APPENDIX R

Water Management and Discharge Plan

TECHNICAL MEMORANDUM

DATE July 24, 2023 **Project No.** 19129150

TO David Hanratty, Mike Lebreton
CBM

CC Heather Melcher

FROM George Schneider, Craig DeVito, Hayley Wallace **EMAIL george.schneider@wsp.com**

WATER MANAGEMENT AND DISCHARGE PLAN - CBM CALEDON PIT / QUARRY

This memorandum provides an overview of the proposed water management and discharge plan for the CBM Caledon Pit / Quarry project.

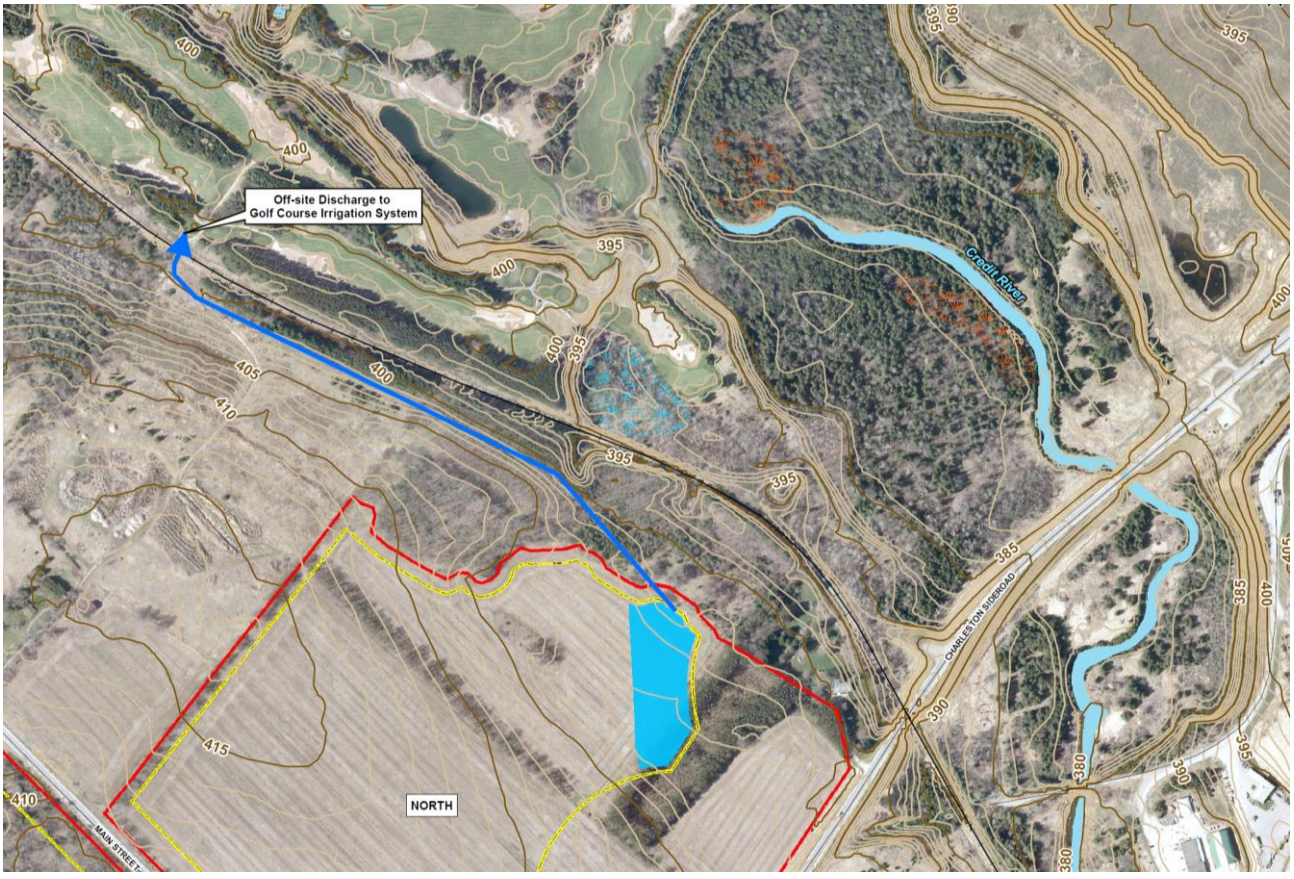


Figure 1: Proposed Water Discharge Location to the Osprey Valley Golf Course

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada T: +1 905 567 4444 F: +1 905 567 6561

OFF-SITE DISCHARGE

A single point of discharge has been identified for water collected from the combined land assemblages of the proposed Caledon Pit / Quarry to the Osprey Valley Golf Course irrigation system infrastructure (Figure 1), where water will be used for irrigation when needed, with excess water stored in the existing pond system which ultimately discharges to the Credit River.

PROPOSED GROUNDWATER MITIGATION SYSTEM

A groundwater mitigation system has been proposed for Phases 3 to 7 of pit / quarry operation, and a portion of the water collected during those phases of operations is expected to be directed to the infiltration trenches that form part of the mitigation system to mitigate impacts of pit / quarry dewatering (Figure 2). The mitigation measures consist of the installation and operation of six infiltration trench zones along a 1,900 m alignment along the west side of the Main Area and the west and south side of the South Area, in the setback area between the licence limit and the limit of extraction.

Water collected in the pit / quarry from dewatering will be reintroduced into the groundwater system through these infiltration trench zones to maintain the groundwater levels west and south of the licence area to levels within their current typical range. Additionally, a slurry wall will be installed in the overburden between the infiltration trenches and the extraction limit, in order to minimize the flow of groundwater back into the pit / quarry from the injection trench. The weathered upper bedrock zone along the proposed slurry wall alignment may be grouted to reduce the permeability of this zone and further reduce the inflow of groundwater into the pit / quarry and help sustain existing groundwater levels outside of the licence area.

If required, the proposed groundwater mitigation system would be implemented in the following stages of pit / quarry operation:

- Phase 3 – Implementation of the slurry wall / grouting of the weathered bedrock zone on the west side of the Main Area prior to the start of Phase 3 extraction.
- Phases 4 and 5 – Implementation of the infiltration trench system (Trench Zones 1 and 2) on the west side of the Main Area prior to the start of Phase 4 and 5 extraction.
- Phase 6 and 7 – Implementation of the second slurry wall / grouting of the weathered bedrock zone and the second phase of the infiltration trench system (Trench Zones 4 to 6) prior to the start of Phase 6 and 7 extraction.

The post-Rehabilitation scenario includes the removal of the slurry wall in the overburden in the southwest corner of the South Area (adjacent to Trench Zones 4 and 5) to reinstate hydraulic connection between the South Area and the lands to the south and southwest of the Site.

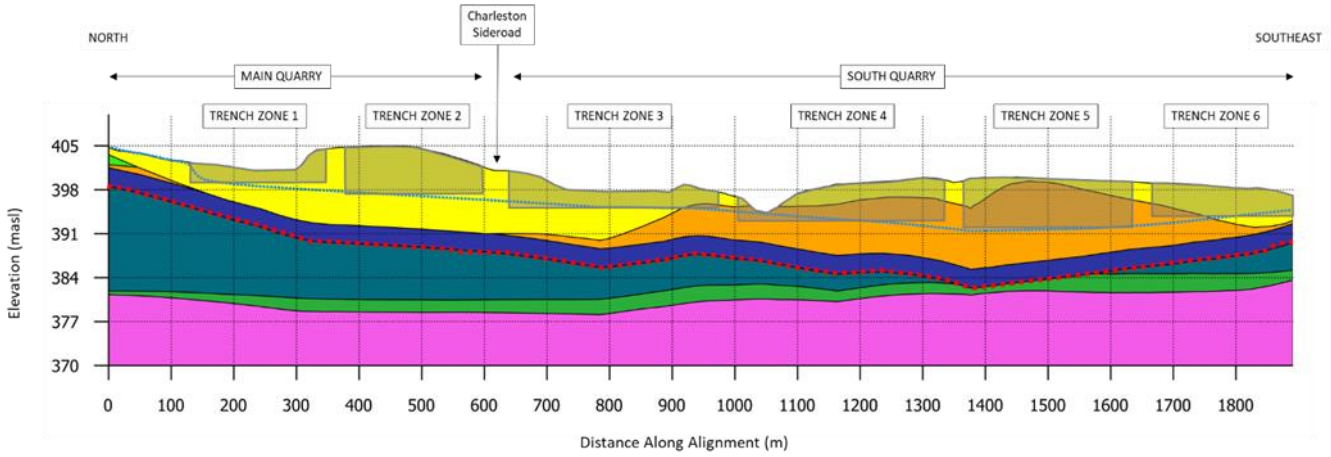


Figure 2: Proposed Groundwater Mitigation System, consisting of six Infiltration Trench zones and two Slurry Wall / Grout zones

WATER INFLOW PREDICTIONS AND WATER MANAGEMENT STRATEGY

Water balance calculations were performed for the pit / quarry areas, at one-year increments, for each year of operation as proposed in the Caledon Pit / Quarry Mining Plan (Mining Plan) dated 12 December 2022, in order to help predict water inflows to the quarry and inform a water management strategy.

The calculations estimated how much water will be generated by pit / quarry operations each year and evaluated options to best manage the water. The calculation was generally performed as follows, with the calculations and results presented in Tables 1 and 2.

- The net annual water surplus was calculated for each of the pit / quarry areas, year by year, for each operational year, based on plan view “snapshots” presented in the Mining Plan.
- These annual snapshots were used to calculate the spatial size of vegetated, till, rock and open water areas, and along with water surplus factors unique to each of the land surface types, a net annual water surplus was calculated for each quarry parcel. It was assumed that the surplus water from exposed till, exposed rock and ponded water areas was captured within the quarry, while surplus water from the undisturbed vegetated areas was not.
- Groundwater seepage was inferred by subtracting the annual water surplus from the total water inflow predicted by the HydroGeoSphere (HGS) simulations at key time steps during pit / quarry operations.
- The annual water surplus from each area including the estimated seepage contributions were summed to estimate the total water generated by quarry operation each year.
- A portion of the pit / quarry water generated each year will be used for aggregate washing, and while washing is largely non-consumptive, we assumed that 0.05 m^3 of water would be lost for every tonne of aggregate washed.

- The net water surplus for each year was then allocated to storage, use in the proposed groundwater mitigation system or discharged to the Osprey Valley Golf Course irrigation pond system, depending on the operational needs for that year. Key water management milestones are highlighted in the table below.

Table 1
Water Generation Estimate - Caledon Quarry

Year	Main Quarry						HGS Inflow Prediction			
	Total area	Veg area	Open Rock area	Till / Rehab area	Pond area	Site Surplus Inflow	Total Model Inflow	Total Model Inflow	GW Seepage (by HGS)	Annual Water Generated
	mm/yr	342	446	365	234					
	m2	m2	m2	m2	m2	m3/yr	m3/d	m3/yr	m3/yr	m3
0	1,245,747	1,245,747	0	0	0	0	0	0	0	0
1	1,245,747	1,130,547	70,475	44,725	0	47,756	154	56,357	34,905	82,661
2	1,245,747	1,130,547	70,475	44,725	0	47,756	309	112,715	69,809	117,566
3	1,245,747	1,093,797	105,825	46,125	0	64,034	463	169,072	104,714	168,747
4	1,245,747	1,047,647	141,025	57,075	0	83,730	618	225,430	139,618	223,348
5	1,245,747	1,026,847	158,625	60,275	0	92,747	772	281,787	174,523	267,270
6	1,245,747	966,372	214,450	64,925	0	119,342	926	338,144	209,428	328,770
7	1,245,747	907,172	256,950	81,625	0	144,393	1,081	394,502	244,332	388,725
8	1,245,747	835,072	298,950	92,725	19,000	171,622	1,235	450,859	279,237	450,859
9	1,245,747	776,672	317,500	132,575	19,000	194,441	1,300	474,356	282,877	477,318
10	1,245,747	769,972	318,900	137,875	19,000	197,000	1,364	497,852	286,518	483,517
11	1,245,747	708,797	378,500	139,450	19,000	224,156	1,428	521,349	290,158	514,314
12	1,245,747	626,447	395,975	204,325	19,000	255,629	1,493	544,846	293,798	549,428
13	1,245,747	589,572	418,382	218,792	19,000	270,904	1,557	568,342	297,439	568,342
14	1,245,747	550,872	427,161	248,714	19,000	285,740	1,544	563,588	276,511	562,251
15	1,245,747	514,122	445,796	266,829	19,000	300,664	1,531	558,834	255,583	556,247
16	1,245,747	476,072	459,375	291,300	19,000	315,652	1,518	554,079	234,656	550,308
17	1,245,747	426,072	480,300	320,375	19,000	335,597	1,505	549,325	213,728	549,325
18	1,245,747	369,297	509,800	347,650	19,000	358,709	1,642	599,184	245,259	603,968
19	1,245,747	323,772	536,660	366,315	19,000	377,501	1,778	649,043	276,790	654,291
20	1,245,747	276,697	573,262	376,788	19,000	397,648	1,915	698,902	308,320	705,969
21	1,245,747	248,497	606,117	372,133	19,000	410,603	2,051	748,761	339,851	750,454
22	1,245,747	208,397	630,800	387,550	19,000	427,239	2,188	798,620	371,381	798,620
23	1,245,747	170,597	654,100	402,050	19,000	442,923	3,170	1,157,055	712,279	1,155,202
24	1,245,747	94,447	705,313	426,987	19,000	474,866	4,152	1,515,491	1,053,177	1,528,042
25	1,245,747	74,147	718,620	433,980	19,000	483,353	5,134	1,873,926	1,394,074	1,877,427
26	1,245,747	41,622	745,352	439,773	19,000	497,390	6,116	2,232,362	1,734,972	2,232,362
27	1,245,747	3,722	775,925	447,100	19,000	513,700	6,267	2,287,534	1,786,761	2,300,461
28	1,245,747	0	799,950	426,797	19,000	517,005	6,418	2,342,706	1,838,549	2,355,554
29	1,245,747	0	811,650	415,097	19,000	517,952	6,570	2,397,878	1,890,338	2,408,290
30	1,245,747	0	808,419	418,328	19,000	517,691	6,721	2,453,051	1,942,127	2,459,817
31	1,245,747	0	808,419	418,328	19,000	517,691	6,872	2,508,223	1,993,916	2,511,606
32	1,245,747	0	808,419	418,328	19,000	517,691	7,023	2,563,395	2,045,704	2,563,395
33	1,245,747	0	808,419	418,328	19,000	517,691	6,624	2,417,825	1,900,061	2,417,752
34	1,245,747	0	808,419	418,328	19,000	517,691	6,225	2,272,254	1,754,418	2,272,109
35	1,245,747	0	808,419	418,328	19,000	517,691	5,827	2,126,684	1,608,775	2,126,466
36	1,245,747	0	808,419	418,328	19,000	517,691	5,428	1,981,114	1,463,132	1,980,822
37	1,245,747	0	813,819	412,928	19,000	518,128	5,029	1,835,544	1,317,489	1,835,617
38	1,245,747	0	813,819	412,928	19,000	518,128	4,630	1,689,973	1,171,845	1,689,973

Table 1
Water Generation Estimate - Caledon Quarry

Year	North Quarry - Scenario 1 - No Flooding Immediately Post-Rehab						HGS Inflow Prediction			
	Total area	Veg area	Rock area	Till area	Pond area	Site Surplus	Total Model Inflow	Total Model Inflow	GW Seepage (by HGS)	Annual Water Generated
	m/yr	342	446	365	234					
	m2	m2	m2	m2	m2	m3	m3/d	m3/yr	m3/yr	m3
0	149,350	149,350	0	0	0	0	0	0	0	0
1	149,350	135,650	0	4,800	8,900	3,835				
2	149,350	135,650	0	4,800	8,900	3,835				
3	149,350	135,650	0	4,800	8,900	3,835				
4	149,350	135,650	0	4,800	8,900	3,835				
5	149,350	135,650	0	4,800	8,900	3,835				
6	149,350	135,650	0	4,800	8,900	3,835				
7	149,350	135,650	0	4,800	8,900	3,835				
8	149,350	135,650	0	4,800	8,900	3,835	0	0	0	3,835
9	149,350	77,950	50,025	12,475	8,900	28,947	49	17,721	6,212	35,159
10	149,350	0	92,056	48,394	8,900	60,803	97	35,441	12,424	73,228
11	149,350	0	56,369	84,081	8,900	57,913	146	53,162	18,637	76,549
12	149,350	0	51,800	88,650	8,900	57,543	194	70,883	24,849	82,391
13	149,350	0	51,800	88,650	8,900	57,543	243	88,604	31,061	88,604
14	149,350	0	51,800	88,650	8,900	57,543	245	89,356	31,814	89,356
15	149,350	0	51,800	88,650	8,900	57,543	247	90,109	32,567	90,109
16	149,350	0	51,800	88,650	8,900	57,543	249	90,862	33,319	90,862
17	149,350	0	51,800	88,650	8,900	57,543	251	91,615	34,072	91,615
18	149,350	0	51,800	88,650	8,900	57,543	251	91,593	34,050	91,593
19	149,350	0	51,800	88,650	8,900	57,543	251	91,571	34,029	91,571
20	149,350	0	51,800	88,650	8,900	57,543	251	91,549	34,007	91,549
21	149,350	0	51,800	88,650	8,900	57,543	251	91,527	33,985	91,527
22	149,350	0	51,800	88,650	8,900	57,543	251	91,506	33,963	91,506
23	149,350	0	51,800	88,650	8,900	57,543	251	91,516	33,974	91,516
24	149,350	0	51,800	88,650	8,900	57,543	251	91,527	33,984	91,527
25	149,350	0	51,800	88,650	8,900	57,543	251	91,538	33,995	91,538
26	149,350	0	51,800	88,650	8,900	57,543	251	91,548	34,006	91,548
27	149,350	0	51,800	88,650	8,900	57,543	251	91,497	33,955	91,497
28	149,350	0	51,800	88,650	8,900	57,543	251	91,446	33,903	91,446
29	149,350	0	51,800	88,650	8,900	57,543	250	91,395	33,852	91,395
30	149,350	0	51,800	88,650	8,900	57,543	250	91,344	33,801	91,344
31	149,350	0	51,800	88,650	8,900	57,543	250	91,293	33,750	91,293
32	149,350	0	51,800	88,650	8,900	57,543	250	91,242	33,699	91,242
33	149,350	0	51,800	88,650	8,900	57,543	244	89,041	31,498	89,041
34	149,350	0	51,800	88,650	8,900	57,543	238	86,839	29,297	86,839
35	149,350	0	51,800	88,650	8,900	57,543	232	84,638	27,095	84,638
36	149,350	0	51,800	88,650	8,900	57,543	226	82,437	24,894	82,437
37	149,350	0	51,800	88,650	8,900	57,543	220	80,235	22,693	80,235
38	149,350	0	51,800	88,650	8,900	57,543	214	78,034	20,492	78,034

Table 1
Water Generation Estimate - Caledon Quarry

Year	North Quarry - Scenario 2 - Flooding Immediately Post-Rehab						HGS Inflow Prediction			
	Total area	Veg area	Rock area	Till area	Pond area	Site Surplus	Total Model Inflow	Total Model Inflow	GW Seepage (by HGS)	Annual Water Generated
	m/yr	342	446	365	234					
	m2	m2	m2	m2	m2	m3	m3/d	m3/yr	m3/yr	m3
0	149,350	149,350	0	0	0	0				
1	149,350	135,650	0	4,800	8,900	3,835				
2	149,350	135,650	0	4,800	8,900	3,835				
3	149,350	135,650	0	4,800	8,900	3,835				
4	149,350	135,650	0	4,800	8,900	3,835				
5	149,350	135,650	0	4,800	8,900	3,835				
6	149,350	135,650	0	4,800	8,900	3,835				
7	149,350	135,650	0	4,800	8,900	3,835				
8	149,350	135,650	0	4,800	8,900	3,835	0	0	0	3,835
9	149,350	77,950	50,025	12,475	8,900	28,947	49	17,721	6,212	35,159
10	149,350	0	92,056	48,394	8,900	60,803	97	35,441	12,424	73,228
11	149,350	0	56,369	84,081	8,900	57,913	146	53,162	18,637	76,549
12	149,350	0	51,800	88,650	8,900	57,543	194	70,883	24,849	82,391
13	131,175	0	51,800	88,650	8,900	57,543	243	88,604	31,061	88,604
14	131,175	0	0	0	131,175	30,695				30,695
15	131,175	0	0	0	131,175	30,695				30,695
16	131,175	0	0	0	131,175	30,695				30,695
17	131,175	0	0	0	131,175	30,695				30,695
18	131,175	0	0	0	131,175	30,695				30,695
19	131,175	0	0	0	131,175	30,695				30,695
20	131,175	0	0	0	131,175	30,695				30,695
21	131,175	0	0	0	131,175	30,695				30,695
22	131,175	0	0	0	131,175	30,695				30,695
23	131,175	0	0	0	131,175	30,695				30,695
24	131,175	0	0	0	131,175	30,695				30,695
25	131,175	0	0	0	131,175	30,695				30,695
26	131,175	0	0	0	131,175	30,695				30,695
27	131,175	0	0	0	131,175	30,695				30,695
28	131,175	0	0	0	131,175	30,695				30,695
29	131,175	0	0	0	131,175	30,695				30,695
30	131,175	0	0	0	131,175	30,695				30,695
31	131,175	0	0	0	131,175	30,695				30,695
32	131,175	0	0	0	131,175	30,695				30,695
33	131,175	0	0	0	131,175	30,695				30,695
34	131,175	0	0	0	131,175	30,695				30,695
35	131,175	0	0	0	131,175	30,695				30,695
36	131,175	0	0	0	131,175	30,695				30,695
37	131,175	0	0	0	131,175	30,695				30,695
38	131,175	0	0	0	131,175	30,695				30,695

Table 1
Water Generation Estimate - Caledon Quarry

Year	South Quarry						HGS Inflow Prediction			
	Total area	Veg area	Open Rock area	Till / Rehab area	Pond area	Site Surplus	Total Model Inflow	Total Model Inflow	GW Seepage (by HGS)	Annual Water Generated
	m/yr	342	446	365	234					
	m2	m2	m2	m2	m2	m3	m3/d	m3/yr	m3/yr	m3
0	581,534	581,534	0	0	0	0				
1	581,534	581,534	0	0	0	0				
2	581,534	581,534	0	0	0	0				
3	581,534	581,534	0	0	0	0				
4	581,534	581,534	0	0	0	0				
5	581,534	581,534	0	0	0	0				
6	581,534	581,534	0	0	0	0				
7	581,534	581,534	0	0	0	0				
8	581,534	581,534	0	0	0	0				
9	581,534	581,534	0	0	0	0				
10	581,534	581,534	0	0	0	0				
11	581,534	581,534	0	0	0	0				
12	581,534	581,534	0	0	0	0				
13	581,534	581,534	0	0	0	0				
14	581,534	581,534	0	0	0	0				
15	581,534	581,534	0	0	0	0				
16	581,534	581,534	0	0	0	0				
17	581,534	581,534	0	0	0	0				
18	581,534	581,534	0	0	0	0				
19	581,534	581,534	0	0	0	0				
20	581,534	581,534	0	0	0	0				
21	581,534	581,534	0	0	0	0				
22	581,534	581,534	0	0	0	0				
23	581,534	581,534	0	0	0	0				
24	581,534	581,534	0	0	0	0				
25	581,534	581,534	0	0	0	0				
26	581,534	581,534	0	0	0	0	0	0	0	0
27	581,534	517,109	43,075	21,350	0	27,004	111	40,348	17,706	44,710
28	581,534	461,384	89,525	30,625	0	51,106	221	80,696	35,411	86,517
29	581,534	437,809	97,775	45,950	0	60,379	332	121,043	53,117	113,496
30	581,534	376,734	130,380	69,670	4,750	84,691	442	161,391	70,822	155,513
31	581,534	314,784	166,025	95,975	4,750	110,190	553	201,739	88,528	198,717
32	581,534	259,984	235,925	80,875	4,750	135,853	663	242,087	106,233	242,087
33	581,534	196,759	274,792	105,233	4,750	162,079	1,669	609,205	453,614	615,693
34	581,534	110,609	364,850	101,325	4,750	200,818	2,675	976,323	800,994	1,001,812
35	581,534	33,584	449,400	93,800	4,750	235,781	3,681	1,343,441	1,148,375	1,384,155
36	581,534	0	524,944	51,840	4,750	254,158	4,686	1,710,559	1,495,755	1,749,913
37	581,534	0	526,550	50,234	4,750	254,288	5,692	2,077,677	1,843,135	2,097,423
38	581,534	0	526,435	50,349	4,750	254,279	6,698	2,444,795	2,190,516	2,444,795

Table 2
Water Consumption and Discharge Scenarios - Caledon Quarry

Year	Scenario 1	Water Consumed		Water Stored					Water Injected to Trench							Water Discharged			
	Annual Water Generated	Agg Prod-uction	Water for Agg Washing	Main Sump Storage	Wash Plant Storage	North Sump Storage	North Quarry Allowed to Fill	South Sump Storage	Trench Zone 1	Trench Zone 2	Trench Zone 3	Trench Zone 4	Trench Zone 5	Trench Zone 6	Total Trench Injection	Water to be Discharged	Off Site Discharge to Credit River	Mitigation Discharge from Main Quarry	Mitigation Discharge from South Quarry
			0.05																
	m3	T	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3		m3	m3	m3	m3
0	0	0	0	0	0	0	0	0							0	0	0	0	0
1	82,661	250,000	12,500	1,000	20,000	40,000	0	0							0	9,161	9,161	0	0
2	117,566	500,000	25,000	0	0	0	0	0							0	92,566	92,566	0	0
3	168,747	750,000	37,500	0	0	0	0	0							0	131,247	131,247	0	0
4	223,348	1,000,000	50,000	0	0	0	0	0							0	173,348	173,348	0	0
5	267,270	1,500,000	75,000	0	0	0	0	0							0	192,270	192,270	0	0
6	328,770	2,000,000	100,000	0	0	0	0	0							0	228,770	228,770	0	0
7	388,725	2,500,000	125,000	0	0	0	0	0							0	263,725	263,725	0	0
8	454,694	2,500,000	125,000	0	150,000	0	0	0							0	179,694	179,694	0	0
9	512,477	2,500,000	125,000	0	0	0	0	0							0	387,477	387,477	0	0
10	556,745	2,500,000	125,000	0	0	0	0	0							0	431,745	431,745	0	0
11	590,863	2,500,000	125,000	0	0	1,000	0	0							0	464,863	464,863	0	0
12	631,819	2,500,000	125,000	0	0	0	0	0							0	506,819	506,819	0	0
13	656,946	2,500,000	125,000	0	0	0	0	0							0	531,946	531,946	0	0
14	651,608	2,500,000	125,000	0	0	0	0	0							0	526,608	526,608	0	0
15	646,356	2,500,000	125,000	0	0	0	0	0							0	521,356	521,356	0	0
16	641,170	2,500,000	125,000	0	0	0	0	0							0	516,170	516,170	0	0
17	640,940	2,500,000	125,000	0	0	0	0	0	0	0					0	515,940	515,940	0	0
18	695,561	2,500,000	125,000	0	0	0	0	0	59,349	36,850					96,199	570,561	474,362	96,199	0
19	745,862	2,500,000	125,000	0	0	0	0	0	118,698	73,701					192,399	620,862	428,463	192,399	0
20	797,518	2,500,000	125,000	0	0	0	0	0	178,047	110,551					288,598	672,518	383,920	288,598	0
21	841,981	2,500,000	125,000	0	0	0	0	0	237,396	147,402					384,798	716,981	332,183	384,798	0
22	890,126	2,500,000	125,000	0	0	0	0	0	296,745	184,252					480,997	765,126	284,129	480,997	0
23	1,246,718	2,500,000	125,000	0	0	0	0	0	387,058	384,145					771,203	1,121,718	350,515	771,203	0
24	1,619,569	2,500,000	125,000	0	0	0	0	0	477,372	584,037					1,061,409	1,494,569	433,160	1,061,409	0
25	1,968,965	2,500,000	125,000	0	0	0	0	0	567,685	783,930					1,351,615	1,843,965	492,350	1,351,615	0
26	2,323,910	2,500,000	125,000	0	0	0	0	0	657,999	983,823	0	0	0	0	1,641,821	2,198,910	557,089	1,641,821	0
27	2,436,668	2,500,000	125,000	0	0	0	0	1,000	651,839	964,416	126,310	0	25,056	20,115	1,787,735	2,310,668	522,933	1,616,254	171,480
28	2,533,517	2,500,000	125,000	0	0	0	0	0	645,678	945,009	252,619	0	50,111	40,230	1,933,648	2,408,517	474,869	1,590,687	342,961
29	2,613,182	2,500,000	125,000	0	0	0	0	0	639,518	925,602	378,929	0	75,167	60,346	2,079,561	2,488,182	408,620	1,565,120	514,441
30	2,706,674	2,500,000	125,000	0	0	0	0	20,000	633,358	906,195	505,238	0	100,222	80,461	2,225,475	2,561,674	336,199	1,539,553	685,922
31	2,801,616	2,500,000	125,000	0	0	0	0	0	627,198	886,788	631,548	0	125,278	100,576	2,371,388	2,676,616	305,228	1,513,986	857,402
32	2,896,724	2,500,000	125,000	0	0	0	0	0	621,037	867,382	757,858	0	150,334	120,691	2,517,302	2,771,724	254,422	1,488,419	1,028,883
33	3,122,485	2,500,000	125,000	0	0	0	0	0	586,513	829,605	750,153	227,281	194,364	132,852	2,720,768	2,997,485	276,717	1,416,117	1,304,651
34	3,360,760	2,500,000	125,000	0	0	0	0	0	551,988	791,828	742,449	454,562	238,394	145,013	2,924,235	3,235,760	311,526	1,343,816	1,580,419
35	3,595,259	2,500,000	125,000	0	0	0	0	0	517,463	754,051	734,745	681,843	282,425	157,175	3,127,701	3,470,259	342,558	1,271,514	1,856,187
36	3,813,172	2,500,000	125,000	0	0	0	0	0	482,939	716,274	727,040	909,124	326,455	169,336	3,331,168	3,688,172	357,005	1,199,212	2,131,955
37	4,013,275	2,500,000	125,000	0	0	0	0	0	448,414	678,497	719,336	1,136,406	370,485	181,497	3,534,634	3,888,275	353,641	1,126,911	2,407,723
38	4,212,802	500,000	25,000	0	0	0	0	0	413,889	640,720	711,631	1,363,687	414,515	193,658	3,738,101	4,187,802	449,702	1,054,609	2,683,491

Max annual discharge to the Golf Course Irrigation Ponds: 557,089 m3
Avg discharge flow rate to the Golf Course Irrigation Ponds (max year): 17.7 L/s

Table 2
Water Consumption and Discharge Scenarios - Caledon Quarry

Year	Scenario 2	Water Consumed		Water Stored					Water Injected to Trench							Water Discharged			
	Annual Water Generated	Agg Prod-uction	Water for Agg Washing	Main Sump Storage	Wash Plant Storage	North Sump Storage	North Quarry Allowed to Fill	South Sump Storage	Trench Zone 1	Trench Zone 2	Trench Zone 3	Trench Zone 4	Trench Zone 5	Trench Zone 6	Total Trench Injection	Water to be Discharged	Off Site Discharge to Credit River	Mitigation Discharge from Main Quarry	Mitigation Discharge from South Quarry
			0.05																
	m3	T	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3	m3		m3	m3	m3	m3
0	0	0	0	0	0	0	0	0							0	0	0	0	0
1	82,661	250,000	12,500	1,000	20,000	40,000	0	0							0	9,161	9,161	0	0
2	117,566	500,000	25,000	0	0	0	0	0							0	92,566	92,566	0	0
3	168,747	750,000	37,500	0	0	0	0	0							0	131,247	131,247	0	0
4	223,348	1,000,000	50,000	0	0	0	0	0							0	173,348	173,348	0	0
5	267,270	1,500,000	75,000	0	0	0	0	0							0	192,270	192,270	0	0
6	328,770	2,000,000	100,000	0	0	0	0	0							0	228,770	228,770	0	0
7	388,725	2,500,000	125,000	0	0	0	0	0							0	263,725	263,725	0	0
8	454,694	2,500,000	125,000	0	150,000	0	0	0							0	179,694	179,694	0	0
9	512,477	2,500,000	125,000	0	0	0	0	0							0	387,477	387,477	0	0
10	556,745	2,500,000	125,000	0	0	0	0	0							0	431,745	431,745	0	0
11	590,863	2,500,000	125,000	0	0	1,000	0	0							0	464,863	464,863	0	0
12	631,819	2,500,000	125,000	0	0	0	0	0							0	506,819	506,819	0	0
13	656,946	2,500,000	125,000	0	0	0	376,000	0							0	155,946	155,946	0	0
14	592,946	2,500,000	125,000	0	0	0	0	0							0	467,946	467,946	0	0
15	586,942	2,500,000	125,000	0	0	0	0	0							0	461,942	461,942	0	0
16	581,003	2,500,000	125,000	0	0	0	0	0							0	456,003	456,003	0	0
17	580,020	2,500,000	125,000	0	0	0	0	0	0	0					0	455,020	455,020	0	0
18	634,663	2,500,000	125,000	0	0	0	0	0	59,349	36,850					96,199	509,663	413,464	96,199	0
19	684,986	2,500,000	125,000	0	0	0	0	0	118,698	73,701					192,399	559,986	367,587	192,399	0
20	736,664	2,500,000	125,000	0	0	0	0	0	178,047	110,551					288,598	611,664	323,065	288,598	0
21	781,149	2,500,000	125,000	0	0	0	0	0	237,396	147,402					384,798	656,149	271,351	384,798	0
22	829,315	2,500,000	125,000	0	0	0	0	0	296,745	184,252					480,997	704,315	223,318	480,997	0
23	1,185,897	2,500,000	125,000	0	0	0	0	0	387,058	384,145					771,203	1,060,897	289,694	771,203	0
24	1,558,737	2,500,000	125,000	0	0	0	0	0	477,372	584,037					1,061,409	1,433,737	372,328	1,061,409	0
25	1,908,122	2,500,000	125,000	0	0	0	0	0	567,685	783,930					1,351,615	1,783,122	431,507	1,351,615	0
26	2,263,057	2,500,000	125,000	0	0	0	0	0	657,999	983,823	0	0	0	0	1,641,821	2,138,057	496,236	1,641,821	0
27	2,375,865	2,500,000	125,000	0	0	0	0	1,000	651,839	964,416	126,310	0	25,056	20,115	1,787,735	2,249,865	462,131	1,616,254	171,480
28	2,472,766	2,500,000	125,000	0	0	0	0	0	645,678	945,009	252,619	0	50,111	40,230	1,933,648	2,347,766	414,118	1,590,687	342,961
29	2,552,481	2,500,000	125,000	0	0	0	0	0	639,518	925,602	378,929	0	75,167	60,346	2,079,561	2,427,481	347,920	1,565,120	514,441
30	2,646,025	2,500,000	125,000	0	0	0	0	20,000	633,358	906,195	505,238	0	100,222	80,461	2,225,475	2,501,025	275,550	1,539,553	685,922
31	2,741,019	2,500,000	125,000	0	0	0	0	0	627,198	886,788	631,548	0	125,278	100,576	2,371,388	2,616,019	244,630	1,513,986	857,402
32	2,836,177	2,500,000	125,000	0	0	0	0	0	621,037	867,382	757,858	0	150,334	120,691	2,517,302	2,711,177	193,875	1,488,419	1,028,883
33	3,064,139	2,500,000	125,000	0	0	0	0	0	586,513	829,605	750,153	227,281	194,364	132,852	2,720,768	2,939,139	218,371	1,416,117	1,304,651
34	3,304,616	2,500,000	125,000	0	0	0	0	0	551,988	791,828	742,449	454,562	238,394	145,013	2,924,235	3,179,616	255,381	1,343,816	1,580,419
35	3,541,316	2,500,000	125,000	0	0	0	0	0	517,463	754,051	734,745	681,843	282,425	157,175	3,127,701	3,416,316	288,615	1,271,514	1,856,187
36	3,761,430	2,500,000	125,000	0	0	0	0	0	482,939	716,274	727,040	909,124	326,455	169,336	3,331,168	3,636,430	305,263	1,199,212	2,131,955
37	3,963,735	2,500,000	125,000	0	0	0	0	0	448,414	678,497	719,336	1,136,406	370,485	181,497	3,534,634	3,838,735	304,101	1,126,911	2,407,723
38	4,165,463	500,000	25,000	0	0	0	0	0	413,889	640,720	711,631	1,363,687	414,515	193,658	3,738,101	4,140,463	402,362	1,054,609	2,683,491

Max annual discharge to the Golf Course Irrigation Ponds: 506,819 m3
Avg discharge flow rate to the Golf Course Irrigation Ponds (max year): 16.1 L/s

Water Management Milestones - Caledon Pit / Quarry

Year	Milestone / Operational Note
1	Establish Main Area sump with 1,000 m^3 storage in low point. Establish 0.5 Ha temporary wash pond with 20,000 m^3 storage. Establish 0.89 Ha settling pond in North Area with 40,000 m^3 storage.
8	Establish permanent 1.9 Ha wash ponds in the Main Area with 150,000 m^3 storage. May decommission temporary wash pond.
10	Establish North Area sump with 1,000 m^3 storage in low point.
13	North Area extraction complete. Assume CBM will continue to dewater it, but CBM could possibly use it for additional water storage capacity, if needed. There is in excess of 300,000 m^3 of additional water storage capacity in the North Area.
17	**Initiate discharge to groundwater infiltration Trench Zones 1 and 2 in the Main Area.** Additional water storage to operate the infiltration trench system, if needed, could be accommodated in the Main Area or the North Area (preferred). Storage of this water is not formally accounted, but there is sufficient water generated to supply the mitigation system.
26	Establish South Area sump with 1,000 m^3 storage in low point. Establish 0.47 Ha sump in South Area with 20,000 m^3 storage. **Initiate discharge to groundwater infiltration Trench Zones 3 to 6 in the South Area.**
38	Last year of scheduled dewatering / water discharge. Discharge of water will cease once the Site has been rehabilitated and the excavated and rehabbed areas are allowed to naturally flood.

QUARRY SUMP(S)

Figure 3 below shows elevation contours for the base of the Gasport Formation, which is the lower limit of extraction and approximately represents the pit / quarry floor surface. As extraction proceeds, it is assumed that at any given time the pit / quarry sump(s) will be located proximal to the low point of the excavation floor.

TRANSFER OF WATER BETWEEN QUARRY PARCELS

During operational phases, it will be necessary to transfer excess pit / quarry water from the South and Main Areas to the North Area, in order to store and convey excess quarry water to the golf course irrigation system at the proposed point of discharge. This will require pumping, and piping would need to be constructed to cross the roadways, either by cut and fill, or directional drilling.

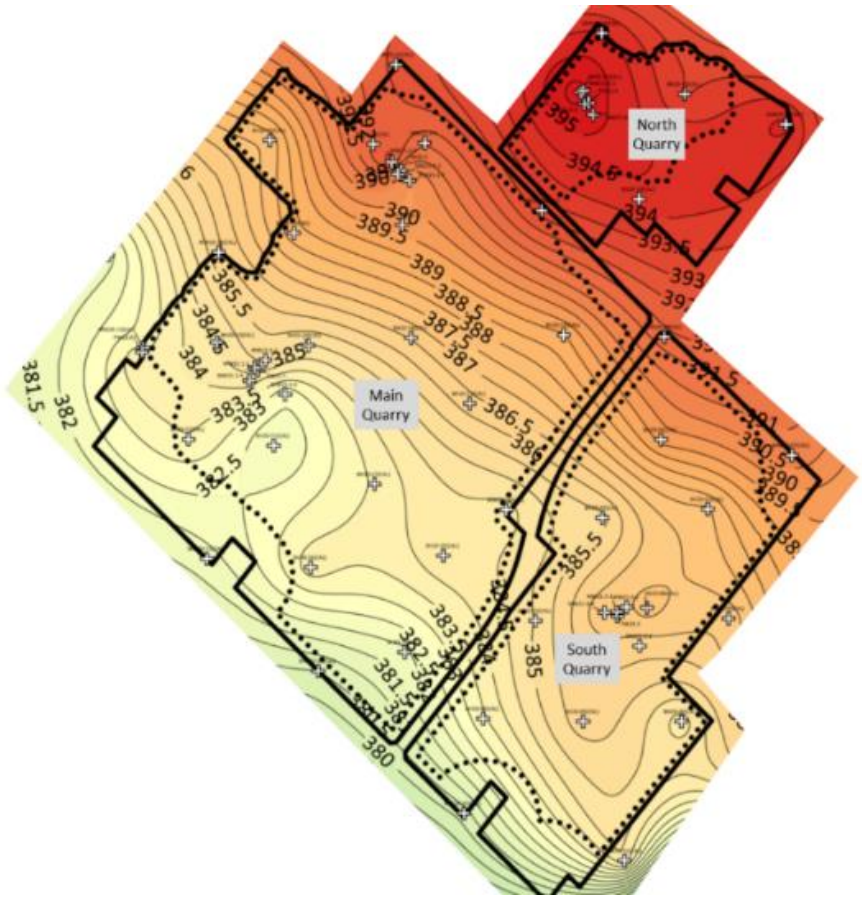


Figure 3: Elevation of the Base of the Gasport Formation (masl)

QUARRY WATER DISCHARGE AND FLOWS

With reference to Table 2, discharges of surplus water to the Osprey Valley Golf Course irrigation system are anticipated to begin during Operational Year 1 with an annual discharge of approximately 10,000 m^3 that year. The rate of discharge is expected to increase annually to a maximum of approximately 560,000 m^3 / year in operational Year 26, and then stabilize and decline in future years. The highest annual average water discharge (Year 26) is expected to be approximately 18 L/s.

It should be noted that additional HGS water model simulations indicated the groundwater mitigation system could be used to re-infiltrate additional groundwater, in the range of 200,000 to 400,000 m^3 / year, without adversely affecting groundwater levels. As such there is an option to re-infiltrate additional groundwater if needed to manage surplus water and reduce the quantity of water discharged to the Osprey Valley Golf Course irrigation pond system.

Because no water will be discharged from the proposed pit / quarry directly to the Credit River, there are no significant changes expected to flows or thermal characteristics of the Credit River.

FINAL POND WATER LEVELS

Upon rehabilitation, the maximum water level in the Main Pond will be controlled by an outflow to the North Pond at an approximate elevation of 400 masl, and the maximum water level in the North Pond will be controlled by an outflow to the Osprey Valley Golf Course irrigation system at an approximate elevation of 399 masl. The simulated post-rehabilitation water level in the South Pond is predicted to be 393.5 masl and will be internally contained, with no outflow. The simulated steady state outflow from the Main and North Ponds to the golf course irrigation system is estimated to be approximately 12.1 L/s.

Table 3: Final Pond Capacities and Water Levels Post-Rehabilitation

Parameter	Units	Main	South	North (Scenario 1)
Base of Gasport (range)	masl	381 - 392.5	383.5 - 390.5	394 - 395
Base of Gasport (average)	masl	386	386	394.5
Pit Shell Area	m2	1,245,747	581,534	149,350
Current High Water Table (range)	masl	406 - 420	392 - 405	398 - 406
Final Pond Water Level	**masl**	**400**	**393.5**	**399**
Pond Capacity Post-Rehab	m3	13,599,000	3,055,000	376,000
Average post-rehab inflow rate (50% of initial post-rehab inflow rate)	m3/yr	844,987	1,222,397	39,017
Time required to fill ponds (average inflow rate)	yr	16.1	2.5	9.6

Notes
1. Main Pond overflow would be directed via a culvert to the North Pond - invert at ~400 masl.
2. North Pond overflow would be directed via main outlet to the Osprey Valley Golf Course Irrigation System - invert at ~399 masl.
3. South Pond does not have an outlet.

With reference to Table 4, it is anticipated that it will require approximately 16.1, 9.6 and 2.5 years for the ponds in the Main, North and South Areas to reach their final water levels, assuming that 50% of the steady state inflow rate for the final operational year is maintained, on average, as the ponds fill post-rehabilitation.

SUMMARY

In summary, we note the following key points with respect to water management at the proposed Caledon Pit / Quarry:

- The Operational Plan for the pit / quarry has been revised to construct a 40,000 m^3 settling pond / holding pond for managing discharge water in the North Area during Year 1, in order provide “immediate” water storage capacity.

- Based on water inflow predictions and mitigation water needs from numerical simulations during operations, enough water will be generated during Years 17 to 38 of operation to supply the water needed for the proposed groundwater mitigation system.
- Additional water storage to operate the groundwater mitigation system, if needed, could be accommodated in the Main Area or the North Area (preferred). If needed, the North Area could be used to store additional water, as there is in excess of 300,000 m^3 of capacity in that area once extraction has been completed at the end of Operational Year 14.
- The maximum annual average rate of discharge throughout pit / quarry operations is approximately 560,000 m^3 / year in Operational Year 26. The peak average annual water discharge rate (in Year 26) is expected to be approximately 18 L/s.
- There is an option to re-infiltrate an additional 200,000 to 400,000 m^3 / year of groundwater if needed to manage surplus water, and reduce the quantity of water discharged to the Osprey Valley Golf Course irrigation pond system.
- Because no water will be discharged from the proposed pit / quarry directly to the Credit River, there are no significant changes expected to flows or thermal characteristics of the Credit River.

CLOSURE

We trust that this memorandum meets your current needs. If you have any questions or require clarification, please contact WSP at your earliest convenience.

HW/CDV/GWS/mp

https://golderassociates.sharepoint.com/sites/114392/project files/6 deliverables/ph 2300-hydrogeology/300e revised water report july 2023/appendices/appr-water management plan/19129150 wmp 24jul2023 r2.docm

APPENDIX S

Groundwater Mitigation System Description

Impact Assessment Methodology for Well Users

Water Well Complaint Response Plan

APPENDIX S1

Groundwater Mitigation System Description

Proposed Caledon Pit / Quarry

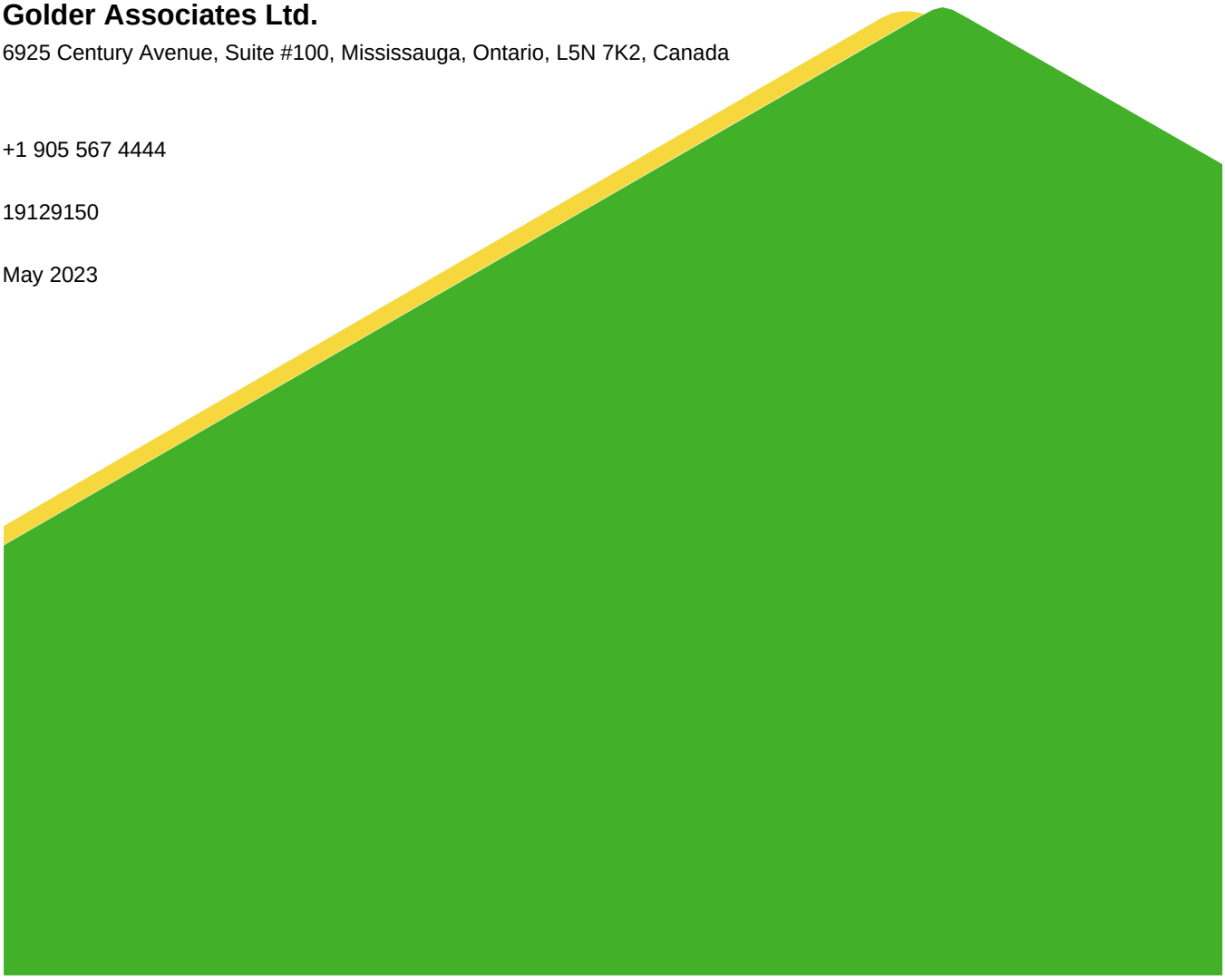
CBM Aggregates (CBM), a Division of St. Marys Cement Inc. (Canada)
55 Industrial Street
Toronto, ON
M4G 3W9

Golder Associates Ltd.
6925 Century Avenue, Suite #100, Mississauga, Ontario, L5N 7K2, Canada

+1 905 567 4444

19129150

May 2023



Distribution List

1 e-copy: CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

1 e-copy: Golder Associates Ltd.

1 e-copy: MHBC

1 e-copy: GSAI

Table of Contents

TABLES

FIGURES (in order following the text)

1.0 INTRODUCTION

CBM Aggregates (CBM), a division of St. Marys Cement Inc. (Canada), is applying to the Ministry of Natural Resources and Forestry (MNRF) for a Class A License (Pit and Quarry Below Water) and to the Town of Caledon for an Official Plan Amendment and Zoning By-law Amendment to permit a mineral aggregate operation for the proposed CBM Caledon Pit / Quarry.

CBM controls approximately 323 hectares of land located at the northwest, northeast and southwest intersection of Regional Road 24 (Charleston Sideroad) and Regional Road 136 (Main Street). Of these lands, approximately 262 hectares are proposed to be licenced under the Aggregate Resources Act and designated / zoned under the Planning Act to permit the proposed CBM Caledon Pit / Quarry. The lands proposed to be licenced under the Aggregate Resources Act are referred to herein as the “Subject Site” (or “Site”) and are legally described as Part of Lots 15-18, Concession 4 WSCR and Part of Lot 16, Concession 3 WSCR (former Geographic Township of Caledon). The area located to the northwest of the intersection of Regional Road 24 and 136 is referred to as the “Main Area”. The area to the northeast of the intersection of Regional Road 24 and 136 is referred to as the “North Area”, and the area located to the southwest of the intersection of Regional Road 24 and 136 is referred to as the “South Area” (Figure 1).

Initial review of the HGS groundwater-surface water model simulations undertaken as part of the Water Report (Golder 2022) indicated that pit / quarry dewatering during later the stages of operations (Phases 4 to 7) would likely result in a decline in groundwater levels in the water table aquifer that would extend southward and to the southwest of the licence area. If so, these predicted changes in groundwater levels could potentially effect natural features, groundwater users, and influence groundwater levels beneath existing aggregate pit #6525 (Lafarge Pit #3) that is currently licenced to extract sand and gravel above the water table.

In order to mitigate the potential effects of these predicted changes in groundwater levels during the operational phases of the proposed CBM Caledon Pit / Quarry, groundwater mitigation measures were developed by Golder and then implemented in the HydroGeoSphere (HGS) modelling simulations for Operational Phase 3 to 7, to assess their effectiveness, as described in the Water Report (Golder 2022).

This appendix report to the Water Report provides a description of the groundwater mitigation system proposed for the Caledon Pit / Quarry based on these simulations, including the conceptual design and proposed implementation phasing of the system.

2.0 SYSTEM DESCRIPTION

2.1 General Configuration

The proposed mitigation system generally consists of a groundwater infiltration trench and slurry wall / grout zone, as shown conceptually on Figure 2, which will be implemented within a 50 m wide zone of the pit / quarry setback, where it is required to sustain groundwater levels during operations.

- The infiltration trench would be constructed within the setback, parallel and a minimum of 3 m from the licence limit. The trench will be excavated down through the sand and gravel overburden to the current water table using 1:1 sloping. Based on current groundwater levels along the proposed trench alignment, the trench would have a maximum depth of 8.5 m, and a typical minimum width at the base of 3 m, making the trench alignment up to 20 m wide at surface.

- A perforated horizontal infiltration pipe would be placed at the base of the trench, and the trench would then be backfilled with coarse granular material, covered with a non-woven geotextile and capped with a topsoil layer at surface. The perforated infiltration pipe would be sized / specified based on infiltration rate requirements. Several air release vent pipes to surface will also be installed along the horizontal infiltration pipe to allow any entrapped air in the granular material to escape and avoid a potential air pressure buildup in the system and help ensure that water flows freely into the infiltration pipe from the trench vault.
- Water collected during pit / quarry operations would be stored and used to supply water to the infiltration trench via an infiltration vault, as may be needed to help maintain groundwater levels in the areas of potential concern at their current typical range during pit / quarry operations.
- An infiltration vault (Figure 3) would consist of prefabricated concrete “box culvert” segments, placed vertically on a concrete slab at the base of the trench, and extending to ground surface. The vault would be sized based on water infiltration requirements. The infiltration vault would be supplied with water via piping from the pit / quarry, which would be installed below the frost line for year-round operation, if required.
- A hydraulic barrier will also be constructed in the setback area, through the sand and gravel overburden and into the upper weather zone of the bedrock, between the infiltration trench alignment and the extraction limit, approximately 10 m from the extraction limit. The hydraulic barrier will consist of two components: grouting the weathered zone in the upper bedrock, followed by constructing a slurry wall through the overburden on the same alignment.
- The target hydraulic conductivity (k) of the hydraulic barrier created by the slurry wall and grout zone within the overburden and weathered bedrock is $1x10^{-7}$ m/s, and this k value was use in the HGS numerical simulations to represent these zones in the scenarios with the mitigation system in place.
- Grouting of the more permeable upper weathered bedrock zone would be performed, typically by means of pressurized injection grouting, where is it required to help create a hydraulic barrier. The slurry wall would extend from ground surface down to the top of bedrock, and would typically be constructed using “one-pass” trenching technology. Given its proposed location within the setback, this hydraulic barrier would be constructed prior to the installation of the berm in that part of the setback area.
- Lastly, monitoring well nests (seven in total) would be constructed at key locations in the setback along the proposed mitigation system between the infiltration trench and the licence limit. Each well nest would consist of a deep piezometer in the Gasport Formation and a shallow piezometer in the overburden. These monitoring well nests would be used initially to establish baseline groundwater levels along the mitigation system, and later to provide “feedback” on groundwater levels, both to “inform” the injection rate needed to sustain groundwater levels and to monitor the performance of the mitigation system.
- When operational, the mitigation system would be used to maintain groundwater levels within their current typical ranges, as illustrated on Figure 3 (proximal to the trench vault) and Figure 4 (along other parts of the trench).

2.2 Mitigation System Zones

To mitigate the potential decline in groundwater levels during later the stages of operations (Phases 4 to 7) due to dewatering, the proposed mitigation system would consist of six infiltration trench zones and two slurry wall / grout zones constructed along a 1,900 m alignment, as shown on Figure 5, and summarized in Table 1.

- North of Charleston Sideroad in the Main Area, two trench zones (Zones 1 and 2) and a 600 m long slurry wall / grout zone are proposed. See the plan view detail on Figure 6.
- South of Charleston Sideroad in the South Area, four trench zones (Zones 3 to 6) and a 1,250 m long slurry wall / grout zone are proposed. See the plan view detail on Figure 7.
- The six individual trench zones would range in length from ~220 to ~335 m and are typically separated from one another by a "gap" of 30 m, except Trenches 2 and 3, which are separated by a gap of ~43 m as they straddle Charleston Sideroad.
- Each trench zone would be assigned a "target" water level to be maintained during mitigation. For the purposes of the conceptual design and testing the feasibility of this mitigation, the steady state current condition water table from the calibrated HGS model was assumed to be the "target" water level in numerical simulations.

Table 1: Proposed Groundwater Mitigation Zones

Mitigation		Start (m)	End (m)	Length (m)	Target Trench Water Level (masl)
Main Area	Slurry Wall	0.0	128.6	N/A	N/A
	Trench Zone 1 / Slurry Wall	128.6	348.7	220.1	399.0
	Trench Zone 2 / Slurry Wall	378.7	596.7	218.0	397.5
South Area	Trench Zone 3 / Slurry Wall	640.1	974.8	334.7	395.5
	Trench Zone 4 / Slurry Wall	1004.8	1334.9	330.2	393.0
	Trench Zone 5 / Slurry Wall	1365.8	1634.5	268.7	392.0
	Trench Zone 6 / Slurry Wall	1664.5	1890.5	226.0	394.0

- With reference to Figure 5 and Table 1, the "average" current condition groundwater table assigned to each trench segment in the HGS model simulation varied along the alignment, from 399.0 masl at the north end in Trench Zone 1 in the Main Area, to as low as 393.0, 392.0 and 394.0 masl at the southernmost trench Zones 4, 5 and 6 in the South Area.
- When the system is eventually implemented, the actual target water level for each trench zone will be determined from baseline water level monitoring data at the monitoring wells nest or nests corresponding to that zone. To replicate variations observed in baseline groundwater levels, the target water levels will account for seasonal variability and climate variability, as much as possible.
- The variable target water levels will be determined from baseline monitoring at the infiltration trench monitoring well nests, acquired for a minimum period of 2 years prior to the start of below water table extraction. Based on the water level variability observed at existing site monitoring wells MW20-01, MW20-02 and MW20-18 for the 2021 period, it is expected that target water levels for the proposed infiltration trench system will vary seasonally by 1.5 to 2 m. It is expected that it will also be necessary to periodically

adjust the range of target levels to account for longer term changes in groundwater levels due to climate trends.

2.3 Phasing of Implementation

Based on numerical simulations for Operational Phases 3 to 7 as described in Section 8 and Appendix Q of the Water Report (Golder 2022), the groundwater mitigation system elements would be implemented in the following operational sequence.

- Phase 3 – Implementation of the slurry wall / grouting of the weathered bedrock zone on the west side of the Main Area prior to the start of Phase 3 extraction (Figure 6).
- Phases 4 and 5 – Implementation of the infiltration trench system (Trench Zones 1 and 2) on the west side of the Main Area prior to the start of Phase 4 and 5 extraction (Figure 6).
- Phase 6 and 7 – Implementation of the second slurry wall / grouting of the weathered bedrock zone and the second phase of the infiltration trench system (Trench Zones 4 to 6) prior to the start of Phase 6 and 7 extraction (Figure 7).

The post-Rehabilitation scenario includes the removal of the slurry wall in the overburden in the southwest corner of the South Area (adjacent to Trench Zones 4 and 5), to reinstate hydraulic connection between the South Area and the lands to the south and southwest of the Site. The other slurry walls would remain in place. The infiltration trenches would also remain in place, the trench vaults could remain in place or be removed, and the piping that supplies water to the trench vaults would be removed.

A summary of the mitigation system elements that were simulated and are proposed to be implemented during pit / quarry operations is presented in Table 2.

Table 2: Implementation Sequence of Groundwater Mitigation System Elements

Phase	Operational Year	Slurry Wall / Grout Zone	Infiltration Trench Zone / Constant Head (masl)
Phase 1	1 to 8	N/A	N/A
Phase 2	9 to 13	N/A	N/A
Phase 3	14 to 17	West side of Main Area	N/A
Phase 4	18 to 22	West side of Main Area	Trench Zone 1: 399.0 Trench Zone 2: 397.5
Phase 5	23 to 26	West side of Main Area	Trench Zone 1: 399.0 Trench Zone 2: 397.5
Phase 6	27 to 32	West side of Main Area West and south side of South Area	Trench Zone 1: 399.0 Trench Zone 2: 397.5 Trench Zone 3: 395.5 Trench Zone 4: 393.0 Trench Zone 5: 392.0 Trench Zone 6: 394.0
Phase 7	33 to 38	West side of Main Area	Trench Zone 1: 399.0 Trench Zone 2: 397.5

Phase	Operational Year	Slurry Wall / Grout Zone	Infiltration Trench Zone / Constant Head (masl)
		West and south side of South Area	Trench Zone 3: 395.5 Trench Zone 4: 393.0 Trench Zone 5: 392.0 Trench Zone 6: 394.0
Post-Rehabilitation	Year 39+	Slurry wall removed along Trench Zones 4 and 5	N/A

2.4 Estimated Pit / Quarry Inflows and Trench Infiltration Rates

Numerical simulations in HGS for each phase of pit / quarry operations, without and with the proposed groundwater mitigation system in place, were used to estimate the inflows, initially with no mitigation (inflows presented in Table 3) as well as with the proposed mitigation system elements in place (inflows presented in Table 4), in accordance with the implementation sequence noted above (Table 2). The estimated inflows by phase, without and then with mitigation, are also shown graphically on Figure 8.

Table 3: Estimated Pit / Quarry Inflows (No Mitigation)

Phase	Period (years)	Forecast Year	Pit / Quarry Inflow – No Mitigation (m3/day)			
			Main Area	North Area	South Area	Total Inflow
1	1 to 8	8	1240	0	0	1240
2	9 to 13	13	1555	243	0	1798
3	14 to 17	17	1513	252	0	1765
4	18 to 22	22	2156	251	0	2407
5	23 to 26	26	3951	251	0	4201
6	27 to 32	32	3593	250	623	4466
7	33 to 38	38	2458	214	1024	3696

Table 4: Estimated Pit / Quarry Inflows (With Mitigation)

Phase	Period (years)	Forecast Year	Pit / Quarry Inflow – With Mitigation Trench (m3/day)				
			Main Area	North Area	South Area	Total Inflow	Additional Inflow
1	1 to 8	8	1235	0	0	1235	0
2	9 to 13	13	1557	243	0	1800	2
3	14 to 17	17	1505	251	0	1756	-9
4	18 to 22	22	2188	251	0	2439	31

Phase	Period (years)	Forecast Year	Pit / Quarry Inflow – With Mitigation Trench (m3/day)				
			Main Area	North Area	South Area	Total Inflow	Additional Inflow
5	23 to 26	26	6116	251	0	6367	2166
6	27 to 32	32	7023	250	663	7936	3470
7	33 to 38	38	4630	214	6698	11542	7846

The HGS model simulations were also used to estimate the quantity of water required to maintain the groundwater tables at the target trench water levels, as summarized in Table 5, and shown graphically on Figure 8. The simulations demonstrate that the volume of water required for the implementation of the groundwater mitigation system is less than the corresponding quarry inflows, indicating that there will be sufficient water available from operation to operate the system throughout all phases of the pit / quarry.

Hydraulic conductivity estimates from field observations and HGS numerical simulations demonstrate that the sand and gravel comprising the overburden along the trench alignments are sufficiently permeable ($k = 1x10^{-4}$ m/s) to receive the proposed groundwater inflow rates, given the size of the contact area within the trench that is available for infiltration.

Table 5: Estimated Recharge Required to Infiltration Trench

Phase	Period (years)	Forecast Year	Recharge Required to Infiltration Trench (m3/day)						
			Trench Zone 1	Trench Zone 2	Trench Zone 3	Trench Zone 4	Trench Zone 5	Trench Zone 6	Total Trench Recharge
1	1 to 8	8	0	0	0	0	0	0	0
2	9 to 13	13	0	0	0	0	0	0	0
3	14 to 17	17	0	0	0	0	0	0	0
4	18 to 22	22	813	505	0	0	0	0	1318
5	23 to 26	26	1803	2695	0	0	0	0	4498
6	27 to 32	32	1701	2376	2076	0	412	331	6897
7	33 to 38	38	1134	1755	1950	3736	1136	531	10241
Max. trench pumping rate (m3/day):			1803	2695	2076	3736	1136	531	10241
Max. trench pumping rate (igpm):			276	412	318	571	174	81	1567

Based on the recharge required for each infiltration trench, as noted in Table 5, a preliminary estimate of the infiltration vault capacity required to supply the infiltration trench system has been made and is summarized in Table 6, with key assumptions noted.

Table 6: Preliminary Infiltration Vault Capacity and Estimated Vault Retention Time

Trench Zone	# Vaults	Vault Height (m)	Vault Capacity (m3)	Total Max Inflow per Trench Zone (m3/min)	Max Inflow per Vault (m3/min)	Retention Time (50% full) (min)
1	2	3.0	35.7	1.25	0.63	28.5
2	2	7.0	83.2	1.87	0.94	44.5
3	2	3.0	35.7	1.44	0.72	24.7
4	1	6.0	71.3	2.59	2.59	13.7
5	1	8.0	95.1	0.79	0.79	60.3
6	1	5.0	59.5	0.37	0.37	80.7

Notes:
1. Assumes the infiltration vaults are constructed using 2.44 x 4.88 m (8 x 16 ft) rectangular concrete box culverts.
2. Vault height is assumed to be approximately equal to the trench depth below ground surface.
3. Two vaults would be utilized for trench zones 1, 2 and 3, based on vault height and estimated rate of infiltration.

The “retention time” shown in Table 6 is calculated as the time required to fill 50% of the infiltration vault at the maximum required infiltration rate, and is intended to be “indicative” of the vault’s approximate retention capacity at the maximum flow rate. The estimated retention times for the vaults at maximum infiltration rates range from ~14 to ~80 minutes, which suggest that vaults of these sizes would be sufficient, as they would provide storage capacity in the event that pumping was briefly interrupted, and they are large enough to minimize turbulence, which will help ensure that the hydraulic head of the water in the vault will be effectively transmitted in the infiltration pipes.

A sensitivity analysis was done on predicted pit / quarry inflows by varying the hydraulic conductivity of the proposed hydraulic barrier to assess the variability of pit / quarry inflows for each of the operational phases. The results are summarized in Table 7.

Table 7: Sensitivity of Pit / Quarry Inflow to Hydraulic Conductivity

Phase	K wall: $1x10^{-6}$ m/s, % change				K wall: $1x10^{-8}$ m/s, % change			
	Main Area	South Area	North Area	Total Inflow	Main Area	South Area	North Area	Total Inflow
3	0%		0%	0%	0%		0%	0%
4	0%		0%	0%	0%		0%	0%
5	8%		0%	8%	-2%		0%	-1%
6	9%	0%	0%	8%	-1%	0%	0%	-1%
7	8%	6%	0%	7%	-1%	-1%	0%	-2%

Notes:
1. The inflows include the surplus applied to the pit / quarry area.

The simulated pit / quarry inflow is more sensitive to an increase in the hydraulic conductivity of the slurry wall / weathered zone grouting to $1x10^{-6}$ m/s, with the increase in total quarry inflow ranging from 7 to 8% when the hydraulic conductivity is increased by an order of magnitude. The reduction of predicted water inflow when the hydraulic conductivity of the slurry wall / weathered zone grouting is reduced to $1x10^{-8}$ m/s is relatively small, ranging from 1 to 2% when the hydraulic conductivity is decreased by an order of magnitude.

2.5 Water Quality

Water collected from the pit / quarry operations and used to supply the infiltration system will first be clarified by settling in a sump or settling pond, to minimize plugging of the filtration trench system with fines. As described in Section 5 and Appendix I of the Water Report (Golder 2022) groundwater quality at the Site is generally good and within the typical range expected for groundwater in this hydrogeologic setting for the parameters tested.

The proposed pit / quarry is not expected to impact existing water quality, as aggregate operations will follow all applicable environmental standards and employ current industry best practices. This includes strict protocols for the handling of fuel on site, on-site storage and servicing of machinery, and the use and storage of hazardous substances.

Pit / quarry water that will be used to maintain groundwater levels via the infiltration trench system will be operated in accordance with the PTTW and ECA Permit requirements (see Section 3.2) and as such, operation of this mitigation system is not expected to impact groundwater quality relative to current baseline groundwater conditions.

3.0 DETAILED DESIGN, PERMITTING, CONSTRUCTION AND OPERATION

3.1 Detailed Design

This appendix report provides a conceptual design for the proposed groundwater mitigation system at the Caledon Pit / Quarry. While this report provides “a proof of concept” for the purposes of supporting this ARA licence application, a detailed design will be required in future to support the permitting and construction of the proposed groundwater mitigation system.

The detailed design would likely require additional hydrogeological and geotechnical characterization of the proposed infiltration trench and slurry wall / grout zone alignment within the Main Area and South Area lands. The detailed design would also recommend preferred construction techniques as well as provide a “life-cycle” cost estimate for construction, operation and decommissioning of the mitigation system.

3.2 Permitting

Prior to implementation of the proposed groundwater mitigation system, CBM would be required to obtain and operate in accordance with a Permit To Take Water and Industrial Sewage Works (ISW) Environmental Compliance Approval (ECA) under the Ontario Water Resources Act to permit the water management activities needed to operate this system.

The PTTW and ECA Permit would be a part of the overall approvals required to operate the pit / quarry, which would include:

- Pumping, collection, storage and discharge of pit / quarry water;
- Operation of the groundwater mitigation system (i.e., infiltration trench system); and
- Construction and operation of an aggregate wash plant.

Regarding the operation of the proposed groundwater mitigation system, the PTTW and ECA Permit would typically need to specifically include and/or address the following key elements:

- A description of the groundwater mitigation system, including a functional (process flow) diagram of the system;
- Target groundwater levels (see Note 1 below);
- Water handling requirements (i.e., water collection, temporary storage, settling, filtration, pumping and re-infiltration);
- Water level and water quality monitoring requirements;
- System operation and maintenance requirements; and
- Reporting requirements.

Note1: The target water level for each trench zone will be determined from baseline water level monitoring data at the monitoring wells nest or nests corresponding to that zone, and will account for seasonal variability and climate variability, as much as possible.

3.3 Construction and Operation

Construction of the various elements of the proposed groundwater mitigation system would be integrated into the overall planned schedule for pit / quarry operations, generally as follows:

- Phase 3 – Implementation of the slurry wall / grouting of the weathered bedrock zone on the west side of the Main Area prior to the start of Phase 3 extraction.
- Phases 4 and 5 – Implementation of the infiltration trench system (Trench Zones 1 and 2) on the west side of the Main Area, including pilot-scale testing, prior to the start of Phase 4 and 5 extraction. This stage of implementation would include pilot test of the system prior to its full implementation
- Phase 6 and 7 – Implementation of the second slurry wall / grouting of the weathered bedrock zone and the second phase of the infiltration trench system (Trench Zones 4 to 6), including pilot-scale testing, prior to the start of Phase 6 and 7 extraction.

The construction of the proposed mitigation system would be carried out concurrently with other operation activities in a manner that would not adversely impact the overall operational schedule.

Additionally, the proposed monitoring well nests (MW-IT-01A/B to MW-IT-07A/B, Figures 6 and 7) along the mitigation system alignment should be installed in the near future, to facilitate the collection of baseline groundwater level data for a minimum period of 2 years prior to the start of below water table extraction.

Signature Page

We trust that this appendix report meets your current requirements. Please contact the undersigned should you have any questions.

Golder Associates Ltd.

George Schneider M.Sc., P.Geo.
Senior Geoscientist

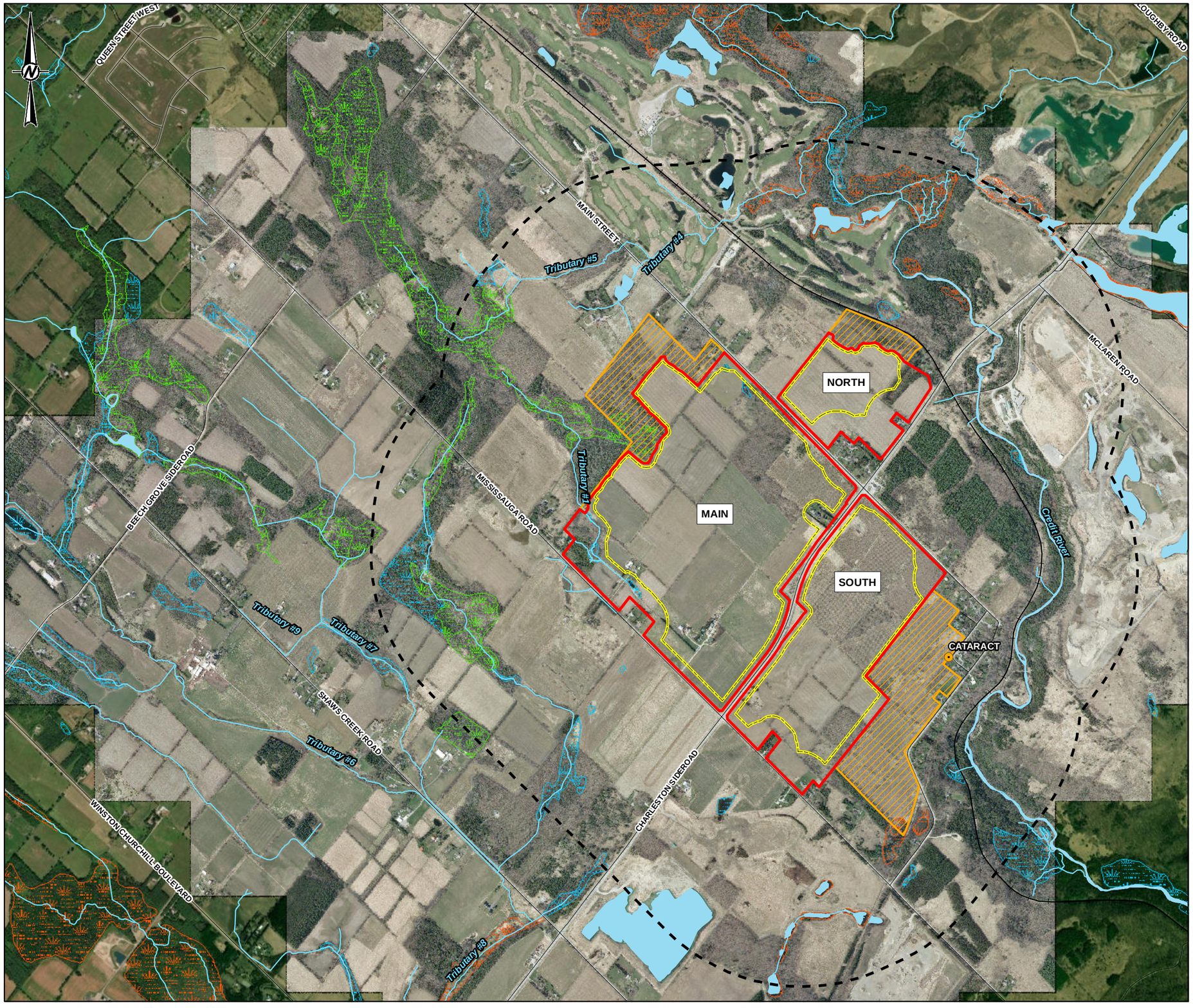
Craig DeVito, P.Eng.
Senior Water Resources Engineer

Frank Barone, Ph.D., P.Eng.
Senior Geo-environmental Engineer

HW/GWSCVD/FSB/

https://golderassociates.sharepoint.com/sites/114392/project files/5 technical work/ph 2300-hydrogeology/36 mitigation work/07 mitigation tm/19129250 apps mitigation system tm 31may2023.docm

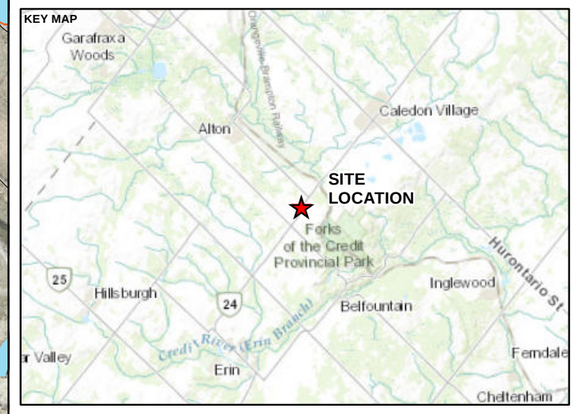
FIGURES



LEGEND

- TOWN/VILLAGE
- ROAD
- RAILWAY
- WATERCOURSE
- WATERBODY
- UNEVALUATED WETLAND
- OTHER EVALUATED WETLAND
- PROVINCIALLY SIGNIFICANT WETLAND
- 1 km LICENCE BOUNDARY BUFFER
- LIMIT OF EXTRACTION
- LICENCE BOUNDARY
- ADDITIONAL LANDS OWNED / CONTROLLED BY CBM

KEY MAP



0 500 1,000

1:20,000 METRES

REFERENCE(S)

1. BASEDATA MNRF LIO OBTAINED APRIL 2020
2. WATERCOURSES OBTAINED FROM CREDIT VALLEY CONSERVATION AUTHORITY OPEN DATA PORTAL, NOVEMBER 2022 IN COMBINATION WITH SITE WATERCOURSE SURVEY PROVIDED BY FIRST BASE SOLUTIONS NOVEMBER 2021.
3. IMAGERY FIRSTBASE SOLUTIONS SPRING 2019 (15CM RESOLUTION) AND SOURCES: ESRI, HERE, GARMIN, INTERMAP, INCREMENT P CORP., GEBCO, USGS, FAO, NPS, NRCAN, GEOBASE, IGN, KADASTER NL, ORDNANCE SURVEY, ESRI JAPAN, METI, ESRI CHINA (HONG KONG), (C) OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY
SOURCE: ESRI, MAXAR, EARTHSTAR GEOGRAPHICS, AND THE GIS USER COMMUNITY
4. LICENCE AND LIMIT OF EXTRACTION PROVIDED BY MHBC JUNE 2023
5. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 17N

CLIENT

CBM AGGREGATES, A DIVISION OF ST. MARYS CEMENT INC. (CANADA)

PROJECT

CALEDON PIT / QUARRY

TITLE

STUDY AREA

CONSULTANT

GOLDER
MEMBER OF WSP

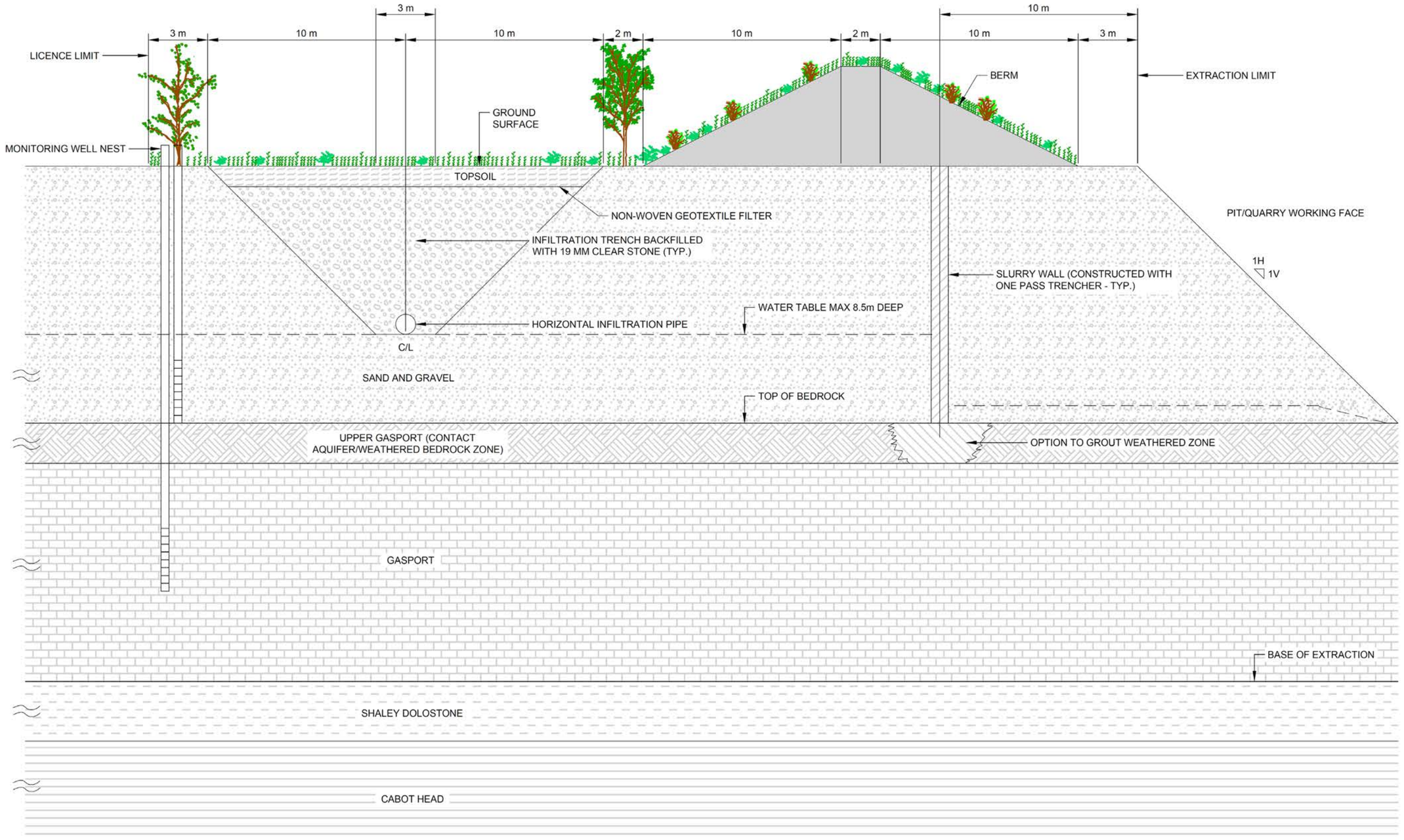
YYYY-MM-DD	2023-07-18
DESIGNED	SO
PREPARED	SO
REVIEWED	GWS
APPROVED	HM

PROJECT NO.	CONTROL	REV.	FIGURE
19129150	0036	0.0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

0 25mm

PATH: S:\Clients\Votoran\m_Cimentos\Long_Par_5_Caledon\99_PRO\11\19129150\40_PROD\0036_Water_Resources\19129150-0036-CH-0001_1.mxd PRINTED ON: 2023-07-18 AT: 7:55:10 PM



NOTES

1. Max trench width 20 m - depth will vary depending on the depth to water.
2. Infiltration piping will be sized to meet required infiltration rate.
3. Infiltration rate will vary to maintain groundwater table within required range.
4. Groundwater level to be monitored at well installed between trench and licence limit.
5. Minimum setback of 50 m needed.
6. Construct slurry wall/grout 10 m from extraction limit.
7. Construct infiltration trench c/l 13 m from licence limit.
8. Construct berm in setback.
9. Main Quarry - slurry wall and infiltration trench to be constructed at the start of extraction phase 4.
10. South Quarry - Slurry wall and infiltration trench to be constructed at the start of extraction phase 6.

CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

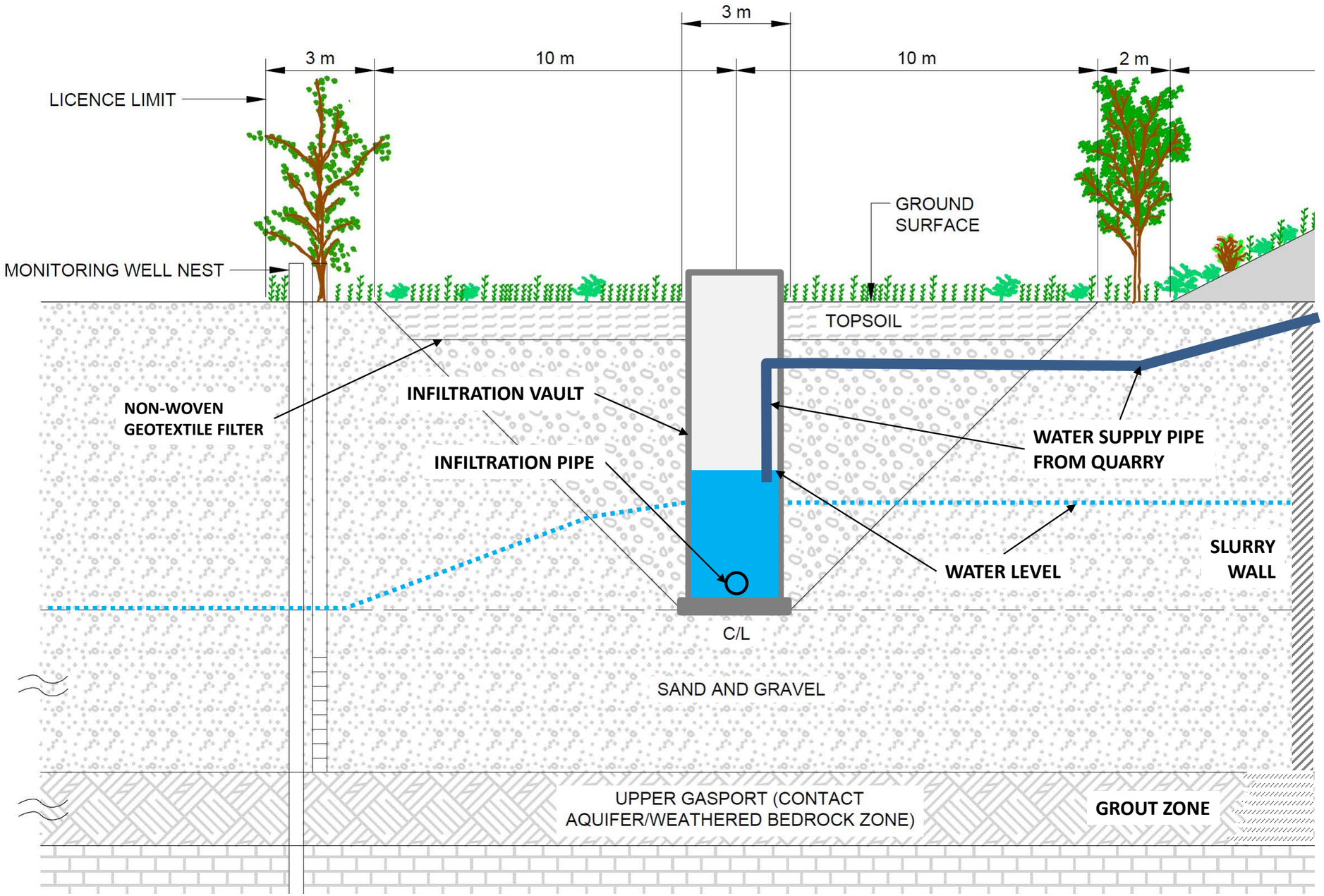
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2023-04-21
PREPARED	DD
DESIGN	GWS
REVIEW	FB
APPROVED	GWS

PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
CONCEPTUAL CROSS-SECTION SHOWING GENERAL CONFIGURATION OF PROPOSED GROUNDWATER INFILTRATION TRENCH AND SLURRY WALL

PROJECT No. 19129150 | Rev. A | FIG. 2



CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

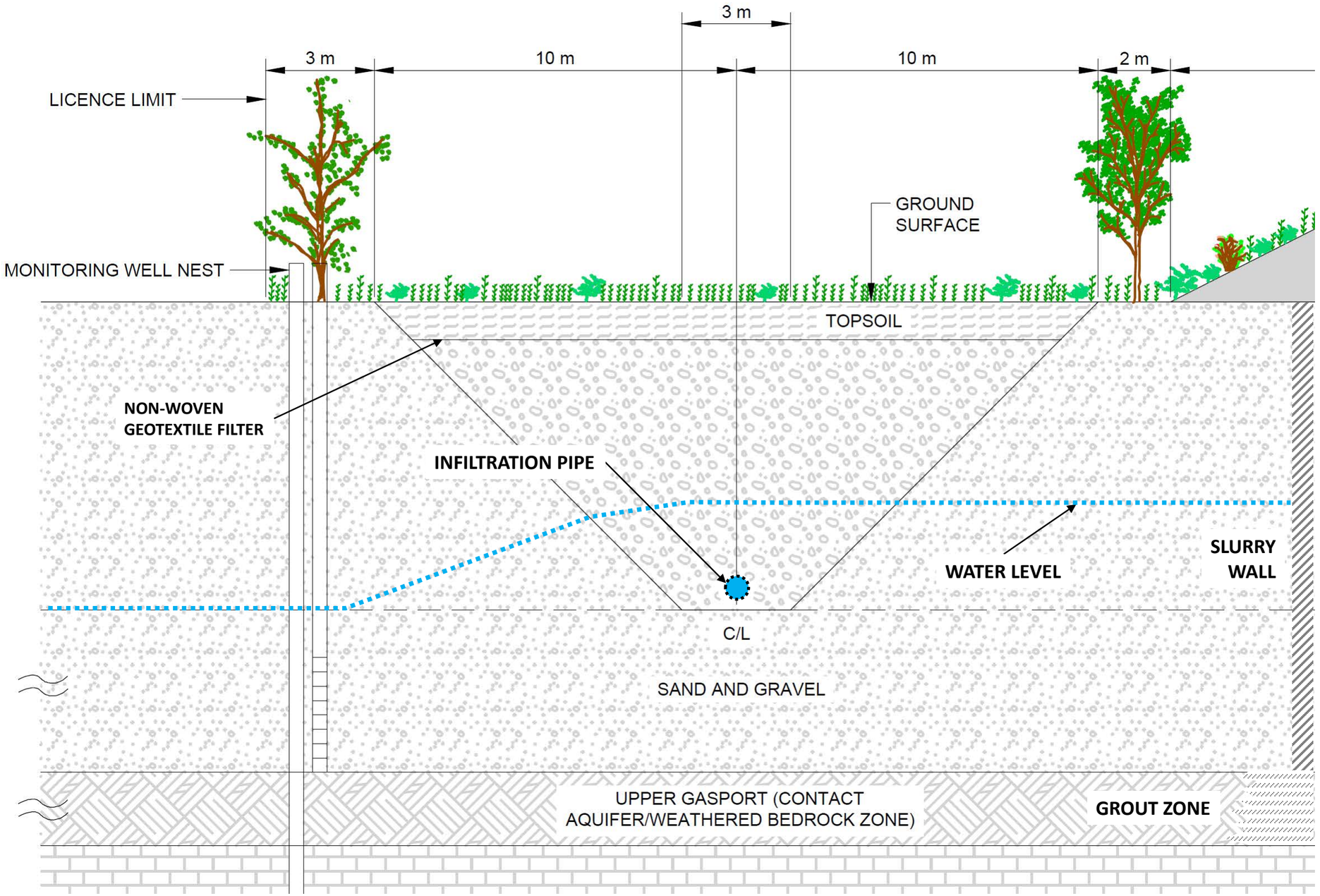
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2023-04-21
PREPARED	DD
DESIGN	GWS
REVIEW	FB
APPROVED	GWS

PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
CROSS-SECTION SHOWING PROPOSED INFILTRATION VAULT DETAIL

PROJECT No. 19129150 | Rev. A | FIG. 3



CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

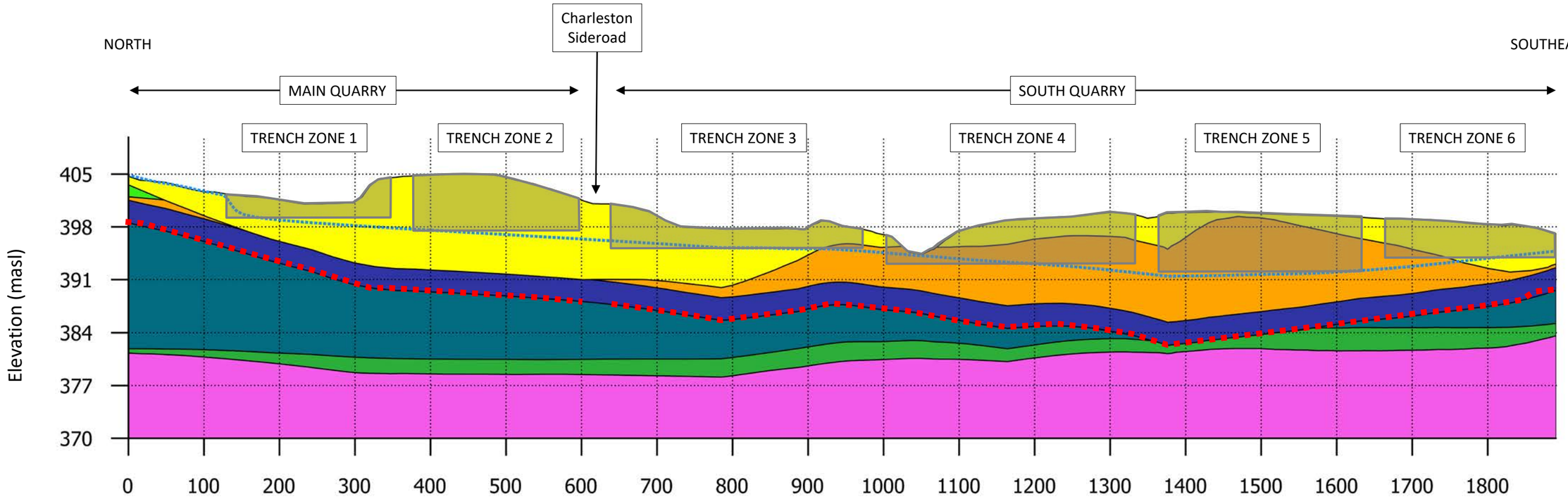
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2023-04-21
PREPARED	DD
DESIGN	GWS
REVIEW	FB
APPROVED	GWS

PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
CROSS-SECTION SHOWING PROPOSED INFILTRATION TRENCH DETAIL

PROJECT No. 19129150 | Rev. A | FIG. 4

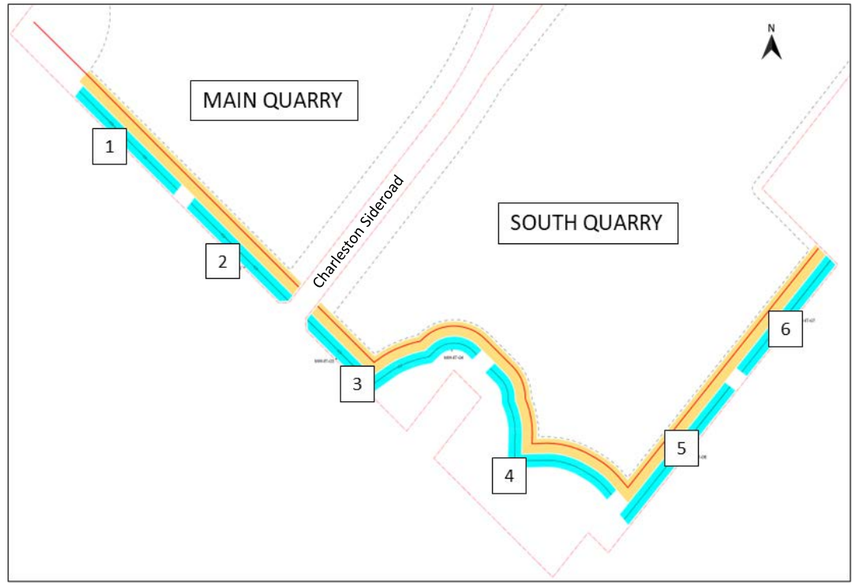


TRENCH AND SLURRY WALL CHAINAGES

	Start (m)	End (m)	Trench Length (m)	Target WL (masl)
Slurry wall only	0.0	128.6	N/A	N/A
Trench Zone 1	128.6	348.7	220.1	399.0
Trench Zone 2	378.7	596.7	218.0	397.5
Trench Zone 3	640.1	974.8	334.7	395.5
Trench Zone 4	1004.8	1334.9	330.2	393.0
Trench Zone 5	1365.8	1634.5	268.7	392.0
Trench Zone 6	1664.5	1890.5	226.0	394.0

LEGEND

- Upper Sand
- Till
- Lower Sand/ Channel Sediment
- Weathered Bedrock
- Gasport Formation (Dolostone)
- Fossil Hill Formation (Shaley Dolostone)
- Cabot Head Formation (Shale)
- Water Table (approx.)
- Base of Slurry Wall / Grout Zone
- Infiltration Trench Zone



CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

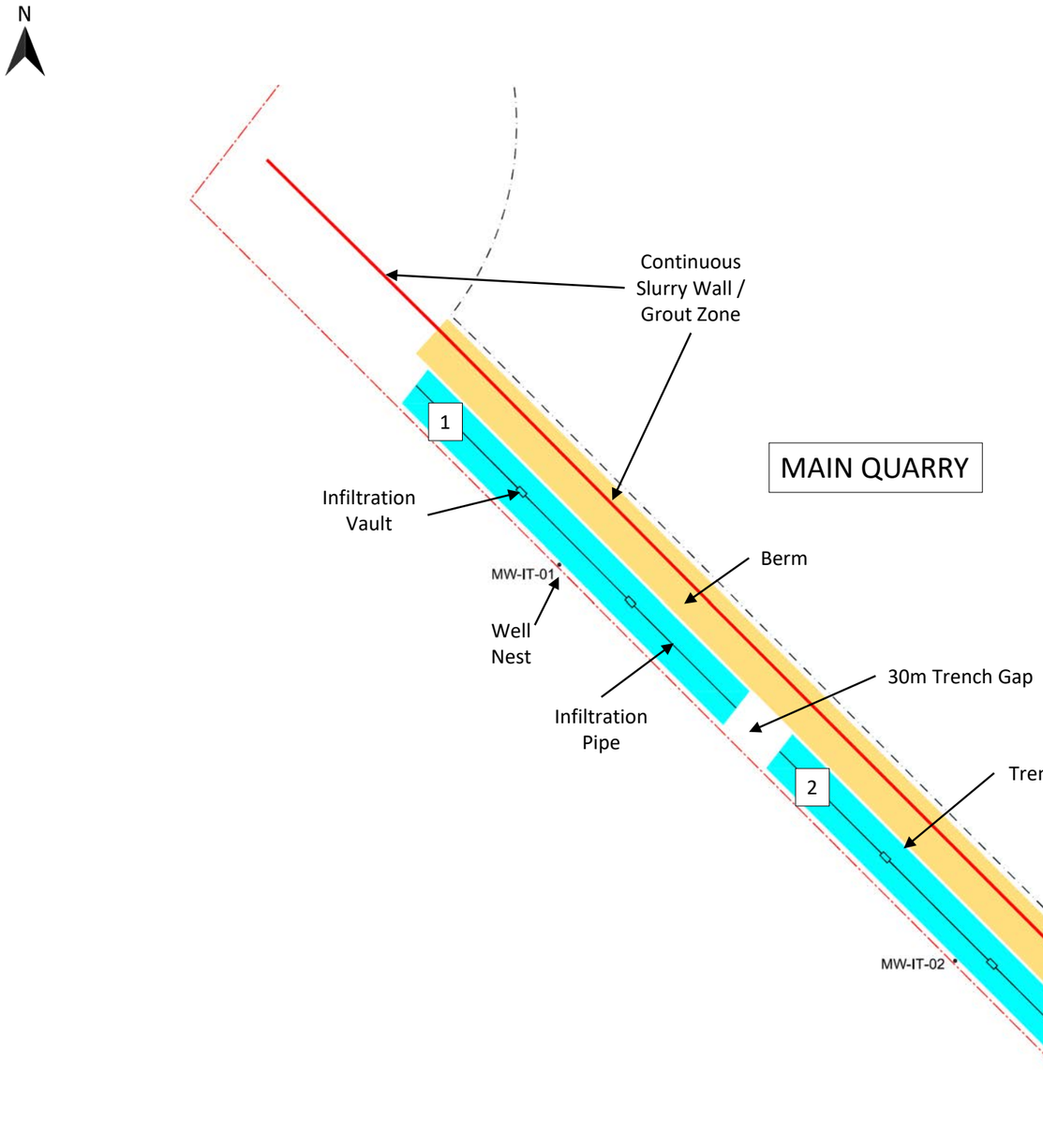
CONSULTANT
GOLDER
MEMBER OF WSP

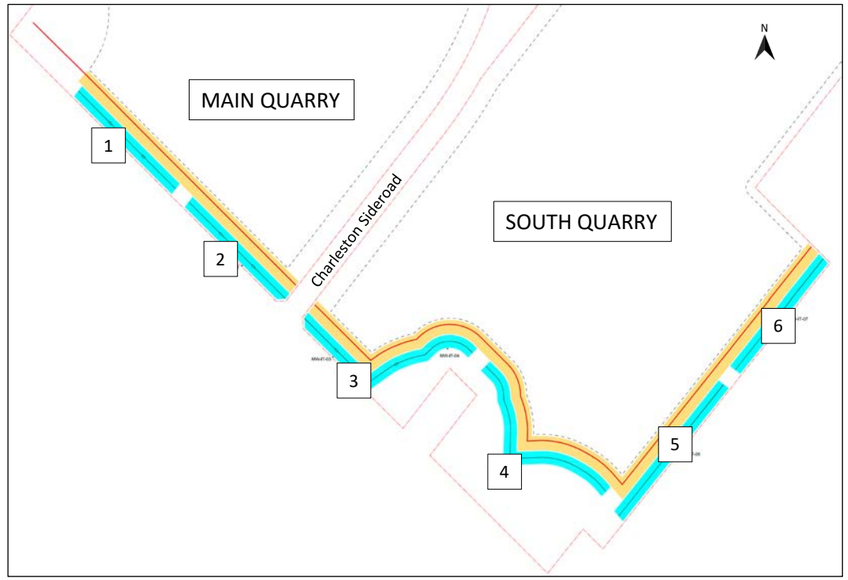
YYYY-MM-DD	2023-04-21
PREPARED	HW
DESIGN	HW/GWS
REVIEW	FB
APPROVED	GWS

PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
HYDROSTRATIGRAPHIC CROSS-SECTION ALONG PROPOSED INFILTRATION TRENCH / SLURRY WALL ALIGNMENT

PROJECT No. 19129150 | Rev. A | FIG. 5





0 metres 100

CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

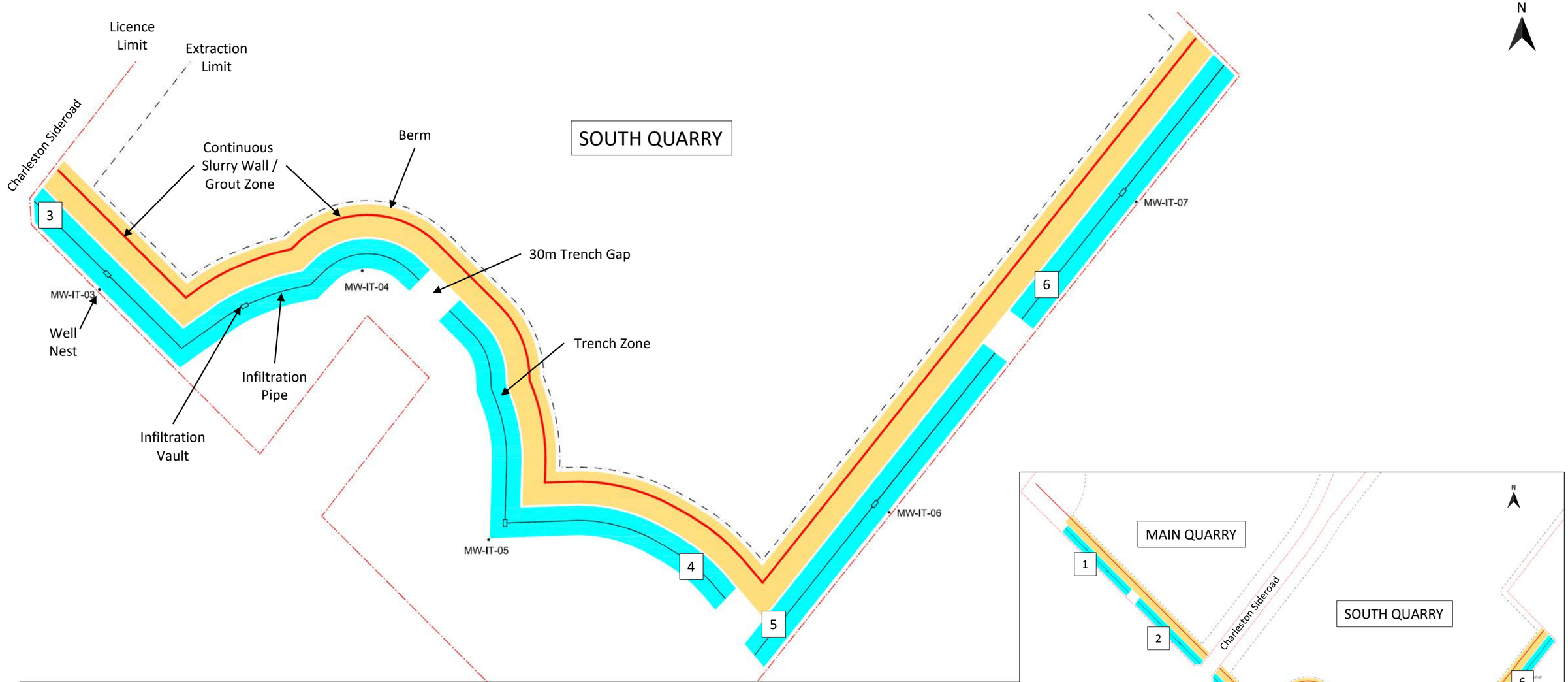
CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2023-04-21
PREPARED	HW
DESIGN	HW/GWS
REVIEW	FB
APPROVED	GWS

PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
PLAN VIEW OF PROPOSED INFILTRATION TRENCH / SLURRY WALL ZONES 1 AND 2 - MAIN QUARRY

PROJECT No. 19129150 | Rev. A | FIG. 6



CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

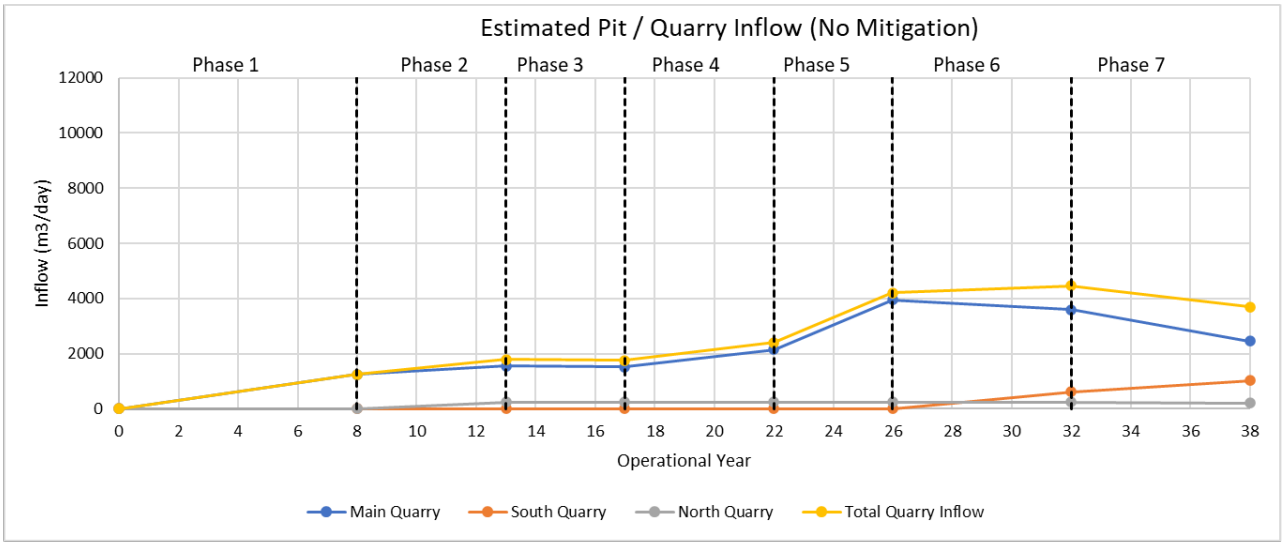
CONSULTANT
GOLDER
MEMBER OF WSP

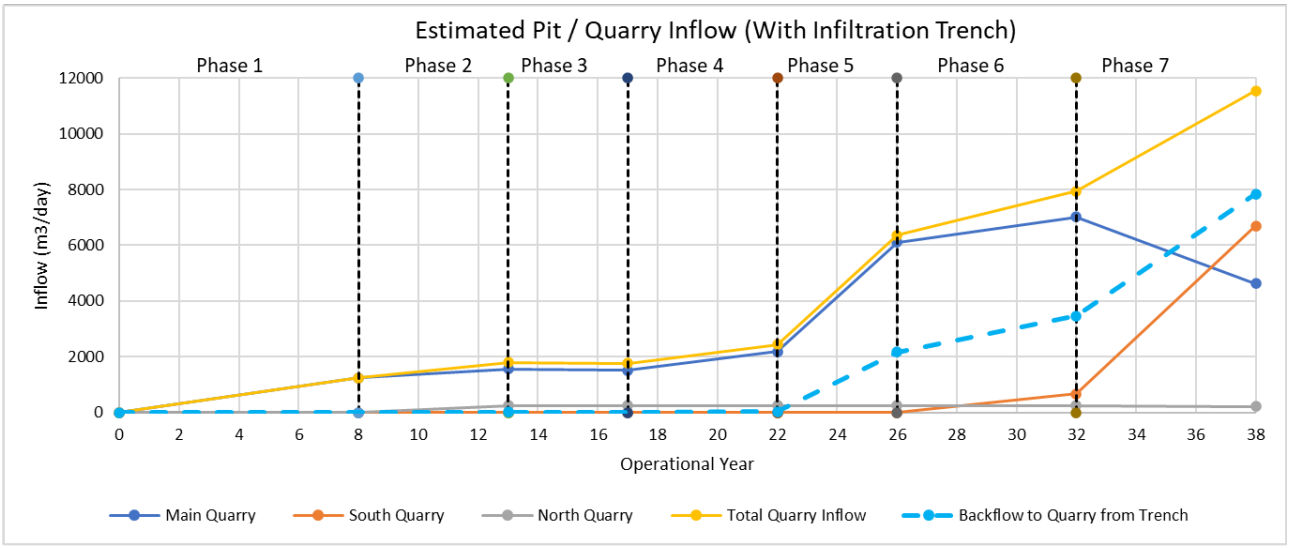
YYYY-MM-DD	2023-04-21
PREPARED	HW
DESIGN	HW/GWS
REVIEW	FB
APPROVED	GWS

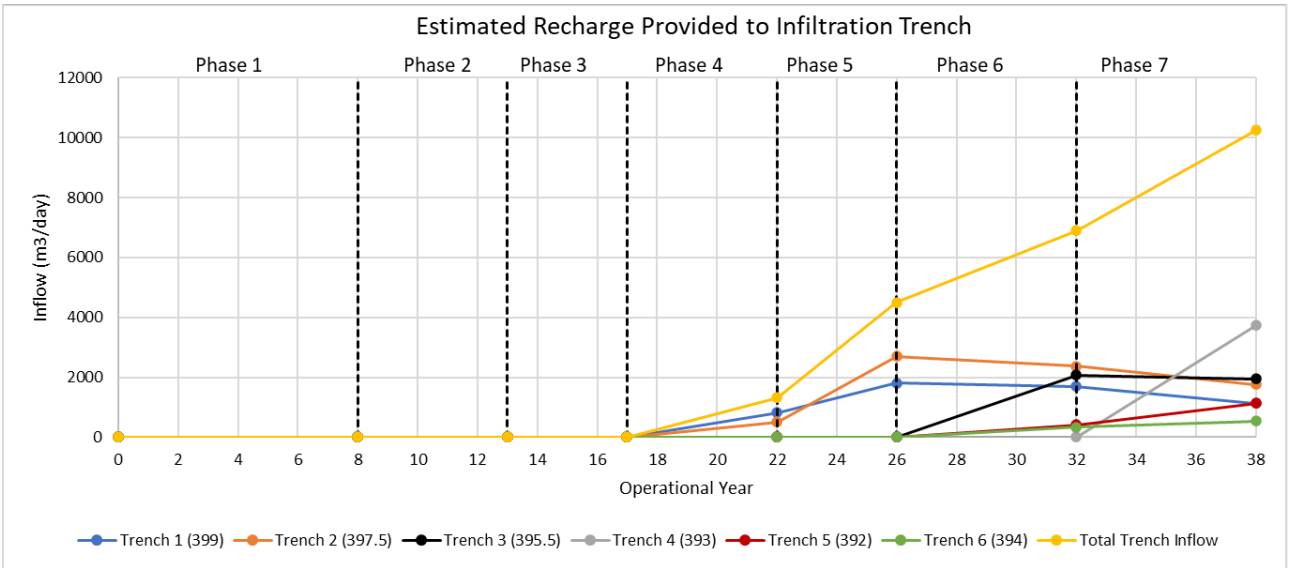
PROJECT
Caledon Pit / Quarry
Water Resources Report

TITLE
PLAN VIEW OF PROPOSED INFILTRATION TRENCH / SLURRY WALL ZONES 3, 4, 5 AND 6 - SOUTH QUARRY

PROJECT No. 19129150 | Rev. A | FIG. 7







CLIENT
CBM Aggregates, a division of St. Marys Cement Inc. (Canada)

PROJECT
Caledon Pit / Quarry
Water Resources Report

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2023-05-03
PREPARED	HW
DESIGN	HW
REVIEW	GWS
APPROVED	GWS

TITLE
ESTIMATED PIT / QUARRY INFLOWS AND INFILTRATION RATES FOR PROPOSED MITIGATION SYSTEM

PROJECT No.
19129150

Rev.
A

FIG.
8

GOLDER
MEMBER OF WSP

TECHNICAL MEMORANDUM

DATE December 5, 2022 **Project No.** 19129150

TO File
Golder

CC George Schneider

FROM Paul Menkveld **EMAIL paul.menkveld@wsp.com**

METHODOLOGY FOR ASSESSING THE POTENTIAL IMPACTS TO WATER WELL USERS – CBM CALEDON PIT / QUARRY

A conservative methodology was applied to assess which water supply wells could potentially be impacted by the proposed Caledon pit / quarry operations. The process is described as follows:

1) Calculate Initial Water Column = Modelled Static Water Level – Well Depth. Modelled static water levels are based on current steady state conditions, prior to any extraction simulation.

2) Establish Maximum Drawdown at each location: Maximum drawdown was established using the HGS predictive model. Since some water supply wells were fully penetrating (screened across multiple aquifer units), the actual amount of drawdown observed at these locations will be a function of the drawdown in all screened aquifers weighted by the transmissivity of those aquifers. A conservative simplifying approach was adopted to represent the drawdown at water supply wells. For each water supply well screen three groundwater level observation points (top, middle, and bottom of the screened interval) were extracted from the HGS model predictions, and the maximum drawdown observed at any of the points was taken to be the (worst case) drawdown at that water supply well. Table S-1 includes the maximum drawdown predicted at each well and the phase of extraction in which it occurred. This conservative scenario was evaluated for purposes of impact assessment.

3) Calculate Minimum Water Column = Initial Water Column – Maximum Drawdown.

4) Calculate Percent Remaining Water Column = Minimum Water Column / Initial Water Column x 100%

5) Apply Criteria 1: <90% Remaining Water Column. If greater than 90% of the initial water column remains available at that location, it is unlikely that the small reduction in water column adversely affects the water supply. If less than 90% of the water column remains available it is considered possible that the water well could be impacted, and Criteria 2 is applied.

6) Apply Criteria 2: <10m Minimum Water Column. If a minimum of >10m of water column is available, it is considered likely that it is sufficient for the water supply needs of the user. If the minimum water column is less than 10m then the water well is considered to be potentially impacted. Wells not identified by these

criteria are considered to have negligible impacts. Despite the classification of the wells as having negligible impacts, well complaints protocol will be in place to address the possibility of unforeseen impacts.

7) Within the category of potentially impacted water supply wells, wells will be considered in detail and classified by the likelihood and intensity of predicted impacts on the water well as a water supply, into subcategories of potential impact: low, moderate, and significant.

Attachments: Table S-1

PGM/

https://golderassociates.sharepoint.com/sites/114392/project files/5 technical work/ph 2300-hydrogeology/30 impact assessment/06_water well impact assessment/methodology/19129150 caledon water well impact methodology 05dec2022.docx

Table S-1 - Water Well Impact Assessment (<1 km from Study Site)
Caledon Pit / Quarry

Well ID	Easting	Northing	Elevation (masl)	Distance from Pit / Quarry (m)	Well Depth (m)	Modelled Static Water Level (m)	Aquifer Description	Well Purpose	Well Use	Initial Water Column Available (m)	Phase 1 Max Drawdown (m)	Phase 2 Max Drawdown (m)	Phase 3 Max Drawdown (m)	Phase 4 Max Drawdown (m)	Phase 5 Max Drawdown (m)	Phase 6 Max Drawdown (m)	Phase 7 Max Drawdown (m)	Rehab Max Drawdown (m)	Maximum Drawdown (any phase) (m)	Phase of Max Drawdown	Minimum Water Column Available (m)	Min Remaining Water Column	Remaining Water Column Rehab	Criteria 1 - Remaining in Water Column	Criteria 2 - Minimum Water Column	Potential for Impact
4905228	578414	4853323	404.47	141	8.50	6.09	Bedrock (Gasport)	Water Supply	Domestic	2.41	0.54	0.51	0.54	0.53	0.49	3.44	2.58	1.87	3.44	6	0.00	0%	22%	<90%	<10m	Significant
4900879	578093	4853722	409.71	213	13.70	9.53	Bedrock (Gasport)	Water Supply	Domestic	4.17	0.77	0.67	0.70	0.71	0.71	0.94	1.21	0.82	1.21	7	2.96	71%	80%	<90%	<10m	Significant
4900878	578079	4853682	410.00	171	15.20	9.27	Bedrock (Gasport)	Water Supply	Domestic	5.93	0.91	0.78	0.81	0.83	0.83	1.12	1.48	0.98	1.48	7	4.45	75%	83%	<90%	<10m	Significant
4900947	578483	4852999	401.04	175	12.80	3.14	Bedrock (Gasport)	Water Supply	Domestic	9.66	0.46	0.40	0.47	0.44	0.43	3.26	2.23	1.54	3.26	6	6.40	66%	84%	<90%	<10m	Significant
4903132	578644	4852923	399.80	352	10.10	4.03	Bedrock (Gasport)	Water Supply	Domestic	6.07	0.23	0.17	0.24	0.23	0.22	1.65	1.27	0.91	1.65	6	4.41	73%	85%	<90%	<10m	Moderate
4900946	578303	4852138	395.31	417	15.80	10.04	Overburden	Water Supply	Domestic	5.76	0.43	0.28	0.60	0.04	0.72	-0.24	-0.12	-0.04	0.72	5	5.04	87%	101%	<90%	<10m	Moderate
4908162	577620	4852099	399.99	157	15.20	7.78	Bedrock (Gasport)	Water Supply	Domestic	7.42	0.75	0.63	1.08	-0.04	1.36	-0.25	0.00	-0.12	1.36	5	6.06	82%	102%	<90%	<10m	Low
4905272	578514	4852723	400.08	356	13.70	4.54	Bedrock (Gasport and Lower)	Water Supply	Domestic	9.16	0.32	0.24	0.34	0.30	0.32	2.21	1.78	1.32	2.21	6	6.95	76%	86%	<90%	<10m	Low
4905365	578514	4852723	400.08	356	29.90	20.64	Bedrock (Gasport and Lower)	Water Supply	Domestic	9.26	0.40	0.21	0.52	0.50	0.68	2.15	1.74	1.27	2.15	6	7.11	77%	86%	<90%	<10m	Low
4907244	577734	4851975	402.01	222	20.10	11.46	Bedrock (Gasport)	Water Supply	Domestic	8.64	0.65	0.51	0.93	-0.02	1.13	-0.35	-0.12	-0.17	1.13	5	7.51	87%	102%	<90%	<10m	Low
4903810	578539	4852873	399.90	284	13.10	3.01	Bedrock (Gasport and Lower)	Water Supply	Domestic	10.09	0.36	0.29	0.38	0.35	0.36	2.43	1.74	1.24	2.43	6	7.66	76%	88%	<90%	<10m	Low
4907589	578457	4853052	401.91	142	15.20	3.68	Bedrock (Gasport and Lower)	Water Supply	Domestic	11.52	0.48	0.43	0.50	0.48	0.47	3.61	2.44	1.65	3.61	6	7.91	69%	86%	<90%	<10m	Low
4903189	578664	4852723	399.93	475	15.20	5.38	Bedrock (Gasport and Lower)	Water Supply	Domestic	9.82	0.25	0.18	0.26	0.24	0.24	1.44	1.11	0.82	1.44	6	8.39	85%	92%	<90%	<10m	Low
4900948	578450	4852848	399.92	229	13.70	2.50	Bedrock (Gasport and Lower)	Water Supply	Domestic	11.20	0.42	0.35	0.44	0.41	0.42	2.80	1.95	1.40	2.80	6	8.40	75%	87%	<90%	<10m	Low
4906635	577507	4854325	415.01	186	21.60	10.55	Bedrock (Gasport)	Water Supply	Domestic	11.05	0.81	0.90	0.84	0.76	0.76	0.78	1.28	1.00	1.28	7	9.77	88%	91%	<90%	<10m	Low
4907201	575983	4853717	430.11	641	21.30	9.13	Overburden	Water Supply	Domestic	12.17	0.07	0.62	0.62	1.62	1.05	1.06	0.89	0.55	1.62	4	10.55	87%	95%	<90%	>10m	Negligible
4900945	578477	4853124	402.48	180	18.30	4.28	Bedrock (Gasport and Lower)	Water Supply	Domestic	14.02	0.42	0.37	0.43	0.42	0.40	3.16	2.20	1.53	3.16	6	10.86	77%	89%	<90%	>10m	Negligible
4904102	576927	4854548	414.92	266	23.20	9.55	Bedrock (Gasport)	Water Supply	Domestic	13.65	0.14	2.50	0.48	0.29	0.21	0.21	0.39	0.20	2.50	2	11.15	82%	99%	<90%	>10m	Negligible
4906023	577964	4853723	408.53	131	19.50	6.53	Bedrock (Gasport and Lower)	Water Supply	Domestic	12.97	1.19	1.04	1.07	1.10	1.12	1.31	1.64	1.18	1.64	7	11.32	87%	91%	<90%	>10m	Negligible
4908005	578546	4852932	399.99	259	21.00	4.07	Bedrock (Gasport and Lower)	Water Supply	Domestic	16.93	0.36	0.28	0.37	0.35	0.36	2.34	1.79	1.29	2.34	6	14.59	86%	92%	<90%	>10m	Negligible
7139063	577237	4854451	415.24	201	29.60	11.73	Bedrock (Gasport and Lower)	Water Supply	Domestic	17.87	0.65	2.06	1.21	0.70	0.69	0.72	1.66	1.18	2.06	2	15.81	88%	93%	<90%	>10m	Negligible
4907018	578029	4853732	409.42	183	30.20	9.52	Bedrock (Gasport and Lower)	Water Supply	Domestic	20.68	1.29	1.15	1.38	1.52	1.70	2.31	2.53	1.29	2.53	7	18.14	88%	94%	<90%	>10m	Negligible
4906521	576787	4852960	406.29	166	22.90	1.15	Bedrock (Gasport)	Water Supply	Domestic	21.75	0.14	0.24	0.49	2.45	2.63	2.63	2.13	1.29	2.63	5	19.12	88%	94%	<90%	>10m	Negligible
C	576448	4853345	416.27	218	53.46	-1.18	Bedrock (Gasport and Lower)	Water Supply	Domestic	54.64	0.60	1.15	1.54	5.85	3.15	3.15	2.87	1.68	5.85	4	48.79	89%	97%	<90%	>10m	Negligible
4905439	578459	4851827	391.72	637	12.80	2.66	Overburden	Water Supply	Commercial	10.14	0.33	0.17	0.48	0.01	0.57	-0.18	-0.03	-0.02	0.57	5	9.57	94%	100%	>90%	-	Negligible
4904297	578630	4852667	400.40	482	32.00	23.76	Bedrock (Below Gasport)	Water Supply	Domestic	8.24	0.29	-0.82	0.37	0.35	0.47	0.86	0.86	0.39	0.86	6	7.38	90%	95%	>90%	-	Negligible
4900950	576546	4854698	416.68	586	5.30	2.30	Overburden	Water Supply	Domestic	3.00	0.01	0.10	0.04	0.06	0.04	0.05	0.04	0.02	0.10	2	2.90	97%	99%	>90%	-	Negligible
4908905	579059	4853784	393.40	922	13.70	9.79	Overburden	Water Supply	Industrial	3.91	0.00	-0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6	3.91	100%	100%	>90%	-	Negligible
7241044	579051	4853788	393.64	917	16.80	11.30	Overburden	Other Status	Purge well	5.50	0.00	-0.11	0.01	0.01	0.01	0.01	0.01	0.01	0.01	6	5.49	100%	100%	>90%	-	Negligible
4904054	578494	4852523	400.33	400	16.80	10.06	Bedrock (Gasport and Lower)	Water Supply	Domestic	6.74	0.13	0.09	0.14	0.12	0.15	0.62	0.46	0.32	0.62	6	6.12	91%	95%	>90%	-	Negligible
4908541	578745	4854123	389.83	551	15.50	8.47	Overburden	Water Supply	Other	7.03	0.01	-0.41	0.01	0.01	0.01	0.01	0.01	0.01	0.01	6	7.02	100%	100%	>90%	-	Negligible
4903950	578514	4851832	389.99	677	14.30	-0.25	Overburden	Water Supply	Commercial	14.55	0.24	0.13	0.35	0.01	0.42	-0.13	0.00	0.00	0.42	5	14.13	97%	100%	>90%	-	Negligible
4901027	576811	4851723	397.74	887	12.20	4.06	Bedrock (Gasport)	Water Supply	Domestic	8.14	0.34	0.26	0.56	-0.03	0.44	0.01	0.00	0.00	0.56	3	7.58	93%	100%	>90%	-	Negligible
4907246	577734	4851975	402.01	222	24.70	11.45	Bedrock (Gasport and Lower)	Water Supply	Domestic	13.25	0.65	0.51	0.93	-0.02	1.13	-0.35	-0.12	-0.17	1.13	5	12.11	91%	101%	>90%	-	Negligible
4900941	578697	4852765	399.57	475	36.60	22.53	Bedrock (Below Gasport)	Water Supply	Domestic	14.07	0.30	0.09	0.37	0.36	0.48	1.41	1.11	0.81	1.41	6	12.66	90%	94%	>90%	-	Negligible
4903630	578379	4852408	399.01	316	24.40	10.70	Bedrock (Gasport and Lower)	Water Supply	Domestic	13.70	0.37	0.13	0.50	0.38	0.67	0.85	0.93	0.38	0.93	7	12.77	93%	97%	>90%	-	Negligible
4905093	578364	4852373	397.48	320	24.70	10.61	Bedrock (Gasport and Lower)	Water Supply	Domestic	14.09	0.67	0.59	0.75	0.46	0.81	0.79	0.88	0.87	0.88	7	13.21	94%	94%	>90%	-	Negligible
4903338	576864	4852003	397.17	651	16.20	1.90	Bedrock (Gasport)	Water Supply	Domestic	14.30	0.53	0.48	0.83	-0.06	0.56	0.05	0.01	-0.01	0.83	3	13.47	94%	100%	>90%	-	Negligible
4906547	577543	4851996	400.04	281	22.60	7.97	Bedrock (Gasport)	Water Supply	Domestic	14.63	0.68	0.56	0.98	-0.05	1.17	-0.16	-0.01	-0.07	1.17	5	13.46	92%	100%	>90%	-	Negligible
4903169	578964	4854353	397.65	768	30.80	17.25	Bedrock (Gasport and Lower)	Water Supply	Commerical	13.55	0.02	-1.36	0.02	0.02	0.02	0.03	0.03	0.02	0.03	6	13.52	100%	100%	>90%	-	Negligible
4906026	577814	4852023	398.72	162	23.50	8.51	Bedrock (Gasport and Lower)	Water Supply	Domestic	14.99	0.65	0.51	0.93	0.09	1.17	-0.18	0.08	-0.12	1.17	5	13.82	92%	101%	>90%	-	Negligible
4907069	575970	4853700	430.25	650	25.90	9.27	Overburden	Water Supply	Domestic	16.63	0.07	0.62	0.62	1.62	1.05	1.06	0.89	0.55	1.62	4	15.01	90%	97%	>90%	-	Negligible
4904178	578464	4852453	398.55	381	29.90	14.16	Bedrock (Gasport and Lower)	Water Supply	Domestic	15.74	0.28	0.02	0.37	0.29	0.48	0.70	0.72	0.33	0.72	7	15.02	95%	98%	>90%	-	Negligible
4907199	575974	4853698	430.08	646	25.90	9.09	Overburden	Water Supply	Domestic	16.81	0.07	0.62	0.62	1.62	1.05	1.06	0.89	0.55	1.62	4	15.19	90%	97%	>90%	-	Negligible
4900882	576819	4854959	400.46	689	17.70	2.25	Overburden	Water Supply	Domestic	15.45	0.02	0.21	0.11	0.16	0.12	0.12	0.12	0.08	0.21	2	15.24	99%	100%	>90%	-	Negligible
4908100	577078	4854560	412.89	300	27.40	11.04	Bedrock (Gasport and Lower)	Water Supply	Domestic	16.36	0.09	0.91	0.27	0.16	0.15	0.16	0.28	0.18	0.91	2	15.45	94%	99%	>90%	-	Negligible
4901026	577033	4852103	398.00	460	19.80	2.88	Bedrock (Gasport)	Water Supply	Domestic / Livestock	16.92	0.60	0.55	0.94	-0.09	0.66	0.05	0.01	-0.02	0.94	3	15.98	94%	100%	>90%	-	Negligible
4904175	578564	4852573	399.87	470	27.70	10.64	Bedrock (Gasport and Lower)	Water Supply	Domestic	17.06	0.28	0.17	0.36	0.32	0.47	0.99	0.82	0.54	0.99	6	16.07	94%	97%	>90%	-	Negligible
4903844	578714	4853073	400.10	400	27.40	7.69	Bedrock (Gasport and Lower)	Water Supply	Industrial	19.71	0.41	0.01	0.50	0.51	0.61	1.24	1.17	0.68	1.24	6	18.47	94%	97%	>90%	-	Negligible
4907628	576570	4855350	401.43	1135	24.40	4.93	Bedrock (Gasport and Lower)	Water Supply	Public	19.47	0.11	0.32	0.27	0.36	0.34	0.36	0.40	0.17	0.40	7	19.07	98%	99%	>90%	-	Negligible
4904052	578644	4852683	400.47	484	29.90	9.27	Bedrock (Gasport and Lower)	Water Supply	Domestic	20.63	0.34	0.25	0.36	0.34	0.46	1.44	1.16	0.91	1.44	6	19.19	93%	96%	>90%	-	Negligible
4908895	578556	4852526	397.51	461	42.10	21.75	Bedrock (Gasport and Lower)	Water Supply	Domestic	20.35	0.25	0.01	0.32	0.28	0.41	0.75	0.72	0.35	0.75	6	19.59	96%	98%	>90%	-	Negligible
4906637	576804	4852922	405.95	176	22.90	1.50	Bedrock (Gasport)	Water Supply	Domestic	21.40	0.12	0.19	0.37	1.48	1.72	1.71	1.38	0.79	1.72	5	19.69	92%	96%	>90%	-	Negligible
4907712	578481	4852565	401.11	387	44.20	22.75	Bedrock (Gasport and Lower)	Water Supply	Domestic	21.45	0.36	0.01	0.46	0.41	0.61	1.00	1.02	0.45	1.02	7	20.43	95%	98%	>90%	-	Negligible
4903186	578664	4852873	398.51	390	41.50	19.88	Bedrock (Below Gasport)	Water Supply	Domestic	21.62	0.35	-1.27	0.44	0.44	0.56	1.05	1.04	0.49	1.05	6	20.57	95%	98%	>90%	-	Negligible
4904252	578537	4852787	400.22	335	43.30	20.32	Bedrock (Gasport and Lower)	Water Supply	Domestic	22.98	0.42	0.22	0.54	0.52	0.70	2.28	1.73	1.21	2.28	6	20.70	90%	95%	>90%	-	Negligible
4907938	578582	4852795	400.11	366	43.60	20.88	Bedrock (Gasport and Lower)	Water Supply	Domestic	22.72	0.39	0.18	0.49	0.48	0.64	1.89	1.45	1.06	1.89	6	20.83	92%	95%	>90%	-	Negligible
4907314	578727	4852899	399.99	438	29.00	6.29	Bedrock (Gasport and Lower)	Water Supply	Domestic	22.71	0.33	0.11	0.42	0.42	0.53	1.34	1.00	0.71	1.34	6	21.37	94%	97%	>90%	-	Negligible
4900943	578639	4852673	400.45	486	34.10	11.34	Bedrock (Gasport and Lower)	Water Supply	Domestic	22.76	0.37	0.27	0.38	0.35	0.42	1.24	1.04	0.83	1.24	6	21.52	95%	96%	>90%	-	Negligible
4905577	578614	4852923	399.49	324	43.00	19.06	Bedrock (Gasport and Lower)	Water Supply	Domestic	23.94	0.42	0.22	0.53	0.54	0.68	1.95	1.48	1.07	1.95	6	21.98	92%	96%	>90%	-	Negligible
4906777	576622	4852090	398.39	760	25.30	1.84	Bedrock (Gasport and Lower)	Water Supply	Domestic	23.46	0.51	0.49	0.80	0.03	0.53	0.17	0.12	0.03	0.80	3	22.65	97%	100%	>90%	-	Negligible
4907364	578609	4852786	399.89	393	31.10	6.67	Bedrock (Gasport and Lower)	Water Supply	Domestic	24.43	0.36	0.20	0.46	0.45	0.60	1.65	1.29	0.96	1.65	6	22.78	93%	96%	>90%	-	Negligible
4907315	578504	4852772	400.15	318	30.50	4.87	Bedrock (Below Gasport)	Water Supply	Domestic	25.63	0.43	0.26	0.55	0.53	0.72	2.38	1.85	1.30	2.38	6	23.25	91%	95%	>90%	-	Negligible
4907794	577104	4854476	411.45	239	33.50	7.74	Bedrock (Gasport and Lower)	Water Supply	Domestic	25.76	0.59	2.04	1.20	1.38	1.41	1.54	1.86	0.76	2.04	2	23.72	92%	97%	>90%	-	Negligible
4909251	578594	4852961	400.00	292	44.80	18.96	Bedrock (Gasport and Lower)	Water Supply	Domestic	25.84	0.45	0.25	0.57	0.57	0.73	1.97	1.63	1.19	1.97	6	23.87	92%	95%	>90%	-	Negligible
4903532	578654	4852763	399.05	442	32.90	7.30	Bedrock (Gasport and Lower)	Water Supply	Domestic	25.60	0.30	0.18	0.38	0.37	0.49	1.49	1.15	0.85	1.49	6	24.11	94%	97%	>90%	-	Negligible
4905163	577264	4851173	396.57	1148	31.40	5.86	Overburden	Water Supply	Domestic	25.54	0.33	0.19	0.54	-0.03	0.54	-0.05	-0.01	-0.01	0.54	3	25.00	98%	100%	>90%	-	Negligible
4908197	578677	4852899	399.94	392	47.20	20.80	Bedrock (Gasport and Lower)	Water Supply	Domestic	26.40	0.37	0.14	0.46	0.46	0.58	1.37	1.10	0.80	1.37	6	25.02	95%	97%	>90%	-	Negligible
4909536	578523	4852953	400.08	228	45.70	18.13	Bedrock (Below Gasport)	Recharge Well	Cooling / AC	27.57	0.50	0.27	0.63	0.64	0.82	2.55	1.84	1.32	2.55	6	25.03	91%	95%	>90%	-	Negligible
4907456	578727	4852899	399.99	438	48.80	21.63	Bedrock (Gasport and Lower)	Water Supply	Domestic	27.17	0.33	0.11	0.42	0.42	0.53	1.34	1.00	0.71	1.34	6	25.82	95%	97%	>90%	-	Negligible
4906974	578659	4852763	398.98	446	34.70	7.22	Bedrock (Gasport and Lower)	Water Supply	Domestic	27.48	0.30	0.18	0.38	0.37	0.49	1.49	1.15	0.85	1.49	6	25.99	95%	97%	>90%	-	Negligible
4900942	578261	4852228	396.31	328	38.70	11.44	Bedrock (Gasport and Lower)	Water Supply	Domestic	27.26	0.47	0.31	0.66	0.33	0.79	0.59	0.75	0.25	0.79	5	26.47	97%	99%	>90%	-	Negligible
4909122	578766	4853889	381.15	640	29.00	1.61	Bedrock (Below Gasport)	Water Supply	Municipal	27.39	0.11	-2.31	0.12	0.12	0.12	0.21	0.20	0.16	0.21	6	27.18	99%	99%	>90%	-	Negligible
4900944	578328	4852575	400.04	235	36.60	6.55	Bedrock (Gasport and Lower)	Water Supply	Domestic	30.05	0.57	0.46	0.66	0.59	0.91	1.96	1.70	1.32	1.96	6	28.09	93%	96%	>90%	-	Negligible
4907787	578576	4852699	400.02	420	36.60	6.54	Bedrock (Gasport and Lower)	Water Supply	Domestic	30.06	0.34	0.19	0.44	0.42	0.57	1.68	1.34	0.99	1.68	6	28.38	94%	97%	>90%	-	Negligible
A	578195	4853972	405.87	169	37.94	7.56	Bedrock (Gasport and Lower)	Water Supply	Domestic	30.37	0.74	0.77	1.02	1.10	1.19	1.57	1.69	0.77	1.69	7	28.68	94%	97%	>90%	-	Negligible
4907362	578398	4852547	400.21	303	38.40	8.12	Bedrock (Gasport and Lower)	Water Supply	Domestic	30.28	0.40	0.31	0.53	0.46	0.72	1.09	1.15	0.74	1.15	7	29.14	96%	98%	>90%	-	Negligible
4907145	577944	4853791	408.86	163	50.30	17.50	Bedrock (Gasport and Lower)	Water Supply	Domestic	32.80	1.13	1.19	1.50	1.68	1.86	2.40	2.69	1.07	2.69	7	30.11	92%	97%	>90%	-	Negligible
4902982	578204	4851713	393.20	616	39.30	8.06	Overburden	Water Supply	Domestic	31.24	0.42	0.24	0.61	0.00	0.70	-0.22	-0.09	-0.08	0.70	5	30.54	98%	100%	>90%	-	Negligible

Table S-1 - Water Well Impact Assessment (<1 km from Study Site)
Caledon Pit / Quarry

Well ID	Easting	Northing	Elevation (masl)	Distance from Pit / Quarry (m)	Well Depth (m)	Modelled Static Water Level (m)	Aquifer Description	Well Purpose	Well Use	Initial Water Column Available (m)	Phase 1 Max Drawdown (m)	Phase 2 Max Drawdown (m)	Phase 3 Max Drawdown (m)	Phase 4 Max Drawdown (m)	Phase 5 Max Drawdown (m)	Phase 6 Max Drawdown (m)	Phase 7 Max Drawdown (m)	Rehab Max Drawdown (m)	Maximum Drawdown (any phase) (m)	Phase of Max Drawdown	Minimum Water Column Available (m)	Min Remaining Water Column	Remaining Water Column Rehab	Criteria 1 - Remaining in Water Column	Criteria 2 - Minimum Water Column	Potential for Impact
7145140	578190	4851490	391.09	793	39.30	6.98	Overburden	Water Supply	Domestic	32.32	0.38	0.18	0.55	-0.01	0.62	-0.18	-0.07	-0.07	0.62	5	31.71	98%	100%	>90%	-	Negligible
4909671	578737	4852935	400.04	437	41.80	8.97	Bedrock (Gasport and Lower)	Water Supply	Domestic	32.83	0.33	0.08	0.41	0.41	0.51	1.05	0.96	0.60	1.05	6	31.79	97%	98%	>90%	-	Negligible
B	577519	4852289	395.45	129	35.65	1.46	Bedrock (Gasport and Lower)	Water Supply	Domestic	34.19	0.94	0.85	1.33	0.87	1.84	1.67	2.00	0.51	2.00	7	32.20	94%	99%	>90%	-	Negligible
4905870	578464	4854173	387.90	266	36.60	2.99	Bedrock (Below Gasport)	Water Supply	Domestic	33.61	0.61	1.02	1.11	1.13	1.14	1.21	0.96	0.61	1.21	6	32.40	96%	98%	>90%	-	Negligible
7218147	578597	4852611	400.00	490	60.40	24.40	Bedrock (Gasport and Lower)	Water Supply	Domestic	36.00	0.25	0.01	0.32	0.30	0.41	0.75	0.74	0.35	0.75	6	35.25	98%	99%	>90%	-	Negligible
4908976	578295	4852370	398.40	266	54.30	17.23	Bedrock (Gasport and Lower)	Water Supply	Domestic	37.07	0.43	0.16	0.58	0.43	0.80	0.90	1.04	0.38	1.04	7	36.03	97%	99%	>90%	-	Negligible
4903765	576349	4853583	421.50	259	42.70	2.23	Bedrock (Gasport and Lower)	Water Supply	Domestic / Livestock	40.47	0.15	0.96	1.19	3.56	2.27	2.27	1.89	1.17	3.56	4	36.91	91%	97%	>90%	-	Negligible
4906636	575684	4854015	436.19	1024	50.30	12.10	Bedrock (Gasport)	Water Supply	Domestic	38.20	0.05	0.48	0.44	1.05	0.70	0.70	0.59	0.36	1.05	4	37.15	97%	99%	>90%	-	Negligible
4907630	577245	4854785	400.03	534	42.70	4.30	Bedrock (Below Gasport)	Water Supply	Commerical	38.40	0.36	0.78	0.69	0.79	0.80	0.87	1.06	0.46	1.06	7	37.34	97%	99%	>90%	-	Negligible
4909948	575639	4853671	427.47	974	50.90	4.88	Bedrock (Gasport and Lower)	Water Supply	Domestic	46.02	0.05	0.34	0.33	0.83	0.56	0.56	0.49	0.28	0.83	4	45.19	98%	99%	>90%	-	Negligible
4900880	578643	4854053	383.99	464	50.90	2.94	Overburden	Water Supply	Domestic	47.96	0.20	-0.69	0.29	0.30	0.30	0.34	0.30	0.21	0.34	6	47.62	99%	100%	>90%	-	Negligible
4909177	577144	4855727	396.20	1454	53.34	5.24	Bedrock (Gasport and Lower)	Water Supply	Commercial	48.10	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.01	2	48.09	100%	100%	>90%	-	Negligible
4907147	576840	4852928	405.77	145	55.20	1.61	Bedrock (Gasport and Lower)	Water Supply	Domestic	53.59	0.86	1.15	1.66	2.50	3.26	3.44	3.48	1.05	3.48	7	50.11	94%	98%	>90%	-	Negligible
7193044	576604	4854580	417.19	463	60.40	8.31	Bedrock (Gasport and Lower)	Water Supply	Domestic / Livestock	52.09	0.39	1.56	0.95	1.22	1.19	1.27	1.43	0.59	1.56	2	50.53	97%	99%	>90%	-	Negligible
4907363	576774	4852986	406.75	152	61.00	4.38	Bedrock (Gasport and Lower)	Water Supply	Domestic	56.62	0.82	1.16	1.67	2.69	3.27	3.44	3.47	1.12	3.47	7	53.15	94%	98%	>90%	-	Negligible
4907629	577340	4854835	399.80	590	67.10	6.00	Bedrock (Below Gasport)	Water Supply	Commerical	61.10	0.29	0.60	0.53	0.58	0.60	0.65	0.80	0.37	0.80	7	60.29	99%	99%	>90%	-	Negligible
4903324	578689	4854153	387.20	492	69.80	6.46	Bedrock (Below Gasport)	Water Supply	Commerical	63.34	0.09	-1.22	0.14	0.14	0.14	0.16	0.14	0.10	0.16	6	63.17	100%	100%	>90%	-	Negligible
4905497	577914	4851923	398.04	282	82.60	9.88	Bedrock (Below Gasport)	Water Supply	Domestic	72.72	0.56	0.40	0.81	0.32	1.09	0.50	0.73	0.16	1.09	5	71.63	99%	100%	>90%	-	Negligible
4900845	579191	4854724	395.27	1085	11.00	12.33	Overburden	Water Supply	Domestic	0.00	0.00	-0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6	0.00	Screened above modelled groundwater level				Negligible
4900876	578952	4852803	402.29	683	13.10	15.97	Overburden	Water Supply	Domestic	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1	0.00	Screened above modelled groundwater level				Negligible

TECHNICAL MEMORANDUM

DATE December 9, 2022 **Project No.** 19129150

TO David Hanratty
CBM Aggregates (CBM), a Division of St. Marys Cement Inc. (Canada)

CC Mike Lebreton (CBM)

FROM Greg Padusenko, George Schneider (WSP Golder) **EMAIL gregory.padusenko@wsp.com**

CALEDON PIT / QUARRY – WATER WELL COMPLAINT RESPONSE PLAN

This water well complaint response plan is intended to help ensure CBM can promptly respond to and remedy, if necessary, potential water supply impacts to any neighbouring private water well user (referred to herein as "resident") should their water supply be affected by the future proposed Caledon Pit / Quarry aggregate operation. As indicated in the Water Report (Golder, 2022), there is a potential for adverse effects to a small number of neighbouring private wells as a result of the proposed aggregate operations.

It should be noted that a water monitoring program (Section 9 of the Water Report; Golder, 2022) shall be implemented throughout the operation of the pit / quarry. The data collected through the monitoring program will allow the aggregate operator to identify the potential for impacts to neighbouring private water wells before they occur. This will provide the aggregate operator with relevant information to proactively address potential interference with neighbouring water supplies before impacts occur. Furthermore, an additional private well survey shall be conducted prior to the start of aggregate operations at the Site, to help establish water use, well construction details and the available drawdown within each neighbouring private well.

Well complaints in the neighbouring area shall be evaluated on a case by case basis and the appropriate actions shall be undertaken to address the issue, as is the current practice by CBM at all its pits and quarries. Although the potential impacts on wells related to the proposed pit / quarry development is generally expected to be minimal, CBM shall respond to well complaints in accordance with the procedures proposed herein. The process is described below.

Water Well Interference Process

If a water well complaint is received by CBM for a private well located within the estimated zone of influence (within 1,000 m) the following actions shall be taken:

- A representative from CBM shall meet with the resident and discuss the complaint. If warranted, CBM shall contact a local well contractor, and the resident shall be immediately supplied a temporary water source if the issue cannot be easily determined and rectified (see steps below).
- If the issue raised by the resident is related to a loss of water supply, CBM shall have a consultant / well contractor determine the likely causes of the loss of water supply, which can result from a number of factors, including pump failure, extended overuse of the well or lowering of the water level in the well from potential

Golder Associates Ltd.
210 Sheldon Drive, Cambridge, Ontario, N1T 1A8, Canada T: +1 519 620 1222 F: +1 519 620 9878

aggregate operations interference. This assessment process would be carried out at the expense of the aggregate operator and the results of the assessment shall be provided to the resident.

- The consultant / well contractor will be able to readily determine if pump failure is the problem and, should the resident choose to have the pump repaired or replaced at their expense, the well contractor would correct the situation for the resident. If well capacity in relation to the demand being placed on the well by the resident (i.e., extended overuse) is determined to be the issue by the consultant / well contractor, recommendations shall be provided to the resident for their consideration, implementation of which would be at their expense.
- If, however, well interference is determined to potentially have been caused by CBM aggregate extraction and dewatering activities, then water well supply mitigation shall be reviewed with the resident and the best course of action to restore an equivalent water supply to the resident shall be implemented at CBM's expense. For instance, if the water level in the well is lowered to a point where it has interfered with pumping, then potential solutions shall be evaluated including adjusting the pump pressure and / or lowering the pump level in the well.
- In the event that the well is incapable of providing an adequate supply of water (i.e., the water level is too low in comparison to the depth of the well), or the repair to the pumping system will be more than a day, the consultant / well contractor shall continue to supply a potable water source to the resident (until restoration of the well is complete). These actions would be carried out at the expense of CBM. In rare cases where the water level in the well has been lowered significantly, the well may have to be deepened, widened or relocated (also CBM's expense).

In summary, should mitigation options be required as a result of CBM's extraction and dewatering activities negatively affecting neighbouring water well levels, these options could potentially include the following measures:

1) lowering of the pump to take advantage of existing storage within the well;
2) deepening of the well to increase the available water column;
3) widening of the well to increase the available storage of water;
4) relocation of the well to another area on the property;
5) installing a cistern for additional storage that can be filled with water from the existing well on a low yield setting; and/or
6) the installation of multiple wells that would collectively deliver the required water supply to the resident.

The requirement for any of these mitigation measures would be determined based on the results of the groundwater monitoring program and the assessment of the specific private water supply well in question. It would also take into account the recommendation of the consultant and/or well contractor that were involved in the assessment.

Contact Information

The public would be provided with contact information for CBM employees in the following positions at the start of operations:

1) Land & Resource Manager
2) Area Manager
3) Plant Manager

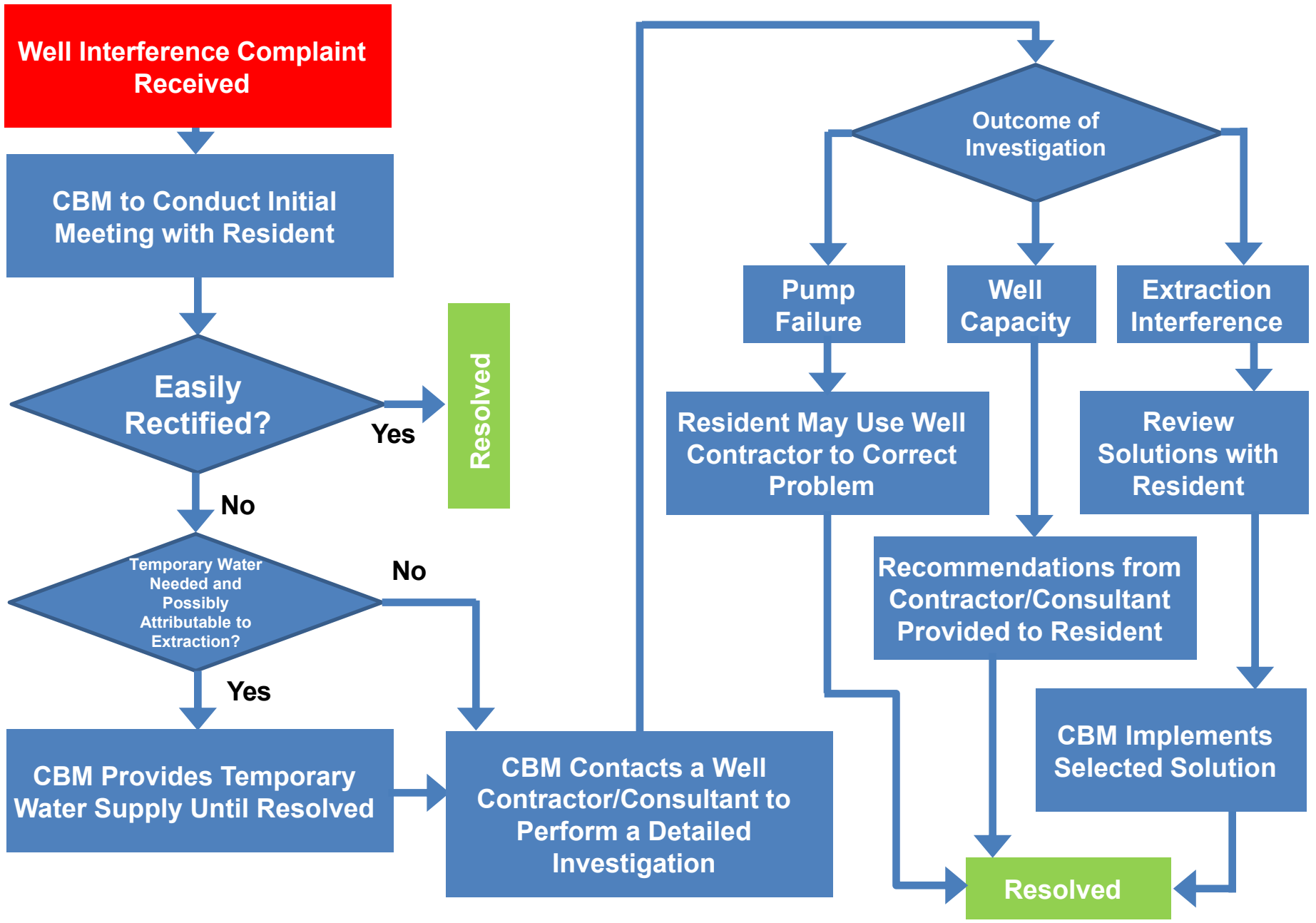
Contact information, including cell phone number and email address, would be provided for each person filling these positions at the start of operations and would be updated, as needed, during the duration of the operation.

Attachments: Well Interference Complaint Response Flow Chart

https://golderassociates.sharepoint.com/sites/114392/project files/5 technical work/ph 2300-hydrogeology/30 impact assessment/07 well complaint protocol/19129150 cbm well complaint response plan 09dec2022.docx

ATTACHMENT

Well Interference Complaint Response Flow Chart



CLIENT
CBM AGGREGATES (CBM), A DIVISION OF ST. MARYS CEMENT INC. (CANADA)

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	2022-12-06
PREPARED	PGM
DESIGN	PGM
REVIEW	GRP
APPROVED	GWS

PROJECT
Caledon Pit and Quarry

TITLE
Well Interference Complaint Response Flow Chart

PROJECT No.	PHASE	Rev.	FIGURE
19129150	2300	A	R-1

APPENDIX T

Project Team CVs

Education

MSc. Earth Sciences, University of Waterloo, 1995

BSc. Honours Earth Sciences, Physics Minor, University of Waterloo, 1987

Areas of Experience

Large Project Management

Aggregates

Water Resources and Protection

Nuclear Waste Management

Mine Site and Tailings Investigations

Explosives Site Assessment

Contaminated Site Assessment

Geothermal Energy

Waste Management

Engineering Geophysics

Archaeology

Applied Geophysics Research

George Schneider, MSc., P.Geo.

PROFESSIONAL SUMMARY

George Schneider is a Senior Geoscientist and Principal with Golder's Greater Toronto Area (GTA) Operations and has over 30 years of professional experience. George received his B.Sc. (1987) and M.Sc. (1995) in Earth Sciences from the University of Waterloo. From 1987 to 1995, he was a researcher in the Geophysics Laboratory at the Centre for Groundwater Research at the University of Waterloo and has co-authored more than 25 technical publications. George joined Golder in 1995; he became an Associate in 2002 and a Principal in 2006. George is a Professional Geoscientist registered in the Province of Ontario.

EMPLOYMENT HISTORY

Principal / Senior Geoscientist, Golder Associates (2013 to Present)

Cambridge, Ontario

Project Manager / Director responsible for multi-disciplinary projects including: nuclear waste management, explosives site remediation, mine site rehabilitation, aggregate resource studies, and groundwater supply and source water protection studies. George has been with Golder for 23 years, he is currently a leader of the Canadian Nuclear Services Group, responsible for project management, business development and client relations.

George is currently serving as a member of the Lake Erie Source Protection Committee (LESWPC) and the Waterloo-Wellington-Brant Regional Committee of the Ontario Stone Sand and Gravel Association (OSSGA).

Principal / Division Manager, Golder Associates (2006 to 2013)

Mississauga, Cambridge and Whitby, Ontario

Project director responsible for a range of multi-disciplinary projects including: environmental investigations at explosive contaminated sites and mine sites, aggregate resource studies, groundwater supply and management studies and nuclear waste management. Managed the Environmental Services Division in the GTA including: Geosciences, Geophysics, Site Characterization and Restoration, Environmental Due Diligence, Hydrogeology and Waste Management and Field Technician Groups.

Associate / Senior Project Manager, Golder Associates (2002 to 2005)

Mississauga, Ontario

Senior geoscientist responsible for the management of a diverse range of projects including: environmental investigations at explosive contaminated sites, aggregate resource studies, hydrogeological studies and geophysical investigations in support of hydrogeological studies, environmental site

assessments, mine site developments, aggregate resource studies and geotechnical investigations.

Intermediate, then Senior Geoscientist, Golder Associates (1995 to 2002)

Waterloo, then Mississauga, Ontario

Responsible for project management, performing geophysical, geological and hydrogeological field investigations, numerical data analysis, data assessment, and reporting for: aggregate resource studies, groundwater resource studies, permits to take water, assessment of contaminated sites, geotechnical investigations and hydrogeologic characterization of mine tailings disposal and open pit mine sites.

Collected, processed and interpreted data for a variety of land and marine geophysical techniques including: time and frequency domain electromagnetics, magnetics, gravity, ground penetrating radar (GPR), seismic reflection and refraction, acoustic tomography, pulse velocity testing of man-made structures, cross-hole seismic testing, leak detection, vertical seismic profiling (VSP), electrical resistivity imaging (ERI), borehole camera logging and geophysical well logging including: natural gamma, gamma-gamma, neutron, temperature, deviation, inductive conductivity, magnetic, caliper, resistivity, heat-pulse flowmeter and optical televiewer.

Geophysicist, Waterloo Centre for Groundwater Research (1987 to 1995)

University of Waterloo, Waterloo, Ontario

Conducted geophysical field investigations and drilling programmes under the direction of Dr. J.P. Greenhouse and Dr. P.F. Karrow in the Waterloo Region related to the quaternary geology and the assessment of water resources in the Region including: seismic surveys, borehole geophysical surveys and two Rotasonic drilling programmes. Compiled three editions of a catalogue of geophysical logs for the Waterloo Region from 1988 to 1993. Co-authored more than 20 research papers, reports and posters, including 13 publications on the quaternary geology and/or water resources of the Waterloo Region.

Designed and constructed borehole and resistivity geophysical instruments, digital data acquisitions systems and developed innovative computer software for geophysical and hydrogeological applications. Carried out surface, borehole and laboratory geophysical investigations in support of more than 85 groundwater-related research projects including: geophysical investigations of DNAPL/LNAPL contamination, delineation of aquifers, groundwater contaminant plumes and karst features.

Other duties included: teaching assistance for University of Waterloo Earth Sciences and Geophysics courses and organization of technical conferences, short courses and field demonstrations.

RELEVANT EXPERIENCE

Project Experience – Large Project Management (>$1M)

Phase 2 Initial Drilling and Testing, Ignace - NWMO (2017- 2020)
Ignace, Ontario

Project manager and senior geoscientist responsible for the Phase 2 Initial Borehole Drilling and Testing in the Ignace Area. Main point of contact to NWMO responsible for project management, HSSE, QA/QC, schedule tracking, budget and earned value tracking, change management, and subcontractors. Managed daily activities on the project including planning and coordination of multiple work packages, including site infrastructure setup, drilling, core logging, core sampling, downhole geophysics, hydraulic testing, and the installation of Westbay monitoring systems.

Phase 1 and Phase 2 Geoscientific and Environmental Studies - NWMO (2009-2017)
Canada

Project manager responsible for geoscientific, geophysical and environmental studies conducted by Golder for NWMO including reports on: assessment of geophysical methods for site characterization, Initial Screenings, Phase 1 Geoscientific Assessments, Phase 1 Reports on Environment and Safety, and Phase 2 OGGF and Detailed Mapping. Specific experience at Ignace and other communities in northern Ontario and Saskatchewan.

IUS Project – Region of Waterloo (2005-2014)
Waterloo Region, Ontario

The hydrogeological assessment and permitting of existing and potential new Municipal supply Wells for the Region of Waterloo's Integrated Urban Supply System. Project manager, responsible for technical tasks, invoicing, budgeting, tendering and contract administration, presentations, interim and final reporting. Performed a technical role in the water supply development and expansion tasks carried out at the Chicopee, Breslau, Fountain Street, Lancaster, Seagrams and Waterloo North study areas.

Coldstream Mine Site - EWL Management Ltd. (2003-2015)
Kashabowie, Ontario

Project Manager and senior geoscientist responsible for environmental investigations and remediation at this former mine site. Work has included surface water, groundwater and ecological studies, assessment of above water and below water tailings management areas, ecological and human health risk assessment, tailings relocation, spillway and watercourse improvements, predictive modelling, public consultation, and negotiations with regulatory agencies.

CIL Explosives Site – Akzo Nobel Coatings Ltd. (1998-2019)
Parry Sound, Ontario

Project Manager and senior geoscientist responsible for environmental investigations and remediation at this former mine site. Work has included surface water, groundwater and ecological studies, assessment of above water and below water tailings management areas, ecological and human health risk assessment, tailings relocation, spillway and watercourse improvements, predictive modelling, public consultation, and negotiations with regulatory agencies.

McMasterville Site – Akzo Nobel Coatings Ltd. (1999-2016)
McMasterville, Quebec

Project manager for the assessment and remediation of this former explosives and fertilizer manufacturing site, which operated from the 1890 to 1999 and manufactured a wide range of products including TNT, nitroglycerine, PETN, slurries, and fertilizers. Work has included: geophysical investigations, remote control drilling for explosives contaminants, Phase I ESA, Phase II ESA, risk assessment, ecological assessment, diversion and repatriation of a creek, construction of an onsite landfill and risk-managed area, and ongoing surface water and groundwater monitoring.

Project Experience – Aggregates

Aggregate Licence Investigations (2019-present) Caledon, Ontario	Project Director and Senior Technical Reviewer for resource and hydrogeological technical studies at the Caledon properties for CBM Aggregates for a future below water table quarry licence application near Caledon, Ontario.
Aggregate Licence Investigations (2018-present) Peterborough, Ontario	Project Director and Senior Technical Reviewer for hydrogeological, natural environment and cultural heritage technical studies at the Blezard property for CBM Aggregates near Peterborough, Ontario.
Resource Evaluation – CBM (2018) Ayr, Ontario	Project Manager and Senior Technical Reviewer for an aggregate resource assessment at the Bromberg Pit for CBM Aggregates near Ayr Ontario.
Resource and Hydrogeological Investigation – CBM (2018) Dorchester, Ontario	Project Director and Senior Technical Reviewer for aggregate resource and hydrogeological studies at the Dorchester Pit for CBM Aggregates to support a Site Plan Amendment.
Resource and Hydrogeological Investigation – CBM (2018) Thamesford, Ontario	Project Director and Senior Technical Reviewer for aggregate resource and hydrogeological studies at the Thamesford Pit for CBM Aggregates to support a Site Plan Amendment.
Aggregate Licence Investigations – CBM (2018-present) Puslinch, Ontario	Project Director and Senior Technical Reviewer for hydrogeological, natural environment and cultural heritage studies at the Lake property for CBM Aggregates in Puslinch, Ontario.
Resource and Hydrogeological Investigation – CBM (2017) Puslinch, Ontario	Project Director and Senior Technical Reviewer for aggregate resource and hydrogeological studies at the Lanci Pit for CBM Aggregates to support a Site Plan Amendment.
Resource Evaluation – CBM (2017) North Dumfries, Ontario	Project Manager and Senior Technical Reviewer for an aggregate resource assessment at the Dabrowski Pit for CBM Aggregates.
Resource Evaluation – CBM (2017) Puslinch, Ontario	Project Manager and Senior Technical Reviewer for an aggregate resource assessment at the McNally Pit in support the expropriation of land for highway development at the McNally Pit for CBM Aggregates.
Resource and Hydrogeological Investigation – CBM (2016) North Dumfries, Ontario	Project Director and Senior Technical Reviewer for an aggregate resource evaluation and Level 1&2 Hydrogeological Assessment at the Dance Pit for CBM Aggregates in North Dumfries, Ontario.
Imported Fill Investigation – CBM (2016) Limehouse, Ontario	Project Manager for a soil sampling investigation to confirm imported soil quality at the CBM Pit near Limehouse, Ontario.
Resource Evaluation – CBM (2016) Orangeville, Ontario	Project Director and Senior Technical Reviewer for an aggregate resource evaluation at the Gray Pit for CBM Aggregates near Orangeville, Ontario.

Resource and Hydrogeological Investigation – CBM (2016) North Dumfries, Ontario	Project Director and Senior Technical Reviewer for an aggregate resource evaluation and Level 1&2 Hydrogeological Assessment at the Dance Pit for CBM Aggregates in North Dumfries, Ontario.
Aggregate Investigations - MTO Northeast (2015) North Bay, Ontario	Project Manager for aggregate investigations on numerous Crown land sites for MTO Northeast. Work included resource assessments, Level 1 / 2 Hydrogeological, Natural Heritage and Cultural Heritage Assessments, in support of Pit and Quarry Permits.
Resource Evaluation and Expert Testimony- Ministry of Transportation Ontario (2013-2014) Ontario	Provided specialized forensic engineering / geological advice and services related to aggregate resources on a property in northern Ontario. Work included resource modelling and resource valuation for a variety of potential land development scenarios.
Resource Evaluation Arriscraft International (2011) Ontario	Conducted a geological testing program and completed a resource evaluation of the Hill Top Pit Property in Kitchener, Ontario. Resource evaluation results were used in the appraisal of the property for the purposes of acquisition.
Aggregate Properties Valuation – Confidential (2011) Ontario, Alberta	Conducted valuation studies of more than a dozen aggregate properties in Ontario and Alberta to estimate the net present value of these properties for the purposes of financing.
Aggregate Source Investigations – MTO (2010-2011) Northeastern Ontario	Project Director and senior technical reviewer for the geological and hydrogeological components of the 2010 Northeastern Region Aggregate Source Investigation (MTO Assignment NO. 5010-E-0003) which included assessment and permitting studies for 23 sites across Ontario.
Resource Evaluation, Weeks Pit and Quarry – Altus Group (2010-2011) Parry Sound, Ontario	Senior technical review for an investigation to estimate the total aggregate resources available at the Weeks Pit and quarry property, in order to assist in the valuation of the property to settle an expropriation dispute with the owner and the MTO.
Feasibility Assessment – Lafarge (2010) Harvey Township, Ontario	Senior technical review for an investigation to assess the feasibility for the development of a limestone quarry on the Buckhorn Property in support of the renewal of a mining lease for the property.
Soil Borrow Search - IBI Group (2009-2010) Niagara, Ontario	Senior technical reviewer for a soil borrow search in the Niagara Region for the MTO, in support of new construction activities on Highway 406.
Geophysical Investigation – Confidential (2007) Ontario	Project manager and senior technical advisor for a geophysical and test pitting investigation at a confidential quarry site in Ontario to assess the potential presence of buried waste, as part of a legal claim.
Preliminary Resource Evaluation – SCAW (2004) Caledon, Ontario	Directed junior staff in a preliminary assessment of the potential for aggregate resources to be present on a property in Caledon, Ontario on behalf of the property owner.

Borehole Geophysical Logging – Confidential (2004)
Brechin, Ontario

Acquired gamma and conductivity borehole geophysical logs at a property near Brechin, Ontario for a confidential client.

Acton Quarry Escarpment Seep Investigation - Dufferin Aggregates (2003)
Acton, Ontario

Led a multidisciplinary project team in an investigation to assess hydrogeologic conditions at Phase 2 of the Acton Quarry and develop conceptual designs for short term and long term hydrogeologic mitigation systems to maintain seep flow in the Guelph-Amabel Formation along the Niagara Escarpment, immediately adjacent to advancing quarry workings.

Resource Evaluation – Dufferin Aggregates (2003)
Ontario

Led a project team to carry out a resource evaluation of the Mosport West Pit property for Dufferin Aggregates. The project involved the integration of high quality coring methods, gradation testing of core samples and ERI (electrical resistivity imaging) geophysical surveying to develop realistic 3D subsurface geologic models for these properties, from which available resources were then estimated and areas of preferred extraction were identified. Duties included: planning, ERI field QA/QC, ERI interpretation, correlation of geophysical and gradation data to establish empirical relationships between ERI response and resource quality and reporting.

ERI Investigation – Nelson Aggregates (2003)
Burlington, Ontario

Directed junior staff in an ERI geophysical investigation to map overburden thickness and assess the underlying rock for karst potential as part of a Level 2 Hydrogeological Assessment under the Aggregate Resources Act, for the planned expansion of the Nelson Quarry in Burlington, Ontario.

Aggregate Resource Evaluation – Confidential (2003)
Sudbury, Ontario

Carried out an evaluation of the potential aggregate resources present on properties in Dill Township near Sudbury, Ontario in support of the appraisal of the properties, which were to be expropriated from the owner by the MTO for the construction of an interchange and highway realignment.

Overburden Investigation – Dufferin Aggregates (2002)
Milton, Ontario

Conducted an ERI (electrical resistivity imaging) and test pitting investigation to develop a 3D model of overburden thickness and the top of bedrock to assist in planning overburden stripping requirements for Dufferin Aggregates in the Western Extension of the Milton North Quarry. Responsible for all aspects of planning, acquisition, processing, interpretation and reporting, as well as client liaison.

Gravel Pit Evaluation - Township of Perth East (2002)
Shakespeare, Ontario

Conducted an investigation to complete a resource evaluation, assess the net present value and make recommendations for optimization to the Perth East Gravel Pit near Shakespeare, Ontario. The Project Team consisted of Golder Associates Ltd., Beck and Associates GeoConsultants Inc. and MHBC Planning Ltd.

Aggregate Properties Valuation – Confidential (2002)
Ontario

Led a multidisciplinary project team which conducted valuations studies of four large aggregate properties in Ontario to estimate the net present value of these properties for the purposes of obtaining bank financing. The Project Team consisted of Golder Associates Ltd., Beck and Associates GeoConsultants Inc. and MHBC Planning Ltd.

Acton Quarry Resource Evaluation – Dufferin Aggregates (2002)
Acton, Ontario

Conducted a resource evaluation and estimated overburden stripping requirements for Phase 3 of the Acton Quarry, which involved ERI geophysical surveying, test pitting and drilling. Responsible for all aspects of

planning, acquisition, processing, interpretation and reporting, as well as client liaison.

Overburden Investigation – Dufferin Aggregates (2001)
Milton, Ontario

Conducted a GPR and test pitting investigation to develop a 3D model of overburden thickness and the top of bedrock to assist in planning overburden stripping requirements for Dufferin Aggregates in the Milton North Quarry. Responsible for all aspects of planning, acquisition, processing, interpretation and reporting, as well as client liaison.

Quarry Resource Assessment – Dufferin Aggregates (2001)
Ontario

Acquired, processed, interpreted and reported gamma and conductivity geophysical log surveys in test boreholes at the Ogden Point Limestone Quarry to identify the stratigraphy within a Regional context and infer the suitability of strata within the quarry for use in the manufacture of cement products, based on experience elsewhere in Ontario.

Resource Evaluations – Dufferin Aggregates (1998-1999)
Ontario

Helped conduct sand and gravel resource evaluations as part of a multidisciplinary project team for Dufferin Aggregates at sand and gravel properties in Ontario including Mosport Pit 1 and 2, Bethany, TRT, Mill Creek, Paris and Naylor properties. The projects involved the integration of high quality coring methods, gradation testing of core samples and ERI (electrical resistivity imaging) geophysical surveying to develop realistic 3D subsurface geologic models for these properties, from which available resources were then estimated and areas of preferred extraction were identified. Duties included: ERI modelling and interpretation, 3D geological modelling, correlation of geophysical and gradation data to establish empirical relationships between ERI response and resource quality, volume and tonnage estimates and reporting.

Project Experience – Water Resources and Protection

Hydrogeological Assessment – Cambridge Zone 3 Class EA – Region of Waterloo (2016-2019) Cambridge, Ontario	As a subcontractor to GM BluePlan, completed a hydrogeological assessment for the Region of Waterloo of the Cambridge Zone 3 Well Field, as part of a class EA, to examine options to increase the sustainable water supply capacity of the well field. Project Director and Senior Technical Reviewer.
Hydrogeological Assessment – Harrington McAvan (2015 – 2019) Puslinch, Ontario	Carried out a hydrogeological and geotechnical assessment to support the re-zoning and future redevelopment of a property near Puslinch, Ontario for Farhi Holdings, including a preliminary assessment of potential water resources and septic capacity. Project Manager and Senior Technical Reviewer.
Municipal Well Construction and Testing (2015-2019) Waterloo Region, Ontario	Project manager, contract administrator and senior technical reviewer for the construction and testing of new municipal supply wells in 2015 at K21, K4A and W6A/B and in 2016 at NH3 and Maryhill. Designed, constructed and permitted new supply wells at each of these sites in order to replace older wells with performance problems, provide system redundancy and help ensure the well fields can deliver their full permitted capacity.
Hydrogeological Assessment of Production Wells K23 and K24 (2014-2018) Waterloo Region, Ontario	Senior technical reviewer for the hydrogeological assessment of wells K23 and K24, initiated in 2014 to better understand increasing nitrate concentrations in the wells due to nearby anthropogenic sources, primarily septic systems and agricultural fertilizers. The investigation is developing an improved understanding of the hydrogeology, aquifer vulnerability and water quality in areas around the supply wells and the interrelationships between the wells and potential contaminant sources.
Hydrogeologic Data Analysis Software System Update (2014-present) Waterloo Region, Ontario	Project manager and senior technical reviewer for the selection and implementation of a new hydrogeologic data analysis (HDA) system for the Region. The project involved a detailed assessment of the Region's current and future data needs, the procurement and evaluation of potential commercial software solutions, and the implementation of the new software database and tools.
Hydrogeologic and Source Water Protection Services (2013-2018) Centre Wellington, Ontario	Senior technical reviewer for hydrogeologic and source water protection services provided on an as-needed basis to the Township of Centre Wellington. The work includes on-going investigations and monitoring related to source water "Issues", as well as the evaluation of the hydrogeological aspects of infrastructure and development projects on behalf of the Township.
Hydrogeologic Services - Cambridge Aggregates (2008-present) North Dumfries and Brant, Ontario	Senior technical reviewer for various projects for Cambridge Aggregates related to the development of large volume groundwater supply wells and Permits to Take Water for aggregate washing, and hydrogeological assessments in support of new licence applications and licence expansions under the Aggregate Resources Act.
Water Supply Class EA – Region of Waterloo (2010-2012) West Montrose, Ontario, Canada	Senior technical reviewer for the hydrogeological component of a Water Supply Class Environmental Assessment for West Montrose. The hydrogeological component involved the exploration for an additional water supply within West Montrose. Through a field program involving drilling, hydraulic testing and water quality sampling a potential groundwater supply source was identified and carried forward as part of the assessment.

TICS Project – Region of Waterloo (2009-2012) Waterloo Region, Ontario	Project manager for the Threats Inventory and Circumstances Survey (TICS) project for the Region of Waterloo. The project involved conducting Canada's largest drinking water census across the Waterloo Region and the evaluation of potential threats to drinking water sources in the Waterloo Region for each well field and surface water intake source.
Waterloo North Water Supply Class EA – Region of Waterloo (2008-2012) Waterloo Region, Ontario	Senior technical advisor to the class EA project carried out for the Region of Waterloo with AECOM to develop additional groundwater supply wells in North Waterloo and Erbsville. The project involved the drilling of a new test supply well and a long term pumping test of three new supply wells, along with an extensive groundwater monitoring program.
New Wells Project – Region of Waterloo (2008-2009) Waterloo Region, Ontario	Senior technical advisor to the project to install over 40 new monitoring wells nests throughout the Waterloo Region. Focus was on senior technical review and the interpretation of overburden and bedrock stratigraphy based on core logs, core photographs and samples, grain size analysis and geophysical logs, using nomenclature recently developed by the Ontario Geologic Survey (OGS).
Land Use Designations for Source Water Protection – Brookfield Homes (2007) Paris, Ontario	Manager and senior technical review on a project to evaluate potential changes in land use designation within WHPAs and the associated change in risk to groundwater to well fields, that have high aquifer vulnerability ratings for a proposed development in Paris, Ontario.
Geophysical Investigation, Middleton Wellfield – Stantec (2005) Cambridge, Ontario	Manager and senior technical reviewer on a project to use geophysical methods to map the top of bedrock and identify buried infrastructure around the Middleton Wellfield, in order to identify potential contaminant pathways to the shallow bedrock aquifer system.
IUS Project – Region of Waterloo (2005-present) Waterloo Region, Ontario	The hydrogeological assessment and permitting of existing and potential new Municipal supply Wells for the Region of Waterloo's Integrated Urban Supply System. Assistant project manager, responsible for technical tasks, invoicing, budgeting, tendering and contract administration, presentations, interim and final reporting. Performed a technical role in the water supply development and expansion tasks carried out at the Chicopee, Breslau, Fountain Street, Lancaster, Seagrams and Waterloo North study areas.
Permit to Take Water – Lafarge (2002) Guelph, Ontario	Completed a hydrogeologic study to support a permit to take water (PTTW) application for Lafarge Canada at the Guelph Asphalt and Ready Mix Concrete Plant in Guelph, Ontario.
Permit to Take Water – Lafarge (2002) New Lowell, Ontario	Completed a hydrogeologic study to support a permit to take water (PTTW) application for Lafarge Canada at the Home Pit in New Lowell, Ontario.
Permit to Take Water – Heritage Golf Club (2002) Barrie, Ontario	Completed a hydrogeologic study to support a permit to take water (PTTW) application for Heritage Golf Club near Barrie, Ontario. The work included the supervision and analysis of a 24 hour pumping test.
Geophysical Logging Investigation – Golder (1994) Cambridge, Ontario	Acquired, processed, interpreted and reported on gamma and neutron geophysical logs in a test supply well in Cambridge East, Ontario as part of a water supply development programme for Golder Associates.

Groundwater Study - Victoria County (2000) Oak Ridges Moraine, Ontario	Acquired gamma and conductivity geophysical logs in deep boreholes in the Oak Ridges Moraine as part of the Groundwater Study for Victoria County.
Oxford County Groundwater Study – Oxford County (2000) Stratford, Ontario	Acquired gamma, conductivity, heat pulse flowmeter and optical televiewer geophysical logs in Municipal Supply wells in the Town of Stratford, Ontario, as part of the Oxford County Groundwater Study.
Permit to Take Water – Lafarge (2001) New Dundee, Ontario	Completed a hydrogeologic study to support a permit to take water (PTTW) application for Lafarge Canada at Warren Bitulithic's Seibert Pit in New Dundee, Ontario.
Rotasonic Drilling Programme – Waterloo Region University of Waterloo (1990-1991) Waterloo, Ontario	Under the direction of Dr. P.F. Karrow, carried out all aspects of two drilling programmes in 1990 and 1991 including: siting, permitting, utility clearances, drill supervision, well development, geophysical logging, vertical seismic profiling and reporting.
Borehole Geophysical Logging and Well Log Catalogue for the Waterloo Region University of Waterloo (1987-1993) Waterloo, Ontario	Under the direction of Dr. J.P. Greenhouse, acquired the first digital geophysical logs in the Waterloo Region including: gamma, density, neutron, resistivity, conductivity and caliper log data. Collected and digitized historic logs, as well as digital logs from local consultants. Compiled these logs into a Catalogue in Viewlog format. This log catalogue formed the basis of the current understanding of the quaternary geology and overburden aquifer system in the Waterloo Region.
Seismic Reflection and VSP Studies – Waterloo Region - University of Waterloo (1987-1995) Waterloo, Ontario	Under the direction of Dr. J.P. Greenhouse, carried out pioneering investigative work to optimise high resolution shallow seismic reflection and vertical seismic profiling geophysical methods for the characterisation of geology and aquifers in the Waterloo Region. This work culminated in the development of a controlled vibratory source for high resolution seismic surveys.

Professional Affiliations

Practising Member, Association of Professional Geoscientists of Ontario

Active Member, Society of Exploration Geophysicists

Member, Canadian Nuclear Society

Publications

Monier-Williams, M.E., Davis, R.K., Paillet, F.L., Turpening, R.M., Sol, S.J.Y. and Schneider, G.W. 2009. Review of Borehole Based Geophysical Site Evaluation Tools and Techniques. NWMO Technical Report TR-2009-25, 174 p.

Emsley, S., Schneider, G.W., Sol, S.J.Y., Fleming, J. and Fairs, J. 2008. Review of Satellite, Airborne and Surface Based Geophysical Tools and Techniques for Screening Potential Nuclear Repository Candidate Sites. NWMO Technical Report TR-2008-15, 143 p.

Gill, J.B. and Schneider, G.W. 2005. Innovative Aggregate Resource Evaluations using Electrical Resistivity Imaging. In the proceedings of the 56th Highway Geology Symposium, Wilmington, North Carolina, May 2005, 15 p.

Schneider, G.W., Nobes, D.C., Lockhard, M.A. and Greenhouse, J.P. 1997. Urban Geophysics in the Kitchener-Waterloo Region, Ontario. In: Environmental Geology of Urban Areas, Geological Association of Canada, Edited by Nicholas Eyles, pp. 457-464.

Nobes, D.C. and Schneider, G.W., 1996. Results of Downhole Geophysical Measurements and Vertical Seismic Profile from the Canandaigua Borehole of New York State Finger Lakes. In: Subsurface Geologic Investigations of New York Finger Lakes: Implications for Late Quaternary Deglaciation and Environmental Change, Special Paper 311, The Geological Society of America, Edited by Henry T. Mullins and Nicholas Eyles, pp. 51-64.

Schneider, G.W. and Vanderkooy, J., 1996. A vibratory seismic system for high-resolution applications. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Keystone, Colorado, April 28-May 1, 1996, pp. 181-188.

Sanderson M., Karrow P.F., Greenhouse J.P., Paloschi G.V.R., Schneider G., Mulamoottil G., Mason C., McBean E.A., Fitzpatrick P.N., Mitchell B., Shrubsole D., Child E., 1995. Canadian Water Resources Journal, Vol. 20, No. 3, pp. 145-160.

Schneider, G.W., Nobes, D.C., Lockhard, M.L., and Greenhouse, J.P., 1994. Urban Geology 4. Urban Geophysics in the Kitchener-Waterloo Region. Geoscience Canada, Volume 20, Number 4, pp. 149-156.

Sanderson, M., Karrow, P.F., Greenhouse, J.P., Paloschi, G.V.R., Schneider, G.W., Mulamoottil, G., Mason, C., Fitzpatrick, N., McBean, E., Mitchell, B., and Shrubsole, D., 1994. Susceptibility of groundwater to

contamination in Kitchener-Waterloo: A case study with policy implications. Waterloo '94, Abstracts of GAC-MAC Annual meeting, May, 1994.

Greenhouse, J.P., and Schneider, G.W., 1994. Geophysics and Groundwater Supply in the Waterloo Region. A Poster. Waterloo '94, Abstracts of GAC-MAC Annual Meeting, May, 1994.

Schneider, G.W., and Greenhouse, J.P., 1994. The Geophysical Log Catalogue for the Waterloo Region. A Poster. Waterloo '94, Abstracts of GAC-MAC Annual Meeting, May, 1994.

Endres, A.L., Coe, R.D., Gilson, E.W., Zawadzki, A.A., Schneider, G.W. and Greenhouse, J.P., 1993. The use of neutron logging methods for the detection and monitoring of chlorinated solvents: A quantitative study. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, San Diego, California, April 18-22, 1993, pp. 39-50.

Karrow, P.F., Greenhouse, J.P., Paloschi, J.V.R., and Schneider, G.W., 1993. The 1990-91 Rotasonic drilling programme. Final Report to the Ontario MOEE as part of work under grant #E564G, 181 p.

Schneider, G.W. 1993b. Geophysical well logs for the Waterloo Region and surrounding areas: A catalogue (Third Edition). Quaternary Sciences Institute Publication #9, Department of Earth Sciences, University of Waterloo, 699 p.

Schneider, G.W., DeRyck, S.M., and Ferre, P.A., 1993a. The application of automated high-resolution DC resistivity in monitoring hydrogeological field experiments. Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, San Diego, California, April 18-22, 1993, pp. 145-162.

Annan, A.P., Brewster, M.L., Greenhouse, J.P., Redman, J.D., Schneider, G.W., Olhoeft, G.R., and Sander, K.A., 1992. Geophysical monitoring of DNAPL migration in a sandy aquifer. Expanded Abstracts SEG 62nd Annual Meeting, October, New Orleans, USA.

Brewster, M.L., Annan, A.P., Greenhouse, J.P., Schneider, G.W., and Redman, J.D., 1992. Geophysical detection of DNAPLs: Field experiments. IAH Conference "Modern Trends in Hydrogeology", May 10-13th, Hamilton, Ontario, Canada.

Schneider, G.W., and Greenhouse, J.P., 1992. Geophysical detection of perchloroethylene in a sandy aquifer using resistivity and nuclear logging techniques. Proceedings of the Symposium of the Application of Geophysics to Engineering and Environmental Problems, April 26-29th, 1992, Oakbrook, Illinois, USA, pp. 619-628.

Greenhouse, J.P., Brewster, M.L., Schneider, G.W., Redman, J.D., Annan, A.P., Olhoeft, G.R., Lucius, J., Sander, K.A., and Mazzella, A., 1991. Geophysics and solvents: The Borden experiments. The Leading Edge, Vol. 12, pp. 261-267.

Greenhouse, J.P., Nobes, D.C., Schneider, G.W. and Lockhard, M.L., 1991. Modification of the Shallow Seismic Reflection Method for Urban Geophysical Studies in Southern Ontario. Ontario Geological Survey Miscellaneous Paper #156, pp. 121-130.

Schneider, G.W., Nobes, D.C., Lockhard, M.L., and Greenhouse, J.P., 1991. Urban geophysics in the Kitchener-Waterloo region. Geological Association of Canada Program with Abstracts, Vol. 16, pp. A111. Presented at the 1991 Annual Meeting of the Geological Association of Canada, Toronto, Ontario, Canada.

Greenhouse, J.P., Nobes, D.C., and Schneider, G.W., 1990. Groundwater beneath the city: A geophysical study. Ground Water Management, Vol. 2, pp. 1179-1191. Proceedings of the Fourth Annual Outdoor Action Conference on Aquifer Restoration, Groundwater Monitoring and Geophysical Methods, Las Vegas, Nevada, USA.

Schneider, G.W., and Greenhouse, J.P., 1989. Geophysical well logs for the Waterloo Region and surrounding areas: A catalogue (Second Edition). Report of the Geophysics Lab, Department of Earth Sciences, University of Waterloo, 158 p.

Schneider, G.W., and Greenhouse, J.P., 1988b. The Columbia Test Site: Targets for EM/Magnetics/GPR Calibration. Report of the Geophysics Lab, University of Waterloo, 55 p.

Schneider, G.W., and Greenhouse, J.P., 1988a. Geophysical well logs for the Waterloo Region and surrounding areas: A catalogue. Report of the Geophysics Lab, Department of Earth Sciences, University of Waterloo, 110 p.

Nobes, D.C., Schneider, G.W., and Hodgson, S., 1987. Discussion on: "Effects of porosity and clay content on wave velocities in sandstones". Geophysics, Vol. 52 pp. 1439.

Education

BSc Engineering (Co-op), University of Guelph, Guelph, Ontario, 2007

Languages

English – Fluent

Golder Associates Ltd. – Mississauga

Employment History

Golder Associates Ltd. – Mississauga, Ontario
Water Resources Specialist (2007 to Present)

Responsible for conducting water quantity and water quality investigation programs that include hydraulic and hydrologic modelling, analysis of riverine and lacustrine environments, the design, execution and management of meteorological, hydrological and water quality field programs and development of water balance and water quality modelling analyses. Currently working on various surface mine and mine rehabilitation investigations of hydrology and water quality. Completes water resources projects from desktop reviews to design, construction monitoring and erosion and sediment control inspection.

Golder Associates Ltd. – Mississauga, Ontario
Water Resources (Co-Op) (May 2006 to December 2006)

University of Guelph, Environmental Biology – Guelph, Ontario
Co-Op Student (May 2005 to August 2005)

Ontario Clean Water Agency – Toronto, Ontario
Water Resources (Co-Op) (January 2005 to April 2005)

Hydromantis Inc., Consulting Engineers – Toronto, Ontario
Co-Op Student (June 2004 to September 2004)

PROJECT EXPERIENCE – WATER SUPPLY FORECASTING

City of Iqaluit , Nunavut, Canada

Developed a water balance model (using GoldSim) to quantify water deficit risks under future population growth and climate change scenarios. Analytical output and recommendations were subsequently provided in order to assist the City in water license application process for a supplementary source and provide a risk matrix of long-term probabilistic water supply deficits. (2012 to 2013)

City of Rankin Inlet Rankin Inlet, Nunavut, Canada

Water supply deficits were evaluated using a water balance model (using GoldSim) under future growth and climate change scenarios. The model evaluated water taking from the supply reservoir and an adjacent river while maintain use for aquatic live and social activities. (2015)

PROJECT EXPERIENCE – CHANNEL / CROSSING DESIGN

County of Northhumberland Cobourg, Canada

Ongoing support regarding a channel remediation design/assessment for the County of Northhumberland on a reach of Brookside Creek located downstream of the closed Eagleson Landfill to reroute unaffected surface water flows away from a zone of leachate influenced groundwater – conducted field studies, fluvial geomorphic and hydraulic analyses, preparation of conceptual/detailed design plans, liaison with contractor and reporting. (2009 to 2015)

Region of Durham Whitby, Canada	Completed a hydraulic analysis and fluvial geomorphic assessment at East Corbett Creek and tributary of East Corbett Creek. The analyses were conducted in support of a proposed extension of Consumers Drive that includes culvert crossings at the two watercourses – conducted field investigations, fluvial geomorphic analyses, hydraulic modelling, environmental permitting and reporting. (2014 to 2016)
Confidential Client Timmins, Canada	Ongoing support of a natural channel diversion design/assessment for a proposed pit mine. The channel design incorporates fluvial geomorphic processes to accommodate fish passage and habitat. Hydraulic modelling was conducted to limit erosion and maintain stability of the channel banks and crossings. (2015)
Canadian National Railway Southern Ontario, Canada	Many rail crossings were evaluated at locations of aging bridges, collapsed culverts and areas of flooding. Sites were visited and surveyed to confirm conditions and provide detailed data for desktop analysis. Hydraulic analyses were completed for each site to evaluate existing infrastructure. New crossing designs were evaluated based on MTO and CN guidelines and developed to conceptual and final designs. (2016 to 2020)
Trans Canada Pipelines Channel Rehabilitation Dryden, Ontario, Canada	Designed a stream channel rehabilitation to remediate TransCanada Line 100-1 exposure caused by erosion and beaver activity near Dryden, Ontario. The project progressed from conceptual design through to construction monitoring. The final design was focused on improving channel stability over the pipelines to reduce meander and erosion. (2017)
Trans Canada Pipelines Channel Rehabilitation Barrie, Ontario, Canada	Developed the design and supported construction of channel rehabilitation works at a tributary of Bear Creek that is crossed by TransCanada pipelines Line 100-1 and Line 100-2 near Barrie, Ontario. The goal of the rehabilitation is to improve long term channel stability at the watercourse crossing. The work includes the completion of field studies and hydraulic modelling, development of conceptual designs, and the preparation of environmental permitting. (2016 to 2017)

PROJECT EXPERIENCE – EROSION AND SEDIMENT CONTROL

Prodigy Gold Inc. Wawa, Ontario, Canada	Completed Erosion and Sediment Control Plans for a variety of earth work projects at the Magino Mine Project. These plans for stream diversions, embankments and shorelines were completed as part of a LRIA permitting package. (2021 to 2022)
Prodigy Gold Inc. Wawa, Ontario, Canada	Managed the monitoring and inspection of erosion and sediment control measures site-wide that included various earth work projects. The continuous monitoring was responsible for identifying erosion and sedimentation issues and recommend corrective actions. (2021)

PROJECT EXPERIENCE – ENVIRONMENTAL COMPLIANCE APPROVALS, WATER DISCHARGES

Canadian National Railway Algonquin Park, Ontario, Canada	Completed an Environmental Compliance Approval for Industrial Sewage Works for a temporary water treatment facility which was designed to treat contaminated water and sediments from a historic train derailment. The facility discharged to a nearby lake within the Park. (2015 to 2017)
Essroc Aggregates Cambridge, Ontario, Canada	Managed and completed an Environmental Compliance Approval for Industrial Sewage Works for an aggregate pit and wash plant in Cambridge, Ontario. The application included supporting documentation of the wash ponds which only discharged to the environment through the groundwater. (2016 to 2017)
Fish and Bird Emporium Innisfil, Ontario, Canada	Lead a team that completed an Environmental Compliance Approval for Industrial Sewage Works for a tropic fish warehouse and distribution centre. The application included multiple water filtration facilities designed to reduce the effluent contaminant concentrations without impacting the health of the fish at the site. (2016)
Lafarge Canada Inc. – Soares Dundas, Ontario, Canada	Carried out field investigations, water budget analysis and coordinated various project tasks related to the proposed Lafarge Soares License Application. (2007 to 2009)
Amherst Quarries Ltd. Windsor, Ontario, Canada	Performed reconnaissance of the local watersheds and hydrologic features of the quarry sumps. Carrying out quarterly volumetric flow monitoring and water quality sampling. Local drainage channels were evaluated using computer models including HEC-RAS. Developed a water balance to model drainage from the site and the adjacent Canard River. (2008)
O'Shanter Development Company – Arbour Farms Dufferin, Ontario, Canada	Conducting annual dry weather volumetric flow monitoring and groundwater well monitoring related to the Arbour Farms assessment of the proposed quarry. (2007 to 2021)
Brampton Brick – Norval Norval, Ontario, Canada	Performed field investigations and coordinated various project tasks related to the proposed Brampton Brick Norval quarry development. (2007 to 2008)
Lafarge Canada Inc. West Paris, Ontario, Canada	Completed baseline monitoring, including flow and water level monitoring, water quality monitoring. Supported license applications for extension properties and Permit to Take Water applications and continued site plan monitoring. (2016 to 2022)
Lafarge Canada Inc. Wellington, Ontario, Canada	Conducted baseline investigations of site drainage, local watercourses, including the Speed River. Potential impact on the water resources as a result of below water extraction was evaluated to support Permit to Take Water Applications and Environmental Compliance Approvals. (2015-2022)
Lafarge Canada Inc. Woodstock, Ontario, Canada	Completed water quality, water level and flow monitoring at local water features. Developed potential effects assessment of quarry extraction and drain realignments in support of a Major Site Plan Amendment. (2015-2022)

Nelson Aggregate Company Burlington, Ontario, Canada	Carried out volumetric flow monitoring throughout neighbouring watersheds for the proposed Lafarge Nelson License Application. Performed wetland mapping on the proposed quarry site. (2006 to 2007)
CBM Aggregates Various Sites in Southern Ontario	Various aggregate properties have been monitored and evaluated for aggregate license applications. this monitoring included water level monitoring, stream flow monitoring, groundwater piezometer monitoring and meteorological monitoring. Detailed site water balances as well as site and water course characterization have been evaluate and reported as part of the multidisciplinary applications. (2007 to 2022)

PROJECT EXPERIENCE – SITE REHABILITATION

Client Confidential Bancroft, Ontario, Canada	Completed surface water investigations at a decommissioned mine site (uranium) near Bancroft, Ontario, including meteorology, flow and water quality monitoring. Developed a detailed water balance to evaluate the site drainage and adjacent stream networks. Characterized and reported the surface water networks and their impacts. (2010 to 2022)
Client Confidential Near Kenora, Ontario, Canada	Completed surface water investigations at a former mine (nickel) near Kenora, Ontario, including meteorology, flow monitoring, water column profiling and water quality sampling. Flow regimes were characterized and modelled to evaluate impacts of adverse water quality on downstream environments. (2009 to 2018)
Niagara Peninsula Conservation Authority Welland, Ontario, Canada	Completed stream sediment investigations on Lyon's Creek, downstream of the Welland Canal, including a stream survey, sediment sampling, loading, scour and re-suspension analysis. Reported investigation results as part of the Niagara River remedial options. (2009 to 2010)
Lafarge Canada Inc. Bath, Ontario, Canada	Reporting annually on volumetric flow monitoring and water quality data collected monthly on and adjacent to the Lafarge Bath cement kiln dust landfill and rehabilitation. Engineering drainage features on site was also completed. (2006 to 2008)
Canadian Gypsum Company Ltd. Haggersville, Ontario, Canada	Performing volumetric flow monitoring, water quality and continuous water level monitoring on Boston Creek adjacent to the mine site. Annual reporting was also conducted until rehabilitation completion. (2006 to 2015)

PROJECT EXPERIENCE – THREATS ASSESSMENT

Hanson Brick Ltd. – Tremaine Bronte Creek Burlington, Ontario, Canada	Evaluated the risks of a potential drinking water intake on Bronte Creek. Risks in the watershed were evaluated and analysed using plume dispersion algorithms to estimate contaminate impacts on the potential intake. Evaluation was completed using computer models including HEC-RAS. (2008)

Teck Resources Elk Valley, British Columbia, Canada	Conducted water quality modelling to support mine site investigations for a mining project in British Columbia. Water quality parameters were modelled throughout the watersheds from natural sources, mining and metal processing activities as well as their reactions within the watershed. Modelling efforts were used to evaluate treatment options and water handling / management. (2013 to 2015)

PROJECT EXPERIENCE – URBAN WATER MANAGEMENT

Metrolinx Toronto, Ontario, Canada	Project manager for the program which included stormwater sampling of a Metrolinx rail yard. The sample results were compared to the municipal stormwater sewer quality limits and reported at the season. (2017 to 2018)
Toronto Transit Commission Vaughan, Ontario, Canada	Task Manager of the stormwater monitoring and reporting as part of the ECA requirements at the 407 subways station. The monitoring involved storm event water quality monitoring to evaluate Stormwater Management Pond performance, erosion and sediment control inspections, annual reporting and recommendations for performance improvements. (2018 to 2019)
Town of Oakville Oakville, Ontario, Canada	Project manager for the program which included dry weather outfall sampling and wet weather storm sewer sampling. Results were analysed to develop water quality trends in order to estimate contaminate sources and evaluate the effectiveness of Best Management Practices and Stormwater Management Plans (Town of Oakville). (2008 to 2012)
City of Barrie Barrie, Ontario, Canada	Performing volumetric flow monitoring under flash flooding or melting conditions in areas of low permeability in the City of Barrie. (2008)
Black and McDonald Ltd. – Castrol Toronto, Ontario, Canada	Conducted reconnaissance and water quality sampling regarding the Castrol Oil storm water discharge to the city storm sewer. Testing performance of the on-site water treatment equipment and evaluating replacements. (2007)

PROJECT EXPERIENCE – MINING OPERATIONS AND EXPLORATION

Adrianna Resources Lac Otelnuk, Quebec, Canada	Conducted transducer installations and collected cross sectional geometry information at surface water points of interest influencing site drainage and watersheds adjacent to Lac Otelnuk. (2010)
Xstrata, Copper Las Bambas, Peru	Conducted transducer installations at surface water points of interests influencing the site drainage and watersheds located on and adjacent to site Las Bambas. (2008)
Xstrata, Copper Antapaccay, Peru	Conducted transducer installations at surface water points of interests influencing the site drainage and watersheds located on and adjacent to site Antapaccay. (2008)

Xstrata, Nickel Loma Miranda, Dominican Republic	Managed and carried out quarterly field campaigns for Loma Miranda and Energy Conversion Project, which involved installation and monitoring of river hydrology, water quality sampling and rain data collection. Quarterly reporting was conducted, summarizing campaigns. (2007 to 2010)

PROJECT EXPERIENCE – PIPELINE WORK

Trans Canada Pipelines New Gas Line Vaughan, Ontario, Canada	Managed and supported continuous instream turbidity monitoring of many watercourse crossings as part of the Vaughan Mainline pipeline construction and Gravenhurst pipe replacement. This program included site reconnaissance, equipment installation, intensive 24-hour monitoring and troubleshooting, daily and final reporting. (2017 to 2018)
Trans Canada Pipelines New Gas Line South Eastern, Ontario, Canada	Completed watercourse baseline investigations for Eastern Mainline Expansion in Ontario (260 km long new gas pipeline spanning central and eastern Ontario). Responsible for field data collection of baseline conditions at major watercourse crossings and evaluating the hydrotechnical characteristics of each potential crossing. (2015 to 2016)
Trans Canada Pipelines Gas Line Construction Brampton, Ontario, Canada	Designed drainage improvements at a gas pipeline valve station to control flooding in the area to allow maintenance staff to work safely. The work involved conservation authority permitting and negotiation with landowners and other stakeholders. (2018-2020)

PROJECT EXPERIENCE – ENVIRONMENTAL ASSESSTMENT AND PERMITTING

Walker Environmental Group Inc. Ingersol, Ontario, Canada	Completed baseline evaluation and impact assessment for the proposed landfill in the Town of Ingersol. This included the flow and water quality monitoring of the Thames River and local tributaries. Desktop analysis of the potential impacts utilized hydrologic models, climate change predictions, water quality models and stormwater design. (2018-2019)
Marten Falls First Nation Marten Falls, Ontario, Canada	Drafted existing surface water conditions report and impact assessment to support the proposed all season road from Marten Falls to Nakina Ontario. This work involved watercourse crossing surveys utilizing helicopter transportation. The field studies visited a subset of the crossings to evaluate the impacts of the road alignment. (2019-2020)
NextBridge Northern Ontario, Canada	Completed water quality and hydrotechnical analysis to support the NextBridge Infrastructure East-West Tie Transmission Line Project in Northern Ontario (430 km long new transmission line). Conducted baseline studies, effects evaluations, permitting support through hydrotechnical analysis and preliminary design criteria. (2018)
Hydro One Northern Ontario, Canada	Completing baseline evaluation and impact assessment for the proposed power transmission corridor from Thunder Bay to Dryden. This work involved watercourse crossing surveys in remote areas of a subset of the crossings to evaluate impacts of the proposed transmission line corridor. (2019-2022)

Cambridge

Kevin M. MacKenzie M.Sc. (Eng.) P.Eng. Water Resources Engineer

Mr. MacKenzie joined Golder Associates in 1997. Principal responsibilities include hydrologic and hydraulic modelling, design of hydraulic structures and erosion control measures and providing technical water resources support for a wide variety of environmental studies. Project experience includes unsteady hydraulic modelling of mixed sub and supercritical flood waves, prediction of flood flows from extreme design storms, flow monitoring and rating curve development, regional hydrological analyses, water budgets and balances, water management planning and consideration of fluvial geomorphology and ecological principles in design. Water resources work has been completed for clients in the Power Generation, Power Transmission, Aggregate and Mining Sectors as well as Regional Government Agencies and Environment Canada. Prior to joining Golder Associates, Mr. MacKenzie was involved in water resources research for four years, as part of his graduate studies, then as a research associate at the University of Guelph. Mr. MacKenzie has an excellent understanding of a wide variety of hydrology, hydraulics, soil erosion and fluvial geomorphology disciplines.

Education

PhD Candidate Water Resource Engineering, University of Guelph, Guelph, In Progress

M.Sc. (Eng.) Water Resource Engineering, University of Guelph, Guelph, 1995

B.Sc. (Eng.) Water Resource Engineering, Minor: Environmental Engineering, University of Guelph, Guelph, 1993

Languages

English – Fluent

Employment History

Golder Associates Ltd. – Cambridge, Ontario

Water Resources Engineer, Principal (1997 to Present)

Responsible for management of water resources assessments including hydrology, hydraulics, upland and in stream erosion, water quality and water management for a wide variety of government, power generation, industrial, mining and aggregate producing clients. Being part of a comprehensive client service team for aggregate producers in Ontario has facilitated an excellent understanding of the aggregate business and how water management affects their operations. Water resources assessments have been completed in support of Environmental Assessments (EA) and Permitting and Approvals under Federal, provincial and international regulations. Peer reviewer for two Ontario Source Water Protection projects and water resources sections of a new international airport in Quito, Ecuador. Responsible for managing and implementing field data collection studies, including stream flow monitoring, water budget assessments, meteorology and water quality. Other abilities include assessments of upland soil erosion, natural channel design and fluvial geomorphology.

University of Guelph – Guelph, Ontario

Hydrologist (1996 to 1996)

Responsible for collection and analysis of four large databases of rural hydrology parameters in Southern Ontario. Frequency distributions were found for event, daily and yearly runoff coefficients and detailed daily water budgets were synthesised for the duration of each record. Estimated evapo-transpiration in the absence of meteorological data required for the Penman equation.

PROJECT EXPERIENCE – HYDROLOGY/HYDRAULICS

Moira River Flood Mitigation Alternatives Assessment
Foxboro, Ontario

Reviewed and updated floodplain mapping for the Foxboro area, identified several alternative flood mitigation alternatives ranging from floodways and hydraulic controls to lot level flood proofing. Alternatives were assessed and compared based on triple bottom line scores. Triple bottom line analysis considered detailed economic analysis using regions specific flood damage curves developed by Golder's project partner.

Garson Mine Water Management and Inundation Study
Sudbury, Ontario

Senior review and technical advice for flood inundation study downstream of the Vale Garson Mine near Sudbury Ontario. The study included an options assessment, development of improved water management operating practices and conceptual design of reservoir retrofits.

International Falls Dam Rule Curve Cultural Study
Rainy River, Ontario

The effects of a recently updated operating rule curve at the International Falls Dam on water levels in Rainy River and the potential for changed water levels to affect locations of cultural significance are being investigated on behalf of the International Joint Commission on the Great Lakes.

Credit River Floodline Mapping
Mississauga, Ontario

Golder completed the most recent comprehensive update of the flood risk investigation and floodline mapping for the Credit River between Old Derry Road and Lake Ontario. This reach alternately flows through an entrenched bedrock valley and remnant beach plains adjacent to Lake Ontario in the most urbanised part of Mississauga. Mr. MacKenzie served as project staff on this project.

Water Quality Forecasting and Infrastructure
Annapolis Basin, Nova Scotia

Golder was part of a project team working with the Atlantic Innovation Fund / Applied Geomatics Research Group to develop a complex water quality forecasting tool for use by the shell fishing industry in the Digby Gut area. Real time weather forecasts were used to drive real time hydrology and database scenario models of runoff, water quality (bacteriological) and Bay of Fundy tidal fluctuations and their effects on contaminant movement in the Digby Gut. Hydrodynamic modelling was used to estimate contaminant movement and exposure of shell fishing areas to contamination. This information was packaged for use by shell fishers in order to minimize harvests of contaminated shellfish, thereby protecting the resource and minimizing post-harvest dupurification costs. Mr. MacKenzie was the hydrology and hydrometry technical lead for Golder on this project.

Brookfield Homes – Channel Rehabilitation
Brantford, Ontario

Assisted a channel rehabilitation/stabilization assessment and associated 'field fit' design for Brookfield at a tributary of Fairchild Creek to address debris removal and channel instability - responsible for field investigations and construction supervision/inspections.

River Diversion Design
Northern Ontario

Technical advisor for baseline channel hydraulics and fluvial geomorphic studies in support of a major mine development project in Northern Ontario to characterize baseline conditions at several stream channels, as well as to advance a conceptual design for a proposed diversion channel.

Borer's Creek Modelling and Restoration Design
Dundas, Ontario

HEC-RAS modelling and assessment of a failing reach of Borer's Creek that threatened to expose a high-pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.

Voisey's Bay Nickel Mine
Voisey's Bay, Labrador

A theoretical tailings dam breach was investigated using DAMBREAK to quantify potential impacts on an environmentally sensitive creek. Flood passage downstream of the breach was complicated by several small ponds and alternating sub and supercritical river reaches. Proposed mining operations at the Voisey's Bay nickel deposit require extensive management of surface waters. Five small dams were considered to safely convey clean water around the proposed tailings facility and to contain and treat tailings water. Modelling and design of the reservoirs and outflow structures was completed using GAWSER.

Plains Midstream – Dechlorination and Approval
Sarnia, Ontario

Technical advisor for the design and permitting of a dechlorination system for the Plains Midstream fractionation plant in Sarnia, Ontario. The system is being designed to reduce the free chlorine concentration in the wastewater discharge. Golder is also preparing the ECA (Industrial Sewage Works) amendment package for the facility, to include additional Limited Operational Flexibility (LOF) for the facility for the additional of the dechlorination system, and future sewage work modifications. LOF for the facility will grant future modifications to the works through the appropriate MOE reporting progress, if a professional engineer can demonstrate the modifications will not alter the process discharge quantity and quality limits established for the facility.

Channel Restoration Design
Algonquin Park, Ontario

Technical advisor for the hydraulic design of a stream re-alignment with associated grade controls at an historic train derailment site. Contaminated materials will be removed from the stream bed and banks and adjacent railway embankment. Removal of the contaminated materials will result in a net loss of stream substrate and a change to the fluvial geomorphology of the reach. Grade and stream bank controls were designed to minimize the risks of mobilizing residual contaminants and of significant channel migration.

Omya – Stormwater Management Design and Approvals
Perth, Ontario

A review of existing stormwater management infrastructure was completed for an industrial mineral processing site near Perth Ontario. As a result of incremental development of the site, parts of the stormwater management infrastructure were found to be inadequate. Additional stormwater management works were conceptualized and submitted to MOE for approval. Following approval, Golder provided liaison with the local Conservation Authority, completed basic design drawings suitable for design-build and applied for permitting under the Conservation Authorities Act.

OSSGA Carden Plain Cumulative Impact Assessment
Carden, Ontario

Due to the increased level of aggregate extraction activity in the Carden Plain area, the Ontario Ministry of the Environment (MOE) requested a multidisciplinary study and impact assessment to evaluate the potential cumulative impacts of quarry dewatering at multiple sites on groundwater, surface water and ecological receptors. Golder was retained by the Ontario Stone, Sand & Gravel Association to complete the required study. The project included extensive interaction with the MOE and the Ministry of Natural Resources (MNR). The objectives of the study were to screen out areas where cumulative impacts are unlikely, identify areas where cumulative impacts are likely, and to provide a preliminary assessment of the potential magnitude of predicted cumulative impacts. For the purpose of this study, a cumulative impact was defined as the additive effect of multiple quarry dewatering operations on groundwater, surface water and/or natural environment features. Golder was responsible for all aspects of this project including the development of the final field programs in consultation with personnel from the MOE. Mr. MacKenzie was the surface water lead for the project and participated in the public consultation aspects of the project.

Technical Reviewer Contaminated Site Channel Design
Mississauga, Ontario

Golder was retained to review an options analysis and remedial channel design for a PCB contaminated channel in Mississauga. The remedial design included removal of the most contaminated material and design of a hardened channel lining to secure residual contaminants in-situ. Mr. MacKenzie reviewed the hydraulic channel analysis and design and provided a technical review report for consideration by the municipality and the channel designer.

Contaminated Site Channel Stability Analysis
Welland, Ontario

Golder recently completed Phase IV of an assessment of 12 sites in the Niagara River Area of Concern that were identified in the RAP Stage 1 Update as requiring further assessment. The Phase IV study is a detailed assessment of remedial alternatives for the site including passive and intervention options. In support of the passive treatment options, Golder completed a detailed investigation of the complicated stream and wetland hydraulics of one of the sites on Lyon's Creek. In the intervening years since the historic contamination, the site had developed into a wetland, which provided habitat for threatened plant and animal species. The hydraulic conditions were evaluated using one- and two-dimensional hydraulic models (HEC-RAS and RIVER-2D) to identify areas that are at risk for re-suspension of contaminated sediments and areas that are likely to accumulate new un-contaminated sediment with time. The results supported the passive treatment alternative. Mr. MacKenzie led the hydraulic investigation component of the Lyon's Creek study.

Confidential Mine Site Closure
Eastern Ontario

Technical advisor for comprehensive surface water investigations in support of a risk assessment at two former uranium mines near Bancroft, Ontario. The studies included meteorology and flow monitoring, water column profiling with a particular focus on lake stratification and turnover, and water quality sampling.

Confidential Mine Site Closure
Northern Ontario

Technical advisor for surface water investigations, including streamflow studies, lake column profiling and water quality sampling, at a former nickel mine near Kenora, Ontario.

OPG Atikokan – Environmental Compliance Approval
Northern Ontario

Technical advisor for the Environmental Compliance Approval ('ECA') Sewage (including Stormwater) amendment application for the Atikokan GS Biomass Conversion project. The study included a review of existing sewage works and associated ECA and MISA conditions. Implications from the proposed site changes to the sewage works, consisting of process streams (Furnace Ash Treatment Plant, Condenser Cooling Water), sanitary sewage system/lagoons and the coal pile runoff pond, along with their associated ECA conditions.

Confidential Manufacturing Client
Norval, Ontario

Baseline characterisation and impact assessment modelling of a proposed shale quarry in order to quantify and where necessary mitigate potential flow, water quality and thermal effects of the quarry on nearby watercourse and wetlands. Included conceptual design of mitigation measures and preparation of application materials for re-zoning and license under the Ontario Aggregate Resources Act.

Big Bay Point Water Balance
Barrie, Ontario

Monthly and annual water budgets were prepared using the Thornthwaite Water Budget method. This water budget assessment was performed to determine the rate of marina water pumping required from the proposed development area at Big Bay Point, to the golf course and Environmental Protection Area in support of detailed design of stormwater management facilities to meet post-development peak flow targets. Mr. MacKenzie provided technical advice and senior review for this project.

Baseline Hydrology Study for Proposed Mine
Ring of Fire, Northern Ontario

Technical advisor for baseline hydrology studies and effects evaluations in support of a major mine development project in Northern Ontario. Assessments were prepared as part of a multi-disciplinary Environmental Impact Statement (EIS) and Environmental Assessment (EA) under the Canadian Environmental Assessment Act (CEAA).

Quarry License Expansion
Flamborough, Ontario

A level II hydrogeology study was completed in support of a rock quarry license expansion application. The surface water component of the study included establishment of eight continuous stream flow gauges and associated baseflow separation analysis. The baseflow separations were used to estimate mean annual recharge to groundwater. This information was provided to Golder hydrogeologists for use in estimating boundary conditions for the FEFLOW groundwater model. In addition, monthly and annual surface water balances were modelled using the Thornthwaite Water Budget method coupled to a GIS procedure. The fraction of surplus water that infiltrates was estimated using GIS and the method outlined in MOE 2003. The infiltration estimates were initially assumed to equal recharge. The resulting modelled groundwater levels were reviewed to identify areas of upward gradient or minimal downward gradient. This information was used in subsequent iterations to adjust the recharge estimates.

Quarry License Expansion
Northern Ontario

A level II hydrogeology study is underway in support of a rock quarry license expansion application. Surface water features in the area are characterized by shallow intermittent streams flowing on top of bedrock above a small escarpment running through the site. Below the escarpment, there is a line of small watercourses connecting a series of small lakes. The surface water study includes monitoring of several of the small intermittent watercourses and the outlet of two of the small lakes. Surface hydrological. The results of this analysis will form input to the groundwater modelling discipline. Recharge will initially be assumed to equal infiltration in the groundwater model; however, we expect this will cause mounding in parts of the model. Further iterations will be used to calibrate the recharge estimates subject to a mass balance at the surface.

Aggregate Site Water Use Study
Southern Ontario

Participated in a “typical water use” study for the aggregate industry. The study was initiated by the Aggregate Producers Association of Ontario (now the Ontario Stone Sand and Gravel Association) in preparation for planned changes, by the MOE, to the Permit to Take Water application process. Changes to the process were anticipated to include charges for water taking or use. The MOE was simultaneously working on new Source Water Protection legislation. As a result, the APAO felt it would be prudent to quantify actual water use versus maximum permitted water taking rate and to illustrate typical water use at aggregate sites.

Aggregate Site Permitting and Approvals
Southern Ontario

Application packages including MNRF and MECP applications and supporting studies and reports have been prepared for numerous aggregate sites across Southern Ontario. Applications have been completed for aggregate pit and quarry licenses under the Aggregate Resources Act, Permits to Take Water (PTTW) to allow quarry dewatering and for Environmental Compliance Approvals (ECA) under Section 53 of the Ontario Water Resources Act to allow offsite discharge of quarry and storm water.

Simcoe County Groundwater Studies
Simcoe County, Ontario

A base flow survey was conducted to quantify groundwater discharge in a series of watershed in Simcoe County. The project was conducted in two phases, one for North Simcoe and one for South Simcoe. Water budget and average annual infiltration calculations were completed in support of groundwater modelling. Surface-groundwater interactions were estimated throughout the region to provide a water balance.

Hydrology Studies for Quarry Developments
Ottawa Region, Ontario

A series of water resources investigations were completed for aggregate producing clients in the Ottawa area. The studies were completed in support of Certificate of Approval applications made under Section 53 of the Water Resources Act. Each study included a water balance analysis for the quarry and an estimate of future quarry discharge rates. These data were used to estimate the effects of quarry development on downstream water resources.

Water Supply Studies
Sudbury, Ontario

Two municipal water supplies were investigated as Groundwater Under Direct Influence of surface water (GUDI). Surficial water resources were investigated, and a water balance was prepared in support of groundwater modelling studies.

Hydrological Effects Assessment Hagersville, Ontario	A long-term field monitoring programme was designed and implemented to track changes in flow regime resulting from closure of an underground Gypsum mine. Part of the mine was closed and allowed to flood. Three flow monitoring stations were established in Boston Creek, which flows over the mine. The stations were selected to represent background conditions upstream of the mines influence, conditions above the mine and downstream of the mine influence. Data loggers and transducers were installed to continuously (hourly) record water levels and flows in the creek.
GORO Nickel Mine New Caledonia	The GORO Nickel mine is located in an area of extreme precipitation. Hydrological and preliminary erosion assessments were completed in support of mine development planning and design. These data were used, by the multi-disciplinary project team, to design tailing basin capacities, diversion ditches and dams.
Round Lake Water Level Control Study Engelhart, Ontario	Flow exiting Round Lake flows down several kilometres of a very mild sloped reach of the Blanche River before cascading down a set of rapids at a rock outcrop. The rock outcrop was historically blasted to facilitate log driving practices. This modification has caused large fluctuations in water levels in Round Lake and the Blanche River. A hydrological and hydraulic study of the river and lake were completed and a fish-friendly rock-fill weir was designed to stabilise water levels.
Bruce Nuclear Generating Station Bruce County, Ontario	Participated in background water quality assessments in the surrounding environment. This work included water quality sampling in Baie du D'Or and Lake Huron. The data were used to assess potential effects of the generating station on the quality of surrounding water resources.
Pickering-A Nuclear Generating Station Pickering, Ontario	A multi-disciplinary environmental assessment was completed for the re-start of four CANDU reactors at the Pickering A generating station. A comprehensive review of existing water quantity and quality data was completed. Potential effects, of operating the station, on surrounding water resources were identified and evaluated.
Falconbridge Smelter Area Closure Falconbridge, Ontario	Performing a detailed analysis of water quantity and quality to address potential long-term impacts of the closure on the watersheds of Coniston and Emery Creeks. A daily water budget and reservoir routing model was implemented on a spreadsheet to investigate the efficiency of a variety of different closure scenarios. Also involved in hydrometry, automated water level monitoring, water quality sampling, hydrologic modelling.
Fire Water Intake Blind River, Ontario	Alternative designs for a fire water intake structure modification were assessed to minimise maintenance and sediment deposition and increase safety. Two-dimensional finite element flow modelling of the intake environment and one dimensional, coupled, unsteady, sediment and hydraulic modelling of the river reach was completed. Modelling results indicated that relocating the intake structure would reduce the risk of failure resulting from sediment accumulation.
Asacha Gold Mine Russia	The Asacha gold mine lies close to the divide between a pristine watershed and a partially developed watershed. Hydrologically modelled areas potentially affected by mining operations to aid in developing a safe and detailed water management plan.

PROJECT EXPERIENCE – LINEAR INFRASTRUCTURE

Trans Canada Pipelines Vaughan Mainline Expansion
Vaughan, Ontario

Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process and construction planning and design for a ~12 km pipeline expansion in the Greater Toronto Area.

Trans Canada Pipelines Eastern Mainline Expansion
Vaughan, Ontario

Senior technical advisor for baseline hydrology studies, effects assessments and permitting in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing for the Eastern Mainline Expansion in Ontario (~260 km long gas pipeline through central and eastern Ontario).

Trans Canada Pipelines Parkway West Connection
Vaughan, Ontario

Senior technical advisor for baseline hydrology studies, effects assessments and permitting, in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) filing process for a local service connection in the Greater Toronto Area.

Trans Canada Pipelines Kings North Connection
Ontario

Surface water discipline lead for the Kings North Connection Project, including baseline hydrology studies and effects assessments in support of the environmental and socio-economic assessment (ESA) under the National Energy Board (NEB) process. Scour assessments, sag-bend setback recommendations and permitting were also completed to support construction activities.

Pipeline Corridor Investigations
Timmins, Ontario

A pipeline was proposed to slurry tailing from the Kidd Metallurgical Site to the Kidd Mine, approximately 35 km away. The tailings are to be used for paste back-filling of depleted areas of the underground mine. An environmental review of water resources along the proposed pipeline corridor was completed. Larger watercourse crossings were mapped, and directional drilling was proposed to mitigate environmental effects.

Trans Canada Pipelines Borer's Creek Modelling and Restoration Design
Dundas, Ontario

HEC-RAS modelling and assessment of a failing reach of Borer's Creek that threatened to expose a high pressure natural gas pipeline. Design of remedial measures for failing banks and restoration of the affected reach. Coordinated regulatory approvals. The project was successfully implemented before the spring freshet and significantly reduced the risk of damage to the pipeline.

PROJECT EXPERIENCE – CLIMATE CHANGE

Goldcorp Sudbury Integrated Nickel Operations – East End Water Management
Sudbury, Ontario

Senior review and technical advisor for an assessment of potential climate change effects and vulnerabilities on a multi-site water management system including eight reservoirs, flooded underground mine works, an active smelter complex, a water treatment plant and associated dams and infrastructure. A Goldsim model of the water management system was constructed and validated. Ensemble Global Circulation Model (GCM) results, from approximately ninety model runs, were obtained for the 2050 horizon. Monte Carlo simulations were used to simulate daily weather patterns constrained by the GCM results and the same daily weather patterns were used to model a potential future range of water management scenarios using the Goldsim water management model.

Goldcorp Sudbury Integrated Nickel Operations – East End Infrastructure Assessment
Sudbury, Ontario

Evaluated climate change risks to several small flow conveyance structures including culverts, pipes and flow measurement structures. Peak flows from small sub-catchments are typically sensitive to short duration intense precipitation events. A trend analysis and curve fitting exercise was completed on observed maximum annual events, over recent site history, for a range of event durations ranging up to 24 hours. The trend analysis was used to estimate potential changes to Intensity-Duration-Frequency statistics at the 2050 horizon. This information was used to assess the capacity of existing flow conveyance infrastructure in small sub-catchments.

Meteorological Service of Canada – Environment Canada
Ottawa and across Canada

Participated on a national research team studying the effects of climate change on hydrological variables. Contribution to the study was to complete a regionalization study based on measured hydrologic variables from the Reference Hydrometric Basin Network (RHBN) including mean annual flow, lowest annual daily flow and peak annual daily flow. The data series were grouped according to their similarity using a cluster analysis routine. The homogeneous hydrologic regions identified by this method were compared to hydrologic regions identified in previous studies using meteorological and physiographic variables. Cluster analysis results consistently identified three homogeneous regions in the British Columbia mountains as well as several regions in Ontario, the Maritimes and along the St. Lawrence. The study demonstrated a significant lack of RHBN coverage in the northern part of the Prairie Provinces and the North West Territories, such that homogenous regions, if they exist in these areas, could not be identified by cluster analysis.

Infrastructure Ontario (Ontario Realty Corp.) – Infrastructure Climate Risk Assessment
Ontario

Completed the water resources and drainage components of a climate risk assessment on three typical buildings owned by Infrastructure Ontario. Risk was assessed using guidance provided in Engineers Canada's PIEVC protocol. Co-led focus group workshops with building operators and subject matter experts to assess potential future risk.

Iqaluit Water Supply
Nunavut

Senior technical reviewer for a climate risk investigation of the Town of Iqaluit's water supply. A Goldsim model was developed for the lake-based water supply. Various scenarios were investigated to assess the vulnerability of the supply to climate change.

BHP Billiton
Elliot Lake, Ontario

Technical advisor for applying climate change projections to extreme precipitation events used to assess potential climate change implications for tailings storage facilities and water management ponds. This work was completed as a part of the Dam Safety Surveillance and Management program at BHP Billiton's closed Canadian and U.S. sites.

PROJECT EXPERIENCE – SOURCE WATER PROTECTION

Ontario Clean Water Agency
Lake Ontario, Canada

Hydrology and river boundary conditions lead for the Ontario Clean Water Agency (OCWA) Lake Ontario Decision Support System (DSS). OCWA, in partnership with GTA municipalities, is developing a DSS for managing Lake Ontario based drinking water intakes. Golder teamed with DHI to develop a hydrodynamic, thermodynamic and water quality model to integrate into a web-based forecasting platform for Lake Ontario. The system is expected to go live in 2021 to provide municipalities with the advance information to anticipate and mitigate the effects of accidental spills on water supply infrastructure.

Source Water Protection: Midland and Penetanguishene Tier 3
Midland, Ontario

Surface water lead for the Midland and Penetanguishene Tier 3 water budget and water quantity risk level assessment. This study involved implementation of a combined surface and groundwater model using MIKE-SHE. The modelled recharge distribution was applied to a groundwater model developed by Golder using FEFLOW in order to further refine drawdown effects in close proximity to wells and surface water features. The study area included the whole of the Midland Peninsula and areas of provincially significant wetlands in close proximity to municipal wells with GUDI designation. Groundwater and surface water interactions, both recharge and discharge areas were significant in spatial scale and an important part of this project.

Source Water Protection: Peer Reviewer York Region Tier 3
York Region, Ontario

Peer reviewer for the surface water components of the ongoing York Region Tier 3 water budget and water quantity risk level assessment for the area between and surrounding Aurora and Stouffville. The project team is proposing to use GSFLOW to model both the surface and groundwater systems. GSFLOW is an integrated surface and groundwater hydrology model developed by the US Geological Survey, based on MODFLOW and PRMS components. The study area is complex as it includes the southern flank of the Oak Ridges Moraine and straddles the divide between Lake Ontario and Lake Simcoe. Stouffville is in the headwaters of the Rouge River watershed.

Source Water Protection: Peer Reviewer Halton Hills Tier 3
Halton, Ontario

Peer reviewer for the surface water components of the ongoing Halton Region Tier 3 water budget and water quantity risk level assessment for the Georgetown and Acton areas. The project team used MIKE-SHE to model surface and groundwater hydrology and applied the modelled recharge distribution to FEFLOW to provide further discretization around key areas of interest including wells and surface water features. The study area is complex as it includes the Niagara Escarpment, the Acton re-entrant valley and several buried bedrock valleys which are believed to play and important role in delivering groundwater to the area. The study area also straddles the divide between the Grand River and Credit River watersheds.

Source Water Protection: Peer Reviewer Orangeville Tier 3
Orangeville, Ontario

Peer reviewer for the surface water components of the ongoing Orangeville, Mono and Amaranth Pilot Tier 3 water budget and water quantity risk level assessment. The project team is using HSPF and MODFLOW to model surface and groundwater hydrology respectively. The study area is complex as it includes the Niagara Escarpment and the Oak Ridges Moraine. The study area also straddles the divides between the Grand River, Credit River and Nottawasaga River watersheds.

Source Water Protection: Peer Reviewer CTC Tier 1 and Tier 2
Southern Ontario

Peer reviewer for the surface water components of the Tier 1 and Tier 2 water quantity stress assessments for the CTC Source Protection Region, which includes the Credit River (CVC), Toronto Region (TRCA) and Central Lake Ontario (CLOCA) watersheds. Data availability and modelling approaches used by the different conservation authorities and their consultants varied across the CTC region.

Source Water Protection: Lower Speed River (Guelph) Tier 3
Guelph, Ontario

Golder Associates teamed with AquaResource to complete a Tier 3 water budget and water quantity risk level assessment for the Lower Speed River watershed. The study area includes the City of Guelph, part of Cambridge and contributing drainage and recharge areas located north and east of Guelph. An extensive baseflow survey was conducted across the study. Baseflow was measured at thirty-two locations during the spring, summer and autumn of 2008. This information was used to estimate varying groundwater discharge and recharge rates to support definition of boundary conditions for the groundwater model.

Source Water Protection: Nickel District CA Valley East Tier 3
Sudbury, Ontario

Senior technical advisor for the Valley East Tier 2 and Tier 3 water quantity stress assessment. The City of Sudbury draws drinking water from several wells located in the Valley East area. Worked with project team to identify a modelling approach that would make the best use of, sometimes limited, existing data. The Tier 2 results led to the initiation of the Tier 3 Local Area Water Budget for the groundwater supply in Valley East.

Source Water Protection: Ramsay Lake Tier 1 and Tier 2
Sudbury, Ontario

Senior technical advisor for the Ramsay Lake Tier 3 water budget and water quantity risk level assessment. The City of Sudbury draws water directly from Ramsay Lake for part of its drinking water supply. Ramsay Lake and its contributing drainage areas are being modelled using HEC-HMS (Hydraulic Engineering Corps - Hydrological Modelling System). Based on existing information, it appears that the hydrology of Ramsay Lake is dominated by surface water inputs and as such, there is no plan to include groundwater modelling at this time. HEC-HMS will be used to complete the risk level assessments. Additional field data collection has been initiated to fill existing data gaps regarding key inflows to the lake and the outflow adjacent to Science North.

Source Water Protection: Bronte Creek
Halton, Ontario

Golder Associates were commissioned to undertake a Threats Assessment of a potential intake at Bronte Creek. Mr. MacKenzie directed the project for Golder. The intake, intended to deliver surface water to a small water treatment plant, was identified as one potential alternative for providing a drinking water supply to nearby residential properties possibly affected through the construction of an adjacent quarry. The Threats Assessment identified eleven water quality issues at the potential intake location, attributing causes to a number of likely contaminant sources throughout the watershed. In accordance with MOE Draft Guidance Modules, the work undertaken as part of this assessment included stakeholder liaison, hydraulic modelling, IPZ delineation, vulnerability analysis, the compilation of issues and threats inventories and a description of data knowledge gaps. Should surface water abstraction from Bronte Creek be identified as the preferred alternative for providing long-term drinking water supply, this Threats Assessment report will provide the basis for the Tier 2 assessment.

Source Water Protection: Timmins IPZ Study
Timmins, Ontario

An Intake Protection Zone (IPZ) and the vulnerability scores for the City of Timmins drinking water treatment plant on the Mattagami River were assessed. The delineation of the IPZ included the consideration of river flow conditions, influences of dam operation, location of significant potential upstream sources of contamination, local transportation routes, storm sewer drainage patterns and the behaviour of spills in the river. The project also included the collection of site-specific data through a field program. The field program used non-conventional methods to measure travel time due to restrictions on the use of dye tracers in the river because of the presence of private drinking water intakes. The field program collected detailed velocity data that was used to estimate dispersion and to calibrate a HEC-RAS model that was used to predict the travel time under various flow conditions,

PROJECT EXPERIENCE – WASTE MANAGEMENT

Barrie Landfill Reclamation
Barrie, Ontario

Technical advisor for stormwater management modelling and conceptual stormwater infrastructure design. The project included a significant removal and replacement of historic municipal waste. Daily and permanent cover design required new stormwater management strategies and facility design. Interacted with groundwater modellers to develop representative and conservative boundary conditions for modelling.

Nexcycle
Southern Ontario

Technical advisor in support of the ECA (Sewage) application package for a glass recycling facility. The project included conceptual design of Best Management Practices and source controls to improve stormwater quality.

Eagleson Landfill Brookside Creek Channel Design
Northumberland, Ontario

Ongoing support regarding a channel remediation design/assessment for the County of Northumberland on a reach of Brookside Creek located downstream of the closed Eagleson Landfill to reroute unaffected surface water flows away from a zone of leachate influenced groundwater.

Edgewood Landfill Monitoring
Flamborough, Ontario

Designed and implemented a flow and water quality monitoring programme to assess potential historic effects of watercourses surrounding the closed Edgewood Landfill site in Flamborough Ontario. This work was completed as part of an inventory and assessment of historic landfill operations in the City of Hamilton.

Bath CKD Landfill Design and Monitoring
Kingston, Ontario

Monitored existing water quality and flows associated with an existing Cement Kiln Dust landfill. Designed stormwater control measures for design of a new landfill cover for the existing landfill as well as four new cells to increase the capacity of the landfill.

Brow Landfill Storm-water Management Plan
Flamborough, Ontario

Developed a storm-water management plan to address drainage requirements for the site and mitigation measures required to control potential impacts as part of the closure process. Designed drainage channels, a stormwater management pond, hydraulic flow control structures and a drop structure to safely convey stormwater over the edge of the Niagara Escarpment into a purpose designed plunge pool.

Adams Mine Landfill
Kirkland Lake, Ontario

Completed a baseline hydrology assessment including flow and water quality monitoring as part of an investigation into the feasibility of a proposed land-filling operation at Adams Mine. Monitoring included flow measurements from boats in medium to large rivers.

SUPPLEMENTAL SKILLS

Soil Erosion
Upland inter-rill soil erosion by rainfall impact; Upland soil erosion by concentrated flow in rills and gullies; In stream, bed and bank erosion and transport.

Hydrology
Stream-flow monitoring and hydrometry; Hydrologic modelling and calibration for event and continuous simulations; Potential and actual evapo-transpiration estimates; Single station frequency analysis; and Water balance calculations.

Hydraulics
Sediment transport hydraulics; Velocity profiling; Flood-wave routing in complex channels; Channel erosion potential analysis, including tractive force indices; and Hydraulic design of water management structures.

Fluvial Geomorphology
Initiation of sediment movement; Constructed bed-form frequency and channel stability issues; Channel plan-form and section morphology; Impacts of sediment transport on channel morphology and Stream form classification using the Rosgen Classification Scheme.

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario

Engineers Nova Scotia

PUBLICATIONS

MacKenzie, K.M., Singh, K., Binns, A.D., Whiteley, H.R. and Gharabaghi, B., 2022. Effects of urbanization on stream flow, sediment, and phosphorous regime. *Journal of Hydrology*, *612*, p.128283.

MacKenzie, K.M., Gharabaghi, B., Binns, A.D. and Whiteley, H.R., 2022. Early detection model for the urban stream syndrome using specific stream power and regime theory. *Journal of Hydrology*, *604*, p.127167.

Rose, G. T and MacKenzie, K. M. (2013). Water Quality Forecasting and Infrastructure Optimization System. Meeting #68 of the Atlantic Coastal Zone Information Steering Committee (ACZISC). Bedford Institute of Oceanography, Halifax, Nova Scotia, January 16-17, 2013.

S. I. Ahmed, K. MacKenzie, B. Gharabaghi, R.P. Rudra, W.T. Dickinson. (2011). Within-storm rainfall distribution effect on soil erosion rate. ISELE Paper Number 11000. International Symposium on Erosion and Landscape Evolution. Anchorage, Alaska September 18-21, 2011.

Bell, J., K. MacKenzie and J. Southwood. (2011). Down Under Up North - Could an Australian water- sensitive urban design project work in the Canadian context? Water Canada July/August 2011.

DeVito, C. and MacKenzie K. (2011). Critical Shear Velocity Estimates Improved with In-Situ Flume. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

Davidson C. and MacKenzie K. (2011). Golder Daily Climate Record Generator. 20th Canadian Hydrotechnical Conference, Ottawa Ontario June 14th to 17th 2011.

MacKenzie, Kevin. (2009). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2009.

MacKenzie, Kevin. (2007). Industrial Wastewater Approvals. Canadian Environmental Compliance Conference and Trade Show (CANECT). Metro Toronto Convention Centre, April 2007.

Mackenzie, K.M., R.P. Rudra and W.T. Dickinson. (1996). Modelling the inter-rill detachment process: Some considerations for improving model results. ASAE Paper No. NABEC96-94, Amer. Soc. Agr. Engr., St. Joseph, MI.

MacKenzie, K.M., R.P. Rudra and W.T. Dickinson. (1995). The effect of temporal distribution of rainfall on inter-rill detachment. ASAE Paper No. 95-2378, Amer Soc. Agr. Engr., St. Joseph, MI.

Education

B.A.Sc Geological Engineering (Water Resources Option) University of Waterloo, Waterloo, Ontario, 1997

M.Sc. Earth Sciences (Hydrogeology), University of Waterloo, Waterloo Ontario, 2001

Certifications

Registered Professional Geoscientist, Association of Professional Geoscientists Ontario (PGO)

Registered Professional Engineer, Association of Professional Engineers Ontario (PEO)

Golder Associates Ltd. – Cambridge

Project Manager / Hydrogeologist

Greg is a Project Manager/Hydrogeologist within Golder's Cambridge office with over 20 years of experience in groundwater resource consulting. He is a graduate of the M.Sc. program in hydrogeology at the University of Waterloo where he studied groundwater contamination from agricultural activities near a municipal well field in Southern Ontario. Greg has technical experience in assessment of aquifer and well yields, groundwater exploration, development and protection, groundwater/surface water interactions, source water protection, groundwater under the direct influence of surface water investigations, groundwater monitoring, borehole geophysics interpretation, groundwater modelling, well installations, well maintenance and decommissioning and aggregate resource investigations. He is typically responsible for hydrogeologic analysis, interpretation and assessment, field supervision, report preparation and project management. Greg has been a project hydrogeologist and project manager for several large and challenging aggregate resource development projects in Ontario.

Employment History

Golder Associates Ltd. – Cambridge, Ontario

Hydrogeologist (2009 to Present)

Hydrogeologist and project manager responsible for the implementation and management of hydrogeological projects that encompass groundwater supply, development and protection. Greg has technical experience in assessment of aquifer and well yields, groundwater exploration, development and protection, groundwater/surface water interactions, source water protection, groundwater under the direct influence of surface water investigations, groundwater monitoring, borehole geophysics interpretation, well installations, well maintenance and decommissioning, and aggregate resource investigations.

Lotowater Technical Services Inc. – Paris, Ontario

Hydrogeologist (2000 to 2009)

Project hydrogeologist and project manager responsible for hydrogeologic assessments, water supply, development and protection projects, groundwater under the direct influence of surface water investigations and source water protection studies. Responsibilities included hydrogeologic analysis, interpretation and assessment, field supervision, report preparation, development and coordination of field investigation and/or monitoring programs and liaison with regulatory agencies. These projects typically included both a field investigation/testing component and a desk-top assessment/analysis. Projects included the exploration and development of groundwater supplies for various uses, assessing the associated impacts and developing water resources protection strategies. Several large and challenging groundwater resource and development projects have been undertaken in southern Ontario.

Research Experience – Woodstock, Ontario
M.Sc. Thesis (1997 to 2001)

Research on groundwater contamination from agricultural land use activities. The study investigated the increasing nitrate concentrations at a municipal well field located in an urban/rural area. The investigation included a hydrogeological investigation to assess the impacts of agricultural activities at the regional scale on nitrate quality in an urban/rural well field and to evaluate potential strategies to minimize the impacts within a reasonable time period. The research included the installation and monitoring of numerous monitoring wells, a large-scale aquifer test and numerical modelling of the aquifer system. The results were used to aide in protecting the municipal aquifer.

PROJECT EXPERIENCE – AGGREGATE RESOURCES

CBM Aggregates North Dumfries Township, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the Cambridge Pit Expansion. The application is for aggregate extraction below the water table and the study includes a Level 1/2 Water Report. The study also included a drilling and testing program to evaluate the resource.
CBM Aggregates North Dumfries Township, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the David Pite Expansion. The application is for aggregate extraction below the water table and the study includes a Level 1/2 Water Report. The study also included a drilling and testing program to evaluate the resource.
CBM Aggregates Caledon, Ontario, Canada	Senior Reviewer and Field Program Lead for an integrated impact assessment to support a future licence application for the Caledon Pit / Quarry. The proposed licence is intended to permit the extraction of aggregate and rock from below the water table.
CBM Aggregates Dorchester, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment supporting a major Site Plan amendment at the Dorchester Pit. The proposed amendment is intended to permit the extraction of additional available aggregate resources from below the water table at the existing pit.
CBM Aggregates Sunderland, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the Sunderland South Pit Expansion. The application is for aggregate extraction below the water table and the study includes a Level 1/2 Water Report. The study also included a drilling and testing program to evaluate the resource.
CBM Aggregates Peterborough County, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the Godfrey Pit Expansion. The application is for aggregate extraction above and below the water table and the study includes a Level 1/2 Water Report. The study also included a drilling and testing program to evaluate the resource.
Lafarge Canada Glen Morris, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the Glen Morris Pit. The application is for aggregate extraction above and below the water table and the study includes a Level 1/2 Water Report. The study also included a drilling and testing program to evaluate the resource.

CBM Aggregates North Dumfries Township, Ontario, Canada	Lead Hydrogeologist for an integrated impact assessment to support a future licence application for the Dance Pit Extension to an existing licence. The application is for aggregate extraction above the water table and the study includes a Maximum Predicted Water Table Assessment.
Cambridge Aggregates Ayr, Ontario, Canada	Lead Hydrogeologist for a Level 1/2 Hydrogeological Assessment in support of a licence application for the Ayr Pit. Work was conducted in a sensitive area and included the preparation of trigger levels and a contingency plan. Aggregate extraction is above the water table.
Cambridge Aggregates North Dumfries Township, Ontario, Canada	Lead Hydrogeologist for a Level 1/2 Hydrogeological Assessment in support of a licence application to expand the North Dumfries Pit. Aggregate extraction is above the water table. Work also included testing a supply well to provide water for aggregate washing along with the associated permitting.
Preston Sand and Gravel North Dumfries Township, Ontario, Canada	Lead Hydrogeologist for a Level 1/2 Hydrogeological Assessment in support of a licence application for the Henning Pit. Aggregate extraction is above the water table.

TRAINING

Aquifer Mapping/Wellhead Delineation Workshop, 2001

Source Water Protection Best Management Practices and Other Measures for Protecting Drinking Water Supplies, 2003

Borehole Geophysics Short Course, 2007

Critical Thinking in Aquifer Test Interpretation, 2011

Interpreting Aquifer Tests in Fractured Rock, 2012

PUBLICATIONS

Padusenko, G. 1997. Undergrad Thesis (B.A.Sc.): The Influence of Scale on Hydraulic Conductivity Measurements.

Padusenko, G. 2001. Masters Thesis (M.Sc.): Regional Hydrogeologic Evaluation of a Complex Glacial Aquifer System in an Agricultural Landscape: Implications for Nitrate Distribution.

Padusenko, G. 2003. Presentation: A Comparison of Particle Count Data to On Line Turbidity From a Pumping Well. OWWA Conference.

Lotimer, T. and Padusenko, G. 2008. Presentation: Constructed Preferential Pathways: Where Did My Well Go? OWWA Conference.

Chapman et. al., 2015. Paper: Hybrid Multilevel System for Monitoring Groundwater Flow and Agricultural Impacts in Fractured Sedimentary Bedrock. National Groundwater Association – Groundwater Monitoring and Remediation.

St. Catharines

Senior Hydrogeologist and Principal

As a Senior Hydrogeologist with Golder, Dr. McFarland has more than 30 years of professional experience and a broad background in conducting, managing and directing aggregate waste management, mining, power, oil and gas, and ground management and protection projects. He served as the project director for work programs for proposed mines, aggregate operations and industrial facilities.

He has a broad background in licensing and permitting of pits and quarries. This includes the licensing for the expansion of the Lafarge Dundas Quarry, the expansion of the Lafarge Woodstock Quarry, the expansion of the Nelson Aggregate Quarry, the RW Tomlinson license application, the St. Mary's cement Bonis Quarry, the ongoing expansion of the Port Colborne Quarry, and the Lafarge Goodwood Pit and other sites. He is also involved in numerous PPTW applications for pits and quarries. In addition, he has extensive experience in site selection studies and resource evaluations for aggregate sites.

Sean acted as the Project Director and Senior Hydrogeologist for the 2014 and 2015 annual landfill monitoring reports for the Vale Port Colborne site and for 8 landfill monitoring programs in Niagara Region. He was the Project Manager and Senior Hydrogeologist for the extensive Adams Mine landfill project, which involved the successful permitting of a 20 million tonne hydraulic containment engineered landfill facility, within a 200 m deep former open pit mine, following hydrogeological investigations collected over an 8-year period that involved extensive monitoring well installation, electronic instrumentation and testing, pump test analyses and groundwater flow modelling. He has also been an expert witness for hydrogeology at Environmental Assessment (EA) and Ontario Municipal board (OMB) hearings and has been involved in extensive contaminated site investigations including legal disputes.

Additional project experience includes hydrogeological assessments for the low level radioactive (LLRWM) facility concepts of waste management for the Canadian federal government Siting Task Force Secretariat (STFS) in limestone bedrock beneath the Great Lakes, and fractured and faulted Precambrian granitic gneiss at the Chalk River Nuclear Reactor site in northern Ontario, Canada. Further project experience in fractured rock includes the proposed Steetley Landfill, in limestone bedrock of the Niagara escarpment, including an extensive EA level hydrogeological investigation, over a 5-year period, and the existing Brow Landfill including an EPA level investigation, a long-term monitoring program and remediation.

Education

PhD Osgoode Hall Law School, York University, 2013

LLM Osgoode Hall Law School, York University, 2005

MBA Centre for Innovative Management, Athabasca University, 2001

M.Sc. Earth Sciences, Brock University, 1997

B.Sc. Geological Sciences (Honours), University of Toronto, 1985

Certifications

Professional Geoscientist, P.Geo., Ontario

Certified Professional Accountant, CPA, Ontario

Certified Management Consultant, CMC

Project Management Professional, PMP

Languages

English – Fluent

Employment History

Golder Associates Ltd. – Mississauga, Ontario

Senior Geoscientist and Principal (1987 to Present)

Hydrogeologist then Senior Hydrogeologist (1987-present)
Managing Principal, Vice President, Canada (2005-2014)
Associate - 1997 appointment
Principal - 2003 appointment
Geologist and Hydrogeologist (1985 to 1987)

Characterization of proposed and existing metal and industrial mineral facilities and impact assessments for industrial facilities.

Regina Associates Ltd. – Kingston, Ontario
Geoscientist (1983 to 1987)

Characterization of proposed and existing metal and industrial mineral facilities in Ontario, Nova Scotia, Newfoundland, British Columbia and the Northwest Territories; and hydrogeological impact assessments for industrial facilities.

SELECTED PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Aggregate Resource Evaluation Regional Municipality of Peel, ON	Project Manager and geologist for evaluation of sand and gravel and bedrock resources in the Regional Municipality of Peel, Ontario for the provincial Ministry of Municipal Affairs and Housing (MMAH). The project was carried out as part of the development of the official plan for the Region.
Region of Peel Regional Municipality of Peel, ON	Technical advisor for ARIP (Aggregate Resource Inventory Paper) report for the Regional Municipality of Peel. The project involves and evaluation of shale and gravel, limestone and shale resources in the Region and was submitted to the Ontario Geological Survey for publication as a government document ARIP Paper.
Navan Quarry Navan, ON	Project Manager and geologist for evaluation of sand and gravel and bedrock resources in the Regional Municipality of Peel, Ontario for the provincial Ministry of Municipal Affairs and Housing (MMAH). The project was carried out as part of the development of the official plan for the Region.
Brockville Quarry Brockville, ON	Project Manager and hydrogeologist for hydrogeological evaluation of the Permanent Lafarge Brockville Quarry. The results of the evaluation were used to negotiate the liability of the quarry to alleged water well interference associated with quarry expansion with the Ontario Ministry of the Environment.
Dufferin Aggregates ON	Project Director and senior hydrogeologist for numerous aggregate projects at quarries and sand and gravel pits within Ontario including resource evaluations, hydrogeological investigations and environmental assessments.
Due Diligence Studies Southern Ontario	Project Manager and senior hydrogeologist for due diligence studies as part of the potential purchase of aggregate companies and operating pits and quarries in Ontario.
Site Selection Studies Southern Ontario	Project Director for site selection studies for development of quarries and sand and gravel operations in Ontario.
Lafarge - North Quarry Flamborough, ON	Project Director for hydrogeological program at the Lafarge (formerly Redland) Quarry Operations in Flamborough, Ontario, to meet the regulatory requirements of the Ontario Ministry of the Environment.
Proposed Halminen Quarry Buckhorn, ON	Project Manager for a private application for a license for a proposed limestone quarry near Buckhorn, Ontario. The project involved management of multi-disciplinary project team public meetings, and application for a Class A licence under the Aggregate Resources Act.
Votorantim Cimentos Bowmanville, ON	Project Director for the development of a limestone/dolostone mine under Lake Ontario. The work programs involve drilling and testing of a 275m deep borehole under the lake, development of an underground mine plan, preparation of an EA document for regulatory approvals and public participation programs.

Milton Limestone Quarry Peer Review Milton, ON	Project Director for the peer review of the hydrogeological and adaptive management plan report for the proposed Dufferin Aggregates Milton Quarry expansion. The work program involved meetings with the hydrogeological consultant and legal counsel and attendance at Ontario Municipal Board hearings.
SAROS Study Greater Golder Horseshoe, ON	Evaluation of supply and demand of aggregate resources in the Greater Golden Horseshoe for the MMNR (Ministry of Natural Resources and Forestry). The project includes resource estimates for 25 quarries and 120 pits and unlicensed sand and gravel resources in the study area.
Nelson Quarry Expansion Burlington, ON	Project Director for the proposed Nelson Quarry extension including extensive borehole drilling and monitoring well installations, water quality sampling, a surface water program, groundwater flow modeling, impact assessments, preparation of an Adaptive Management Plan (AMP), reporting and acting as an expert witness at an Ontario Municipal Board hearing.
Lafarge South Quarry Expansion Dundas, ON	Project Director for a hydrogeological and hydrological work programs in support of a license application for the expansion of the Lafarge South Quarry near Dundas, Ontario (ongoing). The work program involves borehole drilling and monitoring well installations, geophysical borehole logging, water quality sampling and analyses, hydrological analyses of streams and wetlands, a karst assessment, a water well survey, geological and hydrogeological interpretation, groundwater flow modeling, agency interaction and attendance at public meetings.
Lafarge Fonthill Pit PTTW Renewal Fonthill, ON	Project Director for a hydrogeological work program in support of a Permit to Take Water (PTTW) application for the Lafarge, The work program included interpretation of pumping wells records, evaluation of drawdown in water wells related to pumping, water quality analyses and preparation and submission of a report in support of the permit application.
Lafarge North Quarry Expansion Dundas, ON	Project Director for a hydrogeological work program conducted in support of a license application for the expansion of the Lafarge North Quarry. The work program involved borehole drilling and monitoring well installations, pumping tests, groundwater flow modelling, a water well survey, an impact assessment of potential effects on water wells and an adjacent provincially significant wetland, agency interaction and preparation of a report submitted in support of the license application. The application was approved with an Ontario Municipal Board hearing.
Lafarge PTTW Monitoring Programs ON	Project Director for hydrogeological monitoring programs for a portfolio of more than 50 pits and quarries in Ontario. The programs involved water level and water quality monitoring, evaluation of pumping records, effects assessments and preparation and submission of monitoring reports for compliance with the permits.

RW Tomlinson Quarry License Application
Brechin, ON

Project Co-director for the hydrogeological work program for a hydrogeological work program performed in support of a license application for a dolostone quarry in the Carden Plain. The work program involved borehole drilling and monitoring well installation, geophysical borehole logging, packer testing, well response testing, pump testing, water quality sampling, groundwater flow monitoring, an impact assessment including potential effects on surrounding water wells and an adjacent wetland, development of a monitoring program preparation of a report in support of the application and agency interaction.

Proposed Lafarge Glen Morris Pit
ON

Project Director and senior hydrogeologist for the hydrogeological work program in support of a license application for the proposed Glen Morris Pit. The work program included borehole drilling, monitoring well installations, groundwater level monitoring and the provision of data and preparation of a hydrogeological report.

Lafarge Wellington Quarry PTTW and ECA Renewal
ON

Project Director and senior hydrogeologist for the Lafarge Wellington Quarry Renewal. The field program involved borehole drilling, packer testing, monitoring well installations, groundwater level monitoring, a field pumping test, development of a water budget and groundwater quality sampling. A hydrogeological impact assessment was developed to assess the potential impacts of quarry groundwater level drawdown related to quarry dewatering activities on surrounding private water wells and municipal wells. The work program included the modification of the regional source water protection to incorporate site data to assess the potential affects on the Guelph municipal wells.

Lafarge Regan Resource Drilling
ON

Project Manager and senior geoscientist for resource drilling at the Lafarge Regan site using some drilling techniques. The results of the work program were provided to Lafarge for their resource assessment.

Lafarge Hagersville Quarry
Hagersville, ON

Senior Hydrogeologist for the assessment of quarry dewatering and pumping for the Lafarge Hagersville Quarry as part of the PTTW monitoring program.

Arbour Farms License Application
ON

Senior Hydrogeologist for the Arbour Farms license application for a pit below water. The work program included borehole drilling, installation of monitoring wells, groundwater level monitoring and assessment of potential affects on an adjacent water course. Three-dimensional groundwater flow and heat transport modeling was completed to assess the potential thermal impacts on the surrounding surface water courses.

Rankin Construction Port Colborne Quarry Extension
Port Colborne, ON

Project Director for a multi-disciplinary work program for a license application for an extension of the Port Colborne Quarry. The work program involved hydrogeological, hydrological, blasting, noise, air, natural environment, planning, agricultural and archaeological studies and a resource estimate. Senior Hydrogeologist for the hydrogeological work program that involved borehole drilling, monitoring well installations, groundwater quality sampling and analysis, an impact assessment and a monitoring and response program for potential impacts on surrounding water wells.

Lafarge Goodwood Pit Extension Goodwood, ON	Project Director and senior hydrogeologist for a license application for the Lafarge Goodwood Pit extension, for a Category 1 Class EA pit below water. The objective of the work program was to characterize the existing hydrogeological and hydrological conditions in the vicinity of the site, including the depth and elevation of the water table and assess potential affects of the operational and rehabilitation scenarios. The work program involved borehole drilling, monitoring well installations, groundwater level monitoring, development of a water budget and a hydrogeological impact assessment.
Lafarge Woodstock Quarry Expansion Woodstock, ON	Project Director and senior hydrogeologist for the hydrogeological investigation of the Woodstock quarry for support of a license amendment. The field program involved borehole drilling, packer testing, monitoring well installations, groundwater quality sampling and analysis, a field water well survey and development of a water budget. An impact assessment was conducted to assess the potential affect of quarry related groundwater level drawdown on surrounding water wells and surface water courses.
CRH Resource Evaluation and Due Diligence ON	Project Manager and senior geoscientist for a resource evaluation of a property near Orangeville, Ontario for potential acquisition for quarry development. The work program included borehole drilling, geological logging of the rock core, monitoring well installations to determine the depth of the water table, aggregate quality testing and reporting.
Limestone and Sandstone Resource Evaluation and Due Diligence Regional Municipality of Peel, ON	Project Director and senior hydrogeologist for a resource evaluation for a property developer for potential acquisition of an existing quarry near Mississauga. The work program involved borehole drilling, core logging, aggregate quality testing and reporting.
Stouffville Resource Drilling Stouffville, ON	Project Manager and senior hydrogeologist for the resource drilling at Lafarge Stouffville Quarry. The drilling was conducted using a sonic drill rig with continuous core sampling. The results were provided to the Lafarge geologist for the resource assessment.
Lakeridge Resource Drilling ON	Project Manager and senior geoscientist for the resource drilling at the Lafarge Lakeridge site. The drilling was conducted using sonic coring and the results provided to the Lafarge geologist for development of a resource assessment.
Votorantim Thomas Quarry License Application ON	Senior hydrogeologist for the hydrogeological component of the Votorantim Thomas Quarry Extension license application. The work program involved borehole drilling, packer testing, geophysical borehole logging monitoring well installations and groundwater quality sampling and analysis. Three-dimensional groundwater flow monitoring was conducted to assessment the potential hydrogeological impacts of the quarry.
Lafarge Pinkney Pit #3 ON	Senior Hydrogeologist for the hydrogeological work program for the Lafarge Pinkney Pit #3 license application. The work program involved borehole drilling, monitoring well installations and a hydrogeological impact assessment.

Lafarge Mosport Resource Drilling
ON

Project Manager and senior geoscientist for the sonic borehole drilling at the Lafarge Mosport Pit. The results of the resource drilling were provided to the Lafarge geologist as part of the site resource assessment.

Lafarge Goodwood Resource Drilling
ON

Project Manager and senior geoscientist for sonic borehole drilling of the resource near the Lafarge Goodwood Pit. The results of the drilling were provided to the Lafarge geologist for a resource assessment.

APAO (Aggregate Producers Association of Ontario) Water Consumption Study
ON

Project Director for a study for the APAO to determine the consumption of water associated with pits and quarries.

Lafarge Sunningdale Pit Monitoring Program
ON

Senior Hydrogeologist for the Lafarge Sunningdale Pit Monitoring Program. The work program includes hydrogeological monitoring, an assessment of potential impacts and preparation of an annual monitoring report.

Votorantim Resource Assessment
ON

Project Manager and senior geoscientist for a resource assessment at a Votorantim Quarry in central Ontario. The work program involved borehole drilling and borehole geophysics were used to identify and correlate the geological formations and members at the site.

Cox Construction Monitoring Well Network
Wellington County, ON

Project Manager and senior hydrogeologist for borehole drilling and monitoring well installations at a property in Wellington County to provide baseline date for potential future licensing as a quarry. The wells were installed in the thick sequence of Amabel Formation at this locates. Groundwater level monitoring was performed to determine the depth to water table.

Cox Construction Resource Evaluation and Due Diligence
ON

Project Director for a drilling program to evaluate to the limestone resource for potential acquisition of a property for development. The work program involved borehole drilling, geological logging of the rock core, monitoring well installations, aggregate quality testing and reporting.

SELECTED PROJECT EXPERIENCE – WASTE MANAGEMENT

Adams Mine
Kirkland Lake, ON

Project Hydrogeologist and Project Manager for the hydrogeological assessment of the Adams Mine near Kirkland Lake, Ontario over a five-year period as part of the proposed development of 20 million tonne engineered landfill facility for solid non-hazardous waste. The facility will receive waste from the Greater Toronto Area (GTA) via a rail line system. The landfill facility incorporates a hydraulic containment design, which prevents outward migration of contaminants from the landfill, which reduces environmental impacts and long-term operating costs. Provided expert witness testimony in an environmental assessment (EA) hearing.

Brow Landfill Dundas, ON	Project Hydrogeologist then Project Manager for hydrogeological assessment for landfill expansion of the existing Redland Quarries Inc. (formerly Steetley Quarry Products Ltd.) solid industrial waste Brow Landfill in Flamborough, Ontario. Subsequent work included ongoing groundwater and surface water quality monitoring and preparation monitoring reports submitted to the MOE, followed by development of a closure plan and an ongoing compliance monitoring program.
South Quarry Landfill Flamborough, ON	Project Hydrogeologist for hydrogeological assessment of the proposed Redland Quarries Inc. (formerly Steetley Quarry Products Ltd.) South Quarry in Flamborough, Ontario for the proposed development of an engineered landfill facility. Participated in environmental assessment (EA) hearings and assisted with the preparation of final arguments with legal counsel.
Siting Task Force Secretariat Chalk River, ON	Project Hydrogeologist, then Project Manager for geological and hydrogeological characterizations of the Chalk River Nuclear laboratories property, near Chalk River, Ontario for siting of a proposed facility for the disposal of low-level nuclear waste for the federal Siting Task Force Secretariat (STFS).
Siting Task Force Secretariat Port Hope, ON	Project Hydrogeologist then Project Manager for geological and hydrogeological characterization of the Lakeshore site in Port Hope, Ontario, for the federal Siting Task Force Secretariat (STFS). The work was carried out as part of the feasibility level I study for dispose of low-level waste in engineered caverns beneath Lake Ontario and the Cameco Uranium fuel processing facility in Port Hope.
Interim Waste Authority Regional Municipality of Peel, ON	Project Hydrogeologist for geological and hydrogeological characterization comparative evaluation of five short-listed sites for siting of an engineered landfill facility as part of the provincial Interim Waste Authority (IWA) landfill site selection process for the Region of Peel.
Guelph-Wellington County WMMP Wellington County, ON	Project Hydrogeologist for geological and hydrogeological characterization of five candidate sites and identification of a preferred site in Wellington County for siting of an engineered municipal landfill facility, as part of the joint City of Guelph - County of Wellington Waste Management Master Plan (WMMP).
Model City Landfill Lewiston, NY	Project Hydrogeologist for hydrogeological investigation of the Model City hazardous waste landfill, near Lewiston, New York, carried out as part of landfill expansion.
Welland-Wainfleet WWMP Townships of Welland and Wainfleet, ON	Project Hydrogeologist for the identification of preferred sites for development of a municipal landfill facility, as part of the Welland-Wainfleet Waste Management Master Plan (WMMP).
Brock South Landfill Pickering, ON	Project Hydrogeologist for assessment of the proposed Brock South Landfill near Pickering, Ontario, to assess the suitability of the site for development of an engineered municipal landfill facility for Metropolitan Toronto.
Redland Queenston Quarry Queenston, ON	Project Hydrogeologist for hydrogeological assessment of the Redland Quarries Inc., Queenston Quarry to determine the suitability of the site for disposal of waste rock saline shale, from the construction of the proposed diversion tunnels of the Sir Adam Beck III hydroelectric generating facility in Niagara Falls, Ontario.

Fly Ash Disposal Facility ON	Project Hydrogeologist for hydrogeological investigations at four quarries located near Hagersville, Cayuga, Smithville and Milton to determine their suitability for development an engineered landfill for disposal of fly ash from the Ontario Hydro Lakeview Power Generating Station.
Mohawk Street Landfill Brantford, ON	Project Hydrogeologist for assessment of groundwater and surface water quality impacts at the municipal Mohawk Street Landfill in Brantford, Ontario.
Vale Industrial Landfill Port Colborne, ON	Project director for the preparation of an annual report for the groundwater monitoring program for an industrial waste landfill at a former nickel refinery. The work program included interpretation of groundwater flow directions and water quality trends, evaluation of the extent of the leachate plume, and an impact assessment.
Vale Industrial Refinery Landfill Monitoring Port Colborne, ON	Project Director and senior hydrogeologist for an evaluation of the effectiveness of the purge well system at a former nickel refinery and the development of mitigation and rehabilitation measures for well clogging. The work program involved step drawdown pumping tests, longer term pumping tests, hydraulic analysis of pumping test data, assessment of the decline of well efficiency due to scaling and bio fouling and the development of a work program for well rehabilitation and maintenance including acidification.
Municipal Landfill Annual Monitoring Programs Niagara Region, ON	Project Director for the annual monitoring program for 8 landfills in bedrock and escarpment settings in Niagara Region. The work program involves field water quality sampling, groundwater level monitoring, and provision of progress and annual reports.
Proposed Walker Ingersoll Landfill ON	Senior Hydrogeologist for the hydrogeological investigation for the proposed Walker Landfill near Ingersoll, Ontario. The field program involved borehole drilling, monitoring well installations, packer testing, geophysical borehole logging, downhole flow profiling, groundwater quality sampling and analysis, a karst study and a water well survey. Three-dimensional groundwater flow modeling was conducted to assess the potential impacts of the landfill.

SELECTED PROJECT EXPERIENCE – SHALE INDUSTRY

Canada Brick Mississauga, ON	Specialist for assessment of geological controls upon shale quality at the Canada Brick Britannia Road quarry site. The work was carried out in conjunction with quality control estimate of shale reservoir on the property.
Canada Brick Halton Region, ON	Project Manager for a hydrogeological work program in support on an application for a license for the Hanson Brick Tremaine Quarry in Halton Region, Ontario.
Brampton Brick Limited Halton and Peel Region, ON	Project Director for a hydrogeological and surface water program in support of a license application for a proposed shale quarry for a brick manufacturer. The work programs involved borehole drilling and monitoring well installations, surface water flow monitoring, water quality sampling, groundwater flow modelling and preparation of an Adaptive Management Plan (AMP).

Hanson Brick Limited
Halton Region, ON

Project Director for the assessment of the potential gas migration from a landfill to an adjacent brick manufacturing facility containing a brick kiln. The program identified potential risks and a monitoring and response program.

SELECTED PROJECT EXPERIENCE – MINING

Stanleigh Mine
Elliot Lake, ON

Project Hydrogeologist for assessment of the Rio Algom Stanleigh Mine near Elliot Lake, Ontario. The project included development of a three-dimensional flow model of a low-level radioactive waste tailings facility in Precambrian bedrock of the Canadian Shield. The model was used to develop estimates of seepage rates from the facility and was submitted to the Atomic Energy Control Board (AECB) as part of the regulatory approvals process.

Voisey's Bay Mine
Labrador

Technical specialist for hydrogeological modelling at the Voisey's Bay Mine site involving development of three-dimensional groundwater flow models of a proposed tailings basin, mine waste rock disposal facility, and an open pit mine at the Voisey's Bay Mine Site in Labrador. The modelling was carried out for the Voisey's Bay Nickel Company (VBNC) as part of the hydrogeological assessment of the mine. The work was subject to regulatory review and presented as evidence at an environmental assessment hearing.

Baley Gold Mine
Baley, Russia

Project Hydrogeologist for an Environmental Impact Assessment (EIA) as part of a feasibility study for mine expansion. The hydrogeological component included evaluation of potential for water quality impacts for an open pit mine and tailings basin, reduction of flow in stream and interference with the municipal water well supply.

Asacha Gold Mine
Kamchatka, Russia

Project Hydrogeologist of the proposed Asacha Gold Mine in northeastern Russia. The assessment focused upon chemical water quality and streamflow impacts associated dewatering of an underground mine and construction of a tailings basin. The results of the assessment formed part of the mine feasibility study.

Timmins Mine Water Study
Timmins, ON

Project Hydrogeologist for assessment of flooding of an extensive array of underground mine working beneath the City of Timmins. The assessment included evaluation of the potential impacts arising from the discharge of water from the flooded mine workings at surface within the city.

Cigar Lake Mine
Saskatchewan

Project Hydrogeologist for assessment of potential groundwater inflows into proposed shaft in northern Saskatchewan for the Cigar Lake Mining Corporation (CLMC). The results of the assessment were used as the basis for the engineering design at the shaft.

Denison Mines
Elliot Lake, ON

Project Hydrogeologist for an assessment of low-level nuclear waste tailings basin at the Denison Mines near Elliot Lake, Ontario. The hydrogeology study included assessment of seepage of uranium-impacted groundwater from the basin.

MaCassa Mines
Kirkland Lake, ON

Project Hydrogeologist for hydrogeological assessment at the Lac Minerals MaCassa Mine tailing basins in Precambrian bedrock near Kirkland Lake, Ontario. The work was carried out to evaluate the potential impacts during operation and following decommissioning of the facility.

SELECTED PROJECT EXPERIENCE – CONTAMINATED INDUSTRIAL SITES

ICI
Nobel, ON

Hydrogeological assessment of groundwater and surface water quality at the former ICI explosives and war productions plant near Parry Sound, Ontario for ICI Canada. The program included assessment of groundwater and surface water quality impacts and removal of buried underground fuel storage tanks. The results of the investigations were submitted to the Ontario Ministry of the Environment as part of the site decommissioning.

Ford Motor Company
North York, ON

Dewatering of a groundwater collection gallery and discharge of the contaminated (chlorinated solvent) wastewater to the municipal sewer system (under special conditions), at the Ford Motor Company Plant in North York, Ontario.

Shell Oil
North York, ON

Dewatering of a groundwater collection gallery and discharge of the contaminated (chlorinated solvent) wastewater to the municipal sewer system (under special conditions), at the Ford Motor Company Plant in North York, Ontario.

Beaver Lumber
Cole Harbour, NS

Excavation of underground storage tank (fuel oil) at the Beaver Lumber store at Cole Harbour, Nova Scotia. The results of the investigation favoured Beaver Lumber, by indicating that damage to the store was due to lack of delivery of the fuel supplier rather than leakage from the site fuel storage tank.

ICI Surfactants
Oakville, ON

Hydrogeological impact assessment of cadmium concentrations in groundwater at the ICI Surfactants (formerly Atkemix) site in Oakville, Ontario. The results of the monitoring were submitted to the Ministry of Environment and Energy for regulatory purposes.

Bata Footwear
Batawa, ON

Participation in the hydrogeological investigation of chlorinated solvent contamination of a bedrock limestone aquifer at the Bata Footwear plant site in Batawa, Ontario. The results of the hydrogeological impact assessment were submitted to the Ministry of Environment and Energy and used during subsequent legal proceedings to determine financial liability of Bata Footwear for the groundwater contamination.

Niagara Recycling Centre
Niagara Falls, ON

Project Director and senior hydrogeologist for the annual operational and monitoring programs for a hydrogeological work program involving groundwater contaminated with chlorinated solvents at the Niagara Recycling Centre related to prior industrial land use. The work program involved operation of the groundwater injection remediation system, assessment of subsurface contamination and preparation of annual monitoring reports.

Rankin Construction Fill Management Plan
Port Colborne, ON

Project Director and senior geoscientist for the development of a fill management plan for Pit 1 at the Rankin Construction Port Colborne Quarry. The program included a plan to take excess fill from the area to fill Pit 1. This included a sampling and reporting program to meet MECP requirements.

SELECTED PROJECT EXPERIENCE – OIL & GAS

Assessment of Natural Gas Storage Potential
Lake Erie, ON

Project Manager for an assessment of the potential for natural gas storage on Crown Lands beneath Lake Erie. The study involved the assessment of natural gas reservoirs to evaluate their suitability for use as gas storage facilities. Estimated available storage volumes were provided for each of the reservoirs.

Assessment of Natural Gas Storage Potential
Southwestern Ontario

Project Manager for an evaluation of the hydrocarbon resources in Southwestern Ontario for the Petroleum Resources Centre of the Ministry of Natural Resources. The study included the interpretation and mapping of pool boundaries for major pools, calculations of in place and recoverable reserves, tabulation of reservoir characteristics, and estimation of potential hydrocarbon resources in the Ordovician strata of southern Ontario.

SELECTED PROJECT EXPERIENCE – MUNICIPAL GROUNDWATER STUDIES

Groundwater Study for the County of Victoria
ON

Project Director and senior hydrogeologist for a large-scale groundwater study for the County of Victoria with funding from the Provincial Water Protection Plan (PWPP). The work program involved a groundwater resource assessment, evaluation of existing groundwater usage, contamination assessment, development of management options and protection strategies, and an economic evaluation.

Groundwater Study for the City of Stratford
ON

Project Director and senior hydrogeologist for a Groundwater Study for the City of Stratford involving an assessment of groundwater resources, source of contamination, pump testing of deep wells in limestone bedrock, and development of groundwater management options and protection strategies.

Simcoe and South Simcoe Groundwater Studies
ON

Provided specialist hydrogeological services for both the North Simcoe Groundwater Study and South Simcoe Groundwater Study. The work program involved a characterization of the hydrogeology of the study areas and numerical groundwater modelling of Well Head Protection Areas for municipal wells (WHPAs).

SELECTED PROJECT EXPERIENCE – KARST

Nelson Quarry Extension
ON

Project Director and Senior Hydrogeologist for karst assessment of the proposed Nelson Quarry extension that involved mapping of the Amabel Formation along the exposed cliff faces of the Mount Nemo outlier, identification of karstic springs in the Medad Valley and associated water courses, mapping of karst features along more than 1 km of exposed quarry faces. Examination of surface karst features including sinkholes and internal drainage were mapped in the area of the quarry. An ERI (Electrical Resistivity Imaging) survey was conducted over a linear distance to identify potential anomalies that could represent karstic features. Boreholes were drilled into the karstic features to evaluate karstic conditions. The boreholes were video logged along the length of the hole to evaluate karstic features such as solution enlarged fractures and voids. The flow in the boreholes were pumped and logged during an impeller flow meter to assess inflow into boreholes from potential karstic features. An array of 8 wells and a pumping well were drilled to conduct a tracer test using fluorescein dye. The dye was injected into the wells and the travel time and dye concentrations were recorded to evaluate karstic flow paths and velocities. The results were incorporated in a report submitted as part of the regulatory approvals process and presented and defended at an Ontario Municipal Board hearing.

Proposed Redland Quarries Landfill
ON

Project Hydrogeologist for a karst study as part of a geological and hydrogeological evaluations of a proposed hydraulic containment engineered landfill facility in a quarry near Dundas, Ontario. The karst study involved examination and evaluation of karstic features in the vicinity of the quarry including solution-enhanced weathering and extensive network of surficial dolostone plain, and examination of epi-karst on more than 1 km of quarry faces including solution enlarged and materialized vertical joints. The results of groundwater level monitoring results were evaluated for patterns indicative of presence of karst including rapid rises in groundwater levels (‘spiking’). Pump tests were analysed to evaluate the drawdown and recovery responses characteristic of karst.

Proposed Dundas Quarry Extension
ON

Project Director and Senior Hydrogeologist for a karst assessment as part of a hydrogeological work program for the approval of an application for a large dolostone quarry near Dundas, Ontario. The work program involved an ERI surface geophysical survey along more than 500 m of line to test for potential karstic anomalies. Boreholes were drilled in the areas of identified anomalies to evaluate the potential presence of karst. The faces of the quarries were also examined for layers of karstic groundwater inflow. The results of the karst study have been peer reviewed and are currently being used in support of the license application for quarry expansion.

Karst Remediation
Hamilton, ON

Senior Hydrogeologist for a karst assessment of a remediated industry site in the area of the Eramosa Karst Conservation Area in Hamilton, Ontario. The work program involved a review of literature on karst in the area. An inspection of the karstic features includes sinkholes, internal drainage and inferred subsurface karstic flow pathways was undertaken in areas around the site. A report in support of a property transaction was provided to regulatory authorities and agencies.

Brow Landfill Monitoring Program
ON

Project Hydrogeologist for an assessment of leachate seepage from an industrial solid waste landfill along karstic flow pathways including epi-karst, solution weathered vertical joints and horizontal fracture networks. The assessment involved monitoring of the flow rates from leachate springs and water quality of springs.

Hydrocarbon Reserve Evaluation
Southwestern Ontario

Project Director and Senior Geologist/Hydrogeologist for the estimation of hydrocarbon reserves in Southern Ontario for the Petroleum Resource Centre of Ontario Ministry of Natural Resources. The work program involved extensive analysis of karstic reservoirs formed and dolomitization from solution weathering and collapse along vertical joints and horizontal sub horizontal fracture networks. Prepared a report summarizing the study and provided to the MNR as a commercial publication.

SELECTED PROJECT EXPERIENCE – LAND DEVELOPMENT AND INFRASTRUCTURE

Peer Review, Town of Caledon
Caledon, ON

Peer review of the hydrogeological work program for a proposed residential development in Palgrave for the Town of Caledon planning department. The work program involved review of hydrogeological reports, discussions with the Town and preparation of a peer review reports with recommendations.

Peer Review, Town of Caledon
Caledon, ON

Peer review of the hydrogeological and geotechnical work program for a proposed residential development in Beaverhall for the Town of Caledon planning department. The work program involved review of hydrogeological reports, discussions with the Town and preparation of a peer review reports with recommendations.

Niacon Construction
Niagara-on-the-Lake, ON

Hydrogeological assessment of the potential impacts associated with the development of an infrastructure for a zipline facility along the Niagara river at Thompsons Point. The work program involved an evaluation of the potential for reduction of groundwater seepage along the Niagara Gorge and related environmental effects. A report was prepared that was submitted to agencies as part of the regulatory approvals process.

Time Developments
Niagara Falls, ON

Senior hydrogeologist for the hydrogeological assessment of the existing conditions and potential impacts associated with the development of a condominium adjacent to the Niagara River in Niagara Falls. The work program involved borehole drilling, monitoring wells installation, groundwater level monitoring and assessment of groundwater levels and flow directions. The results of the work program were incorporated into a geotechnical and hydrogeological report.

Time Developments
Niagara Falls, ON

Phase 1 and Phase 2 Environmental Site Assessments (ESA) for regulatory approval for condominium development on River Road in Niagara Falls, Ontario. The work program involved test pitting and surface sampling as well as collection and analysis of soil and water samples and evaluation of potential soil and water contamination.

AECOM Oakville, ON	Hydrogeological assessment of the excavation and construction of a water pumping station in till and bedrock adjacent to a surface water course. The work program involved borehole drilling, monitoring well installations, hydraulic conductivity testing and a hydrogeological assessment of impacts on surrounding private wells associated with construction dewatering.
Geranium Homes Woodview Development ON	Hydrogeological assessment in support of approval for a proposed residential development involving borehole drilling, monitoring well installations, hydraulic conductivity testing, groundwater level monitoring, determination of groundwater levels and flow directions and a hydrogeological impact assessment involving a water balance to evaluate reduction in infiltration and potential interference with surrounding water wells and effects on an adjacent provincially significant wetland. Participated in meetings with the TRCA as part of the approvals process. A report was prepared in support of the approvals process.
Geranium Homes Altona Development ON	Hydrogeological assessment in support of approval for a proposed residential development. The work program involved borehole drilling, monitoring well installations, groundwater level monitoring, development of a water balance and a hydrogeological impact assessment. A report was prepared in support of the application.

Golder Associates Ltd. – Canada

Education

B.Sc. Civil Engineering, University of Waterloo, Ontario, 1988

M.A.Sc. Civil Engineering, University of Waterloo, Ontario, 1990

Mr. Scott Donald, M.A. Sc., P.Eng. (Mining)

Mr. Donald is a Principal and Senior Hydrogeologist with Golder Associates, and a specialist in numerical, analytical and statistical analysis of hydrogeological processes. He has over 30 years of experience applying numerical and analytical techniques to the solution of groundwater flow and solute transport problems over a wide range of projects. Over much of this time these skills have been primarily applied to the mining industry where he has directed or played a leading role in assessing potential hydrologic and hydrogeologic impacts and issues related to the development of new mines or in the mine closure process. This includes issues related to mine water balance, dewatering, aquifer depressurization, and modelling of seepage / solute transport from waste rock piles and tailings facilities. Mr. Donald's project experience includes conceptual hydrogeological model development and groundwater modelling simulations to address mine operation and closure issues for: oilsands operations in Northern Alberta (e.g., Syncrude's Base Mine and Aurora North operation; CNRL Horizon and the Fort Hills project; Teck's proposed Frontier Project, etc.); uranium mine operations/closure studies in Northern Ontario (Denison and Stanrock Mine) and Northern Saskatchewan (Key Lake, Rabbit Lake, Cigar Lake and McArthur River); tailings design/seepage optimization studies in South America (Newmont's proposed Conga Project in Peru, the Pachon project in Argentina, the Gramalote and Quebradona Projects in Columbia; and the Penasquito Project in Mexico). Mr. Donald was also responsible for the development a 3D finite element groundwater model (HydroGeoSphere) for the Brukunga Mine Rehabilitation Program near Adelaide, Australia to evaluate the long-term sustainability of a co-disposed tailings and waste rock facility. For many of the above projects, Mr. Donald has represented the hydrogeological and/or groundwater modelling component of the work at public hearings and/or through expert review panels as part of the formal review process.

PROJECT EXPERIENCE – CONCEPTUAL HYDROGEOLOGICAL MODEL DEVELOPMENT & GROUNDWATER MODELLING

Fort Hills Oil Sand Project EIA
Fort McMurray, Alberta, Canada

Responsible for the technical direction and review of groundwater modelling work completed in support of the Fort Hills Oil Sands Project EIA and associated engineering studies. The work involved an assessment of the impacts of mine development including: dewatering of surficial aquifers; depressurization and re-injection of basal water sands water; management of seepage from an out-of-pit tailings area and the change in groundwater/surface water interactions. Represented the hydrogeological component of the EIA through the public hearing process in Fort McMurray.

Teck Frontier Project EIA
Alberta, Canada

Task leader for the hydrogeological component of the Application. Work involved the development of baseline conditions, construction and calibration of a groundwater flow model and the completion of predictive simulations to support the impact assessment. Estimates of basal aquifer depressurization, overburden dewatering and seepage from tailings storage areas were developed from these calculations. A key component was to establish a sustainable closure landscape recognizing long term seepage from the external tailings disposal areas.

Rabbit Lake In-Pit Tailings Management Facility
Rabbit Lake Mine, Saskatchewan, Canada

Project Manager for completion of a detailed performance assessment of the Rabbit Lake In-Pit Tailings Management Facility. Work included the completion of detailed 3-D groundwater flow and solute transport modelling, and site-wide mass loading estimates derived from the disposal of Cigar Lake Ore Type tailings at the Rabbit Lake site. Source areas considered include waste rock piles and uranium tailings. Environmental fate and transport of metals and radionuclides in both porous media and fractured rock environments were simulated. This work subject to both provincial and federal regulatory review.

Gaertner Pit Waste Rock Disposal Scheme
Key Lake, Saskatchewan, Canada

Team leader for the preparation of decommissioning plans for waste rock at Cameco's Key Lake Mine. Work included mass balance modelling for nickel-rich waste rock deposited in the mined-out Gaertner Pit, as well as relatively clean waste rock above-grade around the perimeter of the pit. Pump and treat time frames and mass loading estimates to the treatment plant were estimated.

Deilmann In-Pit TMF
Key Lake, Saskatchewan, Canada

Project Manager for the completion of detailed groundwater flow and solute transport modelling, supporting Cameco's EIS for the placement of uranium mine tailings in the mined-out Deilmann Pit at Key Lake. Regional and local scale 3-D flow models were developed using MODFLOW to gain a better understanding of the regional groundwater flow system and the detailed distribution of flow in and adjacent to an underground tailings facility. Detailed 2D and 3D flow and solute transport models of the proposed in-pit tailings management facility were then constructed and used to evaluate design cases which included direct placement of tailings in the host sandstone bedrock, placement of tailings within a full pervious surround of coarse rock and filter sand and the placement of tailings within the host rock with a side and bottom drain configuration only.

Cigar Lake Project
Saskatchewan, Canada

Detailed numerical modelling was conducted in support of an EIS submission for the Cigar Lake mine. Both regional and local scale 3-D models were constructed using MODFLOW to gain a better understanding of regional groundwater flow systems and the local groundwater regime in the vicinity of the proposed underground tailings basins. The numerical models were used to predict inflows to the underground facilities during construction and operational phases and to identify potential receptors downgradient of the facilities. Solute mass loadings from the tailings facilities to the identified receptors were estimated using a combination of particle tracking techniques and POLLUTE, an analytical model which established the solute mass fluxes at the interface between the tailings and the host sandstone bedrock. Sensitivity analyses were performed to establish the impact of a low permeability sand-bentonite cap placed on top of the tailings at closure.

Mildred Lake Closure Plan
Fort McMurray, Alberta, Canada

Project Manager for completion of a hydrogeological assessment of Syncrude's proposed Closure Plan for the Mildred Lake facility. Work involved the development of 3-D groundwater flow and solute transport models for the proposed closure landscape including both above grade and in-pit tailings disposal systems, and coke storage areas.

OPTI Long Lake Project EIA
Fort McMurray, Alberta, Canada

Responsible for the technical direction and review of groundwater modelling work completed in support of the Long Lake Project EIA and associated engineering studies. The work involved an assessment of water supply for the SADG operations and the potential environmental impacts associated with groundwater withdrawals and the injection of waste water in the basal water sands.

Falconbridge Smelter Area Closure Plan
Falconbridge, Ontario, Canada

Hydrogeological team leader for a large multi-disciplinary study to develop closure plans for Falconbridge's smelter operations in Falconbridge, Ontario. Development of an effective closure plan required the successful integration of geochemical, hydrogeological, water treatment and surface water issues. 3-D numerical groundwater flow modelling was used to identify the direction of solute migration in groundwater from tailings source areas and to evaluate alternative pump and treat remediation schemes.

Brukunga Mine Closure Plan
Australia

Responsible for the development of an integrated groundwater – surface water numerical model (HydroGeoSphere) to support evaluation of alternative closure strategies for disposal of co-mixed ARD mine rock and tailings. Key to the development of the closure plan was maintaining saturated of the co-disposed material under future climate variability.

Denison and Stanrock Mine Closure Plans
Elliot Lake, Ontario, Canada

Responsible for the completion of detailed 3-D groundwater flow modelling (MODFLOW) at the Denison and Stanrock Mines. Flow modelling was used in the mine closure development process to estimate seepage rates in the project area for several alternative mine closure plans.

Agrium Phosphate Mine
Kapuskasing, Ontario, Canada

Constructed a 3-D groundwater flow model for a proposed phosphate mine in Kapuskasing, Ontario. A parametric analysis (with respect to aquifer storage and hydraulic conductivity) was completed to evaluate pre-dewatering requirements and provide input to the overall mine water budget.

Mildred Lake G-Pit Area
Fort McMurray, Alberta, Canada

Project Manager responsible for the development of a dewatering design for Syncrude's G-Pit borrow area. Work included the geological interpretation of channel deposits and the potential impact of dewatering on a large aboveground tailings impoundment.

Cigar Lake Mine Inflows
Cigar Lake, Saskatchewan, Canada

Constructed a simplified 3-D groundwater flow model to complete a parametric analyses of potential maximum groundwater inflows to the underground mine workings. These scoping level calculations were completed to provide a preliminary indication of potential water treatment requirements.

Mildred Lake T-Pit Area
Fort McMurray, Alberta, Canada

Responsible for the direction of a detailed technical assessment of the T-Pit aggregate borrow area at Syncrude Canada's Mildred Lake Operations. A deep sand and gravel paleochannel above the McMurray Formation oilsands was mapped and a 3-D numerical model constructed, in order to optimize the design of the dewatering system required. Design optimization required consideration of time frames for dewatering, and location of the dewatering wells.

Aurora East Mine Overburden Aquifer Test Analysis Fort McMurray, Alberta, Canada	Project Manager for the analysis of a long-term aquifer test (trench dewatering) in a surficial sand and gravel deposit. A 2-D numerical model was constructed and calibrated to monitoring results at over 6 monitoring well locations. The calibrated numerical model was used to estimate aquifer parameters and subsequently to evaluate alternative dewatering schemes for the entire deposit. Alternative dewatering layouts were provided that allowed for effective dewatering of the aquifer for different time frames under consideration by Syncrude.
Potash Corporation of Saskatchwan, Closure Plans Saskatchewan, Canada	Task leader for the completion of regional and local scale numerical groundwater flow models at five potash mines in Saskatchewan: Rocanville, Allan, Cory, Patience Lake and Lanigan Mine. Numerical modelling was completed to provide an understanding of regional and local scale groundwater flow conditions and to support the development of closure plans for each mine. Density dependent flow modelling was completed at a local scale in order to estimate the impact of the brine ponds present on surface at each location.
Conga Project Cajamarca, Peru	Responsible for the direction of the conceptual hydrogeological model and subsequent numerical modelling to help optimize the design of the tailings management facilty. Design optimization required consideration of extent and nature of liner design requirements, detailed characterization of the saprolitic soils and underlying limestone terrain, and evaluation of the downstream seepage collection systems. The modelling assessment considered solute transport from the tailings facility using a combination of FEFLOW and GoldSim.
Pachon Project Tailings Design Argentina	Together with the Project Engineering Geologist, responsible for the development of the regional conceptual hydrogeological model and numerical FEFLOW groundwater model to assess risks associated with seepage from the tailings facility. The majority of the proposed facility is underlain by intrusive bedrock, though upstream portions required characterization of karstic topography and its interaction with alluvial deposits in the valley bottom.
AngloGoldAshanti Gramalote Mine Project Colombia	Responsible for the technical direction of the hydrogeological team developing the site wide conceptual model, and the regional scale numerical modelling. Design input included: groundwater inflows to the two open pits; seepage from the waste rock piles; and seepage control measures for the tailings facility. Detailed characterization of springs and seeps served to constrain the water balance estimates and support the modelling assumptions; while extensive sensitivity analyses helped frame the potential range of seepages to consider in the design of the facilities.
Newmont Penasquito Project Mexico	Responsible for the technical direction of the hydrogeological team developing the conceptual hydrogeological model for the tailings facility at the Penasquito Mine, including scoping and execution of the field characterization program and subsequent development and application of a 3D numerical groundwater flow model (using HydroGeoSphere). Program objectives were to provide design input related to TMF engineering, including stability analyses and seepage management.

PROFESSIONAL AFFILIATIONS

Registered Professional Engineer, Ontario

Golder Associates Ltd. – Canada

Education

M.E.Sc. Environmental Engineering, University of Western Ontario, Ontario, 2018

B.E.Sc. Civil-Environmental Engineering, University of Western Ontario, Ontario, 2016

Professional Affiliations

Registered Professional Engineer, Ontario

Geo-Environmental Engineer

Hayley is a geo-environmental engineer with Golder Associates. Her experience is in the fields of water resources and hydrogeology, specializing in numerical modelling. Her project experience is in conceptual and numerical groundwater and groundwater-surface water flow model development for hydrogeologic investigations. She has provided technical support for projects utilizing FEFLOW, MODFLOW, Groundwater Vistas, HydroGeoSphere, GoldSim, Surfer, and QGIS. Hayley also has experience with application of field techniques for groundwater monitoring and sampling, and aquifer test analysis related to water supply permitting.

PROJECT EXPERIENCE – NUMERICAL GROUNDWATER MODELLING

Hydrologic Modelling of the Osprey Quarry
Ontario, Canada

Involved in conceptual and numerical model development for a transient groundwater- surface water model developed using the HydroGeoSphere (HGS) code, for the Osprey Quarry site in Ontario. This work included site characterization, transient calibration to 10 years of site surface water and groundwater monitoring data, and forecast simulations of quarry development under several climate scenarios. The model was used estimate the potential impacts of future quarry development on surrounding groundwater and surface water features, as part of the quarry's Adaptive Management Plan (AMP).

Cameco Key Lake Leapfrog Model Development
Saskatchewan, Canada

Involved in updated the conceptual site model using historic and recent drilling data and constructing a 3D Leapfrog model for the Key Lake Mill Terrace Groundwater Model domain. This involved review of site information, data processing to create geologic unit surfaces, and use of the Leapfrog model to refine and populate the 3D HydroGeoSphere (HGS) model. The results of this study were used to evaluate water management options.

Cameco Rabbit Lake Tailings GoldSim Modelling
Saskatchewan, Canada

Involved in simulating solute mass loading from source areas to various downgradient receptors using the Rabbit Lake GoldSim model. The work involved utilizing flow rates derived from groundwater flow modelling as inputs to the GoldSim model and simulating seven different model scenarios with variable source concentrations and volumes. The results of this component of the study assisted in the process of evaluating potential long term impacts and management practices.

City of Barrie Risk Municipal Water Supply Risk Assessment Modelling
Ontario, Canada

Involved in reviewing and updating groundwater model files for two existing groundwater models covering the City of Barrie (MODFLOW and FEFLOW) to reflect several potential future pumping scenarios for the municipal water supply system. This involved assessment of simulated potential changes to groundwater flow patterns and pressures in the municipal aquifer. The results of this study will be used as part of a groundwater drinking water system contingency plan for the City of Barrie.

Quaternary Groundwater Seepage Modelling of the Horizon Oil Sands Mine
Alberta, Canada

Involved in building, calibrating, and modelling long-term post-closure groundwater heads and flows within the mine closure landscape, using an FEFLOW model. This work involved modelling long term groundwater seepage rates and flow directions from the mine structures to potentially sensitive receptors for several climate scenarios. The results of the study are used in conjunction with results of water quality modelling as part of the reclamation planning submitted to the Alberta Energy Regulator (AER).

Simulating Large Scale Dewatering of Hardy Mine Pit Lake
Ontario, Canada

Involved in building, calibrating, and modelling the large-scale dewatering of a mine pit lake, using a FEFLOW model. This work involved characterization of the conceptual geology and building a geologic model using Leapfrog Works. Model simulations of several largescale dewatering options were conducted, including assessment of dewatering rates and potential impact of the water taking. The results of the study will be used in conjunction with construction cost estimates, in an options analysis process.

PUBLICATIONS

Journal Articles

Wallace, H., Wexler, E.J., Malott, S., Robinson, C.E. (2021). Evaluating lacustrine groundwater discharge to a large glacial lake using regional scale radon-222 surveys and groundwater modelling. *Hydrologic Processes.* https://doi.org/10.1002/hyp.14165

Wallace, H., Ji, T., & Robinson, C. E. (2020). Hydrogeological controls on heterogeneous groundwater discharge to a large glacial lake. *Journal of Great Lakes Research*, *46*(3), 476-485.

Other

Wallace, H. and Robinson, C.E. (2020). Assessment of nearshore groundwater discharge to Lake Simcoe, Ontario and identification of regional hydrogeological controls. In Russell, H.A.J. and Kjarsgaard, B.A. Eds. Southern Ontario groundwater project 2014-2019 summary report. Geological Survey of Canada, Open File 8536. https://doi.org/10.4095/321105

Golder Associates Ltd. – Cambridge

Education

Master of Science (Water), Earth Science, University of Waterloo, Waterloo, 2019

Bachelor of Applied Science Geological Engineering (Water Resources Option, Honours), University of Waterloo, Waterloo, 2014

Paul Menkveld, M.Sc., EIT, Environmental Scientist

Mr. Menkveld is an Environmental Scientist and Engineer in Training in the Geoscience Group at WSP Golder's Cambridge office, with more than 7 years experience in engineering consulting and hydrogeology. He is a graduate of the Geological Engineering (B.A.Sc.) and Master of Science (M.Sc.) programs at the University of Waterloo.

During Mr. Menkveld's 6 years at WSP Golder, he has built meaningful experience in hydrogeologic investigations, aggregate licencing, water supply investigations, and project management. He is a skilled hydraulic and aquifer test analyst and has extensive field experience to support lithological and hydrogeological characterization.

Employment History

WSP Golder – Cambridge, Ontario

Environmental Scientist (2016 to Present)

Responsible for the coordination, implementation, analysis, and reporting of hydrogeology projects for a range of applications including: aggregate operations, construction dewatering, municipal water supply, environmental assessments, and land development. Developed project management skills to collect comprehensive environmental data on interdisciplinary teams for permit applications, amendments, and compliance monitoring. Mr. Menkveld has consistently managed projects with attention to detail to implement best practices and meet client expectations.

Mr. Menkveld has coordinated, supervised, and conducted field work including: borehole drilling, soil sampling (including brown field sampling), monitoring well installations, aquifer testing, groundwater sampling, and surface water sampling

University of Waterloo, Earth and Environmental Science Department – Waterloo, Ontario

Researcher (M.Sc. and follow up) (2014 to 2019)

Award winning researcher and conference speaker on the topics of recharge and physical hydrogeology. Mr. Menkveld managed a research project with a significant budget, team, and external partners. During the research program Mr. Menkveld designed field and lab experiments to gather detailed datasets to observe complex recharge processes and their impact on shallow aquifers and well vulnerability. Following the completion of his M.Sc., Mr. Menkveld has continued to support the research group and its initiatives.

WSP Golder – Mississauga, Ontario

Hydrogeological Engineering Intern (2013)

Collaborated in the preparation, execution, and post-processing of numerical models including MODFLOW and FEFLOW to solve physical flow and contaminant transport analyses. Mr. Menkveld built site scale hydrostratigraphic

models, performed a variety of hydrogeological analyses including slug, rising head, and pump tests. He also used VBA and C++ code to analyze data sets, process data files, and prepare figures efficiently.

WSP Global Inc. (formerly GENIVAR and Jagger Hims Ltd.) – St. Catharine's, Ontario

Environmental Engineering Intern (2012)

Performed data analysis, figure preparation, and technical report writing to support landfill monitoring, aggregate extraction, environmental assessments, and groundwater monitoring. Mr. Menkveld conducted a wide variety of field work including ground water monitoring and sampling, supervising drilling and logging in overburden and bed rock, stream gauging, and surface water sampling.

GeoSolv Design/Build Inc. – Aurora, Ontario

Engineering Intern (2012)

Supervised large construction sites during the geotechnical soil improvement stage and coordinated projects with contractors, clients, drillers, and suppliers to maximize project efficiency. Mr. Menkveld supervised the successful application of specialized geotechnical techniques including helical screw piles and rammed aggregate piers.

BMRoss and Associated Ltd. – Goderich, Ontario

Undergraduate Engineer (2010)

Responsible for performing site inspections of infrastructure projects, and CAD drafting of projects such as bridges and water treatment plants.

PROJECT EXPERIENCE – HYDROGEOLOGY

Aggregate Extraction Site Baseline Monitoring Brantford, Ontario, Canada	Project manager of a multi-year baseline surface water and groundwater data collection, permit to take water application, and revision of threshold triggers for extraction. Monitoring was conducted to characterize the groundwater flow system and surface water features on the site to support dynamic management of operations and mitigate environmental impacts.
Cameco Port Hope Aquifer Vulnerability Mapping Ontario, Canada	Developed a site conceptual model, scored aquifer vulnerability of surface contamination, and mapped vulnerability to support regulatory requirements for the protection of groundwater resources at nuclear facilities.
Metrolinx Subway Design and Permitting Ontario, Canada	Supported the hydrogeology and dewatering scope of the project, which included development, single well response testing, groundwater, and headspace sampling, to support design and dewatering calculations.
Niagara Region Closed Landfill Improvements Ontario, Canada	Project's scope included investigative drilling to characterize leachate, observe groundwater conditions, and the use of sheet piles to protect surface water receptors. Supervised field work, including responding to encountered leachate gas and artesian groundwater conditions.
Niagara Region Closed Landfill Monitoring Ontario, Canada	Performed groundwater and surface water monitoring and sampling at various closed landfills in the Niagara Region.
NWMO Ignace Phase 2 Geoscientific Preliminary Field Investigations Ontario, Canada	Supervised drilling operations and fluid management of a deep borehole for preliminary deep geologic repository studies for the Nuclear Waste Management Organization. Responsibilities included managing fluid quantities, specifics of drill operation, preparation of tracer tagged drill water, preliminary borehole geophysics, and site supervision.
NWMO Bruce Power Deep Geologic Repository Baseline Monitoring Ontario, Canada	Performed monitoring, sampling, maintenance, and troubleshooting of Westbay systems to complete baseline hydrogeologic monitoring, for the Nuclear Waste Management Organization.
Agnico Eagle Mining, Meliadine Nunavut, Canada	Responsible for core logging, fluid management, preparation of drill fluid with a tracer, packer testing, and project coordination at a remote helicopter access location.
Cambridge Zone 3 Monitoring Well Construction Ontario, Canada	Supervised the drilling, construction, hydraulic testing, and sampling of three bed rock monitoring well nests, including karst features.
Maryhill Supply Well Drilling Ontario, Canada	Supervised drilling, including wireline PQ coring and tricone mud rotary methods, of a municipal supply wells. Prepared borehole logs and supervised hydraulic testing the well.

Colour Paradise Greenhouses Research Site, Manheim, Ontario, Canada

Conducted an extensive field program to assess the vulnerability of a shallow screened well to transient surface water features. During the course of this research program the field work included: well installation, time domain reflectometry, stream gauging, meteorology station deployment, geophysical soil moisture measurements, optical surface water tracking, groundwater sampling, resistivity measurements, and Guelph Permeameter operation. Lab work included, sieve analysis, permeameter, moisture content analysis, and the construction of a high accuracy Buchner Funnel apparatus.

Technical Advisory Group for Chemtura, Elmira, Ontario Ontario, Canada

Participated in the public review of technical proposals for the remediation of a highly contaminated aquifer, as a member of the Technical Advisory Group, Chemtura Public Advisory Committee. Mr. Menkveld contributed to meetings including government, consultants, industry, and the public stakeholders during a challenging political process.

TRAINING

NSERC Short Course in Reactive Transport Modelling
University of Waterloo, February 2015

PUBLICATIONS

Thesis

Menkveld, Paul G. and Rudolph, David, L., 2019. *A field study of event based, seasonally affected, depression focused recharge in glaciated terrain*, University of Waterloo, Department of Earth and Environmental Sciences, 2019 March. Waterloo, Canada.

Articles

Wiebe, Andrew J.; Menkveld, Paul G.; Hillier, Cailin E.; Mesec, Emilie; Rudolph, David L., 2019. *Meteorological and hydrological data from the Alder Creek watershed*, Grand River basin, Ontario. Federated Research Data Repository, https://doi.org/10.20383/101.0178.

Wiebe, Andrew , Paul Menkveld, Ehsan Pasha, Jacqueline Brook, Mike Christie and David Rudolph. Impacts of Event-based Recharge on the Vulnerability of Public Supply. Sustainability, 13(14) (2021), 7695.

Education

Bachelor of Applied Science Civil Engineering, Queen's University, Kingston, Ontario, 2020

Languages

English – Fluent

Golder Associates Ltd. – Mississauga

Junior Water Resources Engineer-in-Training (E.I.T)

Maxwell Robinson is a Junior Water Resources Engineer-in-Training (E.I.T) with consulting experience in a wide range of water quality, hydrotechnical and fluvial geomorphic related investigations. Project experience includes supporting environmental compliance approval applications, water balance studies, hydrologic and hydraulic modelling, meteorological data analysis, and fluvial geomorphic assessments. He has also assisted in water quality sampling and monitoring stream flows during field campaigns.

Employment History

Golder Associates Ltd. – Mississauga, Ontario

Junior Water Resources Engineer- in-Training (E.I.T) (October 2020 to Present)

Responsible for conducting water quantity and water quality investigation programs that include hydraulic and hydrologic modelling, analysis of watersheds, and the development of water balance and water quality modelling analyses. Currently working on various environmental compliance approval applications and permit To take water applications. Completes water resources projects from desktop reviews to design as well as participating in field programs.

SCS Consulting Group Ltd. – Markham, ON

Cost Sharing Engineering Assistant (May 2019 to August 2019)

PROJECT EXPERIENCE – MUNICIPAL ENGINEERING

Client Confidential
Near Whitby, Ontario, Canada

Carried out a hydrologic budget assessment and reporting as part of the hydrogeological assessment for a proposed development of detached houses, townhouses, underground parking, a SWM pond, and a park. Analysed possible low impact development features including infiltration trenches and downspout disconnection.

Shining Hill Estates Collection Inc.
Aurora, Ontario, Canada

Carried out a hydrologic budget assessment and reporting as part of the hydrogeological assessment for a proposed development of detached houses, townhouses, school, and a park. Analysed possible low impact development features including rear-yard infiltration trenches, bioretention cells and downspout disconnection. Completed additional impact water budget analyses for the surrounding wetlands and watercourses.

PROJECT EXPERIENCE – HYDROLOGY

CBM Aggregates
Various Sites in Southern Ontario

Various aggregate properties have been monitored and evaluated for aggregate license applications. This monitoring included water level monitoring, stream flow monitoring, groundwater piezometer monitoring and meteorological monitoring. Detailed site water balances as well as site and water course characterization have been evaluate and reported as part of the multidisciplinary applications.

PROJECT EXPERIENCE – ENVIRONMENTAL ASSESSMENT AND PERMITTING

Marten Falls Community Access Road
Ontario, Canada

Provided desktop analysis assistance to the fluvial geomorphic studies of the watercourse crossings in support of the surface water conditions report and impact assessment to support the proposed all season road from Marten Falls to Nakina Ontario.

PROJECT EXPERIENCE – STREAM EROSION AND SCOUR ANALYSIS

Roc-Terra Soil Management Inc.
Stoufville, Ontario, Canada

Provided assistance to complete flood and erosion study of Willowgrove Creek in support of the fill management plan proposed for the adjacent extraction pit. Also assisted in design of stormwater channel to downstream receiving watercourse.

HDR Corporation - City of Brampton
Brampton, Ontario, Canada

Assisted in the Brampton Light Rail Transit (LRT) Environment Approval by providing fluvial geomorphology support for the proposed surface and subsurface options for an LRT line crossing over/under Etobicoke Creek. Conducted rapid geomorphic assessment of the creek, estimated scour depths and hazard limits, and assisted in conceptual design of several mitigation and erosion protection options.

Cooksville Creek Sanitary Sewer Crossing
Mississauga, Ontario, Canada

Provided assistance through fluvial geomorphology studies in support of a sanitary sewer connection in Mississauga. Conducted rapid geomorphic assessment of the creek, estimated scour depths and hazard limits, and assisted in conceptual design of several mitigation and erosion protection options.

PROJECT EXPERIENCE – ENVIRONMENT COMPLIANCE APPROVALS, WATER DISCHARGES

Linde Canada Inc.
Mooretown, Ontario, Canada

Assisted in preparing an Industrial Sewage Works (ISW) Environmental Compliance Approval (ECA) application.

West Carleton Sand & Gravel Inc. - Burntlands Quarry
Ramsay, Ontario, Canada

Assisted in preparing a Quarry Water Management (QWM) report in support of an Industrial Sewage Works (ISW) Environmental Compliance Approval (ECA) application and discharge capacity model for the receiving watercourse.

Lafarge Canada Inc. - Osgoode Quarry
Greely, Ontario, Canada

Assisted in preparing an Industrial Sewage Works Environmental Compliance Approval (ECA) application and discharge capacity model for the effluent receiver.

Lafarge Canada Inc. - Dundas Quarry
Dundas, Ontario, Canada

Assisted in preparing an Industrial Sewage Works Environmental Compliance Approval (ECA) Amendment application and settling analysis model of the quarry water management system based on quarry operating expansions. Also helped complete detailed design of pre-treatment SWM pond for the expansion area.

Lafarge Canada Inc. - Brechin Quarry Brechin, Ontario, Canada	Assisted in preparing an Industrial Sewage Works Environmental Compliance Approval (ECA) Amendment application and settling analysis model of the quarry water management system based on proposed flow rates.

TRAINING

Utility Vehicle Training Course
S.M.A.R.T. Adventure Programs, May 19, 2022

ATV Training Course
S.M.A.R.T. Adventure Programs, May 19, 2022

Standard First Aid with CPR/AED Level C
Heaven Can Wait - Emergency First Aid Training, June 4, 2022

Surface Miner Common Core Training
2021

golder.com