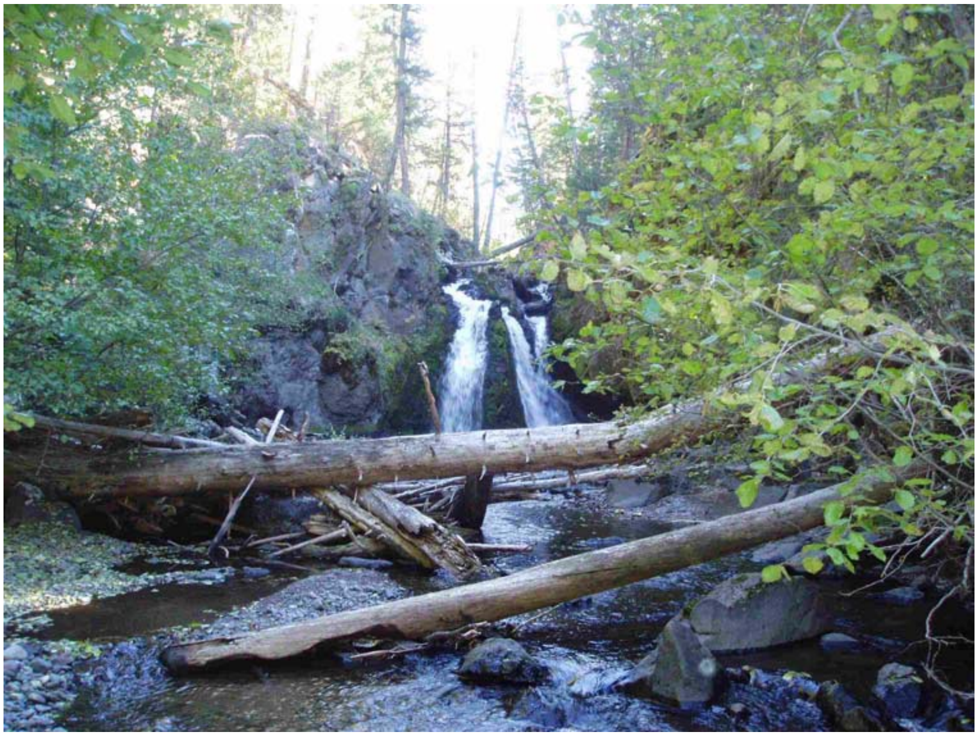
WATER QUALITY MONITORING

For

LAMBLY AND WHITEMAN CREEKS (TFL49)

2008 Annual Report



Prepared for

TOLKO INDUSTRIES LTD

by

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1.0 INTRODUCTION

This report summarizes the work completed in 2008 for the TFL 49 long-term water quality-monitoring project. The water quality-monitoring project was initiated in 1999 as part of the effectiveness evaluation of the Ecological Forest Stewardship Plan that was being developed by Riverside Forest Products Ltd. Data collection was focused on Tree Farm License (TFL) 49 in the Okanagan and Shuswap basins. In 2004, Tolko Industries Ltd. acquired Riverside Forest Products Ltd. and continued the operation of the water quality-monitoring program. Additional background information and history for the water quality-monitoring project can be found in the previous annual reports.

2.0 PROJECT DESCRIPTION

Data was collected at 15-minute intervals on Lambly Creek and Whiteman Creek. This data was routinely downloaded and stored in a database for reference. During routine site visits, the accuracy and precision of the probes was confirmed using known standard solutions and portable field instruments. This data can be compared with baseline data that was established from previous water quality studies. In addition to water quality monitoring, water level and precipitation data were collected at the Lambly Creek site to aid in understanding the relationship between precipitation and stream flow on water quality. The Water Survey of Canada (WSC) operates a hydrometric station at the Whiteman Creek site.

2.1 Sampling Locations

The sites were chosen to provide water samples that are representative of the areas affected by forest development. Access concerns were also addressed during site selection (Refer to Table 1 and Appendix B - location maps) for sampling site locations.

Table 1
Sampling Site Locations and *EMS Identification Numbers

Site	Location	Co-ordinates	*EMS I.D. Number
Lambly Creek	Lambly Creek at the Lakeview Irrigation District intake.	49° 57' 27"N 119° 33' 20"W	E223216
Whiteman Creek	Whiteman Creek at the Water Survey of Canada Hydrometric Station 08NM174	50° 12' 49"N 119° 32' 19"W	E244481

*Environmental Monitoring System – a provincial database for discrete sampling data.

2.2 Automated Sampling

A variety of equipment has been employed to collect and log data every 15 minutes at the two sites. The equipment used and parameters measured at each site are presented in Table 2.

Table 2
Automated Sampling Parameters

Site	Parameters Measured						
	Turbidity	Temperature	Conductivity	pH	Dissolved Oxygen	Precipitation	Water Level
*Lambly	•	•	•	-	-	•	•
**Whiteman	•	•	•	-	-	-	-

*Equipment included an Analite turbidity sensor, a YSI conductivity sensor, a YSI temperature sensor and a Forest Technology Systems tipping bucket rain gauge, all connected to a FTS Model FWS-12-NH data logger. Water level was measured with a Stevens pressure transducer.
**Equipment included a Hydrolab Corporation Datasonde 4 multiprobe connected to a Campbell Scientific Inc. Model CR510 data logger.

2.3 Discrete Sampling

Discrete samples are collected to confirm that the automated sensors are providing reasonable results. Water sampling was conducted according to Resources Information Standards Committee standards as described in the *Ambient Freshwater and Effluent Sampling Manual* (Water Quality Branch, 1997) and *Continuous Water Quality Sampling Programs:* (Operating Procedures 2006).

Water samples were analyzed for turbidity in the field. Increased turbidity (and suspended solids) can result from forest development as a result of surface erosion from roads and landslides[1] as well as channel erosion resulting from increased peak flows.

Field measurements for turbidity, water temperature, air temperature, and conductivity were recorded to confirm proper automated sensor operation. Field turbidity is measured using a LaMotte Model 2020 Turbidimeter, water temperature and air temperature are measured using a Checktemp 1 digital thermometer, and conductivity is measured in the field using an Oakton CON 200 Series conductivity/temperature meter. The field instruments are checked/calibrated against known standards prior to field use.

2.4 Sampling Dates

Typically the greatest variability in water quality occurs during peak flows generated from spring snowmelt freshet. In order to measure the water quality variability during the freshet; samples were collected weekly May through June. Samples were collected less frequently outside of this period, with additional samples collected following rain events.

[1] MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska.

Water samples were field analyzed on the following dates:

- March 29, 2008
- April 16, 2008
- May 6, 15, 20 and 28, 2008
- June 4, 10, and 18, 2008
- July 2 and 15, 2008
- August 5 and 19, 2008
- September 9 and 25, 2008
- October 7 and 27, 2008
- November 12, 2008

2.5 Quality Assurance and Quality Control

Discrete water sampling was conducted according to Resources Information Standards Committee standards as described in the *Ambient Freshwater and Effluent Sampling Manual* (Water Quality Branch, 1997) and *Continuous Water Quality Sampling Programs:* (Operating Procedures 2006). The automated data collection was conducted according to the *Automated Water Quality Monitoring Field Manual* (Water Management Branch, 1999) and *Continuous Water Quality Sampling Programs – Field Procedures*, (Ministry of Environment, 2006). Portable field instruments were also used during each site visit to confirm that the automated sensors were functioning properly and to ensure data quality objectives were being met (Refer to Appendix C Tables 1-4).

2.6 Climatic Conditions and Stream Discharge

Intense rainfall, rapid warming and rain-on-snow events can result in increased run-off and stream flow. Although the maximum peak flow events in the BC interior are normally the result of spring snowmelt, sustained summer and autumn rainfall can also cause extreme runoff events. Increased surface run-off and increased stream flow can cause elevated turbidity and increased suspended sediment concentrations in the streams.

Environment Canada data indicates that in 2008, the Southern BC Mountains Region experienced the 19th coolest and 9th driest spring on record since 1948 (61 years of record). The summer was the 31st warmest and 31st driest on record and the autumn was the 16th warmest and 10th driest on record. (Refer to Appendix D – Climate and Stream Discharge Data). Hourly precipitation data is collected each year at the Lambly Creek site, this data is also found in Appendix D.

The Water Survey of Canada data for Whiteman Creek indicates the maximum daily discharge for 2008 occurred on May 21, (3.43 m^3/s), which equates to a 1-year return period peak flow event. Discharge data for this station is not available from May 15 through May 20, 2008. However, based on the graphic provided on the WSC website (http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp) the actual maximum daily discharge occurred on May 18, 2008 and the discharge was >6.5 m^3/s. This discharge equates to a >2 year event. The maximum daily discharge in Lambly Creek was 7.12 m^3/s and occurred on May 18, 2008.

Discharge data for Lambly Creek is only available since 2001 so return periods have not been calculated. It is assumed that both Lambly Creek and Whiteman Creek experienced similar peak flow return periods in 2008.

Although the maximum flows in the creeks occur during the spring melt; many smaller increased flow events occur following summer and fall rain storms.

3.0 ANALYSIS RESULTS

The following sections provide a summary of the analyses for 2008 (both discrete samples and automated data). Tables 1 and 3 in Appendix C provides the detailed discrete data results. There were incidents at both sites that caused erroneous automated turbidity and conductivity data (leeches and insects attached to the sensors, extremely low flows resulting in sensors out of the water, interference from direct sunlight). Suspect data has been removed from the analysis data set.

3.1 Turbidity

Turbidity describes the "cloudiness" of water. Suspended particles in water cause incoming light to scatter and give water a cloudy appearance. The suspended particles can include clay, silt, fine sand, and organic material (leaf litter and aquatic organisms). In the context of domestic water, turbidity is important since suspended particles can impair the effectiveness of various disinfection processes and is aesthetically displeasing. In many BC interior streams, spring freshet and rain events bring with them sediment laden water, which cause peaks in turbidity levels. Health Canada's guideline for drinking water that does not receive treatment to remove turbidity is a maximum of 1 NTU (nephelometric turbidity units).

Prior to 2006, the acceptable turbidity level for raw water that is to be chlorinated was $\leq$ 5 NTU if it could be demonstrated that disinfection was not compromised by the use of the less stringent value. In 2006, the Interior Health Authority imposed stricter regulations on water suppliers. Now, Water Quality Advisories are required when raw water exceeds 1 NTU, and Boil Water Notices are issued when water exceeds 5 NTU. This public alert process is under review and may be modified for 2009.

In snowmelt-dominated watersheds, turbidity tends to be higher during the spring freshet period mainly as a result of increased surface run-off and peak stream flows. For the TFL the spring freshet, resulting from snowmelt in the upper elevations, typically occurs from April through June. Based on this information the turbidity data has been divided into two separate periods: *clear flow* period and *turbid flow* period. The turbid flow period coincides with spring freshet from April 1 to June 30 with the clear flow period occurring during the remainder of the year. In 2008 turbidity was sampled in the field 14 times at Lambly Creek and 17 times at Whiteman Creek. The turbidity data is arranged by flow period in Tables 3 and 4.

Table 3
Discrete Turbidity Values – Clear Flow Vs Turbid Flow

	Clear Flow Period (July 1 – March 31)			Turbid Flow Period (April 1 – June 30)		
Year	**# Of Samples**	**Range (NTU)**	**Mean (NTU)**	**# Of Samples**	**Range (NTU)**	**Mean (NTU)**
Lambly Creek						
2001	12	0.50 – 0.95	0.68	7	0.87 – 2.30	1.61
2002	9	0.15 – 0.65	0.40	2	1.20 – 1.40	1.30
2003	7	0.35 – 1.10	0.79	8	0.65 – 3.50	1.68
2004	6	0.35 – 1.60	0.69	9	0.70 – 3.00	1.38
2005	8	0.06 – 0.62	0.25	11	0.15 – 2.67	0.85
2006	8	0.00 – 0.58	0.18	9	0.44 – 11.3	3.42
2007	5	0.31 – 1.26	0.71	4	1.12 – 1.95	1.41
2008	9	0.02 – 0.30	0.14	5	0.31 – 5.09	2.35
Whiteman Creek						
2001	12	0.20 – 1.60	0.55	7	0.90 – 3.50	2.14
2002	9	0.15 – 0.40	0.26	9	1.90 - 125	18.8
2003	8	0.15 – 5.20	0.96	8	0.95 – 3.00	1.86
2004	6	0.15 – 1.10	0.42	9	0.90 – 5.20	2.06
2005	8	0.00 – 0.52	0.11	11	0.63 – 4.68	1.91
2006	8	0.00 – 0.42	0.18	9	1.21 – 66.4	10.1
2007	5	0.00 – 2.60	0.52	5	0.84 – 5.90	2.69
2008	10	0.00 – 0.70	0.13	7	0.90 – 43.5	8.81

All of the discrete turbidity values for both creeks are normal and lie within the range of natural variability.

Table 4
Automated Turbidity Values – Clear Flow Vs Turbid Flow

	Clear Flow Period (July 1 – March 31)				Turbid Flow Period (April 1 – June 30)			
Year	**% ≤ 5 NTU**	**% > 5 NTU**	**Range NTU**	**Mean NTU**	**% ≤ 5 NTU**	**% > 5 NTU**	**Range NTU**	**Mean NTU**
	Lambly Creek *(13,451 records)*				***Lambly Creek*** *(8,635 records)*			
2001	99%	1%	0.0 – 133.7	<0.1	96%	4%	0.0 – 264.8	0.27
	(11,485 records)				*(3 289 records)*			
2002	99.97%	.03%	0.0 – 8.8	0.6	98%	2%	0.0 – 40.4	1.03
	(8,711 records)				*(5,177 records)*			
2003	99.9%	0.10%	1.40 – 124.9	2.19	99.6%	0.4%	1.5 – 36.8	2.21
	(13,503 records)				*(7,102 records)*			
2004	99.7%	0.30%	0.0 – 20.2	0.42	94.7%	5.3%	0.0 – 30.8	1.58
	(13,873 records)				*(6,471 records)*			
2005	99.9%	0.10%	0.0 – 5.30	0.12	98.6%	1.4%	0 – 85.2	0.53
	(12,116 records)				*(4,805 records)*			
2006	99.8%	0.20%	0.0 – 135.7	0.20	89.9%	10.1%	0 – 115	1.87
	(13,177 records)				*(7,327 records)*			
2007	99.9%	0.10%	0.0 – 50.3	0.14	95.9%	4.1%	0.0 - 261	1.22
	(12,573 records)				*(7,186 records)*			
2008	100%	0%	0.0 – 2.1	0.07	90.1%	9.9%	0.0 – 123.5	2.07
	Clear Flow Period (July 1 – March 31)				**Turbid Flow Period (April 1 – June 30)**			
	% ≤ 5 NTU	**% > 5 NTU**	**Range NTU**	**Mean NTU**	**% ≤ 5 NTU**	**% > 5 NTU**	**Range NTU**	**Mean NTU**
	Whiteman Creek *(9 122 records)*				***Whiteman Creek*** *(8 315 records)*			
2001	*95%	*5%	*0.0 – 141.0	*1.2	*65%	*35%	*0.0 – 172.0	*5.5
	(8,821 records)				*(6,472 records)*			
2002	99.6%	0.4%	0.0 – 7.8	0.03	79%	21%	0.0 – 272	7.4
	(12,431 records)				*(5,411 records)*			
2003	99.6%	0.4%	0.0 – 491	0.19	93.4%	6.6%	0.0 – 118	1.55
	(13,048 records)				*(7,632 records)*			
2004	98.8%	1.2%	0.0 - 675	0.64	85.6%	14.4%	0.0 - 127	2.09
	(12,720 records)				*(8,182 records)*			
2005	99.8%	0.2%	0.0 - 609	0.16	94%	6%	0.0 - 818	1.72
	(12,060 records)				*(7,346 records)*			
2006	99.6%	0.4%	0.0 - 805	0.46	59.9%	40.1%	0.0 - 369	10.4
	(7,167 records)				*(3,096 records)*			
2007	99.2%	0.8%	0.0 - 281	0.77	96.7%	3.3%	0.0 – 14.6	0.80
	(11,164 records)				*(7,390 records)*			
2008	98.9%	1.1%	0.0 - 867	0.61	69.4%	30.6%	0.0 – 270	10.7

*Data sets in 2001 are not reliable, sensor interference occurred on many occasions (ambient light, obstructions in creek). A stable configuration was established after August 21, 2001 all readings prior to this date are suspect.

High turbidity values occurred on several occasions in both the clear flow and turbid flow periods. However, all of the readings during the clear flow period at the Lambly Creek station are less than the 5 NTU guideline. Most of the clear flow period turbidity values were below 5 NTU at Whiteman Creek, which indicates good water clarity. Many of the short duration turbidity spikes (values >50 NTU) are likely the result of sensor interference caused by relatively large pieces of debris in the water (leaf litter, aquatic insects etc.). The lower incidence of values exceeding 5 NTU in Lambly Creek vs Whiteman Creek is likely due in part to reservoirs in the upper watershed reducing the impact from increased flows. Sediment inputs from traffic on the Whiteman FSR during the rainy fall periods are likely responsible for the increased turbidity observed during the clear flow period.

For both sites, the 2006 turbid flow period had the highest prevalence of values >5 NTU since 2001. The 2008 turbid period for both Lambly and Whiteman Creeks experienced fewer turbidity events greater than 5 NTU than 2006 did. The 2006 peak flow in Whiteman Creek was 11.1 m^3/s, which equates to a 7-year return period and the 2008 peak flow in Whiteman Creek was much lower at 3.43 m^3/s or a 1-year return period. Lambly Creek also had differences in peak flows: 7.45 m^3/s in 2006 and 7.12 m^3/s in 2008. It is likely the reduced peak flow magnitudes in 2008 vs 2006 resulted in fewer incidences of >5 NTU turbidity at both sites.

All automated turbidity values used in the analysis set met the data quality objectives (automated values were within +/- 2 NTU of the field measurements).

Lambly Creek

None of the clear flow period values were above 5 NTU. This is the clearest flow period recorded at the station since 2001. A combination of reduced industrial activity, recreation trail deactivation and very low precipitation likely contributed to the improved water quality.

A rainstorm occurred in the Kelowna area on June 30, 2008. The Kelowna airport weather station reported 3.5 mm however, the rain gauge at the Lambly Creek station reported nearly 12.7 mm. Lambly Creek water levels increased by ~4 cm however turbidity only increased from 0.60 NTU to 1.10 NTU and the turbidity event only persisted for 2 hours following the storm. A similar rain event occurred on June 29, 2007 (18 mm) which resulted in a turbidity event that persisted from 16:30 June 29 to 12:00 PM June 30 with a peak value of 261 NTU.

The report completed in 2006 for the Lakeview Irrigation District[2] (LID) investigated a similar storm event and the related sediment sources. The most significant sediment source was identified as the motorcycle trails that drained towards Bald Range Creek above and below the upper motorcycle staging area. Dobson Engineering Ltd. conducted another overview of the areas in August 2007 and the same erosion paths previously identified were continuing to deliver sediment to Bald Range Creek. Some of the problem recreation trails have since been deactivated. Deactivating problem trails reduces sediment delivered to the stream during run off events. The trail deactivation likely reduced the turbidity in Lambly Creek following the June 30, 2008 storm.

Another turbidity event occurred in Lambly Creek July 15-17, 2008. This was the result of declining water levels and cedar foliage in the sensor tube. Attempts to clear the debris were only successful for several hours, until additional cedar foliage was deposited into the tube by the stream. This has occurred in the past and no clear

[2] Lambly Creek Watershed – June 19, 2006 Post Rain Assessment, Dobson Engineering Ltd., June 2006.

solution to the problem has been identified, the data during this period was removed from the analysis set.

The other turbidity events in Lambly Creek corresponded with rising water levels (rising water caused by snowmelt, rainfall and Lakeview Irrigation District activities).

The water quality criteria/target for turbidity in Lambly Creek (maintain at least 90% of the turbid flow period data below 5 NTU, and maintain at least 99% of the clear flow period turbidity data below 5 NTU) was met in 2008 (refer to Appendix A).

Whiteman Creek

Turbidity data at Whiteman Creek was lost from July 16 to August 6, 2008. Organic debris accumulation, low water periods and sand accumulations at the sensor tube all caused erroneous data.

The June 30 storm that affected Lambly Creek also affected Whiteman Creek. Turbidity increased from 0.0 NTU to a maximum of 5.7 NTU and the turbidity event persisted for over 10 hours following the rain.

The most significant turbidity event occurred during a rain event on November 8, 2008. There was 7.6 mm rain recorded at the Lambly site (Nov. 7-8) and only 2 mm was recorded at the Kelowna Airport. The maximum turbidity was 867 NTU and the event persisted for more than 11 hours.

In 2003 it was discovered that there was sediment entering Whiteman Creek from near the 12 km mark on the Whiteman FSR (which runs adjacent to the creek). During periods of steady rain, sediment-laden runoff flows off the out-sloped portion of the road and enters the creek. Additional sediment enters the creek when vehicles travel the roads during the rainy periods. Overview road assessments conducted in 2004-2008 confirm this is still occurring, and is likely the cause of the high turbidity during rainy periods.

The reservoirs/lakes in the Lambly Creek watershed buffer/reduce sediment transport to the water quality monitoring station. The lack of reservoirs/lakes in the Whiteman Creek watershed increases the likelihood of sediment transport to the monitoring station. Due to the lack of reservoirs in Whiteman Creek, the targets for turbidity in Whiteman Creek should be flexible to allow for the increased likelihood of sediment delivery to the monitoring station from the upper watershed.

3.2 Temperature

Temperature is important to the quality of drinking water supplies for both health and aesthetic reasons. As water temperature increases, so does the potential for biological growth. Increased biological growth can increase chlorine demand and reduce the effects of the chlorination process. In addition, decaying organics in the water can cause taste and odour problems for the consumer. The maximum temperature guideline for drinking water quality is 15°C. Field temperature readings were collected at each site visit to confirm the automated sensor accuracy. The Ministry of Water, Land and Air Protection data quality objectives state that confirmed water temperatures should be within 1°C of the automated sensor reading. The data quality objectives for temperature were met at both sites, therefore the automated data is considered accurate. The automated temperature data is summarized in Table 5.

Table 5
Automated Temperature Data Summary

Year	Range (°C)	Mean (°C)	# Dates >15°C*
	Lambly Creek - Baseline Range (0.0°C – 24.3°C)		
2001	0.4 – 18.8	8.4	33
2002	0.0 – 18.2	10.1	26
2003	0.0 – 20.1	10.6	51
2004	0.1 – 19.9	9.2	53
2005	0.0 – 16.4	8.6	25
2006	0.0 – 19.3	9.2	36
2007	0.3 – 19.2	9.0	34
2008	0.0 – 18.2	8.5	34
	Whiteman Creek - Baseline Range (1.1°C – 24.5°C)		
2001	0.1 – 16.4	7.5	7
2002	0.0 – 16.9	8.5	9
2003	0.0 – 17.3	9.8	38
2004	0.1 – 17.2	8.6	34
2005	0.4 – 15.1	8.3	1
2006	0.0 – 16.4	8.5	7
2007	0.7 – 18.3	7.5	12
2008	-0.2 – 17.1	7.2	12

*The aesthetic guideline for drinking water quality is 15°C. Any day where at least one 15-minute period was greater than 15°C is included.

Stream temperature exceeded the BC drinking water guideline on several occasions at Lambly Creek and Whiteman Creek during July and August, however this is not unusual during summer months. The maximum temperature reported in Lambly Creek was 18.2 °C and occurred on July 2, 2008. For Whiteman Creek the maximum water temperature was 17.1 °C on July 21, 2008.

3.3 Conductivity

Conductivity refers to the ability of a substance to conduct an electric current. The conductivity of a water sample provides an indication of the amount of dissolved ions in the water and as the ion or dissolved solid concentration increases, so does the conductivity. Conductivity is measured in microsiemens per centimeter (μS/cm) and can range from 50 μS/cm to 1500 μS/cm in natural waters.

Increased stream flows, resulting from precipitation or snowmelt events, tend to dilute dissolved ions, resulting in decreased conductivity values. Conversely, when increased amounts of dissolved solids are delivered to the stream, specific conductivity levels increase. Although conductivity is not one of the indicators for this study, measuring it is useful in understanding seasonal water quality dynamics as well as trouble shooting suspicious data. For example, instances where stream flow was too low for representative analysis (for all parameters) were detected by zero conductivity readings (sensor out of the water). This information allows confirmation of erroneous data, which might otherwise not be detected.

There is no established drinking water quality guideline for conductivity in British Columbia, however the Ministry of Environment (*Guidelines for Interpreting Water Quality Data*, 1998) suggests that conductivity can be mathematically converted to total dissolved solids (TDS). There is a criterion of 500 mg/L of TDS, which approximately equates to a conductivity of 700 μS/cm. Field conductivity readings were collected at each site visit to confirm the automated sensor accuracy. The conductivity summary values are in Table 6.

Table 6
Automated Conductivity Data Summary

Year	Range (μS/cm)	Mean (μS/cm)
	Lambly Creek *(22,186 Readings)*	
2001	59 - 234	137
	(14,936 Readings)	
2002	51 - 274	144
	(17,284 Readings)	
2003	54 - 255	138
	(22,234 Readings)	
2004	19 - 250	139
	(22,006 Readings)	
2005	33 - 261	146
	(20,125 Readings)	
2006	43 - 247	153
	(20,525 Readings)	
2007	65 - 206	142
	(19,947 Readings)	
2008	54 - 204	135
	Whiteman Creek *(21,747 Readings)*	
2001	26 - 334	199
	(17,362 Readings)	
2002	64 - 362	224
	(18,812 Readings)	
2003	67 - 420	255
	(21,791 Readings)	
2004	62 – 332	212
	(20,914 Readings)	
2005	66 - 356	210
	(20,235 Readings)	
2006	53 - 399	238
	(16,185 Readings)	
2007	68 - 355	196
	(20,546 Readings)	
2008	56 – 397	246

The conductivity values for both sites are within the expected natural range, and did not exceed 700 μS/cm.

4.0 CONCLUSIONS

- The Lambly Creek station will be useful as a long-term water quality-monitoring site. There is data originating in 1969, data collected by the former Ministry of Environment, Lands and Parks (1996-1999) as well as the seasonal data collected to date. Since Tolko Industries Ltd. will continue development in the watershed; this station is valuable as an index station.

- The Whiteman Creek station is also important for long-term water quality/quantity data. Future data collection will provide much needed water quality/quantity data following the loss of forest cover due to the mountain pine beetle epidemic.

- The maximum daily discharge reported by the WSC at Whiteman Creek occurred on May 21, 2008 and was 3.43 m^3/s, which equates to a 1-year return period event. Discharge data at Lambly Creek is limited so return periods have not been calculated, however the maximum daily discharge occurred on May 18, 2008 and was 7.12 m^3/s.

- The maximum turbidity in Lambly Creek occurred on May 20, 2008 at 1:15 PM and was 123.5 NTU. This reading was associated with a turbidity event during the freshet period.

- The maximum turbidity reading for Whiteman Creek was 867 NTU and occurred on November 8, 2008 at 02:00 AM. This was related to a rain event (~7.6 mm rain at Lambly Creek and 2 mm at the Kelowna Airport).

- The Whiteman FSR at the 12 km marker is a sediment source to Whiteman Creek during snowmelt and rainstorms. Routine road maintenance (grading) might help reduce the potholes at this location. Maintaining a gravel windrow along the creek side of the road or in sloping the road could also reduce the sediment input at this location.

- For Lambly Creek, 90.1% of the automated turbidity values were ≤5 NTU during the turbid flow period and 100% of the accepted turbidity values were ≤5 NTU during the clear flow period. This data meets the water quality criteria/target suggested in Appendix A (maintain at least 90% of the turbid flow period data below 5 NTU, and maintain at least 99% of the clear flow period turbidity data below 5 NTU).

- For Whiteman Creek, 69.4% of the automated turbidity values were ≤5 NTU during the turbid flow period and 98.9% of the turbidity values were ≤5 NTU during the clear flow period. There has been increased forest development in the watershed since 2001; including harvest of mountain pine beetle infested stands. The increased development and traffic on the Whiteman FSR, is likely contributing to the degraded water quality during the spring freshet and fall rain events.

- Although turbidity criteria/targets are not currently in place for Whiteman Creek, they should be less stringent than the Lambly Creek targets. The reservoirs/lakes in the Lambly Creek watershed buffer/reduce sediment transport to the lower stream reaches.

The lack of reservoirs/lakes in the Whiteman Creek watershed increases the likelihood of sediment transport to the lower stream reaches.

- Lambly Creek water temperature exceeded 15°C on 34 days in 2008 and the maximum temperature recorded was 18.2°C on July 2, 2008. Whiteman Creek water temperature exceeded 15°C on 12 days and the maximum temperature recorded was 17.1 °C on July 21, 2008. Temperature values in 2008 indicate no deviation from the baseline temperature data (Lambly Creek baseline range is 0.0°C – 24.3°C, Whiteman Creek baseline range is 1.1°C – 24.5°C).

- Conductivity ranged from 54 μS/cm to 204 μS/cm in Lambly Creek and 56 μS/cm to 397 μS/cm in Whiteman Creek. There is no pre-forest development (1969-1971) data available for conductivity, however, the conductivity values for both sites are within the expected natural range (50 μS/cm to 1500 μS/cm) and did not exceed the guideline of 700 μS/cm.

- Where applicable, the water quality data collected in 2008 remains within the range of the baseline conditions. Baseline (pre-forest development) data for turbidity, suspended solids, and conductivity for Lambly and Whiteman Creeks is limited (data only available from 1969-1971).

- The water level and precipitation data that was collected is useful to aid in understanding temporal changes in water quality (i.e. rainstorms and elevated stream flows can affect turbidity and water chemistry).

5.0 RECOMMENDATIONS

- The gravel windrow along the creek side of the Whiteman FSR at the 12 km marker should be improved annually to reduce runoff (and sediment delivery) from the road surface to the creek. Alternatively, the road could be built up and in-sloped along this section. An onsite investigation by a qualified road engineer is required to determine feasibility and cost estimates for potential changes to the road prism along this section.

- Water quality monitoring at the two sites should continue through 2009 since Tolko Industries Limited has ongoing forest development in the watersheds, and additional data collection is required to better characterize the temporal water quality variability in the study streams.

- Manual sampling should be conducted weekly during freshet and at least monthly during the summer and fall and efforts to sample within 24 hours of late summer/fall rainstorm events should continue. Funding should be secured in April 2009 to ensure adequate site visits can occur to ensure quality data.

- Consideration should be given to establishing water quality monitoring stations immediately above and below future forest development at selected sites within TFL 49 to monitor stand-level forest development impacts on water quality. Water level, turbidity, suspended solids and water temperature data should be recorded at these sites.

Original signed by:	Original signed by:
Prepared by G. VanEmmerik, AScT.	Reviewed by D.A. Dobson, P.Eng.

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APPENDIX A

Rationale for Indicators and Measurables

Forest Stewardship Project
Results Based Water Quality

Rationale for Indicators, Measurables, and Thresholds/Targets/Ranges

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Introduction

The objective for determining long-term water quality as a component of the Forest Stewardship Plan (FSP) is to maintain and protect water resources obtained from the watersheds within the TFL. In the TFL there are community and non-community watersheds that supply drinking water to various communities in both the Okanagan and Shuswap basins. Fish and other aquatic organisms also rely on these watersheds for a source of habitat and food. Three key indicators have been selected to measure the water quality in the TFL: turbidity, water temperature and discharge. As outlined in Section 7 (Monitoring) of the Forest Stewardship Plan, this program has been formatted to include the coarse, medium and fine filter approach to determine if the objectives of this program are being met.

The following sections outline the rationale for using the selected indicators as well as how the program will move from the baseline data collection phase to the monitoring phase and to the adaptive management phase.

Rationale for using the selected Indicators

Although there are several parameters used for measuring water quality, the ones most likely affected by forest development activities are turbidity, water temperature and discharge. If other issues arise (fire, fertilization, etc.), the list of selected indicators and the monitoring plan can be modified to accommodate these changes in forest management.

Turbidity (and suspended solids) can be impacted by forest development as a result of surface erosion from roads and landslides (MacDonald et al, 1991). Although other parameters are important with respect to drinking water quality, turbidity best identifies changes in water quality that result from surface erosion.

Water temperature can be affected by loss of stream shading resulting from riparian harvesting (Teti, 1998). Changes in discharge and channel morphology can also affect water temperatures (MacDonald et al, 1991).

Discharge (peak flows, low flows and the annual water yield) can be affected by forest development activities (MacDonald et al, 1991, Teti, 1993). Harvesting can cause increased snow accumulation on the ground (loss of canopy interception). As well as an increase in snow accumulation, the melt rate in cleared areas is accelerated (loss of shading) (Streamline, 2003). These two factors can combine to change the timing and magnitude of springtime peak flows (earlier and more intense flows) (Teti, 1993). Increased peak flows can have negative effects on stream channel stability and water quality (increased flows can result in increased bank erosion and sediment input/mobilization) (MacDonald et al, 1991). Harvesting can increase summer low flows. Once trees are removed, evapotranspiration is reduced, and this increases the amount of sub-surface or groundwater available (Teti, 1993).

Baseline Data Collection Phase

The historic data collected in the Okanagan Basin Study (1969 to 1972) is proposed to be representative of "baseline water quality conditions" for Powers Creek, Lambly Creek, Whiteman Creek and Naswhito Creek since these watersheds were relatively undisturbed at that time (Dobson, 2001). Discharge data was collected as far back as 1920 on several streams in the TFL. Although much of this data was collected intermittently, it is proposed that the existing data for these streams (prior to the early 1970's) may be considered as baseline data (recognizing recent Environment Canada research suggests stream flows are changing due to global climate change).

Recent water quality data collected in Powers Creek, and Bolean Creek (1996-2000), and data collected in Lambly Creek (1996-2003) and Whiteman Creek (2001-2003) suggests no change in key water quality parameters since this time, so this data may be considered part of the baseline data set as well (Dobson, 2003).

Once baseline data is established for various streams within the TFL and the project becomes operational, the project will progress to the monitoring phase.

Monitoring Phase - Strategies

A difficult and complex issue to address is the overall condition of the all the watersheds throughout the TFL (Dobson, 2001). Since monitoring every stream channel and watershed is impractical, monitoring procedures have been developed to address this issue. By using key "index" long-term stations (Lambly, Whiteman and Bolean Creeks etc.) combined with "roving" stations (portable automated stations run short/mid term in other watersheds) and more site-specific stations (above and below active development) water quality can be assessed throughout the TFL. The information can be used to form baseline data sets in unmeasured watersheds and, where baseline data already exists, the information can be measured against baseline conditions.

Coarse Filter Approach - Long Term Data Collection

Long term data will be collected at index stations (Lambly Creek and Whiteman Creek) to assess the water quality at a watershed level. Additional index stations are being considered in the upper Salmon River watershed as well as in Bolean Creek. This data may also be used to indicate water quality trends for other nearby watersheds with similar physical characteristics (watershed size, geology, soils, topography, etc.).

Medium Filter Approach - Roving Station Data Collection

Data will be collected in various watersheds that do not have a long term index station associated with them. The level of forest development activity in a watershed will be considered when scheduling selected watersheds for these installations. The timing of forest development activity will also be considered when scheduling the time of year (if less than 1 year) these type of stations will be in place.

Fine Filter Approach - Site Specific Data Collection

It is proposed to collect site specific data immediately upstream and downstream from active forest development sites (upstream and downstream from active harvest or road building sites). These sites would be chosen so as to represent development in the various BEC zones. This data may be evaluated with an index station or roving station data in the same watershed to compare and contrast the results. The duration that these monitoring installations would be operational will be based on the level of success in achieving the desired results and on any water quality impacts that may be identified.

The results of the monitoring phase will be reviewed to determine if the target water quality conditions are being achieved. In cases where it appears that the targets are not achieved, further investigations/assessments will be conducted. The results will be incorporated into the Adaptive Management Phase.

Adaptive Management Phase

This phase allows for changes in both the monitoring program as well as changes in forest development practices. If it becomes evident that the target water quality conditions are not being met due to forest practices, then forest practices may have to be modified. If it is evident that the desired water quality results may be inappropriate, then it is possible to revisit the desired results.

1. Indicator: Turbidity

Rationale: Turbidity is a measurement that describes the “cloudiness” of water. Suspended particles in water cause incoming light to scatter and give water a cloudy appearance. The suspended particles can include clay, silt, fine sand, organic material (leaf litter, algae, and other micro-organisms (Hammer, 1986). In the context of domestic water, turbidity is important as suspended particles can impair the effectiveness of various disinfection processes and is aesthetically displeasing. In many BC interior streams, spring freshet and rain events bring with them sediment laden water, which cause peaks in turbidity levels. Health Canada’s guideline for drinking water that does not receive treatment to remove turbidity is a maximum of 1 NTU (nephelometric turbidity units). The acceptable turbidity level for raw water that is to be chlorinated is ≤ 5 NTU if it can be demonstrated that disinfection is not compromised by the use of the less stringent value.

In snowmelt dominated watersheds, turbidity tends to be higher during the spring freshet period mainly as a result of increased stream flows. For the TFL the spring freshet, resulting from snowmelt in the upper elevations, typically occurs from April to June. Based on this information the turbidity data is divided into two separate periods: clear flow period and turbid flow period. The turbid flow period coincides with spring freshet between April 1 to June 30 with the clear flow period occurring during the remainder of the year (Dobson, 2003).

Automated turbidity measurement is subject to interference from direct sunlight, aquatic organisms, bubbles and large pieces of debris (leaf litter etc.) which can result in erroneous data (MWLAP, 1999). Because of the potential for errors in continuous data collection, changes in turbidity that persist for greater than a 1 hour period can be considered true changes. This method of data assessment helps filter out short lived turbidity spikes that are usually the result of sensor interference. In addition to the above stated criteria, large turbidity spikes (versus ramping up of turbidity values) may also indicate sensor interference. In cases where “spikey” data is problematic, turbidity values will be assessed over a 30 day period. In all cases data sets must be critically assessed to determine the reliability of the data (Cavanagh et al, 1998).

Measurable: Nephelometric Turbidity Units (NTU)

Threshold: Site specific, however, using Lambly Creek as an example: When using automated sampling (typically from March to November), maintain 90% of the continuous data at <5NTU during the turbid flow period and maintain 99% of the continuous data at <5 NTU during the clear flow period.

Target: In streams where background turbidity levels are 5 NTU or less, development should not result in increases greater than 2 NTU. In streams with background turbidity >5 NTU, development should not result in increases greater than 10% of background values.

Range: Site specific, using the baseline ranges where they exist.

What to measure?
Key streams (index streams), measure at point immediately upstream from private/Crown land interface, or immediately upstream from Point of Diversion for water intakes. Site specific monitoring upstream and downstream from active road building/maintenance sites and or active cut-blocks or treatment sites (Harvesting, site preparation, etc.).

How to measure it?
Maintain long term monitoring stations on key index streams (Lambly Creek and Whiteman Creek) and establish other key index stations to cover the Salmon River portion of the TFL. Additional roving stations in selected developed watersheds can be used as a “check-up” station to monitor additional watersheds on a short-term basis. Site specific monitoring above and below active forest development sites can be used for site specific effectiveness monitoring. Collect routine grab samples or use automated equipment for continuous measurements (following RISC standards).

What to measure against?
Canadian Drinking Water Guidelines, provincial guidelines, background information where it exists. Also in the case of above and below monitoring sites, measure treated sites against untreated sites.

What does the measurement mean?
If no change in results from background, infer that there is no negative effect from the treatment sites. If changes are detected, investigate possible sources both natural and forest development related, and adjust practices to solve any potential problems.

2. Indicator: Stream Temperature

Rationale: Stream temperature describes the amount of thermal energy in the water. Temperature is important to the quality of drinking water supplies for both health and aesthetic reasons. As water temperature increases, so does the potential for biological growth. Increased biological growth can increase chlorine demand and reduce the effects of the chlorination process (Hammer, 1986). In addition, decaying organics in the water can cause taste and odour problems for the consumer. Air temperature and direct solar radiation affect water temperature (Teti, 1998). The maximum temperature guideline for drinking water quality is 15°C (Nagpal *et. al.*, 1998), however it is not unusual for this temperature to be exceeded during the warm summer months.

Measurable: Degrees Celcius (°C)

Threshold: Maximum daily temperature not to exceed 25°C (based on data from index streams).

Target: Ideally, maintain temperature at or below 15°C at the Point of Diversion for community watersheds (recognizing that extreme summer air temperatures can result in extreme water temperatures). MWLAP, 2001 states: *"The natural temperature cycle characteristic of the site should not be altered in amplitude or frequency by human activities*". Using Lambly Creek as an example, during the summer months, temperature not to exceed 15°C on more than 33 dates during periods of "*normal" summer air temperatures. (*normal as defined by Environment Canada)

Range: 0-25°C based on index stream data.

What to measure?
Key streams (index streams), measure at point immediately upstream from private/Crown land interface, or immediately upstream from Point of Diversion for water intakes. Site specific monitoring upstream and downstream from active road building/maintenance sites and or active cut-blocks or treatment sites (harvesting, site preparation, etc.).

How to measure it?
Use automated/continuous temperature logging devices (RISC approved).

What to measure against?
Background levels, drinking water guidelines for various water uses (drinking water, aquatic life, recreation).

What does the measurement mean?
Stream temperatures exceeding the drinking water guidelines (15°C) should only occur during the hottest summer months. If the threshold or target is exceeded, investigate forest development in the watershed and assess for potential loss of shading on streams, or water diversions (water re-directed via roads, ditches and cutblocks). Adjust practices to alleviate problems.

3. Indicator: Discharge

Rationale: Discharge refers to the volume and rate that water flows in a stream. Stream discharge patterns are primarily affected by local climatic conditions and interior streams experience peak discharge during the spring time snow melt period (Teti, 1993). Intense rainstorms can also affect discharge, as can groundwater levels, soil conditions, watershed geometry and topography. Changes in discharge are important with respect to domestic and agricultural water supplies and aquatic life. Forest development can affect low flows, peak flows and annual water yield (MacDonald et al, 1991, Teti, 1993). If stream flow is not directly measured, the Peak Flow Hazard Rating is a method used to assess the potential impacts forest development has on streamflow patterns. This method uses GIS data to assess the amount of development (road building and forest cover removal) and the potential effects this has on streamflow patterns. Depending on the intensity of development, there are three peak flow hazard categories: low, moderate and high.

Measurable: Cubic meters per second (m^3/s), peak flow hazard rating

Threshold: No net negative affect on channel stability or water quality related to increased peak flows. If using peak flow hazard ratings, manage the watershed to ensure the peak flow hazard does not exceed a moderate rating.

Target: Maintain flows in streams to normal levels (possibly use known discharge data on nearby streams to estimate what normal levels are in streams with unknown baseline data).

Range: Site specific, to be determined.

What to measure?
Key streams (index streams), measure at point immediately upstream from private/crown land interface, or immediately upstream from Point of Diversion for water intakes. Site specific monitoring would not be effective for this parameter.

How to measure it?
Using approved standards (RISC) measure channel cross sectional area and water velocity at various discharges to establish a stage (level) discharge curve (prediction chart relating various water levels to corresponding discharges. The formula used is Q=AxV, where Q= discharge in m^3/s, A= cross sectional area of the channel in m^2 and V=water velocity in m/s.

What to measure against?
Normal (once established) flow patterns (timing and magnitude of flows).

What does the measurement mean?
If flow patterns (hydrographs) exceed or significantly vary from the baseline data, then development needs to be assessed and current snowpack research data could be assessed to determine if climatic conditions or if forest development contributed to the changes in flow patterns.

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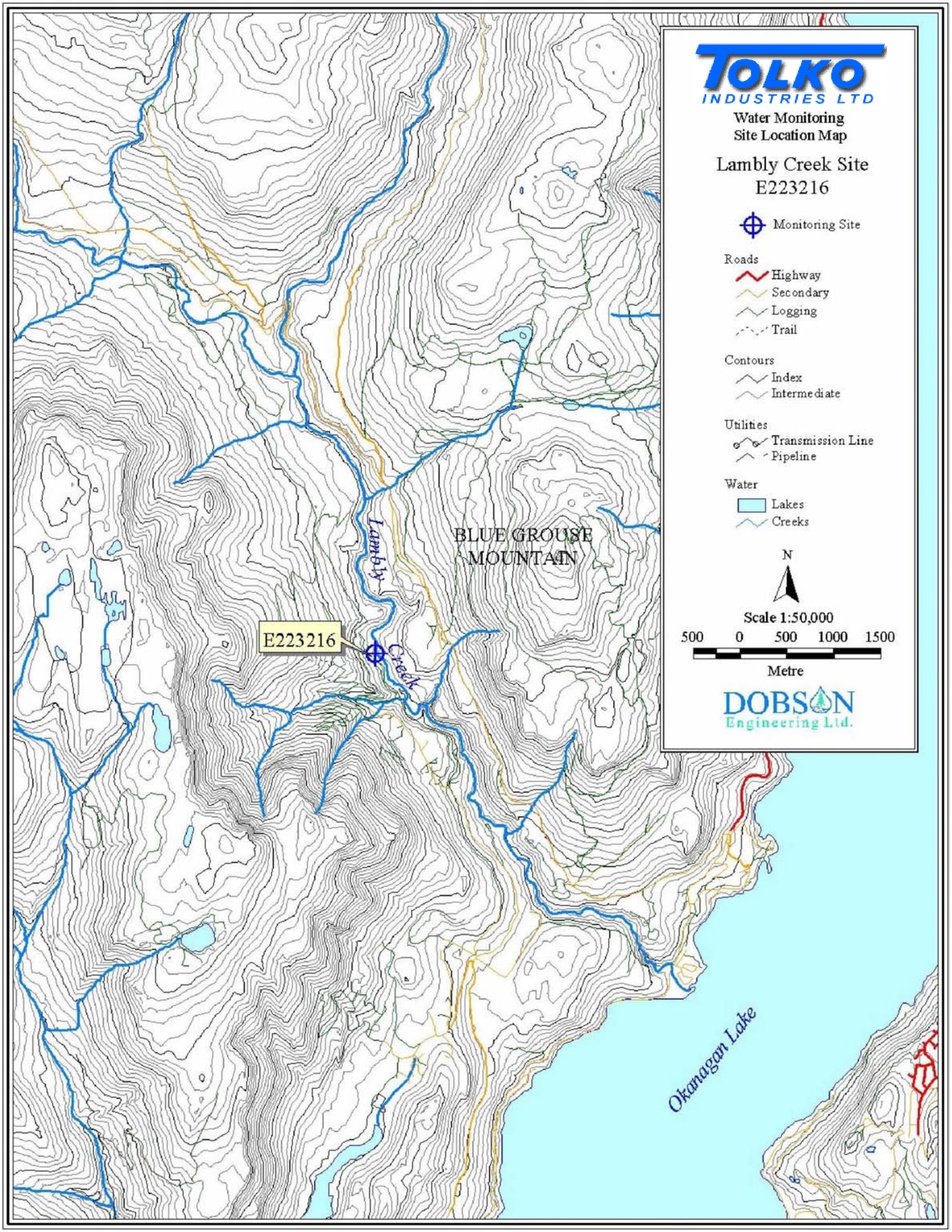
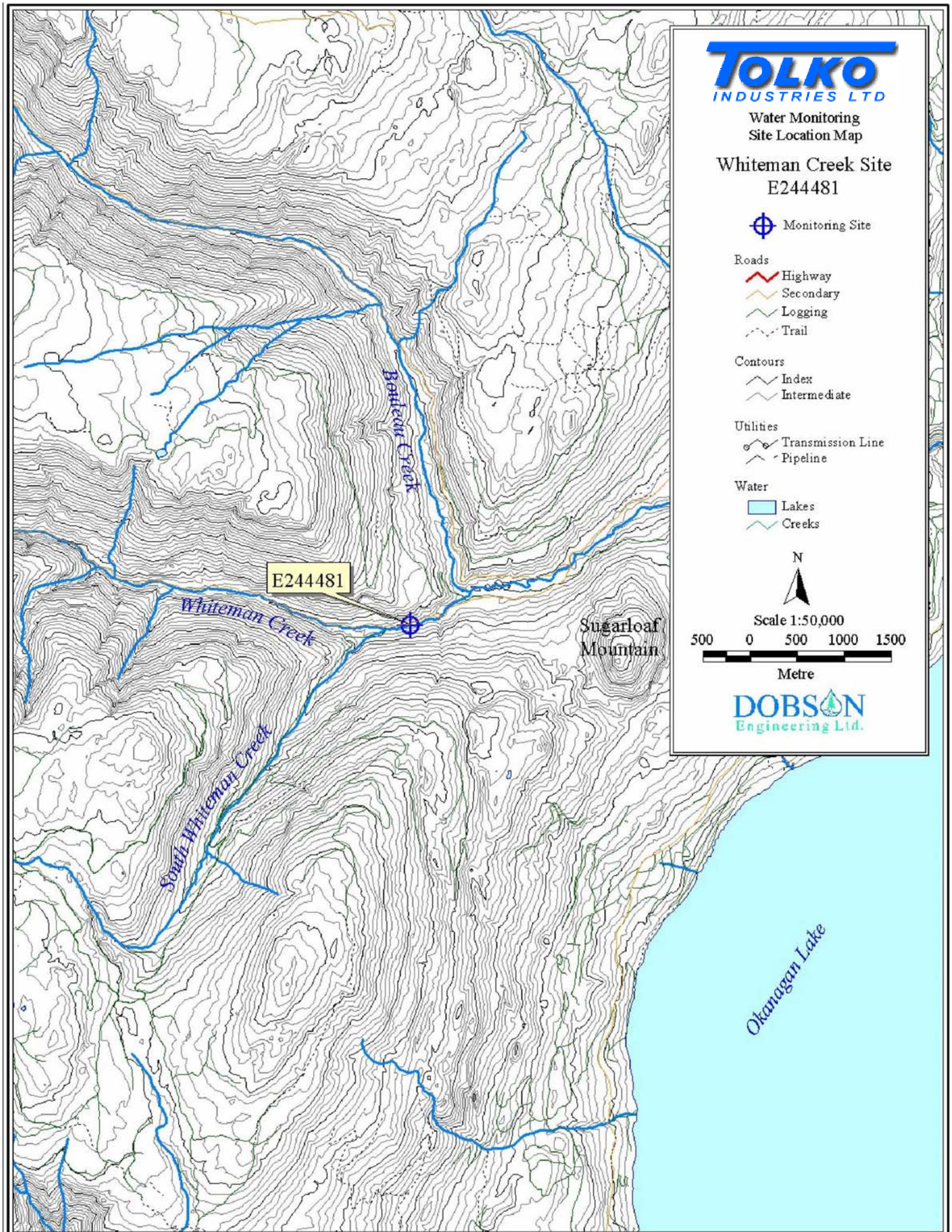
APPENDIX B

Water Quality Monitoring Sites – Location Maps



TOLKO
INDUSTRIES LTD
Water Monitoring
Site Location Map
Lambly Creek Site
E223216
Monitoring Site
Roads
Highway
Secondary
Logging
Trail
Contours
Index
Intermediate
Utilities
Transmission Line
Pipeline
Water
Lakes
Creeks
N
Scale 1:50,000
500 0 500 1000 1500
Metre
DOBSON
Engineering Ltd.
Lambly Creek
BLUE GROUSE MOUNTAIN
E223216
Okanagan Lake



TOLKO INDUSTRIES LTD
Water Monitoring
Site Location Map
Whiteman Creek Site
E244481
Monitoring Site
Roads
Highway
Secondary
Logging
Trail
Contours
Index
Intermediate
Utilities
Transmission Line
Pipeline
Water
Lakes
Creeks
N
Scale 1:50,000
500 0 500 1000 1500
Metre
DOBSON
Engineering Ltd.
Bouleau Creek
E244481
Whiteman Creek
Sugarloaf Mountain
South Whiteman Creek
Okanagan Lake

APPENDIX C

2008 Water Quality Data Summary – Tables 1 - 4

Appendix C - Table 1

Discrete Sample Results for Lambly Creek (E223216)

Date	Time	Temp	Turb	Cond.
2008/04/16	1215	2.2	0.66	171.3
2008/05/06	1130	3.9	4.94	100
2008/05/20	1445	5.8	5.09	61.6
2008/06/10	915	7.4	0.75	89.9
2008/06/18	1110	9.2	0.31	112.4
2008/07/02	810	14.1	0.23	164.8
2008/07/15	745	11	0.03	183.3
2008/08/05	1250	13.9	0.18	127.7
2008/08/19	1340	15.4	0.20	121.9
2008/09/09	930	8	0.10	135.1
2008/09/25	800	7.5	0.09	142.7
2008/10/07	1040	7.6	0.02	147.0
2008/10/27	1115	0.3	0.30	210.0
2008/11/12	1320	5.1	0.13	183.2
Maximum		15.40	5.09	210.00
Minimum		0.30	0.02	61.60
Mean/Median		7.96	0.93	139.35
Std Deviation		4.48	1.74	40.96

Turbid Flow

	Turb.
	0.66
	4.94
	5.09
	0.75
	0.31
N	**5**
Max	**5.09**
Min	**0.31**
Mean	**2.35**

Clear Flow

	0.23
	0.03
	0.18
	0.20
	0.10
	0.09
	0.02
	0.30
	0.13
N	**9**
Max	**0.30**
Min	**0.02**
Mean	**0.14**

Appendix C - Table 2

Discrete Samples for Whiteman Creek (E244481)

Date	Time	Temp	Turb	Cond.
2008/03/29	1315	1.1	0.7	294
2008/04/16	1355	2.5	2.14	237.0
2008/05/06	1310	4	3.85	112.4
2008/05/15	630	5.3	43.50	85.0
2008/05/28	610	8.5	8.50	82.0
2008/06/04	1320	8.2	1.38	102.9
2008/06/10	1111	7.3	1.40	103.3
2008/06/18	1250	9.1	0.90	131.9
2008/07/02	945	13.9	0.31	184.9
2008/07/15	1005	11.8	0.00	232.0
2008/08/05	1015	12.5	0.00	295.0
2008/08/19	1145	14.3	0.00	315.0
2008/09/09	730	8.8	0.00	346.0
2008/09/25	755	7.2	0.00	363.0
2008/10/07	900	6.8	0.00	369.0
2008/10/27	950	1.1	0.00	342.0
2008/11/12	1005	3.8	0.29	292.0
Maximum		14.30	43.50	369.00
Minimum		1.10	0.00	82.00
Mean/Median		7.82	3.89	224.59
Std Deviation		3.93	10.79	109.09

Turbid Flow Period

	Turb.
	2.14
	3.85
	43.50
	8.50
	1.38
	1.40
	0.90
N	**7**
Max	**43.50**
Min	**0.90**
Mean	**8.81**

Clear Flow Period

	Turb.
	0.7
	0.31
	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
	0.00
	0.29
N	**10**
Max	**0.70**
Min	**0.00**
Mean	**0.13**

Appendix C - Table 3

2008 Lambly Autostation Data Verification

		Turbidity		Conductivity		Temperature	
Date	Time	Auto	*Field	Auto	Field	Auto	Field
2008/04/16	1215	0.00	0.66	174.0	171.3	2.7	2.2
2008/05/06	1130	3.30	4.94	100.0	100.0	4.1	3.9
2008/05/20	1445	3.50	5.09	59.0	61.6	6.2	5.8
2008/06/10	915	0.00	0.75	87.0	89.9	7.8	7.4
2008/06/18	1110	0.00	0.31	104.0	112.4	9.5	9.2
2008/07/02	810	0.30	0.23	155.0	164.8	14.2	14.1
2008/07/15	745	0.00	0.03	182.0	183.3	11.4	11.0
2008/08/05	1250	0.20	0.18	125.0	127.7	13.8	13.9
2008/08/19	1340	0.30	0.20	123.0	121.9	15.5	15.4
2008/09/09	930	0.00	0.10	140.0	135.1	8.0	8.0
2008/09/25	800	0.00	0.09	141.0	142.7	7.3	7.5
2008/10/07	1040	0.00	0.02	144.0	147.0	7.7	7.6
2008/10/27	1115	0.00	0.30	196.0	210.0	0.3	0.3
2008/11/12	1320	-	0.13	-	183.2	-	5.1

*Field Value is the average of three sample measurements taken at each site visit.

Appendix C - Table 4

2008 Whiteman Autostation Data Verification

Date	Time	Turbidity Auto	Turbidity *Field	Conductivity Auto	Conductivity Field	Temperature Auto	Temperature Field	
2008/03/29	1315	0.00	0.70	284.0	294.0	1.3	1.1	
2008/04/16	1355	-	2.14	-	237.0	-	2.5	
2008/05/06	1310	3.50	3.85	115.0	112.4	4.2	4	
2008/05/15	1830	50.80	43.50	77.0	85.0	5.4	5.3	Sand and debris affected probes
2008/05/28	1810	10.50	8.50	80.0	82.0	8.7	8.5	
2008/06/04	1320	1.00	1.38	97.0	102.9	8.4	8.2	
2008/06/10	1111	0.80	1.40	103.0	103.3	7.5	7.3	
2008/06/18	1250	0.00	0.90	128.0	131.9	9.0	9.1	
2008/07/02	915	1.50	0.31	181.0	184.9	13.7	13.9	
2008/07/15	1005	0.00	0.00	229.0	232.0	11.9	11.8	
2008/08/05	1115	0.00	0.00	295.0	295.0	12.9	12.5	
2008/08/19	1145	0.00	0.00	321.0	315.0	14.4	14.3	
2008/09/09	730	0.00	0.00	346.0	346.0	8.5	8.8	
2008/09/25	755	0.00	0.00	369.0	363.0	7.2	7.2	
2008/10/07	900	0.00	0.00	362.0	369.0	6.7	6.8	
2008/10/27	950	0.00	0.00	330.0	342.0	0.9	1.1	
2008/11/12	1005	0.40	0.29	281.0	292.0	3.4	3.8	

*Field Value is the average of three sample measurements taken at each site visit.

APPENDIX D

Climate and Stream Discharge Data

Appendix D - South BC Mountains Environment Canada Climate Data (1948-2008)

Regional Precipitation Departures From Normal - Ranked Wettest to Driest, 1948 - 2008
Regional Temperature Departures From Normal - Ranked Warmest to Coolest, 1948 - 2008

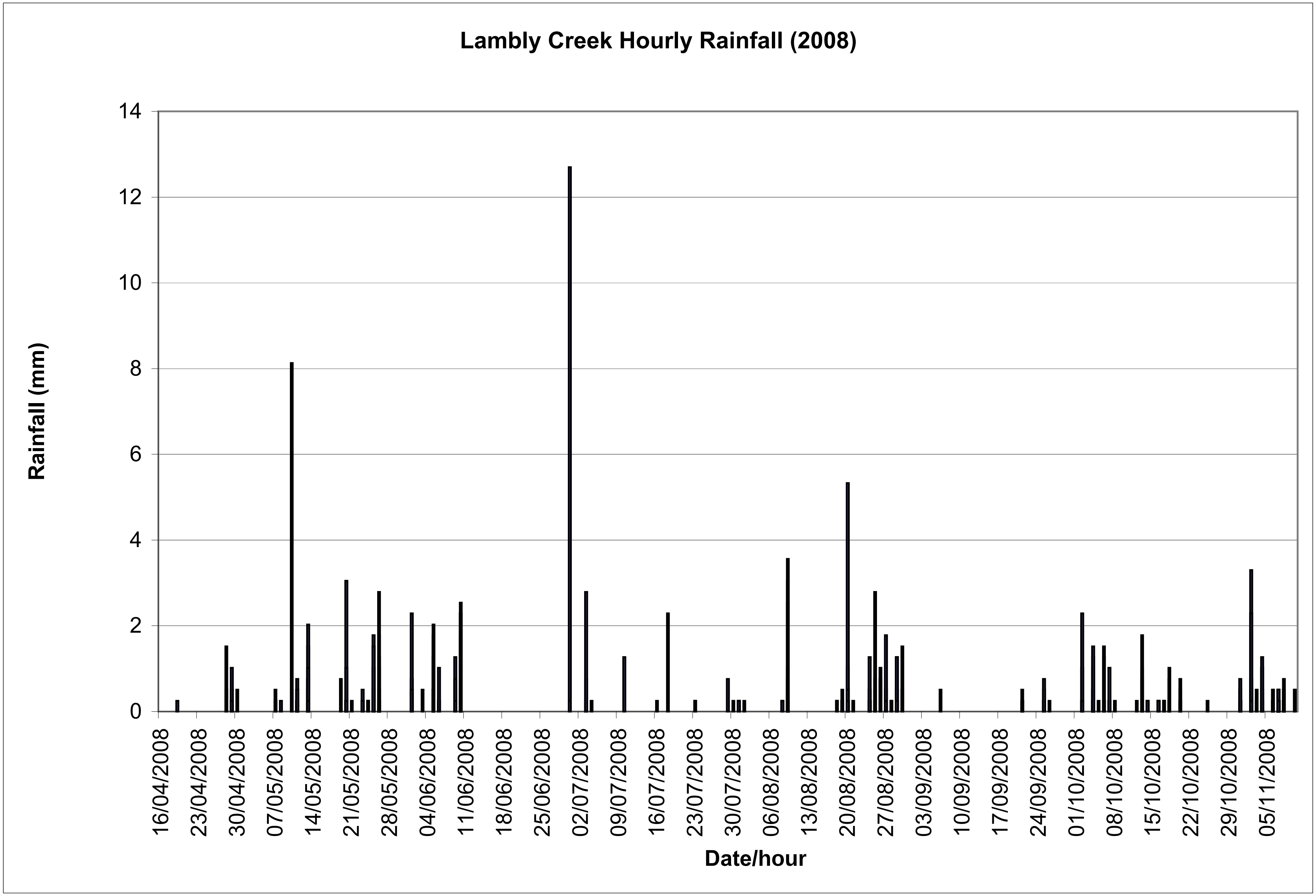
	Winter Precip.		Winter Temp.		Spring Precip.		Spring Temp.		Summer Precip.		Summer Temp.		Fall Precip.		Fall Temp.	
Rank	Yr	Dep. %	Yr	Dep. °C	Yr	Dep. %	Yr	Dep. °C	Yr	Dep. %	Yr	Dep. °C	Yr	Dep. %	Yr	Dep. °C
1	1972	44.1	1992	5	1996	51.9	1992	2.6	1993	71.1	1958	2.4	1959	66.1	1987	2.1
2	1951	30.9	1958	3.6	2002	47.7	2005	2.4	1948	64.7	1998	2.1	1996	61.7	1998	1.6
3	1982	24.7	2003	3.3	1990	38.1	1994	2.3	1983	51.3	1961	2.1	1985	37.1	1953	1.6
4	1950	23.8	1983	3.2	1997	36.9	2004	2.3	1995	45.4	2004	1.8	1998	34	1967	1.5
5	1974	21.9	1987	3.2	1988	36.5	1998	2.2	1976	43.1	2003	1.6	2004	33.7	1963	1.5
6	1956	21.4	2006	3	2003	31	1993	2.2	1964	37.4	2006	1.5	1973	27.6	1988	1.3
7	1965	18.7	1998	3	1959	29.5	1987	1.9	1999	35.7	1967	1.5	1958	26.9	1962	1.3
8	1957	16.7	1981	2.9	1981	26.6	1983	1.7	2005	32.9	1992	1.3	1986	26	1981	1.2
9	1948	14.5	1977	2.9	1984	26.2	1958	1.6	1981	30.4	1994	1.1	2006	25.6	1949	1.2
10	1954	14.2	1967	2.6	1974	23.7	1988	1.6	1954	29	1979	1.1	1990	23.7	1980	1.2
11	1953	13.9	1961	2.6	1960	23.3	1980	1.4	1957	25.8	1970	1	1961	23.3	1952	1.2
12	1959	11.1	1999	2.5	1948	23.3	1981	1.3	1990	25.3	1990	1	1992	22.8	1954	1.2
13	1971	8.2	1953	2.4	1993	19.9	1986	1.3	1963	25.1	2007	0.8	2003	22.3	1989	1.1
14	1966	8	1964	2.3	1961	18.8	1990	1.2	1980	23.3	1989	0.7	1995	20.8	1974	1
15	1952	7.8	2007	2.2	1980	17.8	1969	1.2	2004	19.6	1978	0.7	1984	18.9	1979	0.9
16	1999	7.3	1963	2.2	1955	15.6	1949	1.1	1989	18.8	1971	0.7	1966	16.4	**2008**	**0.9**
17	1962	7	1990	2.2	1968	15.5	1957	1.1	1982	18.6	1965	0.6	1955	14.7	1969	0.9
18	1976	6.8	2005	2.1	1978	14.7	1995	1.1	1959	17.9	2002	0.6	1951	14.4	1995	0.9
19	1975	3.2	1994	2	1998	13.8	2007	1.1	1991	17.5	1985	0.6	1964	13.9	1997	0.9
20	1967	1.3	2002	1.7	2000	12.7	2006	1	1972	16.8	1977	0.6	1950	10.7	2001	0.8
21	1994	0.8	2000	1.7	1969	10.9	1961	0.9	1953	16.5	1987	0.6	2005	10.2	1976	0.8
22	1996	0.7	1970	1.6	1986	10.5	1973	0.9	1997	15.3	1991	0.5	1968	9.8	1999	0.7
23	1958	-1.1	1976	1.6	1977	10.2	1963	0.8	1996	12.9	1986	0.5	1963	9.3	1957	0.6
24	1949	-1.9	2004	1.6	1972	10	1985	0.7	1968	9.6	1982	0.4	1988	8.5	1990	0.5
25	1997	-2.2	1995	1.5	1964	9.7	1977	0.7	1975	9.6	1969	0.4	1962	8.4	1994	0.4
26	1968	-2.9	1986	1.2	1991	9.2	2001	0.7	1966	9.5	1950	0.3	1969	7	2005	0.4
27	1961	-4.2	1955	1.1	1966	8.8	2000	0.7	1988	7.2	1948	0.3	1982	4.6	1991	0.3
28	1990	-4.2	1960	1.1	1987	6.6	1978	0.6	1969	6.2	1997	0.3	1994	4.5	2002	0.3
29	1981	-5.1	1988	1	1950	6.2	1968	0.6	1962	5.9	2005	0.2	1997	4	1993	0.3
30	1980	-5.7	1974	0.9	1989	6	1984	0.5	1987	3.7	1996	0.2	1980	2.9	2004	0.3
31	1969	-9.2	1954	0.9	1967	5.9	1979	0.5	**2008**	**3.2**	**2008**	**0.2**	1977	2.3	1960	0.3
32	1991	-10.5	1968	0.9	1976	5.1	1991	0.4	1986	3.2	1960	0.1	1967	1.4	1966	0.3
33	1963	-17.7	1984	0.8	1994	2.3	1959	0.4	1952	0.5	1951	0.1	1999	1.3	1983	0.2
34	1964	-17.8	1948	0.8	2006	1.8	1989	0.4	2001	0.4	1984	0	1978	1.2	2007	0.1
35	1973	-18.4	2001	0.7	1995	1.4	1953	0.3	1977	-0.7	1956	0	1971	-1.1	2003	0.1
36	1978	-19.5	1980	0.6	1953	1.2	1956	0.2	2000	-0.9	1988	-0.1	1965	-1.2	1975	0
37	1992	-21.4	**2008**	**0.4**	2004	-1.4	1952	0.2	1978	-1.5	1981	-0.1	1960	-2.9	1992	0
38	1955	-21.5	1991	0.1	2007	-2	1997	0.2	1992	-1.8	1972	-0.1	1954	-4.5	1968	0
39	1989	-21.8	1959	0	1962	-2.7	1999	0.2	1971	-1.9	2000	-0.1	1975	-5.7	1948	-0.1
40	2007	-24.1	1966	0	1999	-3	2003	0.1	1984	-2.3	1963	-0.1	1989	-5.9	2000	-0.1
41	1983	-24.7	1962	-0.5	1954	-4	1966	0.1	1955	-4.6	1974	-0.1	1991	-5.9	2006	-0.2
42	2005	-25.9	1975	-0.5	1971	-5	1972	0.1	1994	-4.6	2001	-0.1	1949	-6.4	1965	-0.2
43	1988	-26.7	1997	-0.6	1951	-5.5	**2008**	**0.1**	1965	-5.1	1983	-0.2	1970	-7.2	1986	-0.3
44	1960	-26.8	1989	-0.7	1957	-9.2	1970	-0.1	2007	-5.9	1995	-0.3	2007	-7.2	1958	-0.3
45	**2008**	**-27.1**	1973	-0.7	1983	-10	1960	-0.1	1956	-6.5	1975	-0.3	1983	-8.9	1982	-0.4
46	1995	-30	1971	-0.8	1985	-11.2	1996	-0.2	1950	-12.3	1973	-0.4	1981	-11.1	1956	-0.4
47	2000	-30.4	1951	-0.9	2005	-11.3	1971	-0.3	1949	-15.5	1999	-0.4	1953	-13.1	1951	-0.5
48	1970	-30.7	1996	-1.1	1982	-15	1974	-0.3	1960	-15.7	1952	-0.4	1972	-15.9	1971	-0.6
49	1979	-31	1985	-1.1	1979	-15.3	1976	-0.3	1998	-15.8	1953	-0.5	1948	-16.5	1964	-0.6
50	1986	-31.2	1978	-1.2	1963	-15.6	1962	-0.5	1951	-18.2	1949	-0.6	1974	-16.9	1950	-0.8
51	2006	-31.6	1965	-1.3	2001	-15.6	1948	-0.7	2006	-18.5	1980	-0.7	2000	-20.1	1978	-0.9
52	1985	-31.8	1982	-1.6	1992	-16.2	1965	-0.8	1961	-19.7	1968	-0.7	**2008**	**-20.2**	1972	-0.9
53	2002	-32.1	1952	-2	**2008**	**-17**	1951	-0.8	1974	-20.5	1955	-0.7	1956	-20.8	1977	-1.1
54	1977	-32.6	1993	-2.4	1970	-18.6	1982	-0.9	1985	-25.4	1962	-0.7	1957	-23	1973	-1.3
55	1984	-35.5	1957	-3.2	1958	-18.8	1964	-0.9	1958	-26.8	1959	-0.7	2002	-26.5	1959	-1.5
56	1998	-36.5	1956	-3.4	1949	-19.5	1950	-0.9	1970	-30.7	1993	-0.7	1993	-27.3	1970	-1.6
57	2003	-36.9	1972	-3.9	1952	-23.2	1975	-1.2	2002	-33.2	1966	-0.8	2001	-28.1	1984	-1.7
58	1993	-38.6	1979	-4	1973	-23.4	1967	-1.3	2003	-35.2	1964	-0.9	1979	-35.1	1996	-1.8
59	2004	-42.8	1949	-4.5	1965	-24.7	2002	-1.8	1979	-35.8	1957	-1.2	1987	-40.8	1961	-1.9
60	1987	-50.4	1969	-4.9	1956	-25.3	1954	-1.9	1973	-37	1976	-1.3	1976	-42.7	1955	-2.4
61	2001	-52.7	1950	-5	1975	-27.5	1955	-2.9	1967	-49.2	1954	-1.6	1952	-58.8	1985	-4.1

Lambly Creek and Kelowna Airport Precipitation (mm)
(April through October, 2001 - 2008)

Month	2001		2002		2003		2004		2005		2006	
	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna
April	33.8	33.9	-	10.2	-	30.6	19.3	10.5	15	17.5	29	32
May	26.2	25.8	-	44.0	33.5	26.2	78.0	48.5	14.23	27.5	56.9	53
June	56.6	47.0	17.3	20.5	22.3	21.2	32.3	36.5	68.06	67	34.8	29.5
July	33.5	45.4	13.2	12.4	0.3	0	5.1	19.0	19.29	25	26.7	24.5
Aug.	32.5	20.4	17.8	19.2	2.5	2.4	76.9	79.5	27.18	33	6.3	7.5
Sept.	24.4	27.8	19.6	17.4	15.2	24.6	54.6	45.5	14.97	21.5	16.8	17.5
Oct.	67.6	35.8	2.8	7.2	63.3	58.2	36.1	30.0	42.67	29	21.8	15
Total	**274.6**	**236.1**	***70.7**	**130.9**	***137.1**	**163.2**	**302.3**	**269.5**	**201.4**	**220.5**	**192.3**	**179.0**

*Total does not include April and/or May data, which was not collected in 2002.

Month	2007		2008		2009		2010		2011		2012	
	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna	Lambly	Kelowna
April	0.8	7.5	4.3	7.5								
May	12.4	16.0	41.9	39.0								
June	74.2	78.5	24.9	31.0								
July	45.2	35.5	22.6	8.5								
Aug.	8.6	10.5	40.6	37.0								
Sept.	19.3	28.0	4.3	27.0								
Oct.	73.4	45	25.4	7.0								
Total	**233.9**	**221.0**	**164.0**	**157.0**								


Lambly Creek Hourly Rainfall (2008)
Rainfall (mm)
0
2
4
6
8
10
12
14
16/04/2008
23/04/2008
30/04/2008
07/05/2008
14/05/2008
21/05/2008
28/05/2008
04/06/2008
11/06/2008
18/06/2008
25/06/2008
02/07/2008
09/07/2008
16/07/2008
23/07/2008
30/07/2008
06/08/2008
13/08/2008
20/08/2008
27/08/2008
03/09/2008
10/09/2008
17/09/2008
24/09/2008
01/10/2008
08/10/2008
15/10/2008
22/10/2008
29/10/2008
05/11/2008
Date/hour

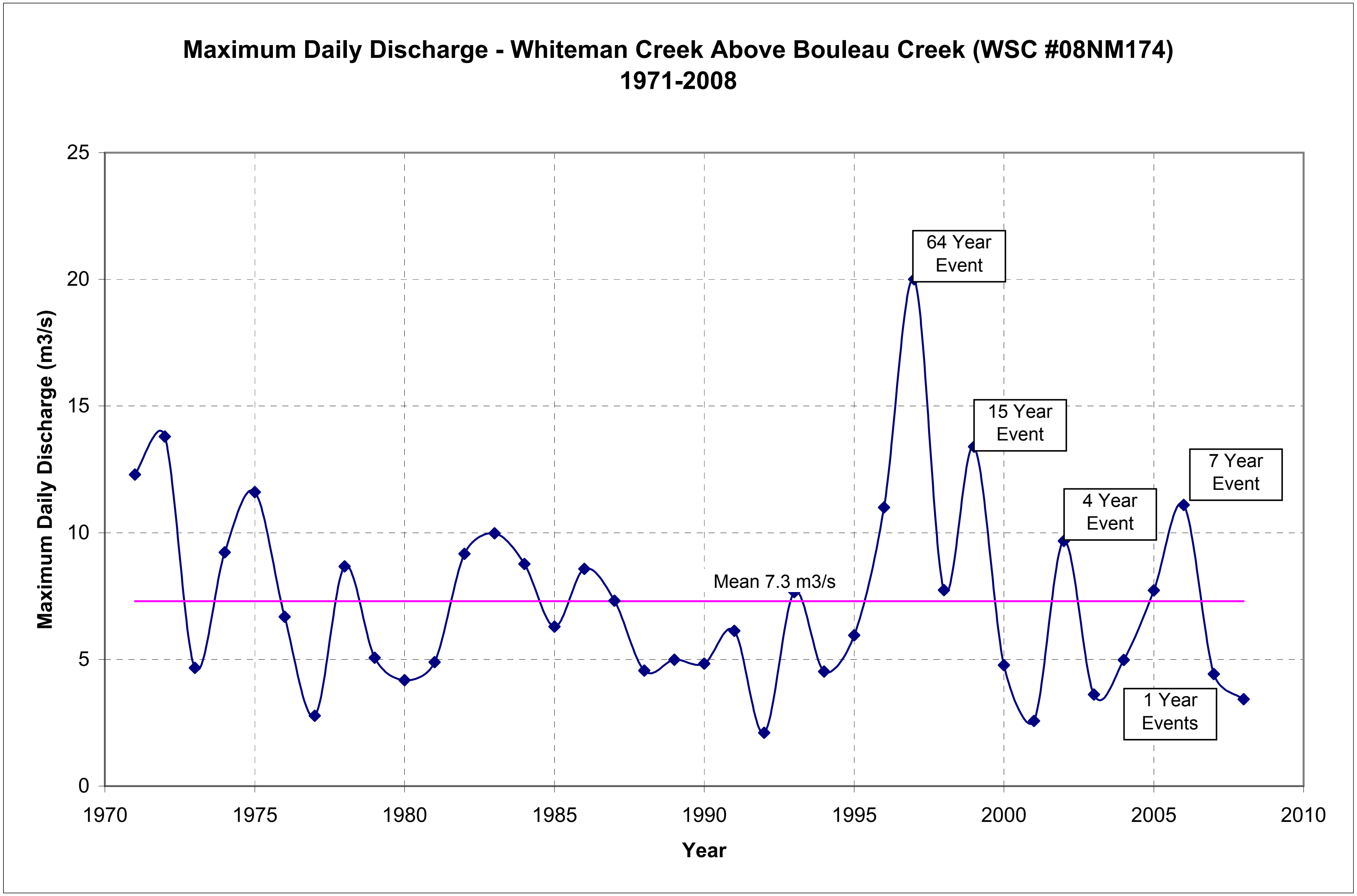
Lambly Creek at LID Intake
2008 Mean Daily Discharge (m3/s)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	-	-	-	-	0.753	2.360	0.019	0.024	0.025	0.006	0.034	-	**1**
2	-	-	-	-	0.675	2.289	0.001	0.021	0.021	0.016	0.046	-	**2**
3	-	-	-	-	1.011	2.075	0.021	0.020	0.016	0.032	0.048	-	**3**
4	-	-	-	-	1.252	1.897	0.089	0.006	0.000	0.046	0.048	-	**4**
5	-	-	-	-	1.792	1.721	0.056	0.000	0.000	0.043	0.045	-	**5**
6	-	-	-	-	2.294	1.896	0.024	0.000	0.000	0.023	0.023	-	**6**
7	-	-	-	-	3.333	1.805	0.005	0.000	0.000	0.031	0.024	-	**7**
8	-	-	-	-	3.523	1.709	0.000	0.002	0.000	0.022	0.045	-	**8**
9	-	-	-	-	3.150	1.533	0.017	0.082	0.000	0.018	0.071	-	**9**
10	-	-	-	-	3.121	1.560	0.025	0.135	0.000	0.020	-	-	**10**
11	-	-	-	-	3.508	1.428	0.048	0.069	0.000	0.020	-	-	**11**
12	-	-	-	-	3.537	1.304	0.010	0.045	0.000	0.027	-	-	**12**
13	-	-	-	-	3.684	1.203	0.000	0.035	0.000	0.035	-	-	**13**
14	-	-	-	-	3.803	1.114	0.001	0.028	0.000	0.077	-	-	**14**
15	-	-	-	-	4.598	1.063	0.002	0.023	0.000	0.019	-	-	**15**
16	-	-	-	0.387	5.798	1.020	0.001	0.017	0.000	0.029	-	-	**16**
17	-	-	-	0.405	6.548	0.974	0.000	0.015	0.000	0.030	-	-	**17**
18	-	-	-	0.480	7.007	0.874	0.002	0.017	0.000	0.045	-	-	**18**
19	-	-	-	0.422	6.438	0.790	0.007	0.025	0.000	0.037	-	-	**19**
20	-	-	-	0.375	5.725	0.703	0.000	0.041	0.000	0.068	-	-	**20**
21	-	-	-	0.368	4.904	0.625	0.040	0.053	0.003	0.098	-	-	**21**
22	-	-	-	0.377	4.254	0.580	0.021	0.037	0.008	0.095	-	-	**22**
23	-	-	-	0.364	3.984	0.432	0.002	0.026	0.010	0.094	-	-	**23**
24	-	-	-	0.297	3.826	0.289	0.034	0.023	0.012	0.091	-	-	**24**
25	-	-	-	0.195	3.670	0.214	0.022	0.041	0.014	0.088	-	-	**25**
26	-	-	-	0.306	4.218	0.129	0.016	0.025	0.010	0.076	-	-	**26**
27	-	-	-	0.403	3.974	0.107	0.011	0.033	0.007	0.080	-	-	**27**
28	-	-	-	0.578	3.452	0.090	0.010	0.033	0.005	0.084	-	-	**28**
29	-	-	-	0.937	3.201	0.067	0.012	0.043	0.005	0.036	-	-	**29**
30	-	-	-	0.918	2.793	0.034	0.029	0.047	0.005	0.022	-	-	**30**
31	-	-	-	-	2.449	-	0.021	0.031	-	0.028	-	-	**31**
Max				**0.937**	**7.007**	**2.360**	**0.089**	**0.135**	**0.025**	**0.098**	**0.071**		
Min				**0.195**	**0.675**	**0.034**	**0.000**	**0.000**	**0.000**	**0.006**	**0.023**		
Mean				**0.454**	**3.622**	**1.063**	**0.018**	**0.032**	**0.005**	**0.046**	**0.043**		

Site was established on April 16, data not available prior to this date. The above values represent only flows over the weir.
LID maintains 0.116 m3/s for fish flows at all times via a bypass pipe, in addition to the above values.
Site was shut down for the year on November 15, data not available beyond this date.

Whiteman Creek above Bouleau Creek - 08NM174 - (Preliminary Data)
2008 Mean Daily Discharge (m3/s)

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Day
1	0.09	0.067	0.108	0.091	0.46	2.791	0.547	0.205	0.057	0.049	0.143	0.102	**1**
2	0.091	0.064	0.109	0.088	0.478	2.642	0.517	0.189	0.045	0.053	0.157	0.102	**2**
3	0.091	0.064	0.114	0.086	0.732	2.399	0.501	0.19	0.041	0.065	0.181	0.093	**3**
4	0.092	0.062	0.114	0.092	1.031	2.247	0.51	0.176	0.044	0.099	0.176	-	**4**
5	0.095	0.068	0.109	0.104	1.585	2.159	0.487	0.159	0.038	0.107	0.189	-	**5**
6	0.091	0.06	0.105	0.104	1.888	2.181	0.457	0.15	0.041	0.095	0.17	-	**6**
7	0.09	0.063	0.107	0.107	2.03	2.306	0.452	0.145	0.051	0.116	0.167	-	**7**
8	0.089	0.062	0.113	0.109	1.861	2.097	0.426	0.136		0.096	0.219	-	**8**
9	0.088	0.059	0.123	0.11	1.679	1.915	0.406	0.207	0.043	0.092	0.268	-	**9**
10	0.087	0.065	0.138	0.122	1.728	1.875	0.409	0.293	0.04	0.091	0.263	-	**10**
11	0.086	0.072	0.145	0.15	1.93	1.709	0.428	0.243	0.041	0.102	0.252	-	**11**
12	0.087	0.07	0.141	0.259	2.022	1.624	0.391	0.206	0.04	0.111	0.245	-	**12**
13	0.087	0.064	0.136	0.328	2.093	1.508	0.371	0.188	0.041	0.115	0.256	-	**13**
14	0.086	0.061	0.135	0.253	2.412	1.465	0.355	0.174	0.039	0.203	0.225	-	**14**
15	0.083	0.063	0.133	0.23		1.346	0.348	0.159	0.034	0.178	0.22	-	**15**
16	0.119	0.062	0.129	0.243		1.258	0.327	0.144	0.035	0.147	0.259	-	**16**
17	0.074	0.06	0.125	0.279		1.18	0.317	0.123		0.16	0.24	-	**17**
18	0.074	0.06	0.124	0.265		1.115	0.308	0.125	0.031	0.228	0.223	-	**18**
19	0.075	0.062	0.12	0.254		1.053	0.314	0.136	0.026	0.216	0.237	-	**19**
20	0.077	0.064	0.12	0.225		1.015	0.296	0.161	0.027	0.188	0.213	-	**20**
21	0.912	0.067	0.114	0.2	3.426	0.975	0.277	0.189		0.19	0.291	-	**21**
22	1.254	0.069	0.11	0.181	3.033	0.955	0.256	0.172	0.044	0.169	0.253	-	**22**
23	0.441	0.075	0.112	0.17	3.334	0.904	0.258	0.148	0.064	0.157	0.06	-	**23**
24	0.117	0.071	0.11	0.163	3.036	0.861	0.248	0.139	0.079	0.148	0.091	-	**24**
25	0.084	0.078	0.102	0.166	2.886	0.832	0.235	0.148	0.082	0.14	0.106	-	**25**
26	0.093	0.076	0.106	0.222		0.794	0.226	0.135	0.075	0.132	0.093	-	**26**
27	0.093	0.079	0.101	0.353		0.745		0.142	0.073	0.119	0.08	-	**27**
28	0.091	0.089	0.096	0.525		0.694		0.136	0.063	0.123	0.078	-	**28**
29	0.089	0.094	0.095	0.534	3.133	0.639	0.184	0.105	0.06	0.104	0.092	-	**29**
30	0.088	-	0.091		3.11	0.592	0.187	0.068	0.055	0.127	0.095	-	**30**
31	0.07	-	0.09	-	3.158	-	0.17	0.062	-	0.133	-	-	**31**
Max	**1.254**	**0.094**	**0.145**	**0.534**	**3.426**	**2.791**	**0.547**	**0.293**	**0.082**	**0.228**	**0.291**	**0.102**	
Min	**0.070**	**0.059**	**0.090**	**0.086**	**0.460**	**0.592**	**0.170**	**0.062**	**0.026**	**0.049**	**0.060**	**0.093**	
Mean	**0.164**	**0.068**	**0.115**	**0.207**	**2.138**	**1.463**	**0.352**	**0.160**	**0.048**	**0.131**	**0.185**	**0.099**	


Maximum Daily Discharge - Whiteman Creek Above Bouleau Creek (WSC #08NM174)
1971-2008
Maximum Daily Discharge (m3/s)
Year
0
5
10
15
20
25
1970
1975
1980
1985
1990
1995
2000
2005
2010
64 Year Event
15 Year Event
4 Year Event
7 Year Event
1 Year Events
Mean 7.3 m3/s