GOLDER
MEMBER OF WSP

July 7, 2021 Project No. 1899975

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MAXIMUM PREDICTED WATER TABLE REPORT
PROPOSED WEST CARLETON QUARRY EXTENSION
CITY OF OTTAWA, ONTARIO

Mr. White,

Thomas Cavanagh Construction Limited (Cavanagh) is applying for a Category 2, Class A license (Quarry Below Water) under the *Aggregate Resources Act* (ARA), as well as an Official Plan Amendment and Zoning By-law Amendment under the *Planning Act* to permit an extension to their existing West Carleton Quarry operation (referred to herein as the "Extension Lands"). The proposed Extension Lands are located directly adjacent to the northwestern portion of the existing West Carleton Quarry. The area proposed to be licensed under the *ARA* is 18.2 hectares (ha) and the proposed extraction area is 16.5 ha. The boundaries of the licensed area and limit of extraction for the existing West Carleton Quarry and the proposed boundaries for the Extension Lands are shown on Figure 1. **To remain consistent with the development plan for the existing West Carleton Quarry, the Extension Lands would be extracted in a series of five lifts to a final base elevation of 107 metres above sea level (m ASL).**

This report summarizes the results of the groundwater level monitoring completed on and in the vicinity of the Extension Lands to fulfill the requirements of the Maximum Predicted Water Table Report as described in the Aggregate Resources Ontario: Technical Reports and Information Standards dated August 2020.

1.0 GROUNDWATER ELEVATIONS

Under Condition 4.2 of the PTTW for the existing West Carleton Quarry (No. 4175-AB4RS4), the ongoing groundwater monitoring program at the site consists of groundwater level measurements at the following on-site monitoring wells:

- DDH03-1A, DDH03-1B, TW-1, TW-2A, TW-2B, TW-2C, TW-3A, TW-3B and TW-6 once during April or May, once during June or July, once during August or September and once during October or November each year.

To gather additional data in support of the ongoing licensing project for the Extension Lands, the frequency of groundwater level measurements at the on-site wells included in the PTTW monitoring program was increased to monthly starting in June 2019.

Monitoring well TW-2 was located within the licensed extraction area of the existing West Carleton Quarry. When TW-2A, TW-2B and TW-2C were removed by progressive quarry development in 2015, the monitoring locations were replaced by MW15-1A, MW15-1B and MW15-1C located in the north western portion of the Extension Lands. The locations of the monitoring wells included in the groundwater monitoring program are shown on Figure 1.

The available groundwater elevation data measured as part of the ongoing groundwater level monitoring program for the site are described below. Figures 2 through 8 show the groundwater elevations plotted versus time at DDH03-1A, DDH03-1B, DDH03-2A, DDH03-2B, TW-1, TW-2A, TW-2B, TW-2C, TW-3A, TW-3B, TW-6, MW15-1A, MW15-1B and MW15-1C. The groundwater elevation data used to generate Figures 2 through 8 is provided in Table 1. The groundwater elevation trends for the monitoring wells are discussed below.

1.1 DDH03-1

Figure 2 presents groundwater elevation data measured at DDH03-1A and DDH03-1B between August 11, 2006 and December 9, 2020. As shown on Figure 2, the groundwater elevations at DDH03-1A and DDH03-1B are generally stable and typically vary annually by less than four metres at both monitoring intervals. The groundwater elevation at DDH03-1A has historically varied between 135.06 m ASL and 140.31 m ASL and the groundwater elevation at DDH03-1B has historically varied between 138.55 m ASL and 145.24 m ASL.

The changes in groundwater elevations at DDH03-1A are considered to represent seasonal variations. There is no significant ongoing decline in the groundwater elevations at DDH03-1A, and the groundwater elevations at this location are not interpreted to be influence by the development of the existing West Carleton Quarry. The changes in groundwater elevation at DDH03-1B shown on Figure 1 typically show changes associated with seasonal variation. During the second half of 2020, a gradual decline in groundwater elevation is observed at DDH03-1B. This decline in groundwater elevation at DDH03-1B below the typical range observed at this location may represent the first influence of quarry development on the groundwater elevation. At the closest point, the edge of the extracted area for the existing West Carleton Quarry is approximately 80 m from DDH03-1. The quarry floor elevation is the area closest to DDH03-1 is at approximately 133 m ASL. During all monitoring sessions, the vertical gradient at DDH03-1 is downward.

1.2 DDH03-2

Figure 3 presents groundwater elevation data measured at DDH03-2A and DDH03-2B between August 11, 2006 and March 15, 2007. DDH03-2 was removed as a result of progressive quarry development following the March 15, 2007 monitoring session. The limited available groundwater elevation data available for DDH03-2A and DDH03-2B indicate both monitoring intervals were generally stable, and the groundwater elevation varied by less than 3 metres at both monitoring intervals. The available groundwater elevation data also indicates that the vertical gradient at DDH03-2 was consistently downward.

1.3 TW-1

Figure 4 presents groundwater elevation data measured at TW-1 between July 9, 2008 and December 9, 2020. TW-1 is a 0.15-m diameter open hole monitoring well. As shown on Figure 4, the groundwater elevations at TW-1 are initially stable around 135 m ASL and steadily decline between June 2009 and July 2010 to an elevation around 127 m ASL. The groundwater elevation returns to around 135 m ASL in April 2012 and remains relatively stable (i.e., varies by less than 3 metres) until October 2016. Between April 2017 and October 2018, the groundwater elevation at TW-1 is consistently above 142 m ASL, followed by a significant decline between

October 2018 and June 2019. Between July 2019 and June 2020, the groundwater elevation at TW-1 remains stable at around 137 m ASL.

The groundwater elevation at TW-1 is typically between 135 and 137.5 m ASL with the exception of one extended period of lower than typical groundwater elevations (September 2009 to November 2011) and one extended period of higher than typical groundwater elevations (April 2017 to October 2018). The cause(s) of the periods of higher and lower groundwater elevations are not known. Overall, there is no significant ongoing decline in the groundwater elevations at TW-1, and the groundwater elevations at this location are not interpreted to be influence by the development of the existing West Carleton Quarry.

1.4 TW-2

Figure 5 presents groundwater elevation data measured at TW-2A, TW-2B and TW-2C between August 11, 2006 and October 6, 2014. TW-2 was removed early in 2015 by progressive quarry development. As shown on Figure 5, the groundwater elevations at TW-2A, TW-2B and TW-2C are generally stable and typically vary annually by less than two metres, although slightly larger variation in groundwater levels were observed during the first 1.5 years of groundwater level monitoring. The groundwater elevation at TW-2A has historically varied between 121.78 m ASL and 126.25 m ASL. The groundwater elevation at TW-2B has historically varied between 133.73 m ASL and 137.72 m ASL and the groundwater elevation at TW-2C has historically varied between 140.91 m ASL and 147.07 m ASL. Although the groundwater elevations at TW-2A and TW-2B display a gradual decline during the period of monitoring, no significant decline in groundwater elevations was observed as the quarry development approached TW-2. During all monitoring sessions, the vertical gradient at TW-2 was downward.

1.5 TW-3

Figure 6 presents groundwater elevation data measured at TW-3A and TW-3B between August 11, 2006 and December 9, 2020. As shown on Figure 6, the groundwater elevations at TW-3A and TW-3B are generally stable and typically vary annually by less than three metres at both monitoring intervals. The groundwater elevation at TW-3A has historically varied between 122.41 m ASL and 126.27 m ASL and the groundwater elevation at TW-3B has historically varied between 123.62 m ASL and 126.69 m ASL. The changes in groundwater elevations at TW-3 are considered to represent seasonal variations.

The existing West Carleton Quarry is located on a topographic rise that slopes down towards the east. TW-3 is located on the east side of the extraction area for the existing West Carleton Quarry where the ground surface is around 126.3 m ASL. The excavation at the site to date has primarily been west of this location removing rock that is topographically higher than the ground surface at TW-3. As such, changes in groundwater elevations at TW-3 associated with the development of the existing West Carleton Quarry to date would not be expected at this time. During most monitoring sessions, the vertical gradient at TW-3 is slightly downward.

1.6 TW-6

Figure 7 presents groundwater elevation data measured at TW-6 between August 11, 2006 and December 9, 2020. As shown on Figure 7, the groundwater elevations at TW-6 are generally stable and typically vary annually by less than two metres. The groundwater elevation at TW-6 has historically varied between 122.25 m ASL and 125.57 m ASL. The changes in groundwater elevations at TW-6 are considered to represent seasonal variations. TW-6 is located at the eastern extent of the licensed boundary for the existing West Carleton Quarry where the ground surface is around 124.5 m ASL. The excavation at the site to date has been west of this location removing rock that is topographically higher than the ground surface at TW-6. As such, changes in groundwater elevations at TW-6 associated with the development of the existing West Carleton Quarry to date would not be expected at this time.

1.7 MW15-1

Figure 8 presents groundwater elevation data measured at MW15-1A, MW15-1B and MW15-1C between April 6, 2016 and December 9, 2020. As shown on Figure 8, the groundwater elevations at MW15-1B and MW15-1C are stable and typically vary by less than one metres. Monitoring intervals MW15-1B and MW15-1C are not interpreted to be influence by the development of the existing West Carleton Quarry.

The groundwater elevations at MW15-1A display greater variability than is observed at MW15-1B and MW15-1C. Initially at MW15-1A, there was a decline in the groundwater elevation between April 2016 and August 2016. In April 2017, the groundwater elevation returns to the higher level observed in April 2016. This decline in groundwater elevation is considered to represent seasonal variations during a dry summer in 2016. Between April 2017 and June 2019, the groundwater elevation at MW15-1A gradually declines by approximately 3 m. The groundwater elevation at MW15-1A declines more rapidly between June 2019 and October 2019 followed by a rise in groundwater elevations between October 2019 and January 2020. Between June 2020 and December 2020, the groundwater elevation generally increased at MW15-1A. Monitoring interval MW15-A is not interpreted to be influence by the development of the existing West Carleton Quarry.

2.0 HORIZONTAL GROUNDWATER FLOW DIRECTION

In the vicinity of the existing West Carleton Quarry, groundwater flow generally follows topography and flows from west to east. Figure 9 provides the available groundwater elevations for all monitoring wells. The highest groundwater elevations are found in monitoring wells installed on the topographically higher west/northwest sides of the site (i.e., MW15-1 and DDH03-1) and the lower groundwater elevations are found in the monitoring wells installed along the eastern edge of the extraction area (TW-3) and further east of the extraction area (TW-6).

3.0 MAXIMUM PREDICTED WATER TABLE

Based on the available groundwater elevation data, the maximum predicted water table within the Extension Land is 151.8 m ASL on the west side (as measured at MW15-1C). Based on the groundwater elevation data measured at DD03-01B located just east of the Extension Land, the water table slopes down moving from west to east, and the maximum predicted water table on the east side of the Extension Lands is approximately 143 m ASL. Because the horizontal groundwater flow direction is from west to east across the Extension Lands, the groundwater elevations are generally consistent moving in the north-south direction through the Extension Lands.

4.0 CLOSURE

If you have any questions, please contact the undersigned.

Yours truly,

Golder Associates Ltd.

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https://golderassociates.sharepoint.com/sites/25725g/deliverables/hydrogeology/maximum predicted water table report/1899975 final maximum predicted water table report_july 2021.docx

Attachments: Table 1 – Groundwater Elevation Data
Figure 1 – Site Plan
Figure 2 through Figure 9 – Groundwater Elevation Data
Attachment 1: Qualifications and Experience of Report Authors

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	11-Aug-06		29-Aug-06		6-Jan-07		15-Mar-07		13-Sep-07		9-Jul-08		23-Sep-08		17-Nov-08	
			Depth to water (m)*	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.28	138.32	12.58	138.02	10.28	140.32	11.42	139.18	13.08	137.52	11.89	138.71	12.25	138.35	12.38	138.22
DD 03-1B	149.99	150.65	8.45	142.20	8.04	142.61	8.02	142.63	8.08	142.57	8.48	142.17	8.49	142.16	9.08	141.57	9.12	141.53
DD 03-2A	148.30	149.21	11.15	138.06	13.71	135.50	12.08	137.13	13.04	136.17	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	2.16	147.05	3.70	145.51	0.94	148.27	1.39	147.82	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	10.38	135.69	11.08	134.99	11.13	134.94
TW-2A	148.33	148.86	24.63	124.23	25.38	123.48	22.61	126.25	25.00	123.86	25.46	123.40	- -	- -	24.77	124.09	24.81	124.05
TW-2B	148.33	148.86	12.81	136.05	13.18	135.68	11.14	137.72	11.88	136.98	13.63	135.23	11.78	137.08	12.09	136.77	12.11	136.75
TW-2C	148.33	148.86	5.81	143.05	7.27	141.59	1.79	147.07	2.52	146.34	7.95	140.91	3.31	145.55	3.49	145.38	3.57	145.29
TW-3A	126.30	126.67	2.58	124.09	3.31	123.36	0.55	126.12	- -	- -	3.42	123.25	1.18	125.49	1.32	125.35	1.41	125.26
TW-3B	126.30	126.69	0.46	126.23	0.78	125.91	- -	- -	- -	- -	0.72	125.97	0.12	126.57	0.17	126.52	0.28	126.41
TW-6	124.50	125.60	2.03	123.57	3.33	122.27	1.51	124.09	1.78	123.82	2.46	123.14	3.31	122.29	3.24	122.36	3.35	122.25
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	14-Apr-09		30-Jun-09		17-Sep-09		17-Nov-09		9-Apr-10		12-Jul-10		24-Sep-10		9-Nov-10	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	10.26	140.34	11.36	139.24	13.55	137.05	13.49	137.11	10.40	140.20	13.67	136.93	13.51	137.09	13.48	137.12
DD 03-1B	149.99	150.65	5.97	144.68	6.72	143.93	8.29	142.36	8.24	142.42	7.15	143.50	8.94	141.71	8.63	142.02	8.59	142.06
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	10.99	135.08	11.06	135.01	13.69	132.38	13.58	132.49	16.49	129.58	19.07	127.00	18.90	127.17	18.97	127.10
TW-2A	148.33	148.86	- -	- -	25.03	123.83	26.10	122.76	25.95	122.91	- -	- -	- -	- -	25.68	123.18	26.61	122.25
TW-2B	148.33	148.86	- -	- -	12.04	136.82	14.21	134.65	14.15	134.72	- -	- -	- -	- -	14.09	134.77	14.10	134.76
TW-2C	148.33	148.86	- -	- -	3.61	145.25	4.68	144.18	4.49	144.37	- -	- -	- -	- -	4.39	144.47	4.33	144.53
TW-3A	126.30	126.67	- -	- -	1.06	125.61	2.33	124.35	2.31	124.37	0.88	125.79	4.26	122.41	2.81	123.86	3.14	123.53
TW-3B	126.30	126.69	- -	- -	0.11	126.58	0.56	126.13	0.52	126.17	0.00	126.69	0.95	125.74	0.51	126.18	0.67	126.02
TW-6	124.50	125.60	1.43	124.17	2.84	122.76	2.23	123.37	2.31	123.29	1.35	124.25	1.94	123.66	2.06	123.54	2.00	123.60
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	12-Apr-11		3-Jun-11		7-Sep-10		14-Nov-11		3-Apr-12		12-Jun-12		29-Aug-12		17-Oct-12	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	10.29	140.31	13.54	137.06	13.69	136.91	13.74	136.86	12.03	138.57	9.24	141.36	13.16	137.44	13.06	137.54
DD 03-1B	149.99	150.65	7.08	143.57	8.64	142.01	8.98	141.67	9.00	141.65	9.12	141.53	12.10	138.55	10.31	140.34	10.20	140.45
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	16.46	129.61	18.69	127.38	19.39	126.68	19.41	126.66	10.54	135.53	10.80	135.27	9.54	136.53	9.23	136.84
TW-2A	148.33	148.86	- -	- -	26.04	122.82	27.04	121.82	27.07	121.79	25.29	123.57	25.36	123.50	27.04	121.82	26.83	122.03
TW-2B	148.33	148.86	- -	- -	14.16	134.70	14.49	134.37	14.54	134.32	13.89	134.97	13.94	134.92	15.08	133.78	14.99	133.87
TW-2C	148.33	148.86	- -	- -	4.41	144.45	4.71	144.15	4.77	144.09	3.96	144.90	4.02	144.84	4.87	144.00	4.80	144.06
TW-3A	126.30	126.67	0.78	125.89	4.09	122.58	3.66	123.01	3.68	122.99	0.40	126.27	0.61	126.06	3.24	123.43	3.11	123.56
TW-3B	126.30	126.69	0.00	126.69	1.01	125.68	1.18	125.51	1.23	125.46	1.34	125.35	1.51	125.18	1.19	125.50	1.09	125.60
TW-6	124.50	125.60	1.33	124.27	2.02	123.58	2.91	122.69	2.93	122.67	1.29	124.31	1.48	124.12	1.92	123.68	1.80	123.80
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	3-May-13		21-Jun-13		23-Aug-13		3-Oct-13		30-Apr-14		4-Jun-14		29-Aug-14		6-Oct-14	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.78	137.82	12.86	137.74	13.06	137.54	13.01	137.59	12.74	137.86	12.89	137.71	12.96	137.64	13.01	137.59
DD 03-1B	149.99	150.65	9.67	140.98	9.73	140.92	9.92	140.73	9.88	140.77	9.60	141.05	9.84	140.81	9.91	140.74	9.97	140.68
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	9.12	136.95	9.19	136.88	10.03	136.04	9.64	136.43	9.29	136.78	9.64	136.43	10.04	136.03	10.40	135.67
TW-2A	148.33	148.86	26.78	122.08	26.84	122.02	27.11	121.75	27.04	121.82	26.56	122.30	26.92	121.94	27.03	121.83	27.08	121.78
TW-2B	148.33	148.86	14.88	133.98	14.93	133.93	15.10	133.77	15.06	133.80	14.79	134.07	15.04	133.82	15.08	133.78	15.13	133.73
TW-2C	148.33	148.86	4.62	144.24	4.69	144.17	4.82	144.04	4.78	144.08	4.54	144.32	4.77	144.09	4.84	144.02	4.80	144.06
TW-3A	126.30	126.67	2.03	124.64	2.00	124.67	2.49	124.18	2.44	124.23	1.62	125.05	2.10	124.57	2.14	124.53	2.20	124.47
TW-3B	126.30	126.69	1.15	125.54	1.19	125.50	1.87	124.82	1.31	125.38	0.80	125.89	1.23	125.46	1.29	125.40	1.61	125.08
TW-6	124.50	125.60	1.53	124.07	1.59	124.01	1.83	123.77	1.74	123.86	1.44	124.16	1.69	123.91	1.88	123.72	1.93	123.67
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	24-Apr-15		8-Jun-15		21-Aug-15		29-Oct-15		6-Apr-16		29-Jun-16		4-Aug-16		7-Oct-16	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	n (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.99	137.61	13.89	136.71	14.56	136.04	14.50	136.10	12.17	138.43	15.12	135.48	15.07	135.53	15.03	135.57
DD 03-1B	149.99	150.65	10.14	140.51	11.23	139.42	11.40	139.25	11.38	139.27	10.18	140.47	11.11	139.54	11.29	139.36	10.91	139.74
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	8.66	137.41	8.78	137.29	9.09	136.98	9.09	136.98	7.93	138.14	9.15	136.92	9.06	137.01	9.36	136.71
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	1.58	125.09	2.87	123.80	3.89	122.78	3.27	123.40	1.10	125.57	3.88	122.79	3.82	122.85	3.72	122.95
TW-3B	126.30	126.69	0.78	125.91	1.96	124.73	2.18	124.51	2.00	124.69	0.82	125.87	2.51	124.18	2.45	124.24	3.07	123.62
TW-6	124.50	125.60	1.45	124.15	1.71	123.89	2.19	123.41	2.12	123.48	1.47	124.13	2.32	123.28	2.47	123.13	2.39	123.21
MW15-1A	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	5.10	148.54	11.60	142.04	12.07	141.57	10.70	142.94
MW15-1B	152.08	153.66	- -	- -	- -	- -	- -	- -	- -	- -	2.01	151.65	2.95	150.71	2.67	150.99	2.34	151.32
MW15-1C	152.08	153.64	- -	- -	- -	- -	- -	- -	- -	- -	1.94	151.70	2.87	150.77	2.54	151.10	2.30	151.34

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

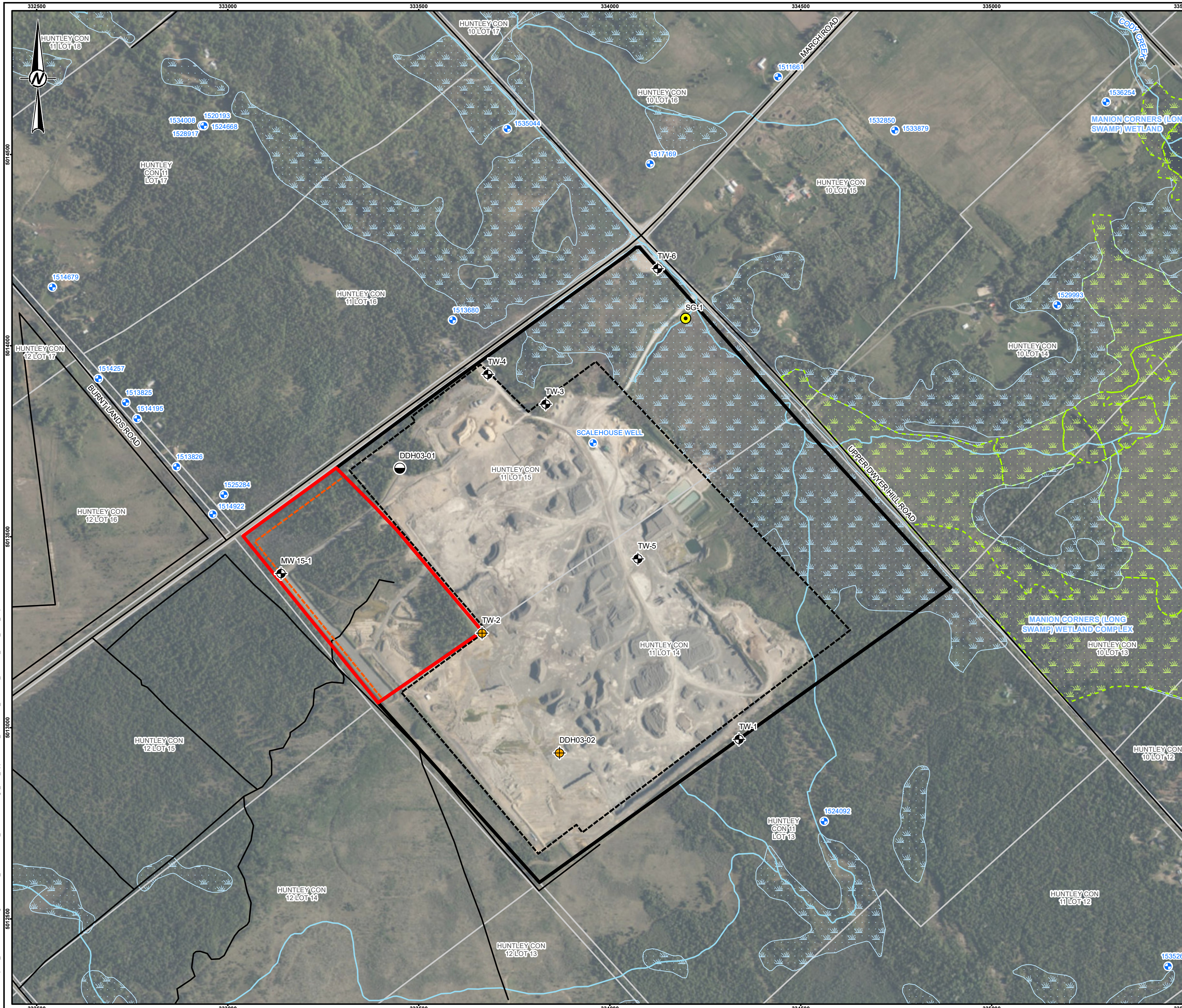
Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	10-Apr-17		21-Jun-17		28-Sep-17		23-Nov-17		3-Apr-18		27-Jun-18		14-Aug-18		2-Oct-18		13-Apr-19	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	12.12	138.48	12.18	138.42	13.10	137.50	13.16	137.44	13.06	137.54	13.26	137.34	13.57	137.03	13.39	137.21	13.40	137.20
DD 03-1B	149.99	150.65	9.75	140.90	9.83	140.82	10.60	140.05	10.63	140.02	5.41	145.24	5.55	145.10	5.78	144.87	5.64	145.01	8.33	142.32
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	3.12	142.95	3.40	142.67	3.89	142.18	4.01	142.06	0.20	145.87	2.92	143.15	3.25	142.82	3.16	142.91	12.13	133.94
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	0.97	125.70	2.74	123.93	3.66	123.01	2.94	123.73	1.79	124.88	2.08	124.59	2.52	124.15	2.39	124.28	0.71	125.96
TW-3B	126.30	126.69	0.64	126.05	1.69	125.00	2.14	124.55	1.79	124.90	1.12	125.57	1.49	125.20	1.72	124.97	1.64	125.05	0.33	126.36
TW-6	124.50	125.60	1.29	124.31	1.37	124.23	1.77	123.83	1.80	123.80	1.44	124.16	1.64	123.96	1.98	123.62	1.88	123.72	1.32	124.28
MW15-1A	152.08	153.64	4.57	149.07	4.65	148.99	5.01	148.63	5.04	148.60	5.76	147.88	5.88	147.76	6.15	147.49	6.01	147.63	7.41	146.23
MW15-1B	152.08	153.66	1.84	151.82	1.94	151.72	2.30	151.36	2.33	151.33	1.97	151.69	2.18	151.48	2.46	151.20	2.30	151.36	1.98	151.68
MW15-1C	152.08	153.64	1.78	151.86	1.88	151.76	2.21	151.43	2.24	151.40	1.90	151.74	2.12	151.52	2.29	151.35	2.26	151.38	1.90	151.74

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	28-Jun-19		16-Jul-19		20-Aug-19		18-Sep-19		3-Oct-19		18-Nov-19		20-Dec-19		23-Jan-20		7-Feb-20	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	13.82	136.78	14.02	136.58	15.54	135.06	15.52	135.08	15.48	135.12	14.89	135.71	14.94	135.66	13.18	137.42	13.16	137.44
DD 03-1B	149.99	150.65	8.62	142.03	9.28	141.37	8.91	141.74	8.92	141.73	8.80	141.85	8.64	142.01	8.67	141.98	8.29	142.36	8.31	142.34
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	13.80	132.27	8.64	137.43	8.79	137.28	8.73	137.34	8.94	137.13	8.75	137.32	8.90	137.17	8.42	137.65	8.31	137.76
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	2.21	124.46	2.62	124.05	2.74	123.94	2.70	123.97	2.65	124.02	2.33	124.34	2.44	124.23	2.01	124.66	2.08	124.59
TW-3B	126.30	126.69	1.71	124.98	1.57	125.12	2.60	124.09	2.54	124.15	2.50	124.19	1.83	124.86	2.01	124.68	1.35	125.34	1.4	125.29
TW-6	124.50	125.60	1.71	123.89	1.86	123.74	2.28	123.32	2.23	123.37	2.34	123.26	1.87	123.73	1.97	123.63	1.58	124.02	1.63	123.97
MW15-1A	152.08	153.64	7.62	146.02	8.74	144.90	11.58	142.06	11.59	142.05	12.07	141.57	10.55	143.09	10.61	143.03	8.71	144.93	8.7	144.94
MW15-1B	152.08	153.66	2.17	151.49	2.22	151.44	2.45	151.21	2.43	151.23	2.45	151.21	2.04	151.62	2.09	151.57	2.07	151.59	2.11	151.55
MW15-1C	152.08	153.64	2.11	151.53	2.17	151.47	2.40	151.24	2.38	151.26	2.40	151.24	2.00	151.64	2.02	151.62	2.00	151.64	2.05	151.59

TABLE 1
GROUNDWATER ELEVATION DATA
WEST CARLETON QUARRY EXTENSION

Well	Surface Elevation (m ASL)	Top of Casing Elevation (m ASL)	2-Mar-20		10-Apr-20		13-May-20		23-Jun-20		24-Jul-20		12-Aug-20		14-Sep-20		15-Oct-20		16-Nov-20		9-Dec-20	
			Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)	Depth to water (m)	Elevation (m ASL)
DD 03-1A	149.99	150.60	13.82	136.78	14.01	136.59	14.14	136.46	14.20	136.40	13.08	137.52	12.49	138.11	13.24	137.36	13.31	137.29	13.46	137.14	13.44	137.16
DD 03-1B	149.99	150.65	7.42	143.23	10.11	140.55	10.48	140.17	10.53	140.12	10.70	139.95	11.04	139.61	11.03	139.62	11.48	139.17	11.96	138.69	12.03	138.62
DD 03-2A	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
DD 03-2B	148.30	149.21	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-1	145.946	146.068	8.69	137.38	8.04	138.03	8.34	137.73	8.46	137.61	8.38	137.69	8.33	137.74	8.22	137.85	8.36	137.71	8.26	137.81	8.58	137.49
TW-2A	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2B	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-2C	148.33	148.86	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
TW-3A	126.30	126.67	2.04	124.63	1.74	124.93	2.03	124.64	2.09	124.58	2.30	124.37	2.64	124.03	2.97	123.70	3.01	123.66	2.88	123.79	2.69	123.98
TW-3B	126.30	126.69	1.30	125.39	1.14	125.55	1.35	125.34	1.42	125.27	1.50	125.19	1.46	125.23	1.43	125.26	1.50	125.19	1.39	125.30	1.20	125.49
TW-6	124.50	125.60	1.49	124.11	1.56	124.04	1.80	123.80	2.01	123.59	1.94	123.66	1.88	123.72	1.82	123.78	1.74	123.86	1.78	123.82	1.61	123.99
MW15-1A	152.08	153.64	8.80	144.84	8.80	144.84	10.02	143.62	10.14	143.50	9.49	144.15	8.69	144.95	6.62	147.02	6.16	147.48	6.08	147.56	5.58	148.06
MW15-1B	152.08	153.66	2.01	151.65	2.01	151.65	2.30	151.36	2.39	151.27	2.20	151.46	1.99	151.67	2.05	151.61	2.12	151.54	2.10	151.56	2.03	151.63
MW15-1C	152.08	153.64	1.94	151.70	1.94	151.70	2.24	151.40	2.36	151.28	2.23	151.41	1.90	151.75	1.98	151.66	2.02	151.62	2.00	151.65	1.98	151.66



LEGEND

- WATER WELL LOCATION (AS PER MECP WWIS)
- STAFF GAUGE LOCATION
- TEST WELL
- DIAMOND DRILLHOLE (2003 GOLDER ASSOCIATES INVESTIGATION)
- TEST WELL OR DIAMOND DRILLHOLE REMOVED BY QUARRY DEVELOPMENT
- PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LICENSE BOUNDARY
- PROPOSED WEST CARLETON QUARRY EXTENSION LANDS LIMIT OF EXTRACTION
- EXISTING WEST CARLETON QUARRY LICENSE BOUNDARY
- EXISTING WEST CARLETON QUARRY LIMIT OF EXTRACTION
- ROADWAY
- WATERCOURSE
- WETLAND
- SIGNIFICANT WETLAND
- LOT FABRIC

NOTE(S)

1. ALL LOCATIONS ARE APPROXIMATE

REFERENCE(S)

1. LAND INFORMATION ONTARIO (LIO) DATA PRODUCED BY GOLDER ASSOCIATES LTD. UNDER LICENCE FROM ONTARIO MINISTRY OF NATURAL RESOURCES, © QUEENS PRINTER 2014
2. PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83 COORDINATE SYSTEM: MTM ZONE 9 VERTICAL DATUM: CGVD28

CLIENT
THOMAS CAVANAGH CONSTRUCTION LIMITED

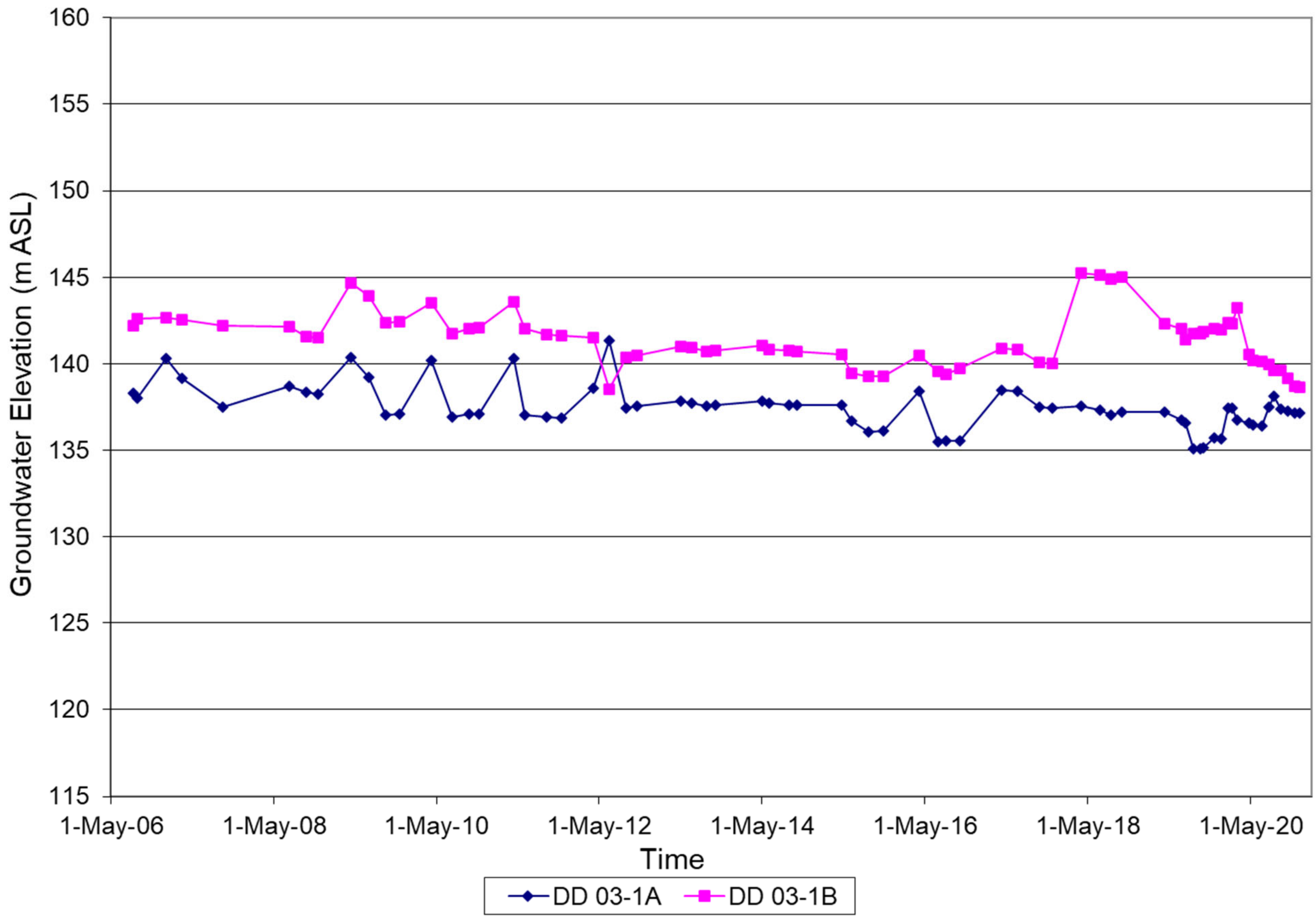
PROJECT
MAXIMUM PREDICTED WATER TABLE REPORT – PROPOSED WEST CARLETON QUARRY EXTENSION

TITLE
SITE PLAN

CONSULTANT
GOLDER

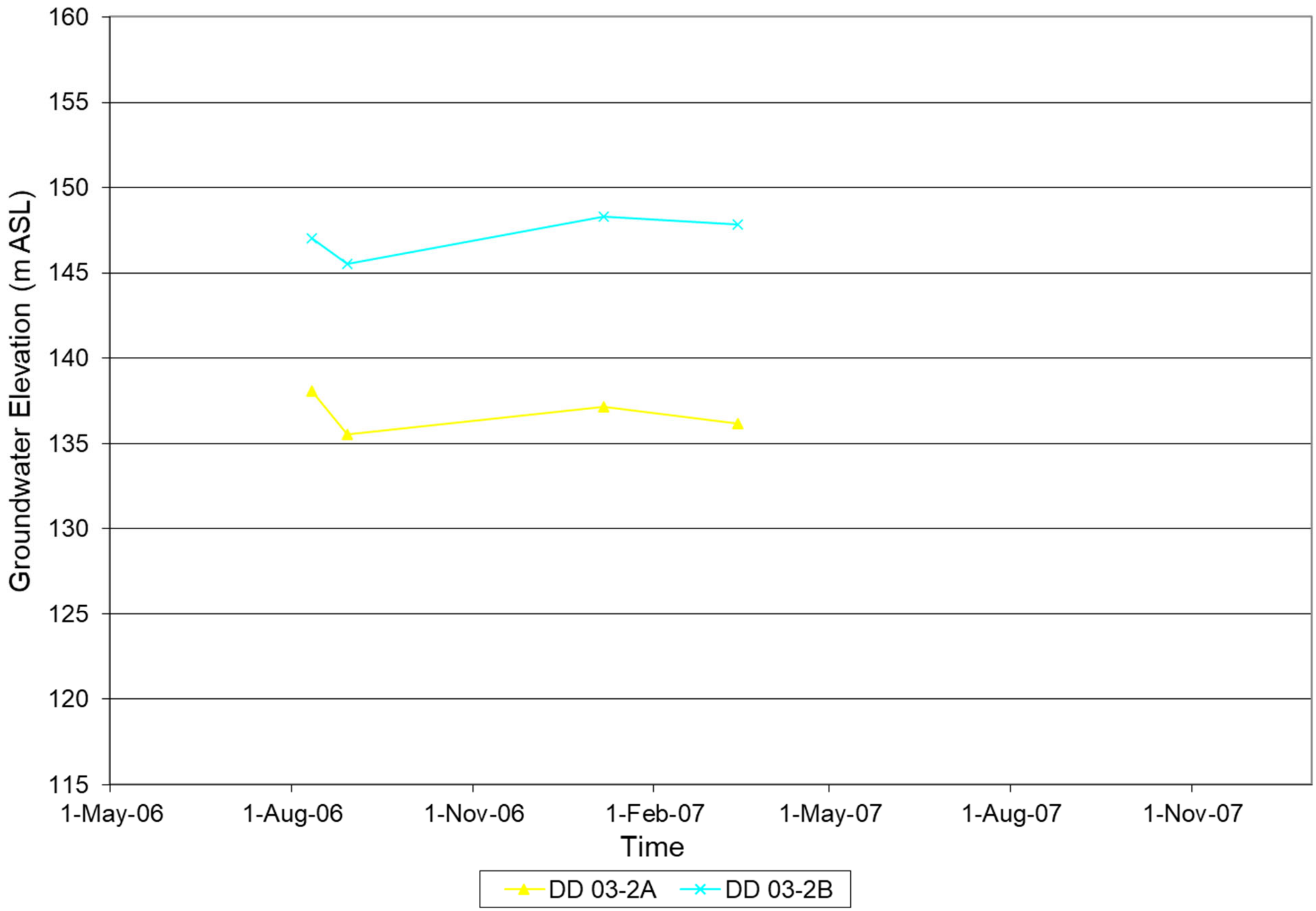
YYYY-MM-DD	2021-05-14
DESIGNED	----
PREPARED	BR
REVIEWED	JPAO
APPROVED	KAM

PROJECT NO.	CONTROL	REV.	FIGURE
1899975	0012	0	1

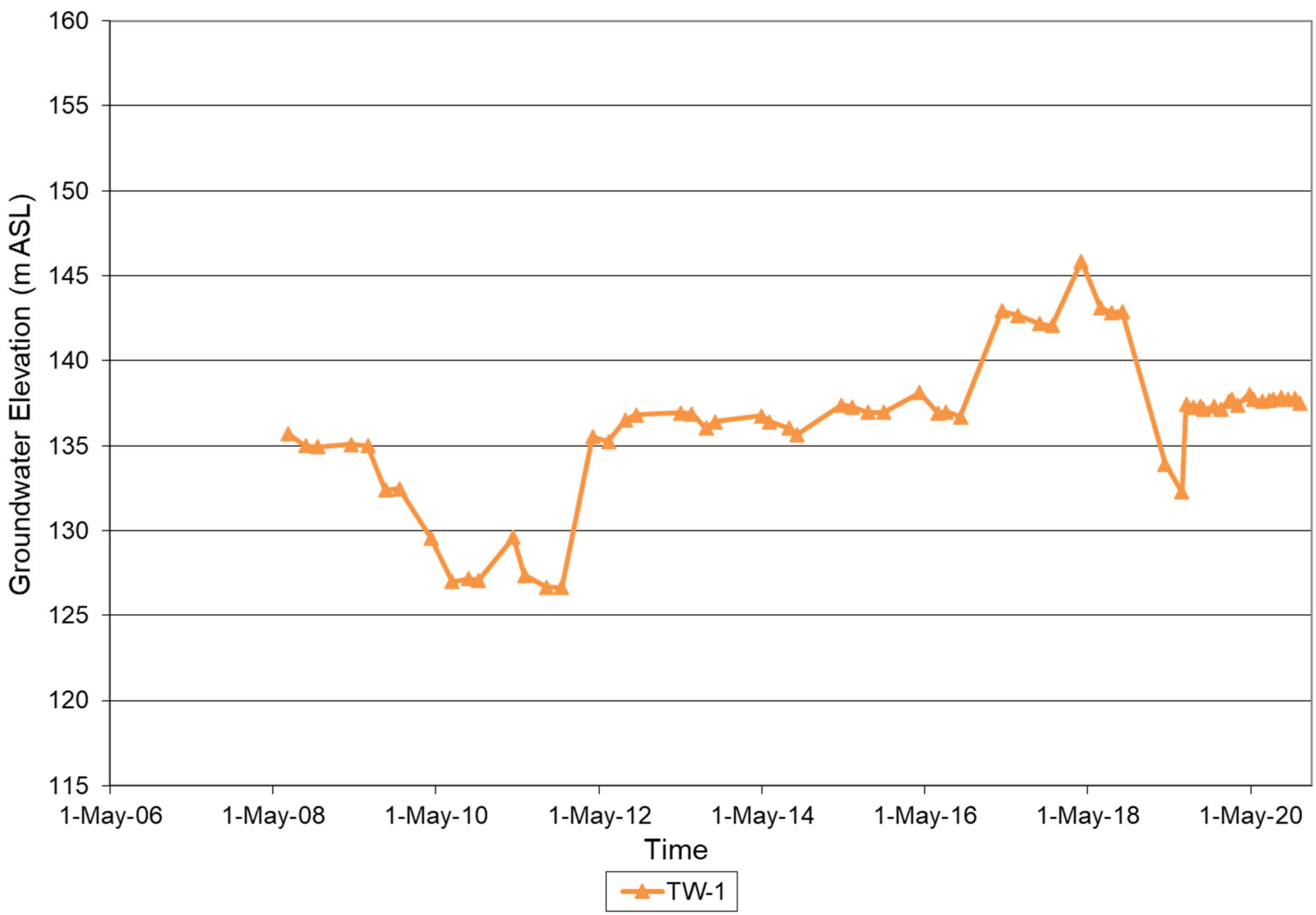


GOLDER MEMBER OF WSP	Date: April 2021 Drawn: JPAO Project: 1899975 Checked: KAM	DDH03-1 Groundwater Elevation Data August 11, 2006 to December 9, 2020

FIGURE 2



GOLDER MEMBER OF WSP	Date: April 2021 Drawn: JPAO Project: 1899975 Checked: KAM	DDH03-2 Groundwater Elevation Data August 11, 2006 to March 15, 2007	FIGURE 3



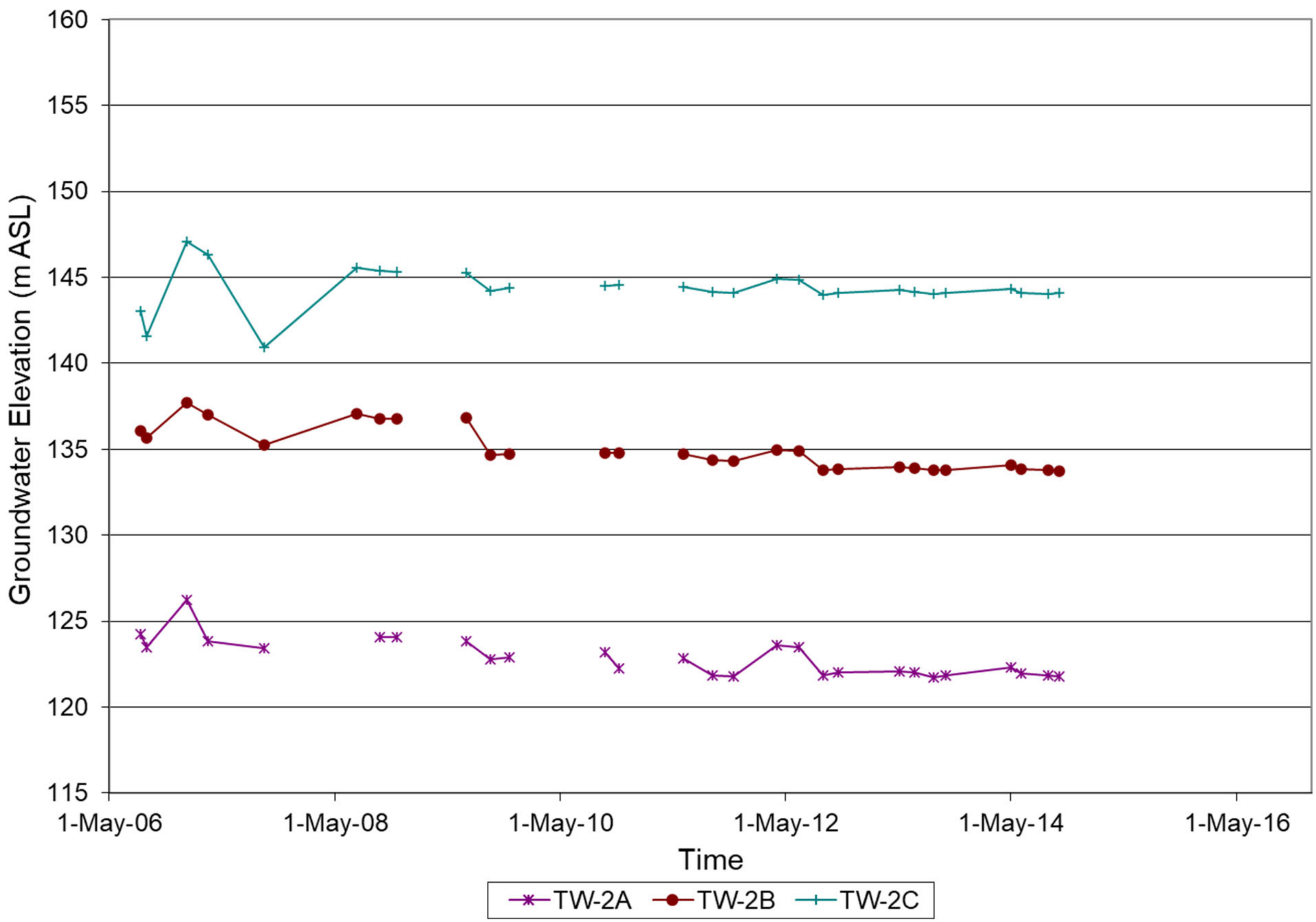
GOLDER
MEMBER OF WSP

Date: April 2021 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-1 Groundwater Elevation Data
July 9, 2008 to December 9, 2020

FIGURE 4



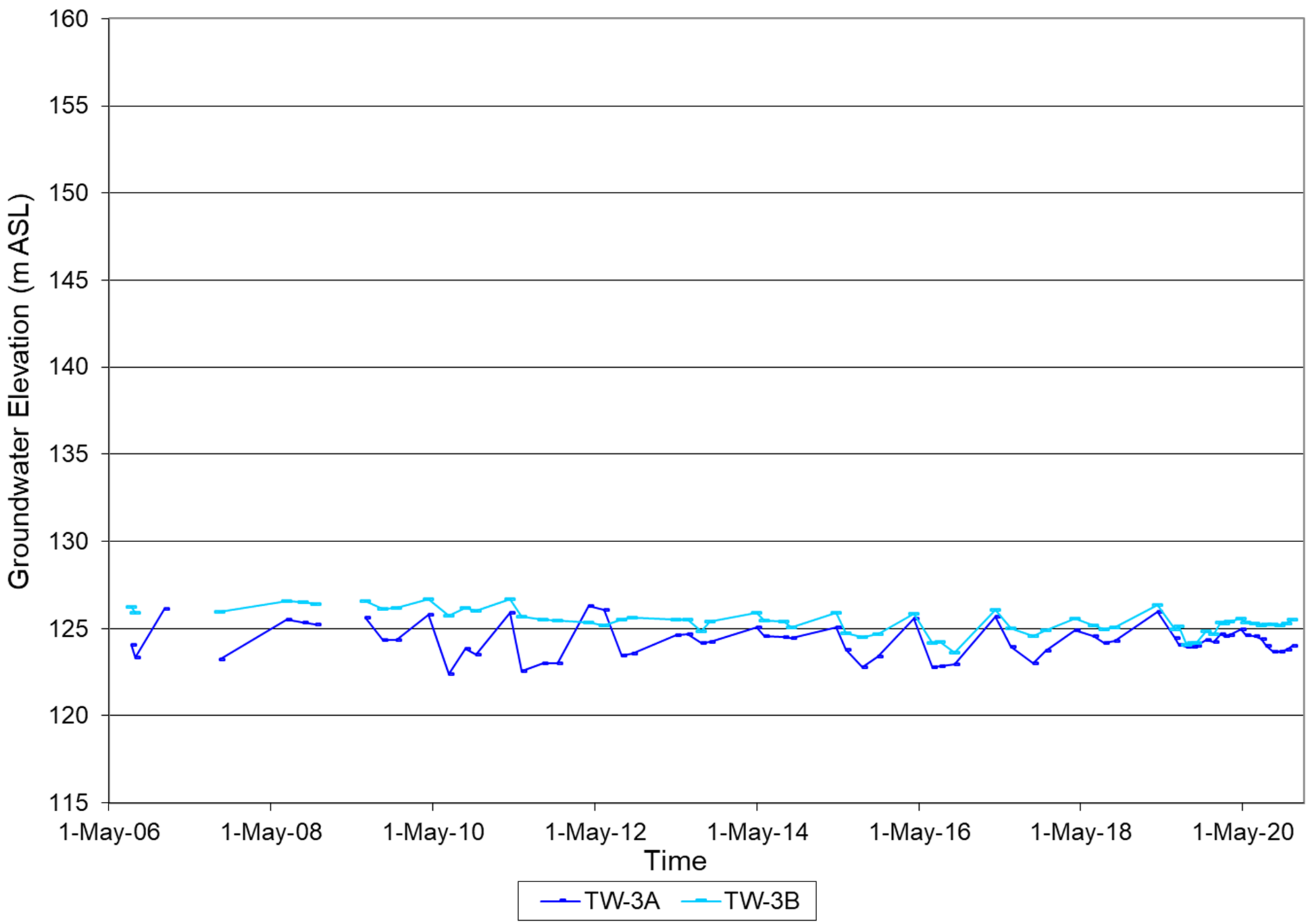
GOLDER
MEMBER OF WSP

Date: April 2021 Drawn: JPAO

Project: 1899975 Checked: KAM

TW-2 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

FIGURE 5



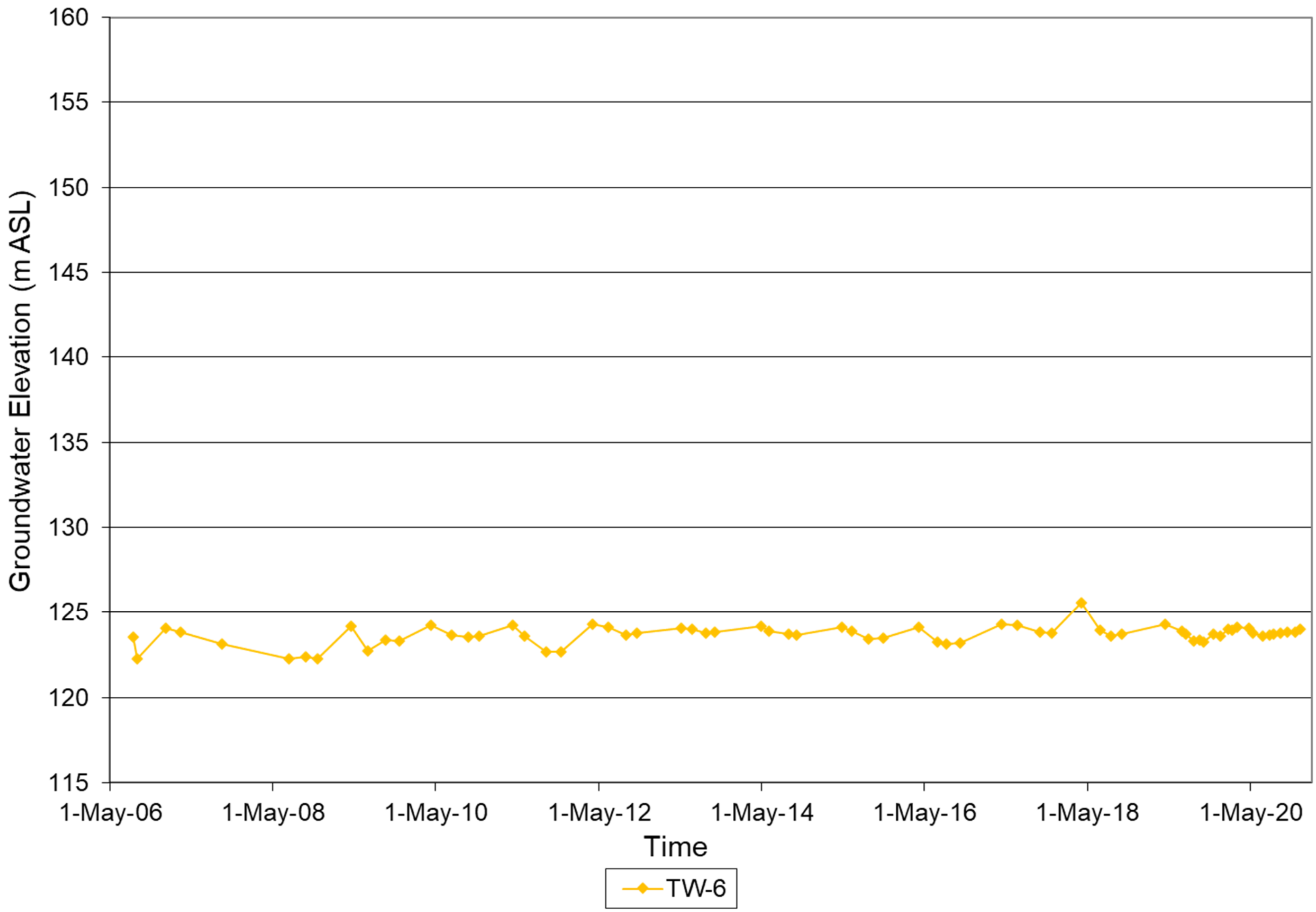
GOLDER MEMBER OF WSP

Date: April 2021 Drawn: JPAO

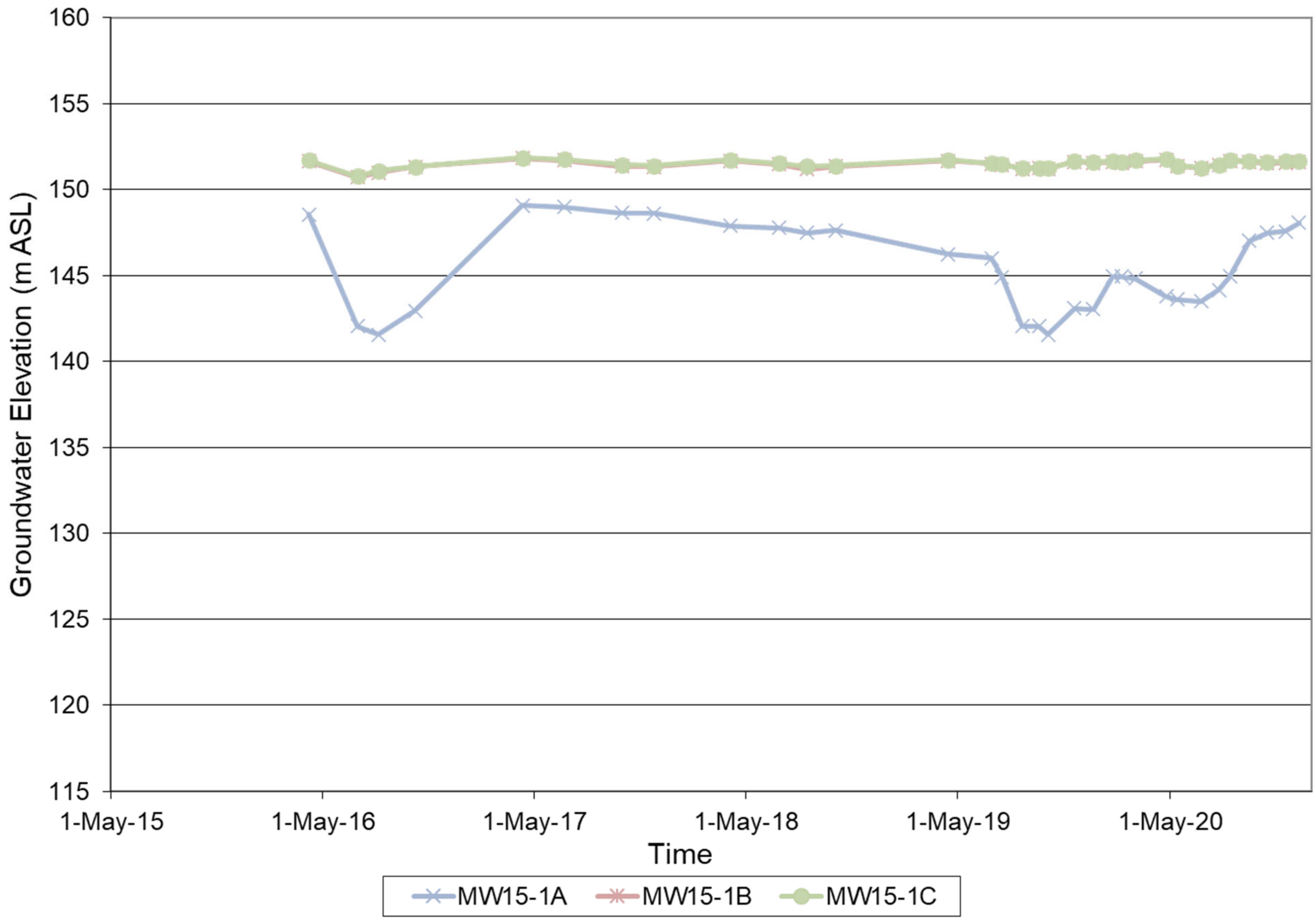
Project: 1899975 Checked: KAM

TW-3 Groundwater Elevation Data
August 11, 2006 to December 9, 2020

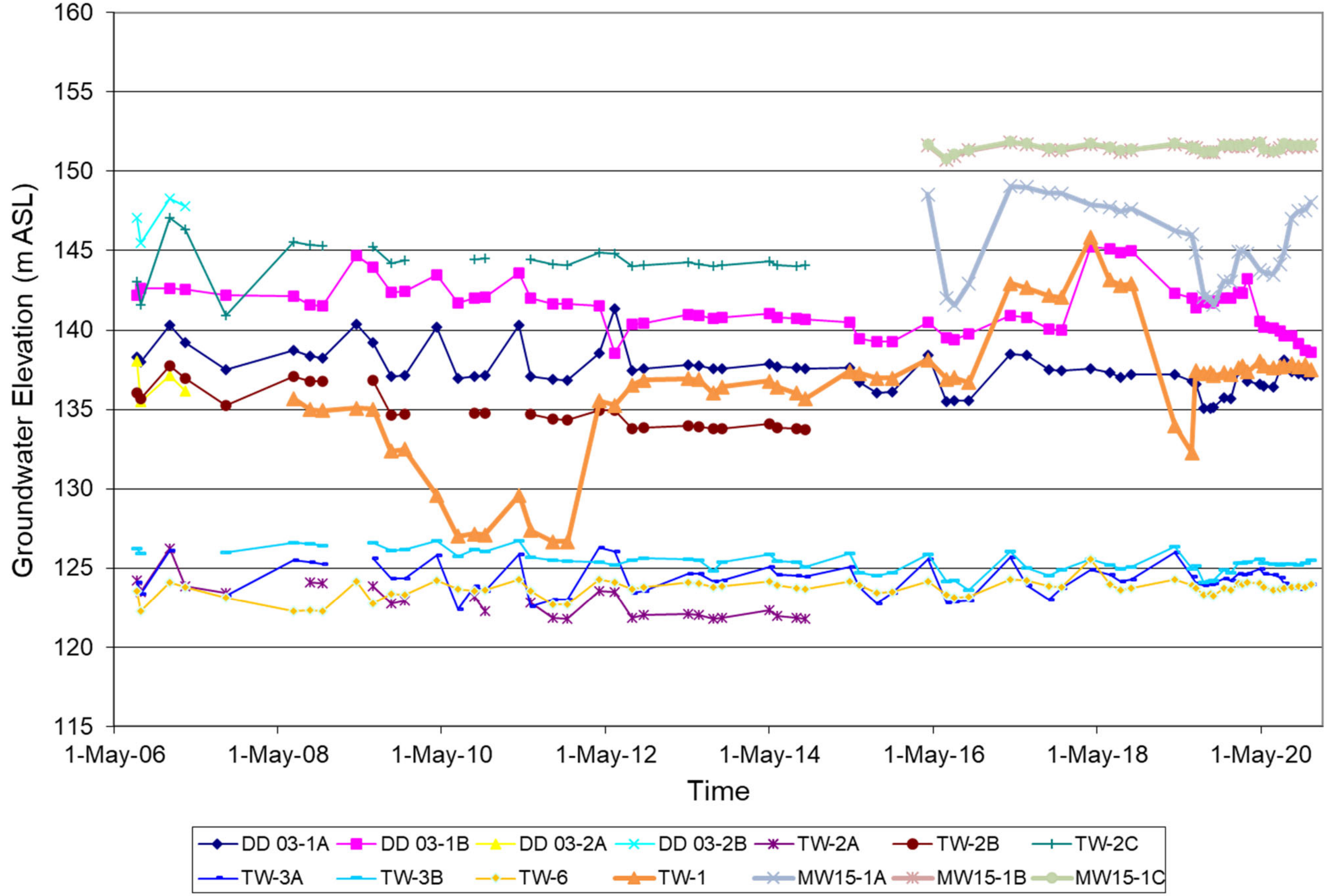
FIGURE 6



GOLDER MEMBER OF WSP	Date: April 2021 Drawn: JPAO Project: 1899975 Checked: KAM	TW-6 Groundwater Elevation Data August 11, 2006 to December 9, 2020	FIGURE 7



GOLDER MEMBER OF WSP	Date: April 2021 Drawn: JPAO Project: 1899975 Checked: KAM	MW15-1 Groundwater Elevation Data April 6, 2016 to December 9, 2020	FIGURE 8



GOLDER
MEMBER OF WSP

Date: April 2021 Drawn: JPAO	Groundwater Elevation Data	FIGURE 9
Project: 1899975 Checked: KAM	All Monitoring Locations	

ATTACHMENT 1

Qualifications and Experience of Report

Education

M.Sc. Civil Engineering: Hydrogeology
Queen's University
Kingston, Ontario, 2001

B.Sc. Environmental Science: Earth Sciences Stream, Honours
Brock University
St. Catharines, Ontario 1998

Certifications

Registered Professional Geoscientist Ontario

Golder Associates Ltd. – Ottawa

Senior Hydrogeologist

Jaime Oxtobee has over 20 years of broad experience in the field of physical hydrogeology that includes hydrogeological impact assessments in support of the licensing of pits and quarries under the *Aggregate Resources Act*, water supply development and regional scale groundwater studies.

Employment History

Golder Associates Ltd. – Ottawa

Associate and Senior Hydrogeologist (2001 to Present)

Jaime is responsible for project management, technical analysis and reporting for a variety of hydrogeological and environmental projects. Jaime is also often responsible for senior technical review of hydrogeological investigations.

Projects have included groundwater resources studies; hydrogeological investigation programs in support of licensing/permitting pits and quarries and in support of Permit to Take Water applications for local construction dewatering projects, ready-mix concrete plants, golf courses and quarries; communal water supply investigations; wellhead protection studies; contaminated site investigations; and, providing senior review for landfill, pit and quarry monitoring reports.

Queen's University – Kingston, Ontario

Teaching Assistant (2000 to 2001)

Teaching assistant for university courses relating to groundwater flow and contaminant transport in porous media and fractured rock environments.

Phase IV Bedrock Remediation Program – Smithville, Ontario

Project Manager (1999)

Coordinated and conducted a groundwater/surface water interaction study downgradient from the PCB-contaminated site in Smithville, Ontario. The study involved detailed numerical modelling, as well as an extensive field program including stream surveys, stream gauging, construction and installation of mini-piezometers, seepage meters and weirs, fracture mapping, groundwater and surface water sampling.

SELECTED PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Hydrogeological and Hydrological Assessments for Quarry Licensing
Township of Drummond-North Elmsley, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for two new below water quarries on either side of an existing below water quarry. Jaime led the hydrogeological and hydrological assessment component of the project, and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessments for Pit Licensing
Township of Lanark, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit above the water table. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program and preparing the required reporting.

Hydrogeological and Hydrological Assessments for Quarry Licensing
Ramara, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological and archaeological studies to support an application under the *Aggregate Resource Act* for licensing the extension of an existing quarry. The application was for one new below water quarry adjacent to an existing below water quarry. Jaime led the hydrogeological and hydrological assessment component of the project. Jaime was responsible for development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting.

Hydrogeological Assessments for Pit Licensing
Township of Leeds and Thousand Islands, Ontario, Canada

Golder carried out the necessary hydrogeological studies to support an application under the *Aggregate Resource Act* for licensing a new pit below the water table. Jaime led the hydrogeological assessment component of the project. Jaime was responsible for the development and execution of the hydrogeology field program and completing the hydrogeological impact assessment/reporting.

Hydrogeological Assessment for Quarry Permitting
Township of Bomby

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime led the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development and execution of the hydrogeology field program, development of the site conceptual model and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Pit Permitting
District of Kenora, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new pit. The application was for a below water pit located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the pit and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological Assessment for Quarry Permitting
District of Kenora, Ontario, Canada

Golder carried out the necessary hydrogeological, ecological and archaeological studies to support an application under the *Aggregate Resource Act* for permitting a new quarry. The application was for a below water quarry located on Crown Land. Jaime provided input to the hydrogeological assessment component of the project and was responsible for coordinating the multi-disciplinary team. Jaime was responsible for the development of the site conceptual model in the vicinity of the quarry and completion of the hydrogeological impact assessment/reporting. Jamie also provided input to the integration of the findings from the multiple disciplines.

Hydrogeological and Hydrological Assessment for Quarry Licensing
City of Kawartha Lakes, Ontario, Canada

Golder carried out the necessary hydrogeological, hydrological and ecological studies to support an application under the *Aggregate Resource Act* for licensing a new quarry. The application was for a below water quarry located adjacent to a provincially significant wetland. Jaime provided input to the hydrogeological assessment component of the project, which included the installation of over 80 monitoring intervals and the completing of three pumping tests. Jaime was involved in data analysis and the completion of the impact assessment and reporting for the hydrogeology assessment.

TRAINING

Beyond Data: Conceptual Site Models in Environmental Site Assessments
Golder U, 2011

Health and Safety Modules 1, 2, 3 and 4
Golder U, various years

Critical Thinking in Aquifer Test Interpretation
Golder U, 2011

HydroBench (Proprietary Aquifer Test Interpretation Software)
Golder U, 2011

Project Management
Golder U, 2007

Short course: Environmental Isotopes in Groundwater Resource and Contaminant Hydrogeology
2007

Short course: Hydrogeology of Fractured Rock – Characterization, Monitoring, Assessment and Remediation
2002

OSHA 40 Hour Hazardous Waste Site Worker Training
2002

PROFESSIONAL AFFILIATIONS

Member, Association of Professional Geoscientist of Ontario

Member, Ottawa Geotechnical Group

PUBLICATIONS

Conference Proceedings

West, A.L., K.A. Marentette and J.P.A. Oxtobee. 2009. *Quantifying Cumulative Effects of Multiple Rock Quarries on Aquifers*. 2009 Joint Assembly, May. Toronto, Canada.

Novakowski, K.S., P.A. Lapcivic, J.P.A. Oxtobee and L. Zanini. 2000. *Groundwater Flow in the Lockport Formation Underlying the Smithville Ontario Area*. 1st IAH-CNC and CGS Groundwater Specialty Conference, October. Montreal, Canada.

Oxtobee, J.P.A. and K.S. Novakowski. 2001. *A Study of groundwater/Surface Water Interaction in a Fractured Bedrock Environment*. Fractured Rock 2001 Conference, March. Toronto, Canada.

Journal Articles

Oxtobee, J.P.A. and K.S. Novakowski. Groundwater/Surface Water Interaction in a Fractured Rock Aquifer. *Journal of Ground Water*, 41(5) (2003), 667-681.

Oxtobee, J.P.A. and K.S. Novakowski. A Field Investigation of Groundwater/Surface Water Interaction in a Fractured Bedrock Environment. *Journal of Hydrology*, 269 (2002), 169-193.

Other

Oxtobee, J.P.A., 1998. Environmental Assessment of Grapeview, Francis and Richardson's Creeks, St. Catharines, Ontario. B.Sc. Thesis, Brock University, Earth Sciences Department pp.119.

Education

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

Golder Associates Ltd. – Cambridge

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, 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.

University of Guelph – Guelph, Ontario
Research Assistant (1994 to 1996)

Responsible for designing and performing experiments concerning soil erosion by rainfall. Erosion rates from single drop impacts and 1.0 m^2 erosion plots were quantified and related to rainfall intensity and energy flux rate. A model of the inter-rill detachment process was developed for use in future large-scale erosion models.

University of Guelph – Guelph, Ontario
Teaching Assistant (1994 to 1996)

Taught weekly seminars on engineering mechanics (statics and dynamics) and on engineering design and report writing. Emphasis was placed on three-dimensional vector analysis and excellence in communicating technical information through text and verbal presentations.

PROJECT EXPERIENCE – HYDROLOGY/HYDRAULICS

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 MOE application forms and supporting studies and reports have been prepared for numerous aggregate sites across Southern Ontario. Applications have been completed for 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.

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.

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.

Brimley Road Slope Failure
Toronto, Ontario

Detailed statistical analysis of the rainfall amounts in the 30 days prior to a major slope failure. Historical records of rainfall and snowmelt were analysed and compared to the precipitation in the days preceding the failure.

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 – 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

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.

PROFESSIONAL AFFILIATIONS

Professional Engineers Ontario

Engineers Nova Scotia

PUBLICATIONS AND PRESENTATIONS

Other

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

M.Sc. Geology, University of Windsor, Windsor, Ontario, 1988

B.Sc. Geology, Honours, University of Windsor, Windsor, Ontario, 1986

Certifications

Registered Professional Geoscientist, 2002

Languages

English – Fluent

Golder Associates Ltd. – Ottawa

Employment History

Golder Associates Ltd. – Ottawa, Ontario

Principal/Senior Hydrogeologist (1997 to Present)

Mr. Kris A. Marentette, M.Sc., P.Geo., is a Principal and Senior Hydrogeologist in the Ottawa office of Golder and has 20 years of broad experience in the fields of water supply development, physical hydrogeological characterization studies, regional scale groundwater studies, aggregate resource evaluations and the licensing and permitting of quarry development and expansion projects, waste management and contaminated sites assessment /remediation. Kris is responsible for business development, project management, and senior technical review of hydrogeology, quarry and sand and gravel pit development and expansion, golf course irrigation, site assessment and remediation projects, and waste facility siting, design, operation and environmental compliance monitoring assignments from the Ottawa office.

Kris has been the Golder Project Manager on a number of Ministry of Natural Resources quarry and pit licensing projects for both new operations and expansions to existing operations and has extensive experience in managing these complex, multi-disciplinary projects. Participated in comprehensive aggregate resource evaluations of Paleozoic sedimentary sequences (limestone) and Precambrian marble deposits at quarries in eastern Ottawa for the purpose of developing preferred site development plans to maximize the production of high quality aggregate products. The aggregate resource evaluations have typically included borehole coring, geological core logging, geophysical evaluations and comprehensive laboratory testing programs.

Golder Associates Ltd. – Ottawa, Ontario

Hydrogeologist/Senior Hydrogeologist (1988 to 1997)

Responsible for business development and the initiation, implementation and direction of hydrogeological investigations from the Ottawa office. Projects have included test well drilling programs for private services developments; subsurface investigations as related to the installation of subsurface sewage disposal systems; communal water supply investigations; and, regional hydrogeological studies to assist in establishing planning policies for future private services developments and to develop standards for water well construction.

Project manager for numerous hydrogeological studies of existing/proposed landfill sites including the assessment of impacts on water resources and developing and implementing monitoring programs and contingency and remedial action plans. Participated in hydrogeological aspects of waste management studies, preparation and submission of documentation to obtain Emergency Certificates of Approval and Site Interim Expansions of landfill sites under both the Environmental Assessment Act and Environmental Protection Act. Projects have included preparation of landfill site development and operations plans including evaluations of landfill final cover design options. Expert testimony at hearings before the Environmental Assessment Board.

Also responsible for investigation, design and implementation of soil and groundwater remediation programs at hydrocarbons, metals, solvents, and PAH contaminated sites including the risk assessment approach to site management. Projects have included third party peer review of site remediation programs.

Conducted hydrogeological assessments of quarry developments/expansions and pre-acquisition environmental site audits.

PROJECT EXPERIENCE – AGGREGATE INDUSTRY

Stittsville Quarry
Township of Goulbourn (Ottawa), Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class "A" license for a 44 million tonne quarry which intends to extract limestone from below the established groundwater table. Assignment also included preparation and submission of applications to the Ontario Ministry of Environment for approval under Section 34 (Permit to Take Water) and Section 53 (Industrial Sewage Works) of the Ontario Water Resources Act. All required approvals were obtained and the quarry became operational in September 2002. Kris continues to be involved as Project Director on all environmental compliance monitoring requirements associated with the Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Rideau Road Quarries
City of Gloucester (Ottawa), Ontario, Canada

In 2003, Golder Associates was retained by R.W. Tomlinson Limited to provide geoscience and engineering services and to co-ordinate a multi-disciplinary study team in the preparation of the supporting documents, for a submission to the Ontario Ministry of Natural Resources, in support of an application for a Category 2, Class "A" license for a 40 hectare parcel of land adjacent to Tomlinson's existing quarry operations. The quarry was designed to extract limestone from below the established groundwater table for the production of high quality aggregate suitable for all types of asphalt pavements. Kris was Project Director and Project Hydrogeologist for this assignment and Golder Associates' primary responsibilities included preparation of Level 1 and Level 2 Hydrogeological studies and Natural Environment evaluations of the property. Of particular significant for this project was the innovative approach develop by Golder Associates (in consultation with the Ministry of Natural Resources) for the purpose of addressing the presence of the American ginseng plant species and butternut trees on the property. The aggregate license was issued by the Ministry of Natural Resources in 2006.

Tatlock Quarry
Township of Lanark Highlands, Ontario, Canada

Project Director and Project Hydrogeologist retained in 2002 by Omya Canada Inc. to conduct Level 1 and Level 2 hydrogeological studies in support of an application to the Ministry of Natural Resources for a Category 2, Class “A” license for the extraction of calcitic marble (crystalline limestone) at the Omya Tatlock Quarry located northwest of Perth, Ontario. Golder Associates was also responsible for the preparation of an application for an industrial sewage works approval under Section 53 of the Ontario Water Resources Act. The quarry license application was issued by the Ministry of Natural Resources in April 2006 and the industrial sewage works approval was issued by the Ministry of Environment in March 2006. Kris continues to advise Omya Canada Inc. on matters related to environmental compliance monitoring and other issues pertaining to Ministry of Natural Resources aggregate license and the Ministry of Environment approvals under Section 34 and 53 on the Ontario Water Resources Act.

Dunvegan Quarry
Township of North Glengarry, Ontario, Canada

Project Hydrogeologist retained by the Township of North Glengarry to conducted a peer review of the hydrogeological aspects of the Cornwall Gravel Company Ltd. Dunvegan Quarry license application. The peer review focused on developing an opinion as to whether the Hydrogeological Assessment Report addressed the various components specified as part of a Hydrogeological Level 1 study and Hydrogeological Level 2 study in the context of a Category 2, Class “A” Quarry Below Water.

Klock Quarry
Aylmer, Quebec, Canada

Golder Associates was retained by Lafarge Canada Inc. to conduct the hydrogeological and natural environment assessments associated with obtaining approval for the extraction of limestone from a property situated adjacent to the existing Klock Quarry. Kris is responsible for overall project co-ordination and direction of a multi-disciplinary team.

Brechin Quarry
City of Kawartha Lakes, Ontario, Canada

Project Manager and Project Hydrogeologist retained by R.W. Tomlinson Limited to complete the necessary hydrogeological, hydrological and ecological studies to support an application under the Aggregate Resources Act. The proposed Brechin Quarry is located in the former Township of Carden within the City of Kawartha Lakes, Ontario. The property covers an area of approximately 206 hectares and involves an aggregate resource of 70 million tonnes with an expected operational timeframe of over 70 years. The assignment involves a comprehensive assessment of the potential effects of quarry development on private water supply wells and an adjacent Provincially Significant Wetland and other natural environment (biological) features as well as consideration of the potential cumulative impacts associated with multiple quarry developments in the area of the proposed Tomlinson Brechin Quarry. This project involves extensive municipal and public consultation as well as interaction with representatives of the Ontario Ministry of Natural Resources and Ontario Ministry of Environment. The aggregate license was issued by the Ministry of Natural Resources in 2009.

TRAINING

Ministry of Environment Approvals Reform and Air Emission Summary and Dispersion Modelling Report Workshop
Ministry of the Environment, 1998

Site Specific Risk Assessment Seminar
Ottawa, 1998

Contaminated and Hazardous Waste Site Management
1997

Occupational Health and Safety Course
1989, 1995

Groundwater Protection in Ontario Conference
Toronto, 1991

Short Course in Dense, Immiscible Phase Liquid Contaminants (DNAPLs) in Porous and Fractured Media
Waterloo Centre for Groundwater Research, 1990

PROFESSIONAL AFFILIATIONS

Associate Member, Ontario Stone Sand and Gravel Association (OSSGA)

Member, Association of Groundwater Scientists and Engineers (N.G.W.A.)

Member, International Association of Hydrogeologists

Member, Ottawa Geotechnical Group, The Canadian Geotechnical Society

Member, Ontario Water Well Association