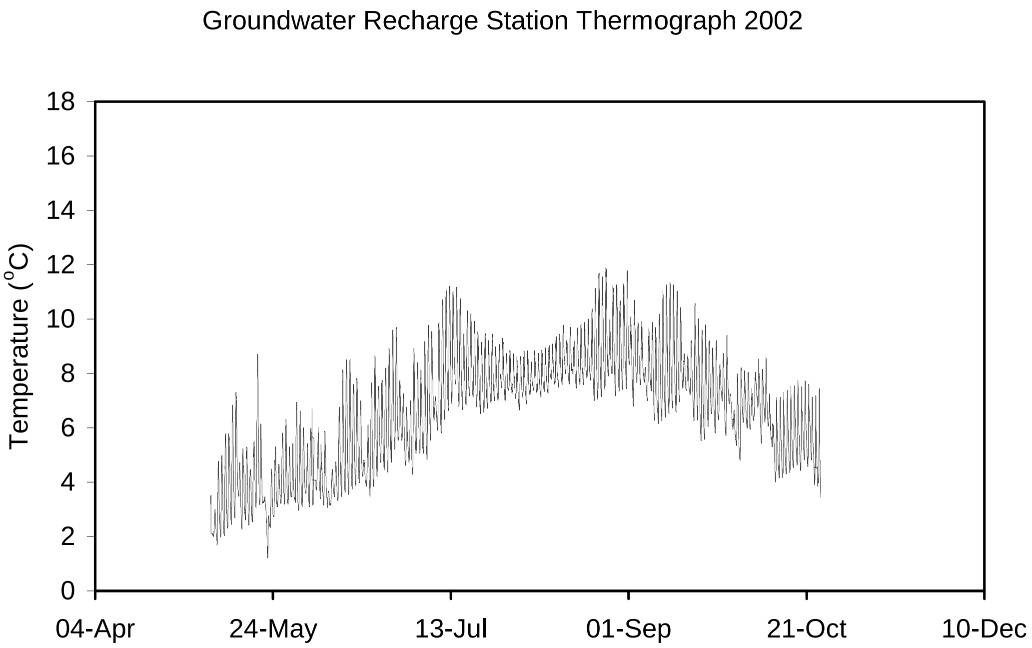


Figure 4.2.1. Raw water temperatures (15 min. interval) collected for the Wigwam River at the hydrometric and groundwater recharge monitoring stations, 2002.

rising air temperatures with declining water levels. It appears that the increased snow pack and corresponding melt in 2002 recharged area aquifers and was reflected in the stable, cool temperatures (groundwater signature) recorded at this site at a time when many other streams are approaching summer maximums.

In addition to lacking a summer peak, water temperatures at the groundwater station in 2002 were less variable that those measured further downstream at the hydrometric station (Figure 4.2.1). Again, the increased variability in summer water temperatures at the hydrometric station is a reflection of influence of air temperatures on water. As in previous years, water temperatures at the hydrometric station were significantly correlated with air temperatures (Spearman rank: r = 0.865, P < 0.05, Figures 4.2.2) and air temperatures did not significantly differ among years (Mean daily temp 1999-2002: Kruskal-Wallis χ^2 = 7.069, P>0.05).

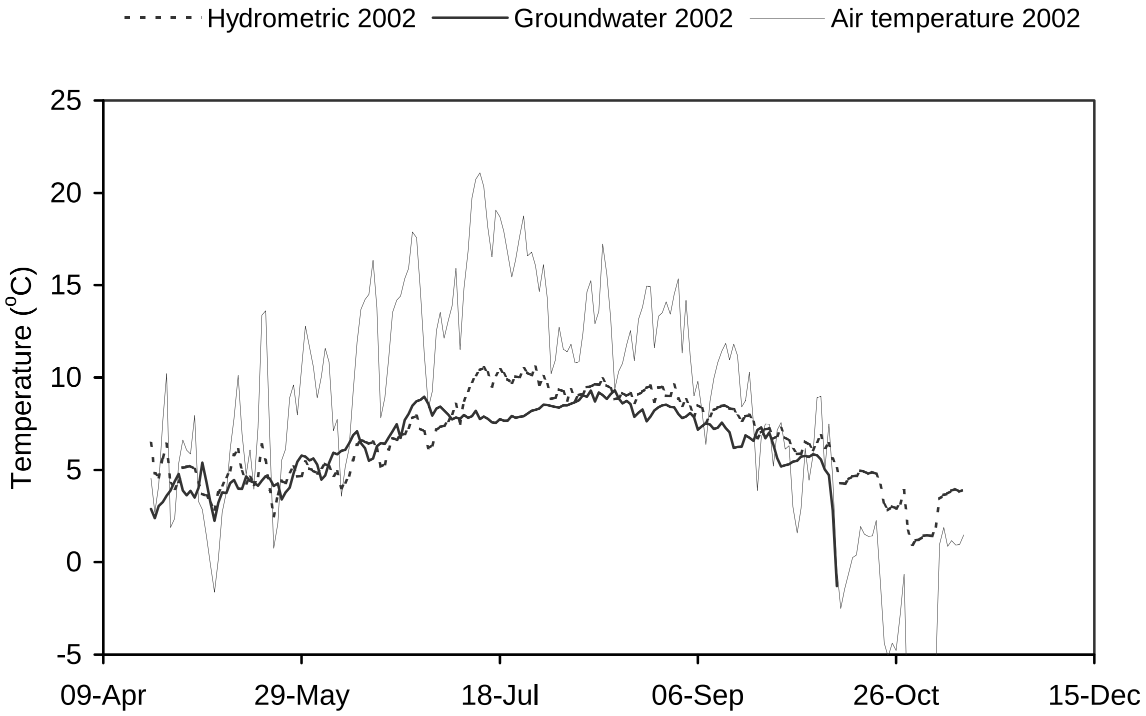


Figure 4.2.2. Mean daily water and air temperatures for the Wigwam River hydrometric and groundwater stations, 2002.

Unlike last year, the mean weekly maximum water temperatures for the Wigwam River did not exceed the provincial guideline of 15°C for streams with bull trout in 2002 (Figure 4.2.3, Table 4.2.1). Last year, temperatures at the groundwater station exceeded guidelines when water levels dropped to only a few centimeters of available depth in August (Prince and Morris 2002). However in 2002, peak mean weekly maximum water temperatures only reached 12.64°C and occurred during the week of 15-21July (Figure 4.2.3, Table A17 Appendix A).

In addition to being reduced in amplitude, the 2002 water temperature peak occurred a full three weeks earlier than the peak last year and is believed to have resulted from an increase in groundwater recharge post freshet. Reduced temperatures were not only measured at the groundwater monitoring site but also 10 km downstream at the hydrometric station. Thus, the groundwater recharge in 2002 appears to have dampened the effect of increasing air temperatures on the Wigwam River overall (Figure 4.2.3).

As in previous years, the mean weekly maximum temperatures at the hydrometric station dropped below 9.0°C during the last week of September and remained less than 9.0°C through November (Figure 4.2.3). Since bull trout spawn in the Wigwam between 15 September and 15 October, the 2002 spawning population of bull trout experienced waters below the recommended 9.0°C temperature limit for bull trout reproduction (Table 4.2.1).

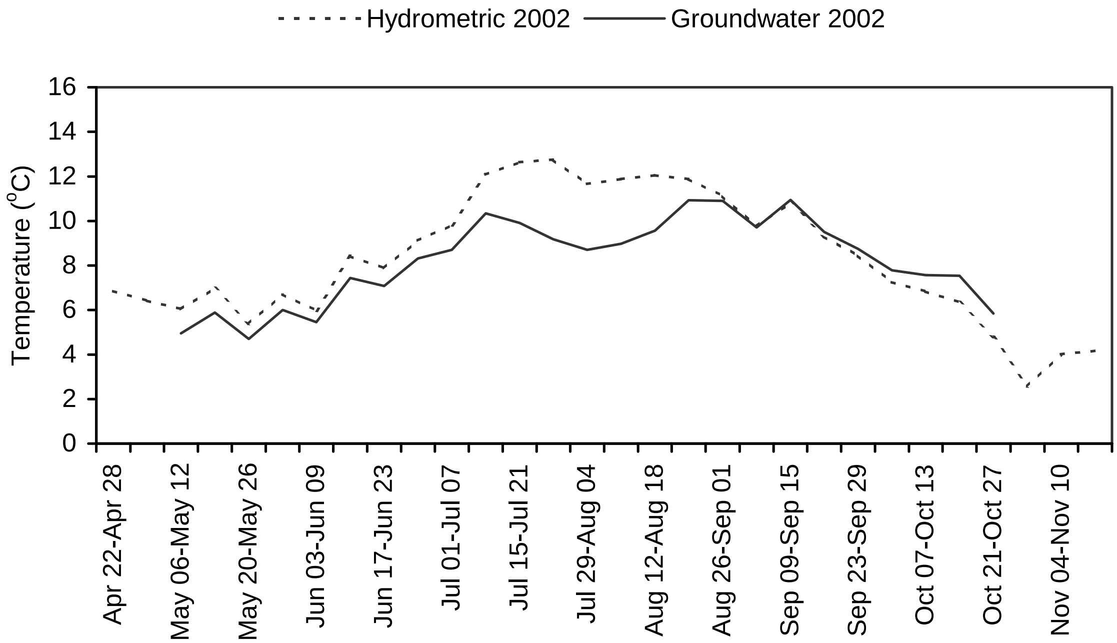


Figure 4.2.3. Mean weekly maximum water temperatures for the Wigwam River hydrometric and groundwater stations, 2002.

Unlike in previous years, this year there was a significant difference in mean weekly maximum water temperatures between the groundwater and hydrometric sites (Wilcoxon, P>0.05, Figure 4.2.3); again that difference is believed to result from the increase in recharge at the groundwater station. When examining maximum water temperatures within sites, the hydrometric and groundwater stations showed no inter-annual differences (Kruskal-Wallis, P>0.05, Figures 4.2.4). Therefore to date, the natural temperature cycle for the Wigwam River appeared unchanged by human activities in the valley.

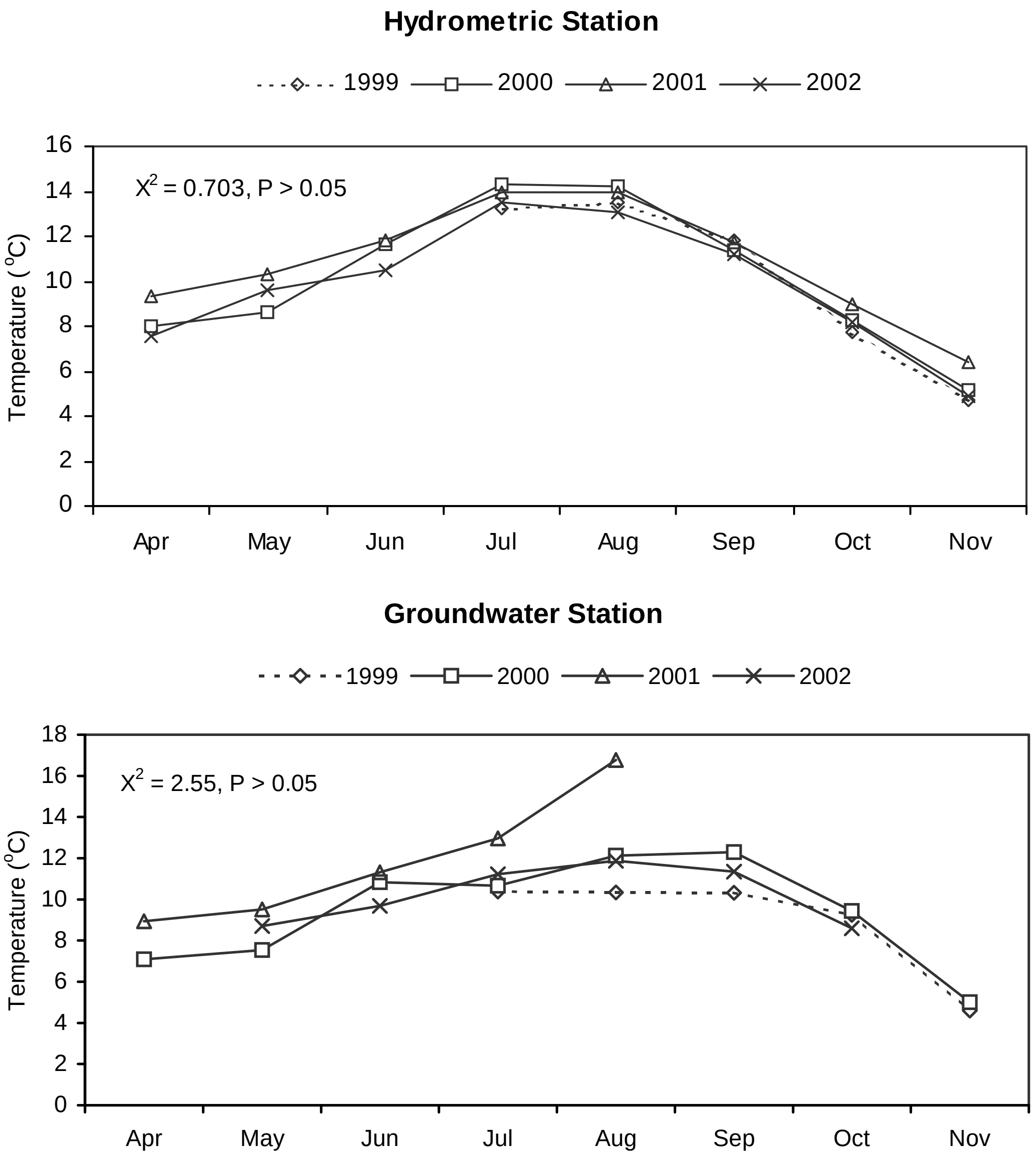


Figure 4.2.4. Inter-annual comparison of monthly maximum water temperatures in the Wigwam River collected during two years of pre-treatment monitoring (1999 & 2000) and two years of post treatment monitoring (2001 & 2002).

4.2.2 Tributaries

Figure 4.2.5 depicts the thermographs of the tributary streams to the Wigwam River that were monitored in 2002. Recall that the four new stations added in 2001 (T5, T6, T7 & T8) were intended to serve as controls for those tributaries crossing cut blocks (T1-T4). The tributary traversing cut block 168 has always been intermittent in nature with temperatures at T2 normally increasing as the water levels decrease. Temperatures collected when the creek had gone subsurface were omitted from analysis (refer to Table 3.2.3); but, are provided in the raw data Table A8-A16, Appendix A.

The effects of air temperatures on a waterway are apparent in the increased variability among water temperatures at the downstream location compared with the upstream location. The exception to this general trend is in the tributary that traverses block 172 (T3/T4) where upstream temperatures show great variability (Figures 4.2.6). The upstream tributary site (T3) has less canopy cover than its downstream monitoring location (T4) and thereby allows for increased thermal conductance.

All but one tributary were below the mean weekly maximum temperature guideline of 15^{o}C for trout (Figure 4.2.6). The exception, a tributary traversing cut block 172, hosts only a population of cutthroat trout (Wright 1998). In reference to cutthroat, the upper temperature guideline for incubation was exceeded by 1-2 ^{o}C for four weeks (Figure 4.2.7). Last year this site also exceeded the recommended guidelines for incubation and spawning (Figure 4.2.7); however, background temperature levels for this tributary indicate that this is often the case (Figure 4.2.8).

Nevertheless, there was some concern that this tributary may have been affected by land use activities as in addition to exceeding recommended temperature guidelines, T3 showed significantly warmer water temperatures after harvest (2001) compared with pre-treatment years (Kruskal-Wallis, $P<0.05$, Prince and Morris 2002). Again this year, there was temporal homogeneity among monthly maximum water temperatures in all sites except for those measured at T3 (Kruskal-Wallis, $P>0.05$, Figures 4.2.8). However, the inter-annual difference detected is attributable to the high temperatures recorded in 2001. Water temperatures recorded in 2002 at T3 returned to background levels (Figure 4.2.8); thus, the harvesting activities that occurred in 2001 appear not to have increased the water temperatures in this tributary. Similarly, the harvesting of block 168 in 2001 appears not to have altered water temperatures in the tributary traversing the block (Figure 4.2.8).

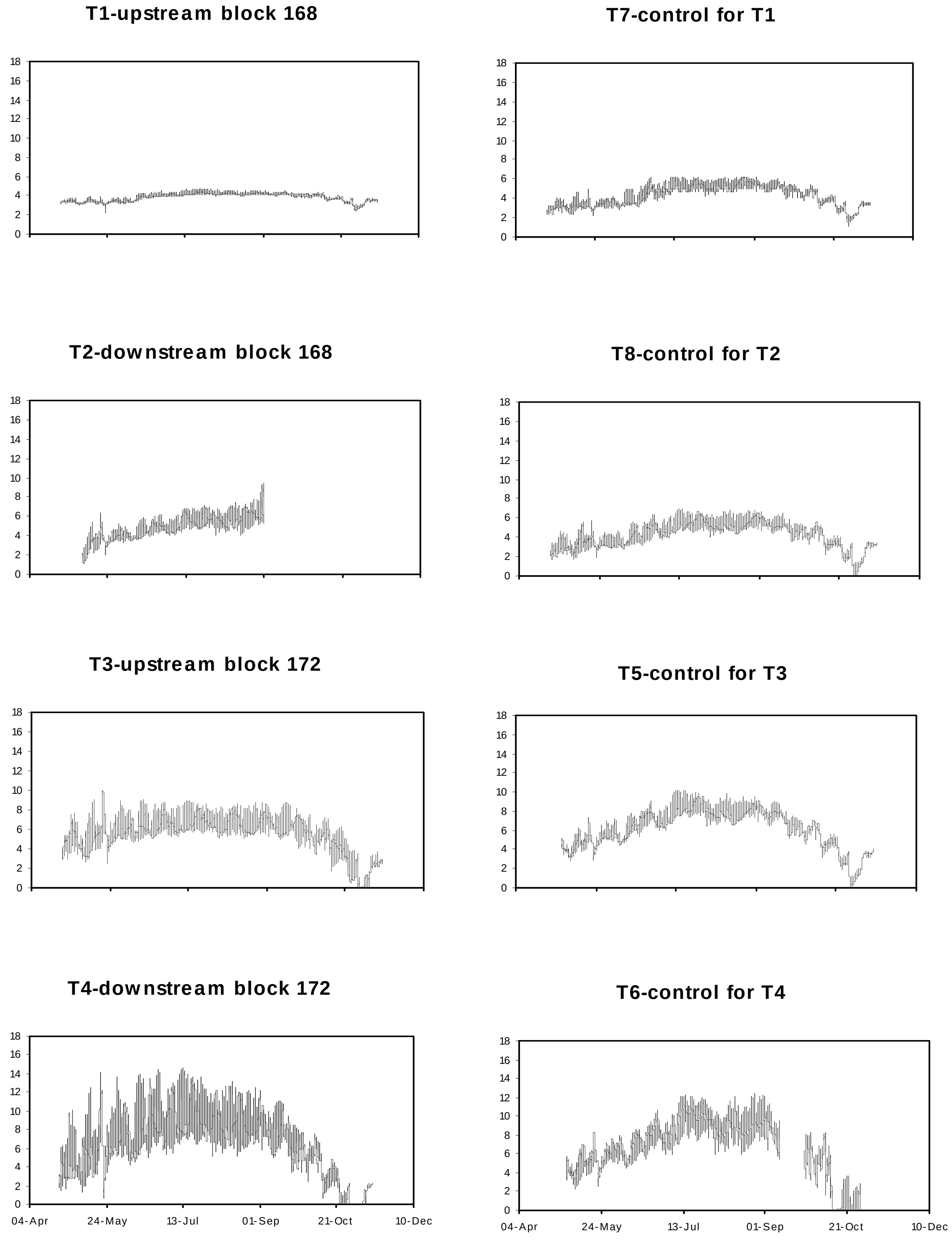


Figure 4.2.5. Water temperatures (15 min. interval) of tributaries to the Wigwam River. Tributaries T1/T2 & T3/T4 traverse cut blocks that were harvested in 2000/01 and 2002 respectively. Tributaries T5/T6 & T7/T8 were selected to serve as controls.

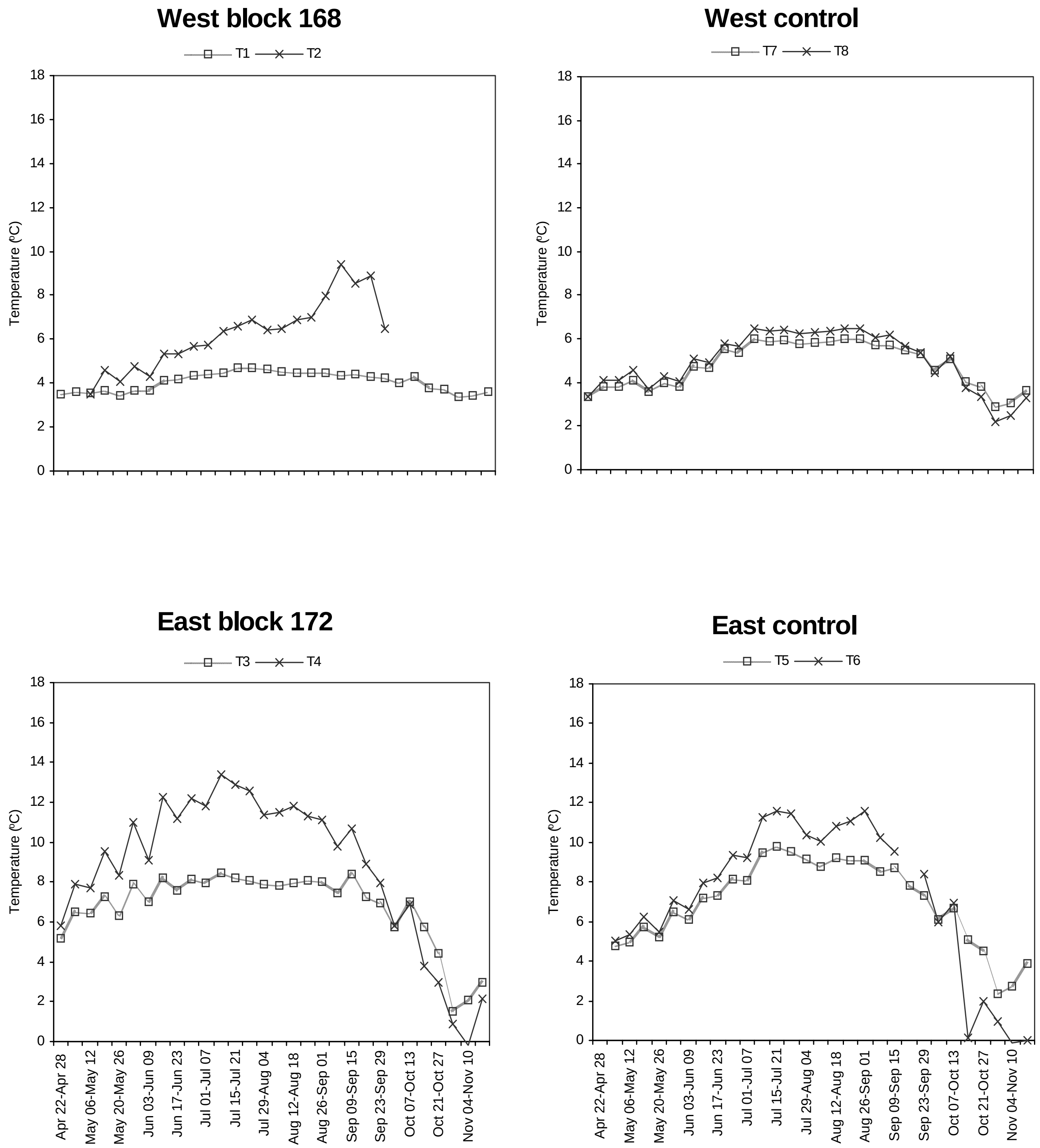
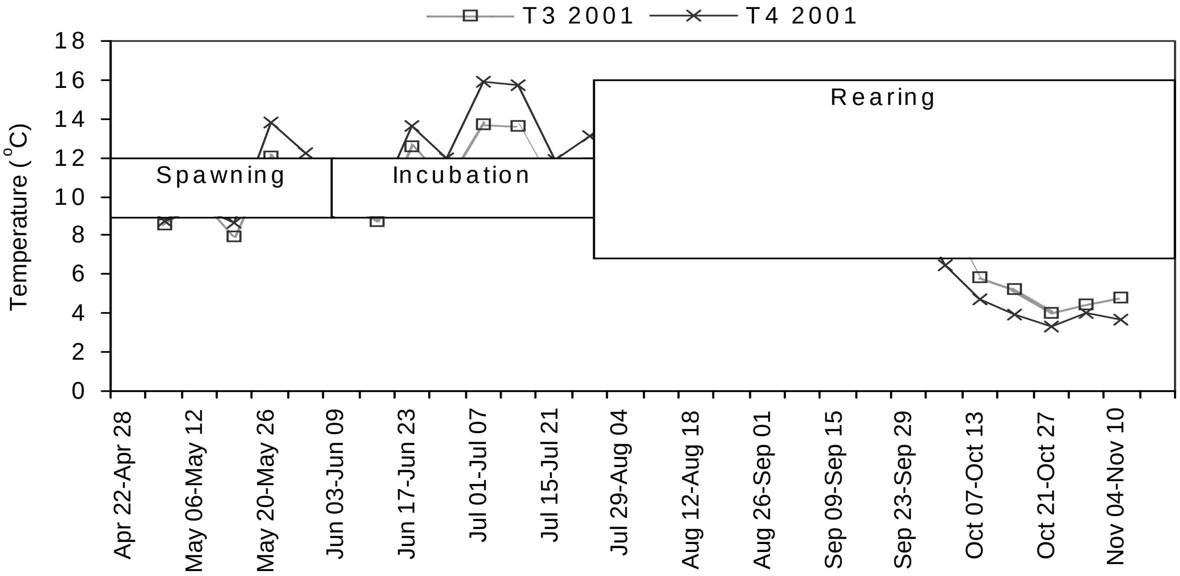


Figure 4.2.6 Mean weekly maximum water temperatures of four tributaries to the Wigwam River, 22 April to 10 November 2002.



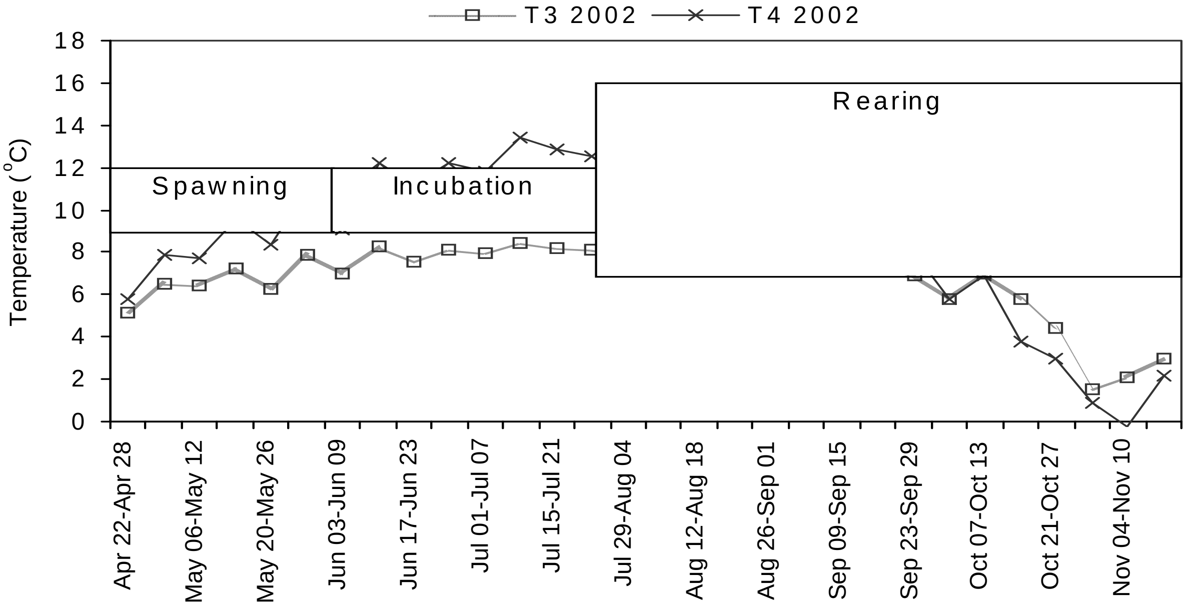


Figure 4.2.7 Mean weekly maximum temperatures for an S4 tributary housing a population of Westslope cutthroat trout in relation to recommended guidelines for optimal temperature ranges of specific life history stages: spawning 9-12, incubation 9-12, rearing 7-16. (BC water quality temperature guidelines, Oliver and Fidler 2001).

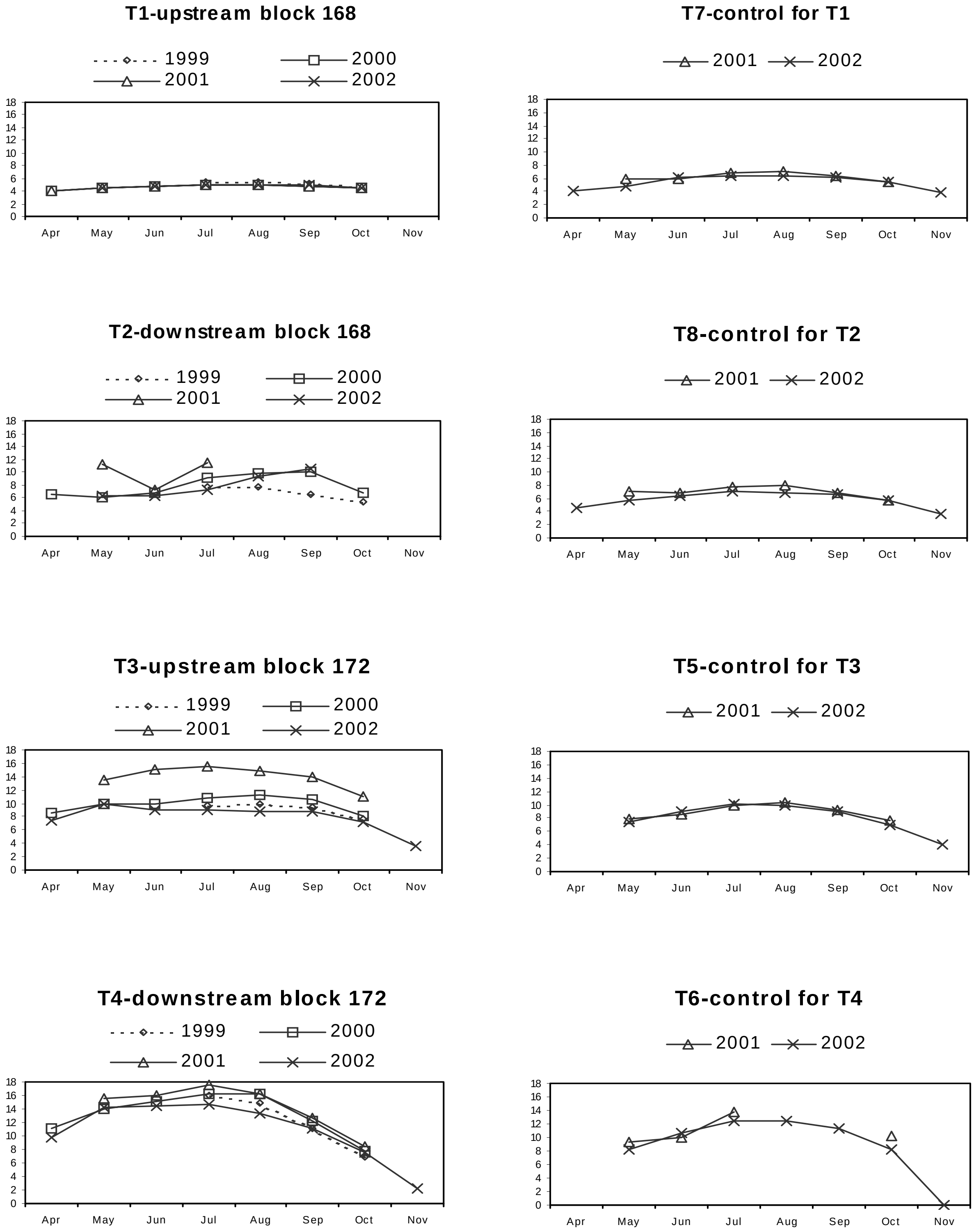


Figure 4.2.8. Inter-annual comparison of monthly maximum water temperatures measured upstream and downstream of proposed cut blocks 168 and 172. Background levels were measured in 1999 and 2000. Harvesting occurred in 2001 & 2002. Conclusion: T3 in 2001 is the only site that differed among years (Kruskal-Wallis $P<0.05$).

4.3 Water Quality

The purpose of this Water Resource Inventory is to enable short and long-term evaluation of the water resource. The monitoring program has been designed to achieve a better understanding of existing conditions for select parameters, especially as they relate to fish spawning habitat quality. These conditions may then be tracked over time as forest development progresses.

This year, the ambient water quality guidelines for turbidity and suspended sediment were updated to recognize that exposure duration plays a key role in the toxicity response (Anon. 2001). The definition of a guideline is:

"A maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental conditions" (Anon. 2001).

There are now distinct guidelines for periods of clear and turbid flow (Table 4.3.1). The terms clear flow and turbid flow are used to describe the portion of the hydrograph when suspended sediment concentrations are low (i.e. less than 25 mg/L or less than 8 NTU) and relatively elevated (i.e. greater than or equal to 25 mg/L or greater than or equal to 8 NTU respectively). The clear and turbid flow periods for individual stream systems are defined using data on the background concentrations of suspended sediment at the site-specific level.

Table 4.3.1 Summary of water quality guidelines for interpreting water quality data of the Wigwam River (Anon. 2001).

Water Quality Parameter	Flow Period	Provincial Guideline	Guideline Summary
Turbidity	**Clear**	Induced turbidity should not exceed background levels by more than 8 NTU during any 24-hour period (hourly sampling preferred). For sediment inputs that last between 24 hours and 30 days (daily sampling preferred) the mean turbidity should not exceed background by more than 2 NTU.	8 NTU in 24 hours when background < or = to 8 NTU. Mean of 2 NTU in 30 days when background is < or = to 8 NTU.
Turbidity	**Turbid**	Induced turbidity should not exceed background levels by more than 8 NTU at any time when background turbidity is between 8 and 80 NTU. When background exceeds 80 NTU, turbidity should not be increased by more than 10% of the measured background level at any one time.	8 NTU when background is between 8 and 80 NTU. 10% when background is > or = to 80 NTU.

TSS	**Clear**	Induced suspended sediment concentrations should not exceed background levels by more than 25 mg/L during any 24-hour period (hourly sampling preferred). For sediment inputs that last between 24 hours and 30 days (daily sampling preferred), the average suspended sediment concentration should not exceed background by more than 5 mg/L100 mg/L	25 mg/L in 24 hours when background < or = to 25 mg/L. Mean of 5 mg/L in 30 days when background is < or = to 25 mg/L.
TSS	**Turbid**	Induced suspended sediment concentrations should not exceed background levels by more than 25/mg/L at any time when background levels are between 25 and 250 mg/L. When background exceeds 250 mg/L, suspended sediments should not be increased by more than 10% of the measured background level at any one time.	25 mg/L when background is between 25 and 250 mg/L. 10% when background is > or = to 250 mg/L.

For the detection of effects from land use activities, it is recommended that sampling should focus on third order streams or smaller (Anon. 2001). The Wigwam program has been designed to incorporate these streams (i.e. T1-T8, Brewery, and Desolation Creeks), but also includes the larger 4th order Wigwam mainstem. Inclusion of the mainstem is important in this study as the majority of activity occurred nearest the Wigwam River (Figure 2.1.2). The only timing requirement for sampling turbidity and suspended sediments are during periods of clear flows. It is imperative that samples taken during periods of clear flows incorporate periods of low flow when the background turbidity is both low and consistent (Anon. 2001). Even though the majority of sediment load in streams is transported during spring freshets and storm events, these high-flow periods have been excluded from the determination of background levels in clear flows due to the extreme variability found in relationships between suspended sediment concentrations and discharge flows (Anon. 2001).

4.3.1 Critique of Inventory Protocols

To assure quality reporting in the water quality data for TSS, we examined the difference in measurements for samples analyzed within 72 hours and those that had exceeded the recommended time limits across both clear and turbid flow periods (Table 4.3.2). Many of our samples exceeded the time limits as they were collected daily via the automated pump sampler (ISCO) but were only retrieved once per month. In total, there are now 20 occasions during which both a grab sample and a pump sample have been collected on the same day. Results indicate that differences between samples are not significant (Wilcoxon P>0.05). Thus it appears that results from the ISCO sampler that exceed the recommended holding time are similar to results from the manual samples and no calibration factor need be developed for the pump samples.

Table 4.3.2 Results of TSS analysis for samples collected on the same day by two different methods: 1) pump sample and 2) grab sample. While manual grabs were analyzed within the 72-hour recommended holding time for TSS, automated pump samples often exceeded this time allowance. Regardless, there was no difference among the results of the two methods (Wilcoxon P>0.05).

Date	Monitoring Station	TSS (mg/L) for Isco pump samples (exceeding 72 hr holding time) (taken at 16:00 hrs)	TSS (mg/L) for manual grab samples (within 72 hr holding time) (taken btwn 10:00-14:00 hrs)
7-May-01	Hydrometric	1	1
14-May-01	Hydrometric	17	19
28-May-01	Hydrometric	9	10
4-Jun-01	Hydrometric	2	1
5-Jun-01	Hydrometric	1	1
18-Sep-01	Hydrometric	0.5	0.5
7-Aug-01	Rabbit Creek	1	1
9-Oct-01	Rabbit Creek	0.5	0.5
22-Apr-02	Rabbit Creek	0.5	1
6-May-02	Rabbit Creek	0.5	0.5
14-May-02	Hydrometric	3	3
22-May-02	Hydrometric	88	97
29-May-02	Hydrometric	68	57
11-Jun-02	Hydrometric	8	11
11-Jun-02	Rabbit Creek	4	4
3-Jul-02	Hydrometric	11	7
21-Aug-02	Hydrometric	0.5	0.5
21-Aug-02	Rabbit Creek	0.5	0.5
23-Sep-02	Hydrometric	0.5	0.5
23-Oct-02	Rabbit Creek	3	0.5

Date	Monitoring Station	TSS (mg/L) for Isco (within 72 hr holding time) (taken at 16:00 hrs)	TSS (mg/L) for Manual Grab (within 72 hr holding time) (taken btwn 10:00-14:00 hrs)
27-May-02	Hydrometric	13	12
28-May-02	Hydrometric	38	39
31-May-02	Hydrometric	150	148
3-Jun-02	Hydrometric	40	56
10-Jun-02	Hydrometric	15	15

Besides comparing the two grab sample collection methods across time, we were also able to examine the spatial differences between the two methods. Manual grab samples are collected in mid-channel while the ISCO pump samples are collected near shore to protect the equipment. Five pump and manual grab samples were collected during freshet and analyzed within the recommended 72 hr holding times (Table 4.3.2). Again, results indicate that differences between these samples are not significant (Wilcoxon $P>0.05$); however, there appeared less variation in TSS among those samples with spatial variation (i.e. manual and pump samples analyzed within holding times) than among those with temporal variation (i.e. manual and pump samples analyzed outside of holding times) (Table 4.3.2).

In addition to using different sampling methods (manual and automated pumps), we used two analysis methods for turbidity; one method used a portable Lamotte 2020 turbid meter, the other, a laboratory. Since organic material and microorganisms are a component of turbidity, it is not surprising to find some differences between turbidity measured in the field and those measured by a laboratory some time later as organisms die and settle out of suspension. In general, lab values for turbidity were consistently lower than field measurements (Table B1 Appendix B). While the measurements of field and laboratory turbidity were highly correlated (Spearman rank $r=0.945$, $P<0.05$ $n=86$), the relationship to TSS was improved with samples analyzed on-site (2002 data Spearman rank $r=0.953$, $P<0.05$ $n=86$). The improved predictive power that on-site turbidity measurements have had over lab measurements has been consistently demonstrated throughout the monitoring program from 1999-2002 (Prince and Cope 2001). The ability to predict TSS from field turbidity measurements has several advantages. First, it allows for a reduction in the number of samples that required laboratory analysis thereby providing cost savings to the program. Second, it provides instant information on a water quality parameter that would otherwise take up to a week or more before the lab results could be made available. Consequently, when choosing a parameter on which to base analysis, we chose on-site turbidity.

4.3.2 Quality Control

Quality control is an essential element of a field quality assurance program. Field quality control requires the submission of blank and replicate samples. Blanks are samples that do not contain the variable to be analyzed, and are used to assess and control sample contamination. Replicated samples are independent samples collected as closely as possible to the same point in time and space, and are intended to be identical. Quality control measures are to be applied at least twice during the yearly sampling program (Anon 1998).

In 2002, we submitted one blank sample and two replicates, one from each of the clear and turbid flow periods. The blank sample contained distilled water and analysis results were below detection limits (Table 4.3.3). While the replicate samples collected during the clear flow period were identical, the samples collected during peak freshet differed by 5 mg/L which, is not unexpected due to the variability of sediment transport during extreme flows.

Table 4.3.3 Results of TSS (mg/L) analysis for blank and replicate samples submitted during the 2002 Wigwam River water quality monitoring program.

Date	Monitoring Station	TSS (mg/L) Manual Grab (within 72 hr holding time) (taken btwn 10:00-14:00 hrs)	TSS (mg/L) Manual Grab (within 72 hr holding time) (taken btwn 10:00-14:00 hrs)
14-May-02	Hydrometric*	0.5	0.5
31-May-02	Rabbit Creek**	41	36
14-Nov-02	Hydrometric**	0.5	0.5

* Blank sample of distilled water
**Replicate grab sample collected in the same location and time

4.3.3 Wigwam River Mainstem

Figure 4.3.1 illustrates TSS levels measured at three locations from 2000-2002 in the Wigwam River: the hydrometric station located downstream of forest development, the groundwater recharge station immediately upstream of the primary bull trout spawning area, and the Rabbit Creek station, located upstream of the bulk of forest development (Figure 2.1.2). Background monitoring of sediment in the Wigwam River revealed spatial heterogeneity between Rabbit Creek and Hydrometric stations. Thus, it was concluded that there exists significant natural inputs of TSS between the two locations (Prince and Cope 2001). Consequently, the differences in TSS and turbidity observed between these two sites in 2002 were not unexpected. Maximum TSS concentrations of 148 mg/l were recorded on 31 May 2002 during spring freshet at the hydrometric station (Figure 4.3.1). The 2002 peak measurement is 7 times higher than that measured in 2001. In general, each spike in TSS exhibited upstream at Rabbit creek during spring run-off was also amplified when measured at the hydrometric station (Figure 4.3.1). TSS concentrations at Rabbit Creek peaked on the same day at 41 mg/L, which was four times higher than last years peak (Figure 4.3.1). As in previous years, the groundwater recharge monitoring station showed the lowest concentrations of sediment but it peaked at 21 mg/L on 28 May, which was 20 times higher than levels measured last year.

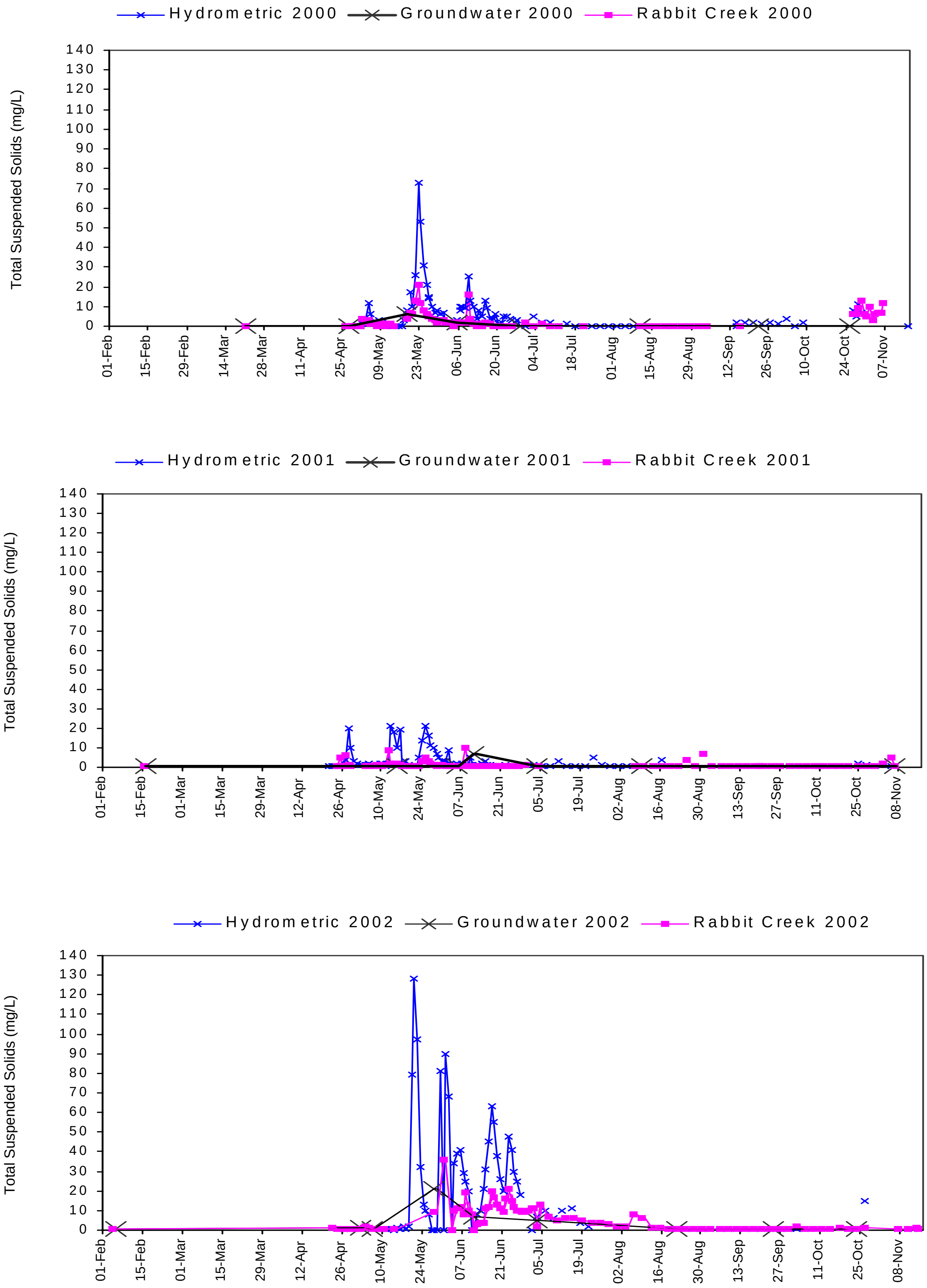


Figure 4.3.1. Concentrations of total suspended solids (mg/L) at upper (above Rabbit Creek confluence), middle (above Brewery Creek confluence) and lower (bridge crossing) sections of the Wigwam River, February to November 2000-2002.

As expected, TSS in the Wigwam River was significantly correlated with mean daily discharge (hydrometric station data, Spearman rank r=0.924, P<0.05, n=83)(Figure 4.3.2). The highest values of TSS were recorded on the same day as peak discharge 31 May 2002 (Figure 4.3.2). Though there were significant precipitation events in the fall (Figure 4.1.4), they did not result in measurable sediment transport. Similarly, the only elevated TSS measurement in the late fall was not associated with any flow or precipitation event (Figure 4.3.2, Table A1, Appendix A).

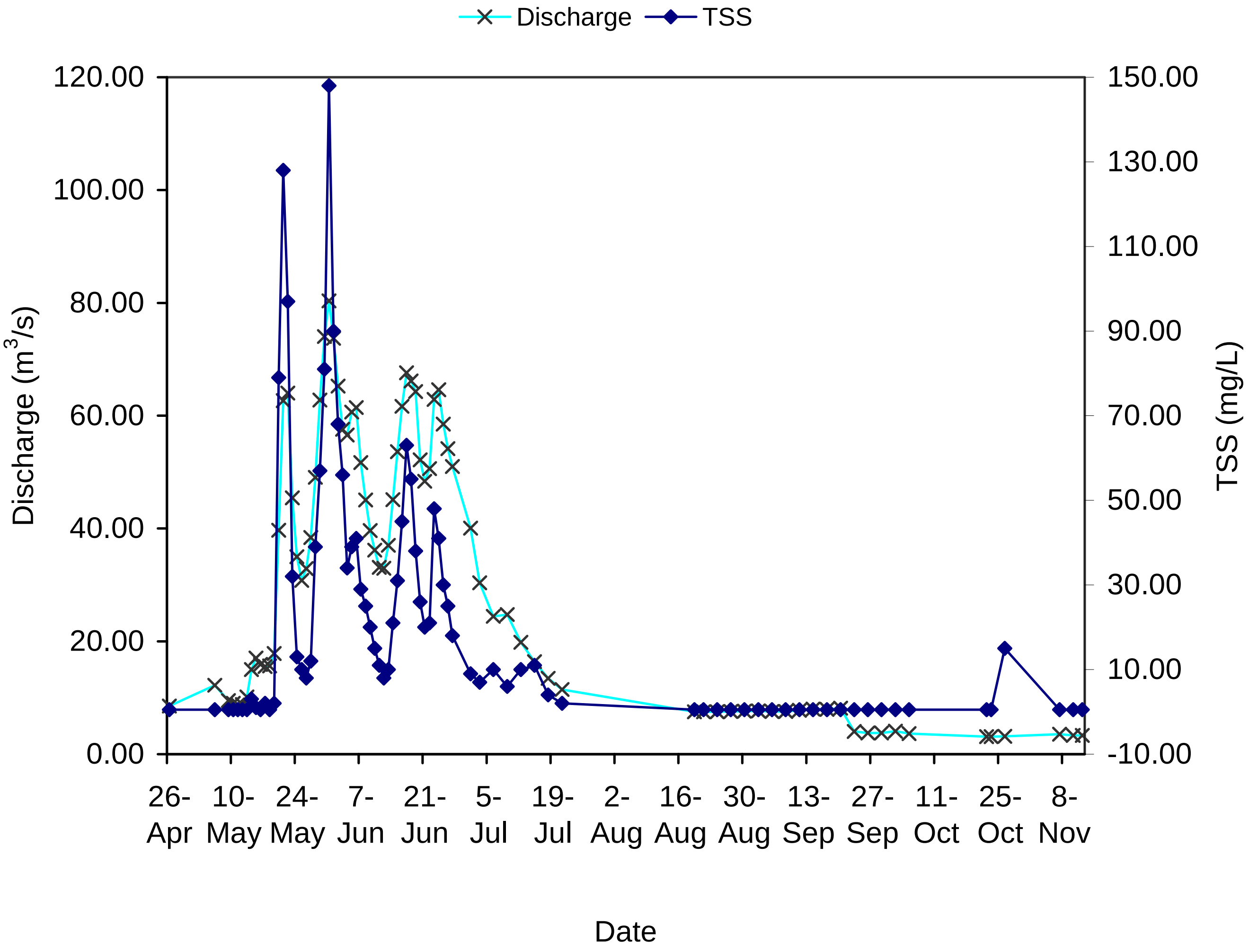


Figure 4.3.2. Wigwam River TSS (mg/L) in relation to discharge (m^3/s) as measured at the hydrometric station from February to November 2002.

TSS in 2002 was also significantly correlated with turbidity in the Wigwam River (Spearman rank r=0.953, P<0.05, n=86). Like TSS and discharge, the highest measured turbidity was also from the sample collected on 31 May 2002 (67.8 NTU) (Table B1 Appendix B). Turbidity is a measure of all suspended particulate matter in a water body and includes organic materials and microorganisms whereas TSS is a measure of inorganic particulate matter only. The high degree of correlation between the two parameters in the Wigwam River is indicative of a low organic component. Since the program's inception, this correlative relationship between TSS and turbidity has been observed, thus, we now have a means by which to rapidly determine TSS levels in the Wigwam River with a reasonable degree of precision (Figure 4.3.3).

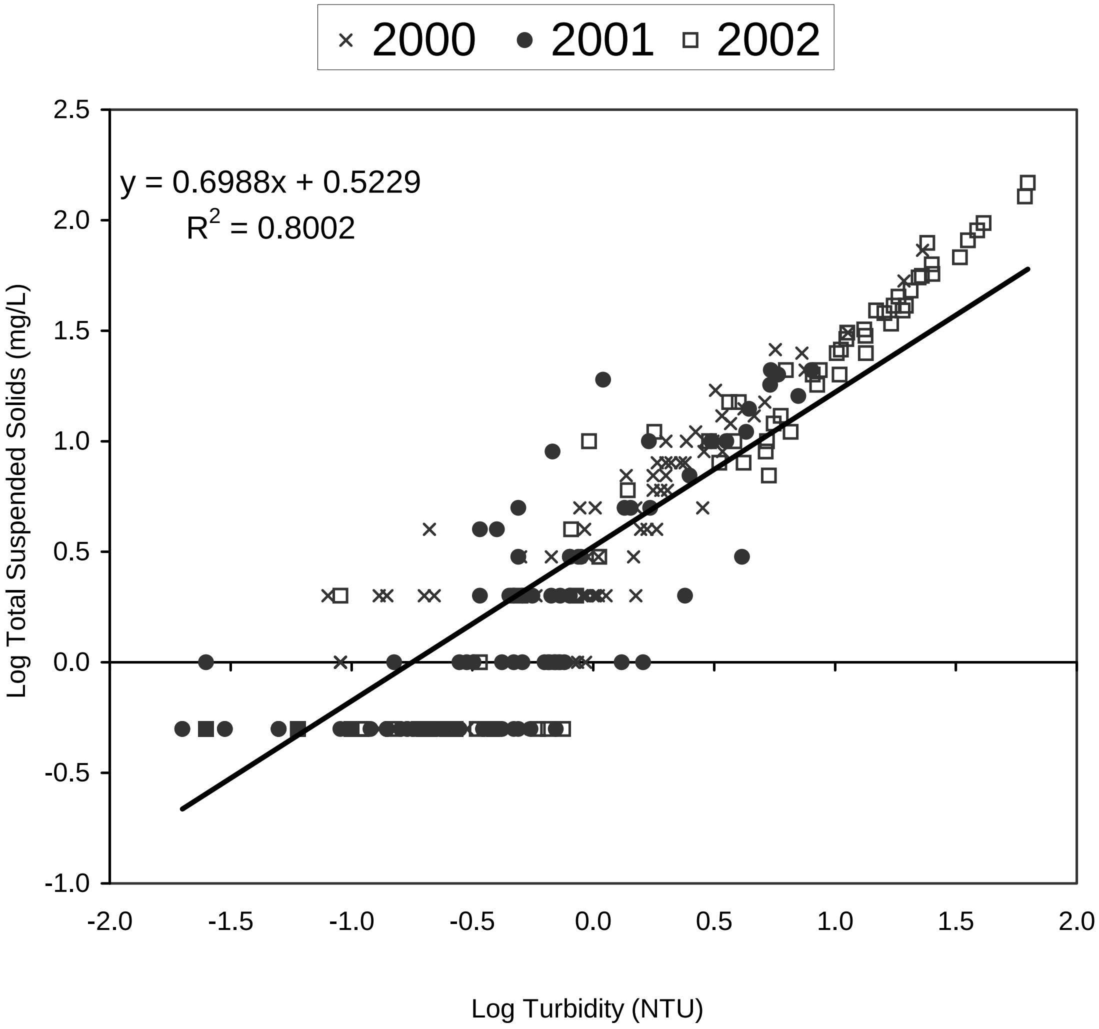


Figure 4.3.3 Relationship between TSS and turbidity measurements in the Wigwam River (2000-2002).

Before examining whether or not the water quality parameters of the Wigwam River are meeting current provincial guidelines for suspended sediment and turbidity, we first had to define the rivers' clear and turbid flow periods using the data collected on background concentrations at a site-specific level (Anon. 2001). Since logging activities in the watershed began in 2001, the background years of monitoring were 1999 and 2000. At the Hydrometric and Rabbit Creek stations, the clear flow periods were identified from July to April of each year and the turbid flow periods were from May-June (Figure 4.3.1)(Cope and Prince 2000, Prince and Cope 2001).

The data collected for TSS and turbidity were summarized with respect to clear and turbid flow periods (Table 4.3.4). Based on two years of background data, the clear flow guidelines for TSS and turbidity at the Hydrometric station were determined to be 6.67 mg/L and 2.41 NTU respectively. Similarly, the turbid flow guidelines were determined to be 98 mg/L and 31 NTU. The guidelines for the Rabbit Creek monitoring site were similar to those for the Hydrometric site during clear flow periods; however, they were significantly reduced during turbid flow periods (Table 4.3.4). In total, 5.7% of samples collected at the hydrometric station in 2002 exceeded the TSS guideline and 15.38% of samples exceeded the turbidity guideline during the turbid flow period. In contrast, neither TSS or turbidity guidelines were exceeded during the clear flow period (Table 4.3.4).

Not only did some samples exceed guidelines in 2002; but, they showed temporal heterogeneity. The values presented in Table 4.3.5 summarize the annual water quality results for samples collected in the mainstem and tributaries of the Wigwam River. Overall, suspended sediment levels were significantly higher at both the Hydrometric and Rabbit Creek stations in 2002 compared with background levels (2000 & 1999, Table 4.3.5)(Kruskal-Walis $P<0.05$); however, the groundwater station did not differ among years (Kruskal-Walis $P>0.05$).

4.3.3 Tributaries

As in previous years, TSS concentrations were near detectable limits at all S6, S5, and S4 tributaries monitored (Table 4.3.5). Suspended sediment levels did not differ among years in any of the tributaries traversing cut blocks (T1-T4) (Kruskal-Walis $P>0.05$)(Table 4.3.5). With background levels below detectable limits, guidelines allow for samples to measure from 5 to 25 mg/L for TSS and from 2 to 8 NTU for turbidity during clear and turbid flow periods respectively (Table 4.3.4). Thus, suspended sediment or turbidity guidelines were not exceeded at any of the smaller S4 & S6 tributaries monitored (T1-T8)(Table 4.3.5).

Overall, suspended sediment levels did not differ among years (2002, 2000 & 1999) at any of the Brewery or Desolation Creek monitoring stations (Kruskal-Walis $P>0.05$)(Table 4.3.5). As in the

Wigwam River mainstem, sediment levels (TSS) in Brewery and Desolation creeks peaked on 31 May 2002 and exceeded guidelines during the turbid flow period (Table 4.3.6 and Table 4.3.7). In addition, Brewery creek had one sample that exceeded background levels of TSS during the clear flow period that was collected on 21 August 2002. The source of the sediment is unknown as there was no precipitation within 48 hours of the sample being collected and the upstream site (near planned cutblock 001) measured 10 mg/L higher than downstream of the bridge crossing (Table B1 Appendix B). Desolation Creek also had one sample that exceeded turbidity guidelines during the turbid flow period (Table 4.3.7).

Table 4.3.4 Summary of 2002 suspended sediment and turbidity measurements for the Wigwam River in relation to site-specific guidelines based on background levels. Clear and Turbid flow periods were identified from July-April and May-June respectively. TSS detection limits are 1 mg/L and turbidity 0.05 NTU. For analysis purposes, measurements recorded at or below detection limits were assigned a value equal to one half of the detection limit.

	Wigwam River at Bighorn (E238242)							Wigwam River at Rabbit (E238250)						
	TSS (mg/L)							TSS (mg/L)						
Clear flow period (July-April)	Mean	Min	Max	SD	N	TSS Guideline (mean background + 5 mg/L)	% Samples above guideline (N)	Mean	Min	Max	SD	N	TSS Guideline (mean background + 5 mg/L)	% Samples above guideline (N)
2002	2.54	<	15.00	3.96	34	(1.67 + 5) = 6.67	0 (0)	2.18	<	13.00	3.00	56	(3.06 + 5) = 8.06	0 (0)
2000 (background)	1.67	<	11.00	2.32	42			3.06	<	13.00	3.82	33		
1999 (background)	0.51	<	1.00	0.08	43			0.50	<	0.50	0.00	5		
Turbid flow period (May-June)						(max background + 25 mg/L)							(background + 25 mg/L)	
2002	31.90	<	148.00	33.11	52	(73 + 25) = 98	5.7 (3)	8.76	<	36.00	7.37	41	(21 + 25) = 46	0 (0)
2000 (background)	8.25	<	73.00	12.36	60			3.10	<	21.00	4.15	52		
1999 (background)	24.00	24.00	24.00		1							0		

	Turbidity (NTU)							Turbidity (NTU)						
Clear flow period July-April	Mean	Min	Max	SD	N	Turbidity Guideline (mean background + 2 NTU)		Mean	Min	Max	SD	N	Turbidity Guideline (mean background + 2 NTU)	
2002	0.78	<	5.33	1.40	34	(0.41 + 2) = 2.41	0 (0)	0.66	<	2.79	0.73	56	(0.97 + 2) = 2.97	0 (0)
2000 (background)	0.41	<	2.84	0.70	43			0.97	<	3.80	1.37	41		
1999 (background)	0.06	<	0.27	0.06	42			0.03	<	0.03	0.03	5		
Turbid flow period June & July						(max background + 8 NTU)							(max background + 8 NTU)	
2002	13.66	<	62.70	14.40	52	(23 + 8) = 31	15.38 (8)	1.96	0.05	10.37	1.92	41	(5.87 + 8) = 13.87	0 (0)
2000 (background)	2.66	<	23.00	4.04	60			0.91	<	5.87	1.09	52		
1999 (background)	7.64	7.64	7.64		1							0		

Table 4.3.5 Annual summary of Water Quality Parameters for the Wigwam River study area (1999-2002). Note that detection limits for TSS = 1 mg/L and for Turbidity = 0.05 NTU. For analysis purposes, measurements recorded at or below detection limits were assigned a value equal to one half of the detection limit.

	2002					**2001**					**2000**					**1999**				
	TSS (mg/L)					TSS (mg/L)					TSS (mg/L)					TSS (mg/L)				
Site Location (EMS ID)	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N
Wigwam River at Bighorn (E238242)	20.30	<	148.00	29.53	86	2.89	<	21.00	4.85	102	5.54	<	73.00	10.10	102	1.05	<	24.00	3.54	44
Wigwam River at Brewery (E238246)	3.69	<	21.00	7.17	9	<	<	<	0.00	6	1.38	<	6.00	1.94	8	<	<	<	0.00	6
Wigwam River at Rabbit (E238250)	4.96	<	36.00	6.20	97	1.16	<	10.00	1.76	95	3.08	<	21.00	4.00	85	<	<	<	0.00	5
Brewery Creek U/S bridge (E238245)	6.91	<	40.00	12.58	11	1.22	<	7.00	2.17	9	0.83	<	2.00	0.66	9	<	<	<	0.00	4
Brewery Creek D/S bridge (E238244)	3.67	<	31.00	9.11	11	<	<	<	0.00	9	0.72	<	2.00	0.51	9	<	<	<	0.00	4
Desolation Creek U/S bridge (E238249)	7.32	<	57.00	17.19	11	0.78	<	3.00	0.83	9	1.72	<	10.00	3.14	9	<	<	<	0.00	5
Desolation Creek D/S bridge (E242997)	8.96	<	72.00	21.62	11	0.69	<	2.00	0.53	8	<	<	<	0.00	4					0
S6 U/S cutblock 168 (E238248)	0.60	<	1.00	0.21	10	<	<	<	0.00	8	0.83	<	2.00	0.66	9	<	<	<	0.00	6
S6 D/S cutblock 168 (E238247)	1.50	<	6.00	2.06	7	<	<	<	0.00	8	2.00	<	9.00	3.44	6	0.75	<	2.00	0.61	6
S4 U/S cutblock 172 (E238253)	1.00	<	4.00	1.08	10	<	<	<	0.00	8	1.63	<	4.00	1.16	8	1.83	<	4.00	1.29	6
S4 D/S cutblock 172 (E238252)	1.05	<	3.00	0.83	10	1.89	<	5.00	1.87	9	1.94	<	5.00	1.37	8	1.00	<	3.00	1.00	6
Block 172 control U/S (E243974)	0.85	<	4.00	1.11	10	0.75	<	2.00	0.53	6										
Block 172 control D/S (E243975)	1.25	<	6.00	1.74	10	1.06	<	5.00	1.59	8										
Block 168 control U/S (E243972)	0.85	<	2.00	0.63	10	<	<	<	0.00	8										
Block 168 control D/S (E243973)	0.72	<	2.00	0.51	9	<	<	<	0.00	8										

	2002					**2001**					**2000**					**1999**				
	Turbidity (NTU's)					Turbidity (NTU's)					Turbidity (NTU's)					Turbidity (NTU's)				
Site Location (EMS ID)	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N	Mean	Min	Max	SD	N
Wigwam River at Bighorn (E238242)	8.57	<	62.70	12.85	86	0.91	<	8.00	1.53	103	1.72	<	23.00	3.30	103	0.23	<	7.64	1.16	43
Wigwam River at Brewery (E238246)	1.49	<	7.03	2.64	9	0.19	<	0.43	0.17	5	0.42	<	1.90	0.63	8	0.04	<	0.11	0.03	6
Wigwam River at Rabbit (E238250)	1.21	<	10.37	1.50	97	0.34	<	3.95	0.61	95	0.94	<	5.87	1.21	93	<	<	<	0.00	5
Brewery Creek U/S bridge (E238245)	1.07	<	5.35	1.91	11	0.07	<	0.30	0.09	9	0.20	<	0.76	0.28	13	<	<	<	0.00	4
Brewery Creek D/S bridge (E238244)	1.38	<	8.24	2.66	11	<	<	0.10	0.03	9	0.16	<	0.70	0.22	13	<	<	<	0.00	4
Desolation Creek U/S bridge (E238249)	1.94	<	14.30	4.00	9	0.23	<	1.07	0.34	9	0.56	<	2.70	0.87	13	<	<	<	0.00	5
Desolation Creek D/S bridge (E242997)	0.20	<	1.76	4.28	11	0.20	<	1.76	0.26	9	<	<	<	0.00	5					0
S6 U/S cutblock 168 (E238248)	0.06	<	0.15	0.04	10	0.06	<	0.30	0.10	8	<	<	0.20	0.05	12	0.03	<	0.05	0.01	6
S6 D/S cutblock 168 (E238247)	0.25	<	0.89	0.31	7	<	<	0.07	0.02	5	0.24	<	1.62	0.56	8	<	<	<	0.00	6
S4 U/S cutblock 172 (E238253)	0.86	<	2.82	0.80	10	0.57	<	2.50	0.81	8	0.68	<	1.13	0.40	10	0.31	<	0.58	0.18	6
S4 D/S cutblock 172 (E238252)	0.96	0.15	2.63	0.70	10	0.75	<	1.79	0.51	9	0.89	0.17	1.85	0.46	12	0.38	0.25	0.51	0.11	6
Block 172 control U/S (E243974)	1.07	<	2.80	1.07	10	0.83	<	3.79	1.23	8										
Block 172 control D/S (E243975)	1.17	<	4.10	1.43	10	0.90	<	3.43	1.20	8										
Block 168 control U/S (E243972)	0.16	<	0.72	0.21	10	0.14	<	0.95	0.33	8										
Block 168 control D/S (E243973)	0.15	<	0.46	0.15	9	0.33	<	1.58	0.58	8										

Table 4.3.6 Summary of 2002 suspended sediment and turbidity measurements for Brewery Creek in relation to site-specific guidelines based on background levels. Clear and Turbid flow periods were identified from July-April and May-June respectively. TSS detection limits are 1 mg/L and turbidity 0.5 NTU. For analysis purposes, measurements recorded at or below detection limits were assigned a value equal to one half of the detection limit.

	Brewery Creek U/S of bridge (E238245) TSS (mg/L)						% Samples above guideline (N)	Brewery Creek D/S of bridge (E238244) TSS (mg/L)						% Samples above guideline (N)
Clear flow period (July-April)	Mean	Min	Max	SD	N	TSS Guideline (mean background + 5 mg/L)		Mean	Min	Max	SD	N	TSS Guideline (mean background + 5 mg/L)	
2002	1.50	<	7.00	2.43	7	(< + 5) = 5.0	14 (1)	<	<	<	0.00	7	(< + 5) = 5.0	0 (0)
2000 (background)	<	<	<	0.00	6			<	<	<	0.00	6		
1999 (background)	<	<	<	0.00	4			<	<	<	0.00	4		
Turbid flow period (May-June)						(max background + 25 mg/L)							(max background + 25 mg/L)	
2002	16.38	<	40.00	18.12	4	(2 + 25) = 27	25 (1)	9.23	<	31.00	14.56	4	(2.0 + 25) = 27	25 (1)
2000 (background)	1.50	<	2.00	0.87	3			1.17	<	2.00	0.76	3		

	Turbidity (NTU)							Turbidity (NTU)						
Clear flow period July-April	Mean	Min	Max	SD	N	Turbidity Guideline (mean background + 2 NTU)		Mean	Min	Max	SD	N	Turbidity Guideline (mean background + 2 NTU)	
2002	0.16	<	0.67	0.24	7	(< + 2) = 2.0	0 (0)	0.15	<	0.86	0.31	7	(< + 2) = 2.0	0 (0)
2000 (background)	<	<	<	0.00	6			<	<	<	0.00	6		
1999 (background)	<	<	<	0.00	4			<	<	<	0.00	5		
Turbid flow period June & July						(max background + 8 NTU)							(max background + 8 NTU)	
2002	2.65	<	5.35	2.60	4	(0.73 + 8) = 8.73	0 (0)	3.54	<	8.24	3.70	4	(0.7 + 8) = 8.7	0 (0)
2000 (background)	0.41	<	0.73	0.36	3			0.36	<	0.70	0.34	3		

Table 4.3.7 Summary of 2002 suspended sediment and turbidity measurements for Desolation Creek in relation to site-specific guidelines based on background levels. Clear and Turbid flow periods were identified from July-April and May-June respectively. TSS detection limits are 1 mg/L and turbidity 0.5 NTU. For analysis purposes, measurements recorded at or below detection limits were assigned a value equal to one half of the detection limit.

	Desolation Creek U/S of bridge (E238249)						% Samples above guideline (N)	Desolation Creek D/S of bridge (E242997)						% Samples above guideline (N)
	TSS (mg/L)					TSS Guideline (mean background + 5 mg/L)		TSS (mg/L)					TSS Guideline (mean background + 5 mg/L)	
Clear flow period (July-April)	Mean	Min	Max	SD	N			Mean	Min	Max	SD	N		
2002	0.57	<	1.00	0.19	7	(< + 5) = 5	0 (0)	0.57	<	1.00	0.19	7	(< + 5) = 5.0	0 (0)
2000 (background)	<	<	<	0.00	6			<	<	<	0.00	4		
1999 (background)	<	<	<	0.00	5									
Turbid flow period (May-June)						(max background + 25 mg/L)							(background + 25 mg/L)	
2002	19.13	<	57.00	26.33	4	(10 + 25) = 35	25 (1)	23.63	<	72.00	33.28	4	(10 + 25) = 35	25 (1)
2000 (background)	4.17	<	10.00	5.11	3									

	Turbidity (NTU)					Turbidity Guideline (mean background + 2 NTU)		Turbidity (NTU)					Turbidity Guideline (mean background + 2 NTU)	
Clear flow period July-April	Mean	Min	Max	SD	N			Mean	Min	Max	SD	N		
2002	0.20	<	0.86	0.31	7	(0.1 + 2) = 2.1	0 (0)	0.21	<	0.82	0.31	7	(< + 2) = 2	0 (0)
2000 (background)	0.10	<	0.34	0.13	6			<	<	<	0.00	4		
1999 (background)	<	<	<	0.00	5									
Turbid flow period June & July						(max background + 8 NTU)							(max background + 8 NTU)	
2002	4.99	0.27	14.30	6.43	4	(2.7 + 8) = 10.7	25 (1)	5.53	0.25	16.10	7.30	4	(2.7 + 8) = 10.7	25 (1)
2000 (background)	1.18	<	2.70	1.37	3									

5 Discussion

5.1 Hydrology

The flow regime of the Wigwam River is comparable to most interior systems with a snowmelt dominated peak occurring in late spring (May-June). The error term associated with the stage – discharge relationship was less than +/- 7.0%; thus, the 2001 Wigwam River Water quality and quantity monitoring program has demonstrated the ability to meet the provincial standards for hydrometric surveys and data computation (Anon. 1998). In fact, all data points collected during four years of monitoring from program inception to date (1999-2002) are now able to be characterized by one of four polynomial equations or rating curves to Class A RIC standards (+/-7%): one curve for dynamic or high flow conditions (ascending, peak, and descending) and three curves for steady or low flow conditions (Table 4.1.2). A shift in the stage-discharge relationship appears to occur at a stage of 4.7 to 4.9 m and characterizing the rating curve will require additional measurements within this range to better describe the transition; thus, it is recommended these gauge levels be targeted in future years of metering.

While discharge followed a similar pattern between years, mean monthly discharge in 2002 was significantly higher from April to November than during any previously metered year (Table 4.1.5, Kruskal-Walis $P < 0.05$). The 2002 increase in discharge is most likely explained by the increase in snow pack. Both 2000 and 2001, were considered below average in the Kootenays and 2001 was only 50-53% of normal levels (Environment Canada 2001). Annual hydrographs indicate that snow pack and groundwater recharge determine the discharge of the Wigwam River as it is neither correlated with precipitation or air temperatures.

5.2 Temperature

Temperature affects the solubility of many compounds, and as it increases, it reduces the solubility of oxygen while increasing the metabolic oxygen demands of aquatic life. Bull trout have demonstrated the highest thermal sensitivity of native BC fish species tested. The use of the mean weekly maximum temperature is an approach designed to reduce the risk of cumulative stress leading to death, disease, poor reproductive success or growth and is consistent with guidelines specified in Pacific Northwest States (Oliver and Fidler 2001). The recommended maximum spawning temperature recognizes the lower thermal tolerance of adults to elevated temperatures during the fall spawning period and provides protection from short-term extreme temperature exposures. Bull trout populations are not found in watersheds where water temperatures exceed 18°C and are most abundant in systems where maximum temperatures are 12°C or less (Ford *et. al.* 1995, McPhail and Baxter 1996).

Spawning adult bull trout are known to enter the lower Wigwam River in early August (Cope 1998), a period when maximum water temperatures are often recorded. However, peak mean weekly maximum water temperatures for the Wigwam River in 2002 occurred during the week of 15-21 July (12.64°C), a full three weeks earlier that the peak last year. This shift in peak temperature is believed to have resulted from the increase in groundwater recharge post freshet. In past years (2000 & 2001), water temperatures at the groundwater station increased in July and August reflecting the effect of rising summer air temperatures with declining water levels. In fact last year by August, the groundwater recharge monitoring station exceeded the mean weekly maximum water temperature guideline for bull trout of 15 °C (Prince and Morris 2002). In contrast, this year, water temperatures in 2002 decreased after the third week of July; yet, air temperatures were not significantly different among years (1999-2002; Kruskal-Walis, $P>0.05$). Thus, it appears that the increased snow pack and corresponding melt in 2002 recharged area aquifers that resulted in stable, cool temperatures (groundwater signature) at a time when other systems are approaching summer maximums.

A water temperature of 9.0°C is reported to be a key indicator for the commencement of spawning (McPhail and Baxter, 1996) with peak spawning of Wigwam River bull trout reported to occur between 15 and 30 of September (Westover and Conrad 1997). Mean weekly maximum temperatures for the Wigwam River at Bighorn creek dropped below 9°C during the last week of September and remained so through November. Thus, the 2002 spawning population of bull trout experienced waters below the upper temperature limit for reproduction (Table 4.2.1).

All but one of the tributaries monitored for temperature in 2002 were within provincial guidelines for trout streams (i.e. < 15°C). The exception tributary hosts only a population of resident Westslope cutthroat trout (Wright 1998). In reference to cutthroat trout, the upper temperature guideline for incubation was exceeded by 1-2 °C for four weeks in 2002; however, background temperature levels for this beaver impounded tributary indicate that temperature guidelines are often exceeded during the spawning and incubation periods.

Nevertheless, there was some concern that this tributary traversing block 172 had been affected by forestry activities as it was the only tributary to show significantly warmer than usual water temperatures in 2001 (after harvest) in comparison with previous years (Kruskal-Walis $P<0.05$, Prince and Morris 2002). However this year, temperatures in block 172 did not differ from those recorded during pre-treatment monitoring. Thus, it appears the harvesting activities in block 172 have not significantly increased the water temperatures of this creek. Similarly, water temperatures in the tributary traversing block 168 appear not to have been affected by harvesting as this block was logged in 2001/02 and temperatures did not differ from background.

5.3 Water Quality

Turbidity is a measurement of all suspended particulate matter in a water body and includes materials such as silt, clay, organic materials and microorganisms. High turbidity increases the total available surface area upon which bacteria can grow, reduces light penetration thereby limiting photosynthesis and primary productivity, which in turn may suppress fish productivity. In contrast, TSS is a measure of inorganic particulate matter only. High TSS concentrations may also limit primary productivity and can result in direct damage to fish gills. Furthermore, settling suspended solids can impair spawning habitat (i.e. increase embededness) and smother incubating fish eggs.

This year, the ambient water quality guidelines for turbidity and suspended sediment were updated to recognize that exposure duration plays a key role in the toxicity response (Anon. 2001). There are now distinct guidelines for periods of clear and turbid flow. The terms clear flow and turbid flow are used to describe the portion of the hydrograph when suspended sediment concentrations are low (i.e. less than 25 mg/L or less than 8 NTU) and relatively elevated (i.e. greater than or equal to 25 mg/L or greater than or equal to 8 NTU respectively).

To assure quality reporting in the water quality data for TSS, we examined the difference in measurements for samples analyzed within 72 hours and those that had exceeded the recommended time limits across both clear and turbid flow periods (Table 4.3.2). As in previous years, results of samples collected by the automated pump samplers did not differ from those collected manually and analyzed within the recommended 72 hr holding guideline for TSS and turbidity (Wilcoxon, $P>0.05$). The ability to accurately measure suspended sediment after 72 hours may be explained by the low organic component to Wigwam River water. The high degree of correlation between TSS and turbidity (Spearman rank=0.953, $P<0.05$, $n=86$) further supports this hypothesis. Thus, TSS levels in the Wigwam River may be determined with a reasonable degree of precision without having to ship samples to a laboratory, the results from which may take up to a week or more to receive, or increase the frequency of trips to the remote study area to ensure analysis is conducted within holding times.

The clear and turbid flow periods for the Wigwam River and its tributaries were defined using data on the background concentrations of suspended sediment at a site-specific level. Maximum TSS (148 mg/l) and turbidity concentrations (67.8 NTU) for the Wigwam River were measured on 31 May 2002, during peak discharge (Figure 4.3.2). Since flow is correlated with TSS in the Wigwam River, and flow was significantly greater this year than background (Kruskal-Walis $P<0.05$), it was not surprising to measure TSS values that exceeded guidelines during turbid flow periods. The suspended sediment/turbidity guidelines were adjusted upward for turbid flow periods because it was thought that the guidelines should not be more stringent than the more scientifically defensible guidelines recommended for the sensitive clear flow periods. This was in recognition of the extreme variability found in relationships between suspended sediment concentrations and discharge flows. Given that the only Wigwam River samples to exceed guidelines were collected during the turbid flow period, and the fact discharge was significantly greater in 2002 compared to background, the elevation in suspended sediment should not be attributed to forestry activities in the watershed but rather to natural processes resulting from the increased discharge. Thus, the current water quality of the Wigwam River and its tributaries appear to meet the updated standards for ambient water quality parameters of suspended sediment and turbidity.

6 Management Recommendations

The following recommendations are provided for the protection of the water resource based on inventory data collected. In addition, the recommendations are made to improve upon the program.

1. It is recommended that gauge levels between 4.7 and 4.9 m be targeted to better characterize the rating curve. This change in stage occurs rapidly in early May and would require several visits in one week. However, given the well defined relationship of the high flow curve, effort could be redirected to target the rapidly ascending portion of the Wigwam's hydrograph.
2. Reduce the groundwater recharge monitoring station to collected information on temperature and water quality only. As this area of the river is known to go dry in some years, there was some concern that early dewatering combined with cold temperatures could reduce the egg-to fry survival rate of incubating bull trout; hence, the inclusion of the water level monitoring component in the Wigwam Water Quality Monitoring Program. For the last 5 years, Westslope Fisheries under contract to the Ministry of Water, Land, and Air Protection has conducted juvenile bull trout sampling in the Wigwam River and we have had the opportunity to evaluate this hypothesis (Cope 2003). Within the last four years, the Kootenay region has had record low snow pack, which has resulted in extreme low flows in our area rivers (2000 & 2001). As expected, the dewatering phenomenon that occasionally occurs at this site in early August, appeared to impact the distribution of young-of-the-year bull trout; but not their abundance (Cope 2003). Now that the juvenile bull trout population is no longer being monitored, recording water level at this station would appear to have served its purpose.
3. Given the costs associated with accessing the watershed, and the demonstrated ability to accurately measure suspended sediment and turbidity levels even though recommended holding times have been exceeded, we recommend the automated pump sampler program continue. The sampler allows for fewer visits to the watershed thereby reducing program costs while maintaining the required sample frequency. With the inclusion of solar panels to operate the ISCO samplers, we could further reduce the number of site visits while increasing the number of samples collected on the Wigwam River as most missed samples were a result of power failures. While reduced frequency will result in the need for more time at each site, by eliminating the water level monitoring

component from the recharge stations duties, we could gain the extra time needed to incorporate the extra samples and maintenance activities that will result from decreasing the frequency of station servicing. Thus, a sampling round could still be completed in three days (i.e. time taken to currently complete a site visit).

4. A temperature data logger should be added to the Rabbit Creek site. This site is the only station above the bulk of forest development and therefore serves as an indicator of watershed events (control). At a cost of $160.00 per temperature logger, this represents a minimal expenditure and would provide data on a parameter that has paramount significance to the fishery resource (i.e. bull trout are temperature sensitive).
5. If there is no longer any winter harvesting activities scheduled for the Wigwam (Don Jakobic, Tembec Roads Supervisor, personal communication 13 Nov 2002) then the winter sampling point may be eliminated from the current program.

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8 Glossary

The following glossary of selected terms makes use of the Hydrometric Manual published by the Resource Inventory committee.

Bench mark: a permanent, fixed reference point for which the elevation is known.

Control: The condition downstream from a gauging station that determines the stage discharge relation. It may be a stretch of rapids, a weir or other artificial structure. In the absence of such features, the control may be a less obvious condition such as a convergence of the channel or even simply the resistance to flow through a downstream reach. A shifting control exists where the stage-discharge relation tends to change because of impermanent bed or banks.

Cross section of a stream: A specified vertical plane through a stream bounded by the wetted perimeter and the free surface.

Discharge, Q: The volume of liquid flowing through a cross section per unit of time. It is not synonymous with flow.

Discharge measurement: The determination of the rate of discharge at a gauging station on a stream, including an observation of no flow, which is classed as a discharge measurement.

Flow: The movement of water in a channel without reference to rate, depth, etc.

Gauge correction: Any correction that must be applied to the gauge observation or gauge reading to obtain the correct gauge height.

Gauge datum: The elevation of the zero of the gauge (referenced to bench marks, or GCS datum) to which the level of the liquid surface is related.

Gauge height: The height of the water surface above the Gauge datum; it is used interchangeably with the terms stage and water level.

Gauge reading: An actual notation of the height of the water surface as indicated by a gauge, it is the same as a gauge height only when the 0.000 metre mark of the gauge is set at the gauge datum.

Gauging or measuring section: The cross-section of an open channel in the plane of which measurements of depth and velocity are made.

Gauging station: The complete installation at a measuring site where systematic records of water level and/or discharge are obtained.

Left (right) bank: The bank to the left (right) of an observer looking downstream.

Level check: The procedure followed to determine the movement of a gauge with respect tot the gauge datum.

Manual gauge: A non-recording type of gauge from which observations of stage are obtained.

Mean velocity at a cross section: The velocity at a given cross section of a stream, obtained by dividing the discharge by the cross sectional area of the stream at that section.

Mean velocity depth: The depth below the surface at which the mean velocity on a vertical occurs.

Peak stage: The maximum instantaneous stage during a given period.

Point method (one-; two-; three-; five;-; six-): Method of measuring the velocity in a vertical by placing a current-meter at a number of designated points in the vertical.

Pressure transducer: A sensor that measures the hydrostatic pressure.

Reference point: A point of known elevation from which measurements may be made to a water surface. It is also known as a measuring point.

Shift: A change in the stream control which alters the stage-discharge relationship. This change can be either temporary or permanent.

Sounding: The operation of measuring the depth fro the free surface to the bed.

Stable (unstable) channel: A channel in which the bed and the sides remain stable (unstable) over a substantial period of time and in which scour and deposition during the rising and falling stages are negligible (appreciable).

Staff gauge: A manual gauge consisting of a graduated plate or rod that is set vertically in streambed or attached to a solid structure.

Stage; gauge height; water level: The elevation of the free surface of a stream, lake or reservoir relative to a gauge –datum.

Stage: A general term used to describe the height of a water surface and, in a particular application, may be either a gauge height or a water elevation.

Stage-discharge relation: A curve, equation or table which expresses the relation between the stage and the discharge in an open channel at a given stream cross section.

Steady (unsteady) flow: Condition in which the discharge does not change (changes) in magnitude with respect to time.

Stream gauging: All of the operations necessary for measuring discharge.

Velocity-area method: Method of discharge determination deduced from the area of the cross-section, bounded by the wetted perimeter and the free surface, and the integration of the component velocities in the cross section.

Vertical: The vertical line in which velocity measurements or depth measurements are made.

Wading rod: A light, hand-held, graduated, rigid rod, for sounding the depth and positioning the current meter in order to measure the velocity in shallow streams suitable for wading.

Water level recorder/data logger: An instrument that records water levels in an analogue or digital form.

Appendix A

Hydrometric Data

Appendix B

Water Quality Data

Appendix C

Calibration Certificates

Appendix D

Raw data and Lab Reports