TECHNICAL MEMORANDUM

DATE 7 April 2017 **REFERENCE No.** 1114220046-543-TM-Rev2

TO Derek Holmes, Regional Manager BC Aggregate Operations BURNCO Rock Products Ltd.

CC Don Chorley

FROM Kristina Skeries and Jerry Vandenberg **EMAIL** Jerry_Vandenberg@golder.com

PIT LAKE HYDRODYNAMIC MODELLING FOR BURNCO AGGREGATE PROJECT

1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by BURNCO Rock Products Ltd. to prepare an Environmental Assessment Certificate Application/Environmental Impact Statement (EAC Application/EIS) for a proposed sand and gravel mine project ("the Project") within the Lower McNab Valley, approximately 35 km northwest of Vancouver, British Columbia. The Proposed Project is located on a 30 hectare (ha) portion of a 320 ha property that has been owned since 2008 by 0819042 BC Ltd and BURNCO Rock Products Ltd. Aggregate resources will be mined from a clear-cut area of the property, situated approximately 500 meters (m) from the marine foreshore and extending northward approximately 600 m toward the southern banks of McNab Creek (Figure 1). Sand and gravel will be extracted from a pit using an electric powered floating clamshell dredge equipped with a primary crusher linked to a floating conveyor system. This equipment will be initially placed on the western area of the deposit and will dig downward to form a wetted pit (filled with natural groundwater input). The dredge will float on the surface of the pit pond. From this location, the floating clamshell will extract material based on the aggregate deposit and mine plan, and is anticipated to gradually enlarge the pit pond to size of approximately 28 ha over a period of 16 years. The majority of groundwater seepage from the pit lake will enter the foreshore area downgradient (i.e., south) of the pit.

To support the water quality modelling of the pit lake and to evaluate long-term groundwater seepage from the pit lake thermal and hydrodynamic modelling of the pit lake was performed to generate vertical profiles of water temperature and total dissolved concentration (TDS). This technical memorandum summarizes the hydrodynamic modelling approach, input data and results within the pit lake during the post-closure period of the Project. In addition, using these results groundwater seepage temperatures to downstream creeks (including McNab Creek) are estimated for Year 5, Year 10, and at closure.

2.0 MODELLING APPROACH

The laterally-averaged, hydrodynamic and water quality model, CE-QUAL-W2 (W2; Cole and Wells 2013) was used to predict vertical water temperature and TDS profiles within the pit lake as well as in outflow from the pit lake entering the surface water system. This model has been applied in numerous studies worldwide to predict temperature, stratification and other variables in reservoirs, rivers and pit lakes. A 15-year simulation was set up, consistent with the availability of meteorological data, as described in the following section of input data compilation. The physical setting of the simulation replicated closure conditions when the pit lake is at maximum size, and the 15-year simulation provides a range of outcomes based on climate variability that may occur under those conditions.

2.1 Model Input

The model input data used for the simulations include:

- pit lake bathymetry;
- meteorological data;
- inflow and outflow hydrology;
- inflow temperatures; and
- inflow TDS.

Each of these inputs is described in details in the sections below.

2.1.1 Pit Lake Bathymetry

The model was set up by dividing the pit lake equally into 3 longitudinal segments and 47 vertical layers based on the conceptual profile and water level of the pit lake at closure estimated by water balance analysis. The grid comprises 141 active cells with the cell height of 1 m. The segment orientation was set up based on the flow direction. The characteristics of the BURNCO Pit Lake at closure are summarized in Table 1.

Table 1: Characteristics of the BURNCO Pit Lake at closure

Description	BURNCO pit lake
Storage volume at closure (Mm^3)	10.05
Closure water surface elevation (m)	5.17
Surface area (km^2)	0.276
Mean water depth (m)	40.1
Receptors	McNab Creek (MCF-7), downstream groundwater channels ((MCF-6 and MCF-12)
Segment orientation	North to south

2.1.2 Meteorological Data

Meteorological inputs are the key parameters driving the surface water temperature and mixing in the pit lake. The data used for the model are:

- air temperature;
- dew point temperature;
- wind direction;
- wind speed; and
- solar radiation or cloud cover.

The wind and temperature data used for the model were Environment Canada hourly climate data from Port Mellon, which is close to the project site. The station height at Port Mellon station is 31.85 m above ground surface. Cloud cover data from Vancouver International Airport and solar radiation data from Vancouver UBC were compiled with the Port Mellon station as these data weren't available for that station. The five-year time series from Port Mellon were repeated three times and combined with the longer solar radiation dataset from Vancouver UBC to extend the simulation period to the 15-year record. Meteorological data sources are summarized in Table 2.

Table 2: Summary of meteorological data sources

Station Name	Data	Time Frame
Port Mellon	Air temperature, dew point temperature, wind direction, wind speed.	2008 – 2012
Vancouver International Airport	Cloud cover	2008 – 2012
Vancouver UBC	Solar radiation	1971 – 1988

2.1.3 Inflow and Outflow Hydrology

The water balance at the end of mining was used as the hydrological input for the model (Golder 2014). Monthly average flow rate files were compiled for the following inflows and outflows (Table 3):

- surface runoff inflows;
- groundwater seepage inflows;
- net precipitation and evaporation; and
- surface and groundwater outflow.

All outflows, including surface overflow from the weir at the pit lake outlet and seepages from the pit to downstream groundwater channels and McNab Creek, were combined into a single outflow as they were expected to originate from the same segment and range of layers in the model.

2.1.4 Inflow Temperatures

Precipitation temperature was assumed to be equal to air temperature. Constant groundwater temperature (7.5^{o}C) was assumed for the ground water entering the pit lake from the west. The temperature of groundwater entering the pit lake from the North was assumed to be consistent with temperatures measured in monitoring well DH10-01D in 2011. Water temperatures of other inflows were assumed to be the same as McNab Creek surface water temperature (Table 3).

2.1.5 Inflow Total Dissolved Solids

The concentration inputs to the model were set according to measurements at monitoring stations that were used for input to water quality mass balance model at the end of the operation period (Golder 2014). TDS concentrations were the only chemical input used in the model setup. The median of observed concentrations for each inflow was used and assumed to be constant throughout the simulation period (Table 3).

Table 3: Summary of hydrological, chemical and temperature inputs

Flow (m^3/s)		TDS Concentration (mg/L)		Temperature (° C)	
ID	**Description**	**ID**	**Description**	**ID**	**Description**
Q_Runoff_NP_NF	Runoff from area north of pit (not containing separated fines)	C_Runoff_NP_NF	Baseline water quality at surface water monitoring stations MCF-2 and MCF-3	T_SW	McNab Creek surface water temperature
Q_Runoff_NP_F	Runoff from area north of pit (containing separated fines)	C_Runoff_NP_F	Water quality from sequential shake flask extraction tests	T_Runoff_NP_F	McNab Creek surface water temperature
Q_Prec_Evap	Net precipitation and evaporation	C_Prec_Evap	Assumed pure water	T_Prec_Evap	Air temperature
Q_GW_WP_NF	Groundwater from west of pit (not containing separated fines)	C_GW_WP_NF	Baseline water quality at groundwater monitoring stations DH10-07S, DH10-07D, DH10-06S, DH10-06D and MW05-1	T_GWWest	Constant ground water temperature (7.5°C)
Q_GW_NP_NF	Groundwater from north of pit (not containing separated fines)	C_GW_NP_NF	Baseline water quality at surface water monitoring station MCF-1	T_GW_NP_Update	Monitoring well DH10-01D groundwater temperatures from 2011
Q_GW_NP_F	Groundwater from north of pit (containing separated fines)	C_GW_NP_F	Water quality from sequential shake flask extraction tests	T_GW_NP_Update	Monitoring well DH10-01D groundwater temperatures from 2011
Q_WaterBal_NP	Water balance correction withdrawal (with an annual total about 0.012% of annual total inflow)	C_WaterBal_NP	Baseline water quality at surface water monitoring stations MCF-2 and MCF-3	T_WaterBal_NP	McNab Creek surface water temperature
Total_Outflow	Sum of surface and seepage outflows to McNab Creek and downstream groundwater channels				

2.2 Model Simulations and Sensitivity Analysis

The temperature and TDS vertical profiles during the post-closure period were simulated in the hydrodynamic model according to the proposed mine plan (Golder 2013). A "Base Case" simulation was completed using the inputs described in Section 2.1 and default model coefficients.The model was run for a 15-year period, and median and maximum years of the base case were calculated based on the average annual temperature of the outflow temperature.

Vertical temperature and concentration profiles were generated for each simulation. The surface water temperature near the weir outflow was predicted every three hours at different elevations (top 5 m). The outflow temperature, which is a flow-weighted average of the top 5 m, was also predicted every three hours. The top 5-m water parcel in the pit lake was assumed to be the source of groundwater seepages from the pit lake at closure when the pit lake will be at its maximum extent. Groundwater outflow to downstream creeks will occur through a gravel aquifer. In Year 5 and Year 10, when the pit lake is not at its maximum extent, groundwater seepage to downstream creeks will consist of a mixture of the temperature of the upper 5 m of pit lake water and groundwater that by-passes the smaller pit size. The temperature of groundwater seepage to downstream creeks (including McNab Creek) was calculated as a mixture of groundwater originating from the pit lake and temperature of groundwater by-passing the pit lake.

The pit lake is not constructed yet, so there is no observed temperature and concentration data for calibration and validation to that water body. Because the pit lake model could not be calibrated, a sensitivity analysis was completed by changing hydrodynamic variables that would be likely to affect model predictions. The variables altered for the sensitivity analysis are listed in Table 6.

2.3 Comparison Between Simulated and Observed Surface Water Temperatures

Because the lake has not been constructed, model results could not be compared to existing conditions. Instead, the predicted surface water temperatures were compared with the monitored data of an existing lake with a water surface elevation near mean sea level which is located in a similar climate setting.

Haslam Lake is located in the Town of Powell River, about 100 km northwest of the Project. The lake surface area is 1187 hectares, and the mean depth is 55 m. Recorded temperatures from this lake were used for comparison to the pit lake predictions.

3.0 RESULTS AND DISCUSSIONS

Base case predictions and sensitivity analysis of the future temperature and TDS profiles of the water within the pit lake and groundwater seepage entering the downstream creeks at closure are presented in Section 3.1 and Section 3.2, respectively. A comparison between the simulated results and field measurements in Haslam Lake is described in Section 3.3. An estimate of groundwater seepage temperatures in Years 5 and 10 are presented in Section 3.4 together with a comparison observed temperatures in the Groundwater Channel in 2011 at the downstream station GC-DS (location shown on Figure 1) in 2011. Section 3.4 also includes a comparison between the predicted groundwater seepage temperatures at closure with the observed water temperatures in the groundwater channel (at GC-DS) and in McNab Creek (at location MC-DS in Figure 1) in 2011.

3.1 Base Case- Pit Lake Seepage

The temperature results for the Base Case are listed in Table 4 by vertical layer and in Table 5 by month. A summary of the results is as follows:

- Predicted pit lake water temperatures increased during the summer months (approximately May to August) and gradually decreased by about 5ºC in the winter months (November-March) (Figure 2).
- The maximum predicted temperatures for pit lake water temperatures and the overage of the upper 5 m of the pit lake was 24.9ºC and 15.0ºC respectively (Figure 2). The maximum predicted temperatures in the median year were 23.6ºC and 14.8ºC respectively
- The annual thermal stratification cycle follows an inverse stratification in winter and persists until air temperature warms in spring. Surface warming continues until the temperatures are almost isothermal in March. Thereafter, the surface water temperature increases and thermal stratification re-establishes until the pit lake reaches maximum stability in late summer (late July to early August). Then the lake surface cools as the temperature drops in autumn and the cooler water mixes downward. The isothermal conditions lead to fall turnover in the upper layers, and then the cycle repeats annually (Figure 3).
- The model predicted a very slight vertical gradient of TDS concentrations due to the slightly lower TDS concentrations of the inflows compared to lake concentrations (Figure 3). These are not likely to be measureable.

Table 4: Maximum layer temperatures in segment 4 for the median and maximum base case years.

		Maximum Temperature of Layer (°C)	
		Base case - Median Year	**Base case - Maximum Year**
Layer Depth (m)	**1**	23.7	24.9
	2	23.2	24.1
	3	15.5	15.4
	4	10.0	9.9
	5	8.2	8.0
Combined Pit Outflow from the top 5 m		14.8	15.0

Table 5: Monthly average outflow water temperature (ºC) from the pit lake

Month	Base case - Median Year	Base case - Maximum Year
January	4.6	5.1
February	4.4	4.5
March	5.1	5.3
April	7.9	9.2
May	11.8	11.7
June	13.0	12.7
July	13.4	13.4

Month	Base case - Median Year	Base case - Maximum Year
August	12.7	13.5
September	11.1	11.6
October	9.7	9.4
November	6.6	7.0
December	5.6	6.0

3.2 Sensitivity Analysis – Pit Lake Seepage

The sensitivity analysis yielded the following results:

- Turning off the solar radiation and using simulated solar radiation and measured cloud cover data increased the surface water temperature in the top layer by 1.1%, but decreased the average temperature of the upper 5 m (hereafter referred to as the groundwater seepage temperature at closure) by 2.8% relative to the Base Case.
- Increasing the wind sheltering coefficient decreased the surface water temperature r, but increased the temperature of the groundwater seepage by by 1.3% due to increased vertical mixing.
- Decreasing the sediment temperature to half the annual average air temperature decreases the surface water temperature and groundwater seepage temperature by less than 1%. Similarly, doubling the sediment temperature increased the surface water temperature by 2% and outflow water temperature by less than 1%.
- Doubling the wind speed decreased the surface water temperature in the top layers by 2%, but increased the temperature in lower layers and increased the groundwater seepage temperature by 18.5%.
- Decreasing the beta extinction coefficient by 10% decreased the surface water temperature at the top layer by less than 1%, but increased the temperature at the lower layers by more than 10% and groundwater seepage by 2% due to increased light penetration.

In summary, the sensitivity analysis indicates that the results are robust under a variety of different conditions, and that the main input that could alter the predictions would be a major change in wind conditions compared to those measured at Port Mellon. A doubling of wind speeds is considered unlikely to occur, and the results above should be considered conceptually rather than as a prediction of a likely outcome.

Table 6: Summary of relative changes in surface water temperature in segment 4 as a result of sensitivity runs

Run no.	Description	Percentage difference in temperature compared to base case at different depths (m)					Percentage change of maximum temperature at Pit Outflow
		1	2	3	4	5	
2	Solar radiation off	1.1%	1.0%	-5.2%	-5.0%	-3.3%	-3.3%
3	Fraction of solar radiation at sediment to water (0.5 to 1)	0.1%	0.1%	-1.6%	-1.3%	-0.4%	0.1%
4	Wind sheltering (0.8 to 1.0)	-0.4%	-0.1%	0.4%	0.2%	2.2%	1.3%
5	Sediment temperature (set to half average air temperature)	0.0%	0.0%	-2.0%	-1.9%	-1.5%	-0.1%
6	Sediment temperature (set to double average air temperature)	0.0%	0.0%	-1.5%	0.3%	1.8%	0.2%
7	Double wind speed	-1.8%	-1.1%	23.1%	41.6%	34.7%	18.5%
8	Beta extinction coefficient (0.45 to 0.4)	-0.8%	-0.4%	2.3%	0.6%	0.5%	1.9%

Note: Negative change denotes reduction in temperature.

3.3 Comparison Between Simulated and Observed Surface Water Temperatures

The surface water temperature profiles were compared to Haslam Lake and are shown in Figure 4. Predicted surface water temperatures are superimposed on the observed temperature graph from the Watershed Assessment of Haslam Lake Lang Creek Community Watershed (Carson Land Resources Management Ltd 2003).

- The 5 years (4th year to 8th year) of the simulation period that were compared with the literature data followed the same pattern as observed data, with the peak temperature occurring in early August (greater than 26ºC). Predicted increases, declines and minimum temperatures also matched the observed annual cycles.
- The comparison between the simulated and literature data indicates that the model results are reasonable predictions for the pit lake.

3.4 Groundwater Seepage Temperatures

As discussed above the hydrodynamic model predicted the water temperature in the pit lake at closure when the pit lake was at it maximum extent. The groundwater seepage from the pit lake to the downstream creeks (including McNab Creek) was then estimated by averaging the upper 5 m of the temperature profile. Essentially 100% of the groundwater seepage to the downstream creeks originates from the pit lake at closure and post closure.

In Year 5 and Year 10 of the Project, however, water originating from the pit lake represents only a fraction of the groundwater discharging to the downstream creeks:, the rest is groundwater that by-passes the pit lake. To assess the temperature of the groundwater discharge for Years 5 and 10, the following method was undertaken.

- Percent of groundwater by-passing the pit lake was 60% and 10% respectively for Year 5 and Year 10.
- Groundwater temperature data for Well DH10-02D was used to represent the temperature of the groundwater.
- Groundwater originating from the pit lake was represented by the temperatures predicted by the Hydrodynamic model for the median year.

The results of these analyses are presented in Table 7and 8, and predicted groundwater seepage temperatures at closure in Table 9. In addition, Table 7 and 8 present a comparison with the observed temperatures in the groundwater channel at station GC-DS in 2011(Figure 1); whereas Table 9 presents a comparison with observed water temperatures in McNab Creek at station MC-DS in 2011 (Figure 1). Figure 5s and 6 present the predicted groundwater seepage temperatures at Year 5 and Year 10, respectively together with the observed temperatures in the groundwater channel (at GC-DS0) in 2011. Figure 7 presents the predicted groundwater seepage temperatures at closure together with the observed temperature data in 2011 for McNab Creek at location MC-DS and for the groundwater channel at location GC-DS.

Table 7: Estimated Groundwater Seepage Temperatures (Year 5) and Channel Temperatures

	Estimated Seepage Temperature (Year 5)			Groundwater Channel Temperature Data (2011)		
	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)
Jan	5.21	5.29	5.48	6.31	7.03	7.54
Feb	4.79	4.91	5.18	5.34	6.49	7.27
Mar	4.58	4.96	5.76	5.59	6.35	7.48
Apr	5.90	6.35	6.97	5.61	6.42	7.82
May	7.03	8.14	8.98	5.92	6.89	8.72
Jun	8.64	8.98	9.44	6.46	7.34	10.0
Jul	9.07	9.42	9.91	7.01	7.75	11.0
Aug	8.74	9.34	10.2	7.45	8.25	11.5
Sep	8.54	8.90	9.41	7.89	8.56	9.14
Oct	8.56	9.41	10.2	7.50	8.17	8.79
Nov	7.97	8.17	8.67	7.13	7.82	8.28
Dec	6.80	6.92	7.13	6.39	7.29	8.01

Notes:

1 – Channel and groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)

2 - Mixing temperature is calculated as linearly proportional to end-member temperatures, which assumes uniform density and immediate mixing.

3 – 5-year mixing temperature is calculated as 40% Pit Lake water, and 60% groundwater.

Table 8: Estimated Groundwater Seepage Temperatures (Year 10) and Channel Temperatures

	Estimated Seepage Temperature (Year 10)			Groundwater Channel Temperature Data (2011)		
	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)
Jan	4.50	4.68	5.11	6.31	7.03	7.54
Feb	4.20	4.47	5.07	5.34	6.49	7.27
Mar	4.26	5.12	6.93	5.59	6.35	7.48
Apr	6.64	7.65	9.06	5.61	6.42	7.82
May	8.65	11.2	13.1	5.92	6.89	8.72
Jun	11.6	12.4	13.4	6.46	7.34	10.0
Jul	11.9	12.7	13.8	7.01	7.75	11.0
Aug	10.8	12.2	14.0	7.45	8.25	11.5
Sep	9.90	10.7	11.8	7.89	8.56	9.14
Oct	7.75	9.67	11.4	7.50	8.17	8.79
Nov	6.42	6.88	8.00	7.13	7.82	8.28
Dec	5.57	5.85	6.32	6.39	7.29	8.01

Notes:

1 – Channel and groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)

2 - Mixing temperature is calculated as linearly proportional to end-member temperatures, which assumes uniform density and immediate mixing.

3 – 10-year mixing temperature is calculated as 90% Pit Lake water, and 10% groundwater.

Table 9: Estimated Groundwater Seepage Temperatures (Closure) and Creek Temperatures

	Estimated Seepage Temperature (Closure)			McNab Creek Temperature Data (2011)		
	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)	Monthly minimum (°C)	Monthly average (°C)	Monthly maximum (°C)
Jan	4.36	4.56	5.03	0.46	2.78	4.10
Feb	4.08	4.38	5.05	0.09	2.55	4.21
Mar	4.20	5.15	7.16	1.28	3.07	4.83
Apr	6.79	7.91	9.48	2.94	4.13	7.13
May	8.98	11.8	13.9	3.28	4.94	7.37
Jun	12.2	13.0	14.2	4.67	6.12	8.64
Jul	12.4	13.4	14.6	6.21	8.45	11.6
Aug	11.3	12.7	14.8	8.94	12.0	15.3
Sep	10.2	11.1	12.3	9.52	12.2	15.4
Oct	7.59	9.72	11.6	5.89	8.62	11.0
Nov	6.11	6.62	7.87	2.86	4.97	6.80
Dec	5.33	5.64	6.16	1.50	3.19	4.33

Notes:

1 – Creek and groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)

2 - Mixing temperature is calculated as linearly proportional to end-member temperatures, which assumes uniform density and immediate mixing.

3 – Closure mixing temperature is calculated as 100% Pit Lake water.

4.0 CLOSURE

We trust that this information is sufficient for your immediate requirements..

GOLDER ASSOCIATES LTD.

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Jerry Vandenberg, PChem, BSc, MSc
Principal Environmental Chemist

Reviewed by

Don Chorley, MSc, PGeo
Principal – Hydrogeology

5.0 REFERENCES

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Cole, T. M. and S. A. Wells. 2013. *CE-QUAL-W2: A Two-Dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model*, Version 3.71. Prepared for U.S. Army Corps of Engineers, Washington, DC 20314-1000, 777pp.

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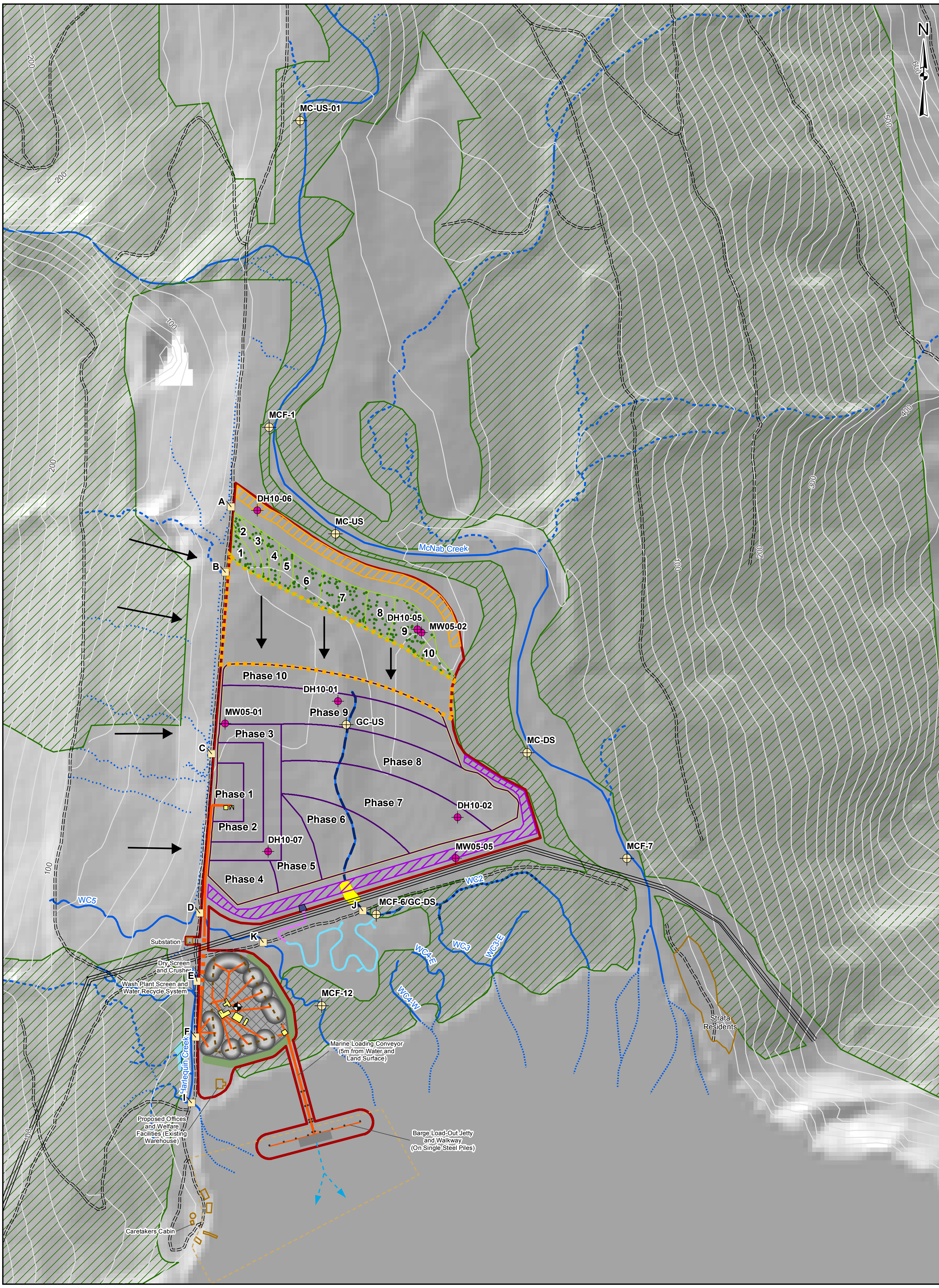


LEGEND

PROJECT COMPONENTS

- Project Area
- Proposed Aggregate Pit Phases
- McNab Creek Flood Protection Dyke
- Pit Lake Containment Berm
- Soil Deposit Area (Salvaged Soil Stockpiles)
- Fines Storage Area
- Processing Area
- Elevated Conveyor
- Underground Conveyor
- Below Pile Conveyor
- Barge Route
- Proposed Groundwater Use Well
- Existing Culvert
- Existing Feature
- Chanel Infill (WC 2 Plug) Riprap and Filter Zone
- WC 2 Extension - Year 1 Construction
- WC 2 Extension - Closure Construction
- Outlet Structure with Spillway and Low-level Outlet
- Final Pit Lake Boundary
- Product Stockpiles
- Possible Processing Infrastructure Configuration
- Processing Area Berm

BASEMAP DATA (TRIM / McElhanney)

- Mature Forest
- Existing Road
- Existing Log Tenure Area
- Existing Transmission Lines
- Contour (20m)
- Permanent /Perennial Watercourse
- Intermittent Watercourse
- Intertidal Watercourse
- Ephemeral Watercourse
- Constructed Watercourse Phase 1 (1985)
- Constructed Watercourse Phase 2 (1996)
- Constructed Watercourse Phase 3 (2001-2003)
- Direction of Flow / Runoff

Monitoring Locations

- Surface Water Monitoring Location
- Goundwater Monitoring Well

REFERENCE

DEM from Geobas. Base data from the Province of British Columbia. Contours from TRIM positional data. Additional detailed site features provided by McElhanney. Projection: UTM Zone 10 Datum: NAD 83

300 0 300

SCALE 1:9,000 METRES

PROJECT

BURNCO ROCK PRODUCTS LTD.
BURNCO AGGREGATE PROJECT, HOWE SOUND, B.C.

TITLE

BURNCO PROJECT SITE MAP

Golder Associates

PROJECT NO. 11-1422-0046			PHASE No.	
DESIGN	KZ	2 Nov. 2016	SCALE AS SHOWN	REV. 0
GIS	JP	6 Mar. 2017	FIGURE 1	
CHECK	KZ	7 Mar. 2017		
REVIEW	DC	7 Mar. 2017		

Path: Y:\Vancouver\Spatial Data\Project Data\BC\McNab\Figures\MXD\Surface Water\Water_License\Figure_01_Project_Site_Map_20170405.mxd

Figure 2: Simulated water temperature at lake surface and in outflow

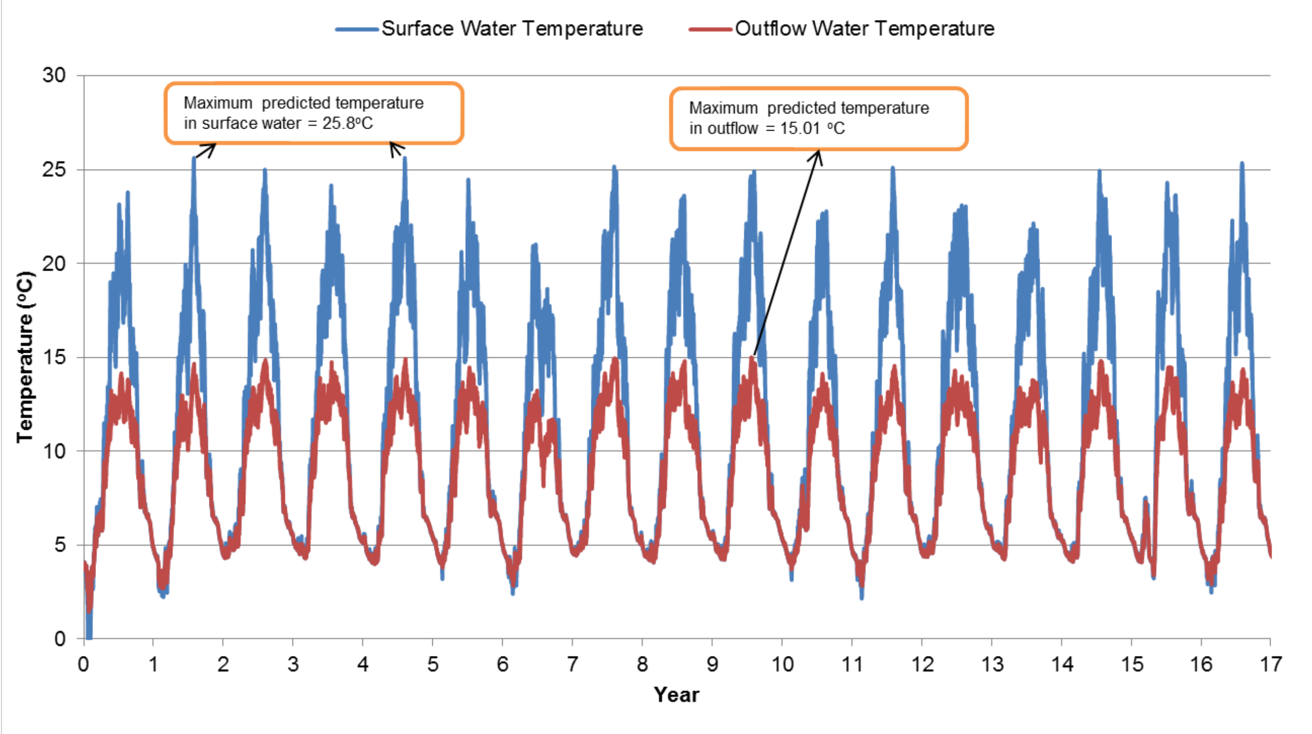
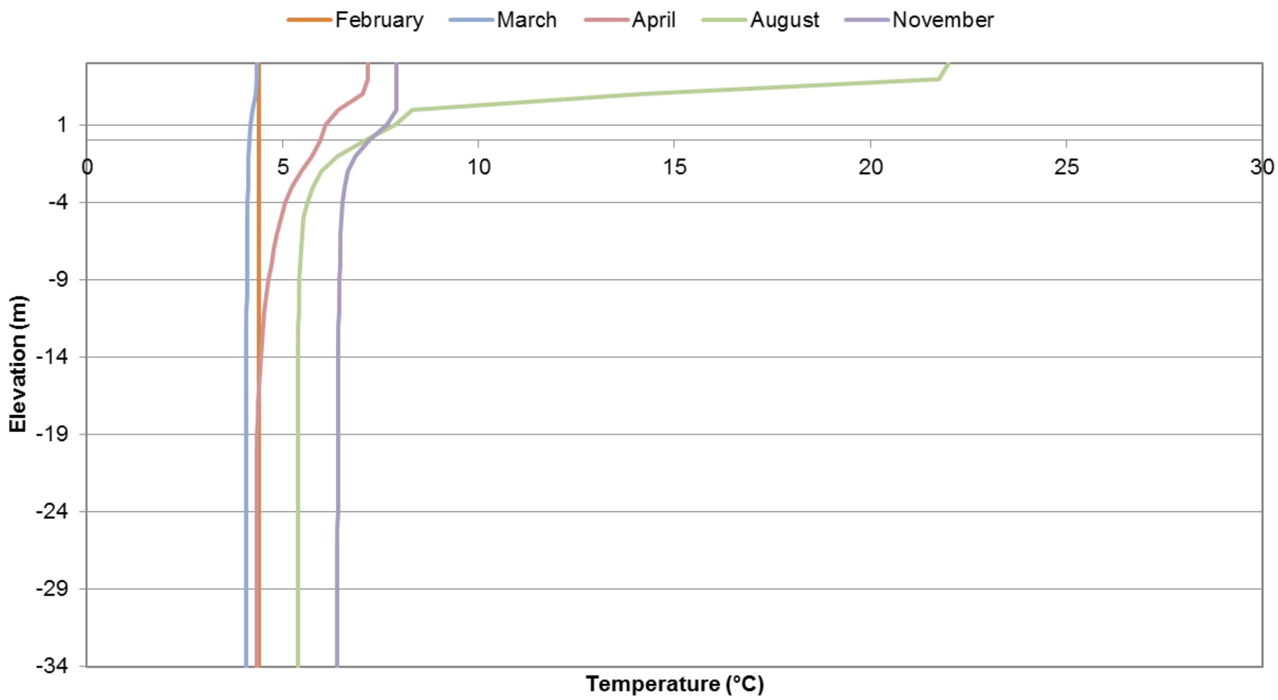
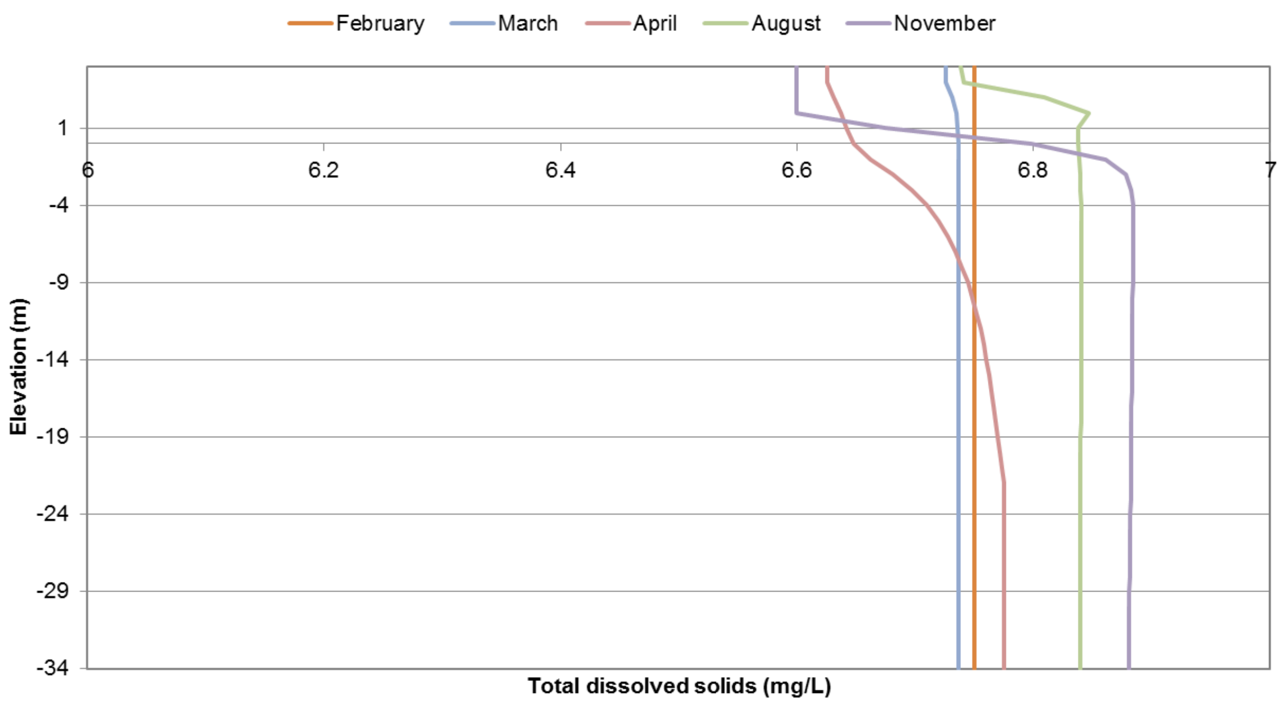


Figure 3: Vertical profiles of simulated surface water temperature and TDS concentrations, typical year

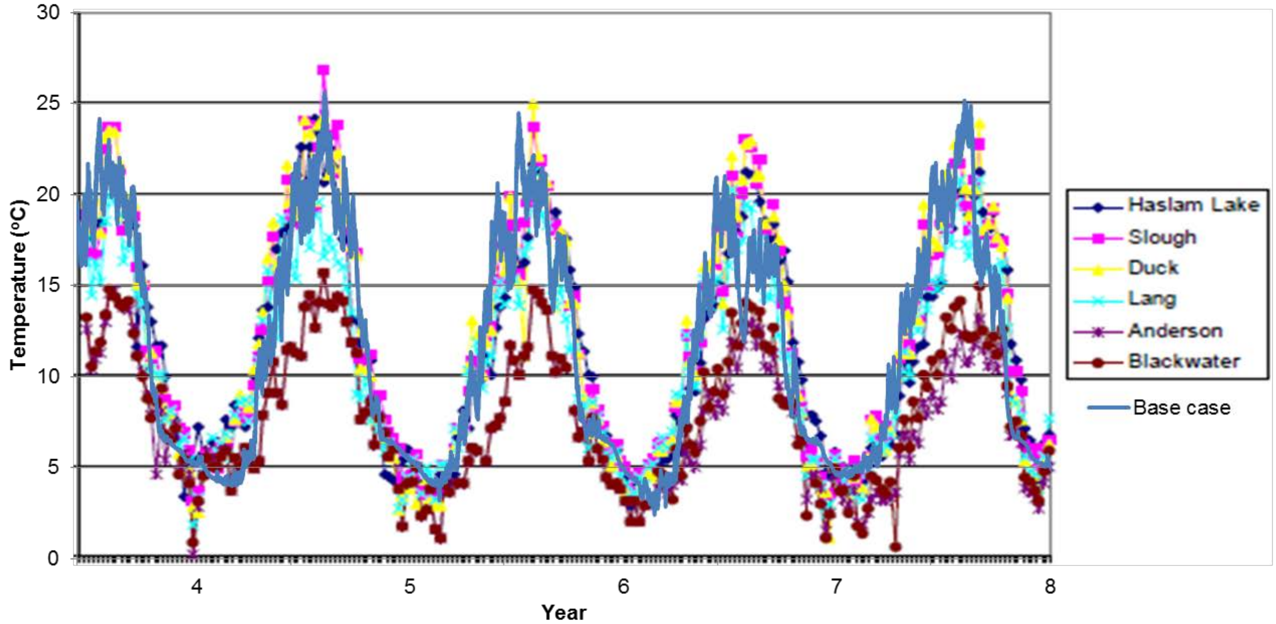


(a) Temperature



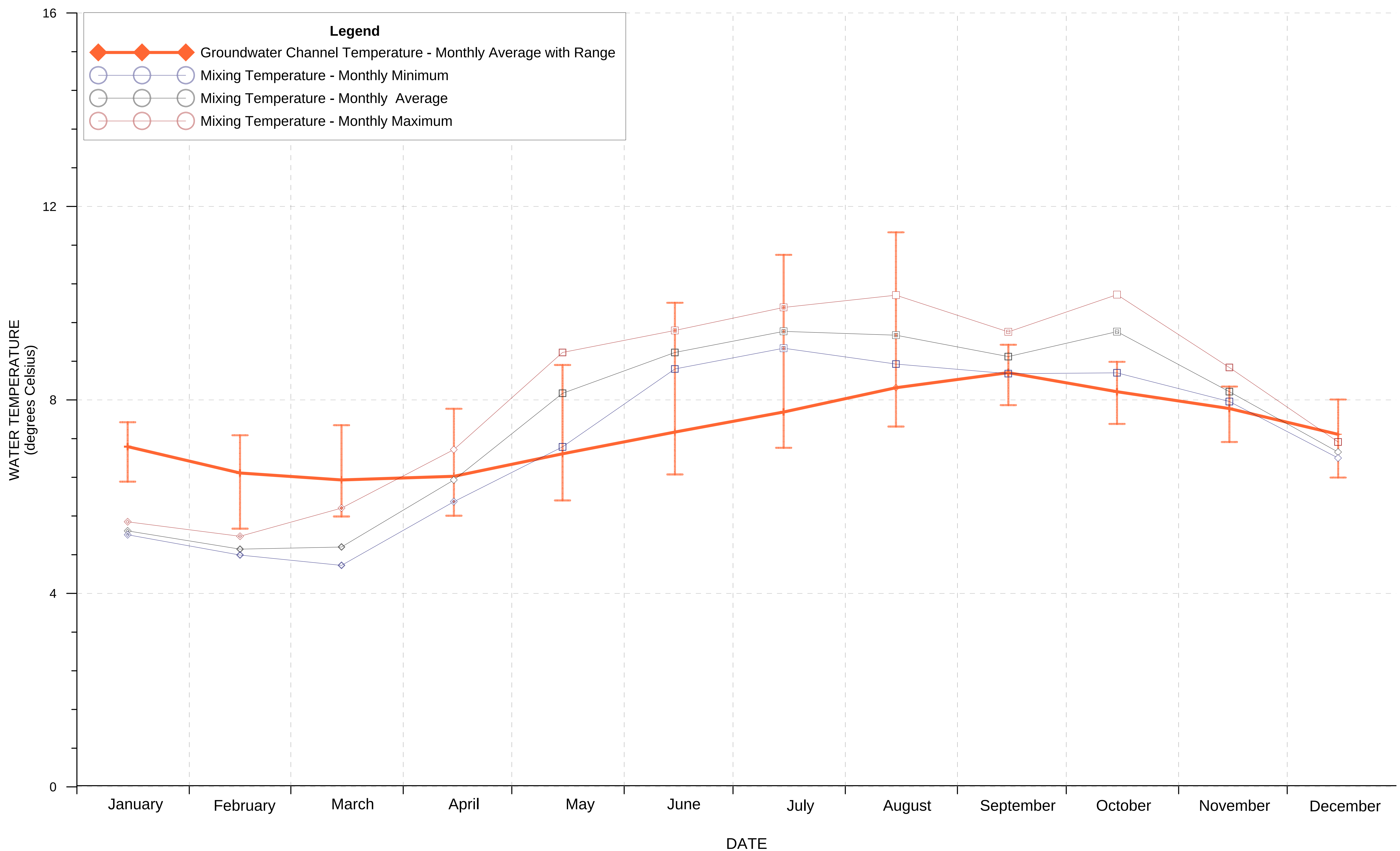
(b) Total dissolved solids

Figure 4: Seasonal patterns of monitored and simulated surface water temperature



Source: Watershed Assessment of Haslam Lake Lang Creek Community Watershed (Carson Land Resources Management Ltd. 2003).

ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES (YEAR 5)



NOTES: 1) Groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)
2) Pit Lake temperatures are weighted averages of the top 5 m of the water body
3) Error bars represent minimum and maximum recorded creek temperatures for each month

Project No.	11-1422-0046
Drawn	MZ
Reviewed	DWC
Date	April 2017

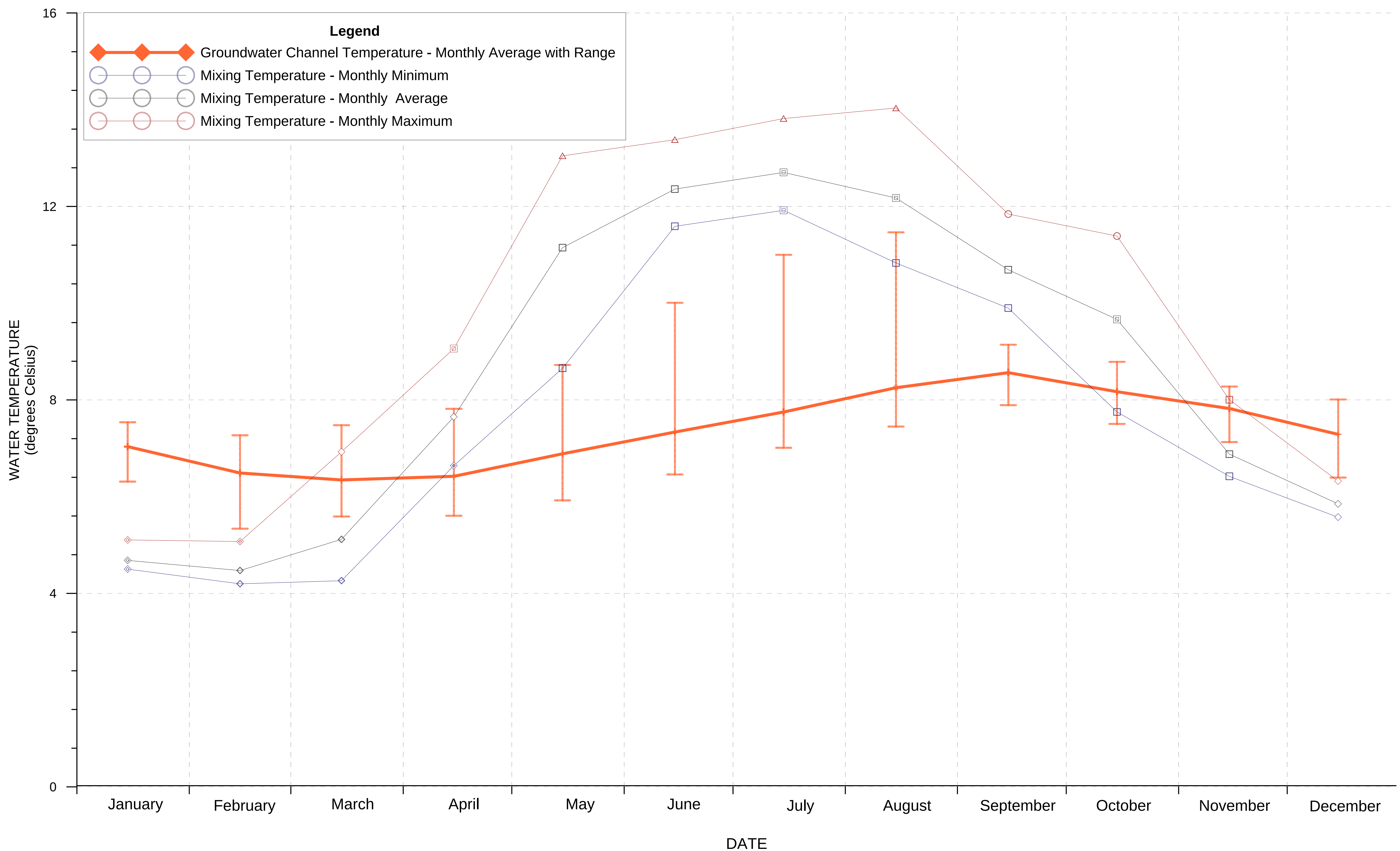
Golder Associates

ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES

BURNCO ROCK PRODUCTS LTD.
MCNAB VALLEY AGGREGATE PROJECT
HOWE SOUND, BC

Fig. 5

ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES (YEAR 10)

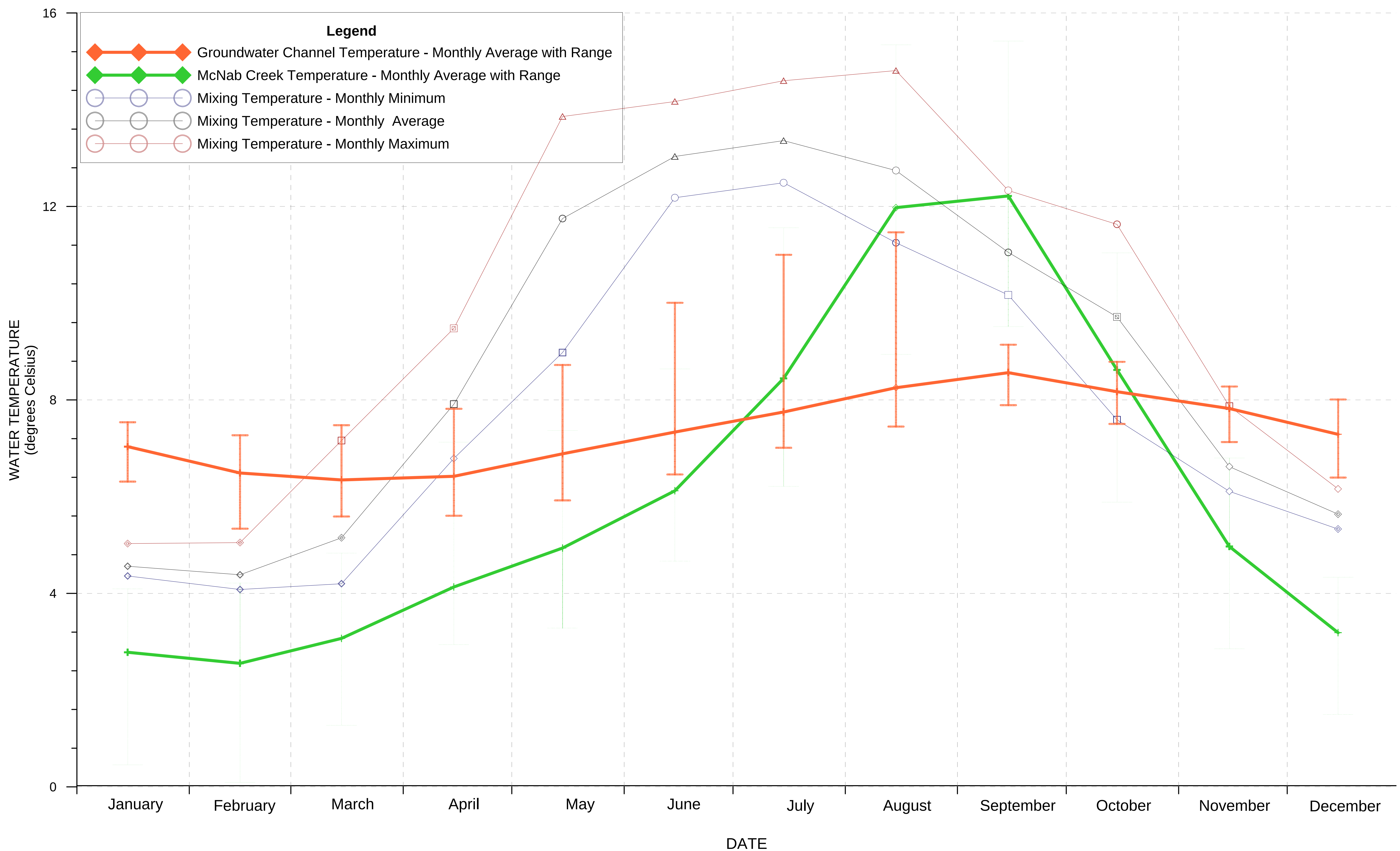


NOTES: 1) Groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)
2) Pit Lake temperatures are weighted averages of the top 5 m of the water body
3) Error bars represent minimum and maximum recorded creek temperatures for each month

Project No. 11-1422-0046 **Drawn** MZ **Reviewed** DWC **Date** April 2017	Golder Associates	**ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES** **BURNCO ROCK PRODUCTS LTD.** **MCNAB VALLEY AGGREGATE PROJECT** **HOWE SOUND, BC**

Fig. 6

ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES (CLOSURE)



NOTES: 1) Groundwater temperature data from automated transducers recording at 15-minute intervals (data from 2011)
2) Pit Lake temperatures are weighted averages of the top 5 m of the water body
3) Error bars represent minimum and maximum recorded creek temperatures for each month

Project No. 11-1422-0046
Drawn MZ
Reviewed DWC
Date April 2017

Golder Associates

ESTIMATED GROUNDWATER SEEPAGE TEMPERATURES

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HOWE SOUND, BC

Fig. 7