Review of Ground Water/Surface Water Interactions Within the City of Merritt

Final Report

Prepared by: Kevin Bennett P.Eng, Water Stewardship and Alan Caverly R.P.Bio, Environmental Stewardship
Ministry of Environment (MOE)
Kamloops, BC

June 2009

INTRODUCTION

The Ministry of Environment (MOE) has observed critically low summer in-stream flows in the Coldwater River at Merritt. These low flows are reducing the amount of aquatic habitat in the river and impairing the "properly functioning condition" of the river ecosystem. MOE is concerned that ground water withdrawals from the Merritt aquifer are exacerbating habitat degradation during late summer low flow conditions. MOE's mandate includes promoting environmental stewardship and providing baseline data on BC's water resources and the ecosystems that rely on it. The purpose of this report is to provide scientific and technical information that supports MOE's observations on surface water and ground water conditions. Information provided in this report can be used to support regional and operational plans such as the recently initiated City of Merritt (COM) *Integrated Source Water Planning* program. MOE expects that the planning program will include developing withdrawal schedules from the deep and shallow aquifers that will mitigate adverse effects to the aquatic environment.

BACKGROUND

In 2004 and 2005, MOE Ecosystems Section staff working with Fisheries and Oceans Canada and the Nicola Tribal Association, measured stream flow in the Coldwater River at the Merritt Mountain Music festival site and at Claybanks Park. The data suggested the loss of surface water to ground water in this section of the river.

MOE has been monitoring ground water levels in the Merritt aquifer since April 1989 via provincial observation well No 296. The Merritt aquifer has been classified by the MOE as a "IA" (heavily developed, highly vulnerable) aquifer. In cooperation with COM, the MOE Water Stewardship Division expanded ground water monitoring in the Merritt aquifer to include the COM monitoring wells located near the Coldwater River. The additional ground water monitoring was completed from April 2007 to April 2008, to add

to the understanding of ground water/surface water interactions between the Coldwater River and the Merritt unconfined aquifer.

CITY OF MERRITT WELL FIELD

COM has five production wells completed in the Merritt unconfined aquifer. Four of these production wells (May Street, Voght Park 1 & 2, Collettville) are located within 20 m to 60 m of the Coldwater River and range in depth from 11 m (May Street) to 45 m (Collettville). The May Street well is not used and slated for closure. In 2007, COM constructed a deep production well at the Kengard School. This deep well is completed in a confined aquifer and screened from 150 m to 168 m below grade. Yield testing and trial production from the deep well is scheduled to begin in 2008. A Site Plan illustrating the production well and monitoring well locations and the Water Survey of Canada (WSC) station on the lower Coldwater River is included as Figure 1. Ground water use by COM, the local hydrogeology, monitoring well installation details and water chemistry is described in the 2006 Surface Water/Ground water interaction report[1] commissioned by COM. Based on this report the COM's average annual withdrawal is 0.100 m^3/sec with a maximum day demand of 0.225 m^3/sec. COM water use records indicate that the average daily pumping rate in August 2007 was approximately 0.124 m^3/sec from Voght Park, 0.020 m^3/sec from Collettville and 0.013 m^3/sec from Farley Park (0.157 m^3/sec total).

AQUATIC HABITAT AND IN-STREAM FLOW MEASUREMENTS

Low flows and high stream temperatures are considered by fisheries agencies to be key limiting factors in the production of important fish such as salmon and trout in the Southern Interior. Low flows directly affect the quantity and quality of aquatic habitats in streams. High stream temperatures limit available fish habitat, promote expansion of non-salmon species such as suckers and redside shiners and can kill fish directly or indirectly by oxygen depletion or increased susceptibility to disease and parasites. Cool tributaries and ground water inflow to surface water often provides critical thermal refuge habitat for fish in summer.[2]

The naturalized (no withdrawals) mean annual flow (MAF) for the Coldwater River at Merritt has been calculated by MOE to be approximately 8.5 m^3/sec. Over several consecutive summers MOE Ecosystem staff have documented extended periods of low flow conditions, high stream temperatures and reductions in aquatic habitat in the lower Coldwater River. These low flow conditions are often well below recommended in-stream flow levels and are inadequate to maintain good aquatic habitat for salmon and trout. Habitat measurements and fish surveys of juvenile salmon and trout on the Coldwater River by MOE indicate that 1.2 m^3/sec (15 % MAF) is quite adequate to

---

[1] BC Ground water Consulting Services Ltd., *Surface Water/Ground water Interaction Study Stage 1*, March 27, 2006.

[2] Walthers, L.C. and Nener, J.C. Continuous Water Temperature Monitoring in the Nicola River, B.C., 1994: Implications of High Measured Temperatures for Anadromous Salmonids Can. Tech. Report of Fisheries and Aquatic Sciences 2158

maintain abundant rearing habitat for salmon and trout juveniles. These observations are consistent with one of the most widely accepted in-stream flow setting procedures in North America, where flows of 10% MAF (0.85 m3/s for the Coldwater River at Merritt) are considered "short term survival flows" only[3]. An evaluation of historic hydrometric data for the Coldwater River demonstrates that an in-stream flow of 1.3 m^3/sec (15% MAF) is a frequently occurring summer low flow at the Coldwater Brookmere WSC station. However, flows recorded in the lower Coldwater River at Merritt are now frequently less than 0.43 m^3/sec (5 % MAF) for extended periods of the summer coincident with high air and water temperatures. This is well under the 10% survival flow. Measurements by MOE in 2004 and 2005 confirm that habitat diminishes rapidly at less than 10% MAF.

MOE has considered the possibility of climate change being responsible for some of the low flow effects in the lower Coldwater River. However, there is no firm evidence in the historic flow record to suggest that these low flow periods are the result of climate change. There is evidence that climate changes have caused low flow conditions to begin earlier in the summer. Low flows are lower than in the past, but there is no clear climate change signal causing this. [4] Cool ground water inputs may be essential to help salmon survive the impacts of climate change. [5]

August and September flow data for the Coldwater River Brookmere and Merritt Water Survey of Canada (WSC) LG010 stations are provided in Table 1. Historical data are included to examine changes in low flow conditions over the last four decades. The WSC Merritt station closed in 1995 but was re-established in 2005 with the assistance of COM and funding from non-government organizations. Data for years up to 2006 are daily values computed by WSC or are taken from direct measurement by MOE. Data for 2006 and 2007 are hourly values from WSC converted to a daily value and then computed for monthly average and minimum. Flows less than 5% MAF are bolded. The September 2005 minimum at Brookmere was 0.43 m^3/sec. The same day at Merritt, the flow was 0.09 m^3/sec. The Brookmere station is located approximately 35 km upriver from Merritt.

MOE has reviewed its water licensing and WELLS database. These records indicate that no new water extraction licenses have been issued for the Coldwater River since 1966 that could account for a large reduction in low flow conditions in the lower Coldwater River. MOE also notes that the COM is the largest single licensee on the Coldwater River with a license of approximately 0.1 m^3/sec.

---

[3] Tennant, D.L. 1975. Instream Flow Regimens for Fish, Wildlife, Recreation and related Environmental Resources. Completion Report. Billings, MT, U.S. Fish and Wildlife Service.

[4] Hatfield, Todd 2007. Nicola River Watershed, Water Use Management Plan Instream Flow Needs for Fish, Solander Ecological Research, Victoria, B.C.

[5] Nelitz, Marc,, Alexander, Clint A.D. and Wieckwoski 2007, Helping Pacific Salmon Survive the Impact of Climate Change on Freshwater Habitats: Case Studies Essa Technologies, Vancouver, B.C.

Table 1
Coldwater River Flow Data

Month	WSC Brookmere		WSC Merritt	
	Monthly Average (m^3/sec)	Monthly Minimum (m^3/sec – 24 hr period)	Monthly Average (m^3/sec)	Monthly Minimum (m^3/sec – 24 hr period)
August 1961			0.98	0.52
August 1965			1.49	1.08
August 1970	0.78	0.52	**0.42**	**0.28**
August 1975	2.19	1.41	1.95	1.23
August 1980	1.46	0.70	1.73	1.43
August 1985	0.73	0.43	0.54	**0.24**
August 1990	1.26	0.93	1.07	0.66
August 1994	0.62	0.41	**0.39**	**0.18**
August 2005	0.53	0.40	**0.23**	**0.08**
August 2006	0.51	0.38	0.46	**0.19**
August 2007	1.40	0.95	1.45	**0.13**
September 1961			1.49	0.67
September 1965			0.88	0.70
September 1970	0.90	0.45	0.60	**0.27**
September 1975	1.23	0.88	1.12	0.78
September 1980	1.57	0.67	2.06	1.40
September 1985	0.96	0.42	0.82	**0.26**
September 1990	1.09	0.69	0.89	0.5
September 1994	0.36	0.24	**0.17**	**0.11**
September 2005	0.91	0.43	0.95	**0.09**
September 2006	0.49	0.38	**0.38**	**0.12**
September 2007	2.08	0.44	0.66	0.46

Brookmere 5% MAF = 0.35 m^3/sec
Merritt 5% MAF = 0.43 m^3/sec
Flow < 5% MAF are in bold

The "Coldwater River at Merritt" station also records surface water temperature. Daytime summer temperatures in the lower Coldwater River are now exceeding lethal limits for salmon, trout and char (24 ^{0}C) and are well above optimums for rearing juvenile fish. Temperature data for the Coldwater River at Merritt from April 2007 to April 2008 are plotted on Figure 2 and illustrate in-stream temperatures exceeding 24 ^{0}C in August 2007. In 1997, a report prepared by Streamline Research for the Fraser Action Plan documented a period of 16 days where lower Coldwater River temperatures exceeded 25 ^{0}C, lethal for salmon and trout. Night temperatures fall below lethal limits for fish. This pattern is typical in interior streams as solar radiation stops for several hours.

In 1982, Fisheries and Oceans Canada commissioned a study that stated that the average Coldwater River temperature was generally colder than the Nicola River above Merritt.[6] Now, recent temperature data collected by MOE and DFO indicates the opposite occurs where the lower Coldwater River is usually warmer than the Nicola River. The increase in summer river temperatures suggests that the lower Coldwater River is not benefiting from periods of ground water influx that could reduce in-stream temperatures. Unfortunately, the period of record for water temperature is limited to specific years such as the 1982 work. There are more recent datasets (with similar high stream temperatures in summer) but inconsistent historic data. Changes to riparian habitats have occurred over a much longer time frame (60 to 80 years). Riparian cover has limited effect cooling in the wide floodplain on the lower mainstem Coldwater during summer low flows when stream margins are not wetted and the sun is directly overhead throughout the day. Community driven efforts to restore riparian areas and recover all benefits of riparian vegetation occurs throughout the Nicola watershed (including Coldwater).

In-stream flow measurements from August and September 2005 are provided in Table 2. Flows were measured at the Merritt Mountain Music festival site just upstream of Merritt and at Claybanks Park within the City of Merritt (Figure1) . All flows measured were less than the guideline "short-term survival flow" of 0.800 m^3/sec or 10 % MAF. Flows less than 0.400 m^3/sec or 5% MAF are marked in bold print.

Table 2
2005 Coldwater River In-Stream Flow Measurements

Date	Mountain Fest (m^3/sec)	Claybanks Park (m^3/sec)	Surface Water Loss (m^3/sec)	Surface Water Loss (% of flow at Mountain Fest)
16-Aug	**0.349**	**0.202**	0.147	42%
22-Aug	**0.323**	**0.201**	0.122	38%
25-Aug	0.44	**0.346**	0.094	21%
08-Sep	**0.346**	**0.214**	0.132	38%
22-Sep	0.762	0.663	0.099	13%
27-Sep	0.619	0.513	0.106	17%

River flow measurements from 2005 indicate that surface water losses up to 0.147 m^3/sec or 40%, were occurring in the Coldwater River between the Mountain festival site and Claybanks Park. River flows were already at critically low levels prior to reaching Merritt. MOE staff confirmed in the field that there were no surface water withdrawals occurring from the surveyed section of the river. The average loss from the six transect measurement sites was 0.12 m^3/sec, with a standard deviation of 0.02 m^3/sec. Ground water monitoring results discussed in the next sections, indicated that this is only a portion of the losing reach of the Coldwater River and that additional river losses have occurred from Claybanks to Voght Park. These loses reduce habitat well below the acceptable levels as confirmed by in-stream flow habitat analysis of the Coldwater River

[6] Kosakoski, G.T. and Hamilton, R.E. 1982. Water Requirements for the Fisheries Resource of the Nicola River, B.C. Can. MS Report of Fisheries and Aquatic Sciences 1680.

by MOE. Flows less than 10% MAF correspond with steep reductions in available habitat.

GROUND WATER MONITORING

In spring 2007 MOE installed pressure transducers in the three COM monitoring wells positioned alongside the Coldwater River. The monitoring wells are located in Voght Park (MW04-1), at Claybanks (MW04-2) and beside the May Street Well (MW04-3). The monitoring wells were installed in 2004 and completed as multi level monitoring points screened at approximately 5 m (referred to as "shallow") and 10 m below ground (referred to as "deep"). At Voght Park and May Street, the multilevel monitoring wells are completed in the unconfined sand and gravel aquifer. At Claybanks, the stratigraphy consisted of approximately 4.5 m of sand and gravel overlying silt that extended to the maximum drilling depth at 9.2 m below ground. The shallow Claybanks monitoring point is screened in the sand and gravel aquifer with the deep monitoring point completed in the underlying silt layer. Ground water movement through the silt layer would be much lower than the sand and gravel units and the silt layer would not be a productive component of the Merritt unconfined aquifer.

Transducers were installed at May Street and Claybanks in April 2007 and at Voght Park in May 2007. The transducers were set to record the ground water level and temperature hourly. These data are also being recorded at the provincial observation well adjacent to the Merritt library. The elevation of the Coldwater River at each monitoring well was surveyed ten times between April 2007 and October 2007 to compare the Coldwater River elevation with the adjacent ground water elevation. The survey data were also used to develop a correlation between the river level at the monitoring well and the water level recorded WSC's station at the Main Street bridge. The correlations were used to estimate river elevation at the three monitoring well locations based on WSC hourly river level measurements. MOE also surveyed the elevation of the three monitoring wells and the provincial observation well to geodetic reference elevations provide to MOE by COM. The monitoring well data were provided to COM in fall 2007 and spring 2008.

Ground water elevation data for the three monitoring wells, the provincial observation well and the Coldwater River are contoured on Figure 3 (June 26, 2007) and Figure 4 (August 3, 2007). Ground water flow on both dates was north-westerly at a gradient of approximately 0.007 m/m (7 m/km).

Ground water and river elevation data from 2007/2008 for May Street, Claybanks and Voght Park are plotted on Figures 5, 6 and 7 respectively. The plotted river elevation at each monitoring well location is based on actual survey data and the estimated correlation with the WSC station (Figure 8). The data indicate that the river elevation was higher than the ground water table at each monitoring well location throughout the monitoring period of April 2007 to April 2008. The elevation difference illustrates a downward gradient from the river to the aquifer and that the river consistently lost water to the aquifer during the monitoring period. The greatest downward gradients occurred at May Street and Voght Park.

Figure 7, Voght Park illustrates a consistent pattern between the elevation of the Coldwater River and the elevation of the ground water table. Operation of the Voght Park production well(s) induced roughly 1 m decrease in the peizometric elevation in the deep monitoring well but much less drawdown – 0.2 m in the ground water table as illustrated by the shallow monitoring well. The effect of pumping at the Voght Park monitoring well was to increase the downward gradient and associated flow rate from the surface of the water table down to depth.

Also Figure 7,, the rise in the ground water table in mid September 2007 reflects a decline in pumping from the Voght Park well(s). The Temperature Chart –Figure 2 illustrates a sharp rise in the deep monitoring well ground water temperature after the pump is shut off. The deep monitoring well ground water temperature before and after shut down of the well suggests that under pumping conditions, the cone of depression extends beyond the Coldwater River – i.e. cooler groundwater from the Collettville side of the Coldwater River is flowing past the deep monitoring well and is mixing with higher temperature river leakage. After the well is shut off, this ground water flow ceases and the ground water temperature is primarily influenced by river leakage.

Figure 9 provides a plot of flow rates in the Coldwater River at Brookmere and the Nicola River at the outlet of the Nicola dam, for the period January 2000 to January 2008. The WSC data set for the Coldwater River at Merritt is incomplete so the Brookmere data are plotted instead. The depths to ground water at the provincial observation well are also plotted for the same period. Provincial observation well data are missing from April 2003 to October 2003. The data illustrate the correlation between river flows and the recharge to the Merritt aquifer as illustrated in the increase of the ground water elevation at the provincial observation well following freshet, with a time lag of 1-2 months in the groundwater level. The observation well data also illustrate a decline in the average elevation of the ground water table from 2000 to 2005 at an average rate of approximately 0.05 m/year. From 1989 to 2005, the ground water table declined approximately 0.7 m. The lowest recorded ground water elevations occurred in August 2004 and August 2005. Since 2005 the average elevation of the ground water table has increased approximately 0.1 m/year.

Temperature data for the three monitoring wells, the MOE Observation well and the Coldwater River are plotted on Figure 2. The data illustrate the strong influence of surface water on ground water temperatures at May Street and Voght Park, with ground water temperature at both shallow and deep monitoring points following seasonal patterns of the river temperature. The temperature fluctuations are further indication of river losses into the unconfined aquifer. Conversely we can see the relatively stable temperature at the MOE observation well which is distant from the initial zone of surface and ground water mixing. The ground water temperature in the Claybanks deep monitoring well was very stable throughout the monitoring period indicating that surface water flow into the silt formation below the Merritt aquifer was minimal.

Ground water temperature is generally close to the average annual temperature and as illustrated in Figure 2, warmer than the Coldwater River in the winter and cooler than the river in summer. We can also see how a river at 24 ^{0}C, gaining ground water at 10^{0}C, would benefit from the influx of ground water that may create thermal refuge habitat during the summer period.

GROUND WATER BUDGET

It is helpful to consider a simplified water budget for the Merritt aquifer in examining the relationship between the Merritt aquifer and the Coldwater and Nicola Rivers. Prior to COM's development of the aquifer in the mid 1960s, the aquifer was in long term equilibrium where water entering the aquifer (recharge) was approximately equal to water leaving the aquifer (discharge). Pumping water from the aquifer adds another discharge and causes the system to seek a new equilibrium. The source of water for pumping is supplied by (1) more water entering the aquifer - recharge, (2) less water leaving the aquifer, (3) removal of water stored in the aquifer or a combination of all three. The total amount of water entering, leaving, and the change in storage in the aquifer must sum to zero, yielding a balanced water budget.

Sources of recharge to the Merritt aquifer are:

- Recharge from precipitation and irrigation percolating down into the unconfined aquifer.
- Recharge/leakage from the Coldwater River and the Nicola River.
- Ground water flow from adjoining soil formations including alluvial sediments upstream of the aquifer within the Coldwater River and Nicola River flood plains, upward flow from the deep confined aquifer(s) and flow from the silt deposits around the aquifer. Ground water inflow points are illustrated on Figure 1.

Discharges from the Merritt aquifer include:

- Flow out of the aquifer in the alluvial sediments within the Nicola floodplain. This alluvium extends downgradient from Merritt to Lower Nicola[7]. MOE has assumed that this outflow boundary will be a position upstream of the COM waste water rapid infiltration basins, and downgradient of the Voght Park supply wells. The estimated outflow boundary is illustrated on Figure 1. This outflow will provide base flow to the Nicola River downstream of the COM.

- Pumping by COM.

Pre-development (no extraction) and post-development water budgets for the Merritt aquifer are provided in Table 3 and Table 4 respectively. Values for ground water inflows and outflows were estimated based on the assumptions and parameters listed below.

[7] Geological Survey of Canada Surficial Geology Map 1393A

River losses were estimated as the volume of inflow required to achieve a balanced water budget. Estimated inflow and outflow values are annual averages.

- Surface area of the unconfined aquifer is 6.5 km^2.
- Precipitation recharge equals 15 mm/year (5% of the total annual precipitation of 322 mm/year) with an additional 100 mm/year at the River Ranch hay fields.
- COM storm water system discharges to the Coldwater River and the Nicola River.
- The hydraulic conductivity of the Merritt aquifer is 0.002 m/sec in the southern half of the aquifer and 0.001 m/sec in the northern half of the aquifer.
- Inflow from the silt formation adjoining the aquifer occurs over a perimeter length of 7.5 km, 10 m thick and at a gradient of 7 m/km. The hydraulic conductivity of the silty soils are estimated at 10^{-7} m/sec.
- Inflow ground water from Nicola River alluvial sediments through a saturated cross-section 500 m wide and 4 m thick at a gradient of 2.5 m/km and hydraulic conductivity of 0.001 m/sec. Saturated thickness estimated from monitoring well logs in COM ground water/surface water interaction report (BC Ground water Consulting 2006).
- Inflow ground water from Coldwater River alluvial sediments through saturated cross-section 300 m wide and 8 m thick at a pre-development gradient of 5 m/km and post development gradient of 6.5 m/km and hydraulic conductivity of 0.002 m/sec. Saturated thickness estimated from record for water well at Mountain Music Festival site.
- Recharge by ground water flowing upward from the deep aquifer(s) across the confining layer and into the shallow (unconfined) aquifer: area of upward flow from the provincial observation well westward (2.4 km^2), confining layer average thickness of 60 m with an average vertical hydraulic conductivity of 10^{-8} m/sec, a pressure head of 3.1 m (4 psi) corresponding to an upward gradient of 0.05 m/m.[8]
- Flow out of the aquifer occurs downgradient of Voght Park thought a section of aquifer 800 m wide, with an average pre-development saturated thickness of 9.5 m and gradient of 7.5m/km, and an average post-development saturated thickness of 8.5 m and gradient of 7 m/km.
- The average annual pumping rate by COM is 100 L/sec.
- Wastewater from the RI basins enters the alluvial sediments downgradient of the outflow boundary and is not captured by the COM well field.
- From 2000 to 2005, the water level in the provincial observation well declined approximately 0.25 m suggesting a net removal of water from storage occurring at 0.05 m/year and providing up to 100,000 m^3/year to the pumping withdrawal. The average ground water level in the provincial observation well has declined approximately 0.5 m from 1990 to 2007, with the greatest rate of decline occurring since 2000. Observation well data are available at http://a100.gov.bc.ca/pub/gwl/disclaimer.do
- An aquifer porosity of 30%.

[8] Personal communication, BC Ground water Consulting Services Ltd

Table 3 – Pre-Development (pre 1965) Ground Water Budget

Inflow (recharge)		Outflow (discharge)	
Precipitation	105,000 m^3/yr	Flow out of aquifer	3,650,000 m^3/yr
Flow from adjacent silt formation	5,000 m^3/yr		
Upward flow from deep aquifer system	40,000 m^3/yr		
Alluvial sediments along Coldwater R	760,000 m^3/yr		
Alluvial sediments along Nicola R	160,000 m^3/yr		
Net River Losses (leakage)	2,580,000 m^3/yr		
Total	3,650,000 m^3/yr	**Total**	3,650,000 m^3/yr

Table 4 – Post-Development (present day) Ground Water Budget

Inflow (recharge) + Storage Contribution		Outflow (discharge)	
Precipitation & irrigation return flow	140,000 m^3/yr	Flow out of aquifer	3,000,000 m^3/yr
Net water removed from storage	100,000 m^3/yr	Pumping	3,150,000 m^3/yr
Flow from adjacent silt formation	5,000 m^3/yr		
Upward flow from deep aquifer system	40,000 m^3/yr		
Alluvial sediments along Coldwater R	980,000 m^3/yr		
Alluvial sediments along Nicola R	160,000 m^3/yr		
Net River Losses (leakage)	4,725,000 m^3/yr		
Total	6,150,000 m^3/yr	**Total**	6,150,000 m^3/yr

The water budgets suggests that river losses are the primarily source of recharge to the Merritt aquifer under both pre-development and post-development/pumping conditions. On an annual average, pre-development river losses were estimated at 2, 580,000 m^3/year or 0.08 m^3/sec. Post-development river losses were estimated at 4,725,000 m^3/year or 0.15 m^3/sec. The water budget suggests that at an annual average pumping withdrawal of 0.10 m^3/sec, river losses increase by approximately 0.07 m^3/sec.

Balancing the annual water budget for the Merritt aquifer suggests that approximately 70% of the ground water withdrawal is provided by river losses, 3% by increased ground water inflow at the east end of the aquifer, 20% by reduced ground water outflow at the west end of the aquifer and 7% by precipitation and storage. River losses are the aquifer recharge feature with the ability to significantly increase in post-development conditions.

CONCLUSIONS

Beginning in 2004, MOE completed a review of available aquatic habitat in the lower Coldwater River with specific focus on summer low flow conditions and elevated river temperature. MOE also examined the surface water/ground water relationship between the Coldwater River and the Merritt unconfined aquifer. This review was completed with the assistance of the COM. Based on this review, MOE concludes the following:

- Ground water and river temperature and elevation data indicate that the reach of the Coldwater River from the May Street well to Voght Park was a losing reach during the entire monitoring period of April 2007 to April 2008.

- Rivers losses are the greatest source of recharge to the Merritt aquifer under both pre-development and pumping conditions

- MOE estimates that annual average river losses to the Merritt aquifer have increased by approximately 0.07 m^3/sec due to an average annual ground water withdrawal of 0.10 m^3/sec.

- Net annual average river loss to the Merritt aquifer under present pumping conditions is estimated at 0.15 m^3/sec and is approaching twice the estimated pre-development loss.

- Coldwater River in-stream measurements in August and September 2005 indicated an average loss of 0.12 m^3/sec between the Mountain Music Festival site and Claybanks Park. Additional losses are expected to occur from Claybanks to Voght Park, based on the losing nature of this reach.

- Surface water losses in the lower Coldwater River are resulting in summer low flows that are well below short term survival levels and only maintains degraded habitat quality and quantity for salmon, trout and aquatic insects that make up their food supply.

- Lower Coldwater River temperatures in summer at low flows are exceeding lethal limits for salmon and trout, contribute to poor growth and survival, and favour non-salmon species.

- An increase in summer low flows will expand the wetted stream habitat with the greatest benefit observed at the lower percentages of the mean annual flow. An increase in wetted stream habitat will reduce thermal heating of the stream bed substrate and reduce the associated heat transfer from the substrate to the surface water.