7.2 Air Quality and Noise

7.2.1 Scope of Assessment

Air quality and noise were not formally assessed at the Minago Project as part of the conducted environmental baseline studies. The air quality at the site is excellent as over 98% of the site is vegetated and the site is located far away from any kind of settlement or development. The closest settlements are the very small settlement of Ponton, MB, approximately 68 km to the north of the Minago Project, and Grand Rapids with approximately 1,000 residents (town and Grand Rapids First Nations), approximately 100 km south of the project. The closest city is the City of Thompson, a regional trade and service centre of Northern Manitoba. Thompson is approximately 225 km northeast of the Minago Project and has 13,500 residents. Besides equipment that was working during the exploration phase at Minago, the noise at the Minago Project is limited to the sounds of wilderness and road traffic in the vicinity of Highway 6.

To obtain air quality results for undeveloped land in northern Manitoba, Manitoba Conservation records were obtained. Currently, Manitoba Conservation compiles air quality records, but only for larger cities and/or cities with or near mine developments. Thus, provincial air quality results are not available for undeveloped land in northern Manitoba.

Manitoba Conservation posts records for air quality stations in Winnipeg, Brandon, Thompson, and Flin Flon in Manitoba and Creighton in Saskatechwan. Creighton is located approximately 4 km from Flin Flon. Winnipeg and Brandon are the two largest cities in Manitoba and are over 485 km away from the Minago Project. Thompson is home to Vale Inco's Manitoba Operations, which include two underground operations, the Thompson Mine and the Birchtree Mine, and the Thompson Open Pit. In addition, Thompson hosts Vale Inco's 15,000-ton per day capacity mill; a smelter, which produces 1,400 anodes per day; and a refinery, which produces more than 130 million pounds of 99.9% pure electrolytic nickel annually (Vale Inco, 2009). Flin Flon has Hudson Bay Mining and Smelting Company as major employer. Hudson Bay Mining and Smelting Company operates two mines, one concentrator, a zinc plant and a copper smelter in Flin Flon and vicinity (Hudson Bay, 2009).

7.2.2 Baseline Conditions

Mean annual ambient air quality results, compiled by Manitoba Conservation, are presented in Table 7.2-1. Listed annual mean air quality did not exceed guideline limits given in Table 7.2-1 and Appendix 7.2, except for ozone.

Table 7.2-2 lists mean annual and maximum 1-hour and 24-hour measurements of Particular Matter (PM). The maximum acceptable limits for PM_{10} (< 10 μm) and $PM_{2.5}$ (< 2.5 μm) were exceeded for several years and at several of the air quality monitoring locations listed in Table 7.2-2.

Tables 7.2-3 lists maximum 1-hour and 24-hour measurements for suphur dioxide and Manitoba guideline limits. Maximum acceptable and tolerable levels sulphur dioxide levels were exceeded in several years and at several air quality monitoring locations in the 2000 to 2007 period.

Table 7.2-1 Manitoba Mean Annual Air Quality

Manitoba Ambient Air Quality Data
Continuous Monitoring

POLLUTANT Conc. Units	STATION NUMBER & LOCATION	2000 ANNUAL MEAN	2001 ANNUAL MEAN	2002 ANNUAL MEAN	2003 ANNUAL MEAN	2004 ANNUAL MEAN	2005 ANNUAL MEAN	2006 ANNUAL MEAN	2007 ANNUAL MEAN	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Desirable Level Concentration µg/m³ (ppm/ppb)	Maximum Acceptable Level Concentration µg/m³ (ppm/ppb)
CARBON (CO) ppm	**9118 WINNIPEG, SCOTIA & JEFFERSON**	0.48	0.46	0.37	0.29	0.24	0.21	0.22	0.3		
	9119 WINNIPEG, 65 ELLEN STREET	0.57	0.67	0.54	0.52	0.36	0.31	0.37	0.46		
NITROGEN DIOXIDE (NO2) pphm	**5131 BRANDON, ASSIN. COMMUN. COLLEGE**	0.69	0.52	0.58	0.61	0.54	0.53	0.5	0.56	60(0.032 ppm)	100(0.053 ppm)
	9118 WINNIPEG, SCOTIA & JEFFERSON	1.24	1.22	0.99	0.97	0.86	0.8	0.74	0.81		
	9119 WINNIPEG, 65 ELLEN STREET	1.66	1.43	1.43	1.4	1.33	1.25	1.27	1.27		
NITRIC OXIDE (NO) pphm	**5131 BRANDON, ASSIN. COMMUN. COLLEGE**	0.38	0.49	0.32	0.35	0.41	0.36	0.25	0.71		
	9118 WINNIPEG, SCOTIA & JEFFERSON	0.62	0.77	0.49	0.44	0.45	0.46	0.32	0.34		
	9119 WINNIPEG, 65 ELLEN STREET	1.1	1.1	0.93	0.89	0.93	0.85	0.73	0.74		
NITROGEN OXIDES (NOX) pphm	**5131 BRANDON, ASSIN. COMMUN. COLLEGE**	0.96	0.98	0.91	0.96	0.94	0.88	0.74	1.26		
	9118 WINNIPEG, SCOTIA & JEFFERSON	1.69	1.83	1.47	1.39	1.28	1.24	1.07	1.14		
	9119 WINNIPEG, 65 ELLEN STREET	2.55	2.48	2.33	2.32	2.26	2.1	2	2.01		
SULPHUR DIOXIDE (SO2) ppm	**7251 FLIN FLON, 143 MAIN STREET**	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	30(0.01 ppm)	60(0.02 ppm)
	7271[?] FLIN FLON, AQUA CENTRE	0	0	0	0	0	0	0	0		
	7281[?] FLIN FLON, HBM&S STAFFHOUSE	0.01	0	0.01	0.01	0	0.01	0.01	0.01		
	7291[?] CREIGHTON, SASK. CITY HALL	0	0	0	0	0.01	0	0	0		
	7301[?] FLIN FLON, HAPNOT COLLEGIATE	0	0	0	0	0	0	0	0		
	7351[?] THOMPSON, WATER TREATMENT PLANT	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7361[?] THOMPSON, EASTWOOD SCHOOL		**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7371[?] THOMPSON, RIVERSIDE SCHOOL		**0**	**0**	**0**	**0**	**0**	**0**	**0**		
	7381[?] THOMPSON, WESTWOOD							**0**	**0**		
	9119[?] WINNIPEG, 65 ELLEN STREET								0.00041		
OXIDANTS OZONE (O3) pphm	**5131 BRANDON, ASSIN. COMMUN. COLLEGE**	2.58	2.64	2.7	2.77	2.22	2.19	2.7	2.5		30(15 ppb)
	9118 WINNIPEG, SCOTIA & JEFFERSON	2.05	1.94	1.94	2.29	1.99	2.03	2.3	2.3		
	9119 WINNIPEG, 65 ELLEN STREET	1.35	1.61	2	2.05	1.74	1.82	2.2	2.1		
(NH3) ppm	**5131 BRANDON, ASSIN. COMMUN. COLLEGE**	0.01	0.02	0.01	0.01	0	0.02	0.02	0		

Notes:
[?] denotes company supplied data
ppm parts per million
pphm parts per hundred million
ppb parts per billion

Source: Manitoba Conservation, 2007f

Table 7.2-2 Manitoba Conservation Mean Annual Particulates

Annual Mean Particulate Matter Monitoring (PM_{10})

POLLUTANT	STATION NUMBER & LOCATION	2000 ANNUAL ARITH/GEO MEAN	2001 ANNUAL ARITH/GEO MEAN	2002 ANNUAL ARITH/GEO MEAN	2003 ANNUAL ARITH/GEO MEAN	2004 ANNUAL ARITH/GEO MEAN	2005 ANNUAL ARITH/GEO MEAN	2006 ANNUAL ARITH/GEO MEAN	2007 ANNUAL ARITH/GEO MEAN
INHALABLE PARTICULATE (PM_{10})	7251 FLIN FLON, 143 MAIN STREET	24.2 / -	22.5 / -	22.6 / -	20.2/ -	16.3/ -	17.57/10.76	16.3/10.2	17.52/11.51
	7283 FLIN FLON, CREIGHTON SCHOOL A				16.9/14.6				
	7283 FLIN FLON, CREIGHTON SCHOOL B				17.1/14.5				
	7283 FLIN FLON, CREIGHTON SCHOOL			21 / 14		20.0/17.0	17.09/13.00	20.81/16.20	20.80/18.04
	7284 FLIN FLON, RUTH BETTS	12.4 / 10.3	14.8 / 12.3	13/11	12.9/11.4	12.0/9.7	10.53/8.69	12.01/9.22	10.24/8.48
	7285 FLIN FLON, SEWAGE PLANT	12.2 / 10.0	10.3 / 9.0	10/09					
	7381 THOMPSON, WESTWOOD					**8.5/ -**	**9.79/6.42**	**10.6/6.9**	**10.39/6.88**
	9119 WINNIPEG, 65 ELLEN STREET	18.7 / -	19.0 / -	21.4 / -	22.3/ -	17.3/ -	18.16/12.65	18.2/12.8	13.05/9.26
	9119 WINNIPEG, 65 ELLEN STREET	20.2 / 16.6	18.9 / 16.2	18.3 / 15.5	19.8/15.9	15.9/13.4	14.15/11.42	17.24/14.76	14.89/11.73
	5131 BRANDON, ASSIN. COMMUN. COLLEGE	19.8 / -	22.3 / -	21.9 / -	23.3/ -	20.9/ -	19.67/11.31	22.26/12.01	23.41/12.92

Notes:

All Concentration units for the above Table are in ug/m^3.

- No data available

Annual Mean Particulate Matter Monitoring ($PM_{2.5}$)

POLLUTANT	STATION NUMBER & LOCATION	2000 ANNUAL ARITH/GEO MEAN	2001 ANNUAL ARITH/GEO MEAN	2002 ANNUAL ARITH/GEO MEAN	2003 ANNUAL ARITH/GEO MEAN	2004 ANNUAL ARITH/GEO MEAN	2005 ANNUAL ARITH/GEO MEAN	2006 ANNUAL ARITH/GEO MEAN	2007 ANNUAL ARITH/GEO MEAN
INHALABLE PARTICULATE ($PM_{2.5}$)	9118[4] WINNIPEG, SCOTIA & JEFFERSON	5.7 / -	5.8 / -	5.7/-	5.6/ -	4.5/ -	4.60/3.03	4.97/3.26	4.90/3.21
	9119[1] WINNIPEG, 65 ELLEN STREET	6.2 / 5.2	6.2 / 5.5	6.5/5.8	8.6/7.2	8.0/6.5	6.13/5.28	7.24/6.25	6.63/5.52
	9119[4] WINNIPEG, 65 ELLEN STREET	4.2 / -	5.5 / -	6.2/-	5.3/ -	4.2/ -	4.48/2.84	4.66/3.00	4.44/2.95
	5131[4] BRANDON, ASSIN. COMMUN.		5.8 / -	5.2/-	6.0/ -	5.0/ -	4.70/2.82	5.52/3.13	4.78/3.04
	7251[4] FLIN FLON, 143 MAIN STREET					4.2/ -	4.21/2.17	5.01/2.39	5.60/2.97
	7381[4] THOMPSON, WESTWOOD					**3.7/ -**	**3.25/1.76**	**3.50/1.76**	**3.43/1.74**
	7283[4?] CREIGHTON SK, HIGH SCHOOL								11.18/9.21

Notes:

All Concentration units for the above Table are in ug/m^3.

1 - 24 Hour sample collected every six days according to NAPS schedule

4 - real-time continuous monitoring

- no data available

Source: Manitoba Conservation, 2007f

Table 7.2-2 (Cont.'d) Manitoba Ambient Air Quality – Maximum Particulate Matter

Maximum 24-hour/1-hour Particulate Matter Monitoring (PM_{10})

POLLUTANT	STATION NUMBER & LOCATION	2000 MAXIMUM VALUES 24/1-HR	2001 MAXIMUM DATA VALUES 24/1-HR	2002 MAXIMUM VALUES 24/1-HR	2003 MAXIMUM VALUES 24/1-HR	2004 MAXIMUM DATA VALUES 24/1-HR	2005 MAXIMUM VALUES 24/1-HR	2006 MAXIMUM VALUES 24/1-HR	2007 MAXIMUM VALUES 24/1-HR	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Measurement Period	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Acceptable Level Concentration
INHALABLE PARTICULATE (PM_{10})	7251 FLIN FLON, 143 MAIN STREET	123.7 / 440.7	197.6 / 500.0	145.2/1359.0	100.1/578.0	66.7/245.1	0	72.8/301.8	87.13/318.00		
	7283 FLIN FLON, CREIGHTON SCHOOL A				42.6/ -						
	7283 FLIN FLON, CREIGHTON SCHOOL B				58.7/ -						
	7283 FLIN FLON, CREIGHTON SCHOOL			93 / -		103.8/ -	97.08/ -	152.08/-	64.71/-		
	7284 FLIN FLON, RUTH BETTS	36.0 / -	66.0 / -	43 / -	28.0/ -	35.2/ -	28.86/ -	56.62/-	24.84/-	24-hour average	50
	7285 FLIN FLON, SEWAGE PLANT	42.1 / -	28.4 / -	38 / -							
	7381 THOMPSON, WESTWOOD					32.1/159.5	45.85/373.60	74.2/372.6	53.24/401.00		
	9119 WINNIPEG, 65 ELLEN STREET	62 / 233	93.9 / 398.4	166.7/501.0	88.7/262.9	104.4/248.6	93.65/433.80	72.0/273.9	154.30/61.90		
	9119 WINNIPEG, 65 ELLEN STREET	44.7 / -	49.7 / -	62.6 / -	45.7/ -	45.7/ -	47.19/ -	47.81/-	39.41/-		
	5131 BRANDON, ASSIN. COMMUN. COLLEGE	143.0 / 498.0	131.4 / 451.5	215.5/499.3	154.3/819.5	156.6/496.9	0	317.1/3975.2	0		

Notes:

All Concentration units for the above Table are in ug/m^3.
-- No guideline or objective
- No data available

Maximum 24-hour/1-hour Particulate Matter Monitoring ($PM_{2.5}$)

POLLUTANT	STATION NUMBER & LOCATION	2000 MAXIMUM VALUES 24/1-HR	2001 MAXIMUM DATA VALUES 24/1-HR	2002 MAXIMUM VALUES 24/1-HR	2003 MAXIMUM VALUES 24/1-HR	2004 MAXIMUM DATA VALUES 24/1-HR	2005 MAXIMUM VALUES 24/1-HR	2006 MAXIMUM VALUES 24/1-HR	2007 MAXIMUM VALUES 24/1-HR	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Measurement Period	MANITOBA AMBIENT AIR QUALITY (JULY 2005) Maximum Acceptable Level Concentration
INHALABLE PARTICULATE ($PM_{2.5}$)	9118[4] WINNIPEG, SCOTIA & JEFFERSON	18.2 / 46.3	22.0 / 70.1	33.6/101.2	21.5/44.3	18.1/67.8	22.0/52.90	17.7/58.5	16.03/69.03		
	9119[1] WINNIPEG, 65 ELLEN STREET	18.3 / -	16.8 / -	18.7/-	25.2/ -	26.5/ -	22.86/ -	22.73/-	33.91/-		
	9119[4] WINNIPEG, 65 ELLEN STREET	9.1 / 32.6	19.5 / 70.1	36.2/88.7	23.2/43.6	19.6/86.9	37.76/390.90	22.0/55.1	12.81/59.00	24-hour average	30
	5131[4] BRANDON, ASSIN. COMMUN.		17.9 / 165.2	25.6/166.1	22.8/144.3	22.9/109.3	21.60/120.20	34.7/307.4	18.55/74.90		
	7251[4] FLIN FLON, 143 MAIN STREET					15.5/82.2	26.14/132.70	44.2/113.3	33.00/136.50		
	7381[4] THOMPSON, WESTWOOD					15.7/63.5	18.28/53.50	32.9/139.9	45.04/155.00		
	7283[4?] CREIGHTON SK, HIGH SCHOOL								40.74/-		

Notes:

All Concentration units for the above Table are in ug/m^3.
1 - 24 Hour sample collected every six days according to NAPS schedule
4 - real-time continuous monitoring
- no data available

Source: Manitoba Conservation, 2007f

Table 7.2-3 Manitoba Conservation Maximum 1-Hour and 24-Hour Sulphide Dioxide Measurements

POLLUTANT Conc. Units	STATION NUMBER & LOCATION	2000 MAXIMUM DATA VALUES 1-HR	2000 24-HR	2001 MAXIMUM DATA VALUES 1-HR	2001 24-HR	2002 MAXIMUM DATA VALUES 1-HR	2002 24-HR	2003 MAXIMUM DATA VALUES 1-HR	2003 24-HR	2004 MAXIMUM DATA VALUES 1-HR	2004 24-HR	2005 MAXIMUM DATA VALUES 1-HR	2005 24-HR	2006 MAXIMUM DATA VALUES 1-HR	2006 24-HR	2007 MAXIMUM DATA VALUES 1-HR	2007 24-HR
SULPHUR DIOXIDE (SO2) ppm	7251 FLIN FLON, 143 MAIN STREET	1.45	0.29	0.52	0.19	0.99	0.17	0.81	0.13	0.65	0.15°	1.16	0.11°	0.5	0.12°	0.98	0.15°
	7271[?] FLIN FLON, AQUA CENTRE	0.12	0.02	0.54	0.06	0.44	0.05	0.67	0.09	0.39	0.11°	0.8	0.07°	0.67	0.09°	1.02	0.22°
	7281[?] FLIN FLON, HBM&S STAFFHOUSE	0.97	0.23	0.47	0.09	0.74	0.1	0.77	0.08	0.39	0.08°	0.84	0.17°	0.48	0.09°	1.02	0.11°
	7291[?] CREIGHTON, SASK. CITY HALL	0.63	0.11	0.55	0.11	0.63	0.11	0.64	0.14	0.68	0.11°	0.66	0.15°	0.58	0.07°	0.93	0.16°
	7301[?] FLIN FLON, HAPNOT COLLEGIATE	0.68	0.12	0.33	0.03	0.38	0.03	0.59	0.04	0.32	0.03°	0.45	0.04°	0.38	0.05°	0.76	0.09°
	7351[?] THOMPSON, WATER TREATMENT	1.02	0.12	0.32	0.04	0.19	0.04	0.78	0.07	0.34	0.08°	0.45	0.08°	0.87	0.09°	0.68	0.09°
	7361[?] THOMPSON, EASTWOOD SCHOOL			0.62	0.06	0.35	0.07	0.41	0.15	0.61	0.09°	0.77	0.08°	0.54	0.06°	0.53	0.04°
	7371[?] THOMPSON, RIVERSIDE SCHOOL			0.45	0.06	0.54	0.09	0.89	0.21	0.59	0.15°	0.35	0.06°	0.54	0.08°	0.46	0.06°
	7381[?] THOMPSON, WESTWOOD													0.54	0.05°	0.37	0.03°
	9119 WINNIPEG, 65 ELLEN STREET															0.0378	0.00395

Notes:

All Concentration units for the above Table are in ug/m^3.

[?] denotes company supplied data

° Using 24-hour moving average

MANITOBA AMBIENT AIR QUALITY (JULY 2005)			
Measurement Period	**Maximum Desirable Level Concentration** ug/m^3 (ppm)	**Maximum Acceptable Level Concentration** ug/m^3 (ppm)	**Maximum Tolerable Level Concentration** ug/m^3 (ppm)
1-hour average	450(0.17)	900(0.34)	
24-hour average	150(0.06)	300(0.11)	800(0.31)

Source: Manitoba Conservation, 2007f

Recent 2008 and 2009 24-hour measurements of particulate matter at the Riverside station in Thompson, MB are given and illustrated in Appendix 7.2. None of those measurements exceeded guideline limits.

The proposed mine development at Minago is smaller than the current residential and mining related development at Thompson, and therefore air quality measured there is expected to be lower than is expected for the Minago Project.

7.2.3 Effects Assessment Methodology

The assessment of project effects on ambient air quality focused on the following Criteria Air Contaminants and Greenhouse Gases, which reflect the project emissions of concern with respect to human and environmental health.

Criteria Air Contaminants (CAC):

- particulate matter, including total suspended particulate (TSP); inhalable particulate matter (PM_{10}) and respirable particulate matter ($PM_{2.5}$) and sulphur dioxide (SO_2);
- nitrogen dioxide (NO_2);
- volatile organic carbon (VOC);
- carbon monoxide (CO);
- Greenhouse Gases:
  - carbon dioxide (CO_2);
  - methane (CH_4);
  - nitrous oxide (N_2O).

A description of these project related air contaminants and the Ambient Air Quality Objectives used to assess potential effects are provided in the following sections. Selected parameters are given in Table 7.2-4.

Temporal Boundaries

The temporal boundaries for the assessment encompass the period for regional air quality data that were used to characterize the baseline air quality as well as all phases of the project when emissions may potentially affect ambient air quality. These phases include construction (Year 2011 – 2013), operation (Year 2014 – 2021), and decommissioning (12 months after end of production). At closure, there will be no further project effects on ambient air quality.

7.2.3.1 Air Quality Parameters

Total Suspended, Inhalable and Respirable Particulate Matter (TSP, PM_{10} and $PM_{2.5}$)

Particulate matter is classified by the size of the particle. Particle size determines the velocity with which gravitational settling occurs, and the ease with which they penetrate the human respiratory tract. Generally, large particles settle out very close to the source, and very fine particles penetrate deep into the respiratory tract. Total suspended particulate matter encompasses all size ranges from approximately 100 micrometers (μm) to the sub micrometer range.

Table 7.2-4 Air Quality Parameters Analyzed, Selection Rationale and Data Sources

Parameter	Rationale for Selection	Linkage to Regulatory Drivers	Baseline Data for EAP
Particulate Matter, Inhalable Particulate Matter, Respirable Particulate Matter, SO_2, CH_4, N_2O	• Indicators of potential project effects from diesel generators and fugitive dust emissions • Parameters of concern with respect to human and environmental health	• Environmental Baseline Study Work Plan • Criteria Air Contaminants under National Ambient Air Quality Objectives	• Project-specific data for emission rates • Regional data for ambient air quality • Qualitative assessments and/or quantitative data
Greenhouse Gases including CO_2, CH_4, and N_2O	• Project will emit greenhouse gases • Contribution to national emissions and potential effects on climate change	• Environmental Baseline Study Work Plan • Kyoto Protocol	• Project specific data for emission rates

Inhalable (PM_{10}) and respirable ($PM_{2.5}$) particulate matter are comprised of very small particles that are less than 10 μm and 2.5 μm, respectively. Particles smaller than 10 μm can make their way deep into the respiratory tract and become lodged there. Over the past few years, greater concern with regard to these fine particles has led to research resulting in new sampling methods and criteria. In June 2000, the Canadian Council of Ministers of the Environment (CCME) adopted in principle Canada-Wide Standard (CWS) for particulate matter. Achievement of the CWS for $PM_{2.5}$ has been proposed for 2010. For it to be enforceable, it must be adopted by the Provincial or Territorial regulatory agencies. The CWS provides for a proposed $PM_{2.5}$ standard of 30 $\mu g/m^3$ (micrograms per cubic metre) for the fine (<2.5 μm) particulate fraction as a 24-hour measurement. Achievement is to be based on the 98th percentile of the ambient measurement annually, averaged over three consecutive years. Victory Nickel will exercise reasonable efforts to meet the $PM_{2.5}$ CWS.

Project-related sources of particulate matter (PM) include internal combustion and fired equipment such as the back up diesel generators and heaters when they are fired. The burning of land clearing debris would also generate PM. Fugitive and process dust is also considered PM. Combustion-related PM is generally in the respirable range (<2.5 μm), while fugitive and process dust are generally above the inhalable range (>10 μm).

Sulphur Dioxide (SO_2)

Sulphur dioxide (SO_2) is a colourless gas with a distinctive pungent sulphur odour. It is produced in combustion processes by the oxidation of sulphur in fuel. At high concentrations, SO_2 can have negative effects on leaf tissue, especially in sensitive species. At very high concentrations, there may be effects on human and animal health, particularly with respect to the respiratory system. The SO_2 can also be further oxidized and may combine with water to form the sulphidic acid component of “acid rain.” Anthropogenic emissions comprise approximately 95% of global atmospheric SO_2. The largest anthropogenic contributor to atmospheric SO_2 is the industrial and utility use of heavy oils and coal. Oxidation of reduced sulphur compounds emitted by ocean surfaces account for nearly all biogenic emissions. Volcanic activity accounts for much of the remainder. Motor vehicles are relatively small contributors to the SO_2 content of the atmosphere (Wayne, 1991).

The mass of sulphur dioxide emissions related to the project are expected to be very low. These emissions are largely confined to construction equipment and back up diesel generators, when they are fired. They will be released through combustion processes of fuels that contain sulphur (gasoline, diesel oil, and waste oil). Propane contains negligible amounts of sulphur. The diesel oil and gasoline utilized on site will be low-sulphur (<15 ppm). Waste oil will contain generally low amounts of sulphur.

Oxides of Nitrogen (NO, NO_2)

Nitrogen oxides are produced in most combustion processes, and are almost entirely made up of nitric oxide (NO) and nitrogen dioxide (NO_2). Together, they are often referred to as NO_x. The NO_2 is an orange to reddish gas that is corrosive and irritating. Most NO_2 in the atmosphere is formed by the oxidation of NO, which is emitted directly by combustion processes, particularly those at high temperature and pressure, such as internal combustion engines. Nitric oxide is a colourless gas with no apparent direct effects on animal health or vegetation at typical ambient levels. The concentration of NO_2 is the regulated form of NO_x.

The levels of NO and NO_2, and the ratio of the two gases, together with the presence of hydrocarbons and sunlight are the most important factors in the formation of ground-level ozone and other oxidants. Further oxidation and combination with water in the atmosphere forms nitric acid, another part of “acid rain”. Anthropogenic emissions comprise approximately 93% of global atmospheric emissions of NO_x (NO + NO_2). The largest anthropogenic contributor to atmospheric NO_x is combustion of fuels such as natural gas, oil and coal. Forest fires, lightning and anaerobic processes in soil account for nearly all biogenic emissions (Wayne, 1991). NO_x

will be released by all internal and external combustion equipment on site, but in relatively small quantities. External combustion processes, such as fired equipment and land clearing burning are also potential sources of NO_x.

Carbon Monoxide (CO)

Carbon monoxide is a colourless and odourless gas. It is a product of incomplete combustion of hydrocarbons such as fossil fuels and wood. Motor vehicles, industrial processes and natural sources (fires) are some common sources. Typical concentrations in the atmosphere are 120 $\mu g/m^3$, while minimum levels known to produce cardiovascular symptoms in smokers is approximately 35,000 $\mu g/m^3$. CO will be released by all internal and external combustion equipment on site, but in relatively small quantities.

Volatile Organic Carbon (VOC)

Volatile Organic Compounds (VOCs) are carbon-containing (organic) compounds that readily evaporate into the air under ambient conditions. Many VOCs are of natural origin including methane. For example, VOCs are largely responsible for the pleasant odour perceived in a forest. Others may be potentially harmful to the environment, either directly through inhalation or indirectly as a contributor to ground level ozone and smog formation. Examples of VOC sources include: hydrocarbon fuels, paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, correction fluids, graphics and craft materials including glues and adhesives, permanent markers, and photographic solutions. While VOCs are naturally present in the atmosphere and emitted by automobiles and industrial processes, the concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. Some VOCs may have short- and long-term adverse health effects.

VOC emissions during construction will be largely generated from heavy equipment operation at the site. During the operations phase, VOC emissions will be generated largely by internal combustion engines (mobile and stationary) and heaters. Emissions of VOC at the project site will be relatively small.

Greenhouse Gases (GHG)

Greenhouse gases are emitted as a consequence of all internal and external combustion equipment on site, plus land clearing burning. Greenhouse gasses generally include all emissions of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). The sum of all greenhouse gasses is generally expressed as a carbon dioxide equivalent (CO_2e). For the project, emissions of CH_4 are virtually absent as natural gas is not available as a fuel (natural gas is mostly methane). Diesel fuel and propane make up nearly all of the fuel used in the Local Study Area (LSA). Nitrous oxide is emitted as a byproduct of high-temperature combustion. These emissions are insubstantial. As such, in this assessment, it was assumed that GHGs are fully represented by emissions of CO_2 (e.g., $CO_2e = CO_2$). However, NO_x emission data is also included for all phases of the project.

There are currently no binding federal or provincial requirements or restrictions on the emission of greenhouse gases. However, aggressive targets for the reduction have been agreed to at the federal level with the ratification of the Kyoto Protocol. The quantities of GHG emissions resulting from the project will be estimated and considered in a larger context, consistent with the guidance provided by the Canadian Environmental Assessment Agency (CEAA, 2003).

7.2.3.2 Federal Ambient Air Quality Criteria

The Canadian (Federal) Ambient Air Quality Objectives are shown in Table 7.2-5. The objectives are denoted as Desirable, Acceptable and Tolerable as follows:

- The Maximum Desirable Level is the long-term goal for air quality and provides a basis for anti-degradation policy for unpolluted parts of the country, and for the continuing development of control technology.
- The Maximum Acceptable Level is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.
- The Maximum Tolerable Level denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

Qualitative Assessment of Effects

In instances where emission rates of Criterial Air Contaminants (CACs) are very low, professional judgement can be used to assess potential effects without application of quantitative tools such as atmospheric dispersion modeling. In this instance, emissions have been estimated and expressed in terms, which allow comparison to other common sources. Baseline conditions have also been defined. As such, potential effects of the Minago Project have been assessed based on predicted and measured effects for like-sized sources in a similar context. In keeping with the Environmental Assessment guidelines, project effects were characterized according to effects attributes, detailed in Table 7.2-6.

7.2.3.3 Determination of Effects Significance

Air Quality

The significance of any adverse residual project and cumulative effects on ambient air quality will be determined based on the defined effects attributes, as follows. A residual effect will be considered significant, if it is a high magnitude effect of any geographic extent or duration. Otherwise, effects will be rated as not significant. A high magnitude effect on air quality is one

Table 7.2-5 Federal Ambient Air Quality Objectives

Pollutant and Units (alternative units in brackets)	Averaging Time Period	Canada-Wide Standards (CWS)			
		Target to be attained by 2010	Ambient Air Quality Objectives		
			Maximum Desirable	Maximum Acceptable	Maximum Tolerable
Nitrogen dioxide (NO_2) µg/m³ (ppb)	1 hour	-	-	400 (213)	1000 (532)
	24 hour	-	-	200 (106)	300 (160)
	Annual	-	60 (32)	100 (53)	-
Sulphur dioxide (SO_2) µg/m³ (ppb)	1 hour	-	450 (172)	874 (334)	-
	24 hour	-	150 (57)	300 (115)	800 (306)
	Annual	-	30 (11)	60 (23)	-
Total suspended particulate matter (TSP) µg/m³	24 hour	-	-	120	400
	Annual	-	60	70	-
PM_{10} µg/m³	24 hour	-	-	50 [1]	-
$PM_{2.5}$ µg/m³	24 hour	30	-	-	-
Carbon monoxide (CO) mg/m³ (ppm)	1 hour	-	15 (13)	35 (31)	-
	8 hour	-	6 (5)	15 (13)	20 (17)
Ozone (O_3) µg/m³ (ppb)	1 hour	-	100 (51)	160 (82)	300 (153)
	8 hour	128 (65)	-	-	-
	24 hour	-	30 (15)	50 (25)	-
	Annual	-	-	30 (15)	-

Sources:

Health Canada <http://www.hc-sc.gc.ca/ewh-semt/air/out-ext/reg-eng.php#a3> (March 10, 2010)

[1] Manitoba Conservation. Objectives and Guidelines for various Air Pollutants: Ambient Air Quality Criteria (updated: July 2005).

Table 7.2-6 Effect Attributes for Air Quality

Attribute	Definition
	Direction
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
	Magnitude
Low	Within normal variability of baseline conditions.
Moderate	Increase/decrease with regard to baseline, but within limits and objectives.
High	Singly or as a substantial contribution in combination with other sources causing exceedances or impingement upon limits and objectives.
	Geographic Extent
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC extends beyond the LSA. Assessment of the project effects on climate change are characterized in the context of contributions to Manitoba emissions and national emissions only.
	Duration
Short-term	< 1 month
Medium-term	< 1-24 months
Long-term	> 24 months
Far future	Effect on VECC extends >10 years after decommissioning and abandonment.
	Frequency (Short-term duration effects that occur more than once)
Low	Frequency is within range of annual variability and does not pose a serious risk to the VECC or its economic or social/cultural values.
Moderate	Frequency exceeds range of annual variability, but is unlikely to pose a serious risk to the VECC or its economic or social/cultural values.
High	Frequency exceeds range of annual variability and is likely to pose a serious risk to the VECC or its economic or social/cultural values.
	Reversibility
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
	Likelihood of Occurrence
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

that results in a change in ambient air quality such that the maximum ground-level concentration of any identified substances of concern (CAC) results in an exceedance of the respective ambient air quality objective as defined by the Maximum Desirable Level.

Climate Change

The science of climate change has not been advanced to the point where a clear cause-and-effect relationship can be established between specific or even provincial/territorial and national emissions and subtle changes in global climate. Climate change is a global issue. The incremental increases in global emissions of greenhouse gases from anthropogenic sources are thought to be a substantial contributor to climate change. It is not possible to conclude with certainty that any given source of GHGs has a measurable cause-and-effect relationship on climate. As such, the incremental contribution of the project to national or global GHG emissions cannot be linked to specific changes in global climate. The estimated GHG emissions from the project are described in context with the total emissions from Manitoba and Canada. Estimates of the total GHG emissions have been obtained from federal regulatory agencies. In the absence of a measurable cause-and-effect relationship between GHG emission levels and climate change, no determination of significance has been made.

7.2.4 Project Effects

Emissions to air from the proposed Minago Project will consist of vehicle and equipment exhaust emissions, fugitive dusts and blasting residues, fugitive dust from ore processing and road dust from vehicle traffic. Although other mines in Manitoba have had dust problems associated with their Tailings Management Facilities (TMFs), no dust will be generated from the Minago TWRMF, where the tailings will be kept wet at all times. A vegetation cover will also be established on the tailings dams where applicable.

Noise emissions from the mine and mill facility will primarily be related to equipment operation, ore and waste rock handling and processing. Noise sources will be detectable to humans while on the mine site but are not expected to be noticeable offsite. Noise emissions from all of these sources will be managed in accordance with the Workplace Health and Safety Act.

The assessment of effects of project-related emissions on ambient air quality was subdivided into construction and operations phases. Emissions during decommissioning will be similar to those of construction, and project-related emissions will cease at closure.

The sources of construction phase emissions are internal combustion engines employed in construction equipment, light and heavy-duty vehicles, mining equipment and diesel electrical generators. There will also be emissions from mine heaters and transportation to and from the mine industrial complex. Operational phase emissions will be mainly fugitive dust from crushers on site, vehicular emissions from concentrate hauling, and emissions from the operation of diesel generators. Minor operational emissions include other road transportation. Estimated emission rates for each phase are based on information about project equipment and transportation activity provided by VNI and literature documenting emission rates for various types of equipment and vehicles. Assumptions that were used for the estimates of project related emissions are described below.

Emission estimates for diesel engines in all phases are based on the US EPA Tier 2 Standard for Non-road Diesel Engines which was in effect from 2001-2006 (US EPA, 2004). Tier 2 Standard Emission Factors/Limits vary according to engine power category; however, the highest emission factors among all engine ratings were employed to account for engine deteriorations and to provide a conservative estimate.

Equipment operation shifts were provided by VNI and were calculated based on Net Operating Hours per year. The estimation of CAC emissions assumes the application of best construction and operational practices and other mitigative actions, which have been confirmed by VNI. For example, emissions of sulphur dioxide are reduced dramatically through the use of low sulphur diesel fuel (<15 ppm) for all internal and external combustion applications. Examples include light and heavy-duty motor vehicles, heavy construction equipment and back up electrical generators. Other mitigation measures for related equipment include maintenance as per the manufacturers recommended schedules and adherence to applicable criteria with respect to emission quality. Fugitive dust will be reduced through the minimization of activities that generate large quantities of dust when windy and the application of a dust suppressant to unconsolidated working surfaces during periods of heavy activity and/or dry periods.

7.2.4.1 Construction

Construction phase emissions will be comprised of construction and mining equipment emissions, and vehicular traffic emissions. A summary of the estimated emissions during the construction and commissioning phases are presented in Table 7.2-7.

The largest source of CACs in the construction phase will be the construction and mining equipment – largely mobile sources. It is expected that the number of vehicles and heavy equipment used during the construction phase will be operated intermittently over time and distributed spatially such that the atmosphere will effectively disperse the emissions and minimize the potential for effects on local air quality.

It is expected that the heavy equipment and vehicles, i.e. the mobile sources of CACs, used during the construction phase will be operated for extended periods, but distributed spatially such that the atmosphere will effectively disperse the emissions. This will minimize the potential for effects on local air quality. Estimated project emissions of GHGs (CO_2) in the construction phase are approximately 0.05% of the total GHG emissions for Manitoba (2015 estimate) and 0.0015% of the projected 2015 emissions for Canada as a whole.

The substances of concern with respect to the combustion sources are $PM_{2.5}$, NO_x and SO_2 from stationary and mobile sources. Based on experience from similar projects, these emissions indicate that the potential for any exceedances of the applicable objectives is insubstantial. Based

Table 7.2-7 Estimated Air Emissions Associated with Minago Project - Construction Phase

Construction Emissions (20% of the operational phase fleet)										
Category of Vehicle / Model	**Quantity**	**Flywheel Horsepower**		**Energy**	**Quantity of Diesel**	**Net operating hours**	**Quantity of litres**	**Quantity of CO_2**		**Quantity of N_2O**
	units	**HP**	**kW**	**MJ/hr**	**litres/ hour**	**hours/ unit per year**	**litres/unit per year**	**Overall kg/ year/ Total**	**Overall kilotonne/ year Total**	**Overall kg/ Year Total**
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	1,237	32,534	88,817	0.09	3
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	1,237	23,074	62,991	0.06	2
218 Tonne Haul Truck – Komatsu 830E – AC	15	2,360	1,761	6,339.6	164.2	1,421	233,383	9,557,021	9.56	280
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	1,237	68,875	188,028	0.19	6
Grader – Caterpillar 16M	1	296	221	795.6	20.6	742	15,294	41,752	0.04	1
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	371	14,982	122,705	0.12	4
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	371	2,111	5,762	0.006	0
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	1,237	137,634	375,740	0.38	11
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	1,237	30,111	82,203	0.08	2
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	80	1,783	4,868	0.005	0
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	80	2,223	6,070	0.006	0
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	247	2,672	7,295	0.007	0
Bus – ABC TD 925	2	450	336	1,209.6	31.3	495	15,512	84,694	0.08	2

Table 7.2-7 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Construction Phase

Construction Emissions (20% of the operational phase fleet)											
Category of Vehicle / Model	**Quantity**	**Flywheel Horsepower**		**Energy**	**Quantity of Diesel**	**Net operating hours**	**Quantity of litres**	**Quantity of CO_2**		**Quantity of N_2O**
	units	**HP**	**kW**	**MJ/hr**	**litres/ hour**	**hours/ unit per year**	**litres/unit per year**	**Overall kg/ Year Total**	**Overall kilotonne/ year Total**	**Overall kg/ Year Total**
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	495	3,924	10,713	0.01	0
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	495	2,678	7,310	0.007	0
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	1,237	12,344	303,301	0.30	9
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	1,237	31,034	762,504	0.76	22
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	742	17,024	46,475	0.05	1
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	1,237	12,344	202,201	0.20	6
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	371	8,996	24,560	0.02	1
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	371	4,118	11,241	0.01	0
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	371	34,774	189,866	0.19	6
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	371	13,356	36,462	0.04	1
Total	**62**	**11,719**	**8,640**	**31,104**	**805.8**	**16,919**	**720,779**	**12,222,578**	**12.21**	**358**

on quantitative estimates of CAC emissions and a qualitative assessment of potential effects during construction, project effects are rated as adverse, low magnitude, site-specific, medium term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

7.2.4.2 Operations

Sources of operations phase emissions include mining equipment, mine heaters, vehicular traffic and diesel generators. Crushing units will be driven by electric motors driven; therefore, emissions from those units are mainly fugitive dust. Fugitive dust estimates were provided by Hatch. Fugitive dust emissions from road traffic were not estimated in this assessment as they are insubstantial compared to those from mining operation.

Fugitive dust emissions during the operational phase were not calculated. However, Victory Nickel will exercise reasonable efforts to mitigate potential sources of fugitive dust. Mitigative measures will include but not be limited to dust suppression methods such as the use of water sprays (on roads, crushing and grinding areas, and in the bag house) and ventilation in confined areas.

Fugitive dust emissions from the mine mill complex crushers will be relatively small on a per annum basis.

The largest source during the operational phase will be the vehicular traffic (mobile sources). The substances of concern with respect to the combustion sources are $PM_{2.5}$, NO_x and SO_2. Inside the LSA, ground level concentrations of NO_2 are expected to be somewhat elevated at the most affected location under worst-case meteorological conditions. For the remainder of the time, the ground level concentrations of NO_2 will be indistinct from baseline conditions. The 1-hour and 24-hour concentrations of NO_2 are expected to be less than the most stringent applicable objective (Maximum Acceptable Level in Table 7.2-5).

For mobile sources of CACs (Table 7.2-8), it is expected that equipment will act as point sources during the operational phase and that emissions from these sources will be distributed spatially such that the atmosphere will effectively disperse the emissions. This will minimize the potential for effects on local air quality. Based on quantitative estimates of CAC emissions and a qualitative assessment of potential detrimental effects during operations, project effects have been rated as adverse, low magnitude, site-specific, medium term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

Total GHG emission in the operations phase will be 61.1 kT/y. This emission was compared to GHG emissions estimates for Canada (2015) and Manitoba (2015) (Table 7.2-9). Estimated project emissions of GHGs (CO_2) in the operational phase are approximately 0.24% of the total

GHG emissions for Manitoba (2015 estimate) and 0.008% of the projected 2015 emissions for Canada as a whole.

Table 7.2-8 Estimated Air Emissions Associated with the Minago Project - Operations Phase

Operational Emissions										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overal kilotonne/ year Total	Overall kg/ Year Total
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	6,186	162,695	444,157	0.44	13
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	6,186	115,387	315,005	0.32	9
218 Tonne Haul Truck – Komatsu 830E - AC	15	2,360	1,761	6,339.6	164.2	7,104	1,166,749	47,778,379	47.78	1400
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	6,186	344,429	940,291	0.94	28
Grader – Caterpillar 16M	1	296	221	795.6	20.6	3,712	76,510	208,871	0.21	6
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	1,856	74,952	613,854	0.61	18
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	1,856	10,559	28,826	0.03	1
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	6,186	688,281	1,879,006	1.88	55
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	6,186	150,579	411,082	0.41	12
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	400	8,916	24,341	0.02	1
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	400	11,117	30,350	0.03	1
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	1,237	13,383	36,535	0.04	1
Bus – ABC TD 925	2	450	336	1,209.6	31.3	2,474	77,527	423,299	0.42	12

Table 7.2-8 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Operations Phase

Operational Emissions										
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overall kilotonne/ year Total	Overall kg/ Year Total
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	2,474	19,613	53,542	0.05	2
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	2,474	13,383	36,535	0.04	1
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	6,186	61,732	1,516,750	1.52	44
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	6,186	155,195	3,813,138	3.81	112
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	3,712	85,164	232,499	0.23	7
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	6,186	61,732	1,011,167	1.01	30
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	1,856	45,006	122,865	0.12	4
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	1,856	20,599	56,234	0.06	2
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	1,856	173,964	949,843	0.95	28
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	1,856	66,816	182,408	0.18	5
Total	**62**	**11,719**	**8,640**	**31,104**	**805.8**	**84,611**	**3,604,285**	**61,108,976**	**61.1**	**1,791**

Table 7.2-9 Greenhouse Gas Emissions for Canada and Manitoba

Year	Estimated Total Greenhouse Gas Emissions	
	Canadian Total (kT CO_2 – equivalent/y)	**Manitoba (kT CO_2 – equivalent/y)**
2020	852,130[1]	27,000[4]
2015	813,000[2]	26,000[4]
2010	769,940[1]	26,000[4]
2005	734,000[3]	20,300[5]
2000	718,000[3]	20,200[5]
1995	642,000[3]	19,000[5]
1990	592,000[3]	18,000[5]

Sources:

1 National Resources Canada. "Trends in Greenhouse Gas Emissions" <http://atlas.nrcan.gc.ca/site/english/maps/climatechange/atmospherestress/trendsgreenhousegasemission> (March 11, 2010).

2 Environment Canada. 2005. National Climate Data and Informative Archive.

3 Environment Canada. "Canada's Greenhouse Gas Emissions: Understanding the Trends, 1990-2006" <http://www.ec.gc.ca/pdb/GHG/inventory_report/2008_trends/trends_eng.cfm#toc_4> (March 11, 2010).

4 "Comparative Greenhouse Gas Emissions (actual and projected) Alberta, Saskatchewan, Manitoba" <http://www.climatechangesask.ca/images/0827(01)GHGSKABMB-1990-2020.pdf> (March 11, 2010)

5 Environment Canada. "National Inventory Report, 1990-2005: Greenhouse Gas Sources and Sinks in Canada" <http://www.ec.gc.ca/pdb/ghg/inventory_report/2005_report/ta11_14_eng.cfm> (March 11, 2010).

Note: Data for 2000 and beyond are projections.

The project site is favorably close to existing infrastructure including PTH6 and a 230 KV high voltage transmission line running beside PTH6 on the eastside of the road. Therefore, there will be no genset (with the exception of back-up diesel generations) on site to provide power. Green power from Manitoba Hydro will be used during the construction, operational and decommissioning phases.

Other energy efficiency measures will be employed where economically viable. It is anticipated that the project operations will not result in discernible changes to regional, national, or global climate patterns. Emissions of GHGs from the project are not expected to result in any significant adverse environmental effects. It is therefore not considered further in the assessment. Under the authority of the Canadian Environmental Protection Act, 1999, the Government of Canada announced mandatory reporting requirements for those facilities in Canada that emit 100 kT or more of CO_2 equivalent annually (Canada Gazette, March 13, 2004). VNI will review GHG emissions once the operations have commenced and prior to the regulatory report date.

7.2.4.3 Decommissioning

In the decommissioning phase of the project, some effects on air quality are expected to occur. The magnitude of these effects is expected to be very low. The decommissioning of the industrial complex, the removal of facilities, and site closure may result in emissions of CACs and fugitive dust. The greenhouse gas emissions from the decommissioning phase are given in Table 7.2-10. The potential effects on air quality that may occur during decommissioning will be similar to those predicted for construction. However, the magnitude, frequency, and duration of those effects are expected to be of a much smaller scale. The limited number of vehicles and equipment usedduring decommissioning will allow for sufficient dispersion of these emissions and will minimize potential effects on local air quality. Estimated project emissions of GHGs (CO_2) in the decommissioning phase are approximately 0.008% of the total GHG emissions for Manitoba (2015 estimate) and 0.0002% of the projected 2015 emissions for Canada as a whole.

Mitigation will include the application of dust suppressants on unconsolidated working surfaces during periods of heavy activity and/or dry periods. The vehicles and heavy equipment will be properly maintained to minimize emissions. These measures will ensure that air quality will remain within the applicable ambient air quality objectives. As for the construction phase and based on quantitative estimates of CAC emissions and a qualitative assessment of potential effects during decommissioning, project effects during decommissioning are rated as adverse, low magnitude, site-specific, medium-term and reversible. The likelihood that effects will occur as predicted is high based on observations of similar facilities in similar baseline conditions.

7.2.4.4 Closure

No further project-related air emissions are expected at closure, with the exception of possible intermittent road or air access for site monitoring. These emissions are considered to be insubstantial and not significant.

7.2.5 Residual Project Effects and Significance

During project construction, operations and decommissioning, there will be emissions of CACs in particular $PM_{2.5}$, NO_x and SO_2. Effects on ambient air quality will be greatest during operations but projected emissions will not result in ground level concentrations in excess of the most stringent air quality objectives (Table 7.2-5). These ‘Maximum Desirable’ objectives represent the long-term goal for air quality. They provide a basis for anti-degradation policy for unpolluted parts of the country. As such, they provide a large margin of safety with respect to effects on soil, water, vegetation, materials, animals, visibility, and personal comfort and well-being.

Table 7.2-10 Estimated Air Emissions Associated with the Minago Project - Decommissioning Phase

Decommissioning Emissions (10% of the operational phase fleet)											
Category of Vehicle / Model	Quantity	Flywheel Horsepower		Energy	Quantity of Diesel	Net operating hours	Quantity of litres	Quantity of CO_2		Quantity of N_2O
	units	HP	kW	MJ/hr	litres/ hour	hours/ unit per year	litres/unit per year	Overall kg/ Year Total	Overall kilotonne/ year Total	Overall kg/ Year Total
Hydraulic Backhoe – Caterpillar 385CL (4 Cu.m.)	1	513	282	1,015.2	26.3	619	16,280	44,444	0.04	1
Utility Backhoe – Caterpillar 336DL (2 Cu.m.)	1	268	200	720	18.7	619	11,546	31,521	0.03	1
218 Tonne Haul Truck – Komatsu 830E - AC	2	2,360	1761	6,339.6	164.2	710	116,609	636,686	0.64	19
Wheel dozer – Caterpillar 854K	1	801	597	2,149.2	55.7	619	34,465	94,090	0.09	3
Grader – Caterpillar 16M	1	296	221	795.6	20.6	371	7,647	20,876	0.02	1
Track Dozer c/w Ripper – Caterpillar D10T	3	581	433	1,558.8	40.4	186	7,511	61,518	0.06	2
Blast hole Stemmer – Caterpillar 262C	1	82	61	219.6	5.7	186	1,058	2,889	0.003	0
Front end loader – Le Tourneau L-1350	1	1,600	1,193	4,294.8	111.3	619	68,873	188,022	0.19	6
Secondary drill – Sandvik Pantera DP 1500	1	350	261	939.6	24.3	619	15,068	41,135	0.04	1
Ambulance – Ford E-150 Commercial	1	320	239	860.4	22.3	40	892	2,434	0.002	0
Fire Truck – Pierce Velocity™ Custom Chassis	1	400	298	1,072.8	27.8	40	1,112	3,035	0.003	0
Vibratory compactor – Caterpillar CS56	1	156	116	417.6	10.8	124	1,342	3,662	0.004	0
Bus – ABC TD 925	2	450	336	1,209.6	31.3	247	7,740	42,261	0.04	1

Table 7.2-10 (Cont.'d) Estimated Air Emissions Associated with the Minago Project - Decommissioning Phase

Decommissioning Emissions (10% of the operational phase fleet)											
Category of Vehicle / Model	**Quantity**	**Flywheel Horsepower**		**Energy**	**Quantity of Diesel**	**Net operating hours**	**Quantity of litres**	**Quantity of CO_2**		**Quantity of N_2O**
	units	**HP**	**kW**	**MJ/hr**	**litres/ hour**	**hours/ unit per year**	**litres/unit per year**	**Overall kg/ Year Total**	**Overall kilotonne/ year Total**	**Overall kg/ Year Total**
Rough Terrane forklift – Sellick S160	1	114	85	306	7.9	247	1,958	5,346	0.005	0
Shop forklift – Hyster H100FT	1	78	58	208.8	5.4	247	1,336	3,648	0.004	0
Pick-up truck – Ford Ranger	9	143	107	385.2	10.0	619	6,177	151,773	0.15	4
Pick-up (crew cab) truck – Chevrolet Silverado 2500HD	9	360	269	968.4	25.1	619	15,530	381,560	0.38	11
Hiab truck (crane picker) – National 880D	1	330	246	885.6	22.9	371	8,512	23,237	0.02	1
Welding truck, Lube/fuel truck, Mechanics truck	6	143	107	385.2	10.0	619	6,177	101,182	0.10	3
Tire Handler – Caterpillar 980H	1	349	260	936	24.2	186	4,510	12,313	0.01	0
Integrated tool carrier – Caterpillar IT38G	1	160	119	428.4	11.1	186	2,064	5,636	0.006	0
Water truck – Caterpillar 785D	2	1,347	1,005	3,618	93.7	186	17,434	95,189	0.095	3
Sanding truck – Komatsu HD325-7	1	518	386	1,389.6	36.0	186	6,696	18,280	0.02	1
Total	**49**	**11,719**	**8,640**	**31,104**	**805.8**	**8,465**	**360,536**	**1,970,737**	**1.952**	**58**

Emissions will cease within approximately three years of decommissioning. Subtle effects on the most sensitive receptors, native vegetation in close proximity to the emissions, are expected to be virtually undetectable in as little as one growing season. Based on the criteria described in previous sections, residual project effects during all phases of the project are determined to be not significant.

These conclusions are based on a qualitative assessment of the emission quantities and preliminary quantitative analyses. Based on professional judgement a dispersion assessment of the largest emission source (mining equipments) was deemed unnecessary given the relatively small quantities of $PM_{2.5}$, NO_x and SO_2 discharged. The likelihood of effects occurring as predicted is high.

7.2.6 Cumulative Effects

The project local study area is relatively remote. It is 225 km from Thompson, Manitoba. Thompson will be the next nearest substantial source of CACs. As such, the Minago Project is not substantially influenced by anthropogenic emissions, save trace amounts of substances transported regionally and/or globally. Following the application of mitigating measures, the residual project effects on air quality are expected to be not significant. The potential for the residual project effects to have a significant effect in combination with effects of other activities in the area is negligible. This includes existing and ongoing activities, approved activities, and projects or activities expected to occur in the reasonably foreseeable future.

7.2.7 Mitigation Measures

Exhaust emissions will be minimized by keeping all vehicles and equipment in good operating condition. Fugitive dust emissions from crushing will be minimized through containment and a dust control system. Fuel emissions will be reduced through measurements such as:

- driver educational training on available fuel efficiency alternatives;
- tire maintenance program;
- vehicle speed control with the governor;
- reducing vehicle idling by turning off vehicles automatically, utilizing idle reduction systems like Auxiliary Power Units/Generator Sets;
- diesel Retrofit Technologies; and
- fuel additives.

Road dust will be managed as necessary through the application of non-toxic dust suppressants. Any effect of the project on ambient noise or air quality will be limited to the immediate project site and will not exceed workplace safety and health standards. A monitoring program that meets the Workplace Health and Safety Act and regulations will be developed to ensure that the human health will not be compromised. Table 7.2-11 summarized proposed mitigation measures for potential project effects and potential cumulative effects.

7.2.8 Monitoring and Follow-up

Follow-up Studies

There are no proposed follow-up baseline studies identified to improve predictive confidence or improve the database for effects monitoring purposes.

Monitoring Programs

There are no monitoring programs identified for project effects or cumulative effects.

Table 7.2-11 Mitigation Measures for Effects on Air Quality

Potential Project Effect	Mitigation Measures
Emissions of CACs, including respirable particulate matter, nitrogen dioxide and sulphur dioxide from vehicles, generators, and heaters potentially affecting human health and the environment, including vegetation and wildlife.	• Use low sulphur fuels including diesel fuel with a sulphur content,15 ppm and propane with negligible sulphur content. • Meet applicable criteria with respect to emission quality on all combustion-related equipment and provide maintenance according to manufactures specifications.
Emissions of fugitive dust from light and heavy duty motor vehicles, heavy construction equipment, construction activities and ore crushing activities potentially emit coarse particulate matter, which is both a nuisance and can potentially affect human health and the environment, including vegetation and wildlife.	• Apply dust suppressant (such as water spray to unconsolidated working surfaces and development rock and ore stockpiles) to minimize fugitive dust during periods of heavy activity and/or dry periods. • Minimize activities that generate large quantities of fugitive dust when windy. • Reseed disturbed areas and topsoil stockpiles to prevent fugitive dust from wind erosion.
Emissions of CACs and GHGs from the construction equipment and vehicular traffic with potential contributions to climate change	• Recover waste heat from the generators to heat the process building, assay lab and camp.
Emissions of CACs and GHGs from land clearing burning	• Apply best practices regarding clearing. • Do not use prohibited materials (waste oil, tires) as accelerants.
Potential Cumulative Effect	**Mitigation Measures**
N/A	• N/A

Notes: N/A = not applicable

7.2.9 Summary of Effects

Table 7.2-12 is a summary of the effects assessment conclusions including the level of effect and the overall effects rating.

Table 7.2-12 Mitigation Measures for Effects on Air Quality

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction								
Fugitive dust emissions from ground disturbance, heavy construction equipment, and vehicles with potential effects on human health, vegetation and wildlife.	Adverse	Moderate	Local	Medium Term	Reversible	High	Not significant	Not significant
Fugitive dust and emissions of CACs from mining equipment and auxiliary site vehicles.	Adverse	Low to Moderate	Local	Medium Term	Reversible	High	Not significant	Not significant
Particulates and VOC emissions from site clearing and burning of woody debris.	Adverse	Low to Moderate	Local	Medium term	Reversible	High	Not significant	Not significant
GHG emissions from combustion engines, diesel generators and land clearing burning	Adverse	Low to Moderate	Local	Medium term	Reversible	High	Not significant	Not significant
Operations								
Fugitive dust emissions from ore crushing and vehicle use with potential effects on human health, vegetation and wildlife.	Adverse	Moderate	Local	Long term	Reversible	High	Not significant	Not significant
Fugitive dust and emissions of CACs from mining equipment and auxiliary site vehicles.	Adverse	Moderate	Local	Long term	Reversible	High	Not significant	Not significant
Decommissioning								
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

7.3 Terrain, Surficial Geology and Soils

7.3.1 Scope of Assessment

7.3.1.1 Issues and Selection of Valued Ecosystem and Cultural Components (VECCs)

Table 7.3-1 provides a list of the terrain, surficial geology and soil ‘Valued Ecosystem Cultural Components’ (VECCs) that have been defined for the Environmental Assessment of the Minago Project.

As identified in Table 7.3-1, these VECCs were chosen for one or more of the following reasons:

- potential for project impacts was unclear;
- construction will alter current baseline conditions;
- impact of construction is unclear; and
- areas of specific concern to be defined.

7.3.1.2 Temporal Boundaries

The temporal scope of this environmental effects assessment includes all project-related environmental and cultural effects for service life of the open pit mine of 9 years, nickel process plant of 8 years and Frac sand process of 10 years. The environmental effects assessment includes baseline studies, construction, operation, decommissioning, and closure activities as described in Section 3.4 of this report.

7.3.1.3 Study Area

The Minago mine development project is located in northern Manitoba at latitude 54º15’N and longitude 99º12’W. It is accessible from Highway 6 between the communities of Grand Rapids and Thompson. The mine is at the boundary between the Minago and William River watersheds, which are both within the Nelson River hydrographic system.

The study area lies within the Localized Permafrost Zone, which was defined by Zoltai (1995). In that zone, permafrost occurs as small isolated lenses in peat. The hydrological and ecological impacts of their melting have been proven to have no significant effect on the surrounding area (Thibault and Payette, 2009). Moreover, Thibault and Payette (2009) have shown that over the last 50 years the southern limit of permafrost distribution has significantly migrated towards the north. Nowadays, it is therefore unlikely to observe permafrost in the Minago area.

The Minago River is a watercourse that flows in the northeast direction into Cross Lake, then the Nelson River. The William River flows from William Lake in the northeast direction. At roughly 20 km downstream of Highway 6, this watercourse turns 90º to the southeast direction and

Table 7.3-1 Terrain, Surficial Geology and Soil VECCs, Selection Rationale and Data Sources

VECC	Rationale for Selection	Linkage to EAP Report Guidelines or other Regulatory Drivers	Baseline Data for the Environment Act Proposal (EAP)
Key terrain features	• General description of project geography linked to terrain hazards and erosion potential. • Influences habitat capability.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Field Data • Surficial Geology Mapping
Surficial materials	• Linkage to terrain hazards and erosion potential. • Construction will alter current baseline conditions and affect recreation potential and post closure ecosystems.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Surficial Geology Mapping program • Field Data • VNI and Government of Manitoba baseline data
Key sediments with high erosion potential	• Areas of specific concern to be defined for planning and management. • Linkage to potential sedimentation of aquatic habitat.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data
Natural terrain hazards	• Areas of specific concern to be defined for planning and management.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data • VNI and Gov't of MB baseline data
Sensitive soil types	• Areas of specific concern to be defined for planning and management. • Construction will alter current baseline conditions and affect reclamation potential.	• Information requested in the EAP Report Guidelines and Biophysical Assessment Work Plan.	• Terrain Mapping Program • Field Data • VNI and Gov't of MB baseline data

discharges into Limestone Bay on Lake Winnipeg. A series of lakes, including Cross Lake, connects Lake Winnipeg to the Nelson River.

Coniferous vegetation and small to medium sized lakes are typical in the vicinity of the Minago Project. Generally, the site has low topographic relief. Limestone outcrops exist along an elevated ridge directly to the south and west of Minago. These outcrops also extend to the north and east of the property.

The Minago site is located in low, water-saturated, perennially flooded muskeg terrain. The soil conditions at the site are dominated by a surface cover of peat underlain by variable thicknesses of clay and then bedrock. There is an exposure of bedrock to the immediate west of the site. The site is generally waterlogged. A detailed description and characterization of the soil conditions encountered are provided herein. The overall mine development area covers about 1,300 ha.

Precambrian crystalline basement rocks underlie the entire Province of Manitoba. The Thompson Nickel Belt (TNB) forms part of these intensely metamorphosed rocks. Phanerozoic sedimentary rocks of the Western Canada Basin (WCB) unconformably overlie crystalline basement. Minago is located close to the north-eastern boundary of the WCB and the younger sedimentary rocks at Minago are typically about 60 metres thick.

The Local Study Area (LSA) for the assessment of project effects on terrain, surficial geology and soils is defined as the potential project disturbance footprint (conservatively defined as the total of VNI's claim areas directly affected by mine site facilities), buffered by 100 m to account for potential edge effects such as changes in drainage or induced localized instabilities. These buffers are large enough to accommodate potential changes in the development design and project footprint. They are also appropriate for the scale of interpretation conducted and can be predicted with a reasonable degree of accuracy and confidence to include the areas where impacts on terrain, surficial materials and soils are most concentrated.

The mine site is identified as the main area for the assessment of effects on wildlife. This area is defined by the potential extent of project disturbance of wildlife (including noise, traffic and human activity), which extends beyond the area of potential ground disturbance (Section 7.10: Wildlife).

A Regional Study Area (RSA) has not been defined for the terrain and soils assessment as the project effects on terrain and soils will be very localized and are not expected to overlap or act cumulatively with effects of other projects or activities in the region.

7.3.2 Assessment of Baseline Conditions

The objective of the baseline geotechnical and biophysical investigations and description was to describe terrain, surficial materials (geology) and soil conditions of the project area as a basis for the infrastructure design and impact and environmental assessment.

7.3.2.1 Data Collection Methods

A significant amount of background data exists for this project area. Previous studies conducted for VNI (including the 2006 Scoping Study) and previous mineral lease holders have presented baseline information including the bedrock geology, surficial materials, terrain hazards, and soil characteristics of the project area. Terrain, surficial materials and soil conditions were compiled and interpreted and supplemented with field geotechnical investigation programs (Wardrop, 2009b).

7.3.2.1.1 Geotechnical Investigation and Soil Sampling Program

Wardrop conducted geotechnical site investigations during the winters of 2007 and 2008, for the purpose of carrying out the feasibility level design of the various components of the project. The results of the investigations were used to define the characteristics of the overburden soils, the upper dolomite bedrock, and groundwater conditions across the site.

The scope of the geotechnical work, conducted to date, includes the following (Wardrop, 2009b):

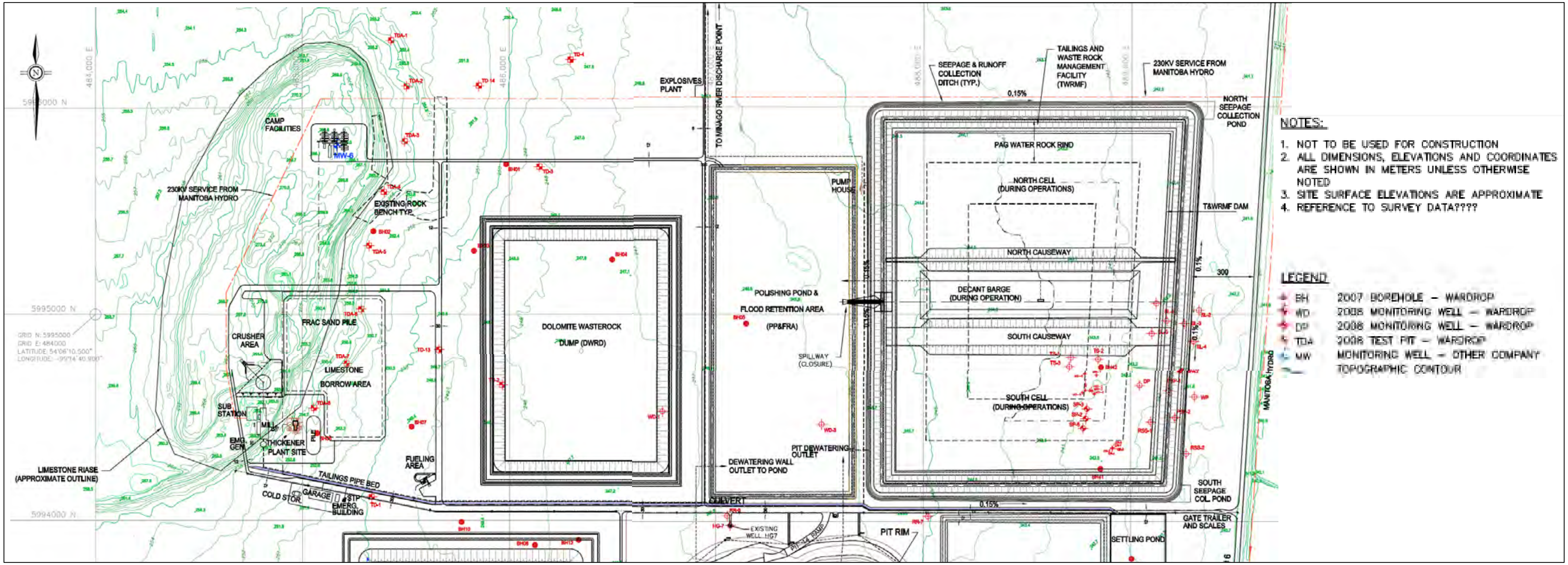
- factual data and laboratory testing;
- site, materials, and tailings characterization;
- study of options for the TWRMF;
- engineering analyses – seepage, stability and settlement;
- geotechnical design of the TWRMF, rock dumps, and Overburden Disposal Facility (ODF);
- water handling and balance for the TWRMF and ODF as a part of the overall site water balance and management;
- conceptual tailings, waste rock and overburden deposition plans;
- construction considerations;
- borrow sources;
- performance monitoring;
- geotechnical closure issues;
- potential future optimizations; and
- Design Basis and Design Criteria.

The subsurface conditions at the site were investigated by drilling total of 90 boreholes and 8 test pits. The locations of the boreholes and test pits are shown on drawing in Figure 7.3-1.

A borehole survey was conducted by Pollock and Wright contracted directly by Victory Nickel in May 2008, approximately one month after completion of the field investigation program. A list of as-drilled boreholes, including their coordinates, elevations, and other pertinent information such as thickness and depth to the surface of the individual soil strata encountered, total drilled depths in overburden and bedrock is provided elsewhere (Wardrop, 2009b).

The bedrock was drilled with additional boreholes without sampling the overburden just beside Boreholes CR1, CR2, CR3, CR4, CR5, MB1, MB2, MB3, SP2, SP3, SP5, WD1, WD3, WD7,

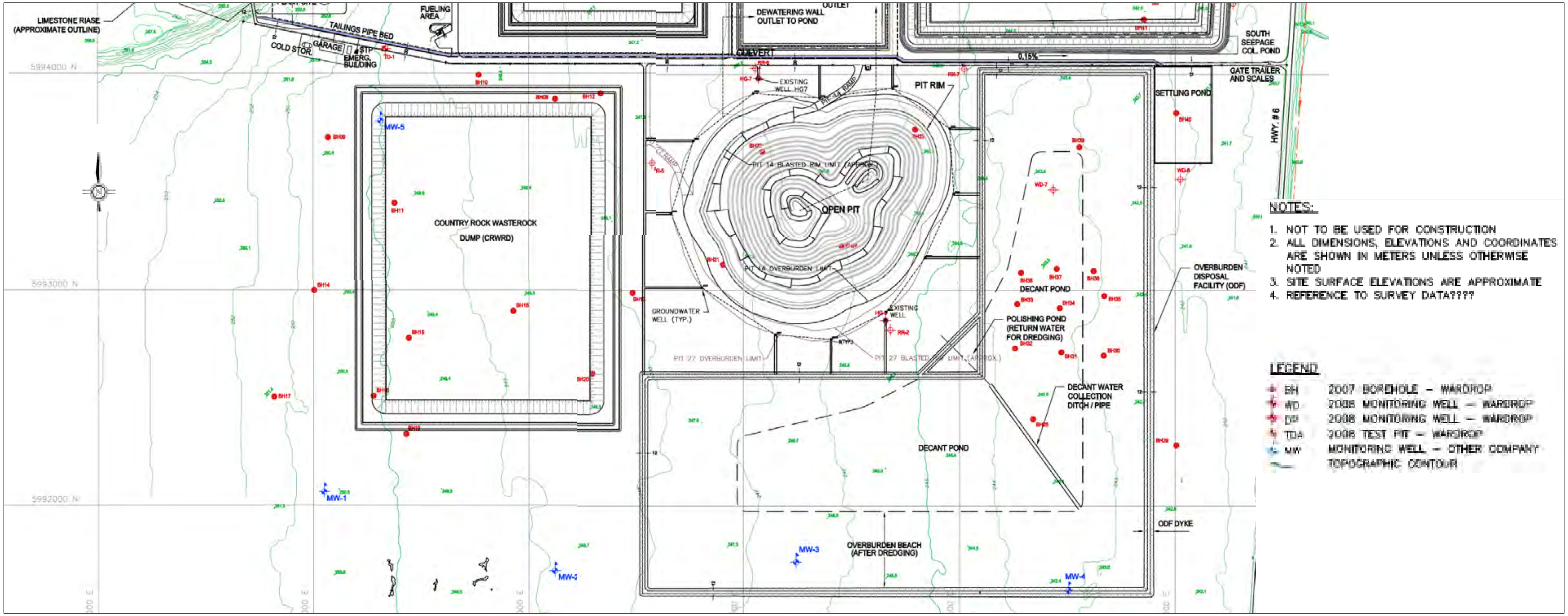
WD8, RR2, RR6, TD2, TD4, TD6, TD10, TD12, TD13 and TD14. Details about the subsurface conditions are provided in the Borehole and Test Pit Logs in Wardrop (2009b).



Source: adapted from Wardrop's Drawing 0951330400-T0002 (Wardrop, 2009b)

Figure 7.3-1 Geotechnical Site Plan for Minago

(**Note:** This Figure was reassembled out of six images taken from the original drawing to enhance the readability of the Borehole Numbers.)



Source: adapted from Wardrop's Drawing 0951330400-T0002 (Wardrop, 2009b)

Figure 7.3-1 (Cont.'d) Geotechnical Site Plan for Minago

(**Note:** This Figure was reassembled out of six images taken from the original drawing to enhance the readability of the Borehole Numbers.)

The drilling was carried out using an Acker Soil Sentry track-mounted hydraulic rig equipped with 125 mm diameter solid/hollow stem continuous flights auger operated by Paddock Drilling Ltd. of Brandon, MB. During drilling, samples from the upper 3.5 m of soils were recovered at 0.76 m intervals using a 50 mm O.D. split-spoon sampler by conducting Standard Penetration Tests (SPTs) in accordance with the procedures outlined in the ASTM Specification D1586. Below this depth, the soil samples were recovered at 1.52 m of intervals until auger refusal was encountered (Wardrop, 2009b).

Thin-walled Shelby tubes were used to extract undisturbed soil samples from the clay overburden. The Shelby tube samples were obtained from the upper firm clay unit in 2007 and from the lower soft to firm clay unit in 2008. Pocket Penetrometer (PP) tests were carried out on recovered cohesive soil samples to obtain index strength values (Wardrop, 2009b).

A total of six Nilcon Vane Tests and eight Standard Vane Tests were conducted in soft/firm formations to measure the in-situ Undrained Shear Strength of the soils. The Standard Vane tests were carried out by means of a Heavy Field Inspection Vane tester, model H-70. This instrument is capable of separately measuring the shear strength of the soils and the friction developed by the drilling rods. However, because the vane wings generally had only penetrated 0.3 m into the undisturbed soils, the evaluation of the test results did not take into account the rod friction (Wardrop, 2009b).

Soil samples obtained from the boreholes were logged and placed in labelled plastic bags. The undisturbed thin walled Shelby tube samples were sealed by paraffin and placed in insulated boxes. These samples were shipped to geotechnical laboratories upon completion of drilling. MDH Engineered Solutions' Saskatoon laboratory and Golder Associates' Mississauga laboratory conducted the soil laboratory testing in 2007 and 2008, respectively (Wardrop, 2009b).

Field identification of the soil strata was based on visual and tactile examination of the samples obtained from the split spoon sampler, a few auger samples and from the bottom of thin-walled Shelby tube samples. The recovered soil samples were then re-examined and inspected subsequently by Wardrop's representatives in Golder Associates' laboratory in July, 2008 (Wardrop, 2009b).

A total of twenty-four boreholes were drilled into the bedrock where the overburden thickness was minimal using HQ size wireline equipment which allowed recovery of 63.5 mm diameter rock cores. The recovered cores were placed in core boxes, logged and photographed and then shipped and stored at Victory's core shack in Grand Rapids, Manitoba. Total Core Recovery (TCR), Solid Core Recovery (SCR), Rock Quality Designation (RQD) values and Fracture Indices (FI) were recorded by Wardrop's representative at the site. These parameters were recorded in accordance with the conventions used by the International Society for Rock Mechanics (ISRM). Selected rock core samples were shipped to Queen's University for Uniaxial Compressive Strength (UCS) and dynamic shear modulus tests. In-situ single packer tests were conducted in the lower 3 m of explored bedrock in selected boreholes to determine the permeability ("k" value) of the Ordovician dolomite. A total of 13 packer tests were carried out in the winter of 2008 of which 11 were successful (Wardrop, 2009b).

The fieldwork was supervised on a full time basis by Wardrop's field representatives who witnessed drilling, sampling and in-situ testing procedures.

A total of seventy-two 50 mm diameter observation wells were installed in the clay overburden across the project site to monitor piezometric heads. An additional twenty-four 50 mm diameter observation wells were installed at the bottom of the boreholes drilled into the bedrock in order to monitor the piezometric heads originating in bedrock. The observation wells were designed with a screened portion at the bottom of a PVC pipe with an above-grade extension of approximately one meter. Well gravel was placed in the annular space between the borehole and the PVC pipe up to 50 mm above the screen segment. A mixture of granular bentonite and soil cuttings was used for sealing the wells above the screen (Wardrop, 2009b).

Additional geotechnical investigations to encompass additional site areas within the recently expanded property limits and to better define current designs are envisaged for future optimizations.

7.3.2.1.2 Geotechnical Characterization of Tailings

A geotechnical characterization of tailings was conducted at SGS Lakefield laboratory in Peterborough, Ontario. The tailings sample was generated from the lock cycle test, one of several metallurgical programs set up for the Minago Project (Wardrop, 2009b).

The tailings sample obtained from the lock cycle testing had solids content of 45% by weight. Additional testing included settling tests, sieve and hydrometer analysis, specific gravity test, Atterberg limits, standard proctor compaction test, hydraulic conductivity test, consolidated undrained triaxial test and an air drying test (Wardrop, 2009b).

Settling tests were conducted for both undrained and drained conditions. The settled sample in the drained settling test was further subjected to a constant head hydraulic conductivity test. Hydraulic conductivity tests were carried out on compacted samples using a flexible wall permeameter. Specific gravity, sieve and hydrometer tests were conducted as per ASTM requirements. The column drying test was conducted as per generic mining method rather than ASTM (Wardrop, 2009b).

7.3.3 Results

A summary of the surficial geology, subsurface conditions and a characterization of the stratigraphy encountered at the site are provided in the following sections.

7.3.3.1 Minago Geology

From a geotechnical standpoint, the relevant units of the stratigraphic column are the upper Ordivician dolomitic limestone and the Quaternary surface cover. Therefore, these units are depicted briefly in the following paragraphs.

7.3.3.1.1 Ordivician Dolomitic Limestone

The dolomitic limestone is fine grained, massive to stratified and varies in colour from creamy white to tan brown to bluish grey. Dolomite thickness ranges from 42 to 62 m with thickness increasing southward. The upper 24 m of the formation is stratified with horizontal clay/organic beds 1 to 5 mm in thickness at intervals ranging from millimetres to a metre. A stratified zone of dolomite breccia and microfracturing characterized by dolomite clasts in a carbonate clay matrix and varying in thickness from 0.3 to 3.0 m is located 15 m to 21 m below the surface of the formation. Scattered throughout the dolomite are occasional soft clay seams ranging from 1 to 2 centimetres (cm) in thickness. The seams may contain dolomite fragments and sand grains and vary in orientation from semi horizontal to semi vertical (Wardrop, 2009b).

7.3.3.1.2 Quaternary Surface Cover

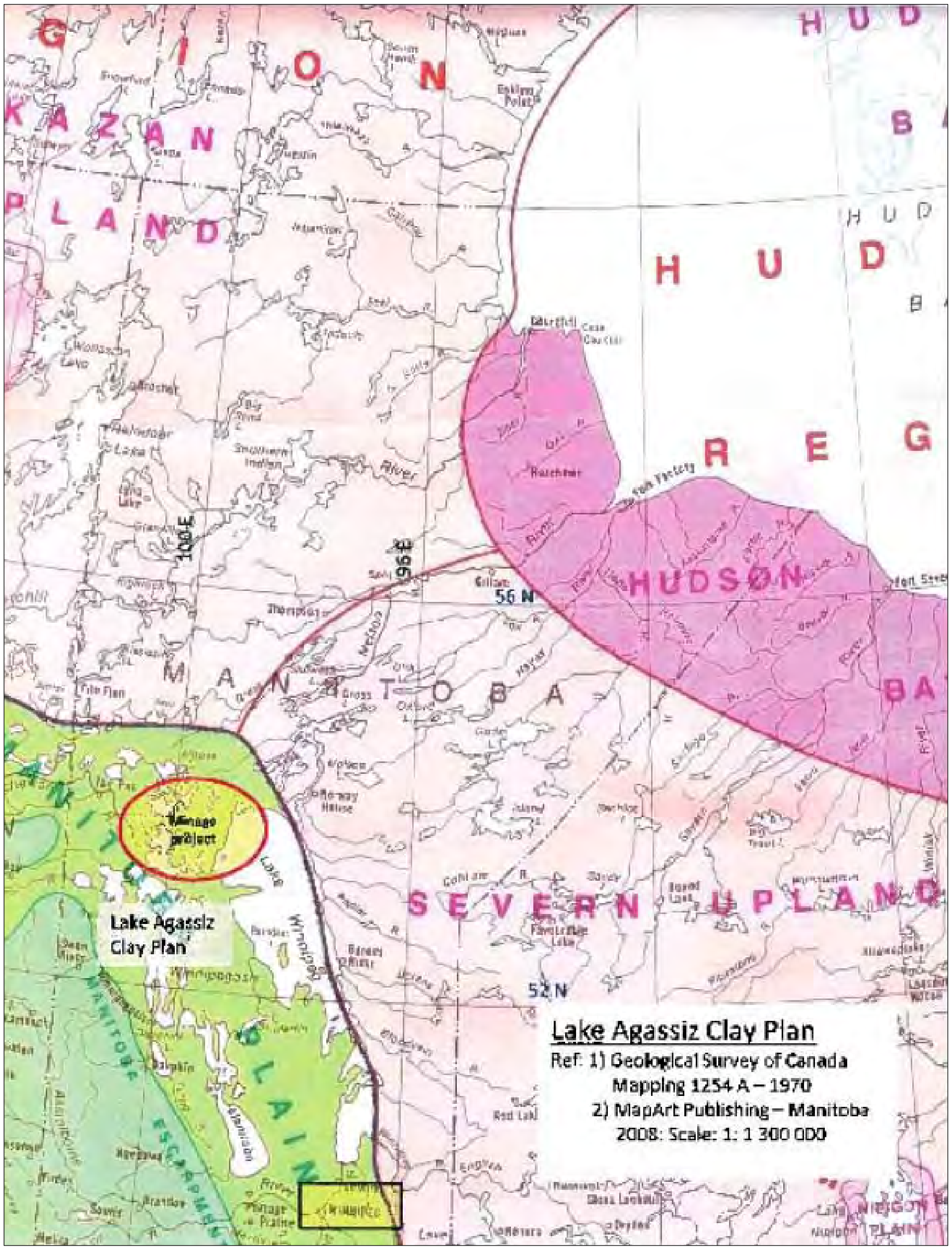
The Quaternary surface cover typically comprises up to 4 m of peat/muskeg that is generally underlain by up to 20 m of low permeability glacial lacustrine clays. The clays are dark brown to grey and carbonate rich. Peat/muskeg is formed by an accumulation of Sphagnum moss, leaves, and decayed matter (Wardrop, 2009b).

The underlying clay and sporadic till was deposited from former glacial Lake Agassiz, which once stretched across portions of Saskatchewan, Manitoba and western Ontario, impounded by retreating and transgressing Laurentian ice sheets. Lake Agassiz finally drained into the Arctic Ocean about 7400 BP (Before Present). Figure 7.3-2 shows the current extent of clays (coloured green) deposited by Lake Agassiz. The deposit contains silt and occasional sand and gravel (Wardrop, 2009b).

Glacial till was found locally below the clay across the project site. Geotechnical work on site identified three components of the glacial lacustrine clay: an upper low plasticity clay, a middle intermediate plasticity clay and a lower, high plasticity clay. Elsewhere in Manitoba, similar glacial lacustrine clay is found in areas prone to flooding and with challenging foundation conditions (Wardrop, 2009b).

7.3.3.2 Seismicity

As the Minago project is located in a region historically exhibiting low seismicity, an extensive evaluation extending beyond an examination of historic earthquakes was not considered necessary (Wardrop, 2009b). The 2005 National Building Code seismic hazard calculation indicating the acceleration levels for given probabilities is presented in Table 7.3-2.



Source: Wardrop, 2009a

Figure 7.3-2 Current Extent of Clays Deposited by Lake Agassiz

Table 7.3-2 Minago Project Area Regional Seismicity

Probability of Exceedance per Annum	Probability of Exceedance in 50 Years (%)	Return Period (years)	Peak Ground Acceleration (PGA) g
0.01	40	100	0.007
0.0021	10	475	0.021
0.001	5	1,000	0.035
0.000404	2	2,475	0.059

Source: Wardrop, 2009b

A return period of 475 years is identified for use in design of structures at the site with a corresponding Peak Ground Acceleration (PGA) of 0.021 g. This design value has been assumed to be applicable for the operational life of the mine. For the longer term post-closure phase, a return period of 2,475 years has been assumed with a corresponding PGA of 0.059 g (Wardrop, 2009b).

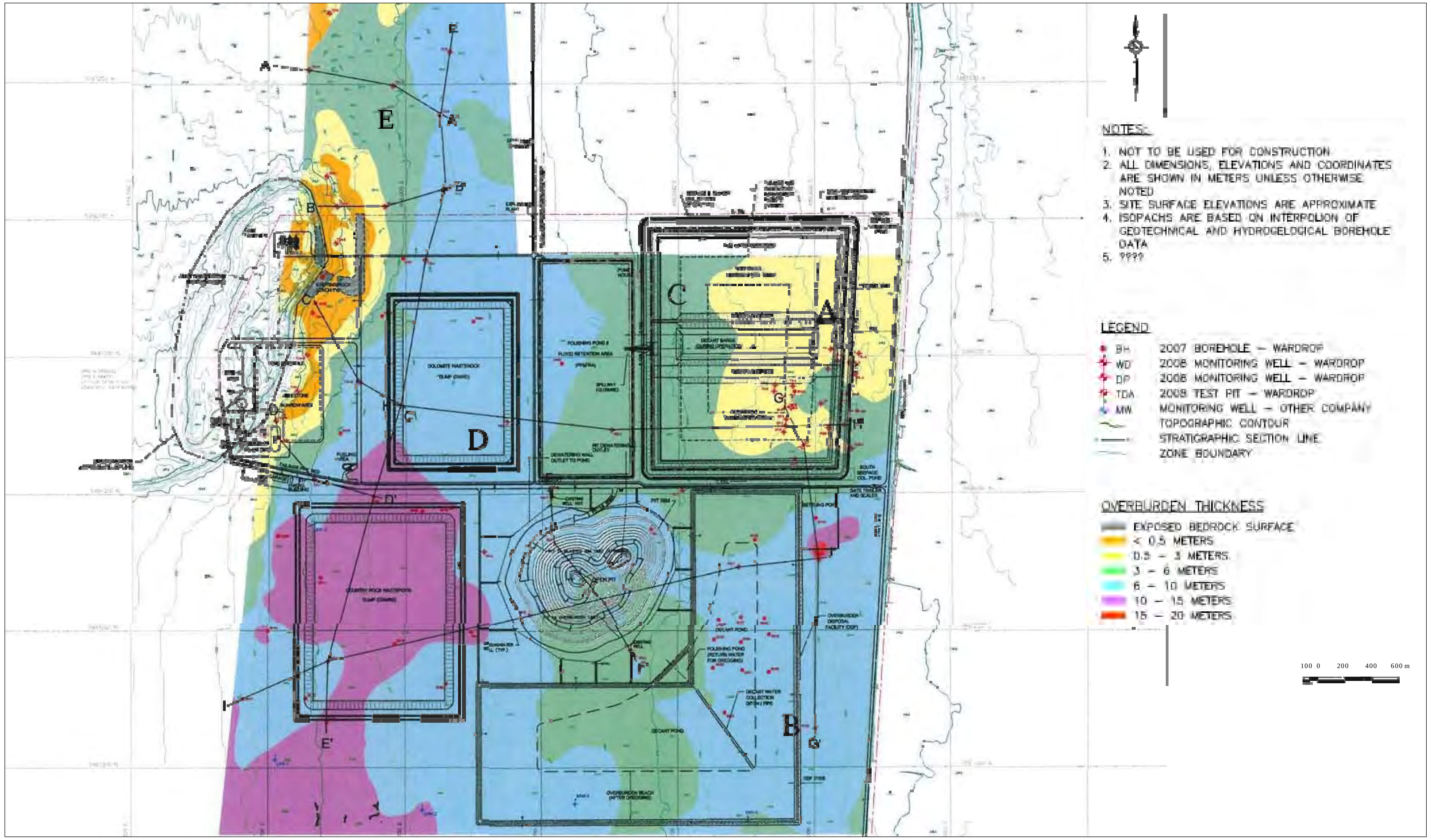
7.3.3.3 Geotechnical Properties

The project site was divided into five sectors in plan for the ease of reference as listed below:

- Zone A:.TWRMF;
- Zone B: ODF;
- Zone C: Polishing Pond and TWRMF;
- Zone D: Waste Rock Dumps; and
- Zone E: Northwestern Sector of the site.

The locations of the selected Zones, the general mine layout, and the overburden thicknesses are shown on Figure 7.3-3. Although Zone E was identified as a possible site for the TWRMF early in the design process, this area is not utilized in the current design.

The thickness and distribution of soil strata vary across the project site, and some of them were not encountered in all site zones. In general, Zone A exhibits relatively thin overburden, within 3 m below the ground surface, while Zone B and D exhibit relatively thick overburden ranging from 6 m to 15 m below the ground surface. One deep overburden pocket (21 m) was encountered within Zone B. The overburden in Zone C varies between 3 m and 10 m. Detailed geotechnical profiles are given elsewhere (Wardrop, 2009b).



Source: adapted from Wardrop's Drawing 0951330400-T0003 (Wardrop, 2009b)

Figure 7.3-3 Minago Overburden Isopach Plan

Five main soil strata were identified within the overburden on the site comprising:

- Peat;
- low plasticity clay (CL);
- intermediate plasticity clay (CI);
- high plasticity clay (CH); and
- glacial till.

The overburden is underlain by a dolomite bedrock, except in a few area within Zone E where limestone outcrops were observed.

Figures 7.3-4 through 7.3-6 illustrate general site conditions of the subsoils. These figures show variations by Zones and by depth of the natural moisture content, recorded SPT N-values and Undrained Shear Strength, measured with a pocket penetrometer (Wardrop, 2009b). Figure 7.3-7 shows a compilation of geotechnical properties for the entire site and Figure 7.3-8 illustrates the variation of undrained shear strength with depth. On the upper part of Figure 7.3-8, the variation of the undrained shear strength obtained from the Nilcon and Standard field vane tests and unconsolidated undrained triaxial tests are shown versus depth. On the lower part of Figure 7.3-8, the normalized undrained shear strengths are plotted versus depth.

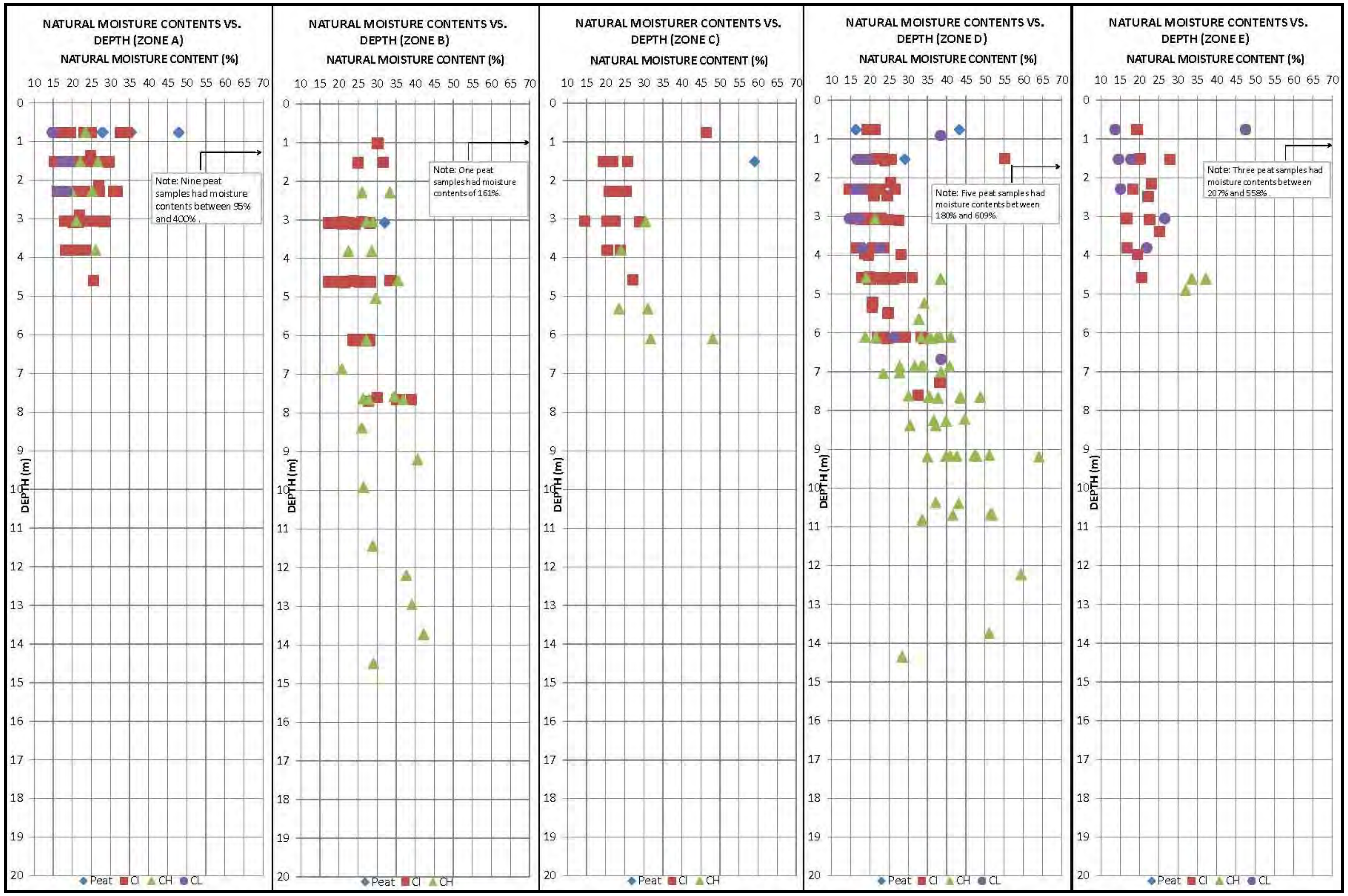
A summary geotechnical profile is presented in the following paragraphs. Detailed information is provided in Wardrop (2009b).

7.3.3.3.1 Peat/Muskeg

Peat with variable thicknesses of up to 4.0 m with an average thickness of approximately 1.6 m covers the entire project area. The peat is composed of fine to coarse but mainly fine fibrous peat of black and brown colour. It generally exhibits high moisture contents, ranging from 16% to 609%, with an average value of 178%. SPT 'N' values ranged from 0 blows per 0.3 m (i.e. drilling rod sunk by own weight) to 6 blows per 0.3 m, with an average value of approximately 3 blows per 0.3 m. The blow counts within this stratum suggest very soft to firm, but generally soft consistency. An Atterberg limits test had a liquid limit, plastic limit and plasticity index of 54%, 20% and 34%, respectively. During the fieldwork, the peat was generally frozen to a depth of approximately 0.5 m (Wardrop, 2009b).

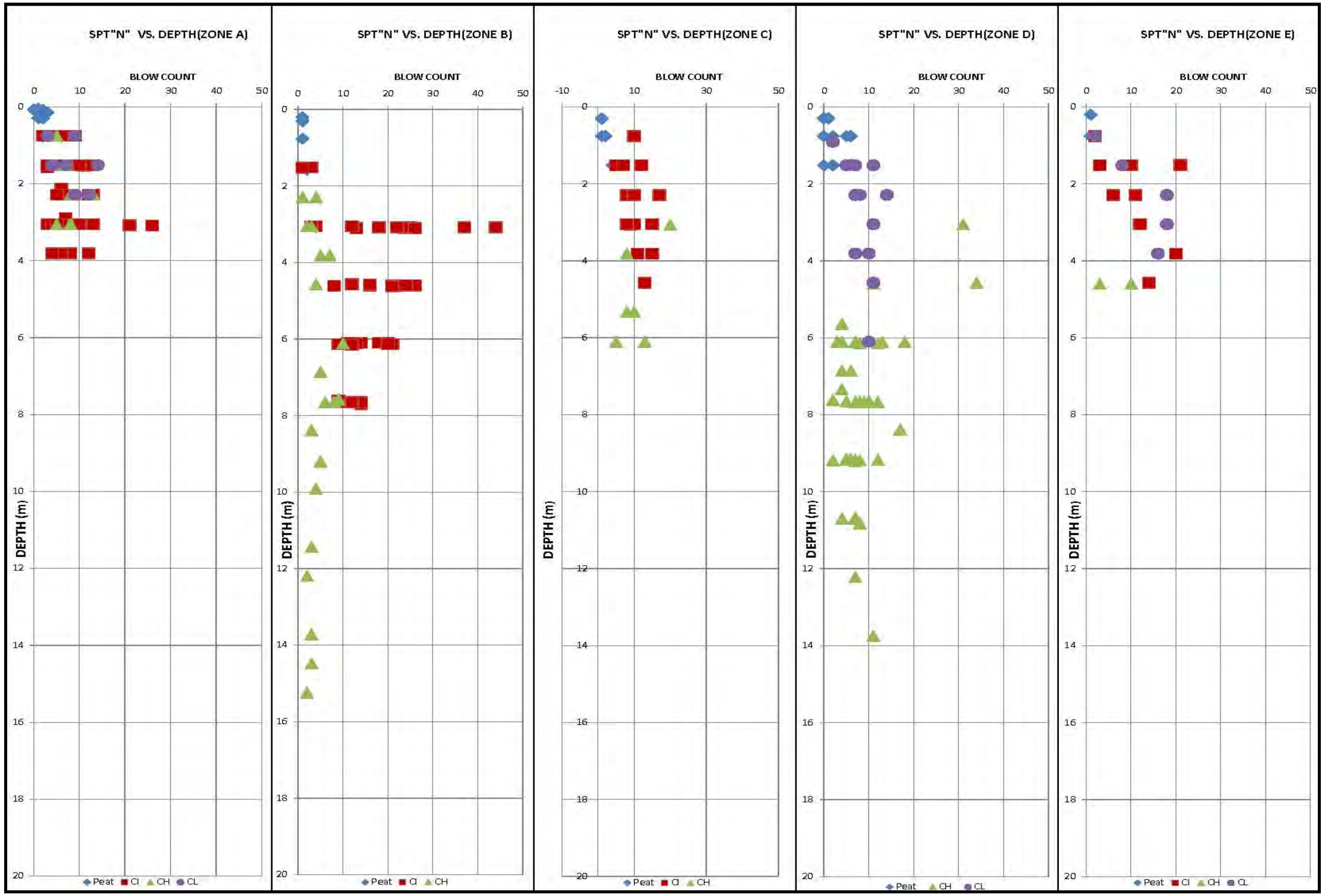
7.3.3.3.2 Low Plasticity Clay (CL)

Low plasticity clay was encountered in places underlying the peat. Based on the results of particle size analyses, this deposit is composed of 48 to 68% of clay, 28 to 44% silt and 4% to 8% sand. A trace of gravel was encountered in places within this clay deposit. The stratum was generally



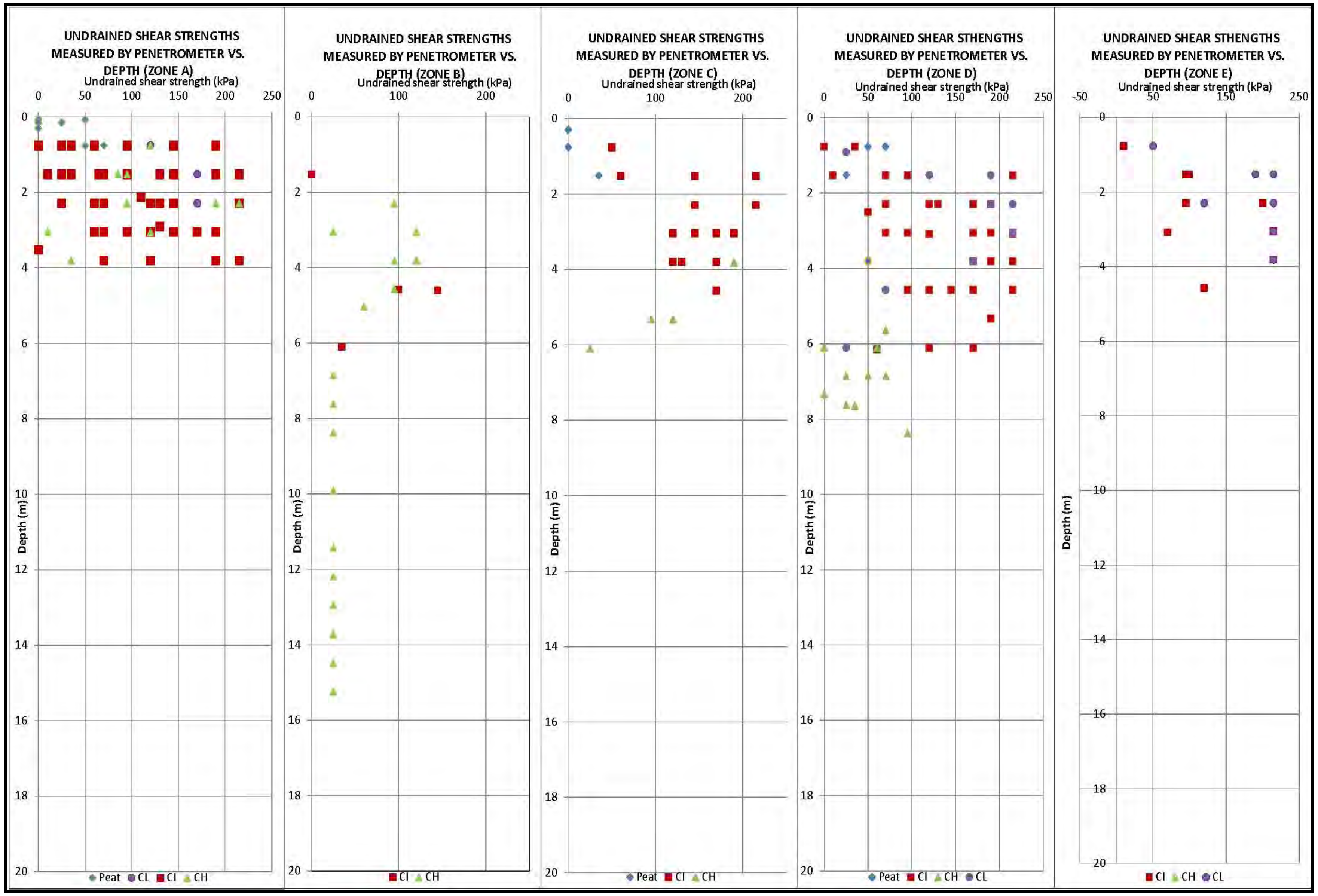
Source: Wardrop, 2009b

Figure 7.3-4 Variation of Natural Moisture Contents with Depth by Zones



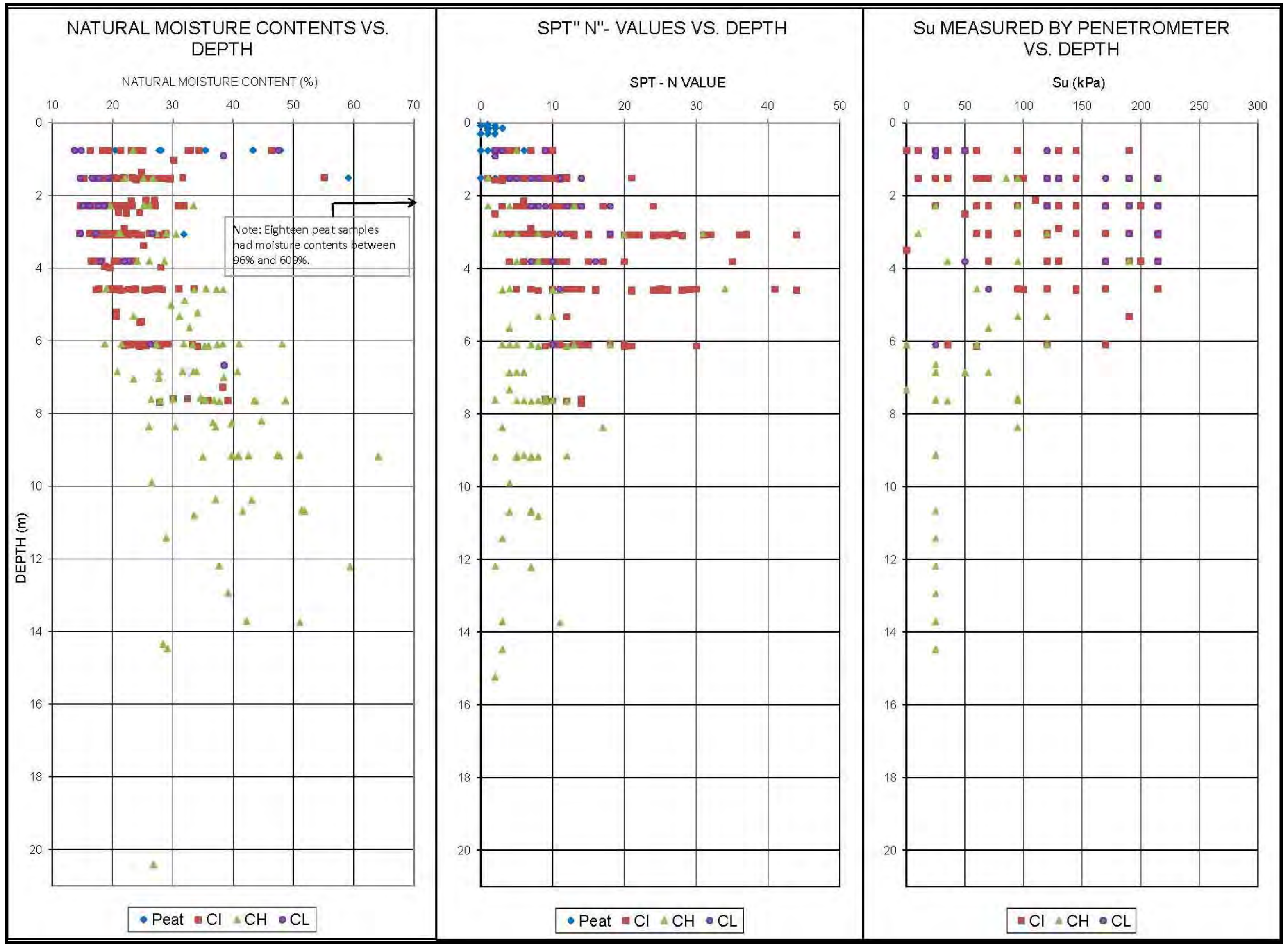
Source: Wardrop, 2009b

Figure 7.3-5 Variation of SPT "N" Values with Depth in the Clay by Zones



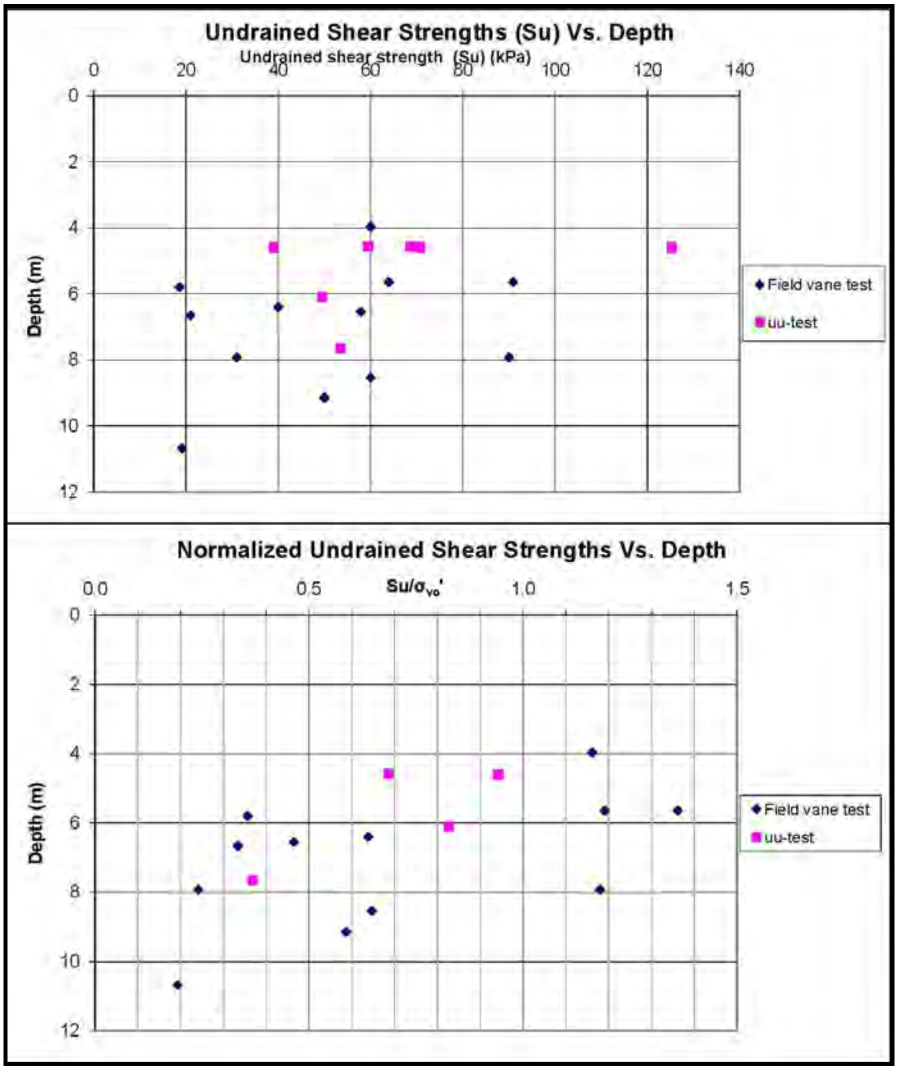
Source: Wardrop, 2009b

Figure 7.3-6 Variation of Undrained Shear Strengths of the Clay with Depth by Zones



Source: Wardrop, 2009b

Figure 7.3-7 Variation of Measured Moisture Contents, SPT "N"-Values and Undrained Shear Strengths with Depth in the Clay



Source: Wardrop, 2009b

Figure 7.3-8 Variation of Undrained Shear Strengths with Depth

brown to grey and moist to wet. The thickness of the stratum varied from 1.8 m to 4.0 m, averaging 3.0 m (Wardrop, 2009b).

The natural moisture contents of tested samples obtained from this deposit were between 14% and 48%, averaging 21%. Based on an Atterberg limits test, its liquid limit, plastic limit and plasticity index were 35%, 16% and 19%, respectively. SPT 'N' values of 2 blows per 0.3 m were generally recorded at the surface of this deposit suggesting a very soft consistency. This soft layer was normally within 1 m below the peat. Further down, the clay formation became firm to stiff with an average N-value of approximately 12 blows per 0.3 m. The unit weight of this clay was 18.1 kN/m³.

The undrained shear strength (Su) measured by Pocket Penetrometer (PP) testing ranged from less than 25 kPa to greater than 215 kPa and averaging about 158 kPa. A nilcon vane test conducted at a depth of 7.9 m in Borehole TD3 yielded an undrained shear strength of 31 kPa (Wardrop, 2009b).

7.3.3.3.3 Intermediate Plasticity Clay (CI)

Intermediate plasticity clay was encountered extensively across the site. This unit was found either immediately underlying the peat or below the low plasticity clay described in the preceding section. Based on the results of particle size analyses, this deposit is composed of 38 to 58% clay, 38 to 47% silt and 4% to 15% sand. A trace of gravel within this clay deposit was encountered in places. This clay was generally brown to grey and moist to wet. The thickness of the stratum varied from 0.5 m to 7.0 m, averaging approximately 3.4 m (Wardrop, 2009b).

The natural moisture contents ranged between 14% and 55%, averaging 23%. Liquid limits, plastic limits and plasticity indices in this deposit ranged from 33% to 54%, 15% to 22% and 18% to 32%, respectively. SPT ‘N’ values ranged between 1 and 54 blows per 0.3 m with an average N-value of 13 blows per 0.3 m, indicating very soft to hard, but generally stiff consistency. Low N-values (i.e. 1 to 2 blows per 0.3 m) indicating very soft consistency were recorded directly underneath the peat (Wardrop, 2009b).

The undrained shear strength (Su) inferred from Pocket Penetrometer (PP) testing ranged from 0 to greater than 215 kPa, averaging approximately 117 kPa. A nilcon vane test and a standard vane test conducted in Borehole TD4 yielded undrained shear strengths of 58 and 60 kPa, respectively. Based on the results of the standard vane test carried out in Borehole TD4, the sensitivity, which is the ratio of the undisturbed to remoulded shear strengths, of this type of clay was 2.1. The results of unit weight tests averaged to 19.6 kN/m^3 (Wardrop, 2009b).

Consolidated Undrained (CU) Triaxial tests with pore pressure measurements were carried out on undisturbed (Shelby tube) samples recovered from BH7, BH11 and BH29. Three samples were trimmed from each Shelby tube and tested under different confining pressures. Each specimen was saturated using the backpressure technique, consolidated and then subjected to compressive loading. The results of the tests, including gradation characteristics, initial and final state parameters (moisture contents, unit weights, void ratios, etc.) as well as the relevant compression shear test charts (e.g. stress-strain charts, stress paths, failure envelopes, etc.) are provided elsewhere (Wardrop, 2009b).

Based on obtained test results, the intermediate plasticity clay unit is considered to be in an over-consolidated state. The average over-consolidation ratio is 2.2. The average compression index (C_c) and recompression index (C_r) were 0.13 and 0.06, respectively (Wardrop, 2009b).

Hydraulic conductivity tests were carried out on undisturbed Shelby tube samples taken from BH9, BH10, and BH15. The tests were conducted under a pressure of 50 kPa applied to the samples. The results of these tests are summarized in Table 7.3-3.

Table 7.3-3 Measured Hydraulic Conductivities for Undisturbed CI Clay Samples

Borehole Sample	k (cm/s)
BH9-3	$6.0x10^{-9}$
BH10-2	$5.0x10^{-7}$
BH15-2	$2.0x10^{-6}$

Source: Wardrop, 2009b

Hydraulic conductivity perrmeability tests were also conducted on a disturbed sample taken from BH40, a combined sample from Boreholes TD4/TD6/TD10/TDA9, a combined sample from Boreholes TD1/TD2/TD13 and a combined sample from Boreholes SL4/SL5/SL6. Prior to the hydraulic conductivity test, these samples were compacted to 95% of their Standard Proctor Maximum Dry Density (SPMDD) (Wardrop, 2009b). The results of the permeability tests are summarized in Table 7.3-4.

The results of these hydraulic conductivity tests show that this type of clay, in compacted condition, is somewhat less permeable than in its natural state.

Table 7.3-4 Measured Hydraulic Conductivities for Compacted CI Clay Samples

Borehole – Sample	k (cm/s)
BH40-2	$7.0x10^{-9}$
Combined TD4/TD6/TD10/TDA9	$1.1x10^{-8}$
Combined TD1/TD2/TD13	$1.4x10^{-8}$
Combined SL4/SL5/SL6	$1.6x10^{-7}$

Source: Wardrop, 2009b

7.3.3.3.4 High Plasticity Clay (CH)

High plasticity clay (CH) is also present extensively across the site. This stratum was found either immediately underlying the peat or below the CL and CI clay. The presence of high plasticity clay appears to be dependent upon the overburden thickness. This unit is generally absent in areas where the overburden is less than 3 m thick. Its thickness increases proportionally with the increased overburden depth reaching a maximum of 9 m in Borehole BH10, where the total overburden was found to be 15 m thick. In a particular case, i.e. Borehole WD8 (sinkhole), the CH unit was 19 m in thickness. The average thickness of the CH stratum was approximately 3.5 m (Wardrop, 2009b).

Based on the results of the particle size analyses, the high plasticity clay is composed of 50 to 70% clay, 15% to 40 silt and 5% to 10% sand and gravel. Based on gradation characteristics, CH can be described as clay to clay and silt, with traces of sand and gravel (Wardrop, 2009b).

The natural moisture content of the tested samples obtained from this deposit varied from 19% to 64%, averaging 32%. Liquid limits, plastic limits and plasticity indices in this stratum ranged from 44% to 63%, 16% to 24% and 28% to 40%, respectively. SPT 'N' values between 1 and 34 blows per 0.3 m were recorded in this deposit indicating very soft to hard, but generally stiff consistency. The average N-value was found to be 8 blows per 0.3 m. Similar to CL and CI units, a soft layer, with up to 1 m in thickness, was found directly underneath the peat. The undrained shear strength (Su) inferred from Pocket Penetrometer (PP) testing ranged from 0 kPa to 215 kPa, averaging 67 kPa. The results of unit weight tests averages 18.6 kN/m³ (Wardrop, 2009b).

Field nilcon vane tests and standard vane tests carried out at selected locations during site investigation indicate that the Undrained Shear Strength for this unit ranges from 19 kPa to 58 kPa and from 40 to 90 kPa, respectively, averaging 50 kPa. Based on the results of six standard vane tests carried out in Boreholes TD4, TD6, WD8 and RR2, the sensitivity, which is the ratio of the undisturbed to remoulded shear strengths, of this type of clay varied from 1.8 to 2.9 (Wardrop, 2009b). Unconfined Compression test conducted on a Shelby tube sample obtained from Borehole BH8 yielded an undrained shear strength of 53 kPa. The results of these tests are given elsewhere (Wardrop, 2009b).

Based on obtained test results, the CH clay unit is considered to be normally consolidated. The tests suggest that the clay has relatively high compressibility (average compression index (C_c) and recompression index (C_r) of about 0.26 and 0.11, respectively) (Wardrop, 2009b).

Hydraulic conductivity tests were conducted on three selected undisturbed Shelby tube samples taken from boreholes SL5, TD6, and TD13. The tests were conducted under pressures of 80 kPa, 140 kPa and 140 kPa applied to the samples, respectively. The results of hydraulic conductivity tests are summarized in Table 7.3-5.

Table 7.3-5 Measured Hydraulic Conductivities for CH Clay Samples

Borehole – Sample	k (cm/s)
SL5-ST	7.0×10^{-9}
TD6-ST	3.8×10^{-9}
TD13-ST1	6.8×10^{-9}

Source: Wardrop, 2009b

7.3.3.3.5 Glacial Till

Localized glacial till unit was found between the clay and the limestone bedrock. The thickness of the stratum was approximately 1.1 m. This unit is broadly graded and is generally composed of 12 to 30% clay, 23 to 35% silt, 33 to 35% sand and 27% to 30% of gravel. SPT-N values recorded in the till were generally greater than 8 blows per 0.3 m (Wardrop, 2009b).

7.3.3.3.6 Dolomite Bedrock

Dolomite bedrock was encountered at variable depths across the site. The greatest depth to the limestone bedrock surface was encountered at the southeastern portion of the site where it lies at approximately 23 m below the ground surface. This area is a suspected sinkhole or an area of deeper bedrock scouring during the glacial retreat. Presence of similar features in bedrock topography at other locations is probable (Wardrop, 2009b).

An elongated dolomite ridge (subcrop/outcrop) with generally south-north orientation is present at the northwestern site limit (Figure 7.3-1). The dolomite encountered in drill cores was generally fine grained with some shell fossils. In some boreholes, the bedrock was found highly weathered from its surface to depths of about 1.2 m. Elsewhere, the Rock Quality Designation (RQD) was generally between 50% and 100%, averaging 83%, indicating fair to excellent, but generally good quality bedrock (Wardrop, 2009b).

Packer test results were obtained for sections between 3 m and 6 m below the bedrock surface in 11 boreholes. The hydraulic conductivity (secondary permeability) calculated from the packer tests ranged from 1.3×10^{-4} cm/s to 1.3×10^{-3} cm/s, indicating relatively permeable characteristics of the bedrock (Wardrop, 2009b). The measured hydraulic conductivities (k values) are summarized in Table 7.3-6.

Table 7.3-6 Summary of Packer Tests for Dolomite Bedrock

Borehole	Depth (m)		k (cm/s)
	From	To	
SP2	11.4	14.4	9.7×10^{-4}
SP3	10.5	13.5	1.3×10^{-3}
SP5	11.7	14.7	1.3×10^{-3}
TD12	10.4	13.4	7.7×10^{-4}
TD13	7.5	10.5	1.0×10^{-3}
TD14	8.4	11.4	3.9×10^{-4}
TD2	6.6	9.6	1.4×10^{-4}
TD4	21.0	24.0	1.3×10^{-4}
WD1	6.6	9.6	8.2×10^{-4}
WD3	6.3	9.3	4.1×10^{-4}
WD8	6.0	9.0	3.6×10^{-4}

Source: Wardrop, 2009b

Uniaxial Compressive Strength (UCS) tests and Dynamic Shear Modulus tests were conducted on selected dolomite core samples. The samples tested were obtained from the footprint currently proposed for the TWRMF. The tests were completed at Queen's University Mining Engineering Rock Mechanics Laboratory in July and August 2008 (Wardrop, 2009b). The test results are summarized in Tables 7.3-7 and 7.3-8.

Table 7.3-7 Uniaxial Compressive Strength Tests in Dolomite

Borehole	Depth (m)	Density (T/m³)	UCS (MPa)	Young's Modulus (GPa)	Poisson's Ratio
CR1	7.1	2.67	108	36.49	0.20
CR2	6.3	2.62	87	38.48	0.21
CR3	6.9	2.66	118	39.88	0.21
CR4	6.8	2.66	88	31.88	0.15
CR5	7.7	2.66	105	41.72	0.17
MB1	5.5	2.54	78	34.11	0.24
MB2	5.3	2.57	129	38.05	0.23
MB3	6.3	2.62	83	34.21	0.22
SP2	3.4	2.57	72	34.16	0.19
SP3	6.2	2.64	116	39.44	0.18
SP5	4.6	2.59	103	41.07	0.18

Source: Wardrop, 2009b

Table 7.3-8 Dynamic Shear Modulus Tests in Dolomite

Borehole	Depth (m)	Solids Density (T/m³)	Shear Velocity (km/s)	Dynamic Shear Modulus (GPa)
SP2	4.9	2.56	3.32	28.29
SP3	5.0	2.60	3.24	27.20
SP5	7.9	2.66	3.59	34.21
MB1	3.9	2.66	2.99	23.81
MB2	4.1	2.57	3.09	24.49
MB3	6.9	2.41	3.00	21.68
CR1	6.8	2.41	3.47	28.99
CR2	7.3	2.66	3.39	30.62

Source: Wardrop, 2009b

7.3.3.3.7 Tailings Characteristics

The grain size distribution test showed that the tailings sample was relatively fine grained, containing 5% clay, 77% silt and 18% fine sand. Atterberg limits test gave a liquid limit of 42%, a plastic limit of 28% and a plasticity index of 14%. A standard Proctor test resulted in a maximum dry density of 1,697 kg/m³ at an optimum moisture content of 16.6%. The initial pulp density for both, drained and undrained conditions was 1.39 t/m³. When the test was completed nine days later, the density in drained and undrained conditions had increased to 1.66 T/m³ and 1.54 T/m³, respectively. The laboratory test results are given in Wardrop (2009b).

Hydraulic conductivity tests on two combined tailings samples (i.e. on initially dry specimen and on slurried sample) were carried out by SGS Minerals Services in Lakefield, ON (SGS) using the falling head testing method. Prior to conducting the tests, both samples were saturated. Based on the test results, the coefficients of permeability “k” were 8.2×10^{-6} cm/s and 2.0×10^{-5} cm/s for the initially dry and slurried samples, respectively (Wardrop, 2009b).

An air drying test was carried out by SGS on a combined tailings sample. The test results show that the bulk of the volume reduction at average room temperature with relative humidity varying between 20 and 50% occurs during the first 800 hours. Details of the test results are given in Wardrop (2009b).

Static and laboratory kinetic subaqueous column test results indicate that potential tailings material is NAG, due to very low sulphide sulphur content and moderate carbonate mineral content (URS, 2009i).

7.3.3.4 Surficial Groundwater Conditions

A total of 96 groundwater observation wells were installed as part of the geotechnical investigation. Seventy-two wells were installed in the overburden and 24 in the bedrock. The groundwater levels in the monitoring wells were measured between 1 day and more than 2 weeks after completion of the boreholes. The results of the ground water observations are listed in Tables 7.3-9 and 7.3-10.

A general representation of surficial groundwater conditions for different zones at the site is shown in Figure 7.3-9. A histogram of average piezometric levels originating from overburden and bedrock is presented in Figure 7.3-10.

As shown in Figure 7.3-9, piezometric levels in the wells with screen in the overburden were generally found within 1.0 m below the ground surface across the site. However, in some wells installed in boreholes in Zone D (BH8, BH13, BH19, and TD3), the groundwater levels were recorded at significantly greater depths, i.e. ranging from 5.7 m to 8.6 m (Wardrop, 2009b). This is also reflected on Figure 7.3-10 showing the average groundwater levels.

The piezometric heads recorded in the wells with screen in the dolomite bedrock indicate a confined aquifer with the exclusion of the bedrock outcrop in Sector E. These records are in general compliance with the interpretations presented by Golder Associates (2008b). In general, the heads reached within the uppermost 1.5 metres from the ground surface and in most cases

Table 7.3-9 Groundwater Level Measurements in Overburden

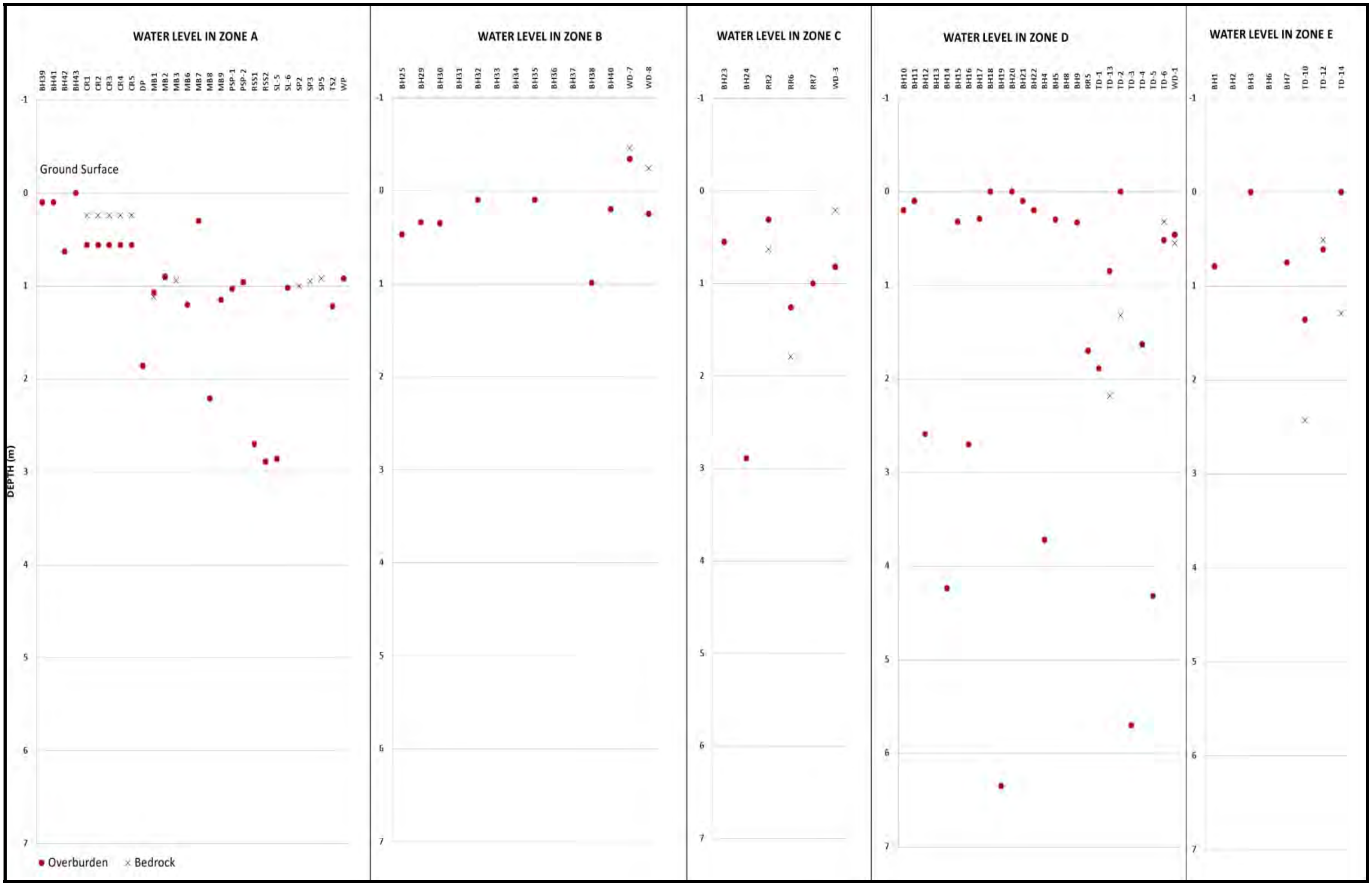
Zona A			Zone B			Zone C			Zone D			Zone E		
BH	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**
BH39	2/29/2007	0.1	BH25	2/29/2007	0.5	BH23	2/29/2007	0.6	BH10	2/29/2007	0.2	BH1	2/29/2007	0.8
BH41	2/29/2007	0.1	BH29	2/29/2007	0.3	BH24	2/29/2007	2.9	BH11	2/29/2007	0.1	BH3	2/29/2007	0.0
BH42	2/29/2007	0.6	BH30	2/29/2007	0.4	RR2	3/6/2008	0.3	BH12	2/29/2007	2.6	BH7	2/29/2007	0.8
BH43	2/29/2007	0.0	BH32	2/29/2007	0.1	RR6	3/6/2008	1.2	BH13	2/29/2007	8.6	TD-10	4/13/2008	1.4
CR1	3/6/2008	0.6	BH35	2/29/2007	0.1	RR7	4/13/2008	1.0	BH14	2/29/2007	4.2	TD-12	4/13/2008	0.6
CR2	3/6/2008	0.6	BH38	2/29/2007	1.0	WD-3	4/13/2008	0.8	BH15	2/29/2007	0.3			
CR3	3/6/2008	0.6	BH40	2/29/2007	0.2				BH16	2/29/2007	2.7			
CR4	3/6/2008	0.6	WD-7	3/6/2008	-0.3				BH17	2/29/2007	0.3			
CR5	3/6/2008	0.6	WD-8	3/6/2008	0.3				BH19	2/29/2007	6.4			
DP	3/6/2008	1.9							BH21	2/29/2007	0.1			
MB1	3/6/2008	1.1							BH22	2/29/2007	0.2			
MB2	3/6/2008	0.9							BH4	2/29/2007	3.7			
MB3	3/6/2008	FROZEN							BH5	2/29/2007	0.3			
MB6	3/6/2008	1.2							BH8	2/29/2007	7.8			
MB7	3/6/2008	0.3							BH9	2/29/2007	0.3			
MB8	3/6/2008	2.2							RR5	4/13/2008	1.7			
MB9	3/6/2008	1.2							TD-1	4/13/2008	1.9			
PSP-1	3/6/2008	1.0							TD-13	4/13/2008	0.9			
PSP-2	3/6/2008	1.0							TD-2	4/13/2008	FROZEN			
RSS1	3/6/2008	2.7							TD-3	4/13/2008	5.7			
RSS2	3/6/2008	2.9							TD-4	4/13/2008	1.6			
SL-5	4/13/2008	2.9							TD-5	3/27/2008	4.3			
SL-6	4/13/2008	1.0							TD-6	4/13/2008	0.5			
SP2	3/6/2008	FROZEN							WD-1	4/13/2008	0.5			
SP3	3/6/2008	FROZEN												
SP5	3/6/2008	FROZEN												
TS2	4/13/2008	1.2												
WP	3/6/2008	0.9												
Highest GW Level		0.0			-0.3			0.3			0.1			0.0
Lowest GW Level		2.9			1.0			2.9			8.6			1.4
Average depth		1.1			0.3			1.1			2.4			0.7

Source: Wardrop, 2009b

Table 7.3-10 Groundwater Level Measurements in Bedrock

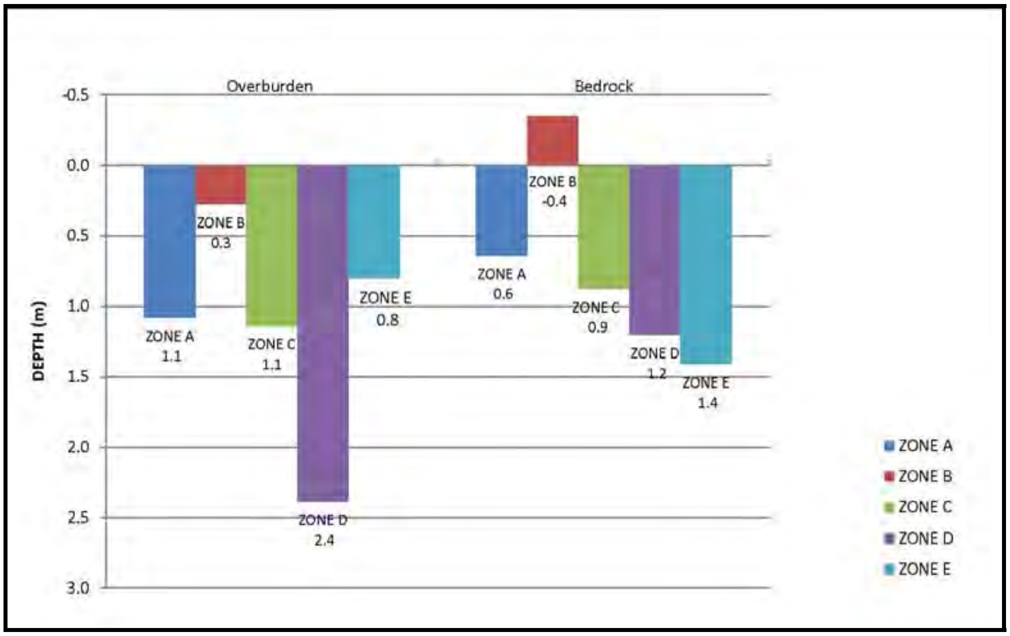
Zone A			Zone B			Zone C			Zone D			Zone E		
BH	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**	**BH**	**Date**	**Depth to the Water Level Below Grade (m)**
CR1	3/6/2008	0.2	WD-7	3/6/2008	-0.5	RR2	3/6/2008	0.6	TD-13	4/3/2008	2.2	TD-10	4/3/2008	2.4
CR2	3/6/2008	0.2	WD-8	3/06/2008	-0.2	RR6	3/6/2008	1.8	TD-2	4/3/2008	1.3	TD-12	4/3/2008	0.5
CR3	3/6/2008	0.2				WD-3	4/3/2008	0.2	TD-4	4/3/2008	1.6	TD-14	4/3/2008	1.3
CR4	3/6/2008	0.2							TD-6	4/3/2008	0.3			
CR5	3/6/2008	0.2							WD-1	4/3/2008	0.6			
MB1	3/6/2008	1.1												
MB2	3/6/2008	0.9												
MB3	3/6/2008	0.9												
SP2	3/6/2007	1.0												
SP3	3/6/2008	1.0												
SP5	3/6/2008	0.9												
Highest GW Level		0.2			-0.5			0.2			0.3			0.5
Lowest GW Level		1.1			-0.2			1.8			2.2			2.4
Average depth		0.6			-0.4			0.9			1.2			1.4

Source: Wardrop, 2009b



Source: Wardrop, 2009b

Figure 7.3-9 Groundwater Levels by Zones



Source: Wardrop, 2009b

Figure 7.3-10 Average Measured Groundwater Levels in Overburden and Bedrock

were somewhat higher (up to 0.5 m) than the ones measured in the overburden clays. This is clearly depicted on Figure 7.3-10. Artesian conditions were measured in Boreholes WD-7 and WD-8 where the piezometric heads reached 0.5 m above the ground surface (Wardrop, 2009b). Piezometric levels in Zone E were generally lower in the bedrock than in the overburden clay (Figure 7.3-10).

7.3.4 Terrain Stability

Terrain stability is a function of bedrock, surficial material, soil texture and thickness, surface expression, potential slip plains, slope, slope position, slope curvature, drainage, and vegetation. The terrain stability hazard classification was based on the criteria outlined in Table 7.3-11. This Table, adopted from work completed in British Columbia (Anonymous 1999), provides a brief interpretative description for each slope stability hazard class and outlines the major management implications expected of operations within the class.

7.3.4.1 Potential Surface Erosion

Erosion via water is the predominate form of erosion in the project area and was the focus of this assessment. Water erosion generally results in the formation of gullies and, on moraine, in the development of gravel covered surfaces where finer particles have been washed away. Surface erosion potential is a qualitative assessment of the potential for sediment generation during and after vegetation removal and construction. Areas of major concern are sensitive landforms, roads, recent landslides, and sites subjected to excessive anthropogenic disturbance.

Table 7.3-11 Terrain Stability Hazard Classification

Terrain Stability Class	Reconnaissance Stability Class	Interpretation
S	Stable	• Minor stability problems can develop. • Vegetation removal should not significantly reduce terrain stability. There is low likelihood of landslide initiation following vegetation removal. • Minor slumping is expected along road cuts, especially one or two years following construction. There is a low likelihood of landslide initiation following road building. • A field inspection by a terrain specialist is usually not required.
P	Potentially unstable	• Expected to contain areas with a moderate likelihood of landslide initiation following vegetation removal and/or road construction. Wet season construction or construction on sites underlain by permafrost will significantly increase the potential for road-related landslides. • A field inspection of these areas is to be made by a qualified terrain specialist prior to any development to address the stability of the affected area.
U	Unstable	• Expected to contain areas with a high likelihood of landslide initiation following vegetation removal or road construction. Wet season construction or construction on sites underlain by permafrost will significantly increase the potential for road-related landslides. • A field inspection of these areas is to be made by a qualified terrain specialist prior to any development to address the stability of the affected area.

Source: Anonymous, 1999.

Table 7.3-12, adopted from Anonymous (1999), provides a brief explanation for each surface erosion potential class mapped within the project area.

Factors influencing surface erosion include vegetative cover, soil texture, depth of surficial materials, vegetative cover, slope gradient and geometry, soil drainage and most importantly, surface water flow. The amount of surface water flow is a function of the amount of precipitation, soil permeability, and soil depth. In areas with high precipitation or snow melt, shallow soils and impermeable soils contribute to an increase in groundwater flow, which increases erosion.

Vegetative cover helps prevent erosion by decreasing the rate at which precipitation reaches the ground via leaves and stems, by forming a protective layer of moss and litter directly on the ground surface, and by anchoring soil in its place via roots. Slope gradient and geometry also play a major role in determining erosion. Increasing slope steepness increases the speed and

eroding potential of the surface water as it flows down the slope. An increase in speed also reduces the time that water has for infiltrating the ground thus contributing to increased surface flow. Erosion potential also increases with increasing slope length because longer slopes can receive and transmit a greater amount of rain or meltwater in total.

Soil texture not only influences soil permeability thus influencing surface water flow, but it also determines the ease by which the soil may be eroded. This is due to factors such as particle size and cohesiveness. Intermediate sized particles such as silt are the most easily eroded. Larger sand particles are not as easily eroded due to their higher cohesion values.

Table 7.3-12 Surface Erosion Potential Classification

Surface Erosion Potential Classes	Surface Erosion Potential	Interpretation
L	Low	• Flat to gently sloping, short slopes including flood plains and organics. • Disturbance of streams could initiate some bank and channel erosion. • Expect minor erosion of fines from ditch lines and disturbed soils. • Exercise care not to channelize water on more sensitive areas.
M	Moderate	• Moderately steep and long slopes and erodible soil textures including fine-textured materials. • Plan preventative remedial actions for disturbed slopes and sites underlain by permafrost. • Expect problems with water channelized down road ditches and across disturbed areas. • Water management is critical. • Plan for complete road deactivation. • Grass seed all disturbed sites.
H	High	• Moderately steep to steep slopes and highly erodible soil textures. • Sites with active surface erosion or gullying. • Major problems exist with water channelized on to or over these sites. • Problem avoidance may permit road development. • Immediate revegetation of all disturbed sites. • Severe surfaces and gully erosion problems exist. • Erosion concerns may take precedence over site disturbance.

Source: Anonymous, 1999

7.3.4.2 Terrain Hazards

Approximately 95% of the project area was classified as 'stable'. The site terrain is low and there are no signs of steep gully side walls and no side wall slumps.

7.3.4.2.1 Flooding Hazards

Floods related to ice-jams, snowmelt and summer rainstorms are possible hazards in lower reaches of most streams in the area. The potential for flooding is low considering the Minago Project site is located further upstream of the Oakley Creek watershed and occupies a small portion of the Oakley Creek watershed.

7.3.4.2.2 Erosion Potential

Ninety-five percent (95%) of the project area was rated as having a low erosion potential due to the occurrence of low terrain throughout the project area.

7.3.5 Effects Assessment Methodology

The objective of this assessment is to predict project and cumulative effects of the Minago Project on terrain, surficial materials and soils; to identify mitigation measures to both minimize adverse effects and associated impacts to terrestrial and aquatic habitat; and to support sound project design. In terms of selected VECCs (Valued Ecosystem and Cultural Components), this assessment concentrates on project effects on:

- surficial materials – alterations to existing surficial material affects local topography, drainage and soil character with associated effects on capacity to support vegetation and related ecological values;
- erosion potential – this is a key issue with any project involving ground disturbance with implications for the design of water management systems and protection of aquatic environments; and
- terrain hazards – this is of concern with respect to both project effects on terrain stability and effects of terrain stability on design and maintenance of facilities.

Information on the key terrain feature (river valleys only as there are no mountains) VECCs has been integrated in the terrain hazards and erosion potential. Further, there are no notable or unique terrain features that will be affected by the project. Information on the sensitive soils VECC has been integrated into the assessment of effects on the other three VECCs.

Potential interactions between project facilities locations and activities and identified VECCs are discussed along with mitigative best practices and requirements for site specific follow-up investigations. Residual project effects, assuming implementation of mitigation measures and follow-up investigations are characterized using the definition of effects attributes provided in Table 7.3-13. Implications of effects to reclamation and capacity for site revegetation are discussed in Section 3.4: Decommissioning and Closure Activities. The ecological context for identified effects on terrain, surficial materials and soils is discussed in Section 7.4: Surface Water Hydrology; Section 7.7: Benthos, Periphyton and Sediment Quality; Section 7.8: Fish Resources; Section 7.9: Vegetation; and Section 7.10: Wildlife.

Table 7.3-13 Effect Attributes for Terrain, Surficial Geology and Soils

Attribute	Definition
Direction	
Positive	Condition of VECC is improving.
Adverse	Condition of VECC is worsening or is not acceptable.
Neutral	Condition of VECC is not changing in comparison to baseline conditions and trends.
Magnitude	
Low	Effect occurs that might or might not be detectable, but is within the range of natural variability and does not comprise economic or social/cultural values.
Moderate	Clearly an effect but unlikely to pose a serious risk to the VECC but does not require specific management from a geotechnical, ecological, economic or social/cultural standpoint.
High	Effect is likely to pose a serious risk to the VECC and represents a significant challenge from a geotechnical, ecological, economic or social/cultural standpoint.
Geographic Extent	
Site-specific	Effect on VECC confined to a single small area within the Local Study Area (LSA).
Local	Effect on VECC within Local Study Area (LSA).
Regional	Effect on VECC within Regional Study Area (RSA).
Duration	
Short term	Effect on baseline conditions or VECC is limited to the <1 year.
Medium term	Effect on baseline conditions or VECC occurs between 1 and 5 years.
Long-term	Effect on baseline conditions or VECC lasts longer than 5 years but does not extend more than 10 years after decommissioning and final reclamation.
Far future	Effect on baseline conditions or VECC extends > 10 years after decommissioning and abandonment.
Frequency (Short Term duration effects that occur more than once)	
Low	Effect on VECC occurs infrequently (< 1 day per month).
Moderate	Effect on VECC occurs frequently (seasonal or several days per month).
High	Effect on VECC occurs continuously.
Reversibility	
Reversible	Effect on VECC will cease to exist during or after the project is complete.
Irreversible	Effect on VECC will persist during and/or after the project is complete.
Likelihood of Occurrence[1]	
Unknown	Effect on VECC is not well understood and based on potential risk to the VECC, effects will be monitored and adaptive management measures taken, as appropriate.
High	Effect on VECC is well understood and there is a high likelihood of effect on the VECC as predicted.

Note: 1. Characterizes the investigator’s confidence that effect will occur as predicted based on the status of scientific or statistical information, experience and/or professional judgement of the author.

7.3.6 Determination of Effects Significance

A residual project or cumulative effect on terrain, surficial materials and soils will be considered significant if it is:

- a high magnitude adverse effect unless it is local in geographic extent; and
- a high magnitude adverse effect that is local in geographic extent and far future (> 10 years) in duration.

Otherwise, effects will be rated as not significant.

7.3.7 Project Effects

Potential effects on VECCs for terrain, surficial materials and soils are discussed by project phase in the following sections. Effects will be greatest during the construction phase and generally persist until decommissioning and site reclamation. The project has been designed to minimize the disturbance footprint as much as possible. Within the LSA, specific areas of ground disturbance will include:

- the open pit mine, waste rock dumps and industrial complex in the upper Oakley Creek drainage;
- the camp, borrow area, and Tailings and Ultramafic Waste Rock Management Facility (TWRMF); and
- the mine access road right-of-way off Provincial Trunk Highway 6 (PTH6) in the upper Oakley Creek drainage.

Table 7.3-13 gives a summary of effect attributes for terrain, surficial geology and soils.

To the extent possible all disturbed areas that become redundant to project activities (spent borrow areas, redundant access roads, laydown areas, etc.) will be progressively reclaimed during the active life of the mine. Accordingly, effects on surficial materials and soils should gradually decrease over the mine life. Major site facilities will be reclaimed in two stages during the decommissioning phase. At the end of operations, the open pit mine and ore processing plant and related site drainage facilities will be decommissioned and the site will be recontoured and reclaimed as much as possible. The Tailings and Ultramafic Waste Rock Management Facility (TWRMF) will remain as a permanent pond feature with passive drainage to the Oakley Creek watershed. In the event that the Communities of Interest (COI) request for some of the transportation corridors (TCs) and facilities to be left in service at closure and during care and maintenance, additional arrangements will be made accordingly.

7.3.7.1 Construction

7.3.7.1.1 Surficial Materials

The construction phase will have the greatest incremental impact on the terrain, surficial geology, and soil VECCs in the project area. Project effects in this phase include mine site and road building processes such as land consumption, movement and alteration of surficial materials and corresponding reductions in soil capability. This includes alteration of the road and project facilities sites, as well as impacts caused by the removal of aggregate from borrow pits for use in surfacing the roads. Aggregate from borrow pits will also be used for construction material and to stabilize sites underlain by soft soils where required. Reduction of soil capability can be caused by a number of factors including loss of topsoil, creation of impermeable layers during overburden replacement, and soil compaction (e.g., bottom of borrow pits).

Various mitigation measures will be employed to minimize these effects. The project has been designed to minimize the disturbance footprint. Much of the mine site, waste rock dumps and industrial complex will be located in an area that has been previously modified by pre-mining (exploration, logging and natural fires) activities. The borrow pit is on level ground, which will facilitate reclamation. Other measures, outlined in Table 7.3-14, include topsoil salvage and stockpiling for use during reclamation, limiting soil compaction where applicable, by limiting clearing and site disturbance to periods when the soil is dry or frozen, and progressive reclamation of disturbed areas during construction (spent borrow areas, laydown areas, road right-of-way). Follow-up studies will be conducted to test soils and develop detailed quantities and remediation requirements, if any, for reclamation purposes (Section 3.4: Decommissioning and Closure Activities). Progressive reclamation throughout the life of the project will provide the opportunity to test reclamation approaches and modify them as required to optimize productive capacity of reclaimed areas.

Based on these mitigation measures, effects on surficial materials and soil capability are characterized as adverse, moderate in magnitude (effects are not expected to give rise to a geotechnical, economic, ecological or socio/cultural management issue beyond identified best practices), local, far future (the road will remain in place at closure for an undetermined period of time), and ultimately reversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at other similar developments.

There is a moderate probability that soils may be contaminated (with petroleum products through spills). Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.1.2 Erosion Potential

Approximately 95% of the LSA was classified as having a low erosion potential. For those areas with erosion potential, mitigation measures include limiting the amount of disturbance and implementation of the Erosion and Sediment Control Plan (Section 9: Environmental

Management Plan). The implementation of the Site Water Management Plan (Section 2.14) will minimize the

Table 7.3-14 Mitigation Measures for Effects on Terrain, Surficial Geology and Soils

Potential Project Effect	Mitigation Measures
Soil compaction and reduction in soil capability during all phases of the project	• Pre-site inspections will allow avoidance, where applicable of sensitive soil types. • Site clearing will be timed to minimize soil compaction. To the extent possible, top soil will by removed and stored. • Where possible, borrow pit locations will be selected based on sites that can be easily reclaimed. • Where possible, disturbed sites will be promptly revegetated (progressive reclamation) with appropriate plant materials and fertilization. • During the decommissioning and closure phases, overburden (surficial materials) will be re-sloped and laid down to avoid the creation of impermeable material. • Site clearing will be minimized during all project phases.
Terrain stability concerns during all phases of the project	• Most disturbances will be restricted to times when soils are dry. • Where possible, disturbed slopes will be re-sloped to a 2H:1V ratio. • Where possible, subsurface and surface drainage will be controlled to prevent slope instability. This includes re-establishing surface drainage as soon as possible. • Pre-site inspections will allow avoidance, where applicable, of unstable or potentially unstable sites.
Soil erosion following disturbance during all project phases	• Sites will be assessed for soil erosion potential and measures to minimize the effects of any such erosion will be employed. • Installation of the site water management system (Section 2.14) during construction and operation throughout the project will minimize drainage and erosion from disturbed areas. • Implementation of the Erosion and Sedimentation Control Plan (Section 9: Environmental Management Plan) throughout the life of the project will reduce soil erosion. • Immediate revegetation with appropriate plant materials and fertilization on all disturbed sites (except roads and mining sites) will minimize this effect. • Where possible, disturbed slopes will be re-sloped to a 2H:1V ratio. • Sites will be cleaned up and progressively revegetated with appropriate plant species when no longer in use.

Table 7.3-14 (Cont.'d) Mitigation Measures for Effects on Terrain, Surficial Geology and Soils

Potential Project Effect	Mitigation Measures
Soil erosion on roads	• Detailed design of the access road will identify requirements for structural elements required for road drainage management, including standard storm water catch basins and/or various forms of check-dams or fords designed to slow drainage. • Implementation of the Erosion and Sedimentation Control Plan (Section 9: Environmental Management Plan) throughout the life of the project will reduce soil erosion. • Where practicable, water barring of roads will also be employed. • Extraneous roads will be reclaimed as soon as practicable. These include roads used for deposit sires and borrow pits, material treatment areas, quarries and other facilities. For example, progressive reclamation techniques will be employed. That is sites and roads will be reclaimed as portions of the project area are decommissioned and closed. Main roads within the project site will remain open until all sites have been decommissioned and closed. This will provide access for reclamation equipment. Once these sites have been reclaimed, applicable roads will be decommissioned.
Contaminated Soils	• Develop appropriate contigency and response measures. • Develop appropriate transport, storage and handeling procedures to contol spills. • Track the volume of hydrocarbons on site (used versus supplied). • Ensure that the oil transfer systems are contained appropriately. • Develop monitoring programs that will identify, if any, contaminated soils.

drainage catchment for disturbed sites and provide a settling pond to minimize effects on receiving streams. If disturbance does occur, sites will be promptly revegetated with appropriate plant materials (e.g., grass mix for quick cover). Sites will be assessed for soil erosion potential and measures to minimize the effects of any such erosion will be employed. Finally, artificial slopes will also be kept to 2H:1V ratios, where possible (Table 7.3-14).

Road erosion will be addressed through detailed planning and design. These processes will outline structural modifications needed during the design of roadways including standard storm water catch basins and/or various forms of check-dams or fords needed to slow drainage. Where practicable, water barring of roads will also be employed and roads will be reclaimed when no longer in use (i.e., exhausted borrow pits, deposit sites, material treatment areas, other facilities, etc.). Impacts on construction on areas of high erosion potentials are expected to be adverse, moderate in magnitude, medium term and irreversible. The likelihood of effects as predicted is high based on observations of effects and mitigation effectiveness at other similar developments.

7.3.7.1.3 Natural Terrain Hazards

Terrain stability concerns may also occur during this phase of the project. This is insignificant because approximately 95% of the LSA was classified as stable. The mapping component of this project combined with pre-site inspections will allow avoidance, where applicable, of unstable or potentially unstable sites and appropriate design to minimize risks to project facilities as a result of terrain hazards. Site disturbance, where practicable, will also be timed (i.e., dry soils) to minimize stability issues. Artificial slopes for the most part will also be kept to 2H:1V ratios. Where possible, subsurface and surface drainage will also be controlled. This includes re-establishing surface drainage as soon as possible (Table 7.3-14).

Impacts associated with terrain stability will be potentially problematic throughout all project phases. For example, moderate slumping can be expected for the first two years following any disturbance. Accordingly, effects of construction on terrain hazards are expected to be adverse, moderate, site specific, long-term and ultimately reversible. The likelihood of effects is unknown until pre-site investigations are conducted. There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils (Manitoba Conservation, 1998). Additional information is given in Section 9: Environment Management Plans.

7.3.7.2 Operations

During operation, there will be little incremental disturbance of surficial materials or terrain hazards or increased erosion. Effects attributes are expected to be similar to the construction phase although some reductions in magnitude are expected as a result of progressive reclamation. Similar mitigation measure will continue to be applied.

There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.3 Decommissioning

7.3.7.3.1 Surficial Sediments

During the decommissioning phase, the majority of impacts on surficial materials are positive with the possible exception of soil compaction. Mitigation measures for soil compaction includes operating on sites when soils are relatively dry. The improvements will be the result of the replacement, re-sloping and revegetating of overburden (including top soil). Overburden will be placed to ensure that an impermeable layer is not created. On sites that have been contaminated or otherwise adversely affected, soils will be removed, placed in a landfill and replaced with soil.

Most impacts on soil erosion will be positive during this phase of the project. Once again, these changes will be the result of topsoil replacement, re-sloping (2H:1V ratio) and revegetation. Some short term site-specific increases in erosion may occur in areas of ground disturbance to decommission facilities and before revegetation. Site water management will remain in place as long as possible during decommissioning to minimize the drainage catchment in these areas prior to restabilization. During this phase, mine roads will be utilized and maintained for the use of reclamation equipment. Once decommissioning of facilities is complete, extraneous mine site roads will be water barred, re-contoured, revegetated and fertilized. The mine access road will remain in place. Stabilization and establishment of vegetation on disturbed areas associated with these facilities during operations will provide ongoing erosion control at closure.

There is a moderate probability that soils may be contaminated with petroleum products through spills. Victory Nickel will establish a monitoring program to determine potential hot spots and develop mitigative and remediation measures to deal with contaminated soils. Additional information is given in Section 9: Environment Management Plans.

7.3.7.3.2 Natural Terrain Hazards

Decommissioning may result in terrain stability issues. If they occur, these issues will be negative and residual. Mitigation measures include re-sloping, revegetating and controlling subsurface and surface drainage.

7.3.7.4 Closure

No further effects on terrain, surficial materials and soils are expected at closure when all the facilities sites have been stabilized and reclamation is complete.

7.3.7.5 Residual Project Effects and Significance

As noted above, effects on terrain, surficial materials and soils are expected to be greatest during the construction phase. At worst, the residual effects on the selected VECCs (surficial materials and soil capability, erosion potential and terrain hazards) are expected to adverse, moderate in magnitude, long-term to far future and ultimately reversible. Most impacts are also avoidable or manageable through planning, pre-disturbance field inspections, ongoing monitoring throughout the operational phase and the implementation of mitigation measures. These effects are determined to be not significant. Based on previous studies, science, observations elsewhere and professional experience there is a high likelihood that these effects will manifest as predicted.

7.3.8 Cumulative Effects

Residual effects on terrain, surficial geology, and soil VECCs are stationary in nature and were all classified as being either site specific or local in extent. There are no other past, present or reasonably foreseeable projects, which will overlap with or increase the magnitude of the effect within the LSA. Accordingly, no cumulative effects expected.

7.3.9 Mitigation Measures

Table 7.3-14 provides a summary of mitigation measures.

7.3.10 Monitoring and Follow-up

7.3.10.1 Monitoring Programs

Table 7.3-15 provides a summary of proposed monitoring and follow-up programs for terrain, surficial geology and soils that have been identified for monitoring project effects (construction, operation, decommissioning, and closure phases). These programs include:

- A seasonal terrain stability assessment monitoring program is needed in identified areas of potential risk to determine if facilities have an impact on terrain stability.
- Contingency plans will need to be implemented if unexpected effects occur.
- A seasonal soil erosion monitoring program is needed to check the effectiveness of the site water management and the Erosion and Sedimentation Control Plan and determine if the construction and operational phases have resulted in the erosion of surficial materials. Contingency plans will need to be implemented, if unexpected effects will have occurred.

In addition, geotechnical monitoring will be required at the site. The proposed geotechnical monitoring program is outlined in the next subsection.

7.3.10.1.1 Geotechnical Monitoring

The site conditions are complex and the feasibility designs are based on interpretation of the geotechnical data. The extrapolations and assumptions used in the designs are best confirmed using an observational method which is a common practice in geotechnical engineering. Geotechnical performance monitoring should be tailored to confirm the feasibility design assumptions. The results of monitoring and their assessment will provide advance warning against potential problems and will allow sufficient time to implement preventative actions, if required (e.g., establishment of alert levels and necessary actions). Also, the monitoring results could be potentially used in optimizing the design if the design assumptions prove to be too conservative.

Initial monitoring involving instrumented test fills and large scale dewatering experiments is recommended during the detailed design geotechnical investigation. Test fills are of particular importance in gaining greater confidence in assumptions on engineering performance of site peat under the Dolomite WRD and Country Rock WRD. Also, large scale peat dewatering experiments could be started during the detailed engineering design stage in preparation for site dewatering required for foundation excavation for major site facilities (such as the TWRMF dam and dyke of the Polishing Pond).

The balance of instrumentation installation and monitoring is recommended during construction/operation/closure. Stage 1 construction of the TWRMF dam and both waste rock

Table 7.3-15 Monitoring and Follow-up Programs for Terrain, Surficial Geology and Soils

Potential Project Effect	Program Objectives	General Methods	Reporting	Implemen-tation
Follow-Up and Monitoring Programs				
Soil chemical conditions limiting reclamation success	• Determine soil chemistry. • Initiate contingency plans to address unexpected effects, as required.	• Soil sampling and chemical analysis prior to construction and soil salvage.	• Internal • MB Gov't as required	Proponent
Soil physical conditions limiting reclamation success	• Determine soil physical conditions. • Initiate contingency plans to address unexpected effects, as required. • Refine materials balance for reclamation planning.	• Soil test pits and trenches to characterize physical conditions, parent materials, depths and approximate volume of suitable soil materials for reclamation.	• Internal • MB Gov't as required	Proponent
Terrain stability concerns	• Perform on site terrain stability assessments prior to development. • Initiate contingency plans to address unexpected effects, as required.	• Terrain stability assessments will determine site specific stability issues.	• Internal • MB Gov't as required	Proponent
Soil Erosion concerns	• Identify surficial materials with high erosion potentials. • Initiate contingency plans to address unexpected effects, as required.	• Erosion potential assessments will determine site specific erosion issues.	• Internal • MB Gov't as required	Proponent
Monitoring Programs				
Terrain stability	• Determine if the project has had an impact on terrain stability. • Initiate contingency plans to address unexpected effects, as required.	• Seasonal terrain stability assessments will determine site specific stability issues.	• Internal	Proponent
Soil Erosion	• Determine if the project has resulted in the erosion of surficial materials. • Initiate contingency plans to address unexpected effects, as required.	• Seasonal erosion assessments will determine site specific stability issues.	• Internal	Proponent
Contaminated Soils	• Determine if the project has resulted in soil contamination. • Initiate contingency plans to address unexpected effects, as required.	• Soil sampling will determine if soils have been contaminated or not.	• Internal • MB Gov't as required	Proponent

dumps are of particular importance. The same instrumentation program will be incorporated into subsequent stages.

Presented in Table 7.3-16 are the minimum instrumentation requirements.

Test fills are recommended to verify practical aspects of initial preloading of the peat at waste rock dump locations, and also the consolidation characteristics of the peat.

Table 7.3-16 Recommended Geotechnical Instrumentation

Instrument Type	Area Needed	Purpose
Piezometers (pneumatic, vibrating wire, etc)	Dam foundation	Monitor pore pressure build-up and dissipation during staged construction
Inclinometer Casings	TWRMF Dam	Monitor lateral deformation of dam crest and slopes
Optical Survey Targets	TWRMF Dam	Monitor deformations and movements
Settlement plates	TWRMF Dam foundation	Monitor ground settlement and heave
Stage / discharge measurement devices	Spillways (TWRMF dam, ODF dyke; runoff/seepage collection ditches; TWRMF decant pond, Polishing Pond , etc.	Monitor contribution of TWRMF to the overall site water balance.
Thermistors	TWRMF dam foundation and rockfill shell	Measurement of frost penetration to be analyzed together with settlement monitoring data; thermal performance of rockfill shell while the TWRMF dam is covered with snow and impacts of this on winter runoff/seepage.

Source: Wardrop, 2009b

It is also recommended that vibrations caused by blasting or by operation of heavy construction equipment near earth slopes be monitored to verify that they are of significance, or otherwise, to the stability of pit slope in overburden.

The geotechnical instrumentation program should be established and implemented in close co-ordination with other monitoring programs involved such as those required for open pit dewatering, water management and environmental purposes.

Further consideration should be given to checking on the potential existence of karstic features in the limestone and their possible implications on the design of foundations and earthworks.

7.3.10.2 Follow-up Studies

Table 7.3-15 provides a summary of proposed follow-up baseline studies needed to improve predictive capabilities or understanding of baseline conditions. These studies include:

- A baseline study to determine soil chemistry on sites that are scheduled to be disturbed. This study is needed to assess soil chemistry and determine if there are any constraints or limitations to achieving vegetation restoration and initiate contingency plans to address unexpected effects, as required (Section 3.4: Decommissioning and Closure Activities).
- A baseline study to determine soil physical conditions on sites scheduled to be disturbed. This study is needed to assess soil physical conditions and determine reclamation suitability and the approximate volume of suitable soil materials for reclamation (Section 3.4: Decommissioning and Closure Activities.
- Detailed terrain stability assessments are needed to determine site-specific stability issues and develop contingency plans to initiate construction techniques to mitigate these issues.
- Detailed soil erosion potential assessments are needed to identify surficial materials with high erosion potentials and develop contingency plans to initiate construction techniques to mitigate these issues.

7.3.11 Summary of Effects

Table 7.3-17 provides a tabular summary of the project effects on terrain, surficial geology and soils.

Table 7.3-17 Program Effects on Terrain, Surficial Geology and Soils

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Construction								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Adverse	Moderate	Local	Long-term to far future	Reversible	High	Not significant	N/A
Increased soil erosion	Adverse	Moderate	Local	Medium term	Reversible	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Long-term	Reversible	Unknown	Not significant	N/A
Operations								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Adverse	Moderate	Local	Medium term to far future	Yes	High	Not significant	N/A
Increased soil erosion	Positive	Moderate	Local	Medium term	Yes	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Long-term	Yes	Unknown	Not significant	N/A
Decommissioning								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	Positive	Low	Local	Medium term to far future	Yes	High	Not significant	N/A
Increased soil erosion	Positive	Moderate	Local	Short term	Yes	High	Not significant	N/A
Terrain stability concerns	Adverse	Moderate	Local	Short term	Yes	Unknown	Not significant	N/A

Table 7.3-17 (Cont.'d) Program Effects on Terrain, Surficial Geology and Soils

Potential Effect	Level of Effect						Effect Rating	
	Direction	Magnitude	Extent	Duration/ Frequency	Reversibility	Likelihood	Project Effect	Cumulative Effective
Closure								
Damage to key terrain features	No effect	No effect	No effect	No effect	No effect	No effect	Not significant	N/A
Modification of surficial materials and reduction in soil capability	No incremental effect	No incremental effect	No incremental effect	Far future	No incremental effect	No incremental effect	Not significant	N/A
Increased soil erosion	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	Not significant	N/A
Terrain stability concerns	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	No incremental effect	Not significant	N/A

Notes: N/A = not applicable.