APPENDIX D

Part 2 Human Health Technical Memoranda

1 WATER QUALITY TECHNICAL MEMORANDUM

TECHNICAL MEMORANDUM

DATE December 21, 2012 **PROJECT No.** 10-1422-0090

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SITE C CLEAN ENERGY PROJECT EFFECTS ON POTABLE WATER QUALITY: SUPPLEMENTARY INFORMATION

The purpose of this Technical Memorandum is to summarise information that was used to support the potable water quality component of Section 33 Human Health Effects Assessment. The Information sources used to prepare this document included the following appendices to Volume 2 of the Environmental Impact Statement, which should be referred to for further detail on these topics:

- Appendix E Water Quality Baseline Conditions in the Peace River
- Appendix F Groundwater Regime Technical Data Report
- Appendix I Fluvial Geomorphology and Sediment Transport Technical Data Report
- Appendix J Mercury Technical Data Reports
- Appendix P Aquatic Productivity Reports

This memorandum includes a summary of the following information from the above appendices:

- Methods used to collect baseline data on drinking water quality parameters
- Summary of baseline results
- Methods used to assess changes to drinking water quality as a result of the Site C Clean Energy Project (the Project)
- Summary of changes to drinking water quality parameters as a result of the Project in relation to Canadian Guidelines for Drinking water Quality (i.e., Health Canada 2012)
- Information and knowledge gaps, and associated recommendations for drinking water quality monitoring in relation to the Project

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1.0 BACKGROUND

1.1 Public Drinking Water Intakes and Sources

The village of Hudson's Hope draws its domestic water supply from the Peace River, downstream of the W.A.C. Bennett Dam. The water intake is located in the river above a limestone bed. At the pump house, the water is treated by chlorination and is subsequently transported to approximately 1000-1100 water users.

Fort St. John's water comes from a well system adjacent to the Peace River located 65 feet under the Peace River in bedrock. The water is taken from an aquifer and the intake system services Fort St. John and adjacent areas of the Peace River Regional District.

Taylor draws its water from three shallow wells located on a gravel bar in the Peace River at the confluence of the Pine and Peace rivers. The pump house for these wells is located on the north bank of the Peace River.

There are 48 registered and seven non-registered drinking water wells within a 2 km lateral distance from the proposed Site C reservoir. These wells are linked to either of the two primary aquifers in the project region:

- A shallow aquifer (usually unconfined) in the unconsolidated sediments laid down during glacial and interglacial periods
- A deeper bedrock (sandstone) aquifer

1.2 Water Quality Screening

A screening process was implemented to identify the drinking water quality parameters that could potentially change as a result of the Project. These parameters are listing in Table 1 with an indication of baseline and project modelling data collected for each parameter.

Table 1: Potable and recreational water quality parameter

Drinking Water Quality Parameter	Surface Water Quality		Groundwater Quality	
	Baseline Data Collected	Project Modelling Implemented	Baseline Data Collected	Project Modelling Implemented
Conventional Parameters				
Temperature	✓	✓	NA	NA
Total suspended solids	✓	✓	NA	NA
Total dissolved solids	NA	NA	✓	NA
Turbidity	✓	✓	✓	NA
Inorganics				
Nitrate	✓	✓	NA	NA
Metals				
Metals (mercury)	✓	✓	✓	NA
Metals (other)	✓	NA	✓	NA
Organic Constituents				
Coliforms	NA	NA	✓	NA
Bacteria	NA	NA	✓	NA

NOTES:
✓ - data collected
NA - Data not collected

Changes in temperature, nutrients (including nitrate which have Canadian Drinking Water Quality Guidelines (Health Canada 2012), and ammonia and total phosphates which do not), total suspended solids (TSS), and mercury are the key water quality parameters considered in the water quality studies completed for the Project. Metals (other than mercury), pesticides and organic constituents have not typically been analyzed in other reservoir studies when assessing effects of reservoir creation on water quality. Other than mercury, project effects on metals and organic constituents were not assessed for surface or groundwater quality (Golder 2012a).

Health Canada (2012) does not provide a health based maximum acceptable concentration for total dissolved solids (TDS), but does provide an aesthetic objective of ≤ 500 mg/L. The aesthetic objective is based on the fact that excessive water hardness, reduction in palatability, increased mineral deposition and corrosion may occur with higher levels of TDS. Change in TDS as a result of the Project was not assessed through the water quality technical studies for the Project due to low existing TDS baseline concentrations and therefore a negligible effect on drinking water quality. Observed baseline TDS concentrations in the Peace River and tributaries were between 7.3mg/L and 96 mg/L on average among observations in the Dinosaur Reservoir and the Peace River, respectively (Golder Associates 2012b).

During project construction, the following management processes will be adhered to:

- Waste treatment and management facilities, hazardous materials storage and refuelling, aggregate and filter processing for the Project will adhere to provincial requirements for waste and hazardous materials handling, spills management, and management and storage practices
- A Contaminated Sites Management Plan will be implemented for management of contaminated or potentially contaminated sites and potential effects on groundwater quality
- A Ground Water Quality Management Plan will be implemented during construction (in accordance with *Contaminated Sites Regulation* and the *Environmental Management Act*) to protect groundwater sources used for drinking water
- An Erosion Prevention and Sediment Control Plan will be implemented in accordance with the Provincial Water Act to avoid or minimize adverse effects of erosion and sediment on receiving surface drinking water quality
- A Surface Water Quality Management Plan will be implemented to control, manage, and treat surface runoff
- Potable water for the onsite construction workforce will be subject to provincial water quality guidelines and treatment

If the above management processes are adhered to, no adverse effects of construction on drinking water quality are anticipated.

Project effects on drinking water quality were considered for the operations phase only, since during the construction phase filling period, the reservoir would not have the hydrodynamic features of a finished reservoir. Furthermore, it is difficult to accurately predict changes to drinking water quality parameters at a point in time during the construction filling period due to fluctuating water quality conditions.

Based on the above, the following drinking water quality parameters were assessed for the Project operations phase:

- Temperature
- Total suspended solids (TSS)
- Turbidity
- Nutrients (nitrates)
- Mercury

2.0 DRINKING WATER QUALITY BASELINE: METHODOLOGY AND RESULTS

2.1 Surface Water

Baseline surface water quality data were obtained at 22 different sampling sites along the Peace River and its tributaries including the existing reservoirs, Peace River mainstem downstream of existing reservoirs, Peace River mainstem above confluence with major tributaries, Peace River mainstem below the proposed dam site, and major tributaries to the Peace River above and below the proposed dam site. These stations were selected based upon their representativeness of various reaches (refer to Figure 1 in Attachment 2). Baseline water quality sampling programs were conducted in 2007, 2008, 2010 and 2011.

Of the 22 sampling sites, ten sites were modeled for project effects on water quality. Table 1 in Attachment 1 summarizes baseline surface water quality concentrations for drinking water quality parameters in comparison with drinking water quality guidelines for these sites. Overall, the measured drinking water quality parameters are at low to very low concentrations in the reservoirs, at higher concentrations in the Peace River mainstem, and at highest concentrations in the tributaries. Concentrations of some drinking water quality parameters increase in a downstream direction, and especially during high flows, while concentrations of other parameters do not have obvious spatial or temporal patterns.

2.1.1 Temperature

In the Peace River and tributaries, temperature was recorded at the surface of the water, but in the reservoirs, temperature was recorded through the water column profile. Mean baseline water temperature was within drinking water quality guidelines (Health Canada 2012) for all sites, however, maximum baseline temperature values in the mouths of the tributaries to the Peace River exceeded drinking water quality guidelines. Surface water temperature was highest in the summer period, ranging between 8ºC and 16 ºC in the reservoirs, 1.4ºC to 16ºC in the Peace River, and 0.1ºC to 17.0ºC in the tributaries.

2.1.2 Total Suspended Solids

In general, loads of TSS in the river showed an increase during spring freshet flows. The Halfway River was a major contributor of particulate parameters to the Peace River, particularly during the spring freshet, and concentrations of particulate bound substances were shown to be substantially higher in the Peace River downstream of the Halfway River (Station Peace-03) as compared to upstream of the Halfway River (Station Peace-02).

Loads from the Moberly River did not show a substantial increase in concentrations in the Peace River. Mean concentrations at Station Peace-04, downstream of the Moberly River, were substantially different than mean concentrations at station Peace-03 for all parameters, during all seasons, or for the combined dataset.

Loads from the Pine River to the Peace River on occasion contributed to noticeable changes in water quality in the Peace River. Station Peace-14 is downstream of the Pine River, while station Peace-04 is upstream of the Pine River.

Total suspended solids concentrations ranged from 1.5 mg/L to 2,760 mg/L across all samples. The highest median value was recorded during spring freshet in Cache Creek. Measured TSS concentrations were an order of magnitude lower in the reservoirs than in the tributaries and the Peace River. The lower concentrations of TSS in the reservoirs, as compared to the Peace River or tributaries, are due to the settling out of TSS in the lower energy (still water) environment of the reservoir.

In the Peace River, mean TSS concentration was highest in spring (178 mg/L) as compared to summer (27 mg/L) or fall (4.4 mg/L), and there was a noticeable increase in mean TSS from upstream of the Halfway River (Station Peace-02; overall mean = 17 mg/L) to downstream of the Halfway River (Peace-03; overall mean = 75 mg/L). Mean TSS concentrations were similar in the Peace River from downstream of the Halfway River (Peace-03) to downstream of the Beatton River (Peace-15), with mean values of 75 mg/L (Peace-03), 93 mg/L (Peace-04), 69 mg/L (Peace-14), and 115 mg/L (Peace-15). By Station Peace-05, downstream of the Kiskatinaw River but upstream of Alces River, mean TSS increased to 521 mg/L.

In the tributaries, TSS concentration was highest in spring, and lowest in summer and fall. Where winter data are available, TSS concentrations were variable (higher standard deviation bars for winter data compared to data from other seasons). Causes of high mean concentration and high standard deviation in the winter samples from Lynx Creek and Cache Creek are unknown.

The relationship between turbidity and TSS in the Peace River and the tributaries was investigated (Golder 2009; Knight Piésold 2012). There is a strong positive relationship between discharge and turbidity for some of the tributaries (e.g., Halfway River and Moberly River), but a weak relationship between discharge and turbidity for the Peace River. The weak relationship in the Peace River may be due, in part, to regulation of discharge in the Peace River (Golder 2009). The tributaries also provide seasonal (spring, summer, and fall) surges of water (with higher turbidity) to the Peace River.

The TSS load in the Peace River is a function of concentration and water discharge. Based on the watershed contributing areas upstream of the proposed Site C dam, the Halfway River is the largest contributing tributary to the Peace River, and it contributes high loads of TSS to the Peace River (Knight Piésold 2012).

2.1.3 Turbidity

Turbidity was shown to be more strongly correlated to TSS concentration in the Peace River tributaries than in the mainstem itself. As with TSS, the highest turbidity was measured in Cache Creek during spring freshet, with a value of 2,120 NTU, followed by the values at the mouth of Halfway River (maximum value = 1,664 NTU). As noted previously, Halfway River is the largest contributor of both TSS and turbidity to Peace River given its higher flow rate. Several stations (all of them in the mainstem except for one) had the lowest turbidity value of 0 (zero) NTU, mostly during fall. In the Peace River mainstem, mean turbidity values presented an upwards trend in the downstream direction from below Peace Canyon Dam (Peace-01, overall mean = 33.1 NTU) to below the proposed Site C Dam (Peace-04, overall mean = 130.4 NTU), to then decrease at the downstream most point (Peace-05, overall mean = 39.7 NTU). The increasing turbidity values in the Peace River mainstem may be attributed to the higher TSS loads of some tributaries, such as Cache Creek and Halfway River, in relation to the TSS load in the mainstem.

Reservoirs had lower turbidity values than the Peace River or its tributaries because of the settling out of TSS in the lower energy environment of the reservoir.

2.1.4 Nitrate

One-hundred and eighty-four (184) nitrate samples were collected in the technical study area. Baseline nitrate concentrations did not exceed the guidelines for drinking water quality. Median concentrations of nitrate by season (spring, summer, and fall) were similar in the reservoirs (0.051 mg/L, 0.052 mg/L, and 0.051 mg/L, respectively) and the Peace River (0.05 mg/L, 0.041 mg/L, and 0.041 mg/L, respectively), but lower in the tributaries (0.026 mg/L, 0.0074 mg/L, and 0.0016 mg/L, respectively). Nitrate concentrations were higher in the reservoirs than in the Peace River or tributaries (Golder 2012c).

Mean nitrate concentrations varied little between stations on the Peace River, ranging from 0.040 mg/L to 0.050 mg/L (Golder 2012c), and 0.029 mg/L to 0.049 mg/L at the BC MOE stations. Concentrations of nitrate in the tributaries show more seasonal variability, but at all tributary stations, nitrate is highest in the spring, and lowest in the fall (Golder 2012c). Variability of nitrate concentrations between seasons and stations are a result of seasonal releases of nitrogen from watersheds, and nitrogen demand in upstream areas (ESSA, Limnoteck and Golder 2012).

2.1.5 Mercury in Water

Health Canada Drinking Water Quality Guidelines for total mercury (i.e., all forms of mercury including methylmercury) for the protection of human health identifies a maximum acceptable concentration for total mercury of 1,000 ng/L (parts per trillion). Baseline concentrations of total mercury in the mainstem of the Peace River averaged 1 ng/L (Azimuth Consulting Group 2012).

2.1.6 Groundwater Quality

Baseline groundwater quality data were sampled within the area that would be inundated by the reservoir, from Peace Canyon Dam to the proposed Site C dam site, including the tributary valleys (i.e., baseline and groundwater modelling data were not obtained for areas downstream of the dam site). As changes to groundwater flow (e.g., water table levels) would extend beyond the proposed reservoir area, baseline water quality data was also collected for areas adjacent to the reservoir that will undergo influence to physical groundwater flow as a result of the creation of the reservoir.

Baseline groundwater quality was evaluated through drinking water well sampling, collected from five drinking water wells between July 9, 2012 and July 10, 2012. These baseline samples were analyzed for the following parameters:

- Alkalinity
- Color
- Hardness
- pH
- TDS
- Turbidity
- Inorganics (chloride, fluoride, nitrate, nitrite, sulfate)
- Total dissolved metals
- Coliforms

Based on groundwater sampling in wells, baseline results are summarized in Table 2, alongside the Canadian Drinking Water Quality Guidelines. Existing baseline conditions for the following parameters were found to exceed the Canadian Drinking Water Quality Guidelines (Health Canada 2012) in a number of drinking water wells:

- pH
- TDS
- Barium
- Iron
- Manganese
- Sodium
- Detectable concentrations of total coliforms

Table 2: Baseline groundwater quality sampling results compared to drinking water quality guidelines

Parameter[b]	Guidelines for Canadian Drinking Water Quality[c]	Well sample ID date sampled				
		Q10	Q19	Q22	Q33	WW 15-13
		12-07-09	12-07-10	12-07-10	12-07-09	12-07-09
Physical Tests						
Alkalinity, Total (CaCO3) (mg/L)	-	657	379	383	613	348
Colour (TCU)	15	<5.0	<5.0	<5.0	<5.0	<5.0
Conductivity (uS/cm)	-	1160	751	754	894	608
Hardness, Total (CaCO3) (mg/L)	-	688	455	426	18.9	375
pH	6.5-8.5	7.93	8	8.01	**8.55**	7.97
Total Dissolved Solids(mg/L)	500	**741**	483	429	**577**	372
Turbidity (NTU)	-	0.2	6.28	0.16	0.2	30.7
Inorganics						
Chloride (mg/L)	250	<5.000	<5.000	6	15.4	1.3
Fluoride (mg/L)	1.5	<0.200	<0.200	0.21	0.39	0.069
Nitrate (mg/L)	10	0.111	<0.050	0.567	<0.050	0.0224
Nitrite (mg/L)	3.2	<0.010	<0.010	<0.005	<0.010	<0.001
Sulfate (mg/L)	500	55.8	86.9	42.5	<5.000	24.2
Microbiological Analysis						
E.coli (MPN/100mL)	<1	<1	<1	<1	<1	<1
Total Coliforms (MPN/100mL)	<1	115	3	2	<1	<1
Dissolved Metals						
Aluminum	-	<10	<10	<10	<20	<10
Antimony	6	<0.5	<0.5	<0.5	<1	<0.5
Arsenic	10	0.1	0.6	0.13	<0.2	<0.1
Barium	1000	198	77	180	**1170**	166
Boron	5000	<100	<100	<100	250	<100
Cadmium	5	<0.2	<0.2	<0.2	<0.4	<0.2
Calcium	-	115000	96200	87800	3870	93200
Chromium	50	<2	<2	<2	<4	<2
Copper	1000	8.5	3.2	1.9	<2	<1
Iron	300	<30	**486**	<30	<30	**1880**
Lead	10	0.52	1.95	<0.5	<1	<0.5
Magnesium	-	97200	52200	50300	**2230**	34500
Manganese	50	<2	**61.1**	<2	4.1	81.1
Mercury	1	<0.2	<0.2	<0.2	<0.2	<0.2
Potassium		2800	2520	2280	1180	3410
Selenium	10	1.6	<1	1.9	<2	<1
Sodium	200000	37400	14600	15400	**233000**	3800
Uranium	20	6.3	1.02	1.81	<0.2	1.76
Zinc	5000	55	<50	<50	<50	<50
Total Metals						
Aluminum	-	<10	-	-	<20	<10
Antimony	6	<0.5	-	-	<1	<0.5
Arsenic	10	0.15	-	-	<0.2	<0.1
Barium	1000	195	65	160	**1140**	176
Boron	5000	<100	<100	<100	260	<100
Cadmium	5	<0.2	-	-	<0.4	<0.2

Parameter[b]	Guidelines for Canadian Drinking Water Quality[c]	Well sample ID date sampled				
		Q10	Q19	Q22	Q33	WW 15-13
		12-07-09	12-07-10	12-07-10	12-07-09	12-07-09
Calcium	-	118000	93800	83100	3700	95200
Chromium	50	<2	-	-	<4	<2
Copper	1000	7.7	-	-	<2	<1
Iron	300	<30	**649**	213	<30	**2880**
Lead	10	0.6	-	-	<1	<0.5
Magnesium	-	98100	52200	49200	2150	35200
Manganese	50	<2	-	-	<4	**82.5**
Mercury	1	<0.2	<0.2	<0.2	<0.2	<0.2
Potassium	-	2760	-	-	1110	3310
Selenium	10	1.6	-	-	<2	<1
Sodium	200000	37700	15100	14600	**237000**	3900
Uranium	20	6.64	-	-	<0.2	1.9
Zinc	5000	<50	<50	<50	<50	55

NOTES
[a] Items in **bold** indicate an exceedance with Canadian Guidelines for Drinking Water Quality
[b] All values are reported as µg/L unless otherwise noted
[c] Guidelines for Canadian Drinking Water Quality (Health Canada, 2012)
SOURCE: Adapted from Hemmera – BGC (2012)

3.0 DRINKING WATER QUALITY – PROJECT EFFECTS METHODOLOGY AND RESULTS

3.1 Surface Water

Baseline water quality conditions at the ten sampling sites along the Peace River and its tributaries were compared to results from two models (Golder 2012d; EBA 2012) to assess future drinking water quality conditions with the Project (refer to Table 2 in Attachment 1 for a summary of model results by sampling site).

The locations of Hudson's Hope, Fort St. John and Taylor's water intakes do not coincide with the locations of the sampling stations, but are straddled by the stations. Hudson's Hope is located approximately 5.2 km downstream of Station Peace 1. Fort St. John is located approximately 10.4 km downstream of station Peace 3 and 1.4 km upstream of station Peace 4. Taylor is approximately 10.4 km downstream of station Peace 4 and 1.7 km downstream of station Pine 16 (Figure 1). The location of the proposed Site C dam is approximately 3.5 km downstream of site Peace 3 and 1 km downstream of the mouth of the Moberly River.

Future water quality conditions with the Project at the sampling stations were simulated by a hydrodynamic, water quality and aquatic productivity model applied by Golder (2012d) and a hydrodynamic and sediment transport model developed by EBA (2012). Model results were available for the ten sampling locations in the report by Golder (2012d), while model results in the report by EBA (2012) were available for only seven of the ten locations. Because the reservoir will flood the existing mouths of Halfway River and Moberly River, among others, the comparisons between baseline and future conditions were conducted at the baseline stations Moberly US and Halfway MID in Moberly Creek and Halfway River respectively.

Modelling results were divided into two timeframes (refer to Table 2). The Early Stage was defined as the period when shoreline erosion and nutrient loading from the flooded lands at the proposed reservoir are at their peak (the first nine years of operation). The Late Stage was defined as thirty years after operations started. EBA(2012) reported results for the Early Stage only.

Drinking water quality parameters were compared with baseline for temperature, total suspended solids, turbidity, and nitrate. However, complete sets of data were not available for both models. Temperature, total suspended solids and turbidity were only available in the model by EBA (2012) for the seven reported stations; however, the report by Golder (2012d) explicitly provides the summary statistics for all parameters (excluding turbidity) at sites Peace 4 and Peace 5 during the Early Stage, including baseline data. At all other locations for the Early Stage and all locations during the Late Stage, summary statistics were derived from the sensitivity analysis results (Golder 2012d). Modelled dissolved oxygen data were not available for sites other than Peace 4 and Peace 5 during the Early Stage.

The available baseline and modelled results were characterized by the minimum, mean, and maximum values for each parameter. The mean of the summary statistics derived from the sensitivity analysis is the mean of the different permutation results run as part of the sensitivity analysis.

The difference between baseline and predicted concentrations was assessed in two ways. The first was the relative percent difference (RPD), defined as the difference between measured and modelled values divided by the average of the two, expressed as a percent. Higher values indicate the model results deviate more substantially from the baseline. Additionally, a check was performed to see whether the maximum value predicted in the model was less than the maximum value measured during the baseline. This check verifies whether the worst-case scenario in the model exceeds historical worst case concentrations.

The greatest differences between measured water chemistry and the Early Stage modelling results were found with nitrates (refer to Table 3 in Attachment 1). Nitrates at all sites other than Peace 4 and Peace 5 exceeded an RPD of greater than 20%. All of the stations with an RPD of greater than 20% had maximum modelled nitrate concentrations greater than historical maximums.

Conversely, no modelled temperature, total suspended solids or turbidity values were found to be above baseline data at any site in the Early Stage. Additionally, modelled turbidity is predicted to remain within the range of historical data in all stations. What these results may indicate is that given the greater volume and residence time of the reservoir compared to those of the river it may be less susceptible to abrupt increases of temperature and suspended solids caused by external inputs.

The greatest differences between baseline water chemistry and the Late Stage modelling results again were found in nitrate which exceeded an RPD of greater than 20% at all sites. Maximum predicted nitrate concentrations exceed historical maximums at all sites in the Late Stage.

According to this analysis, the drinking water intake at Hudson's Hope could experience higher nutrient levels in the Early and Late Stages. The other parameters are expected to remain within the predicted range of variation based on baseline water quality. Groundwater flows through shallow and deeper subsurface soils and bedrock discharges to the Peace River, thus groundwater may influence surface water quality (Hemmera-BGC 2012). However, it is difficult to predict if surface water quality changes are able to influence groundwater quality, especially that of the other two drinking water sources (Fort St. John and Taylor), as these wells are located in the hyporheic zone and no modelling has accounted for changes in this zone. If surface water quality does influence groundwater quality, that influence would be reflected mainly in dissolved parameters since the sands and gravels that often comprise aquifers are expected to filter out particulates (Golder 2012b).

Results indicate a reduction of TSS load at Peace 04 (near Fort St. John's water intake), due to sediment being captured upstream at the Site C dam. If surface water TSS goes down at Peace 4, it is likely that TSS would not be higher than baseline measurements at Taylor. Total suspended solids would not be affected as the dam would decrease TSS from upstream deposition (which may or may not be made up for by TSS transported via the Pine River).

3.2 Groundwater

Project effects on groundwater temperature and nutrients (nitrate) were not assessed. Project effects on TSS, and particulate matter-based water quality parameters (including turbidity) were not modelled as the sands and gravels that comprise the aquifer are expected to filter out particulates.

Of the approximately 55 identified water wells along the Site C reservoir, six are expected to undergo direct submersion (i.e., Site C reservoir will submerge the wells). The remaining wells are anticipated to experience a relative increase in the water level in the well ranging from less than 1 meter to 10 meters depending on their relative location along the Site C reservoir and distance away from the reservoir edge (Hemmera-BGC 2012). The increase in water level is not anticipated to influence groundwater quality within the wells or influence well operations. However, groundwater quality could be affected if either a flooded septic field or contaminated site with impacted groundwater is located in close proximity to operating water wells. General regions where this could occur are wells in proximity to the proposed Site C reservoir in the Hudson Hope area, Lynx Creek, and Farrell Creek areas. If this occurs, there is the potential for groundwater quality to exceed drinking water quality guidelines.

Potential effects of the Project on groundwater quality were assessed up to (not beyond) the Site C dam site. Drinking water intakes for Fort St. John and Taylor are located downstream of the dam site (drinking water is sourced from groundwater aquifers downstream as well).

It is unknown if surface water quality changes would influence groundwater quality, including the drinking water sources at Fort St. John and Taylor (these drinking water wells are located in the hyporheic zone and no modelling accounted for changes in this zone). If surface water quality does influence groundwater quality that influence would be reflected mainly in dissolved parameters since the sands and gravels that often comprise groundwater aquifers are expected to filter out suspended solids/particulates. It is likely that the 65 feet layer that separates the river bed from Fort St. John's aquifer would be adequate to filter out some sediment from the river water, resulting in negligible effects on Fort St John's drinking water quality. A similar scenario could be assumed for Taylor's drinking water supply.

The total mercury concentration in the mainstem of the Peace is not expected to change as a result of the Project (Azimuth Consulting Group 2012). There would be no 'new' source of mercury to the Site C reservoir as the main source of mercury in water is from Williston Reservoir, immediately upstream of Dinosaur Reservoir. Assuming that methylmercury concentrations would double from <0.05 ng/L to 0.1 ng/L in the Site C reservoir, the post-flooding concentrations of methylmercury in the water would still be 10,000 lower than the Canadian Drinking Water Quality Guideline for total mercury concentrations.

4.0 SUMMARY

The results from the water quality studies completed for the Site C Clean Energy Project Environmental Impact Statement indicate that changes to surface water quality as a result of the Project would not result in exceedance of Canadian Drinking Water Quality Guidelines.

In relation to groundwater, baseline conditions at various well sites exceed Canadian Drinking Water Quality Guidelines for a number of drinking water quality parameters. The Project could affect groundwater quality of a few potentially contaminated site properties located within close proximity to the Peace River, due to their susceptibility to a water table increase and/or partial inundation during reservoir formation. It is recommended that monitoring of groundwater quality of these well sites be carried out during the initial period of inundation and early operations.

Project effects on groundwater quality in relation to downstream groundwater wells, inclusive of Fort St. John and Taylor's water intakes were not assessed. Baseline groundwater quality data collection for Taylor and Fort St. Johns drinking water sources and private groundwater wells downstream of the Project, followed up by groundwater quality monitoring at these downstream sites should also be carried out, during initial periods of inundation and early operations.

5.0 CLOSURE

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ATTACHMENT 1

BASELINE CONDITIONS AND MODELLING RESULTS FOR DRINKING WATER QUALITY PARAMETERS

Table 1: Baseline conditions – drinking water quality parameters

Parameter	Statistic	Peace 1	Peace 2	Mouth of Halfway River[a]	Mouth of Cache Creek	Peace 3	Mouth of Moberly River[a]	Peace 4	Peace 4	Mouth of Pine River	Mouth of Beatton River	Peace 5	Peace 5
Temperature	Min	1.6	1.7	1.1	0.0 3	.5 3	.4	0.0 1.9		6.6	5.1	0.0 1.4	
	Mean	7.8	8.7	11.5 11.7		9.4	13.1	6.5 9.6		12.2	14.6	6.8 9.3	
	Max	13.2	13.3	**19.4**	**24.3**	**14.0**	**21.3**	**15.7**	**14.8**	**18.2**	**20.2**	**17.0**	14.2
Total Suspended Solids	Min	1.5	1.5	1.5	3.0 1	.5 1	.5	1.0 1.5		1.5	3.0	1.0 7.5	
	Mean	8.7	17.5	144.4 437.1		74.8	172.8	39.0 93.0		128.8	343.8	101.0 520.9	
	Max	135.0	156.0	1070.0 276	0.0	954.0	824.0	3122.0 101	0.0	946.0	2210.0	4365.0	1640.0
Turbidity	Min	0.0	0.6	4.8	3.4 0	.0 0	.0	- 0.0		2.5	8.6	- 7.1	
	Mean	33.1	37.8	166.5 334.8		68.9	175.4	- 130.4		127.9	377.0	- 39.7	
	Max	405.0	521.0	1204.0 212	0.0	674.0	942.0	- 100	0.0	850.0	1857.0	- 106 0	
Nitrate	Min	0.025	0.025	0.003	0.003 0.023	0.003		0.029 0.022		0.003	0.001	0.034 0	033
	Mean	0.055	0.046	0.031	0.022 0.043	0.019		0.060 0.043		0.049	0.012	0.061 0	044
	Max	0.140	0.071	0.090	0.150 0.072	0.120		0.210 0.072		0.178	0.025	0.280 0	057

NOTES:
[a] The assessment of temperature, total suspended solids and turbidity at the confluences of Halfway River and Moberly River was conducted where the mouths of these streams are predicted to be located once the reservoir is full
Bold values indicate exceedance of Canadian Drinking Water Guidelines (Health Canada 2012)
- data not collected
Units: Temperature = °C; Total Suspended Solids, Nitrate = mg/L.; Turbidity = NTU
SOURCE: Golder Associates (2012c)

Table 2: Modelling results – drinking water quality parameters

Stage	Parameter	Statistic	Peace 1	Peace 2	Mouth of Halfway River[a]	Mouth of Cache Creek	Peace 3	Mouth of Moberly River[a]	Peace 4	Peace 4	Mouth of Pine River	Mouth of Beatton River	Peace 5	Peace 5
Early Stage	Temperature	Min	0.5	0.0	0.1	-	0.1	0.1	0.1	0.4	-	-	0.1	-
		Mean	5.5	6.5	6.4	-	6.7	7.4	6.3	6.3	-	-	6.7	-
		Max	12.9	**17.5**	**19.4**	-	**17.8**	**21.5**	15.0	14.1	-	-	**16.6**	-
	Total Suspended Solids	Min	0.0	0.0	0.7	-	0.1	0.5	0.0	0.1	-	-	0.0	-
		Mean	0.0	11.8	61.2	-	17.0	43.6	18.0	17.5	-	-	92.0	-
		Max	1.2	193.4	1187.2	-	131.5	376.8	366.0	123.2	-	-	3441.0	-
	Turbidity	Min	0.0	0.0	1.1	-	0.1	0.8	-	0.2	-	-	9.7	-
		Mean	0.0	17.4	79.0	-	27.4	62.0	-	28.5	-	-	12.0	-
		Max	0.3	316.4	876.5	-	214.4	367.4	-	202.0	-	-	14.4	-
	Nitrate	Min	0.011	0.011	0.011	0.011	0.011	0.011	0.043	0.011	0.011	0.011	0.043	0.011
		Mean	0.104	0.102	0.101	0.102	0.106	0.108	0.069	0.109	0.106	0.109	0.068	0.109
		Max	0.330	0.310	0.310	0.310	0.320	0.330	0.180	0.320	0.310	0.320	0.240	0.320
Late Stage	Temperature	Min	-	-	-	-	-	-	-		- - -			
		Mean	-	-	-	-	-	-	-		- - -			
		Max	-	-	-	-	-	-	-		- - -			
	Total Suspended Solids	Min	-	-	-	-	-	-	-		- - -			
		Mean	-	-	-	-	-	-	-		- - -			
		Max	-	-	-	-	-	-	-		- - -			
	Nitrate	Min	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
		Mean	0.103	0.097	0.092	0.097	0.101	0.102	0.106	0.106	0.105	0.109	0.106	0.106
		Max	0.330	0.310	0.300	0.310	0.320	0.330	0.310	0.310	0.310	0.320	0.310	0.310

NOTES:
[a] The assessment of temperature, total suspended solids and turbidity at the confluences of Halfway River and Moberly River was conducted where the mouths of these streams are predicted to be located once the reservoir is full
Bold values indicate exceedance of applicable Canadian drinking water guidelines (Heath Canada 2012)
-data not collected
Units: Temperature = °C; Total Suspended Solids and Nitrate = mg/L; Turbidity = NTU
Sources: Golder Associates (2012d); EBA (2012)

Table 3: Difference between baseline and modelled results

Stage	Parameter	Statistic	Peace 1	Peace 2	Mouth of Halfway River[a]	Mouth of Cache Creek	Peace 3	Mouth of Moberly River[a]	Peace 4	Peace 4	Mouth of Pine River	Mouth of Beatton River	Peace 5	Peace 5
Early Stage	Temperature	RDP -34%		-29%	-57%	-	-34%	-55%	-3%	-40%	-	-	-1%	-
		Modelled Max within Baseline Range?	TRUE	FALSE	FALSE	-	FALSE	FALSE	TRUE	TRUE	-	-	TRUE	-
	Total Suspended Solids	RDP	-199%	-39%	-81%	-	-126%	-119%	-74%	-137%	-	-	-9%	-
		Modelled Max within Baseline Range?	FALSE	FALSE	FALSE	-	TRUE	TRUE	TRUE	TRUE	-	-	TRUE	-
	Turbidity	RDP -200%		-74%	-71%	-	-86%	-96%	-	-128%	-	-	-	-
		Modelled Max within Baseline Range?	TRUE	TRUE	TRUE	-	TRUE	TRUE	-	TRUE	-	-	-	-
	Dissolved Oxygen	RDP -		-	-	-	-	-	-2%	-	- -		-4%	-
		Modelled Max within Baseline Range?	- -		-	-	-	-	TRUE	-	-	-	TRUE	-
	Orthophosphate	RDP 42%		21%	-52%	-117%	-32%	-28%	0%	-31%	-142%	-96%	5%	-63%
		Modelled Max within Baseline Range?	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE
	Ammonia	RDP 8%		58%	-2%	-99%	16%	-15%	-52%	17%	134%	29%	-27%	9%
		Modelled Max within Baseline Range?	TRUE	FALSE	FALSE	TRUE	TRUE	FALSE	TRUE		TRUE	FALSE	FALSE	TRUE	FALSE
	Nitrate	RDP	61%	75%	106%	130%	85%	142%	14%	88%	74%	161%	11%	85%
		Modelled Max within Baseline Range?	FALSE	FALSE	FALSE	FALSE	FALSE	FALSE	TRUE	FALSE	FALSE	FALSE	TRUE	FALSE

Stage	Parameter	Statistic	Peace 1	Peace 2	Mouth of Halfway River[a]	Mouth of Cache Creek	Peace 3	Mouth of Moberly River[a]	Peace 4	Peace 4	Mouth of Pine River	Mouth of Beatton River	Peace 5	Peace 5
Late Stage	Temperature	RDP	- -		-	-	-	-	- -		-	-	-	-
		Modelled Max within Baseline Range?	- -		-	-	-	-	- -		-	-	-	-
	Total Suspended Solids	RDP	- -		-	-	-	-	- -		-	-	-	-
		Modelled Max within Baseline Range?		- -		-	-	-	-	-	-	-	-	-
	Nitrate	RDP	60% 71%		99%	127% 81%		139%	56% 86%		73%	161%	54%	82%
		Modelled Max within Baseline Range?	FALSE FALSE		FALSE	FALSE	FALSE	FALSE	FALSE FALSE		FALSE	FALSE	FALSE	FALSE

NOTE:
- = no data or computation not possible due to missing data

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ATTACHMENT 2

FIGURE 1

N

HALFWAY RIVER 168

Halfway 8

Halfway River

Farrell Creek

Red Creek

Cache Creek

Wilder Creek

Charlie Lake

Tea Creek

29

97

Cache 12

07FA006

07FA001

Halfway 9

Peace 2

Peace 3

07FA004

Peace 4

Fort St. John

07FC001

07FD004

Moberly 7

Moberly River

Boudreau Lake

Proposed Site C Dam

Taylor

07FD002

Pine 16

Beatton River

Alces River

07FD010

Peace 5

Beatton 17

Kiskatinaw 18

Farrell 11

Peace River

Dry Creek

Lynx Creek

07FB008

Moberly 6

Pine River

Lynx 10

Hudson's Hope

Williston Reservoir

W.A.C. Bennett Dam

07EF001

Peace 1

Montage Creek

Site 3 Dino

Peace Canyon Dam

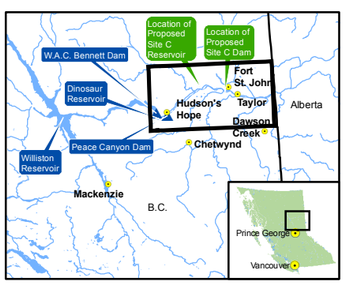
Site 2 Dino

Site 1 Dino

Dinosaur Reservoir

Kiskatinaw River

EAST MOBERLY LAKE 169



Map Notes:

1. First Nations Indian Reserve locations are shown for: A) First Nations whose Indian Reserves are within the Local Assessment Area of the Valued Component and B) First Nations whose reserves are outside the Local Assessment Area, where those First Nations contributed directly to the environmental assessment through the provision of Community Baseline Reports. Information was obtained as reported in Section 33.2.1.5 Aboriginal Community and Traditional Knowledge.
2. Datum/Projection: NAD83/UTM Zone 10N
3. Data Source: BC Hillshade model courtesy BC Environment, Lands and Parks. LiDAR hillshade acquired July/August 2006.
4. Other data provided by BC Hydro.

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Legend

- Sample Site Location
- Water Survey of Canada Hydrometric Station
- Protected Areas, Provincial Parks, Regional Parks, and Ecological Reserves
- Indian Reserve
- City/ District Municipality
- Existing Road
- Existing Highway

1:350,000

0 12,500 m

SITE C CLEAN ENERGY PROJECT

BC hydro

Golder Associates

Figure 1
Water temperature and quality monitoring stations on the Peace River and tributaries

Date	Dec. 20, 2012	DWG NO	1016-C14-B4992	R 0

Construction of the Site C Clean Energy Project is subject to required regulatory approvals including environmental certification

2 AIR QUALITY TECHNICAL MEMORANDUM

CONSULTING ENGINEERS & SCIENTISTS

Memorandum

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Date: **December 18, 2012** **RWDI Reference #:** 0920007A

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Nancy Chan, P.Eng. Nancy.Chan@rwdi.com

Re: **Screening Modelling Summary for Construction Material Source Areas**
BC Hydro Site C

1.0 Introduction

Screening modelling was conducted for the Project construction areas (West Pine Quarry, Del Rio Pit and Portage Quarry) situated outside the dispersion modelling study area (DMSA). Screening models provide conservative estimates of modeled concentration levels. The SCREEN3 model was used to predict worst-case concentrations under a variety of possible meteorological conditions. Results of the SCREEN3 modelling are presented as a flagging device that indicates the potential for unacceptable air quality and to investigate whether refined dispersion modeling, mitigation measures or changes in management practices may be needed.

2.0 Methodology

The US EPA SCREEN3 dispersion model was used to determine maximum criteria air contaminant (CAC) concentrations for a wide range of meteorological conditions (i.e., wind speed and PG stability class combinations). The model makes the conservative assumption of critical trapping for unstable and neutral conditions, which will tend to overestimate the expected concentrations.

Emissions were modelled as volume sources with source release heights of 3 m and 5 m which represent the amalgamated emissions from all construction activities. The initial lateral dimension for the volume source was 100 m and the initial vertical dimension of the volume sources was set to twice the source release height. Receptor height was set to zero m above grade and the rural option was selected for all model runs.

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Activities at Project construction areas outside of the DMSA (West Pine Quarry, Del Rio Pit and Portage Quarry) are scheduled to occur during the day according to the Project schedule in Chapter 4.3 of the EIS. As a result, atmospheric stability classes associated with daytime conditions were modelled (PG classes A through D) and stability classes associated with night-time conditions (PG classes E and F) were not considered.

A unit emission rate of one gram per second was used. Predicted concentrations for each model scenario were calculated by scaling the model results for the unit emission rate based on actual emissions for each pollutant of interest. The model was run for each source release height and stability class for a total of eight model runs. The maximum concentrations from the eight runs were used as a model conservatism. Emission rates were based on the construction year with the greatest amalgamated emission rate estimated at each Project construction area. Resulting model concentrations are presented with and without ambient background concentrations. The 24-hour average was calculated from the 1-hour prediction using the conversion factor of 0.4.

Model results for particulate matter were compared with their respective 24-hour average ambient air quality objectives, while predicted results for NO_2, SO_2 and CO were compared with their applicable 1-hour average ambient air quality objectives. Predicted concentrations of NO_2 and SO_2 were based on 100% conversion of NO_X and SO_X, respectively.

3.0 Results

3.1 West Pine Quarry

Predicted concentrations of TSP, PM_{10} and $PM_{2.5}$ for West Pine Quarry are illustrated in Figures 1 to 3, respectively. No exceedances of the 24-hour average ambient air quality objectives for all three sizes of particulate matter were predicted to occur for the nearest residence (1,500 m). Some exceedance of the 24-hour average ambient air quality objectives for TSP, PM_{10} and $PM_{2.5}$ were predicted to occur up to a distance of 500 m, 1,000 m and 900 m from the West Pine Quarry, respectively, when ambient background concentrations were added to the modelled results. Without background concentrations, exceedances of the 24-hour average ambient air quality objective for TSP, PM_{10} and $PM_{2.5}$ were not predicted to occur

Predicted concentrations of NO_2, SO_2 and CO for West Pine Quarry are illustrated in Figures 4 to 6, respectively. No exceedances of the 1-hour average ambient air quality objectives for NO_2, SO_2 and CO were predicted to occur at the nearest residence. No exceedances of the 1-hour average ambient air quality objectives for NO_2, SO_2 and CO were predicted to occur near the West Pine Quarry.

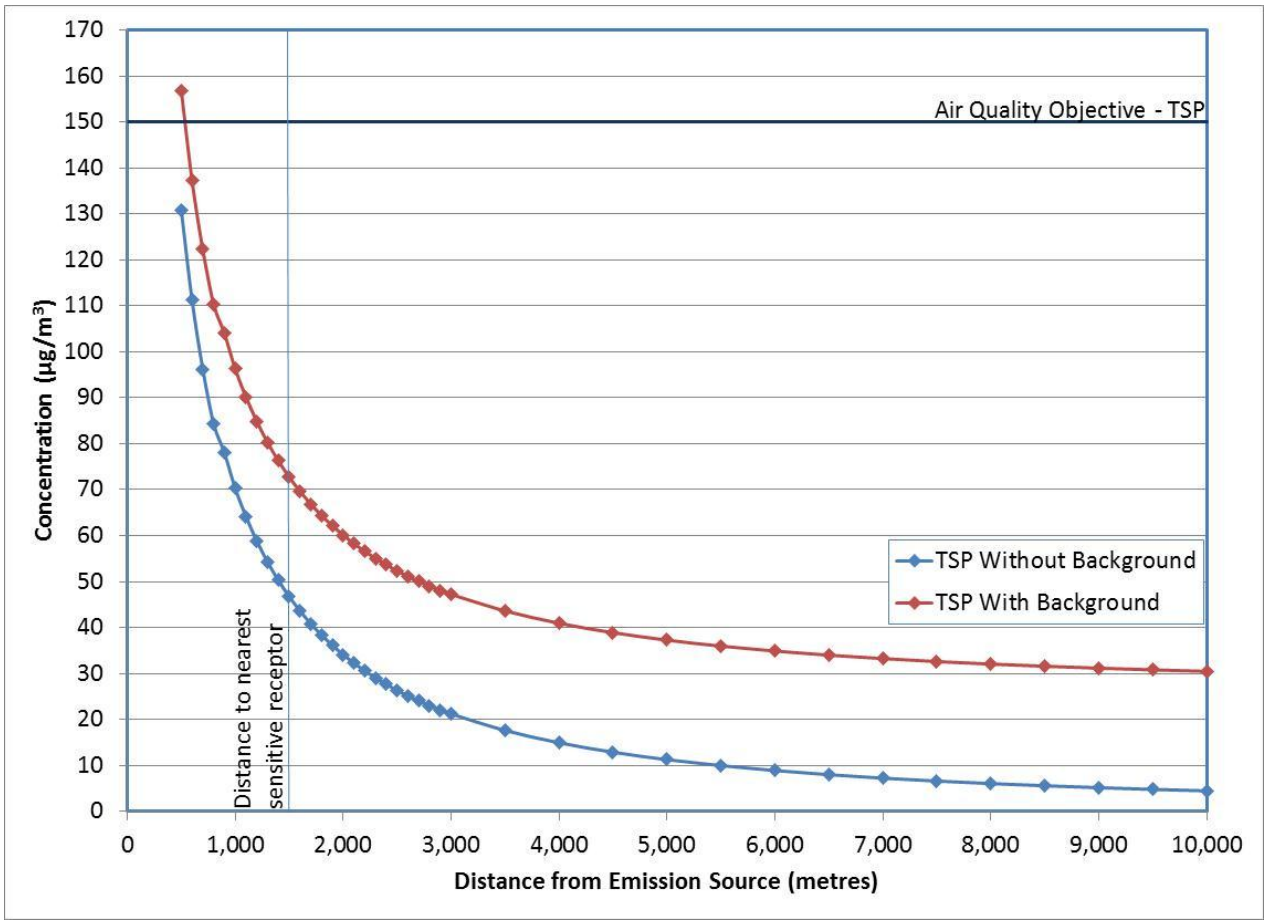

Figure 1: Predicted concentrations of TSP from West Pine Quarry (with and without ambient background)

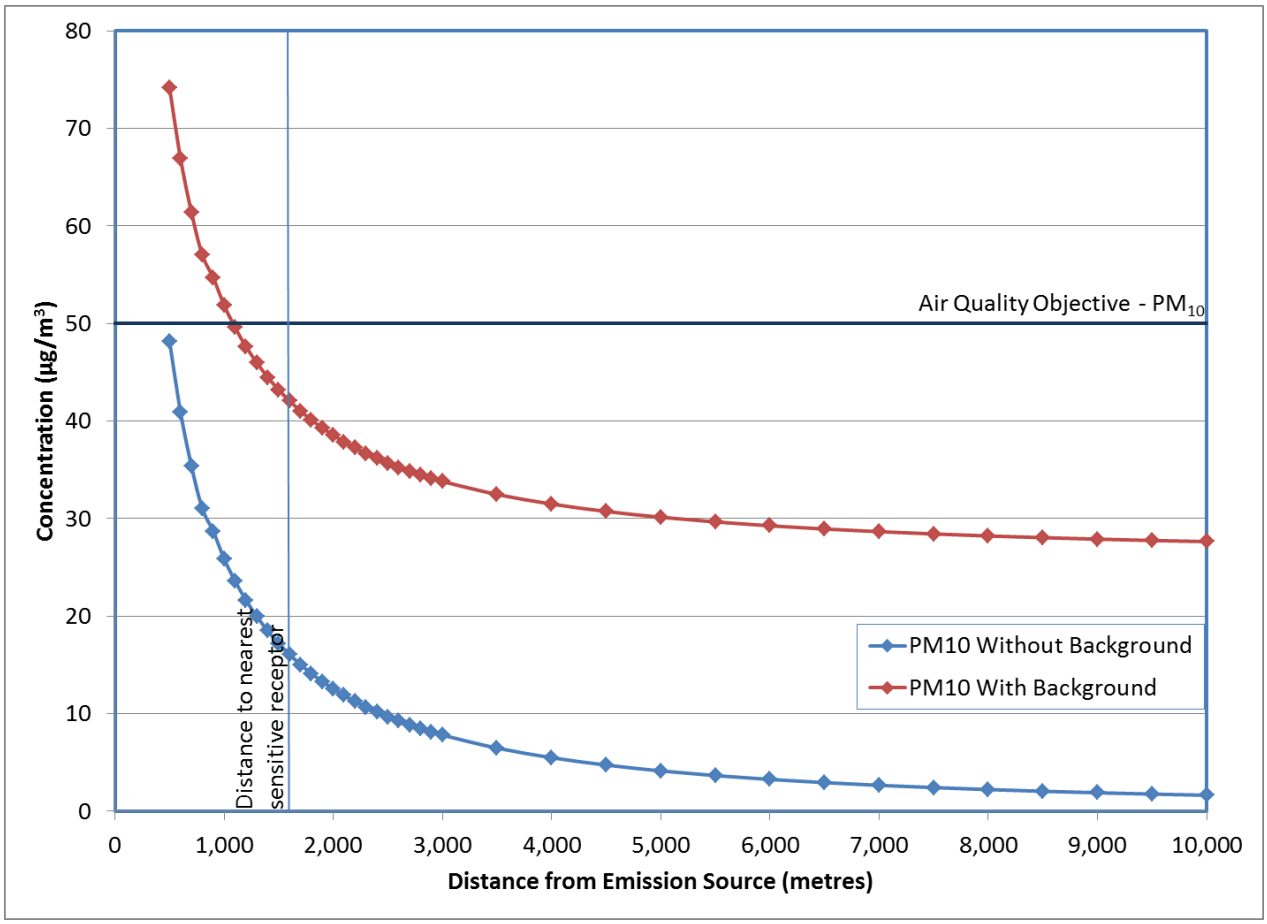

Figure 2: Predicted concentrations of PM_{10} from West Pine Quarry (with and without ambient background)

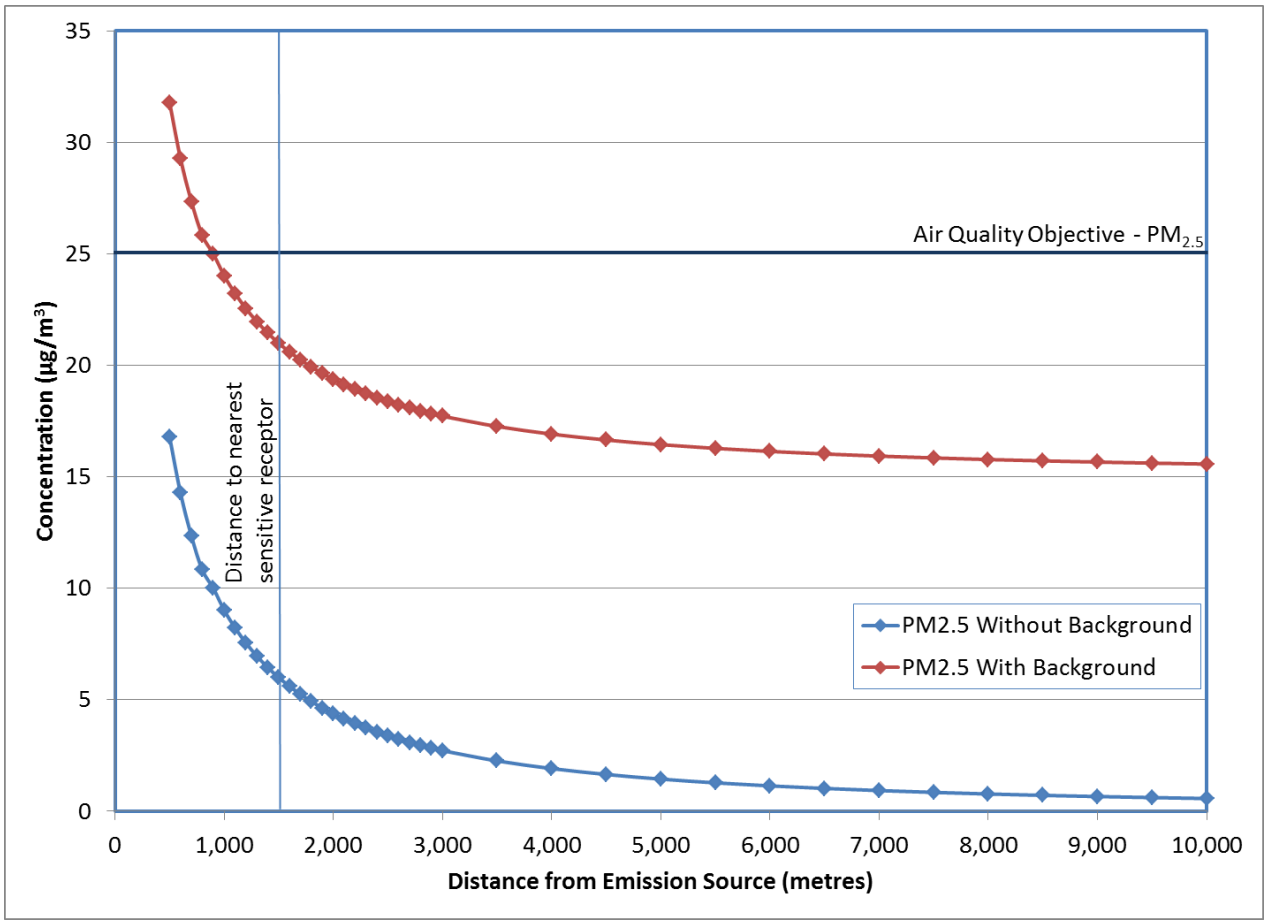

Figure 3: Predicted concentrations of $PM_{2.5}$ from West Pine Quarry (with and without ambient background)

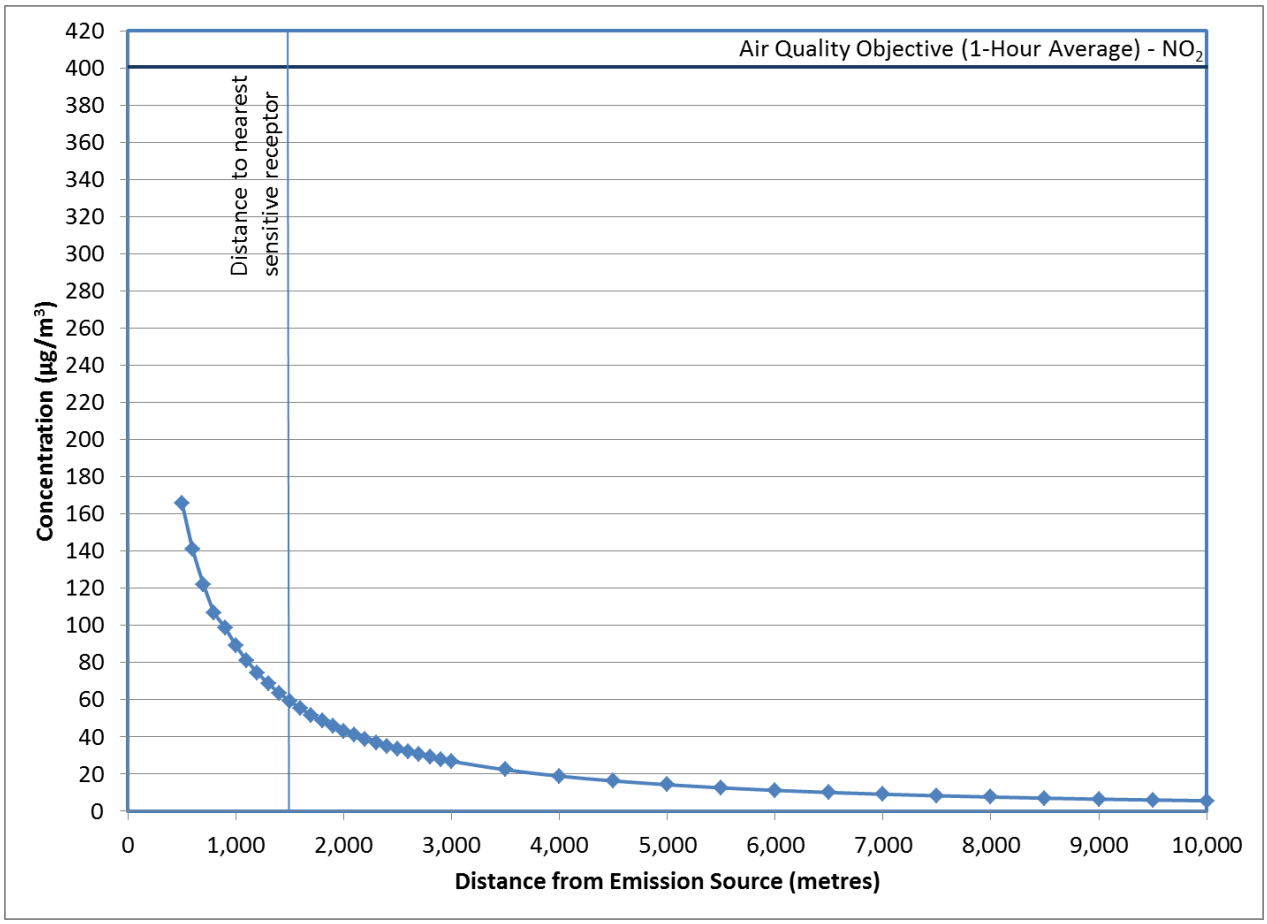

Figure 4: Predicted concentrations of NO_2 from West Pine Quarry (with and without ambient background)

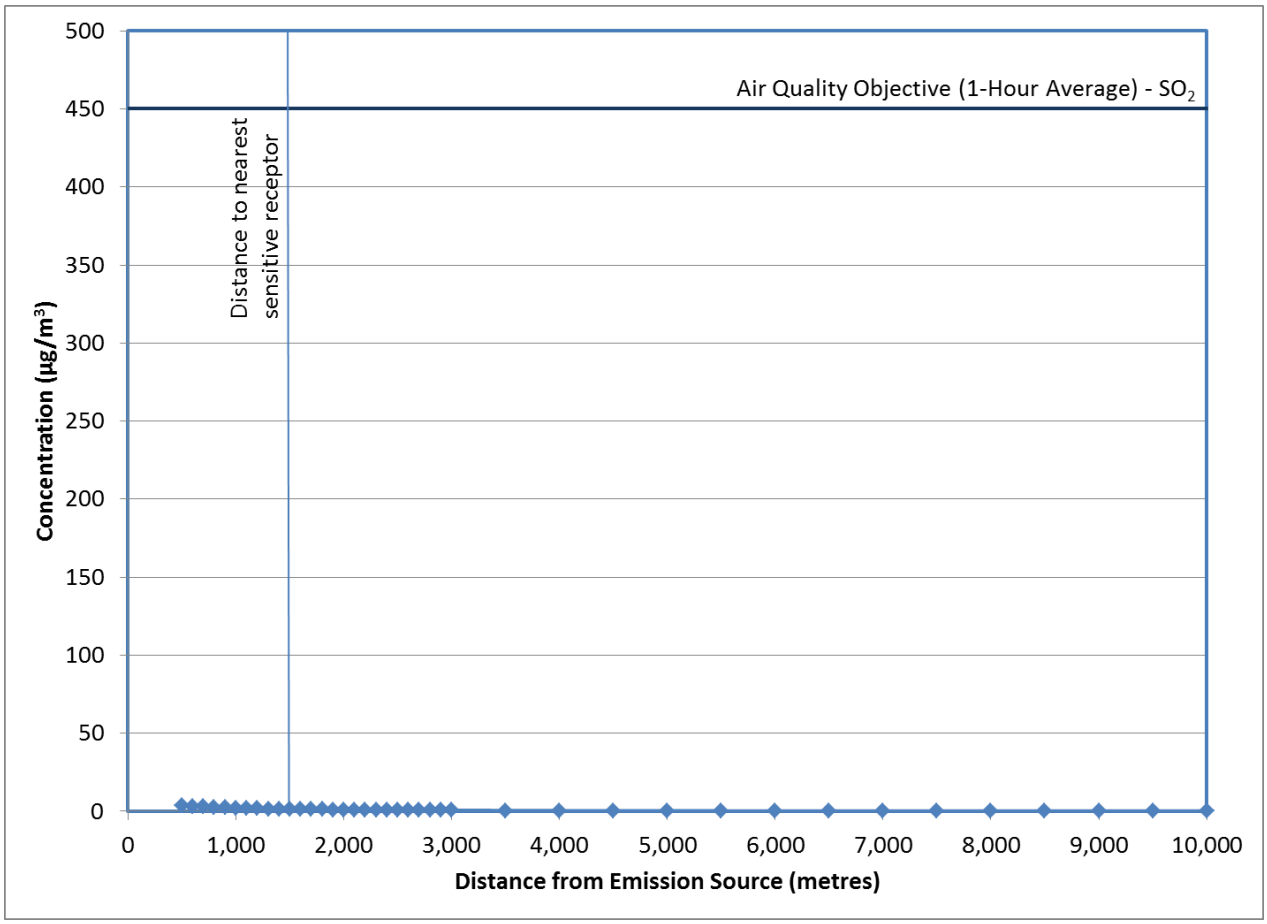

Figure 5: Predicted concentrations of SO_2 from West Pine Quarry (with and without ambient background)

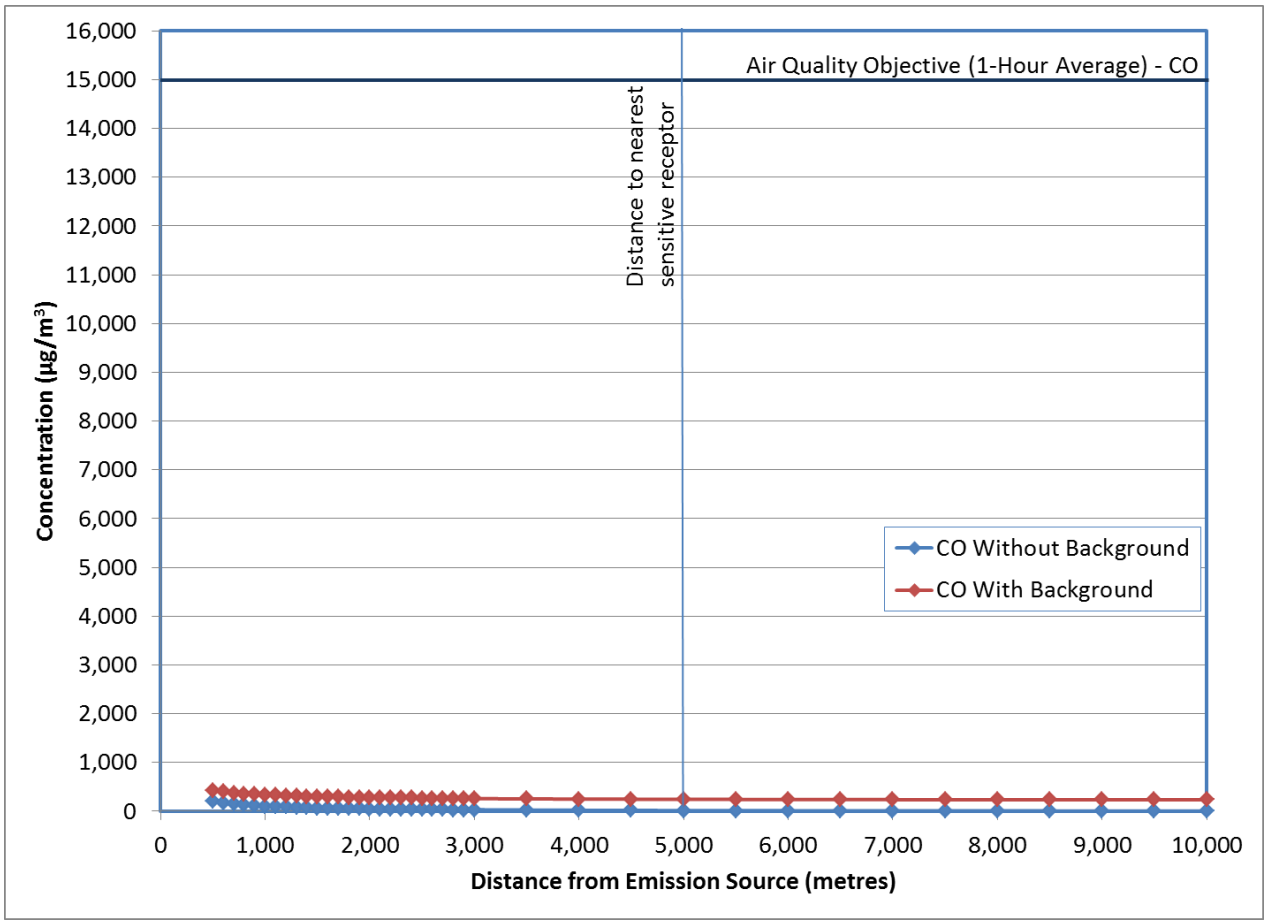

Figure 6: Predicted concentrations of CO from West Pine Quarry (with and without ambient background)

3.2 Del Rio Pit

Predicted concentrations of TSP, PM_{10} and $PM_{2.5}$ for Del Rio Pit are illustrated in Figures 7 to 9, respectively. No exceedances of the 24-hour average ambient air quality objectives for all three sizes of particulate matter were predicted to occur at the nearest residence (5,000 m). No exceedances of the 24-hour average ambient air quality objectives for TSP, PM_{10} and $PM_{2.5}$ were predicted near the Del Rio Pit.

Predicted concentrations of NO_2, SO_2 and CO for Del Rio Pit are illustrated in Figures 10 to 12, respectively. No exceedances of the 1-hour average ambient air quality objectives for NO_2, SO_2 and CO were predicted to occur.

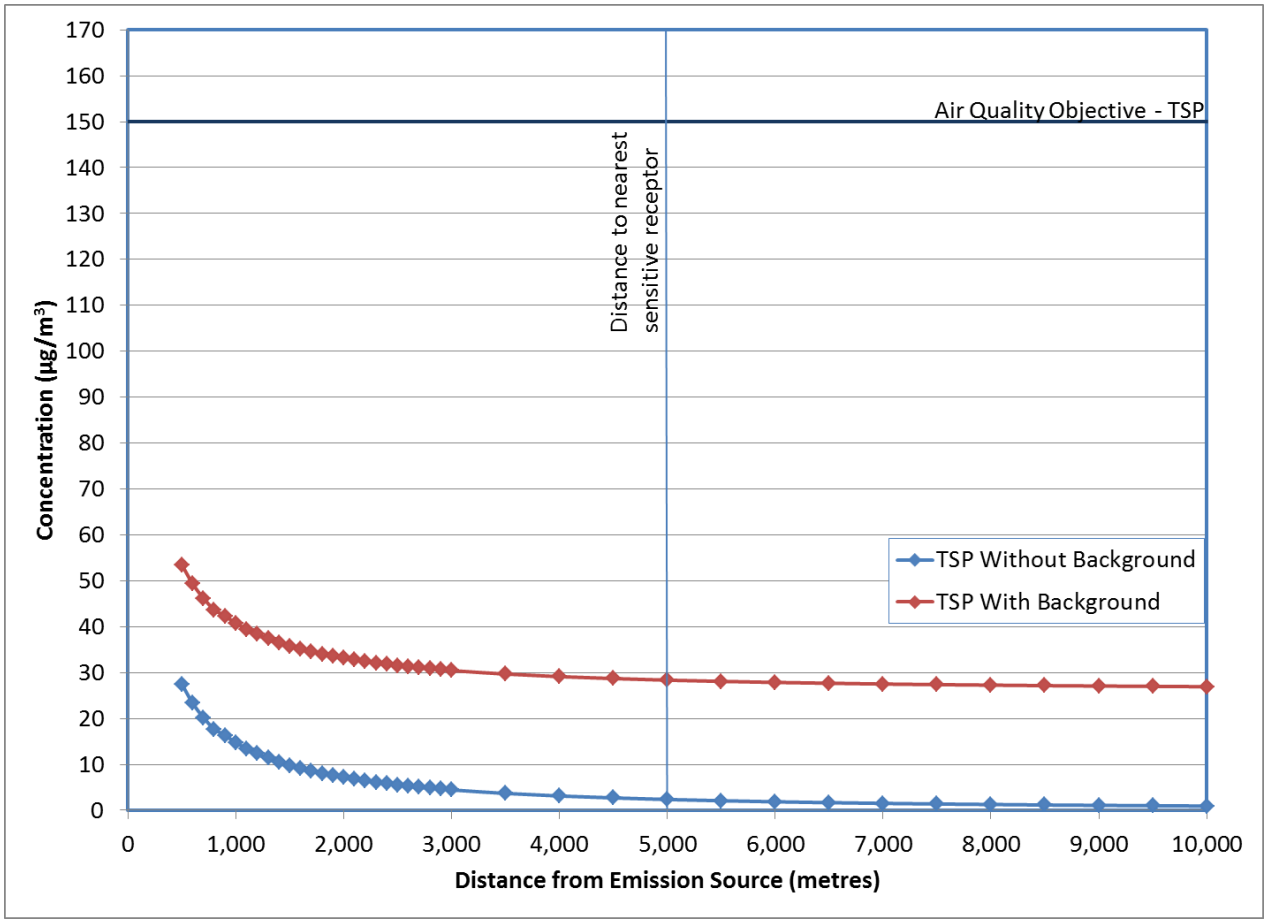

Figure 7: Predicted concentrations of TSP from Del Rio Pit (with and without ambient background)

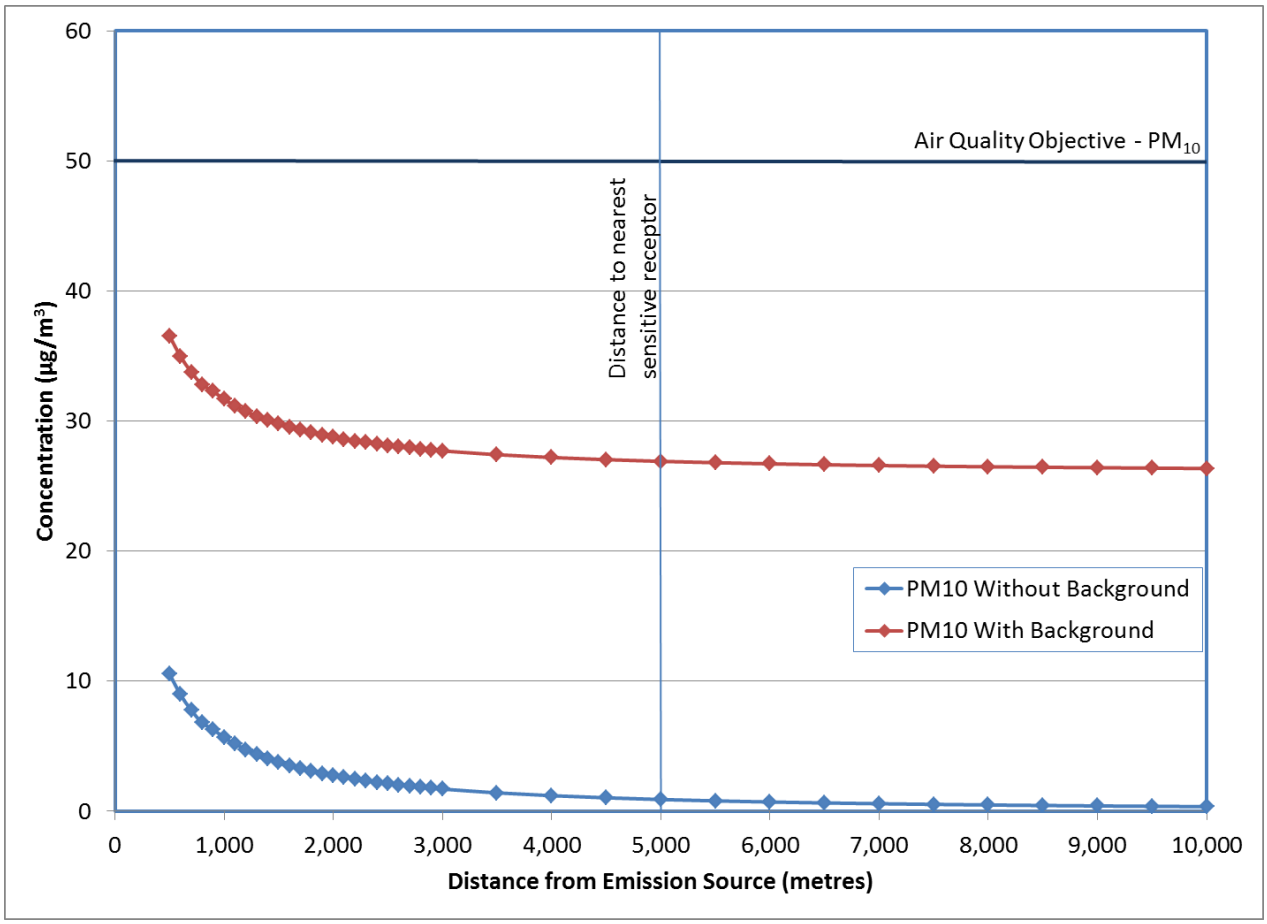

Figure 8: Predicted concentrations of PM_{10} from Del Rio Pit (with and without ambient background)

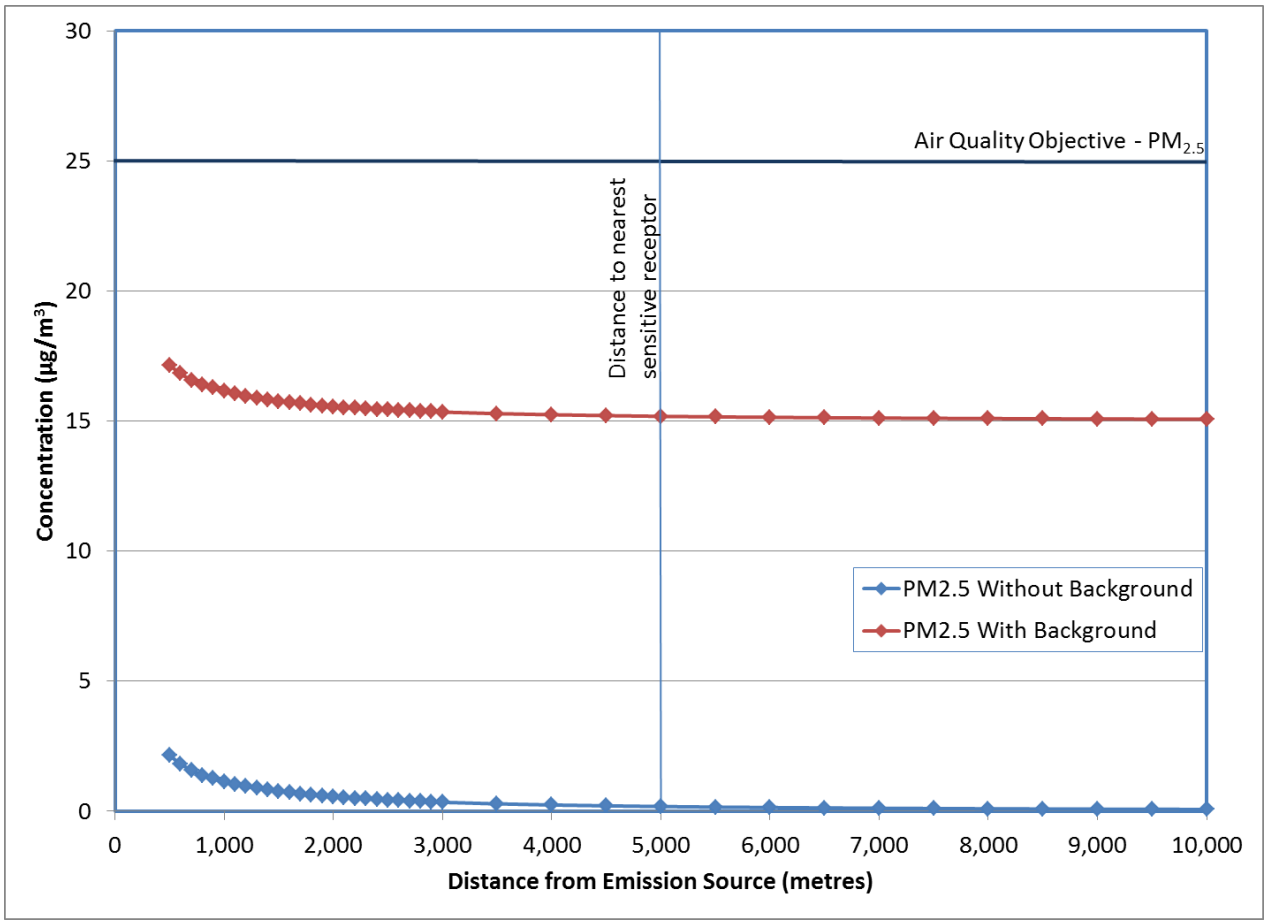

Figure 9: Predicted concentrations of $PM_{2.5}$ from Del Rio Pit (with and without ambient background)

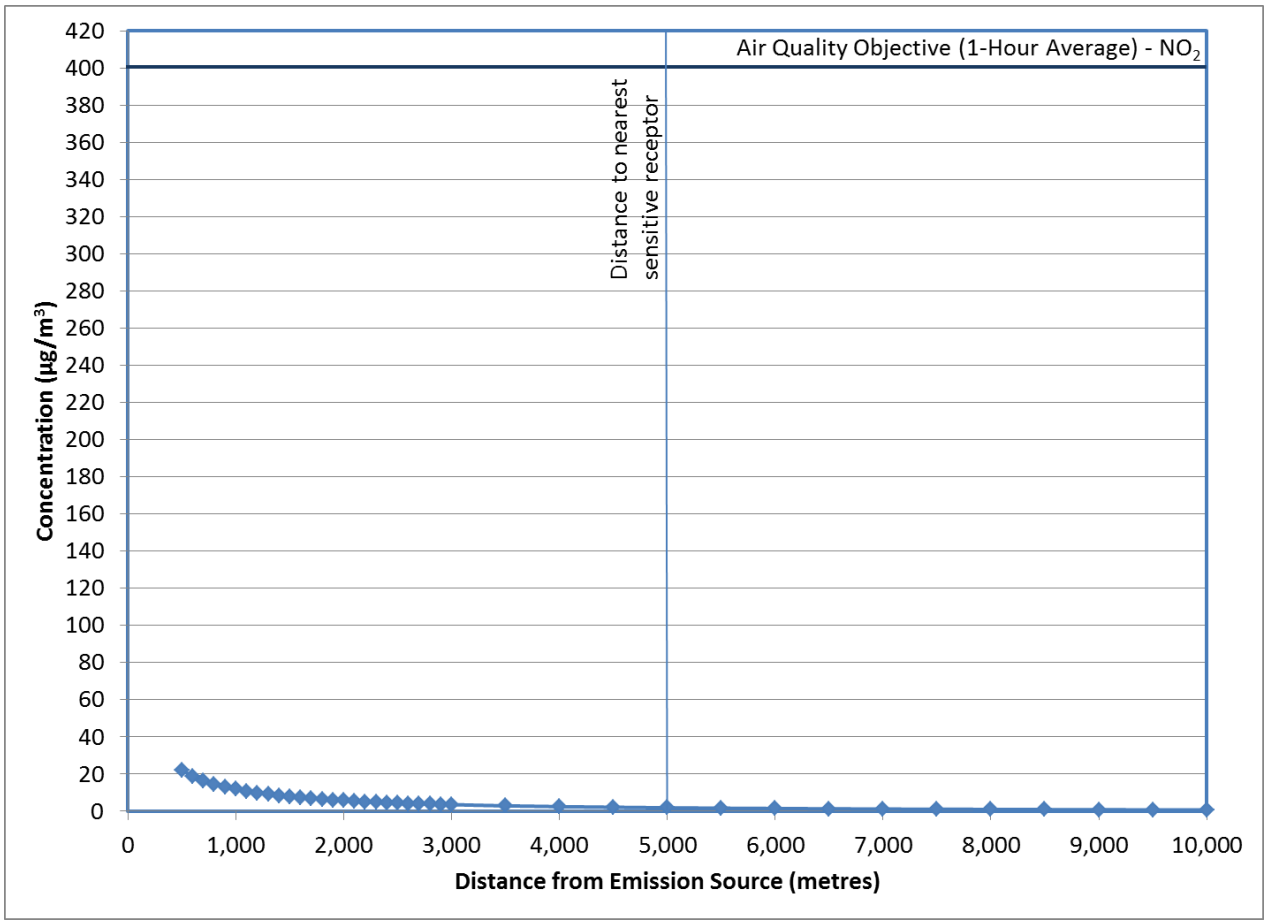

Figure 10: Predicted concentrations of NO_2 from Del Rio Pit (with and without ambient background)

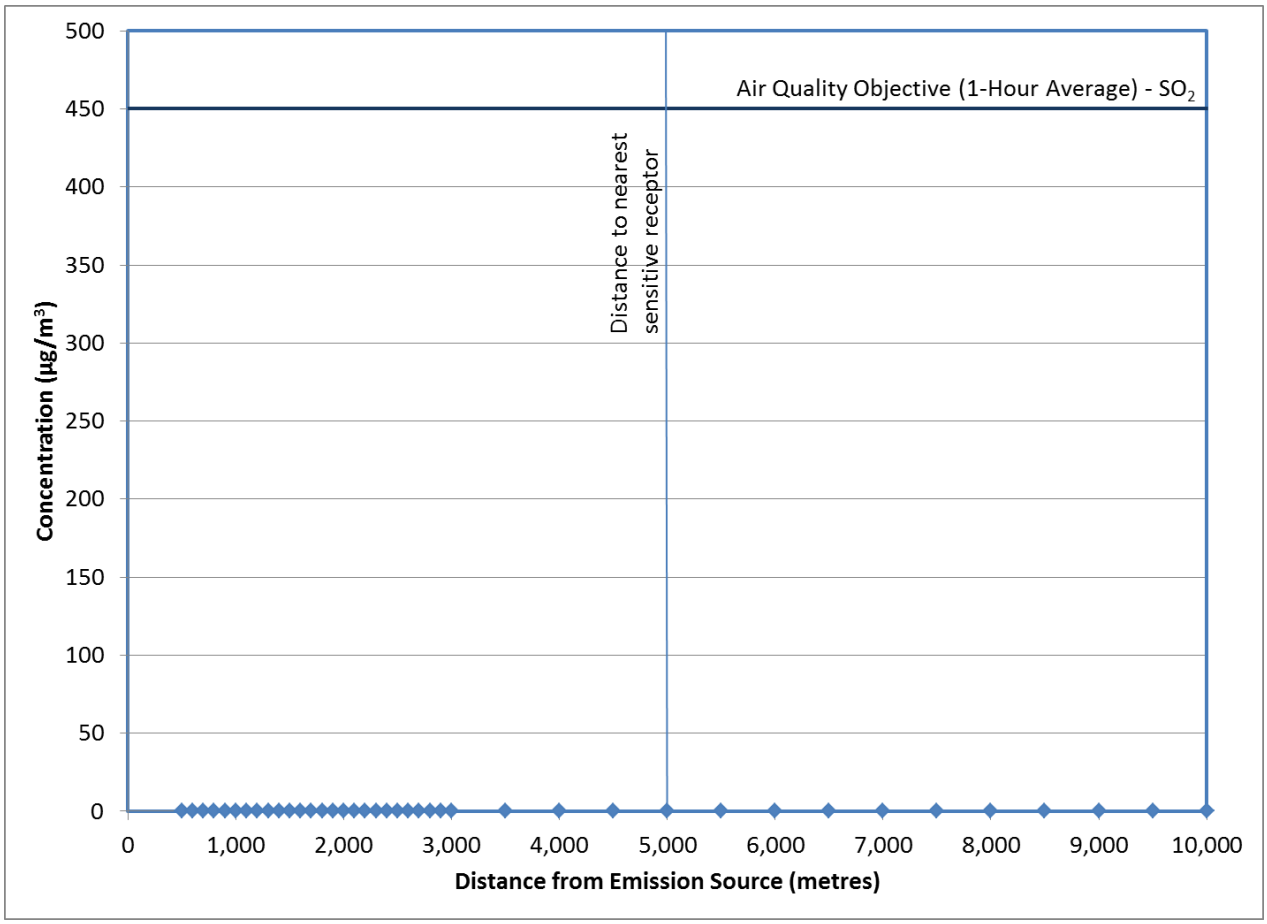

Figure 11: Predicted concentrations of SO_2 from Del Rio Pit (with and without ambient background)

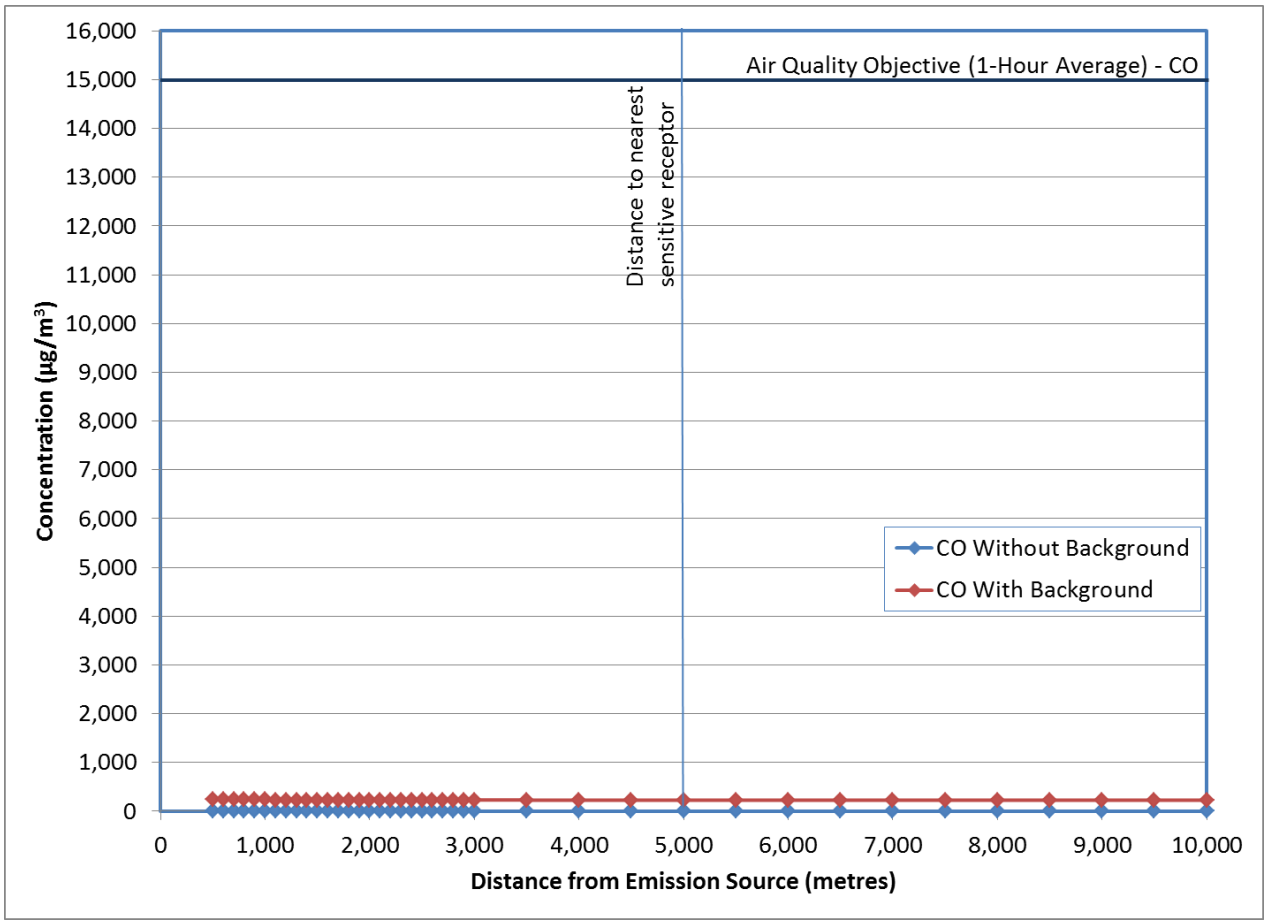

Figure 12: Predicted concentrations of CO from Del Rio Pit (with and without ambient background)

3.3 Portage Quarry

Predicted concentrations of TSP, PM_{10} and $PM_{2.5}$ for Portage Quarry are illustrated in Figures 13 to 15, respectively. No exceedances of the 24-hour average ambient air quality objectives for the three size fractions of particulate matter were predicted to occur at the nearest residence (8,000 m). Exceedances of the 24-hour average ambient air quality objectives for TSP, PM_{10} and $PM_{2.5}$ were predicted to occur up to a distance of 1,500 m, 2,600 m and 2,000 m from the Portage Quarry respectively, when ambient background concentrations were added to the modelled results. Without background concentrations, exceedances of the 24-hour average ambient air quality objectives for TSP, PM_{10} and $PM_{2.5}$ were predicted to occur up to a distance of 1,200 m, 1,400 m and 700 m from the Portage Quarry, respectively.

Predicted concentrations of NO_2, SO_2 and CO for Portage Quarry are illustrated in Figures 16 to 18, respectively. No exceedances of the 1-hour average ambient air quality objectives for NO_2, SO_2 and CO were predicted to occur near the Portage Quarry.

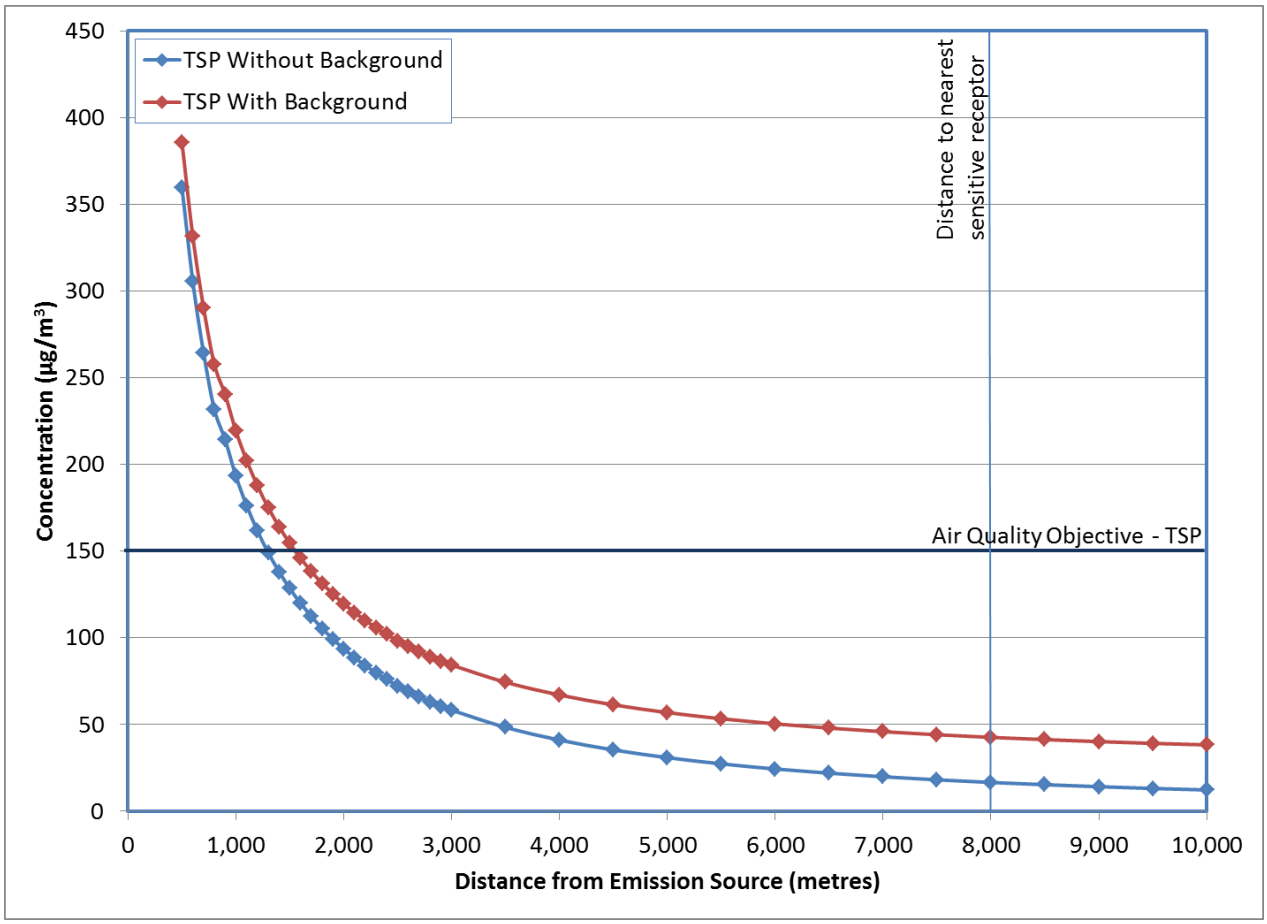

Figure 13: Predicted concentrations of TSP from Portage Quarry (with and without ambient background)

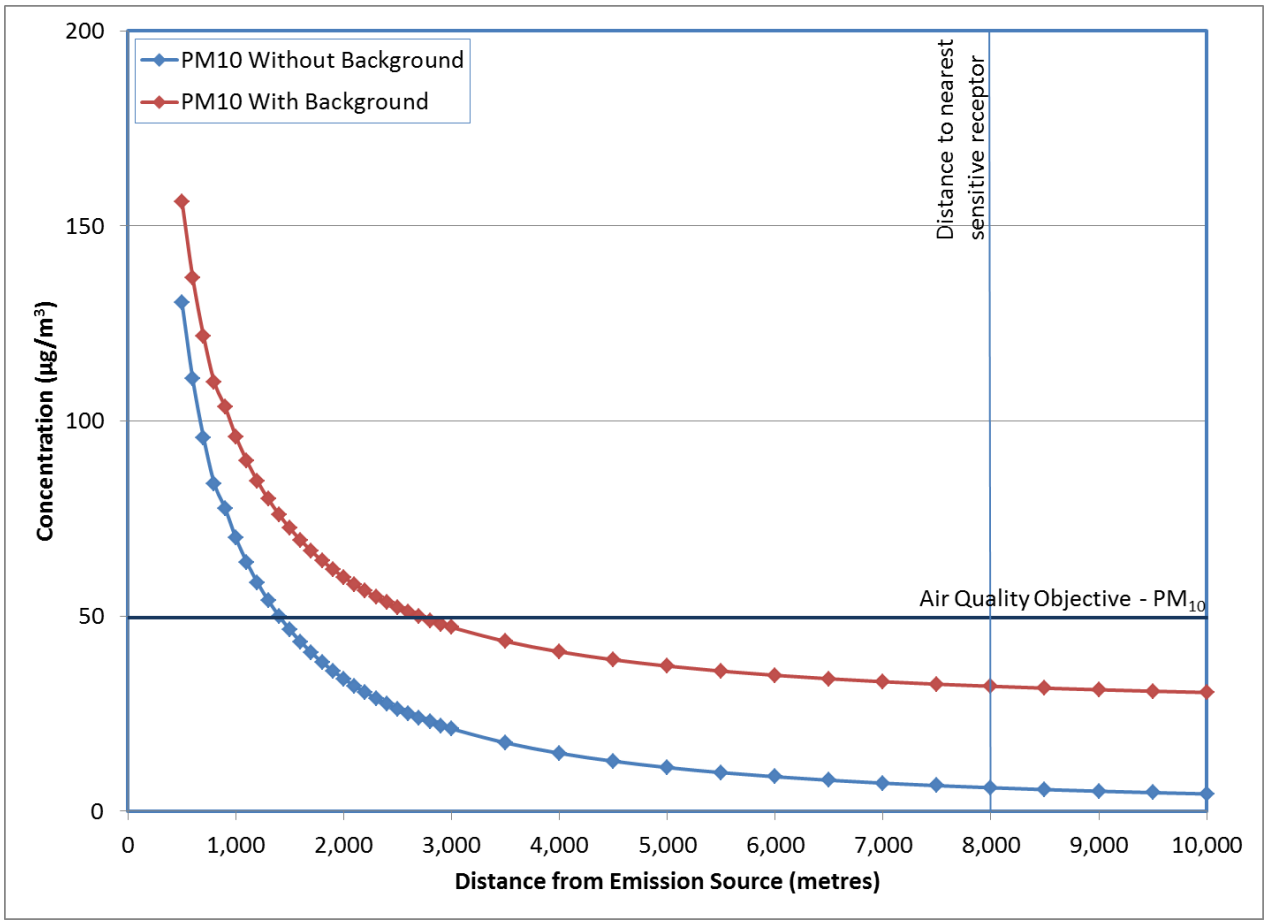

Figure 14: Predicted concentrations of PM_{10} from Portage Quarry (with and without ambient background)

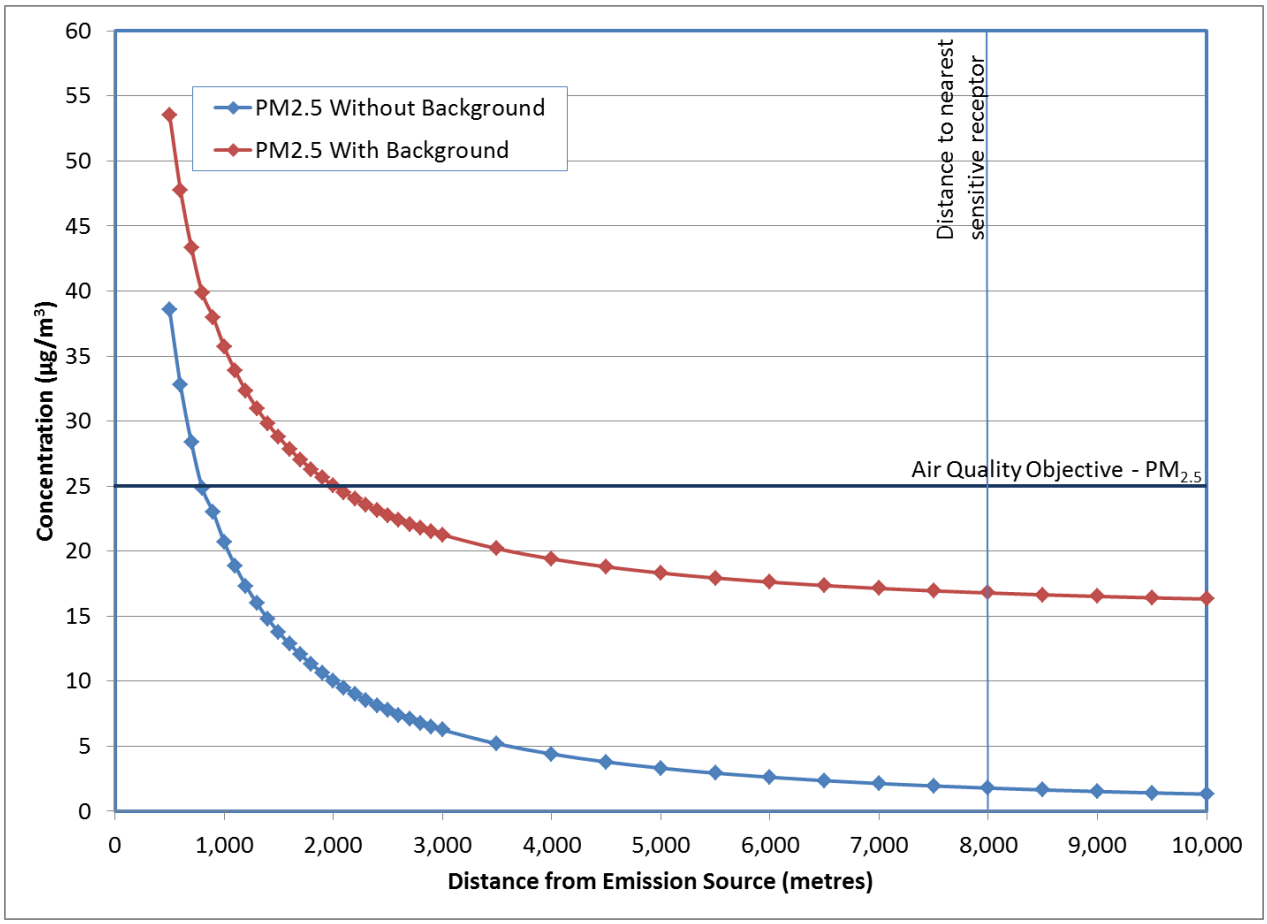

Figure 15: Predicted concentrations of $PM_{2.5}$ from Portage Quarry (with and without ambient background)

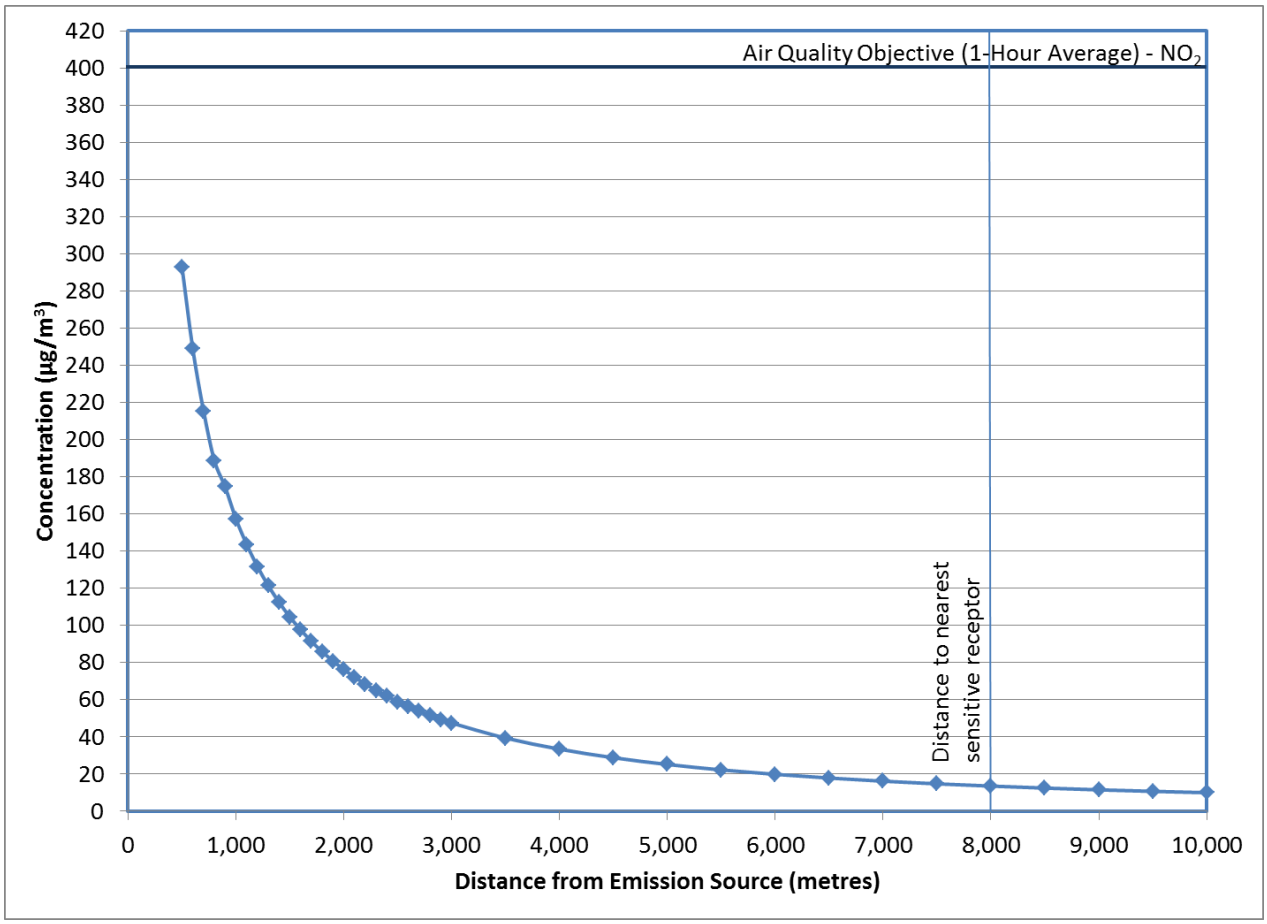

Figure 16: Predicted concentrations of NO_2 from Portage Quarry (with and without ambient background)

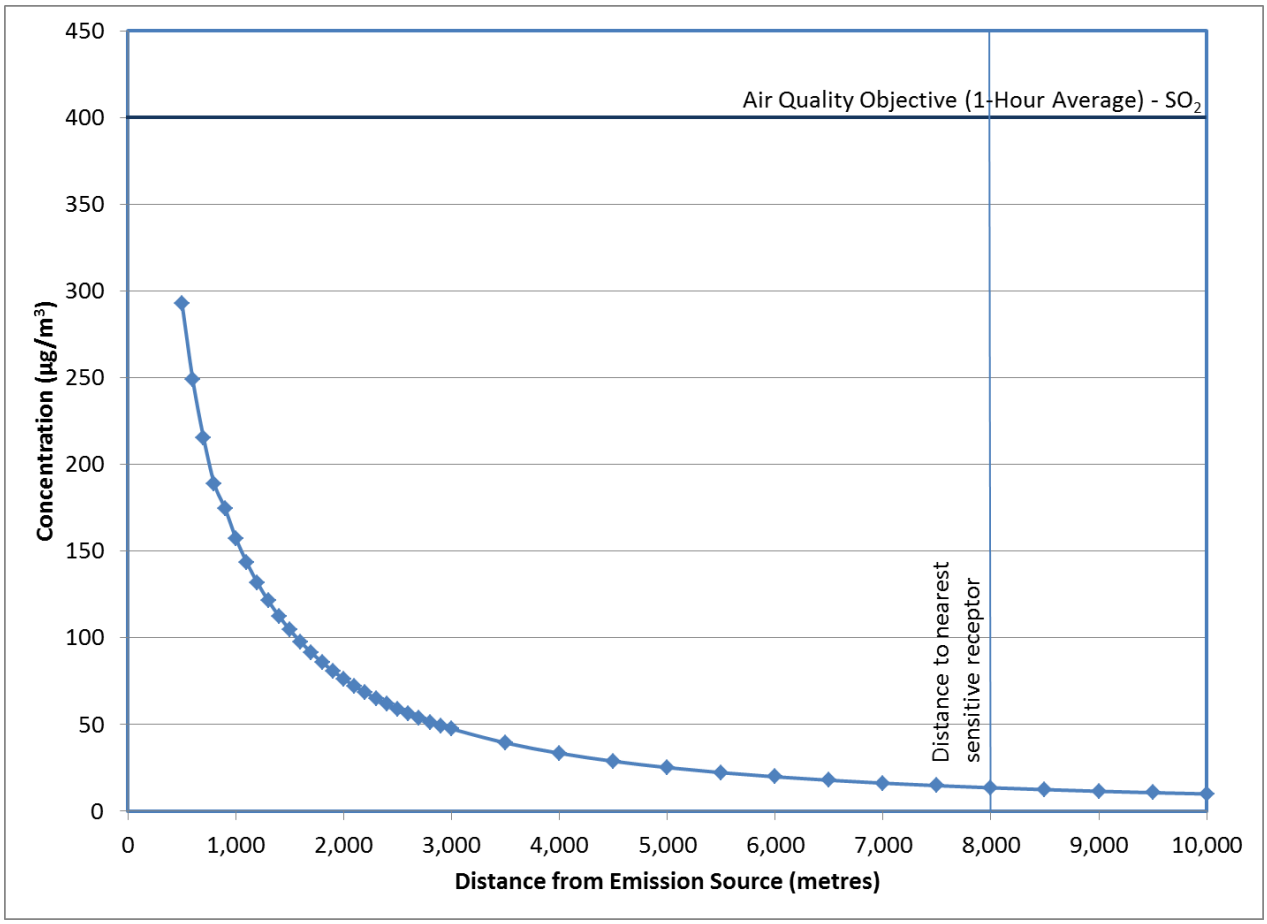

Figure 17: Predicted concentrations of SO_2 from Portage Quarry (with and without ambient background)

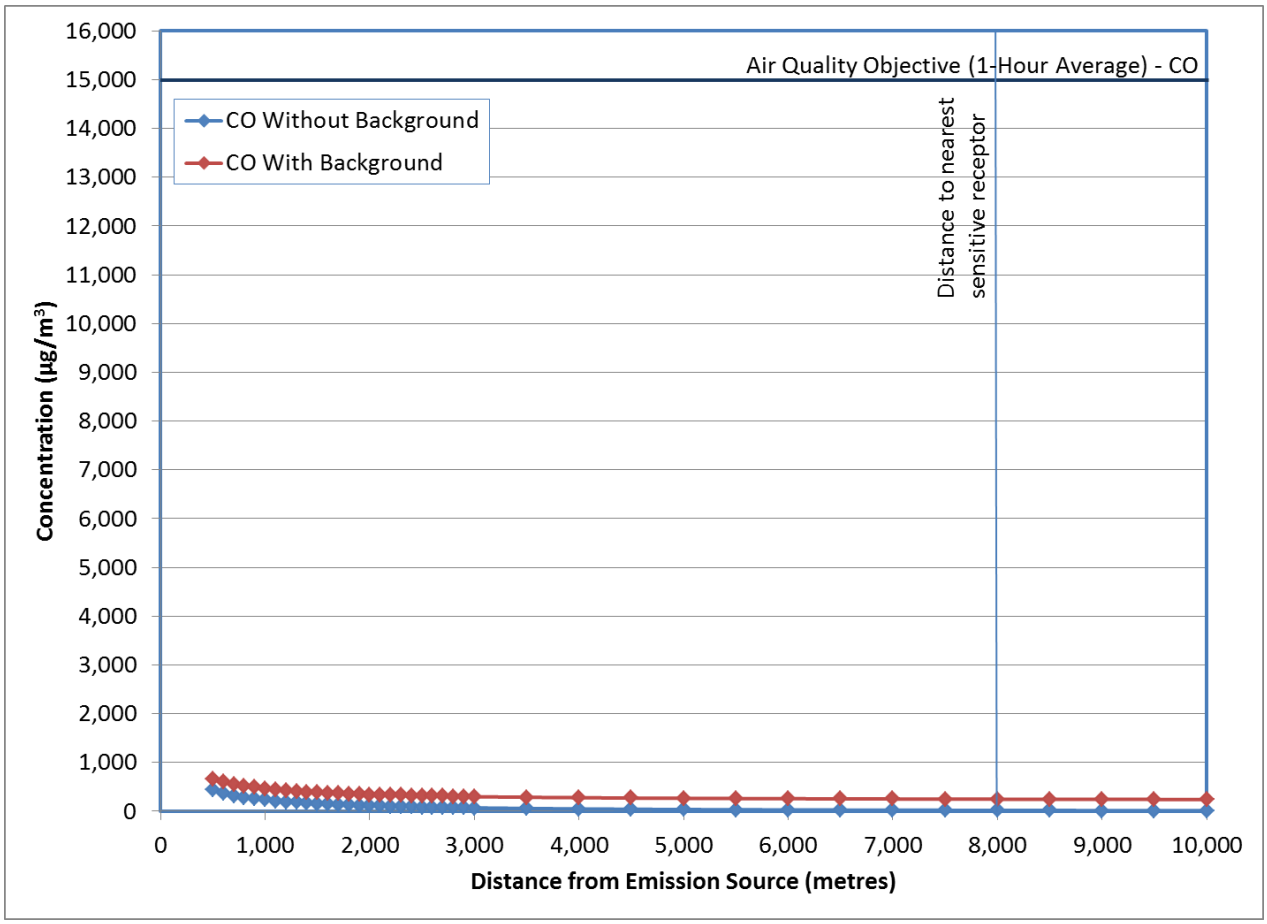

Figure 18: Predicted concentrations of CO from Portage Quarry (with and without ambient background)