Appendix B:
Hydrogeology (Groundwater)

TABLE B1

Monitoring Well Summary

City of Guelph

Clair - Maltby Master Environmental Servicing Plan (MESP) and Secondary Plan (SP)

Monitoring Well	UTM NAD83 Zone 17N Northing	UTM NAD83 Zone 17N Easting	Elevation[1] (masl) Ground Surface	Elevation[1] (masl) Top of Casing	Elevation[1] (masl) Oct. 2016 Ground Water	Elevation[1] (masl) Dec. 2016 Ground Water	Elevation[1] (masl) Jan. 2017 Ground Water	Elevation[1] (masl) April 2017 Ground Water	Elevation[1] (masl) July 2017 Ground Water	Elevation[1] (masl) Oct. 2017 Ground Water	Depth (mbgs) Top of Screen	Depth (mbgs) Base of Screen	Depth (mbgs) Oct. 2016 Water	Depth (mbgs) Dec. 2016 Water	Depth (mbgs) Jan. 2017 Water	Depth (mbgs) April 2017 Water	Depth (mbgs) July 2017 Water	Depth (mbgs) Oct. 2017 Water	Hydraulic Conductivity (m/s)	Method	Stratigraphy of Screened Interval
MW01-D	4817765	566644	337.27	337.85	331.52	331.26	331.26	332.94	332.93	331.95	19.6	21.1	5.75	6.01	5.25	4.33	4.34	5.32	5.8E-07	BR	Clayey Silt (Till)
MW01-S	4817763	566642	337.20	337.71	331.72	331.51	331.51	333.22	333.15	332.28	11.9	13.4	5.48	5.69	4.95	3.98	4.05	4.92	2.1E-04	BR	Sand, Gravel
MW02-D	4817419	566681	335.29	336.11	331.32	331.12	331.12	332.89	332.79	331.74	18.9	20.4	3.98	4.17	3.37	2.41	2.51	3.55	1.5E-03	SG	Gravely Sand
MW02-S	4817425	566682	335.40	336.36	332.00	331.80	331.80	333.60	334.19	332.53	6.7	8.2	3.40	3.60	2.85	1.80	1.21	2.87	2.1E-03	SG	Sandy Gravel
MW03-D	4816950	568080	350.05	350.80	330.89	330.58	330.58	331.31	332.40	331.60	32.6	34.1	19.17	19.48	19.55	18.75	17.66	18.45	2.8E-04	BR	Sand, Gravel
MW03-S	4816949	568083	349.95	350.70	331.17	330.80	330.80	331.45	332.57	331.81	21.6	23.2	18.78	19.15	19.27	18.50	17.38	18.14	NA	SG	Sand
MW04-D	4816485	566169	349.60	350.47	334.60	334.43	334.43	336.18	336.04	334.94	26.8	28.3	15.00	15.17	14.71	13.42	13.56	14.66	2.2E-06	BR	Sandy Silt
MW04-S	4816488	566171	349.63	350.54	336.01	335.80	335.80	337.45	337.69	336.60	19.4	20.9	13.63	13.83	13.58	12.19	11.95	13.03	8.2E-08	KGS	Silt (Till)
MW05-D	4816337	567001	340.17	341.10	334.66	334.46	334.46	335.88	335.93	335.18	22.6	24.1	5.51	5.71	5.32	4.29	4.24	4.99	2.5E-04	KGS	Sand, Gravel
MW05-S	4816335	566999	340.16	341.11	335.07	334.86	334.86	336.32	336.31	335.56	15.2	16.8	5.09	5.31	4.86	3.84	3.85	4.60	5.4E-04	KGS	Sand, Gravel
MW06-D	4816250	567400	352.38	353.20	334.40	334.14	334.14	335.31	335.58	334.94	35.1	36.6	17.98	18.24	18.09	17.07	16.80	17.44	7.6E-06	KGS	Silty Sand
MW06-S	4816247	567401	352.41	353.34	334.71	334.42	334.42	335.40	335.79	335.23	21.4	22.9	17.69	17.99	17.98	17.00	16.61	17.18	5.4E-06	KGS	Silt and Sand
MW07-D	4815512	565479	347.04	347.89	329.61	329.31	329.31	330.25	330.82	330.12	33.1	34.6	17.43	17.73	17.60	16.79	16.22	16.92	4.8E-04	BR	Sand, Gravel
MW08-D	4815489	566248	338.48	339.45	330.90	330.57	330.57	331.66	332.42	331.60	17.7	19.2	7.58	7.91	7.96	6.82	6.06	6.88	2.3E-04	KGS	Sand, Gravel
MW08-S	4815494	566250	338.48	339.40	334.08	333.81	333.81	335.26	334.72	334.22	6.1	7.6	4.40	4.67	4.09	3.22	3.76	4.26	6.6E-04	KGS	Sand, Gravel
MW09-D	4815295	566970	350.51	351.15	331.14	330.81	330.81	331.77	332.77	331.92	32.0	33.5	19.37	19.69	19.77	18.74	17.74	18.59	7.2E-06	BR	Sandy Silt
MW09-S	4815292	566972	350.46	350.98	331.02	330.74	330.74	331.58	332.61	331.74	21.6	23.2	19.44	19.72	19.82	18.88	17.85	18.72	2.2E-04	KGS	Sand, Gravel
MW1-11*	4816210	565410	346.40	347.32	329.85	329.62	329.62	330.71	330.88	---	15.3[AB]	18.3[AB]	16.55	16.77	16.46	15.69	15.52	---	--	--	--
MW2-11*	4816026	565434	343.36	344.37	329.91	329.67	329.67	330.64	330.98	---	12.0[AB]	15.0[AB]	13.45	13.69	13.47	12.72	12.38	---	--	--	--
MW3-11*	4815829	565622	349.03	349.90	331.41	331.48	331.48	331.47	331.48	---	11.6[AB]	17.8[AB]	17.62	17.56	17.55	17.56	17.55	---	--	---	--

Notes:

[1] - elevations are geodetic
[AB] - As reported by Aquifer Beach Ltd. (2012)
* - Pre-existing monitoring well at 132 Clair Road
masl - metres above sea level
NA - not available
BR - Bouwer and Rice method (1976)
KGS - Hyder et al method (1994)
SG - Springer-Gelhar (1991)
(orange highlight) - Indicates an upward flow gradient at the well

Notes:

Water levels were recorded on the following dates:
October 19, 20, 21, 2016
December 13, 2016
January 26, 2017
April 19, 2017
July 17, 2017
October 4, 5, 10, 2017

TABLE B2

Mini Piezometer Summary

City of Guelph

Clair - Maltby Master Environmental Servicing Plan (MESP) and Secondary Plan (SP)

Monitoring Well	UTM NAD83 Zone 17N		Elevation[1] (masl)														Depth (mbgs)
					Oct. 2016		Dec. 2016		Jan. 2017		April 2017		July 2017		Nov. 2017		Ground Surface to Screen Base
	Northing	Easting	Ground Surface	Top of Casing	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	Surface Water	Ground Water	
MP01-D	4816236	565484	341.95	342.86	dry	340.64	dry	340.77	342.11	341.30	342.47	342.10	342.37	342.07	341.91	341.16	1.99
MP01-S	4816236	565484	341.95	342.78	dry	dry	dry	dry	342.12	341.83	342.48	342.26	342.38	341.94	341.94	341.31	1.15
MP02	4816113	565844	345.90	347.16	dry	dry	dry	dry	346.18	345.58	346.78	346.21	346.94	346.43	346.30	345.84	1.04
MP03	4816332	566274	347.42	348.28	dry	347.09	dry	347.23	347.55	347.52	348.08	348.08	347.74	347.74	347.27	347.27	1.44
MP04	4816622	566419	339.30	340.33	dry	339.09	dry	339.25	339.67	339.66	339.74	339.74	339.69	339.68	339.38	339.38	1.27
MP05	4815925	566681	337.70	338.36	dry	337.49	dry	337.64	338.13	338.13	338.16	338.16	338.09	338.09	337.72	337.72	1.64
MP06	4816131	566973	337.39	338.24	dry	337.00	dry	337.02	337.73	337.69	337.94	337.93	337.90	337.89	337.48	337.42	1.45
MP07-D	4816369	567115	337.26	338.37	dry	336.45	dry	336.75	337.43	336.82	337.89	337.49	337.86	337.83	337.42	frozen	2.42
MP07-S	4816369	567115	337.29	338.22	dry	336.97	dry	336.96	337.38	337.32	337.87	337.81	337.85	337.81	337.39	337.31	1.37
MP08	4816745	566739	337.40	338.72	337.38	337.28	337.40	337.29	337.68	337.67	337.86	337.86	337.84	337.82	337.57	337.56	0.98
MP09-D	4817378	566708	333.14	334.00	dry	331.63	dry	331.92	332.99	332.26	333.68	332.46	333.54	333.02	dry	332.89	2.04
MP09-S	4817379	566707	333.14	334.30	dry	332.47	dry	332.45	332.99	332.33	333.74	332.73	333.59	333.07	dry	332.88	1.14
MP10	4815366	565340	330.11	331.58	NA	NA	dry	329.95	330.13	330.10	330.46	330.46	331.07	331.07	330.43	330.42	0.97
MP11	4814531	566385	333.03	334.04	dry	332.98	333.19	333.16	333.33	333.33	333.33	333.34	333.29	333.31	333.19	333.16	1.29
MP12	4816079	567796	334.34	335.61	NA	NA	dry	334.16	334.38	334.33	334.58	334.58	334.59	334.60	334.41	334.31	1.47
MP13-D	4816631	568562	334.03	335.21	dry	333.29	333.99	333.38	334.30	333.99	334.57	334.27	334.43	333.99	destroyed	destroyed	2.17
MP13-S	4816631	568563	334.07	335.04	dry	333.51	333.99	333.74	334.28	333.83	334.56	334.18	334.42	334.42	destroyed	destroyed	1.16
MP14	4815633	568626	326.80	327.54	326.90	326.56	326.90	326.85	326.96	327.11	326.92	327.04	326.93	326.81	326.93	326.74	0.86

Notes:

[1] - elevations are geodetic

masl - metres above sea level

NA - not available

(orange shading) - Indicates an upward flow gradient in the GW system

(green shading) - Indicates groundwater elevation above surface water elevation

Notes:

Water levels were recorded on the following dates:

October 20 and 21, 2016

December 13, 2016

January 26, 2017

April 18, 2017

July 17, 2017

November 17, 2017

TABLE B3

Guelph Permeameter Testing Results

City of Guelph

Clair - Maltby Master Environmental Servicing Plan (MESP) and Secondary Plan (SP)

Location ID	Adjacent MW Nest	Date	Soil Interval		Soil Description*	Field Saturated Soil Hydraulic Conductivity (m/s)
			Top (mbgs)	Bottom (mbgs)		
GP01	MW01	2-Nov-16	0.00	0.19	Clayey Silt, some gravel to cobbles, trace sand	3.7E-06
GP02	MW02	2-Nov-16	0.00	0.22	Silty Clay, trace sand and gravel	4.4E-08
			0.22	0.41	Clayey Silt, some sand, trace gravel	
GP03	MW03	2-Nov-16	0.00	0.22	Clayey Silt, organics	1.6E-06
			0.22	0.34	Very Fine Sand, some silt	
GP04	MW04	1-Nov-16	0.00	0.19	Clayey Silt, trace sand and gravel	3.4E-07
			0.19	0.30	Fine Sandy Silt, trace clay and gravel	
GP05	MW05	1-Nov-16	0.00	0.20	Silty Sand	2.7E-07
			0.20	0.35	Silty Sand, trace gravel	
GP06	MW06	1-Nov-16	0.00	0.10	Silty Clay, organics	2.6E-07
			0.10	0.20	Clayey Silt, trace sand	
			0.20	0.33	Silty Clay, trace sand	
GP07	MW07	1-Nov-16	0.00	0.20	Silty Sand, trace gravel, organics	1.6E-06
			0.20	0.30	Fine Sand, trace silt	
GP08	MW08	2-Nov-16	0.00	0.33	Clayey Silt, trace sand	6.9E-08
GP09	MW09	2-Nov-16	0.00	0.28	Clayey Silt, trace sand and gravel, organics, worms	1.2E-05

Notes:

* - Soil description of hand-augered, near surface soil

TABLE B4

Surface Water Base Flow Results

City of Guelph

Clair - Maltby Master Environmental Servicing Plan (MESP) and Secondary Plan (SP)

Spot Flow Location	Subwatershed	UTM NAD83 Zone 17N		Spot Flows																			
				Summer 2016				Fall 2016				Spring 2017				Summer 2017				Fall 2017			
		Northing	Easting	Flow (L/s)	SW Temp °C	Date	Method	Flow (L/s)	SW Temp °C	Date	Method	Flow (L/s)	SW Temp °C	Date	Method	Flow (L/s)	SW Temp °C	Date	Method	Flow (L/s)	SW Temp °C	Date	Method
HC-HR1	Hanlon Creek	4817074	562217	63.3	18.1	Aug 31	FT	59.9	6.3	Nov 10	FT	175.3	8.3	May 11	FT	64.5	16.4	Aug 16	FT	57.8	5.9	Nov 29	FT
HC-HR2	Hanlon Creek	4816810	562558	0.0	---	Aug 31	V	0.0	---	Nov 10	V	1.0	---	May 11	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
HC-HR3	Hanlon Creek	4816866	562652	2.1	---	Sept 1	L	2.6	10.2	Nov 10	FT	5.7	11.9	May 11	FT	3.0	---	Aug 16	V	2.3	7.2	Nov 29	FT
HC-T1	Hanlon Creek	4816367	562118	14.0	16.5	Sept 1	FT	11.6	6.3	Nov 10	FT	85.2	10.3	May 11	FT	11.5	18.7	Aug 16	FT	24.6	4.6	Nov 29	FT
LSR-D2	Lower Speed River	4814794	562355	0.0	---	Sept 1	V	0.0	---	Nov 10	V	5.0	---	May 11	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
LSR-L1	Lower Speed River	4815033	561481	0.0	---	Aug 31	V	0.0	---	Nov 10	V	25.0	9.8	May 11	FT	0.0	---	Aug 16	V	0.0	---	Nov 29	V
LSR-P1	Lower Speed River	4815726	560821	0.1	---	Sept 1	B	0.1	---	Nov 10	B	35.0	---	May 11	B	9.1	22.0	Aug 16	FT	0.6	---	Nov 29	L
LSR-P2	Lower Speed River	4816066	560757	0.0	---	Sept 1	V	0.0	---	Nov 10	V	0.7	---	May 11	B	0.0	---	Aug 16	V	0.0	---	Nov 29	V
LSR-P3	Lower Speed River	4816551	560703	0.1	---	Sept 1	V	0.3	---	Nov 10	B	20.0	---	May 11	V	1.0	---	Aug 16	L	0.4	---	Nov 29	B
MC-C71	Mill Creek	4812339	566992	0.0	---	Aug 31	V	0.0	---	Nov 9	V	0.5	---	May 10	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
MC-C72	Mill Creek	4812723	566606	0.0	---	Aug 31	V	0.8	---	Nov 9	L	10.0	---	May 10	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
MC-G1	Mill Creek	4813575	569960	36.9	15.2	Aug 30	FT	43.4	7.6	Nov 9	FT	168.9	9.5	May 10	FT	38.6	13.9	Aug 16	FT	49.8	4.8	Nov 29	FT
MC-GN1	Mill Creek	4814253	568042	1.9	21.5	Aug 30	FT	4.7	8.3	Nov 9	FT	3.0	---	May 10	B	2.0	---	Aug 16	V	1.5	---	Nov 29	V
MC-GN2	Mill Creek	4814342	567968	1.9	---	Aug 30	B	2.4	---	Nov 9	B	5.0	---	May 10	B	3.0	---	Aug 16	B	3.5	---	Nov 29	B
MC-GN3	Mill Creek	4813648	568576	73.8	16.9	Aug 31	FT	58.2	8.4	Nov 9	FT	209.2	12.8	May 10	FT	74.2	16.2	Aug 16	FT	69.0	5.0	Nov 29	FT
MC-GN4	Mill Creek	4813263	569173	105.7	23.9	Aug 31	FT	111.4	8.7	Nov 9	FT	411.1	13.1	May 10	FT	108.8	23.5	Aug 16	FT	131.7	3.6	Nov 29	FT
MC-M2	Mill Creek	4818016	569639	---	---	---	---	0.0	---	Nov 10	V	3.0	---	May 11	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
MC-M3	Mill Creek	4814352	566152	0.0	---	Aug 31	V	0.0	---	Nov 9	V	0.0	---	May 10	V	0.0	---	Aug 16	V	0.0	---	Nov 29	V
MC-SR1	Mill Creek	4811552	567674	174.3	21.9	Aug 31	FT	187.2	8.1	Nov 9	FT	676.3	10.8	May 11	FT	208.0	18.3	Aug 16	FT	212.0	4.2	Nov 29	FT
MC-V1	Mill Creek	4813756	571458	16.5	16.4	Aug 30	FT	12.0	7.4	Nov 9	FT	62.8	10.1	May 10	FT	15.3	15.0	Aug 16	FT	15.4	4.1	Nov 29	FT
MC-V2	Mill Creek	4815732	569467	11.2	20.9	Aug 30	FT	5.8	8.0	Nov 9	FT	179.3	9.9	May 11	FT	25.0	18.1	Aug 16	FT	21.1	4.0	Nov 29	FT
MC-W2	Mill Creek	4817137	571205	8.3	---	Aug 30	FT	5.6	6.3	Nov 10	FT	102.2	10.7	May 11	FT	10.2	14.4	Aug 16	FT	5.9	7.1	Nov 29	FT
MC-WL3	Mill Creek	4813824	568493	76.9	17.9	Aug 30	FT	65.8	8.0	Nov 9	FT	206.5	12.8	May 10	FT	84.7	15.7	Aug 16	FT	75.2	5.1	Nov 29	FT
MC-WL4	Mill Creek	4813565	568249	8.4	18.8	Aug 31	FT	13.5	8.1	Nov 9	FT	28.2	13.0	May 10	FT	14.3	14.8	Aug 16	FT	12.7	4.2	Nov 29	FT
TC-C1	Torrance Creek	4820979	565613	---	---	---	---	0.0	---	Nov 10	V	0.3	---	May 10	B	0.0	---	Aug 16	V	0.0	---	Nov 29	V
TC-V1	Torrance Creek	4820265	564884	---	---	---	---	4.0	3.4	Nov 10	FT	39.3	10.2	May 10	FT	8.0	---	Aug 16	V	8.0	---	Nov 29	L
TC-V2	Torrance Creek	4820648	564494	---	---	---	---	0.0	---	Nov 10	V	1.3	9.9	May 10	FT	0.0	---	Aug 16	V	0.0	---	Nov 29	V

Notes:

--- - not recorded

FT - Son-Tek FlowTracker

L - Measured leaf velocity and multiplied by simplified cross-sectional area to estimate discharge

B - Discharge collected in a bucket over a measured amount of time

V - Visual estimate

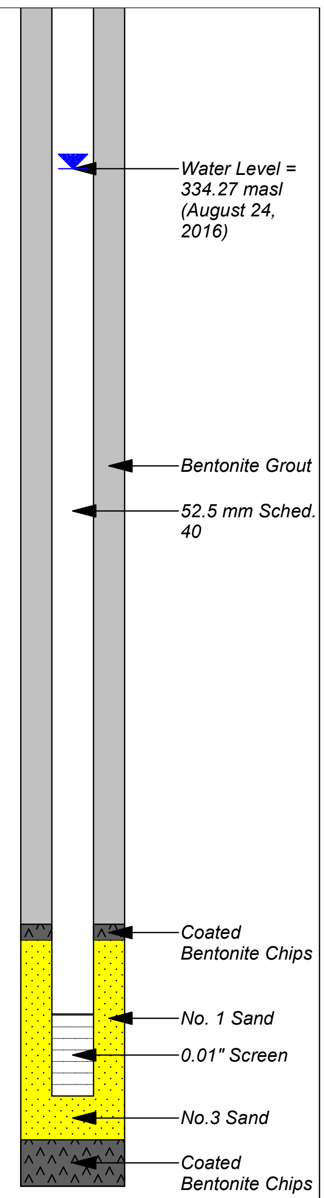
DRILLING LOG — Clair - Maltby Subwatershed Study — MW1-D

Client: **City of Guelph**	Date: **August 18, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.51 m**
Project Area: **Clair - Maltby**	Ground Elevation: **337.27 m asl**	Screened Interval: **18.75 - 20.27 m**	Northing: **4817765.42**
Project No.(MSI): **23089**	Total Depth: **21.64 m**	Slot Size: **0.01"**	Easting: **566643.99**
Field Staff: **J. Melchin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **17.37 - 21.09 m**	

m asl	m bgs	Lithology	Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
337	0		**CLAYEY SILT, trace fine to coarse sand, brown, dry**	0 / 337.27
335.75	1.52		**SANDY GRAVEL, coarse sand, fine to very coarse gravel, brown, poorly sorted, angular to subrounded, dry**	1.52 / 335.75
	9.75		**@ 9.75 m bgs: drill producing water**	
322.64	14.63		**CLAYEY SILT, some fine to coarse sand, trace fine gravel, grey (TILL)**	14.63 / 322.64
315.32	21.95		**PROBABLE BEDROCK** **END OF BOREHOLE @ 21.95 m bgs**	21.95 / 315.32

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA

Completion Details



NOTES: **m asl = metres above sea level**
m bgs = metres below ground surface
CS = cyclone sample

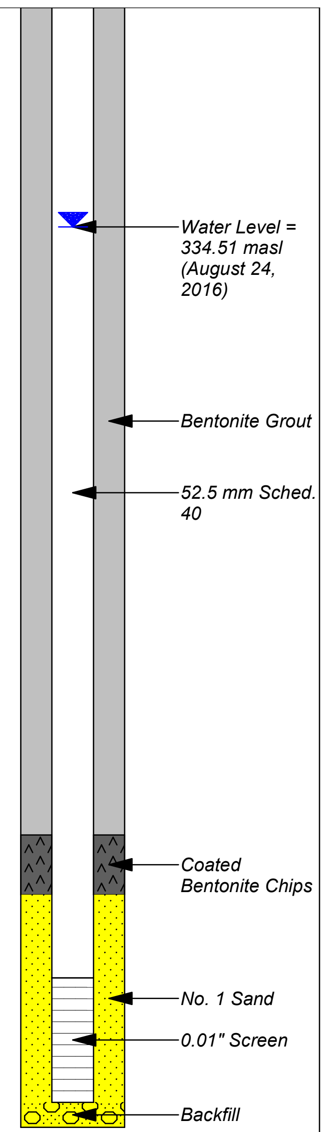
Matrix Solutions Inc.

DRILLING LOG | Clair - Maltby Subwatershed Study | MW1-S

Client: **City of Guelph**	Date: **August 19, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.42 m**
Project Area: **Clair - Maltby**	Ground Elevation: **337.20 masl**	Screened Interval: **11.89 - 13.41 m**	Northing: **4817762.85**
Project No.(MSI): **23089**	Total Depth: **13.72 m**	Slot Size: **0.01"**	Easting: **566641.90**
Field Staff: **J. Melchin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **10.87 - 13.41 m**	

m asl	m bgs	Lithology	Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)	Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
337	0		**CLAYEY SILT, trace fine to coarse sand, brown, dry**	0 / 337.20				
336	1							
			SANDY GRAVEL, coarse sand, fine to very coarse gravel, brown, poorly sorted, angular to subrounded, dry	1.52 / 335.67	5	CS	NA	NA
335	2							
334	3				10	CS	NA	NA
333	4				15	CS	NA	NA
332	5							
331	6				20	CS	NA	NA
330	7				25	CS	NA	NA
329	8		**@ 9.14 m bgs: drill producing water**					
328	9				30	CS	NA	NA
327	10				35	CS	NA	NA
326	11							
325	12				40	CS	NA	NA
324	13			13.72 / 323.48	45	CS	NA	NA
323	14		**END OF BOREHOLE @ 13.72 m bgs**					
322	15							

Completion Details



NOTES:
0.00 to 7.62 m bgs logged from MW1-D
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

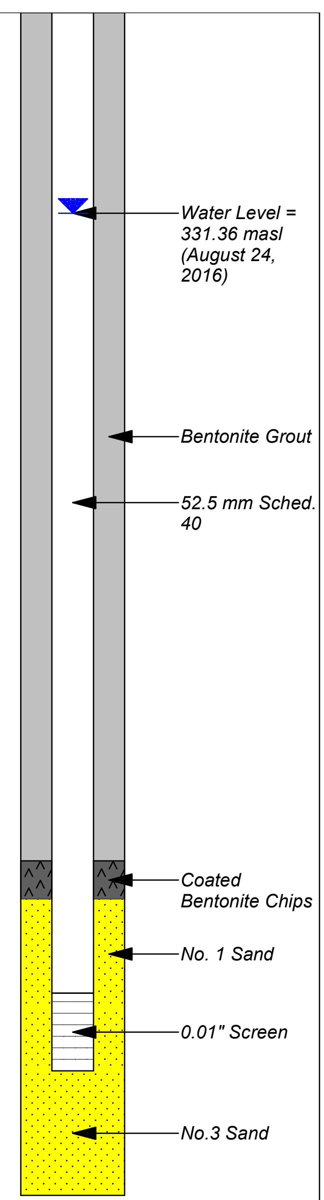
DRILLING LOG — Clair - Maltby Subwatershed Study — MW2-D

Client: **City of Guelph**	Date: **August 3, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.83 m**
Project Area: **Clair - Maltby**	Ground Elevation: **335.29 masl**	Screened Interval: **19.20 - 20.73 m**	Northing: **4817418.83**
Project No.(MSI): **23089**	Total Depth: **23.16 m**	Slot Size: **0.01"**	Easting: **566680.83**
Field Staff: **S. Miller/J. Melchin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **17.37 - 23.16 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
SANDY GRAVEL, fine to coarse sand, medium to fine gravel fining downwards, brown, poorly sorted, angular to subrounded, dry **@4.57 m bgs: moist** **@ 6.10 m bgs: drill producing water**	0 / 335.29
GRAVELLY SAND, fine to coarse sand, fine to medium gravel, grey, poorly sorted, angular to sub rounded, saturated	9.14 / 326.15
fine to very fine SAND, fining downwards, grey, well sorted, saturated	10.67 / 324.63
SILTY fine SAND, grey, moderately well sorted, saturated	15.85 / 319.44
GRAVELY SAND, medium to coarse sand, fine to medium gravel, poorly sorted, subangular to subrounded, saturated	18.29 / 317.01
END OF BOREHOLE @ 23.16 m bgs	23.16 / 312.13

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA
75	CS	NA	NA

Completion Details



NOTES: m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

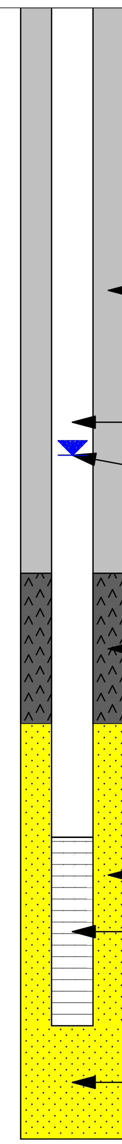
Matrix Solutions Inc.

DRILLING LOG — Clair - Maltby Subwatershed Study — MW2-S

Client: **City of Guelph**	Date: **August 4, 2016**
Project Area: **Clair - Maltby**	Ground Elevation: **335.40 masl**
Project No.(MSI): **23089**	Total Depth: **9.14 m**
Field Staff: **S. Miller/J. Melchin**	Drill Rig: **Foremost DR-12**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**
Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.91 m**
Screened Interval: **6.71 - 8.23 m**	Northing: **4817425.33**
Slot Size: **0.01"**	Easting: **566681.67**
Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Sand Pack: **5.79 - 9.14 m**	

m asl	m bgs	Lithology	Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)	Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
335.40	0		**SANDY GRAVEL, fine to coarse sand, medium to fine gravel fining downwards, brown, poorly sorted, angular to subrounded, dry**	0 / 335.40				
					5	CS	NA	NA
					10	CS	NA	NA
			@ 4.57 m bgs: moist		15	CS	NA	NA
			@ 6.10 m bgs: drill producing water		20	CS	NA	NA
					25	CS	NA	NA
				9.14 / 326.26	30	CS	NA	NA
			END OF BOREHOLE @ 9.14 m bgs					

Completion Details



NOTES: **0.00 to 6.10 m bgs logged from MW2-D**
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

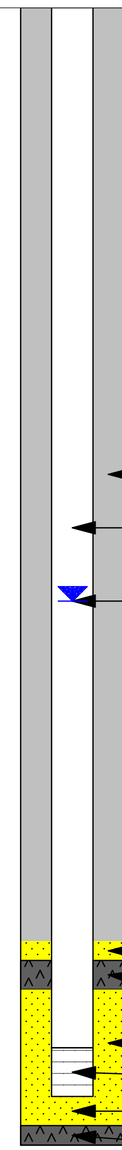
DRILLING LOG | Clair - Maltby Subwatershed Study | MW3-D

Client: **City of Guelph**	Date: **July 25, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.70 m**
Project Area: **Clair - Maltby**	Ground Elevation: **350.05 masl**	Screened Interval: **32.61 - 34.14 m**	Northing: **4816950.32**
Project No.(MSI): **23089**	Total Depth: **35.66 m**	Slot Size: **0.01"**	Easting: **568080.23**
Field Staff: **S. Miller**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **30.78 - 35.05 m**	

Depth (m bgs)/ Elev. (m asl)	Stratigraphic Description
0 / 350.05	**fine to medium SAND, some fine to coarse gravel, brown, poorly sorted, subangular to subrounded gravel, dry** **@18.90 m bgs: moist**
24.38 / 325.67	**medium SAND, brown, well sorted, wet, loose**
25.91 / 324.14	**fine to coarse GRAVEL, some coarse sand, poorly sorted, angular to subrounded, wet**
33.53 / 316.52	**SILTY fine to coarse SAND, trace fine to coarse gravel, grey, poorly sorted, wet**
35.36 / 314.70	**PROBABLE BEDROCK**
35.66 / 314.39	**END OF BOREHOLE @ 35.66 m bgs**

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA
75	CS	NA	NA
80	CS	NA	NA
85	CS	NA	NA
90	CS	NA	NA
95	CS	NA	NA
100	CS	NA	NA
105	CS	NA	NA
110	CS	NA	NA
115	CS	NA	NA

Completion Details



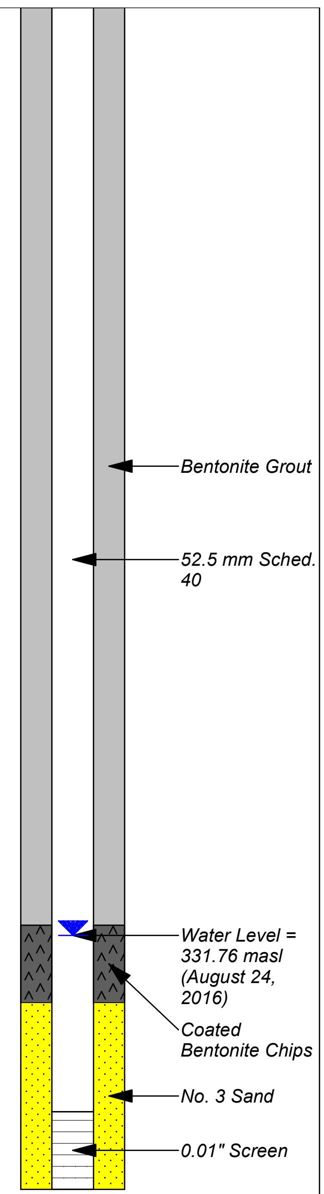
NOTES: m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG | Clair - Maltby Subwatershed Study | MW3-S

Client: **City of Guelph**	Date: **July 26, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.68 m**
Project Area: **Clair - Maltby**	Ground Elevation: **349.95 masl**	Screened Interval: **21.64 - 23.16 m**	Northing: **4816948.56**
Project No.(MSI): **23089**	Total Depth: **23.16 m**	Slot Size: **0.01"**	Easting: **568083.16**
Field Staff: **S. Miller**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **19.51 - 23.16 m**	

m asl	m bgs	Lithology	Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)	Sample ID	Sample Type	Blow Counts (N Value)	% Recovery	Completion Details
	0		fine to medium SAND, some fine to coarse gravel, brown, poorly sorted, subangular to subrounded gravel, dry	0 / 349.95					
349	1				5	CS	NA	NA	
348	2								
347	3				10	CS	NA	NA	
346	4								
345	5				15	CS	NA	NA	
344	6				20	CS	NA	NA	
343	7								
342	8				25	CS	NA	NA	
341	9				30	CS	NA	NA	
340	10								
339	11				35	CS	NA	NA	
338	12				40	CS	NA	NA	
337	13								
336	14				45	CS	NA	NA	
335	15				50	CS	NA	NA	
334	16								
333	17				55	CS	NA	NA	
332	18		@18.90 m bgs: moist		60	CS	NA	NA	
331	19								
330	20				65	CS	NA	NA	
329	21				70	CS	NA	NA	
328	22								
327	23			23.16 / 326.78	75	CS	NA	NA	
326	24		END OF BOREHOLE @ 23.16 m bgs						



NOTES: 0.00 to 19.81 m bgs logged from MW3-D
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG | Clair - Maltby Subwatershed Study | MW4-D

Client: **City of Guelph**
Project Area: **Clair - Maltby**
Project No.(MSI): **23089**
Field Staff: **D. Martin**
Driller: **Highland Water Well Drilling Inc**

Date: **August 22, 2016**
Ground Elevation: **349.60 masl**
Total Depth: **29.87 m**
Drill Rig: **Foremost DR-12**
Boring Diameter: **152 mm**

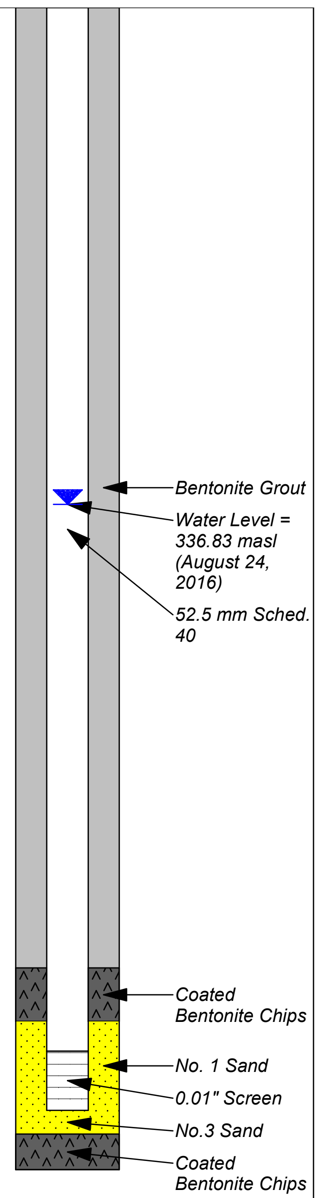
Screen Type: **52.5 mm PVC Sched. 40**
Screened Interval: **26.82 - 28.35 m**
Slot Size: **0.01"**
Casing Diameter: **52.5 mm**
Sand Pack: **26.00 - 29.08 m**

Stick Up: **0.76 m**
Northing: **4816485.40**
Easting: **566169.17**
Datum/Zone: **NAD83 17T**

Depth (m bgs)/ Elev. (m asl)	Stratigraphic Description
0 / 349.60	**SILTY fine to coarse SAND, some fine to medium gravel, grey, poorly sorted, angular, damp (TILL)** **@6.10 m bgs: cleaner SILTY SAND lense, trace fine gravel**
9.91 / 339.69	**fine to coarse SAND, some fine gravel, trace silt, grey, poorly sorted, subrounded, damp**
11.43 / 338.17	**fine to course SANDY SILT to SILTY SAND, occasional layers of fine to medium gravel, grey, very poorly sorted, angular (possible TILL)** **@13.72 m bgs: saturated** **@ 16.76 m bgs: lense of increased SILT content** **@ 22.86 m bgs: layer of fine GRAVELY coarse SAND, trace silt, poorly sorted** **@ 27.43 m bgs: layer of fine GRAVELY coarse SAND, trace silt, poorly sorted** **@ 28.96 m bgs: layer of fine GRAVELY coarse SAND, trace silt, poorly sorted**
29.57 / 320.03	**PROBABLE BEDROCK**
29.87 / 319.73	**END OF BOREHOLE @ 29.87 m bgs**

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA
75	CS	NA	NA
80	CS	NA	NA
85	CS	NA	NA
90	CS	NA	NA
95	CS	NA	NA
97	CS	NA	NA

Completion Details



NOTES: **m asl = metres above sea level**
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

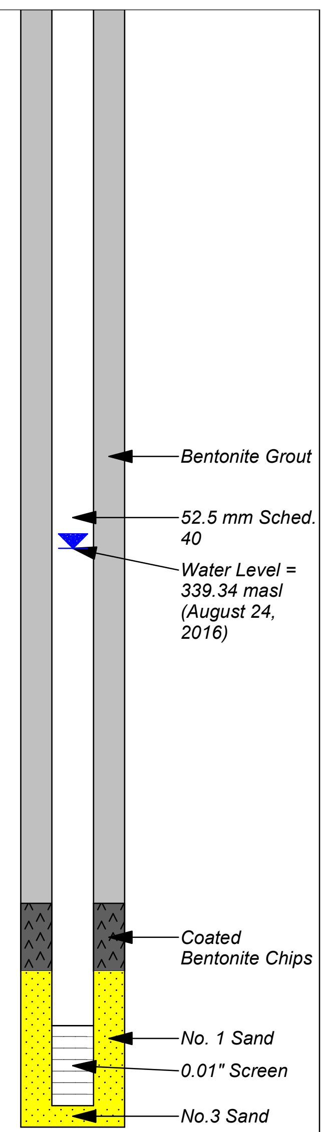
DRILLING LOG | Clair - Maltby Subwatershed Study | MW4-S

Client: **City of Guelph**	Date: **August 22 - 23, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.81 m**
Project Area: **Clair - Maltby**	Ground Elevation: **349.63 masl**	Screened Interval: **19.40 - 20.93 m**	Northing: **4816488.20**
Project No.(MSI): **23089**	Total Depth: **21.34 m**	Slot Size: **0.01"**	Easting: **566170.83**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **18.36 - 21.34 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
SILTY fine to coarse SAND, some fine to medium gravel, grey, poorly sorted, angular, damp (TILL) **@6.10 m bgs: cleaner SILTY SAND lense, trace fine gravel**	0 / 349.63
fine to coarse SAND, some fine gravel, trace silt, grey, poorly sorted, subrounded, damp	9.91 / 339.73
fine to course SANDY SILT to SILTY SAND, occasional layers of fine to medium gravel, grey, very poorly sorted, angular, damp (possible TILL) **@13.72 m bgs: saturated** **@ 16.76 m bgs: lense of increased SILT content**	11.43 / 338.20
END OF BOREHOLE @ 21.34 m bgs	21.34 / 328.30

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA

Completion Details



NOTES: **0.00 to 16.76 m bgs logged from MW4-D**
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG

Clair - Maltby Subwatershed Study

MW5-D

Client: **City of Guelph**
Project Area: **Clair - Maltby**
Project No.(MSI): **23089**
Field Staff: **D. Martin**
Driller: **Highland Water Well Drilling Inc**

Date: **August 10 - 11, 2016**
Ground Elevation: **340.17 masl**
Total Depth: **25.30 m**
Drill Rig: **Foremost DR-12**
Boring Diameter: **152 mm**

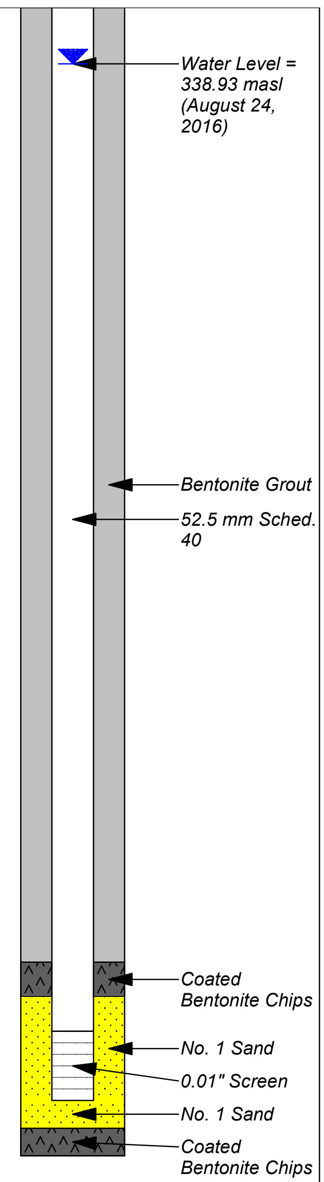
Screen Type: **52.5 mm PVC Sched. 40**
Screened Interval: **22.56 - 24.08 m**
Slot Size: **0.01"**
Casing Diameter: **52.5 mm**
Sand Pack: **21.79 - 24.69 m**

Stick Up: **0.71 m**
Northing: **4816336.75**
Easting: **567001.03**
Datum/Zone: **NAD83 17T**

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
fine clean GRAVEL, well sorted, angular to sub rounded, dry	0 / 340.17
medium to coarse SAND and fine to medium GRAVEL, brown, moderately well sorted, well rounded, dry	1.52 / 338.64
SILTY GRAVELY fine to coarse SAND, fine gravel, brown, poorly sorted, angular to subangular, saturated (TILL)	3.05 / 337.12
coarse SAND and fine GRAVEL, brown, moderately well sorted, well rounded, saturated	8.38 / 331.79
SILTY very coarse SAND, some fine gravel, grey, poorly sorted, angular, saturated	11.43 / 328.74
fine to very coarse GRAVEL up to COBBLES, some coarse sand, poorly sorted, subrounded	14.48 / 325.69
coarse SAND fining downwards to fine SAND, grey, well sorted, sub rounded, saturated **@22.86 m bgs: very trace SILT**	16.76 / 323.40
PROBABLE BEDROCK	24.38 / 315.78
END OF BOREHOLE @ 25.30 m bgs	25.30 / 314.87

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA
60	CS	NA	NA
65	CS	NA	NA
70	CS	NA	NA
75	CS	NA	NA
80	CS	NA	NA
83	CS	NA	NA

Completion Details

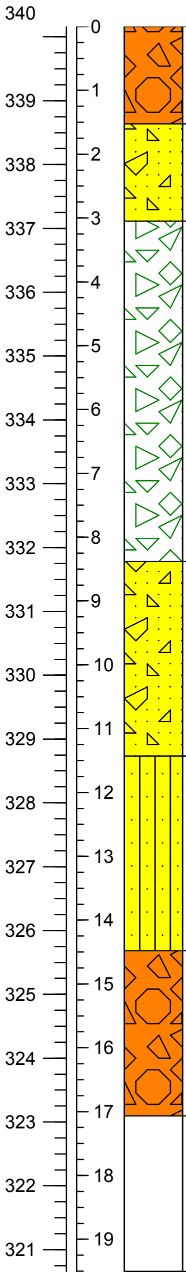


NOTES:
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG | Clair - Maltby Subwatershed Study | MW5-S

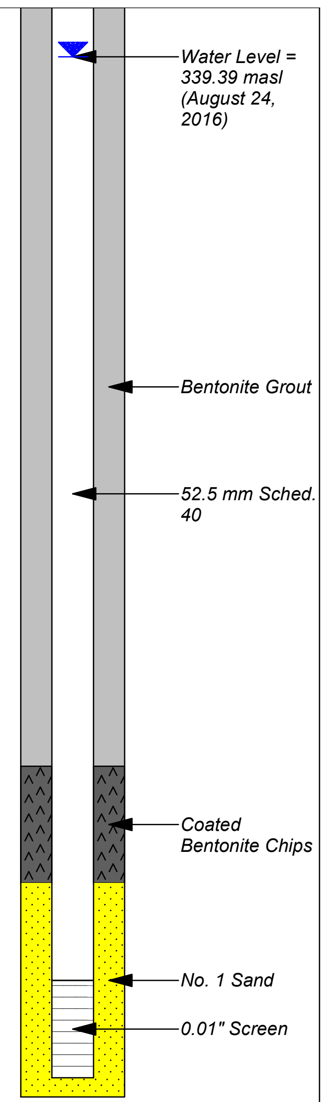
Client: **City of Guelph**	Date: **August 11, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.76 m**
Project Area: **Clair - Maltby**	Ground Elevation: **340.16 masl**	Screened Interval: **15.24 - 16.76 m**	Northing: **4816334.91**
Project No.(MSI): **23089**	Total Depth: **17.07 m**	Slot Size: **0.01"**	Easting: **566998.56**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **13.72 - 16.76 m**	



Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
fine GRAVEL, well sorted, angular to sub rounded, dry	0 / 340.16
medium to coarse SAND and fine to medium GRAVEL, brown, moderately well sorted, well rounded, dry	1.52 / 338.64
SILTY GRAVELY fine to coarse SAND, fine gravel, brown, poorly sorted, angular to subangular, saturated (TILL)	3.05 / 337.12
coarse SAND and fine GRAVEL, brown, moderately well sorted, well rounded, saturated	8.38 / 331.78
SILTY very coarse SAND, some fine gravel, grey, poorly sorted, angular, saturated	11.43 / 328.73
fine to very coarse GRAVEL up to COBBLES, some coarse sand, fine to very coarse gravel, poorly sorted, subrounded	14.48 / 325.69
END OF BOREHOLE @ 17.07 m bgs	17.07 / 323.09

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS	NA	NA
10	CS	NA	NA
15	CS	NA	NA
20	CS	NA	NA
25	CS	NA	NA
30	CS	NA	NA
35	CS	NA	NA
40	CS	NA	NA
45	CS	NA	NA
50	CS	NA	NA
55	CS	NA	NA

Completion Details



NOTES: **0.00 to 10.67 m bgs logged from MW5-D**
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG — Clair - Maltby Subwatershed Study — MW6-D

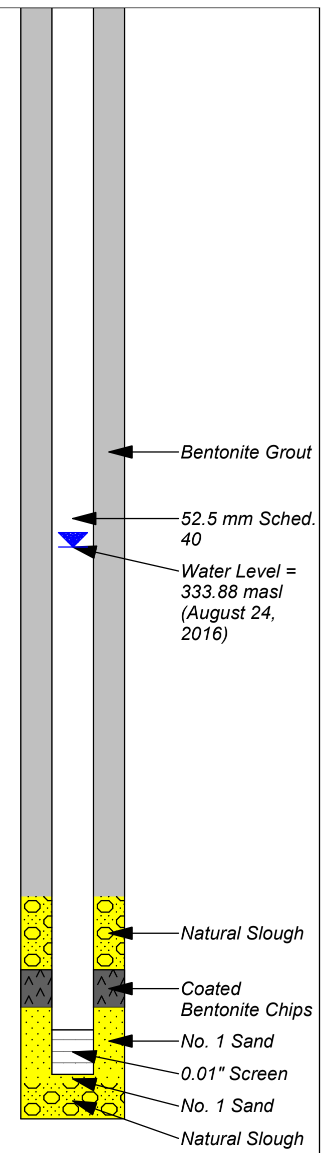
Client: **City of Guelph**	Date: **August 15, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.79 m**
Project Area: **Clair - Maltby**	Ground Elevation: **352.38 masl**	Screened Interval: **35.05 - 36.58 m**	Northing: **4816249.90**
Project No.(MSI): **23089**	Total Depth: **38.10 m**	Slot Size: **0.01"**	Easting: **567400.42**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **34.32 - 36.88 m**	

Depth (m bgs)/ Elev. (m asl)	Stratigraphic Description
0 / 352.38	**GRAVELY SAND, fine to coarse sand, fine to medium gravel, brown, poorly sorted, subangular to subrounded, dry to damp** **@ 9.91 to 12.95 m bgs: GRAVEL, some fine to coarse SAND**
14.48 / 337.90	**fine to very coarse SANDY SILT to SILTY SAND, brown, poorly sorted, angular to subangular, damp**
16.00 / 336.38	**fine to medium SAND coarsening downwards to a GRAVELY SAND, angular to subrounded, damp @18.29 m bgs: saturated**
22.10 / 330.28	**SILT, trace clay, trace coarse sand, grey, poorly sorted, saturated**
23.62 / 328.76	**SILTY fine to medium SAND, fining downwards, brown, poorly sorted, saturated, very loose**
35.81 / 316.57	**GRAVELY SAND (fine to medium gravel, fine to coarse sand), trace silt, grey, poorly sorted, saturated**
37.19 / 315.19	**SILTY CLAY, some fine GRAVEL, grey, poorly sorted, angular to subangular, saturated (TILL)**
37.80 / 314.58	**END OF BOREHOLE @ 37.80 m bgs**

Sample ID	Sample Type
5	CS
10	CS
15	CS
20	CS
25	CS
30	CS
35	CS
40	CS
45	CS
50	CS
55	CS
60	CS
65	CS
70	CS
75	CS
80	CS
85	CS
90	CS
95	CS
100	CS
105	CS
110	CS
115	CS
120	CS
124	CS

Blow Counts (N Value) | % Recovery

Completion Details



NOTES: m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

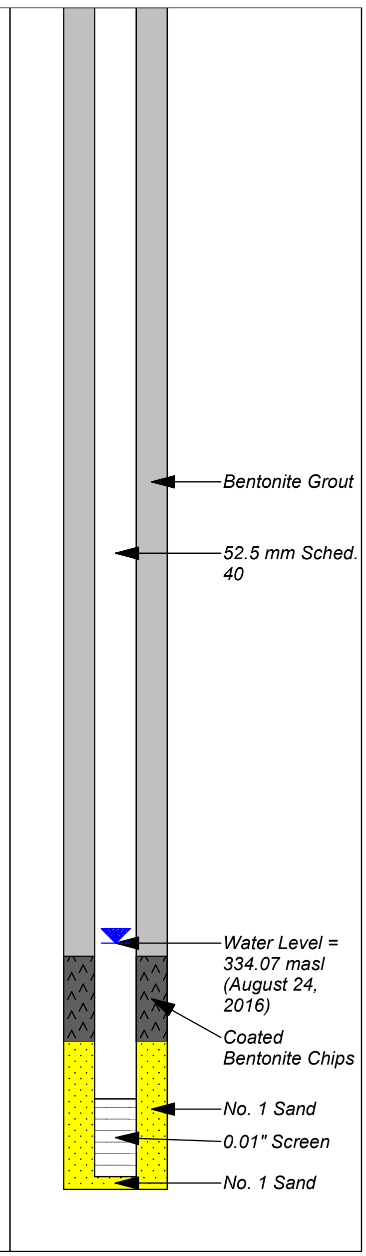
DRILLING LOG | Clair - Maltby Subwatershed Study | MW6-S

Client: **City of Guelph**	Date: **August 16-17, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.79 m**
Project Area: **Clair - Maltby**	Ground Elevation: **352.41 masl**	Screened Interval: **21.39 - 22.91 m**	Northing: **4816246.66**
Project No.(MSI): **23089**	Total Depth: **23.17 m**	Slot Size: **0.01"**	Easting: **567401.07**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **20.27 - 23.16 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
GRAVELY SAND, fine to coarse sand, fine to medium gravel, brown, poorly sorted, subangular to subrounded, dry to damp	0 / 352.41
@ 9.91 to 12.95 m bgs: GRAVEL, some fine to coarse SAND	
fine to very coarse SANDY SILT to SILTY SAND, brown, poorly sorted, angular to subangular, damp	14.48 / 337.93
fine to medium SAND coarsening downwards to a poorly sorted GRAVELY SAND, angular to subrounded, damp	16.00 / 336.40
@18.29 m bgs: saturated	
SILT, trace clay, trace coarse sand, grey, poorly sorted, saturated	22.10 / 330.31
END OF BOREHOLE @ 22.86 m bgs	22.86 / 329.55

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS		
10	CS		
15	CS		
20	CS		
25	CS		
30	CS		
35	CS		
40	CS		
45	CS		
50	CS		
55	CS		
60	CS		
65	CS		
70	CS		
75	CS		

Completion Details



NOTES:
0.00 to 15.24 m bgs logged from MW6-D
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

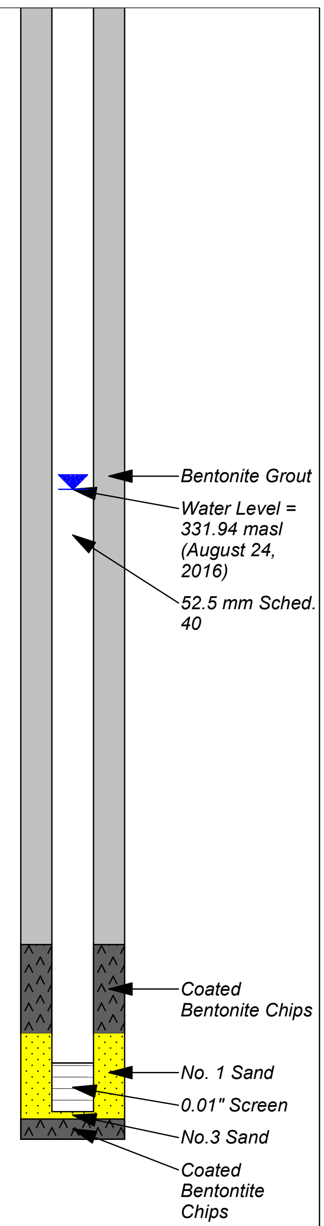
DRILLING LOG — Clair - Maltby Subwatershed Study — MW7-D

Client: **City of Guelph**	Date: **August 23, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.76 m**
Project Area: **Clair - Maltby**	Ground Elevation: **347.04 masl**	Screened Interval: **33.07 - 34.59 m**	Northing: **4815512.35**
Project No.(MSI): **23089**	Total Depth: **35.46 m**	Slot Size: **0.01"**	Easting: **565478.72**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **32.16 - 34.82 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
GRAVELY SAND (fine to medium gravel, medium to coarse sand), brown, poorly sorted, subrounded, dry	0 / 347.04
SILT, trace clay coarsening downwards to SANDY SILT, trace fine gravel, brown, angular, dry	5.33 / 341.70
SANDY GRAVEL, medium to coarse sand, fine to medium gravel, brown, poorly sorted, angular to subangular, moist	11.43 / 335.61
medium to coarse SAND fining downwards, grey, well sorted, saturated	20.57 / 326.46
SANDY SILT to SILTY SAND fining downwards to SILT, grey, well sorted, saturated	26.67 / 320.37
CLAYEY SILT, grey, moderately well sorted, saturated	31.24 / 315.79
SANDY GRAVEL, fine gravel, fine to coarse sand, grey, poorly sorted, angular to subangular, saturated	32.77 / 314.27
END OF BOREHOLE @ 35.36 m bgs	35.36 / 311.68

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS		
10	CS		
15	CS		
20	CS		
25	CS		
30	CS		
35	CS		
40	CS		
45	CS		
50	CS		
55	CS		
60	CS		
65	CS		
70	CS		
75	CS		
80	CS		
85	CS		
90	CS		
95	CS		
100	CS		
105	CS		
110	CS		
115	CS		

Completion Details



NOTES: m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

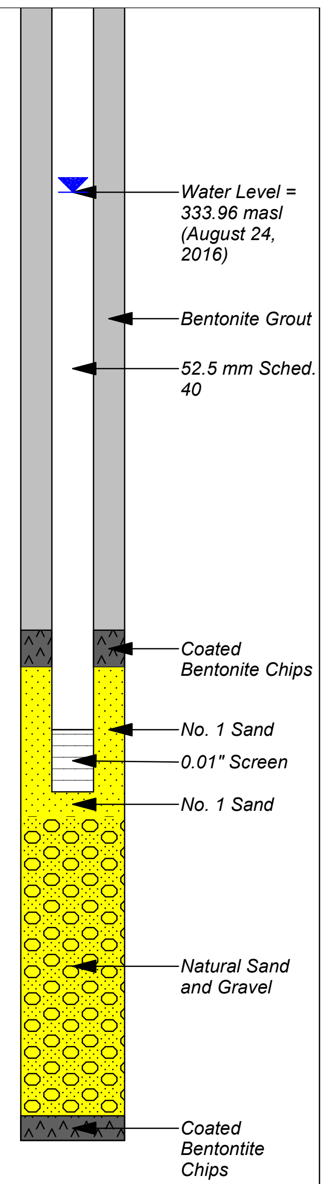
DRILLING LOG — Clair - Maltby Subwatershed Study — MW8-D

Client: **City of Guelph**	Date: **August 9, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.87 m**
Project Area: **Clair - Maltby**	Ground Elevation: **338.48 masl**	Screened Interval: **17.68 - 19.20 m**	Northing: **4815489.34**
Project No.(MSI): **23089**	Total Depth: **27.74 m**	Slot Size: **0.01"**	Easting: **566248.11**
Field Staff: **D. Martin/J. Melchin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc.**	Boring Diameter: **152 mm**	Sand Pack: **16.15 - 19.81 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
fine to coarse SAND and fine to medium GRAVEL, trace silt, brown, poorly sorted, angular to sub-rounded, damp to moist	0 / 338.48
@4.57 m bgs: saturated	
very coarse SAND and fine GRAVEL, slight coarsening downwards to medium coarse gravel, grey, moderately well sorted, saturated	12.95 / 325.52
SILTY CLAY, some fine to coarse sand, some fine to medium gravel, grey, very poorly sorted, angular, saturated (TILL)	23.62 / 314.86
SAND and fine GRAVEL, poorly sorted, subrounded	27.13 / 311.35
PROBABLE BEDROCK	27.43 / 311.05
END OF BOREHOLE @ 27.74 m bgs	27.74 / 310.74

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS		
10	CS		
15	CS		
20	CS		
25	CS		
30	CS		
35	CS		
40	CS		
45	CS		
50	CS		
55	CS		
60	CS		
65	CS		
70	CS		
75	CS		
80	CS		
85	CS		
90	CS		

Completion Details



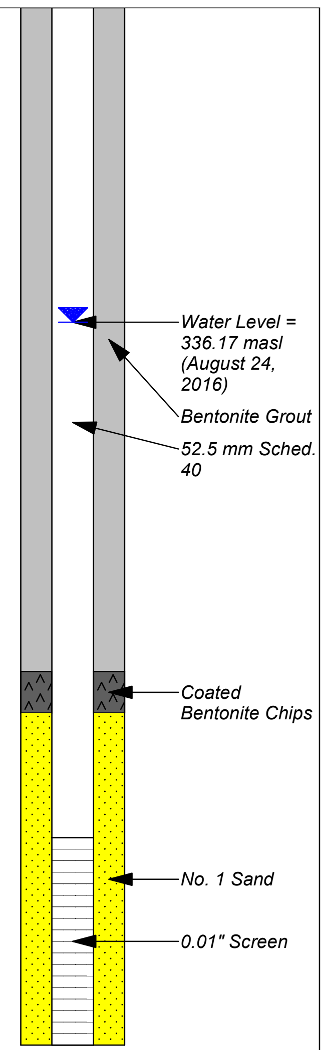
NOTES: m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG — Clair - Maltby Subwatershed Study — MW8-S

Client: **City of Guelph**	Date: **August 10, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.84 m**
Project Area: **Clair - Maltby**	Ground Elevation: **338.48 masl**	Screened Interval: **6.10 - 7.62 m**	Northing: **4815493.95**
Project No.(MSI): **23089**	Total Depth: **7.62 m**	Slot Size: **0.01"**	Easting: **566250.11**
Field Staff: **D. Martin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **5.18 - 7.62 m**	

m asl	m bgs	Lithology	Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)	Sample ID	Sample Type	Blow Counts (N Value)	% Recovery	Completion Details
	0		**fine to coarse SAND and fine to medium GRAVEL, trace silt, brown, poorly sorted, angular to sub-rounded, damp to moist**	0 / 338.48					
338									
	1								
337					5	CS			
	2								
336									
	3				10	CS			
335									
	4								
334			**@4.57 m bgs: saturated**		15	CS			
	5								
333									
	6				20	CS			
332									
	7								
331				7.62 / 330.86	25	CS			
			END OF BOREHOLE @ 7.62 m bgs						
	8								
330									
	9								



NOTES:
0.00 to 6.10 m bgs logged from MW8-D
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

DRILLING LOG — Clair - Maltby Subwatershed Study — MW9-D

Client: **City of Guelph**
Project Area: **Clair - Maltby**
Project No.(MSI): **23089**
Field Staff: **S. Miller/J. Melchin**
Driller: **Highland Water Well Drilling Inc**

Date: **August 4, 2016**
Ground Elevation: **350.51 masl**
Total Depth: **37.03 m**
Drill Rig: **Foremost DR-12**
Boring Diameter: **152 mm**

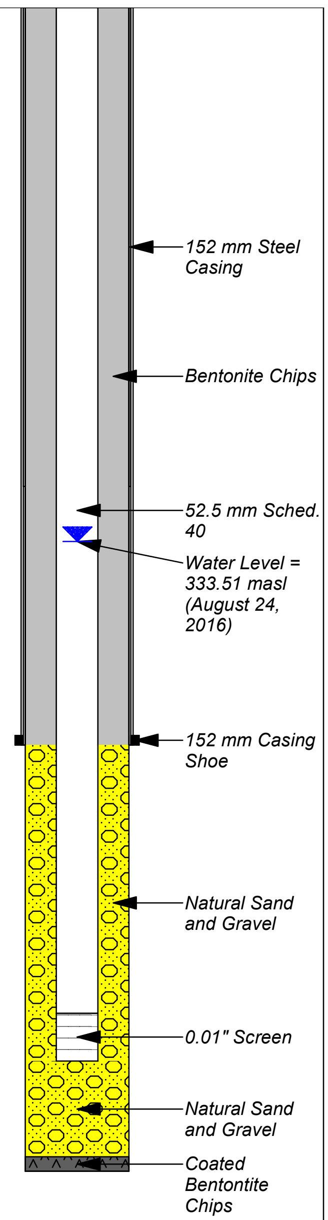
Screen Type: **52.5 mm PVC Sched. 40**
Screened Interval: **32.00 - 33.53 m**
Slot Size: **0.01"**
Casing Diameter: **52.5 mm**
Sand Pack: **29.26 - 36.58 m**

Stick Up: **0.55 m**
Northing: **4815294.75**
Easting: **566970.16**
Datum/Zone: **NAD83 17T**

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
GRAVELY SAND (fine gravel, medium to coarse sand) coarsening with depth, brown, moderately well sorted, subrounded to rounded, dry **@1.52 m bgs: some silt, trace clay** **@ 15.24 m bgs: trace silt**	0 / 350.51
fine to medium SAND, brown, moderately well sorted, dry	16.00 / 334.50
medium to coarse SAND and fine GRAVEL, brown, moderately well sorted, subrounded to rounded, saturated	17.53 / 332.98
medium to very coarse SAND, trace fine gravel, fining slightly with depth, brown, subrounded, saturated	23.62 / 326.88
very fine SANDY SILT, fining downwards to silt, grey, well sorted, saturated	28.19 / 322.31
fine to medium GRAVEL, trace to some coarse sand, grey, subangular to subrounded, saturated	31.24 / 319.26
PROBABLE BEDROCK	36.58 / 313.93
END OF BOREHOLE @ 37.03 m bgs	37.03 / 313.47

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS		
10	CS		
15	CS		
20	CS		
25	CS		
30	CS		
35	CS		
40	CS		
45	CS		
50	CS		
55	CS		
60	CS		
65	CS		
70	CS		
75	CS		
80	CS		
85	CS		
90	CS		
95	CS		
100	CS		
105	CS		
110	CS		
115	CS		
120	CS		

Completion Details



NOTES:
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

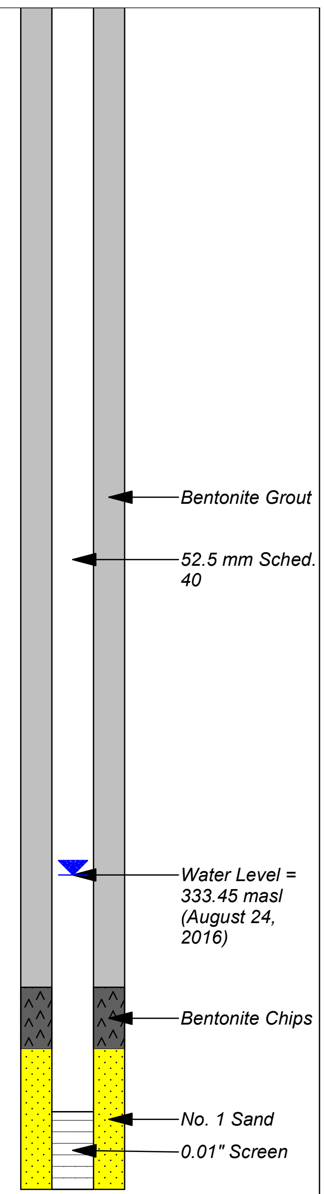
DRILLING LOG — Clair - Maltby Subwatershed Study — MW9-S

Client: **City of Guelph**	Date: **August 8, 2016**	Screen Type: **52.5 mm PVC Sched. 40**	Stick Up: **0.46 m**
Project Area: **Clair - Maltby**	Ground Elevation: **350.46 masl**	Screened Interval: **21.64 - 23.16 m**	Northing: **4815292.49**
Project No.(MSI): **23089**	Total Depth: **23.16 m**	Slot Size: **0.01"**	Easting: **566972.15**
Field Staff: **S.Miller/J. Melchin**	Drill Rig: **Foremost DR-12**	Casing Diameter: **52.5 mm**	Datum/Zone: **NAD83 17T**
Driller: **Highland Water Well Drilling Inc**	Boring Diameter: **152 mm**	Sand Pack: **20.42 - 23.16 m**	

Stratigraphic Description	Depth (m bgs)/ Elev. (m asl)
GRAVELY SAND, fine gravel, medium to coarse sand coarsening with depth, brown, subrounded to rounded, dry **@1.52 m bgs: some silt, trace clay** **@ 15.24 m bgs: trace silt**	0 / 350.46
fine to medium SAND, brown, moderately well sorted, dry	16.00 / 334.45
medium to coarse SAND and fine GRAVEL, brown, subrounded to rounded, saturated	17.53 / 332.93
END OF BOREHOLE @ 23.16 m bgs	23.16 / 327.29

Sample ID	Sample Type	Blow Counts (N Value)	% Recovery
5	CS		
10	CS		
15	CS		
20	CS		
25	CS		
30	CS		
35	CS		
40	CS		
45	CS		
50	CS		
55	CS		
60	CS		
65	CS		
70	CS		
75	CS		

Completion Details



NOTES: **0.00 to 18.29 m bgs logged from MW9-D**
m asl = metres above sea level
m bgs = metres below ground surface
CS = cyclone sample

Matrix Solutions Inc.

Aquafor Beech Limited
920 Princess St.
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-1

Project No.: 65188

Project: Neumann Property EIS

Client: Neumann Group

Enclosure: 1

Location: Guelph, ON

Project Manager: Barry Gorman

SUBSURFACE PROFILE / SAMPLE

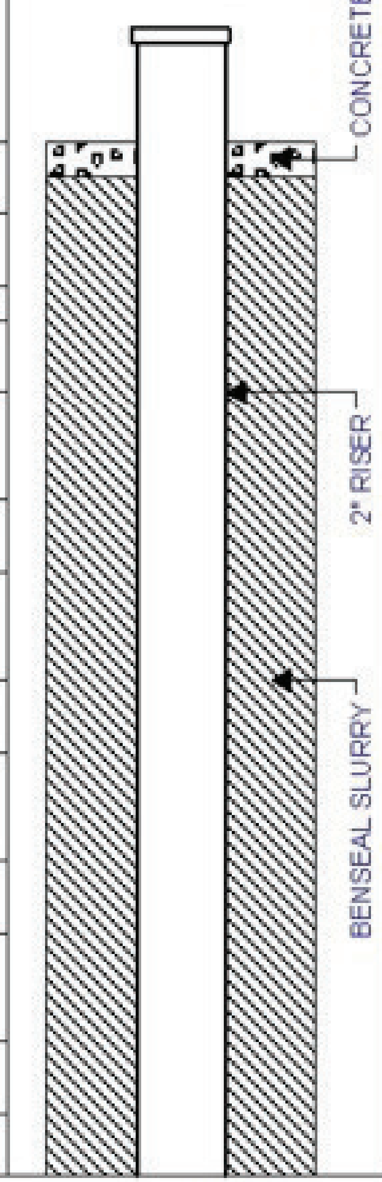
Depth (ft / m); Symbol; Description; Depth/Elev.

Ground Surface — 346.2 / 0.0

- *Topsoil* — brown silty sand loam
- *Silty sand ,gravel, trace clay*
- grinding on boulder - moisture 7%
- Sand 49%, silt 41%, clay 11%
- light brown, cobbles, dry
- Sand 45%, silt 48%, clay 7%
- moist, cobbles - moisture 8.4%
- coarse sand with cobbles

Number	Type	'N' Blows/ft.
1		16
2		10
3		30
4		23
5		36
6		35
7		33

Well Completion Details



Drilled By: Aardvark Drilling Inc.

Drill Method: Hollow-stem auger

Drill Date: Nov. 14, 2011

Hole Size: 210 mm

Datum:

Sheet: 1 of 2

Aquafor Beech Limited
920 Princess St.
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-1

Project No.: 65188

Project: Neumann Property EIS

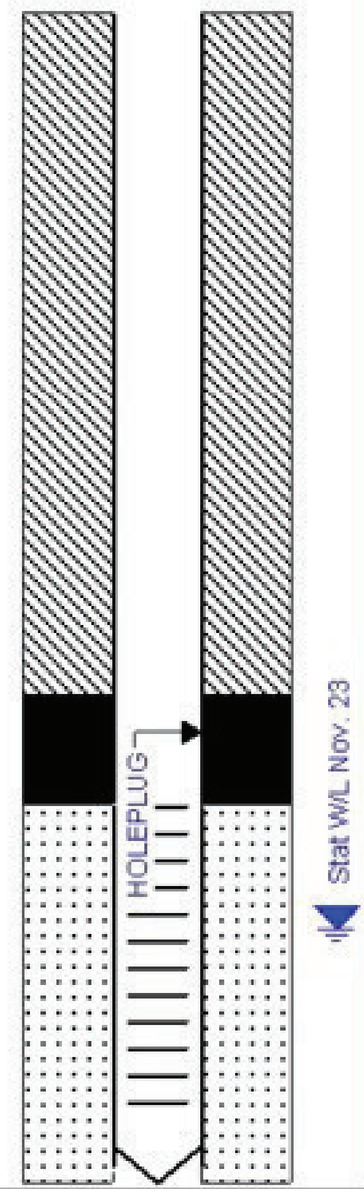
Client: Neumann Group

Location: Guelph, ON

Enclosure: 1

Project Manager: Barry Gorman

SUBSURFACE PROFILE				SAMPLE			
Depth	Symbol	Description	Depth/Elev.	Number	Type	'N' Blows/ft.	Well Completion Details
30		Sand 50%, silt41%, clay 9%		8		64	
32 (10)		moisture 7.3%					
34							
36		reddish tint		9		28	
38							
40 (12)			306.2				
		Gravel and sand	40.0	10		24	
42		Gravel 57%, sand 26%, silt and clay 17%, moisture 4%					
44							
46 (14)				11		78	
48							
50		Gravel 55%, sand 30%, silt and clay 15%		12		86	
52 (16)		some Precambrian pebbles - moisture 3.4%					
54							
56		wet		13		65	
58							
60 (18)			286.2				
			60.0				



Drilled By: Aardvark Drilling Inc.

Drill Method: Hollow-stem auger

Drill Date: Nov. 14, 2011

Hole Size: 210 mm

Datum:

Sheet: 2 of 2

Aquafor Beech Limited
920 Princess St.
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-2

Project No.: 65188

Project: Neumann Property EIS

Client: Neumann Group

Enclosure: 2

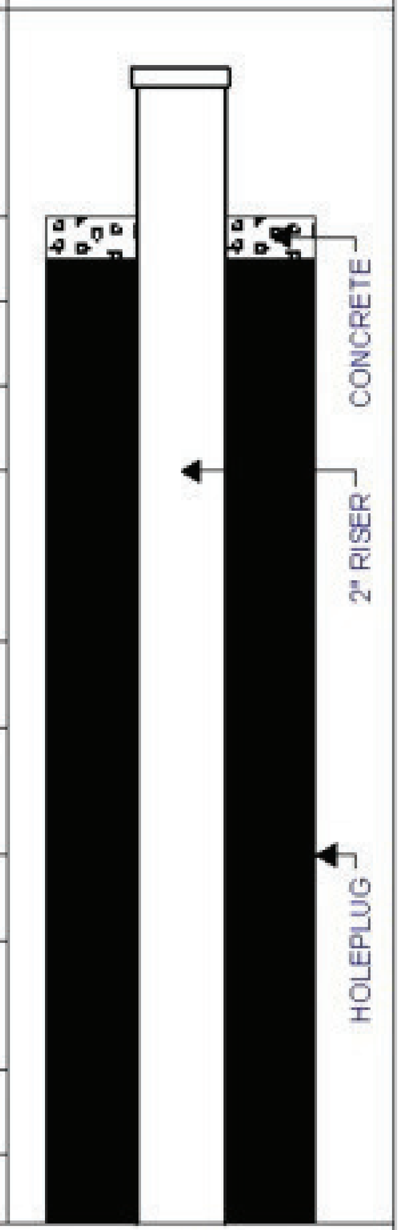
Location: Guelph, ON

Project Manager: Barry Gorman

SUBSURFACE PROFILE / SAMPLE

Depth (ft)	Description	Depth/Elev.	Number	Type	'N' Blows/ft.
0	Ground Surface	344.0 / 0.0			
0–0.5	*Topsoil*		1		5
0.5–3	*Sandy silt* loam		2		24
3	*Silty sand and gravel*	341.0 / 3.0			
5	dry		3		34
11	gravel 33%, sand 37%, silt 24%, clay 6%, damp, moisture 17.7%		4		34
16	high gravel and cobble content, dry		5		34
21			6		47

Well Completion Details



Drilled By: Aardvark Drilling Inc.

Drill Method: Hollow-stem auger

Drill Date: Nov. 23-24, 2011

Hole Size: 210 mm

Datum:

Sheet: 1 of 2

Aquafor Beech Limited
920 Princess St.
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-2

Project No.: 65188

Project: Neumann Property EIS

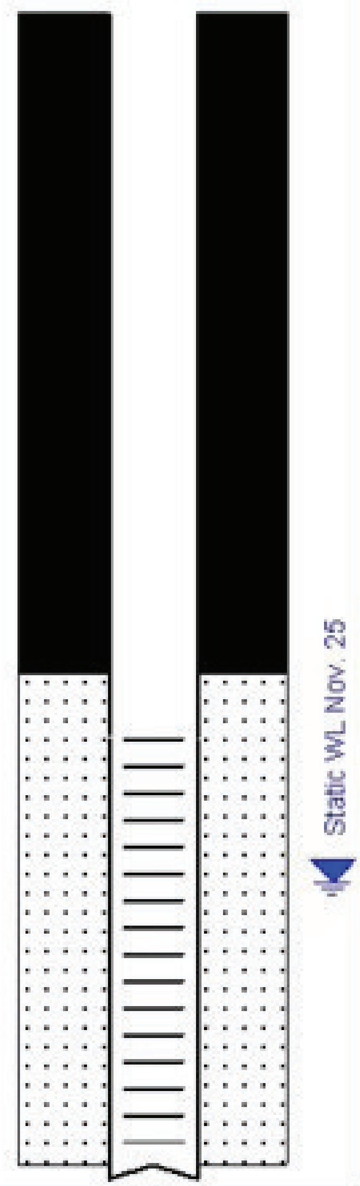
Client: Neumann Group

Enclosure: 2

Location: Guelph, ON

Project Manager: Barry Gorman

SUBSURFACE PROFILE				SAMPLE			
Depth (ft)	Depth (m)	Description	Depth/Elev.	Number	Type	'N' Blows/ft.	Well Completion Details
25–29	9	damp	314.0	7		48	
31		**Silt with gravel** gravel 16%, sand 16%m silt 24%, clay 6%, moisture 6.7%	30.0	8		61	
33–39	11	cobbles	304.0	9		100+	
41		**Sand and gravel** sand and gravel, dry	40.0	10		69	
43–45	13	coarse grey sand 45-46, wet		11		72	
47–49	15	grinding on cobbles	294.0 / 50.0				



Drilled By: Aardvark Drilling Inc.

Drill Method: Hollow-stem auger

Drill Date: Nov. 23-24, 2011

Hole Size: 210 mm

Datum:

Sheet: 2 of 2

Aquafor Beech Limited
920 Princess St
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-3

Project No.: 65188

Project: Neumann Property EIS

Client: Neumann Group

Enclosure: 3

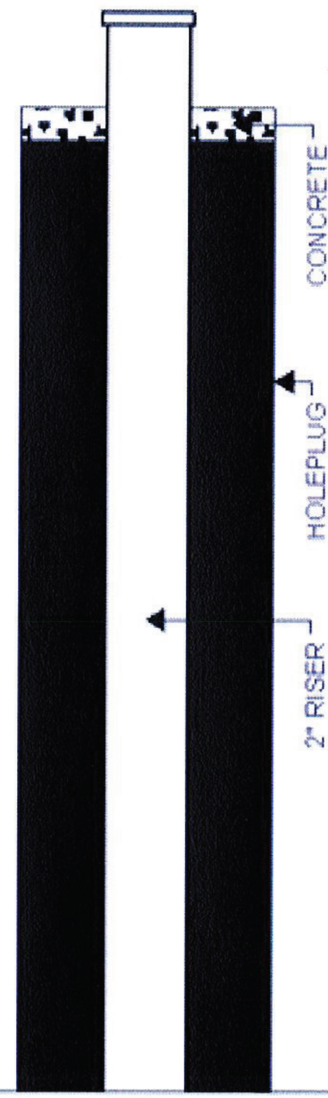
Location: Guelph, ON

Project Manager: Barry Gorman

SUBSURFACE PROFILE / SAMPLE

Depth (ft)	Description	Depth/Elev	Number	Type	'N' Blows/ft.
0	Ground Surface	349.0			
0	Topsoil	0.0			
0–12	Coarse Sand with silt		1		3
			2		5
	light brown		3		5
	grinding on cobbles	337.0	4		15
12–20	Silt and clay with gravel	12.0			
	gravel 7%, sand 8%, silt 50%, clay 35%, moisture 8.0%				
	grinding on boulder		5		63
20–	Gravel with silt and clay	329.0 / 20.0	6		100+
	still dry				
	grinding on boulders and cobbles				

Well Completion Details



Drilled By: Aardvark Drilling Inc.

Drill Method: Hollow-stem auger

Drill Date: Nov. 24, 2011

Hole Size: 210 mm

Datum:

Sheet: 1 of 2

Aquafor Beech Limited
920 Princess St
Kingston, Ontario
K7L 1H1

Log of Borehole: MW-3

Project No.: 65188

Project: Neumann Property EIS

Client: Neumann Group

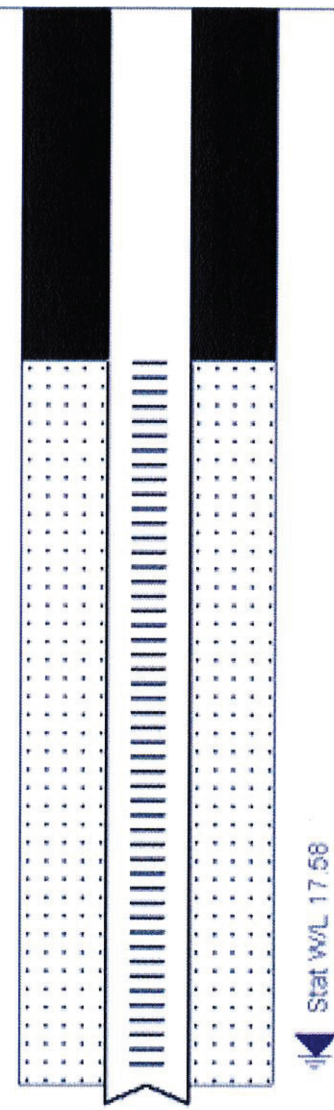
Location: Guelph, ON

Enclosure: 3

Project Manager: Barry Gorman

SUBSURFACE PROFILE				SAMPLE		
Depth (ft / m)	Symbol	Description	Depth/Elev	Number	Type	'N' Blows/ft.
30–32		brown, still dry		7		40
33–36 (10–11 m)		cobbles and boulders				
40–41 (12 m)				8		56
42–43		gravel 40%, sand 31%, silt 16%, clay 13%, moisture 3%				
44		red & grey shale fragments, wet				
45		same, still wet				
46 (14 m)				9		82
51		cobbles, spoon wet		10		100+
52–53 (16 m)		gravel 43%, sand 11%, silt 22%, clay 24%, moisture 6.3%				
56		boulders and cobbles to TD		11		100+
58 (18 m)			290.5 / 58.5			
60						

Well Completion Details



Drilled By: Aardvark Drilling Inc.

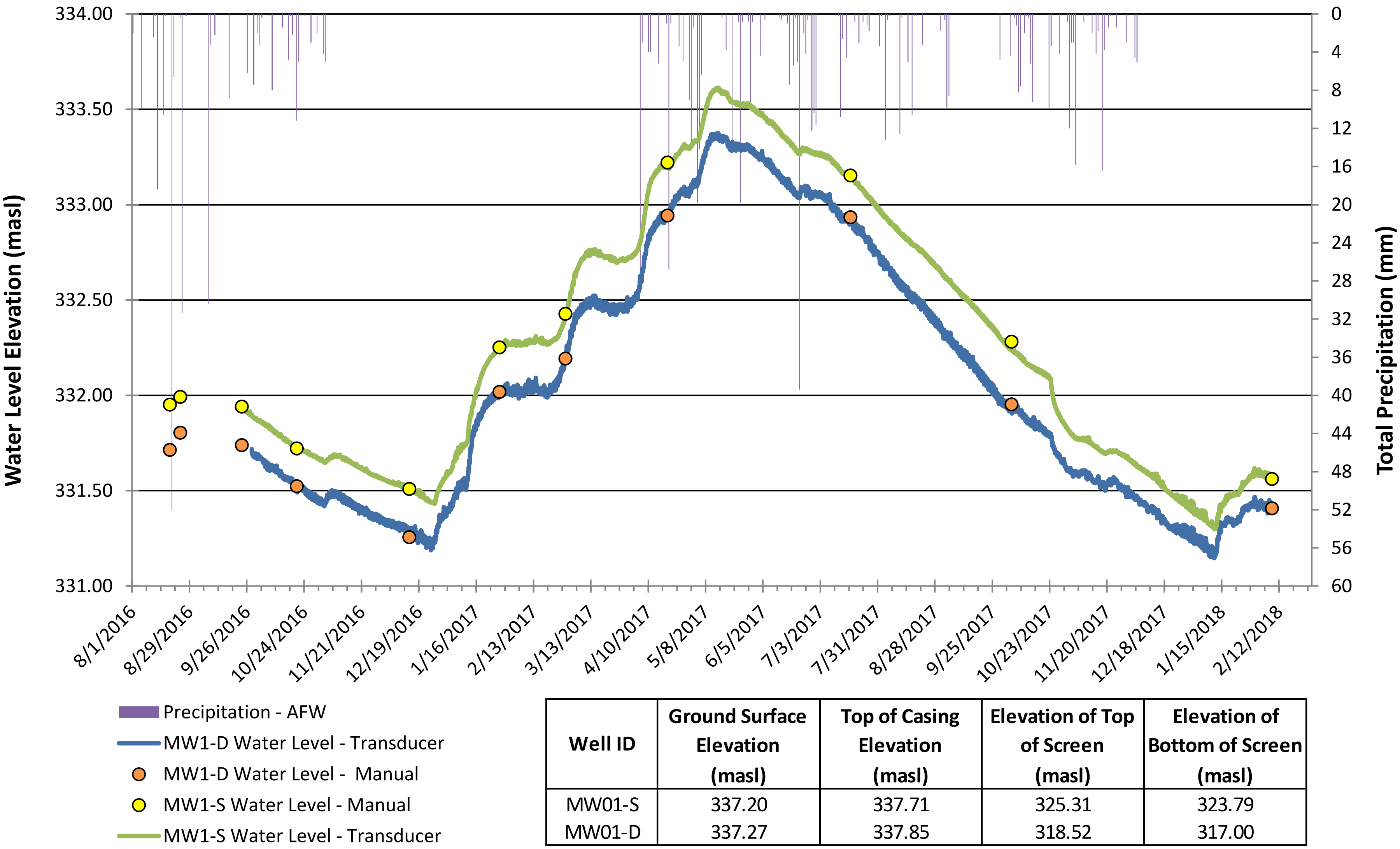
Drill Method: Hollow-stem auger

Drill Date: Nov 24, 2011

Hole Size: 210 mm

Datum:

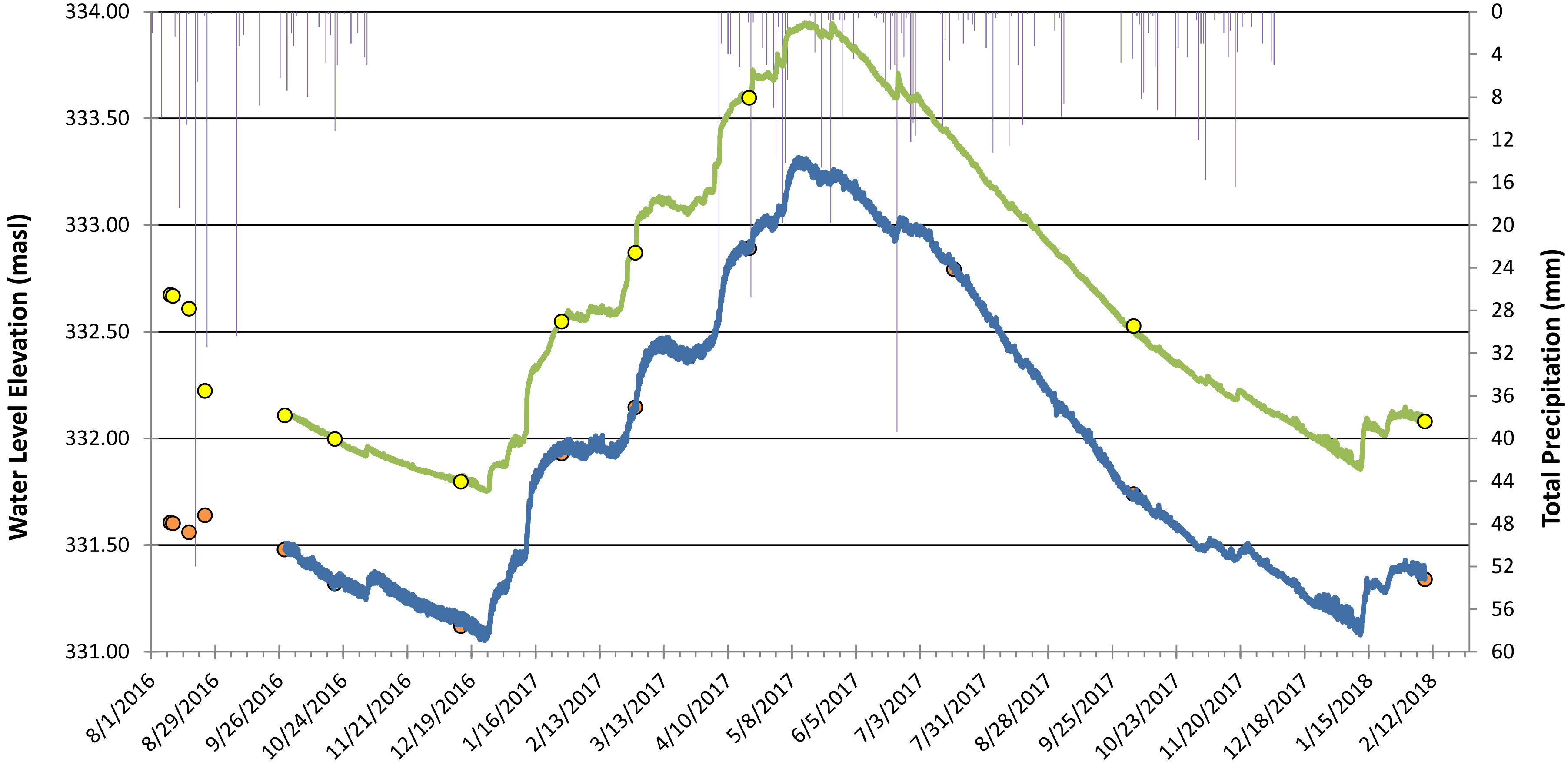
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW1-D & MW1-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW01-S	337.20	337.71	325.31	323.79
MW01-D	337.27	337.85	318.52	317.00

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

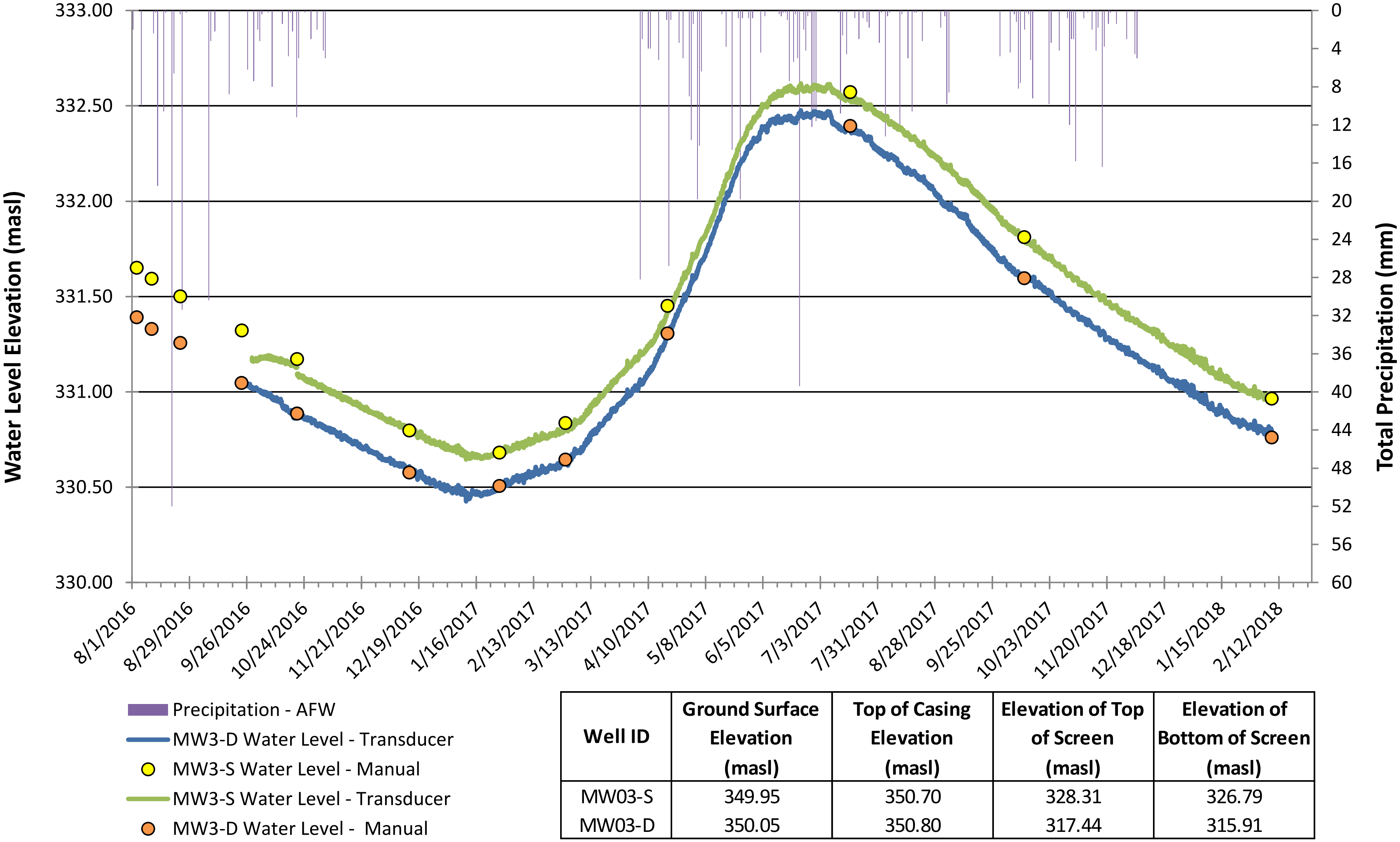
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW2-D & MW2-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW02-S	335.40	336.36	328.69	327.17
MW02-D	335.29	336.11	316.09	314.56

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

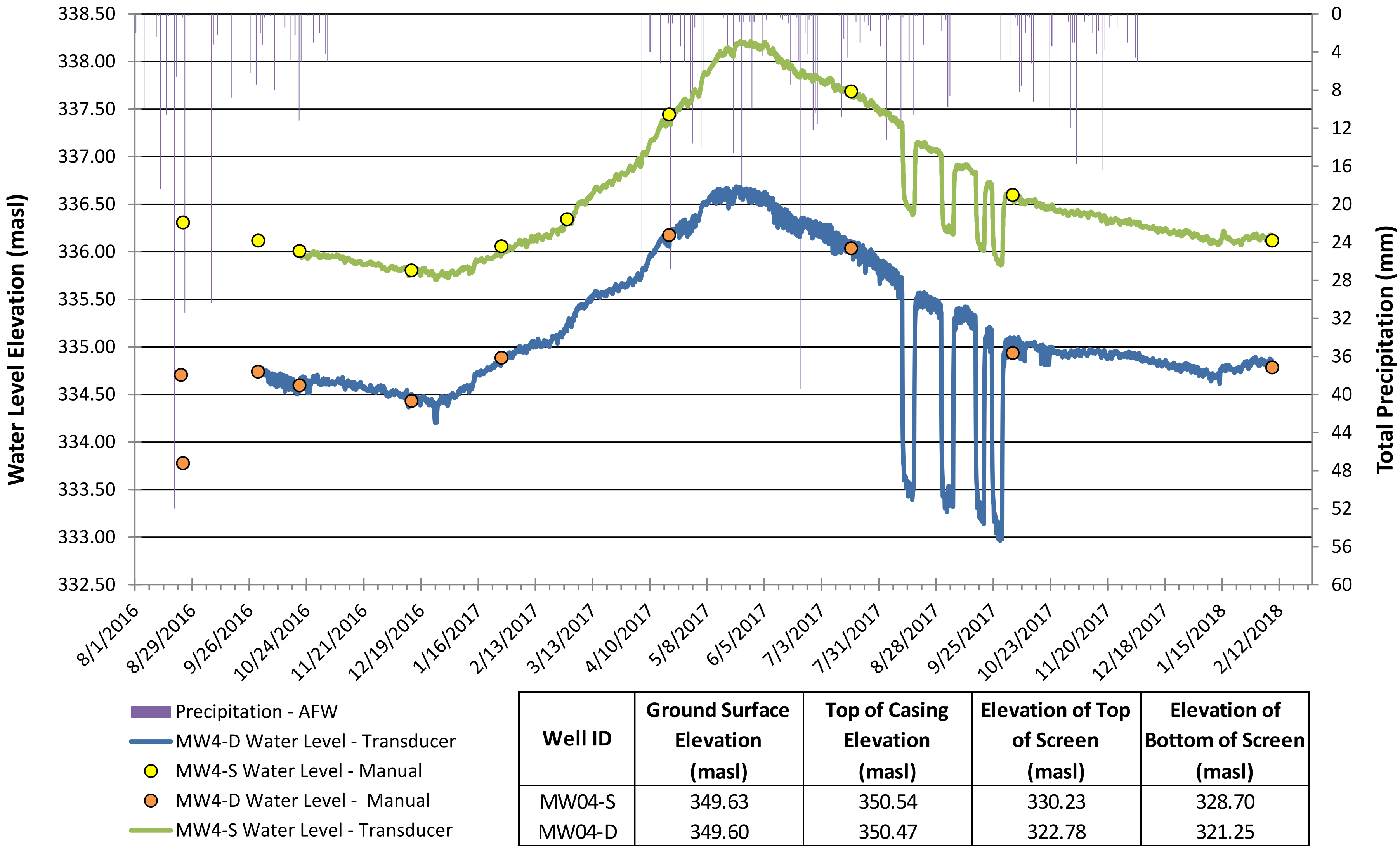
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW3-D & MW3-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW03-S	349.95	350.70	328.31	326.79
MW03-D	350.05	350.80	317.44	315.91

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

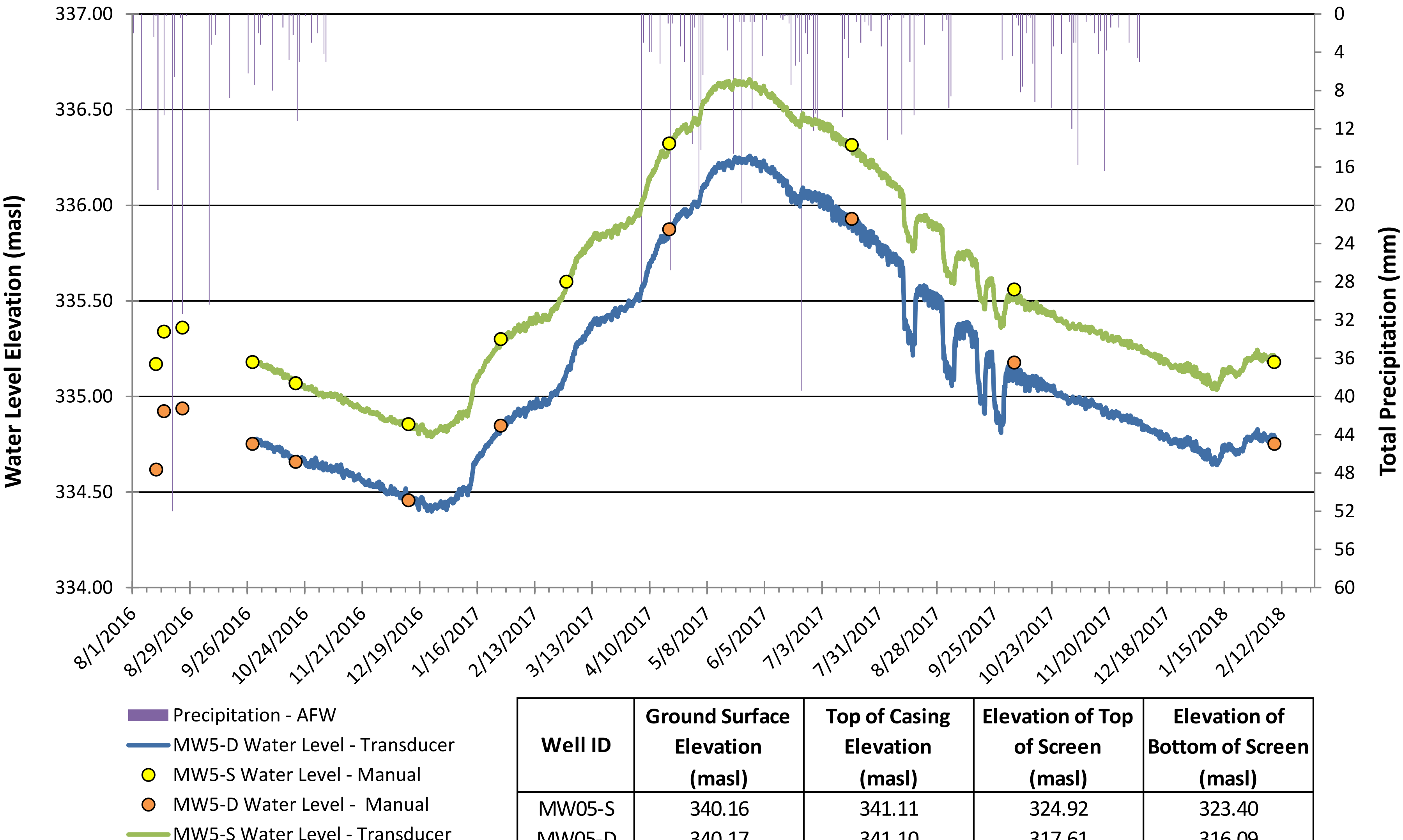
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW4-D & MW4-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW04-S	349.63	350.54	330.23	328.70
MW04-D	349.60	350.47	322.78	321.25

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

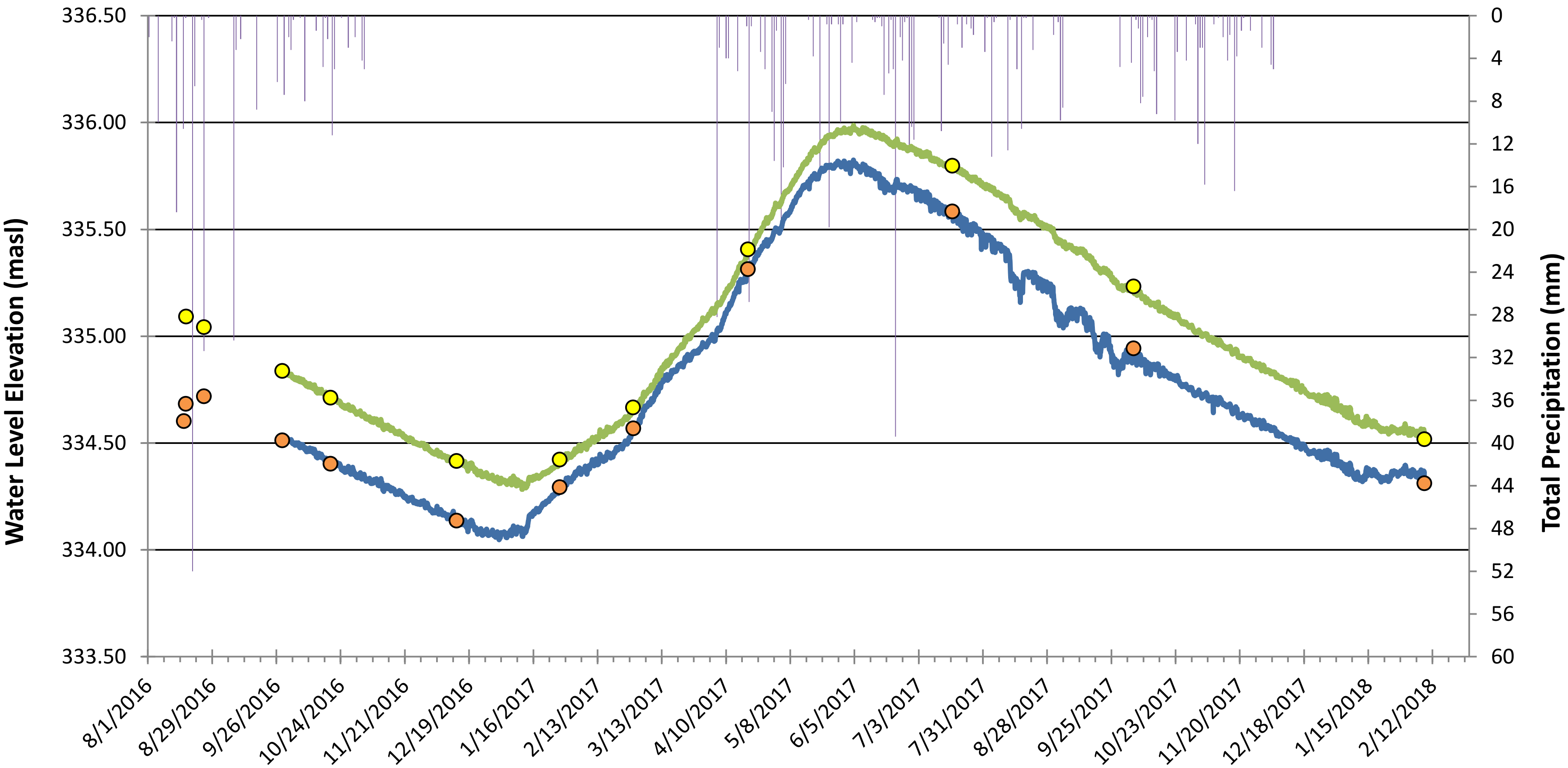
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW5-D & MW5-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW05-S	340.16	341.11	324.92	323.40
MW05-D	340.17	341.10	317.61	316.09

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

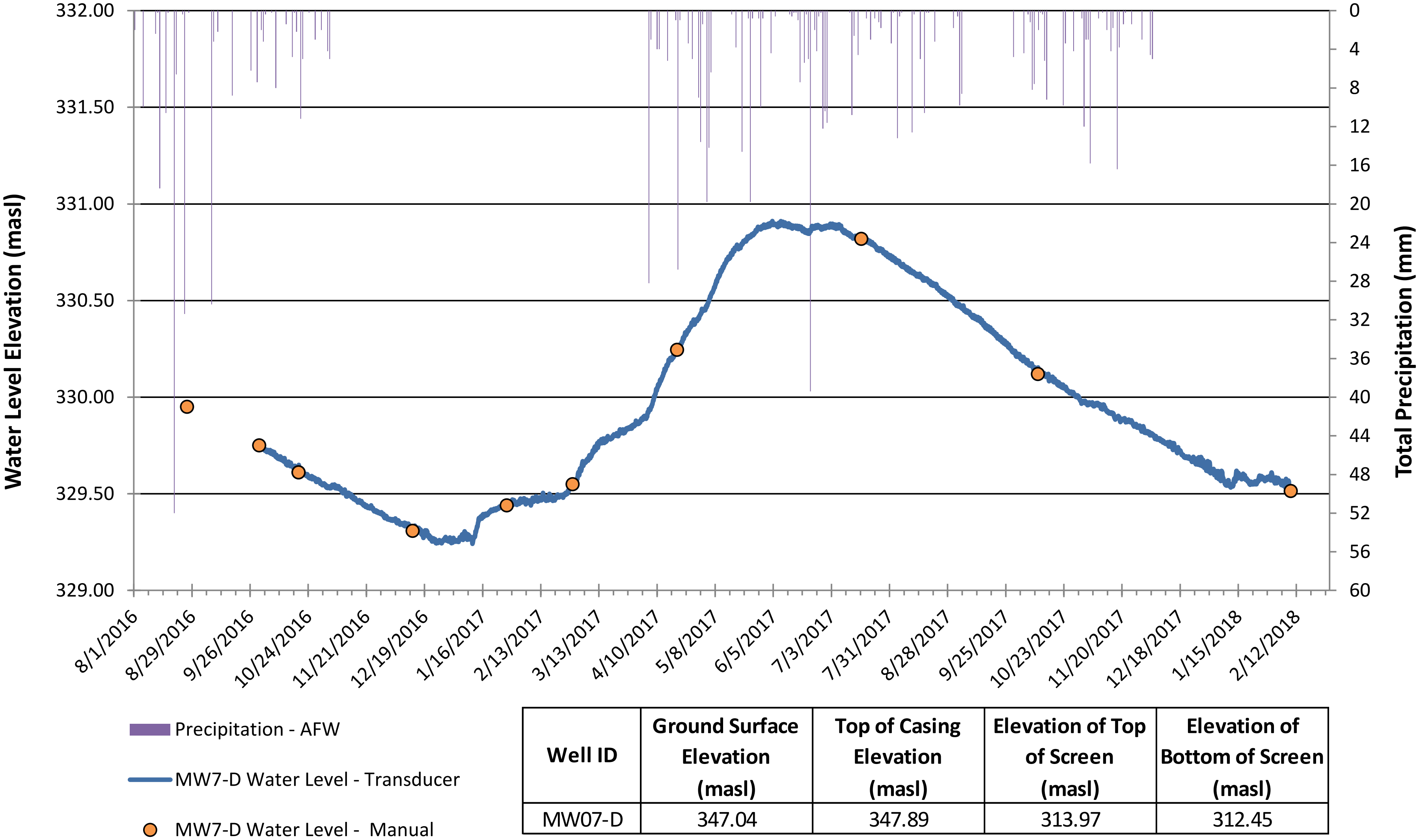
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW6-D & MW6-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW06-S	352.41	353.34	331.02	329.50
MW06-D	352.38	353.20	317.33	315.80

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

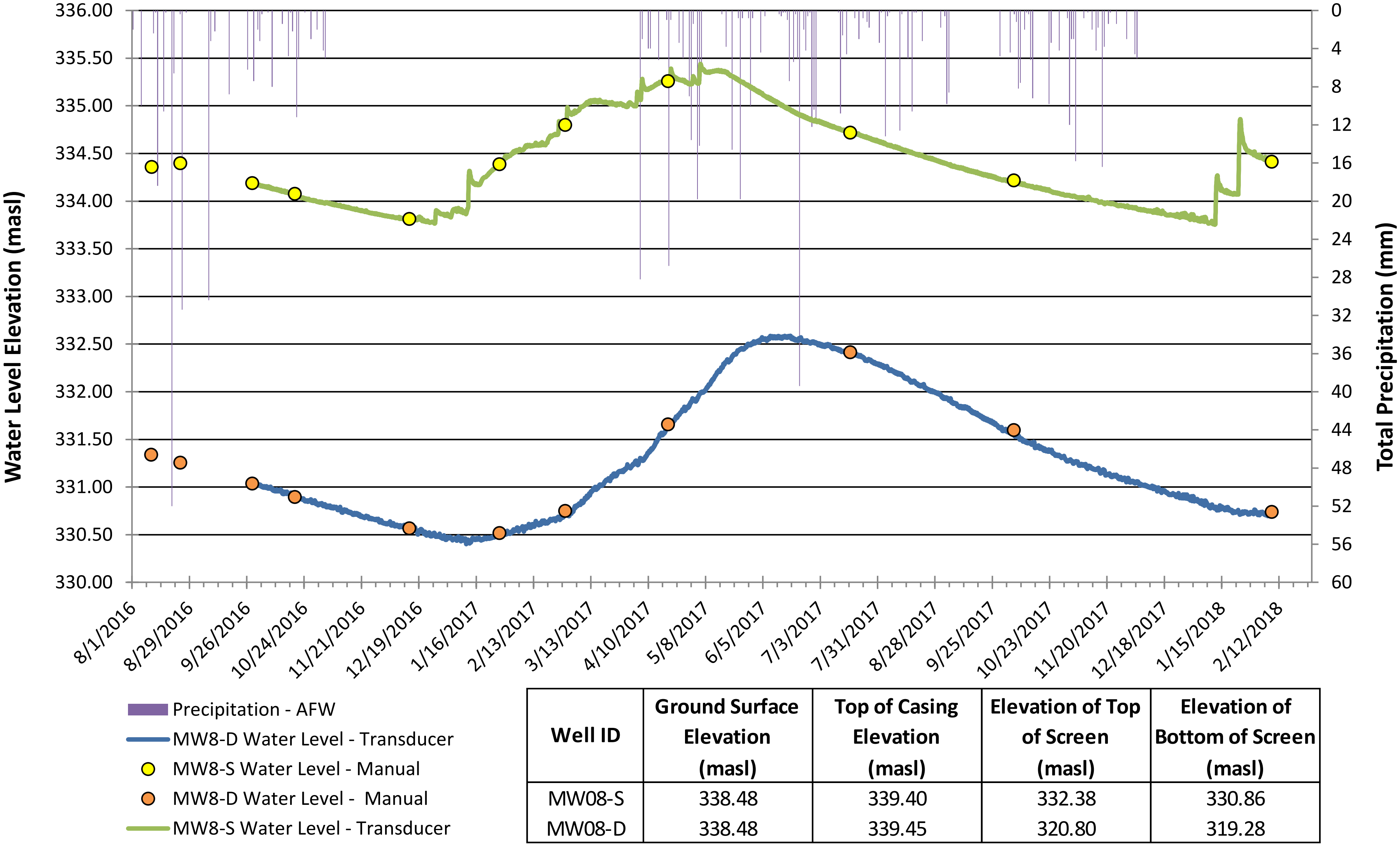
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW7-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW07-D	347.04	347.89	313.97	312.45

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

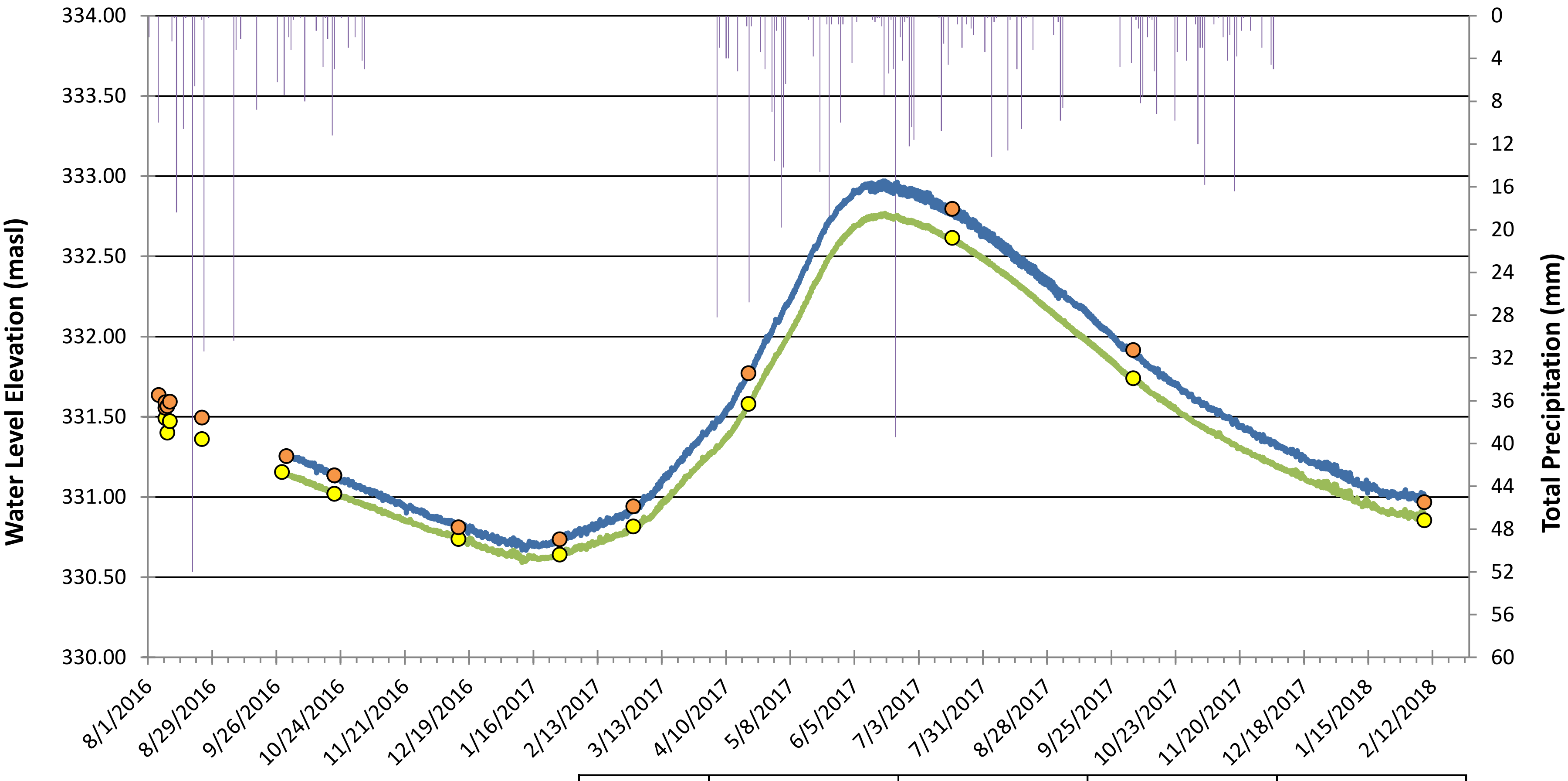
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW8-D & MW8-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW08-S	338.48	339.40	332.38	330.86
MW08-D	338.48	339.45	320.80	319.28

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E

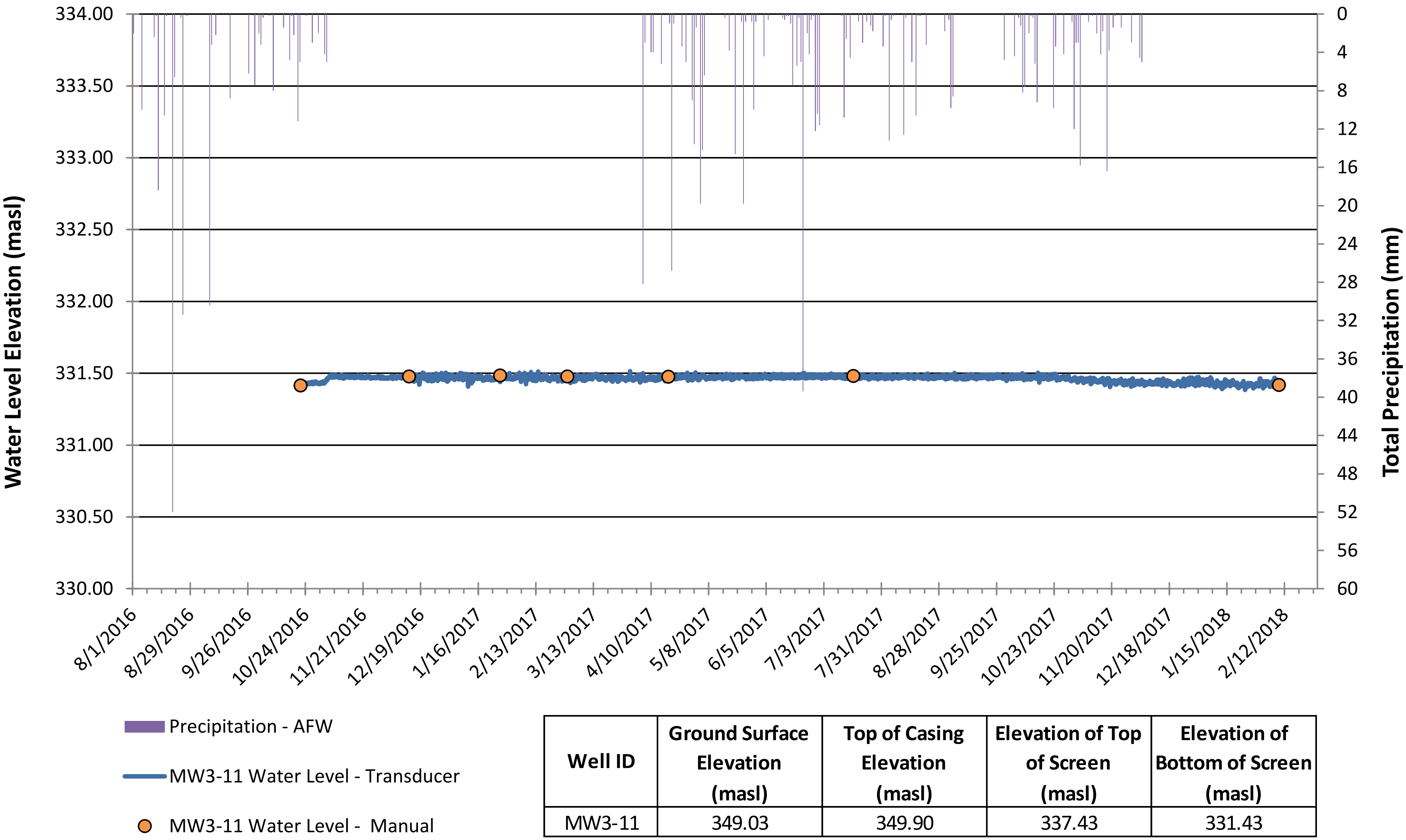
Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW9-D & MW9-S



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW09-S	350.46	350.98	328.82	327.30
MW09-D	350.51	351.15	318.51	316.98

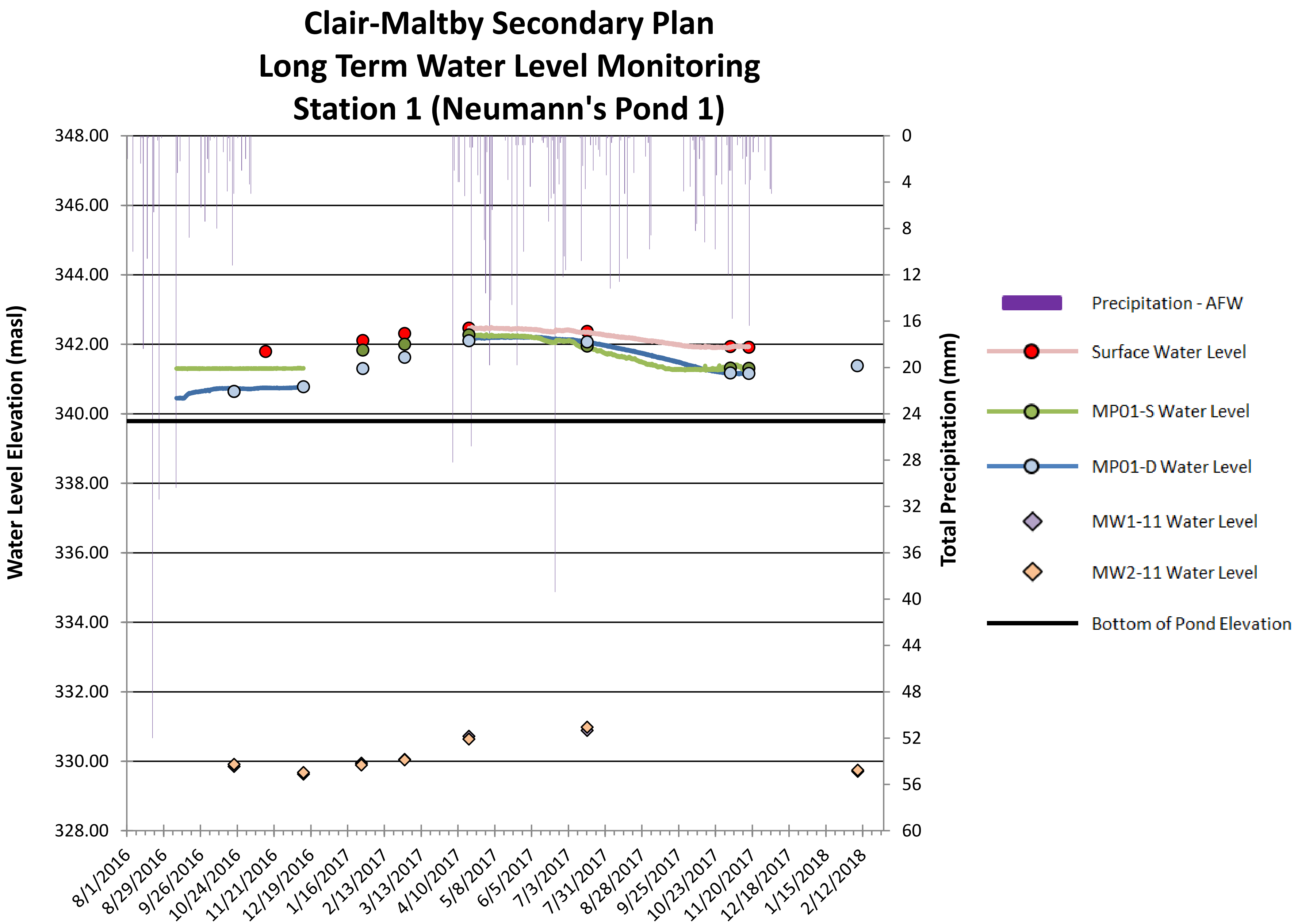
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E

Clair-Maltby Secondary Plan
Long Term Groundwater Level Monitoring
MW3-11

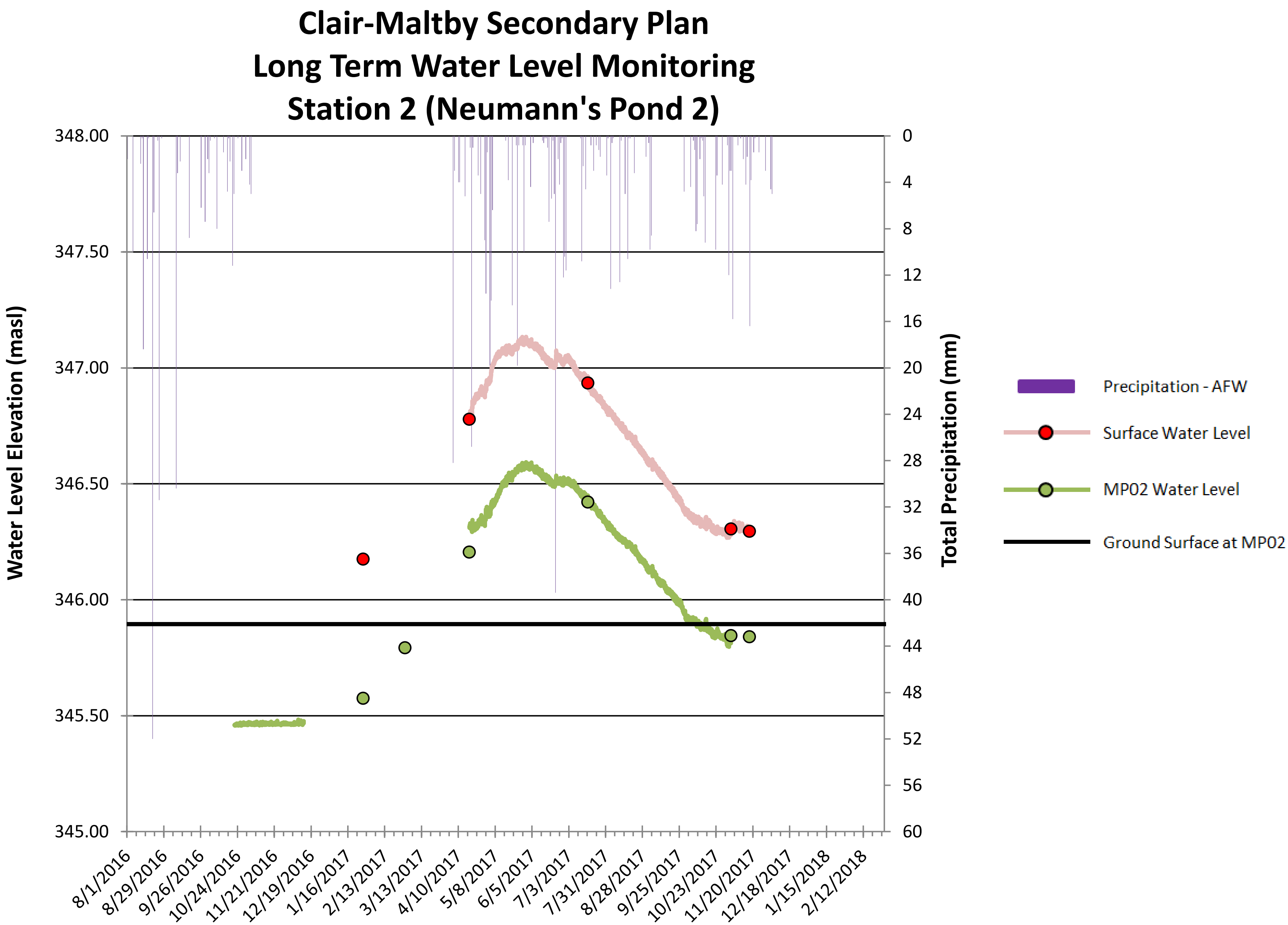


Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW3-11	349.03	349.90	337.43	331.43

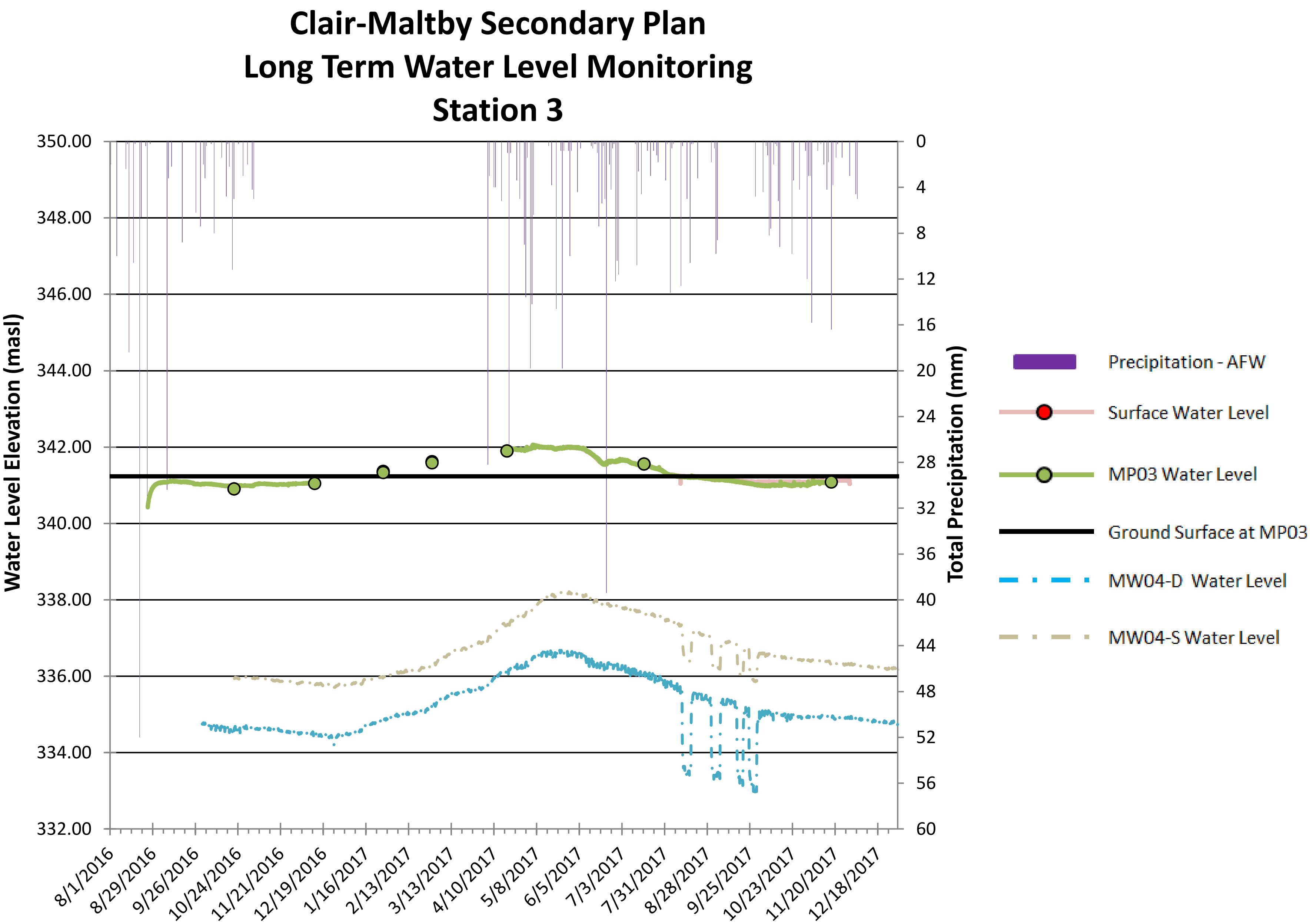
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E



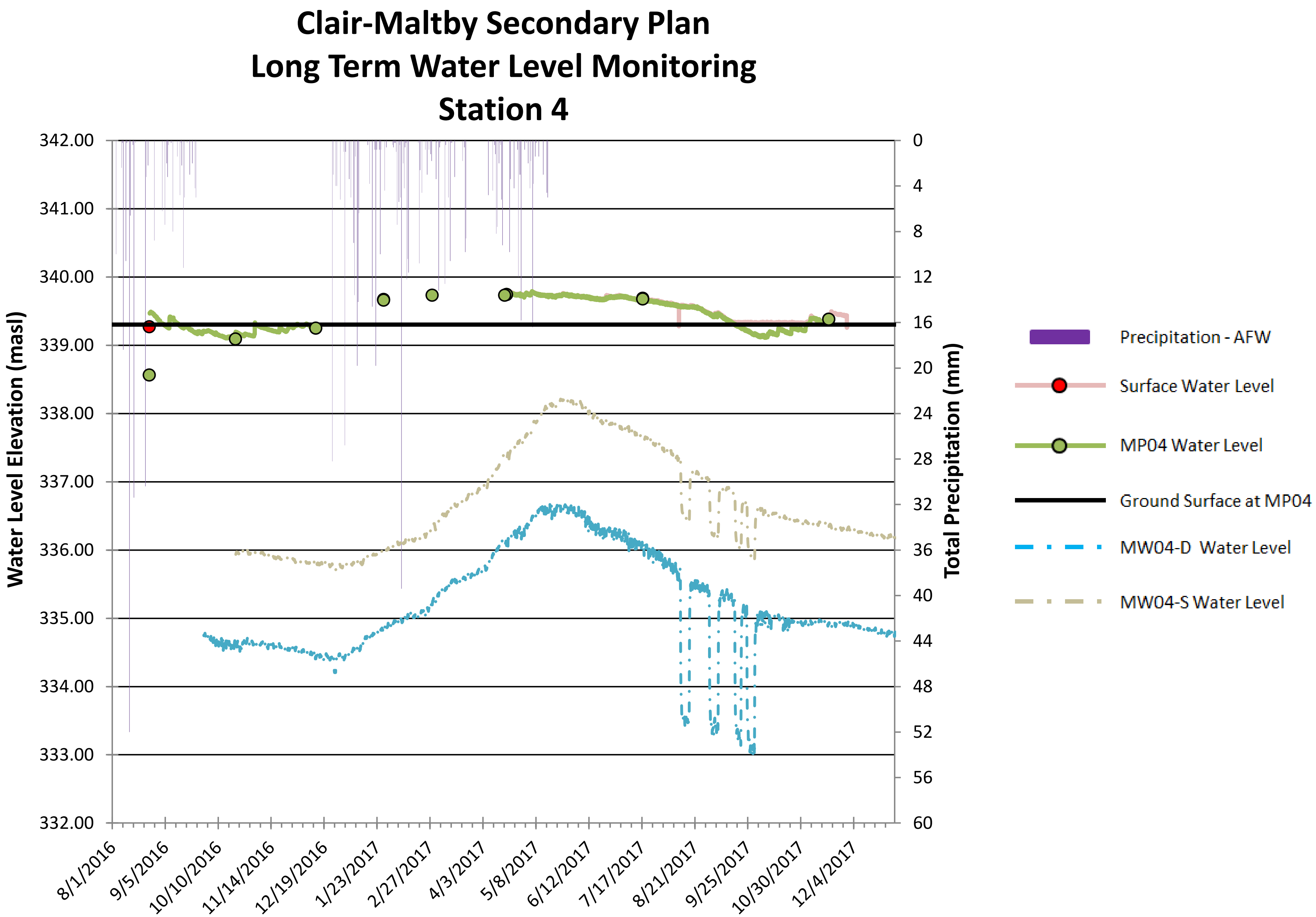
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



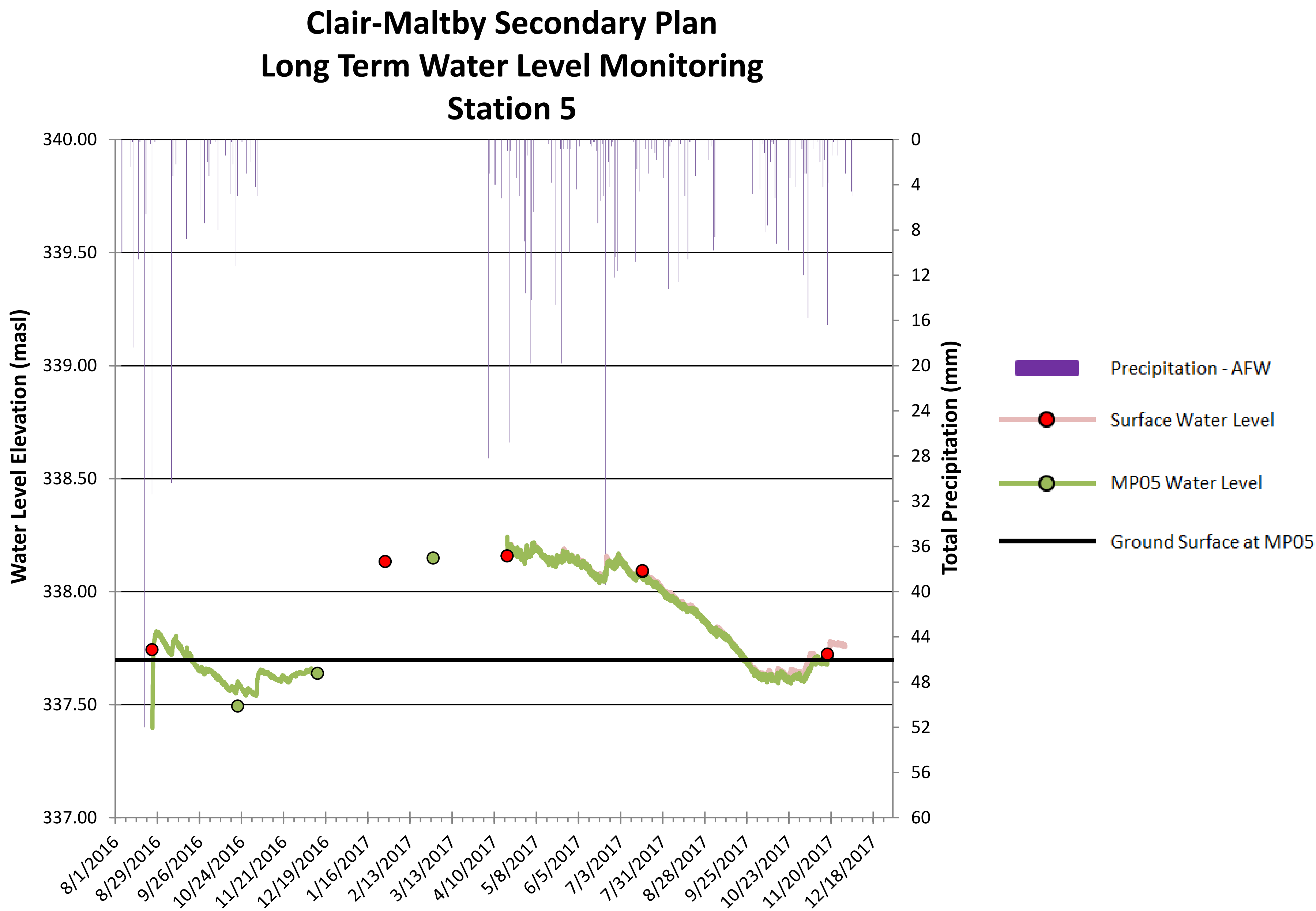
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



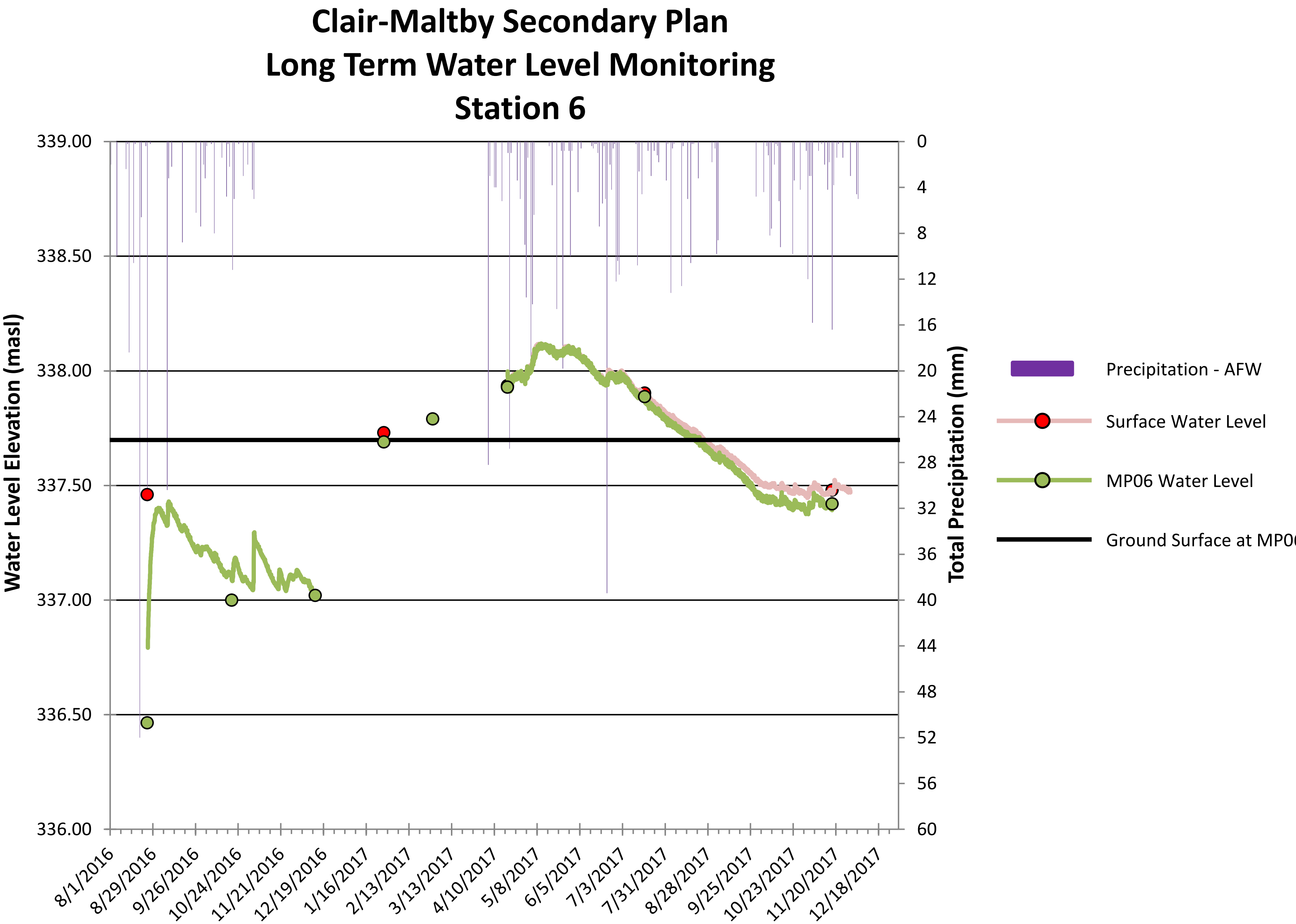
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



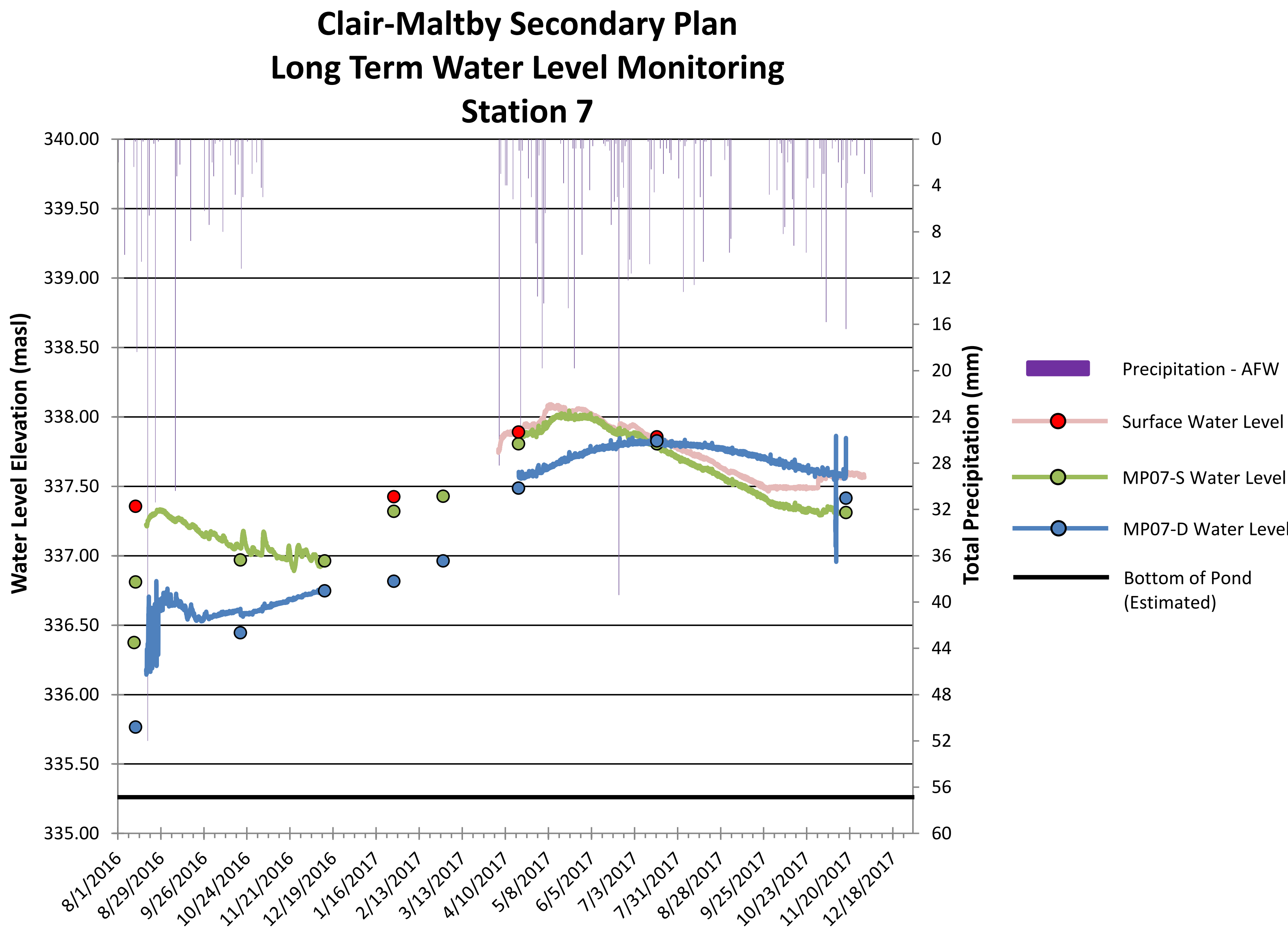
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



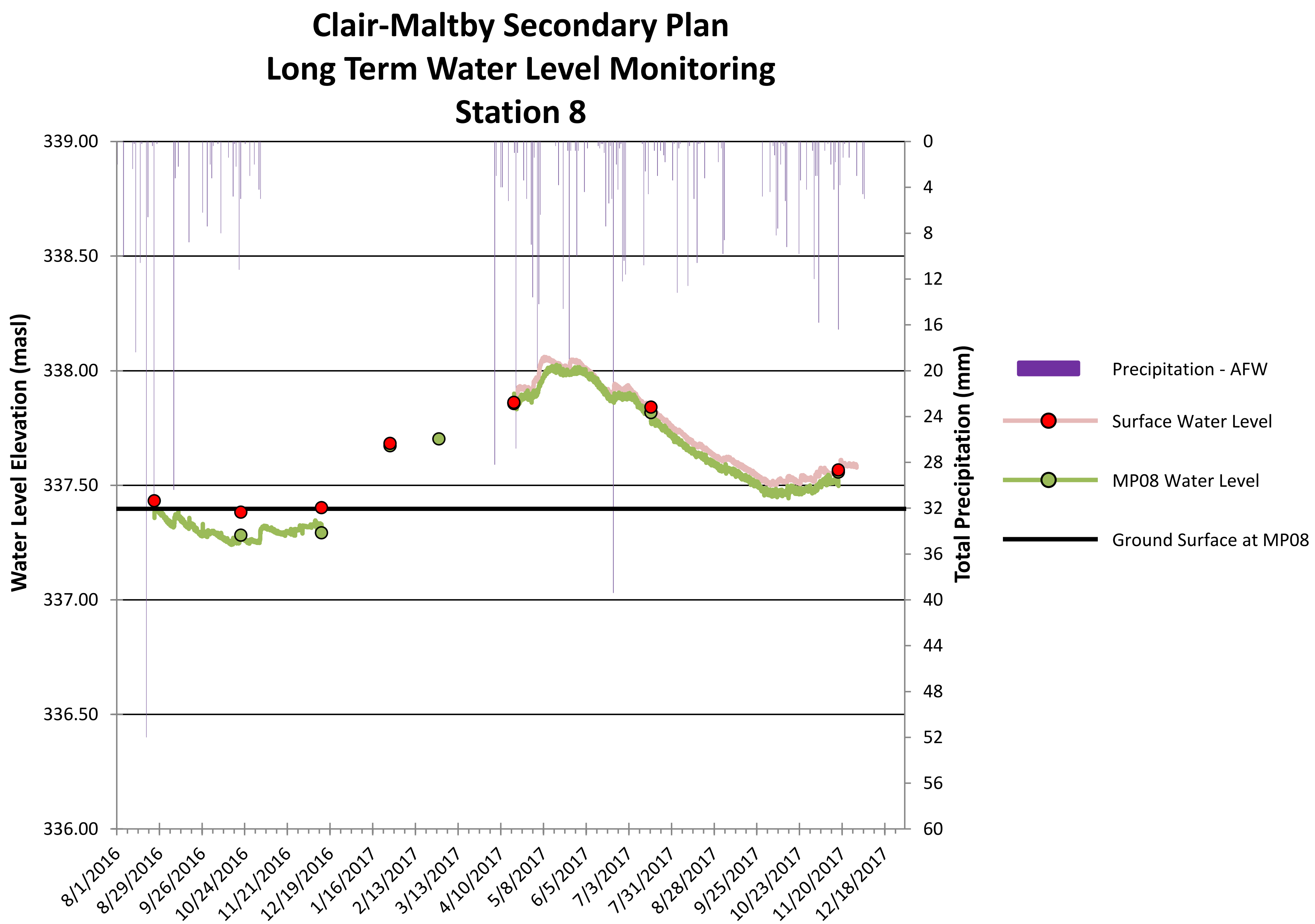
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



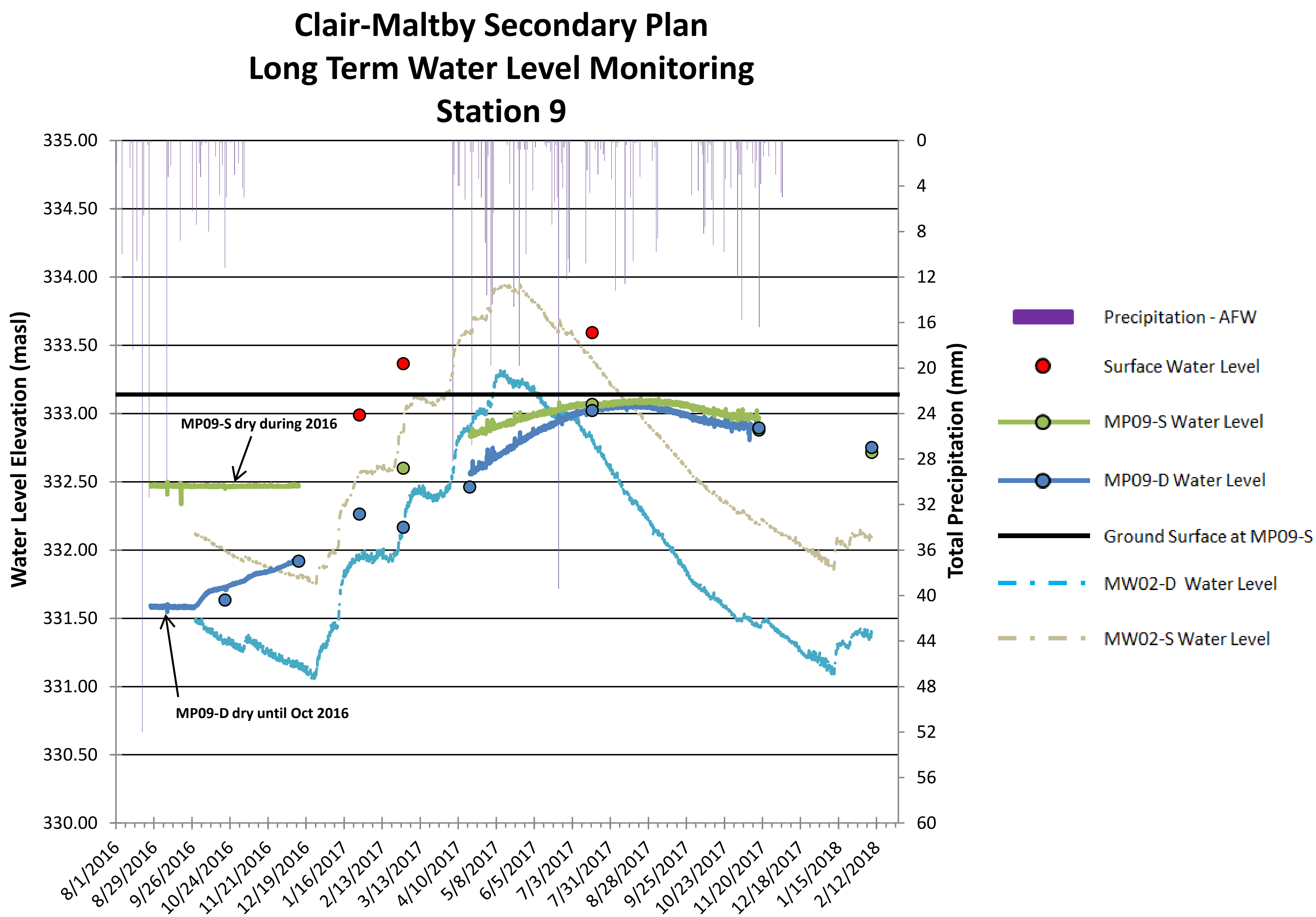
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

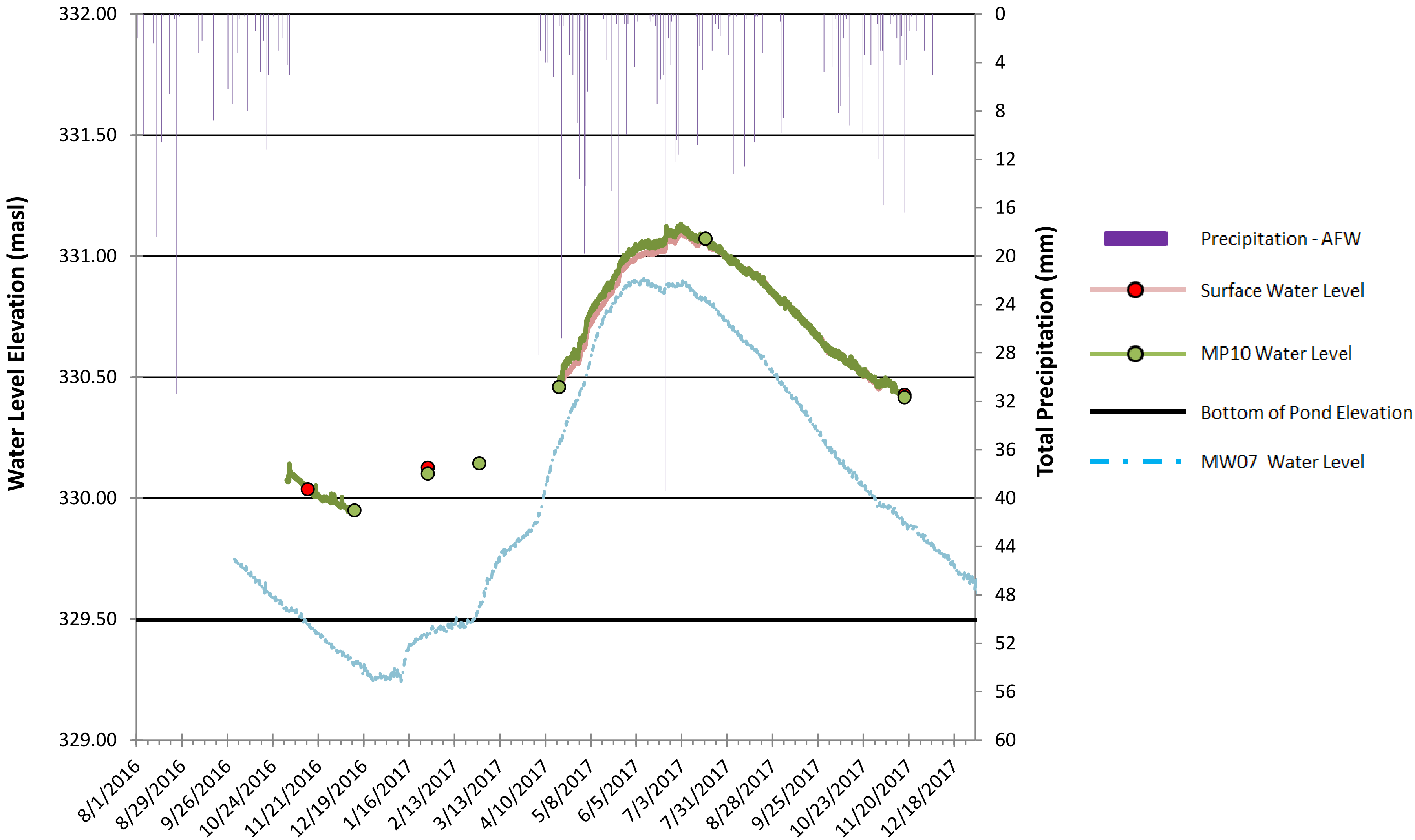


Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

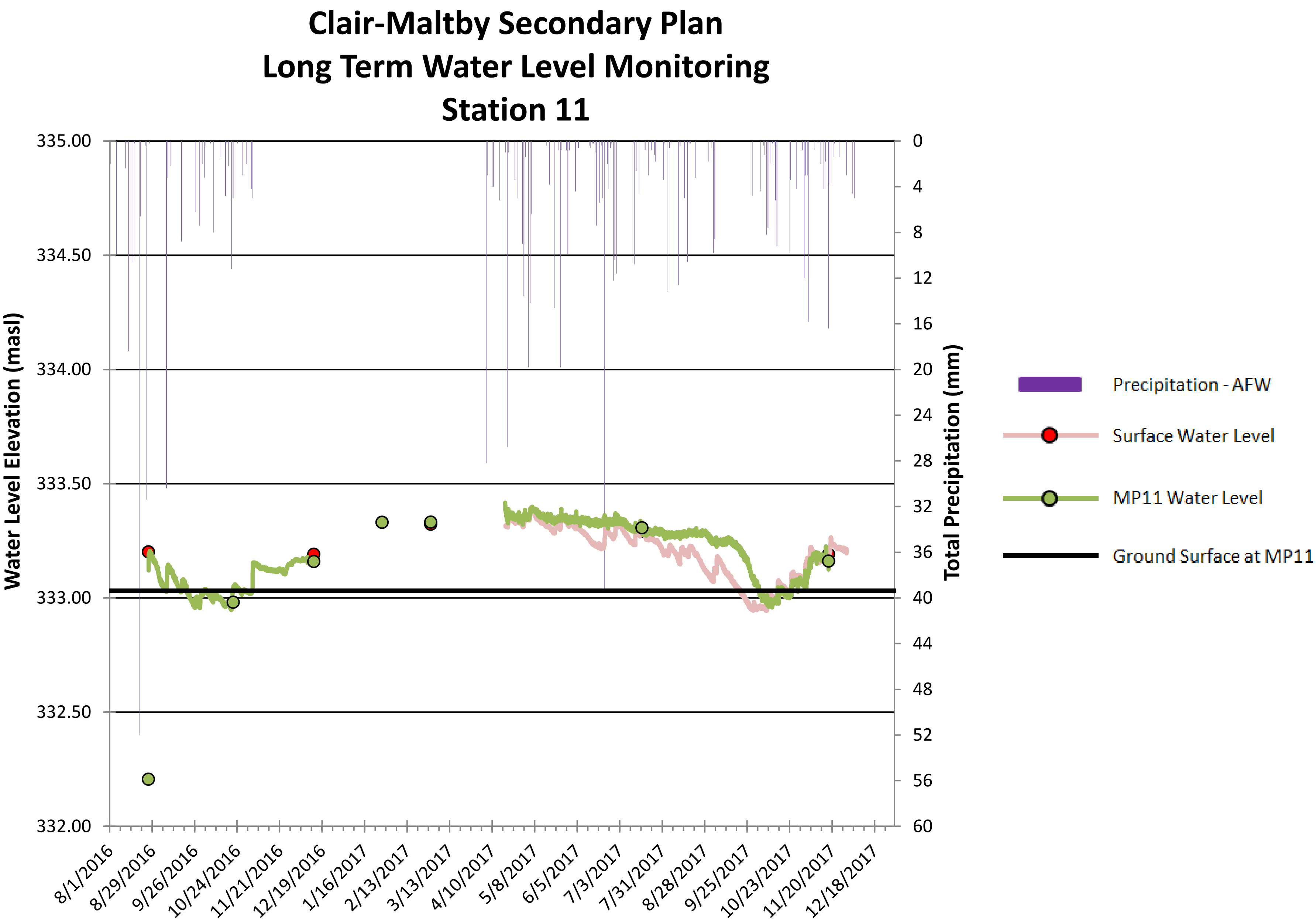


Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

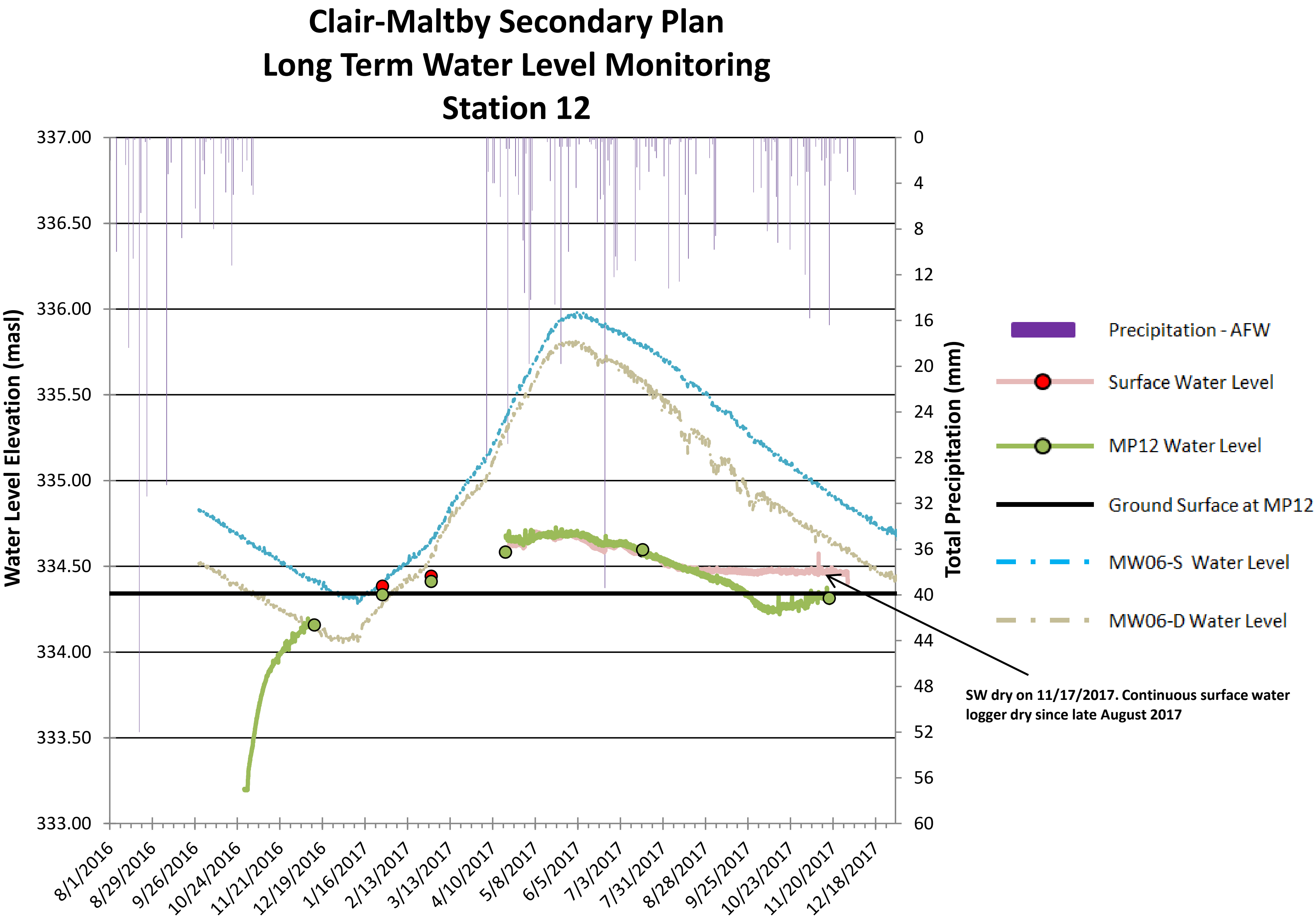
Clair-Maltby Secondary Plan
Long Term Water Level Monitoring
Station 10



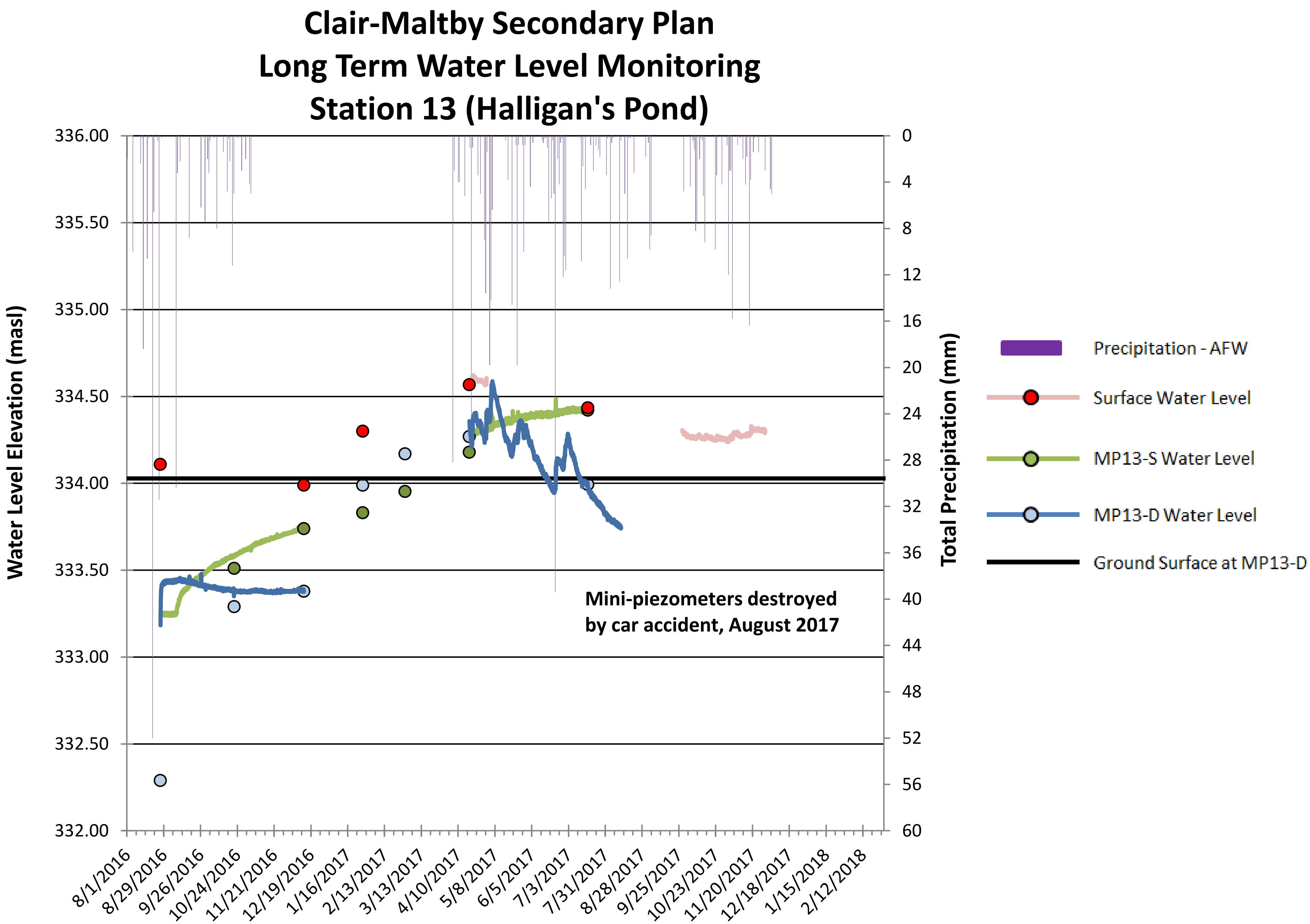
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



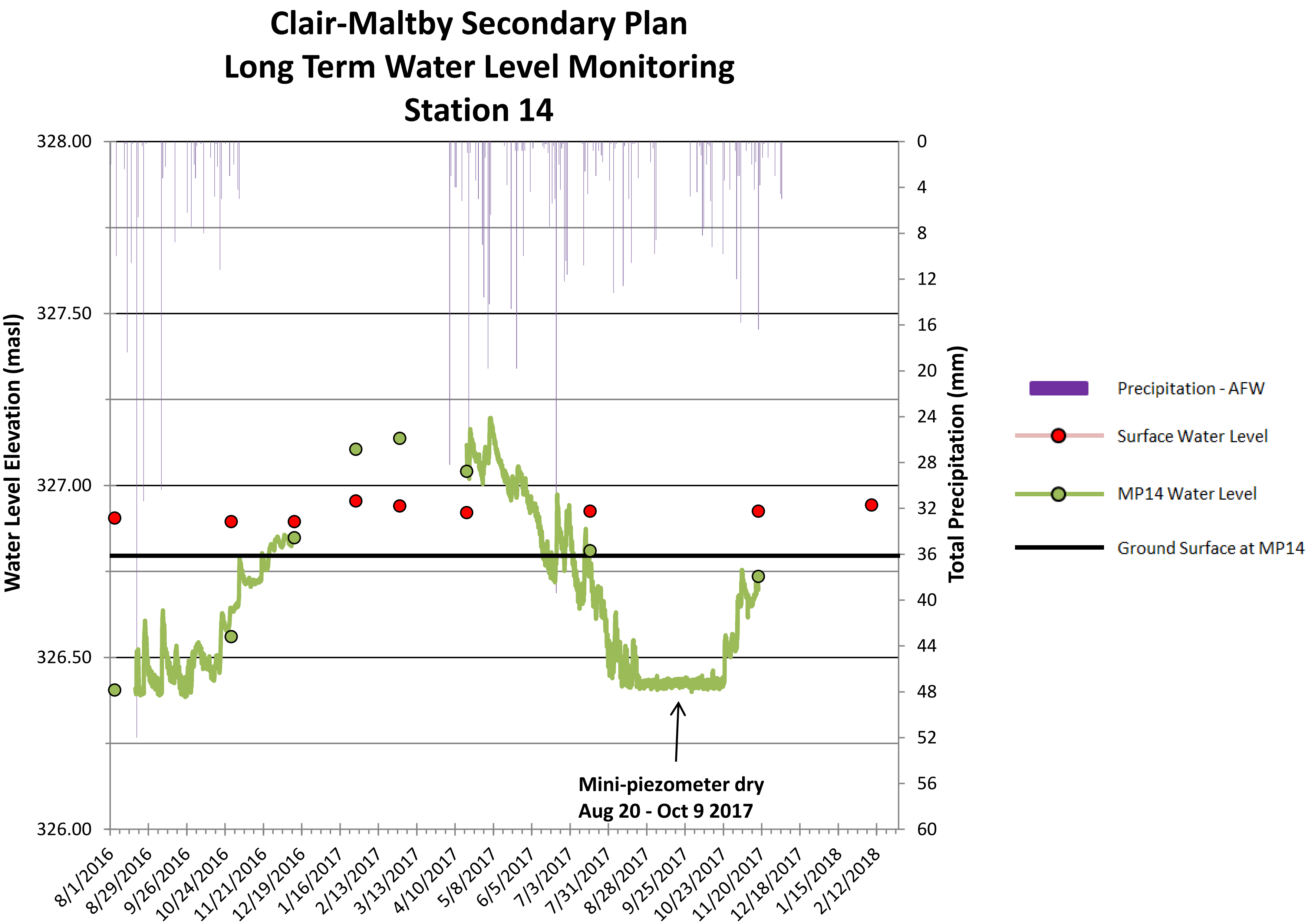
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



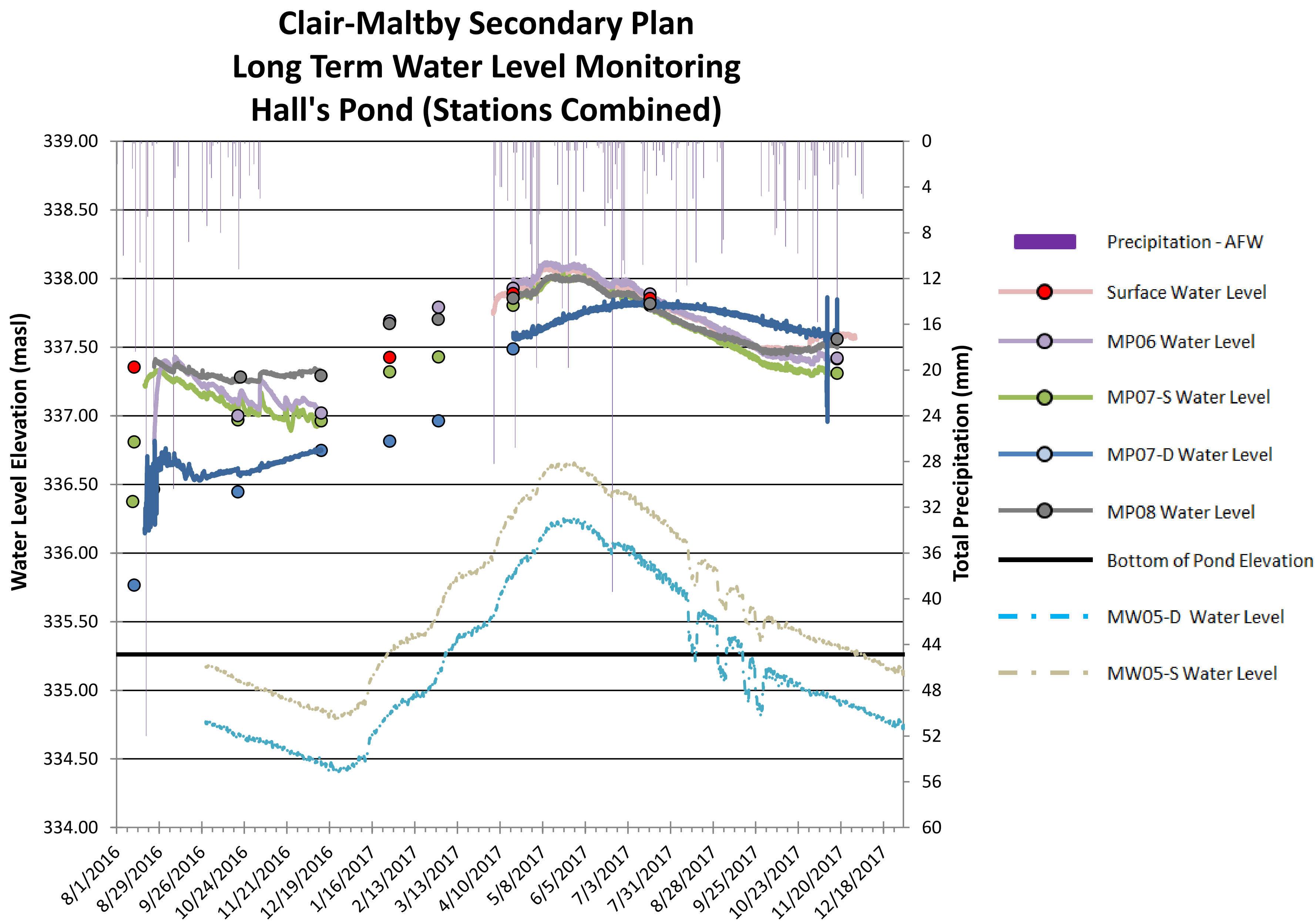
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.



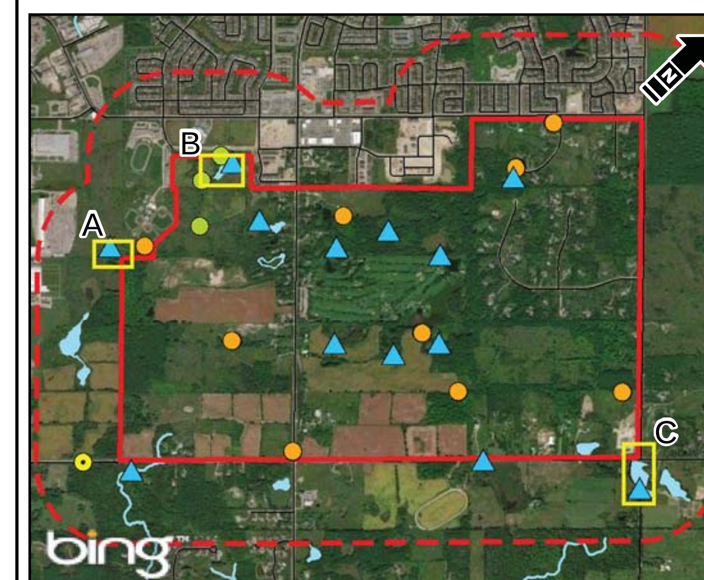
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

B - Neumann's Pond A

A - Unnamed Pond at 950 Southgate Dr.

C - Halligan's Pond

- Primary Study Area Boundary
- Secondary Plan Area Boundary
- Water Body
- Watercourse
- Mini Piezometer
- Spotflow Station
- Monitoring Well (Matrix)
- Monitoring Well (132 Clair Rd.)
- Pond Depth Profile Location
- Pond Bathymetry Contour (m)
- Road



1:45,000 m
600 0 600 1,200
NAD 1983 UTM Zone 17N

Reference: Data provided by the City of Guelph and GeoBase® used under license. Imagery (2016) provided by the City of Guelph (2012), and Bing imagery from © 2013 Microsoft Corporation and its data suppliers.

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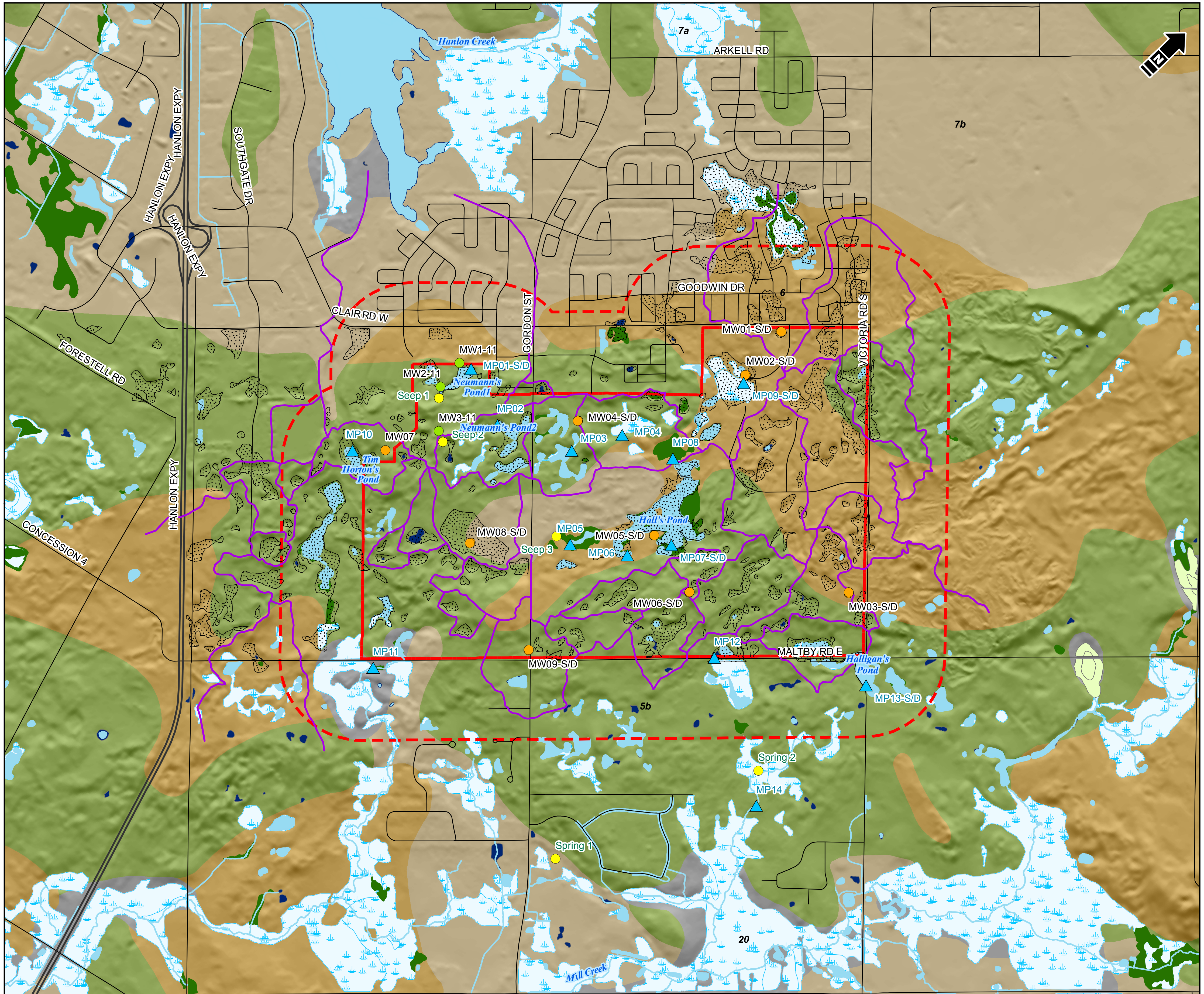
City of Guelph
Clair-Maltby Comprehensive Environmental Impact Study
Year 1 Monitoring Report

DRAFT

Pond Bathymetry

Date:	Project:	Technical:	Reviewer:	Drawn:
02 Mar 2017	23089	J. Melchin	S. Davies	M.Urtheil

Figure 5



Primary Study Area Boundary
Secondary Plan Area Boundary
Closed Depression
Subcatchment
Fen
Bog
Swamp
Marsh
Open Water
Unknown Wetland
Water Body
Watercourse
Highway
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Surficial Geology

5b: Stone-poor, sandy silt to silty sand till
6: Ice-contact stratified sand and gravel deposits
7a: Glaciofluvial Sand Deposits
7b: Glaciofluvial Gravel Deposits
20: Organic deposits (e.g., peat, marl)

Reference: Da ta pro vided b y the City o f Guelph, Geo Base® and Province of Ontario used under license.
Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release— Data 128 – Revised.

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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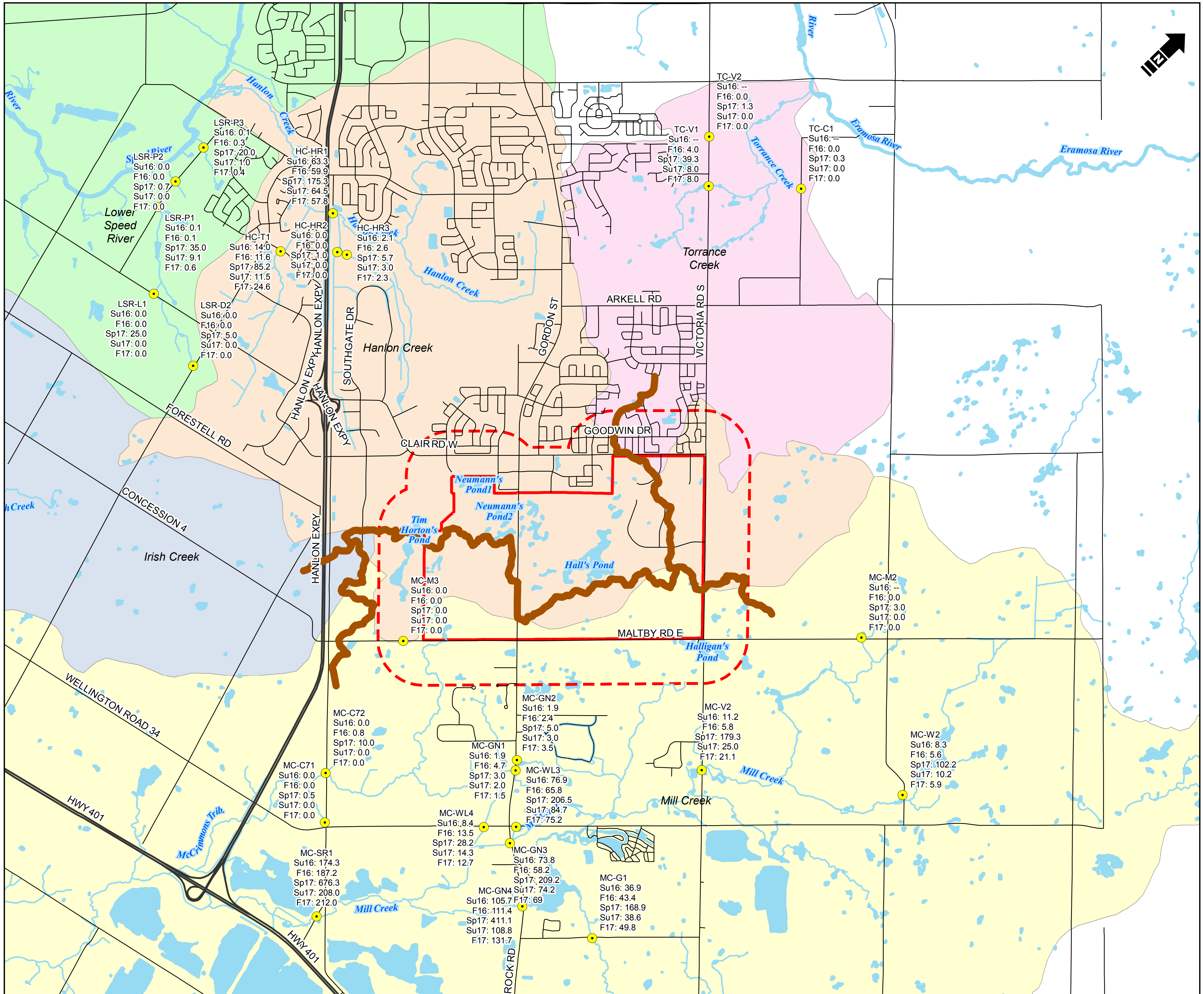
City of Guelph
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Hydrogeology Monitoring Locations

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure GW-1



Primary Study Area Boundary
Secondary Plan Area Boundary
Water Body
Watercourse
Updated Subwatershed Boundary (Wood PLC, 2018)
Highway
Road
Spot Flow Location

Subwatershed

Hanlon Creek
Irish Creek
Lower Speed River
Mill Creek
Torrance Creek

HC-D2 Spot Flow Location
Su16:0 Summer 2016 (Aug.30/31,Sept. 1) Flow Rate (L/s)
F16:0 Fall (Nov.9/10) Flow Rate (L/s)
Sp17:0 Spring 2017 (May 10/11) Flow Rate (L/s)
Su17:0 Summer 2017 (Aug.16) Flow Rate (L/s)
F17:0 Fall (Nov. 29) Flow Rate (L/s)

1:45,000 metres
475 0 475 950
NAD 1983 UTM Zone 17N

Reference: Data provided by the City of Guelph and GeoBase® used under license.

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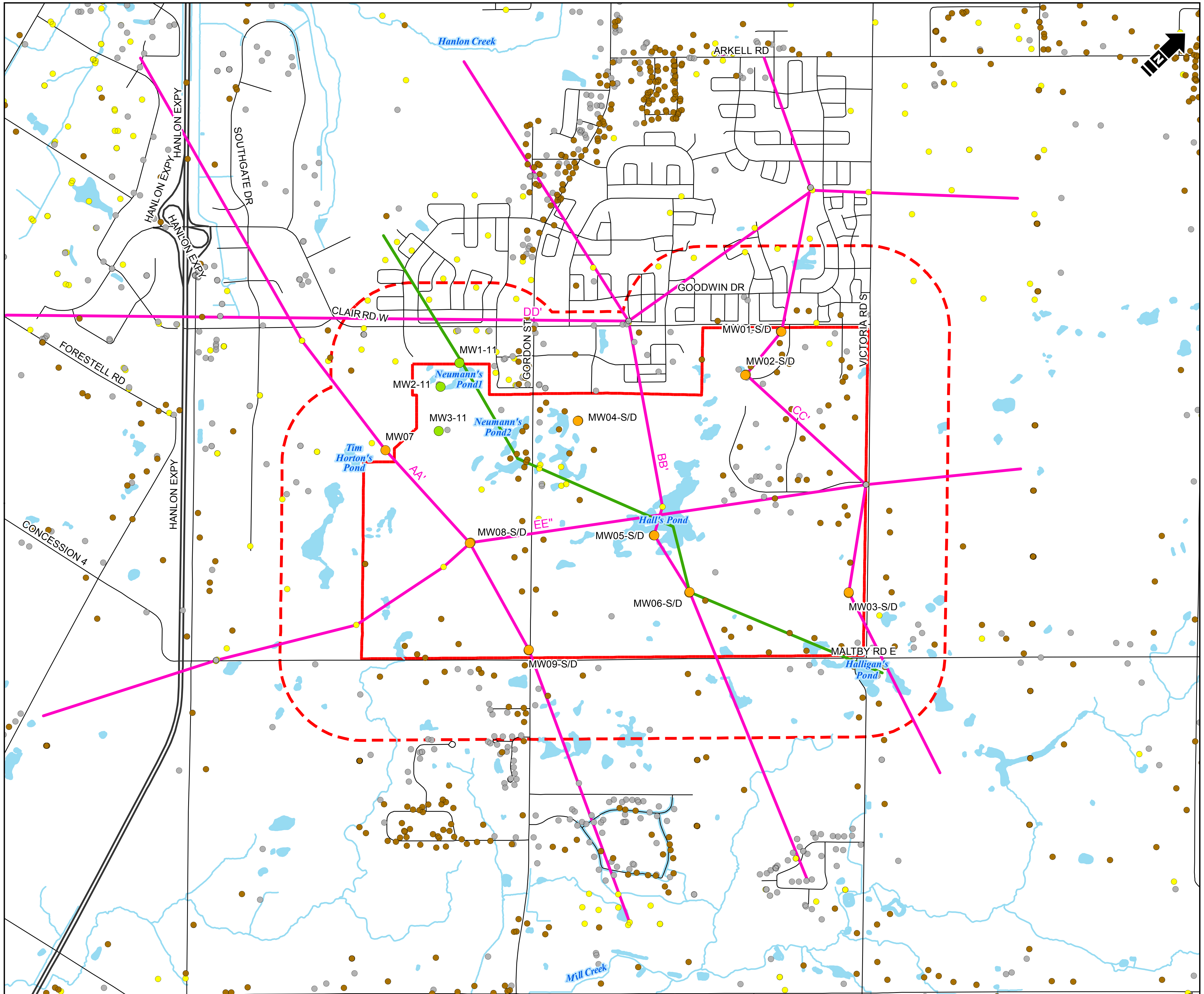
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Spot Baseflow Results

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-2



Primary Study Area Boundary
Secondary Plan Area Boundary
Water Body
Watercourse
Highway
Road
Geological Cross Section Location
Conceptual Groundwater Flow System Cross Section
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Municipal_Well
Consultant Well
GPW Well
WWIS Well

Reference: Da ta pro vided b y the City o f Guelph, Geo Base® and Province of Ontario used under license.
Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release— Data 128 – Revised.

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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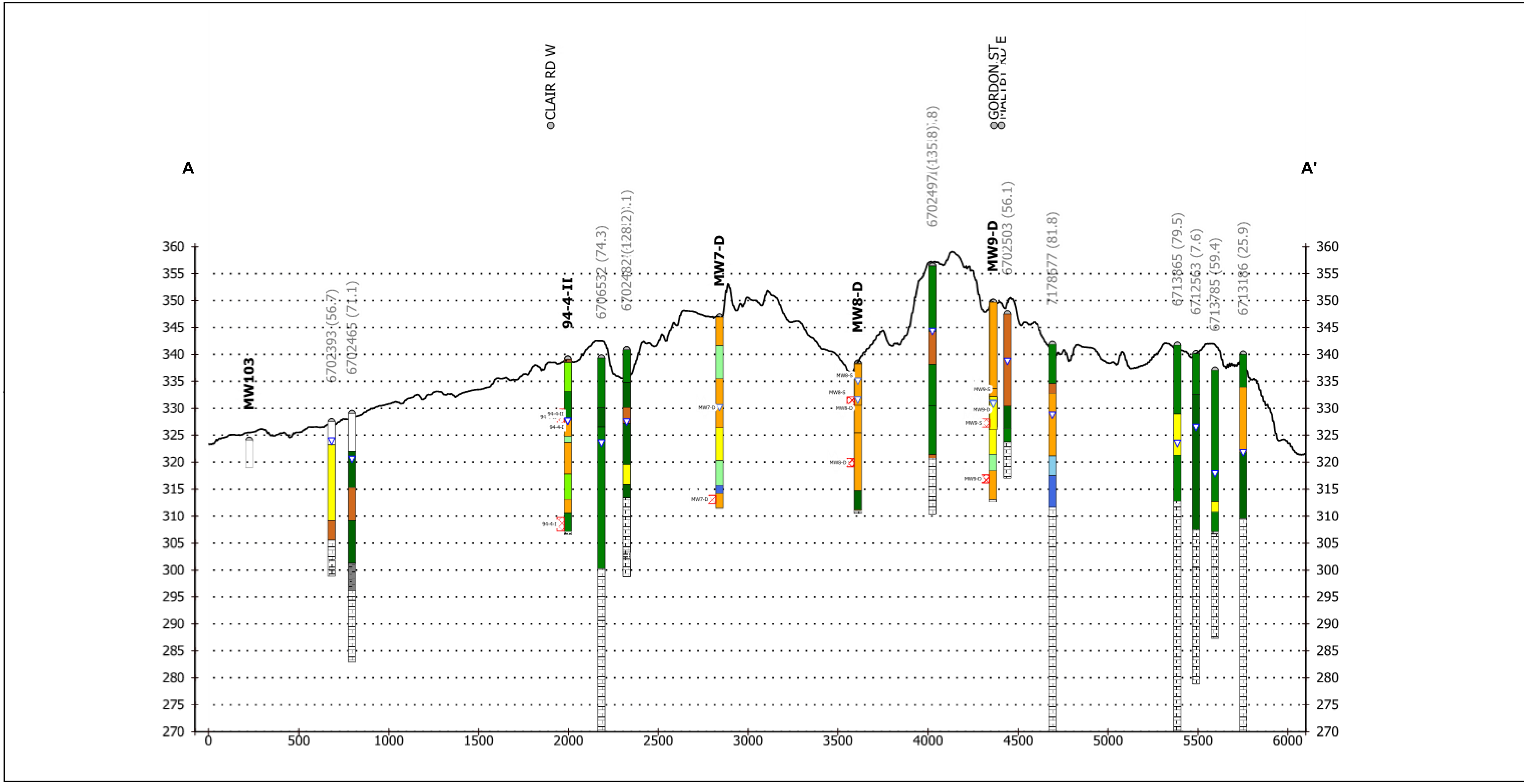
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Borehole and Cross Section Locations

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-3

I:\CityofGuelph\23089\FiguresandTables\QHG\2018\Report\Phase1_Characterization_Report\Figure-GW-3-Borehole_and_Cross_Section_Locations.mxd - Tabloid_L - 25-May-18, 11:21 AM - ccurry - TID005



Surface Features
- Road
- Ponds

Borehole
- water level
- well screen

Borehole Lithology

Overburden
- till
- clay-silt diamict / till
- clay, silty clay, clayey silt
- silt
- silt diamict/ sandy silt
- sand diamict/ silty sand
- sand, fine sand
- gravelly sand, gravel
- gravel
- coarse gravel, stones
- organics
- topsoil / fill
- unknown

Bedrock
- limestone, dolomite, bedrock
- rock
- shale

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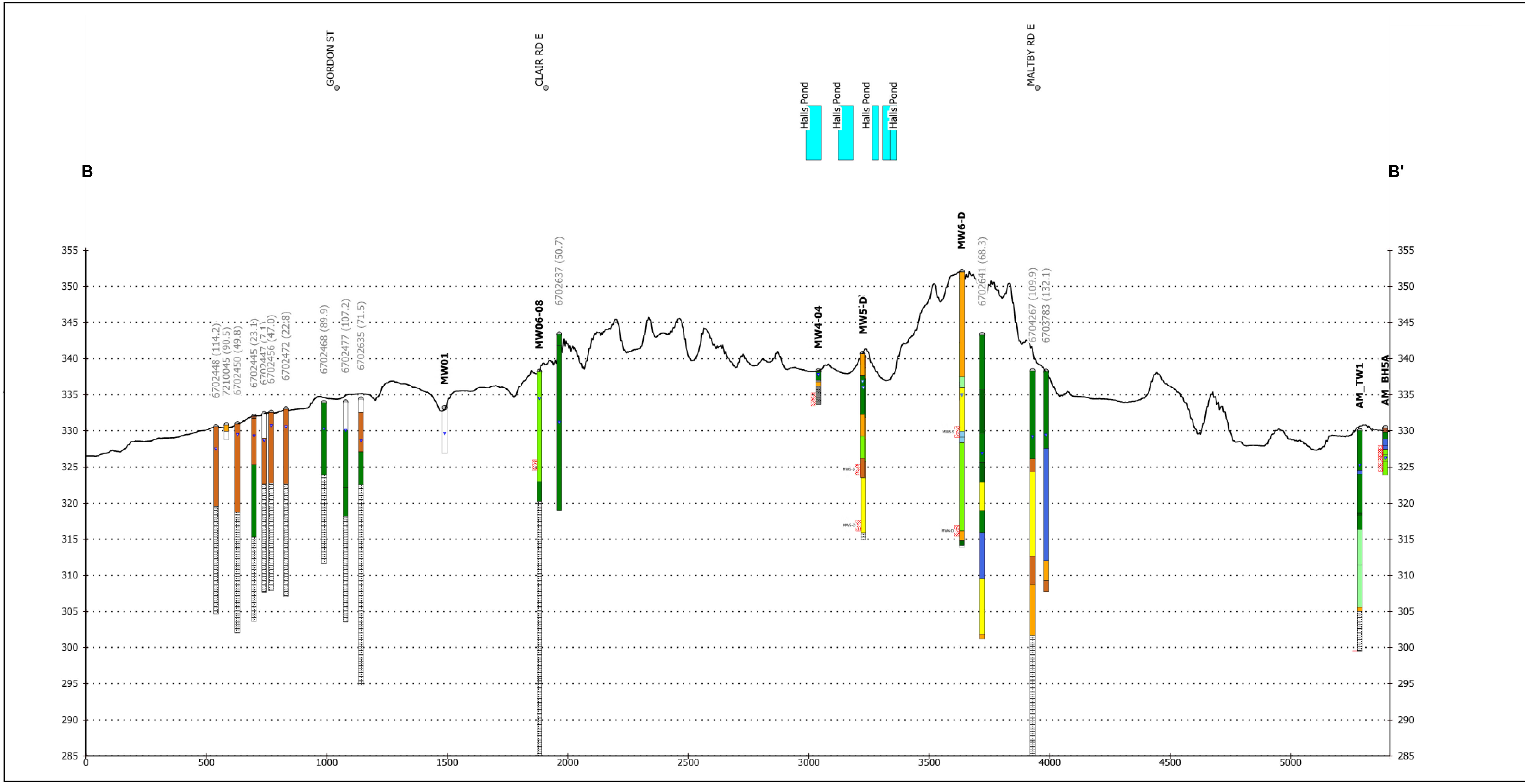
Clair- Maltby Comprehensive Environmental Impact Study Phase 1
Characterization Report

Geological Cross Section A-A'

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-4a



Surface Features

- Road
- Ponds

Borehole

- water level
- well screen

Borehole Lithology

Overburden

- till
- clay-silt diamict / till
- clay, silty clay, clayey silt
- silt
- silt diamict/ sandy silt
- sand diamict/ silty sand
- sand, fine sand
- gravelly sand, gravel
- gravel
- coarse gravel, stones
- organics
- topsoil / fill
- unknown

Bedrock

- limestone, dolomite, bedrock
- rock
- shale

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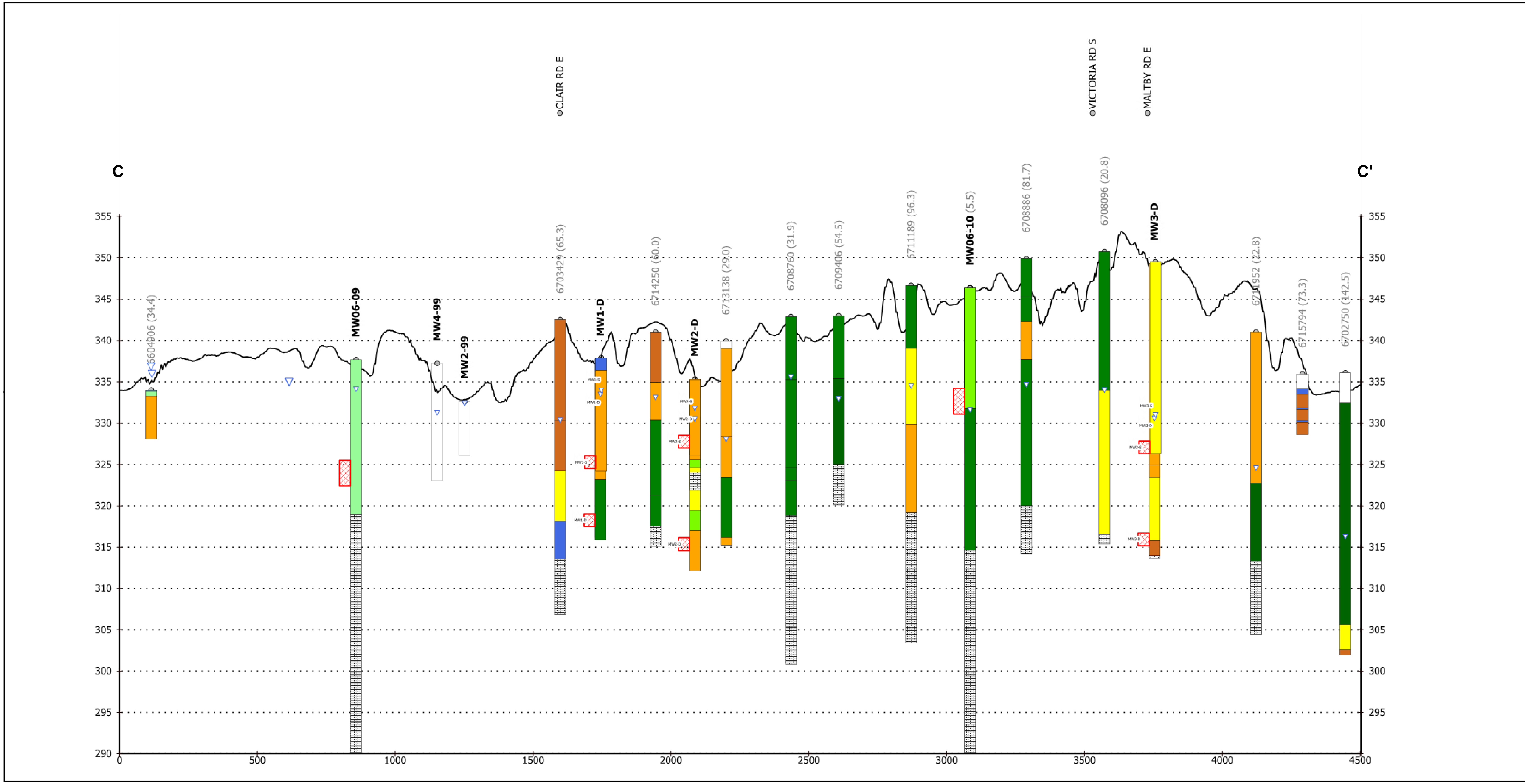
Clair- Maltby Comprehensive Environmental Impact Study Phase 1
Characterization Report

Geological Cross Section B-B'

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-4b



Surface Features
Road
Ponds

Borehole
water level
well screen

Borehole Lithology

Overburden
- till
- clay-silt diamict / till
- clay, silty clay, clayey silt
- silt
- silt diamict/ sandy silt
- sand diamict/ silty sand
- sand, fine sand
- gravelly sand, gravel
- gravel
- coarse gravel, stones
- organics
- topsoil / fill
- unknown

Bedrock
- limestone, dolomite, bedrock
- rock
- shale

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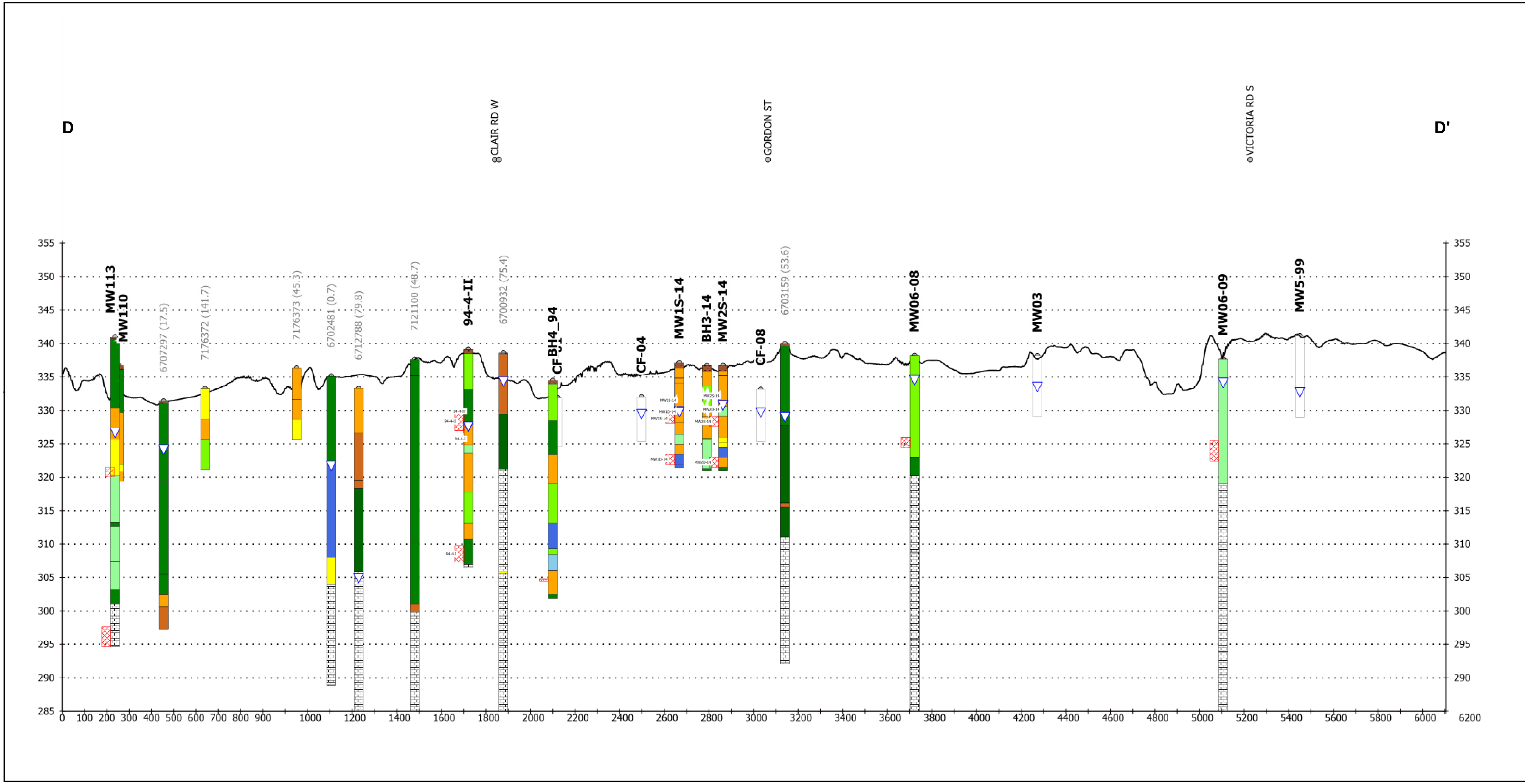
Clair- Maltby Comprehensive Environmental Impact Study Phase 1
Characterization Report

Geological Cross Section C-C'

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-4c



Surface Features
- Road
- Ponds

Borehole
- water level
- well screen

Borehole Lithology

Overburden
- till
- clay-silt diamict / till
- clay, silty clay, clayey silt
- silt
- silt diamict/ sandy silt
- sand diamict/ silty sand
- sand, fine sand
- gravelly sand, gravel
- gravel
- coarse gravel, stones
- organics
- topsoil / fill
- unknown

Bedrock
- limestone, dolomite, bedrock
- rock
- shale

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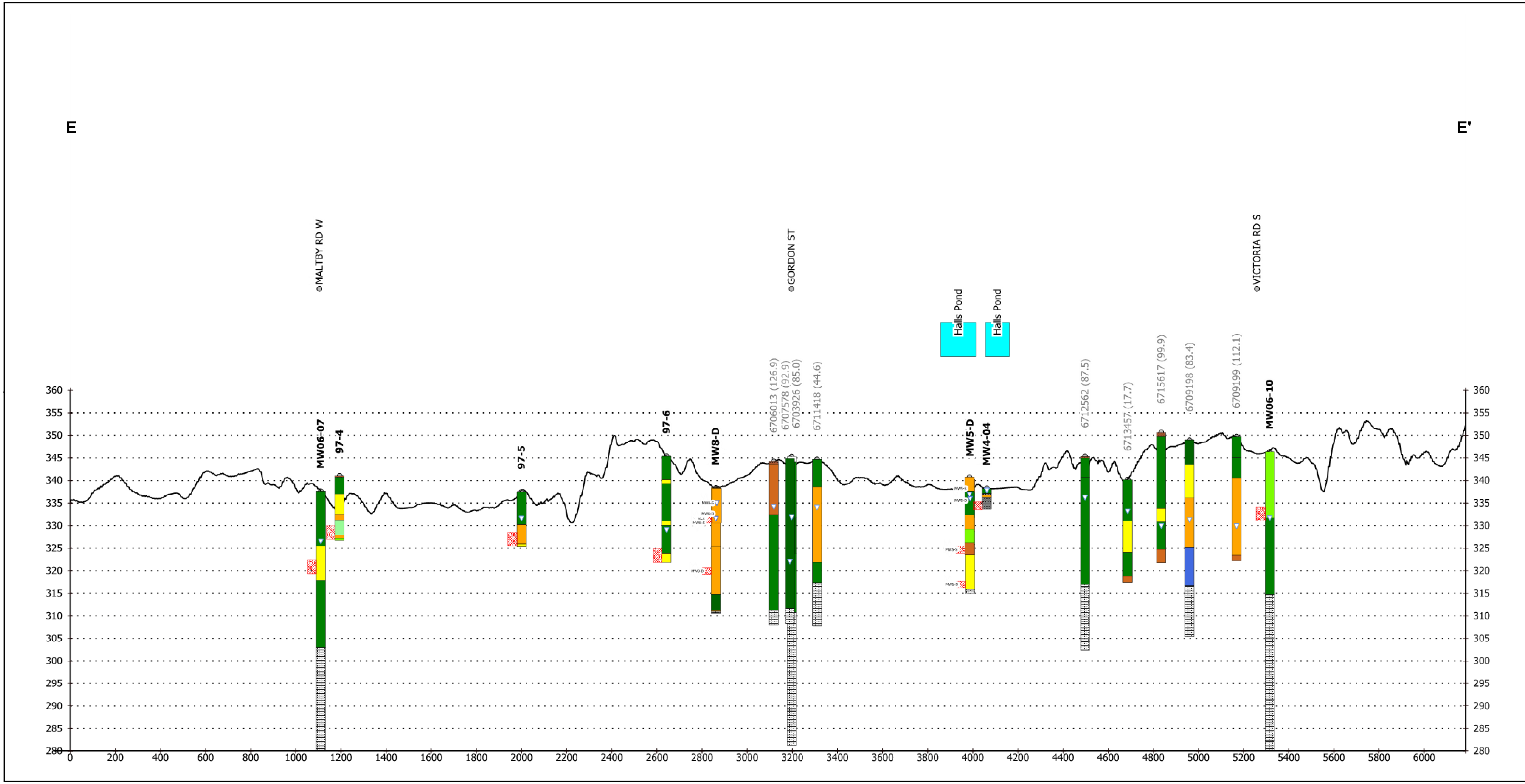
Clair- Maltby Comprehensive Environmental Impact Study Phase 1
Characterization Report

Geological Cross Section D-D'

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-4d



Surface Features
- Road
- Ponds

Borehole
- water level
- well screen

Borehole Lithology

Overburden
- till
- clay-silt diamict / till
- clay, silty clay, clayey silt
- silt
- silt diamict/ sandy silt
- sand diamict/ silty sand
- sand, fine sand
- gravelly sand, gravel
- gravel
- coarse gravel, stones
- organics
- topsoil / fill
- unknown

Bedrock
- limestone, dolomite, bedrock
- rock
- shale

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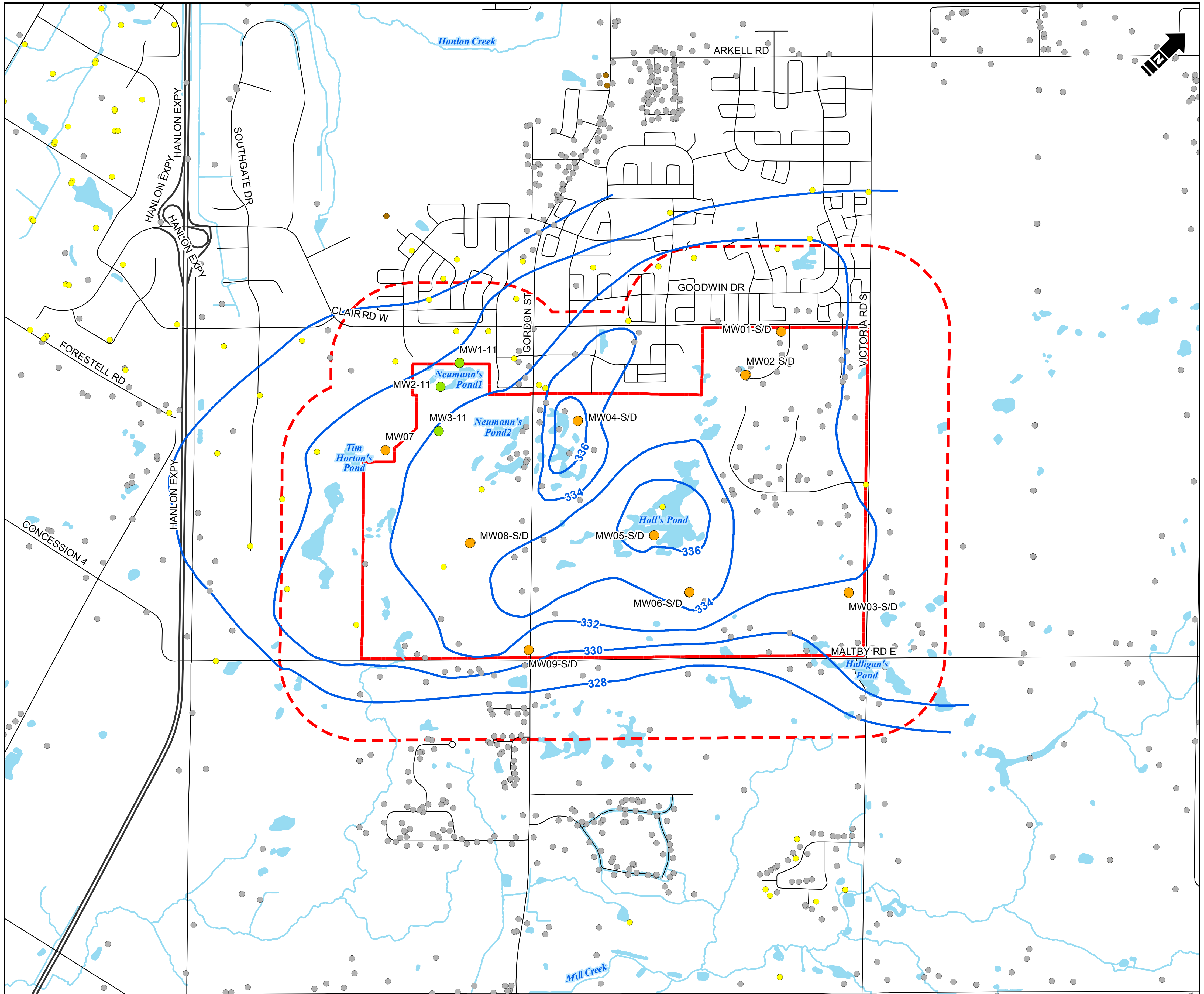
Clair- Maltby Comprehensive Environmental Impact Study Phase 1
Characterization Report

Geological Cross Section E-E'

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-4e



Primary Study Area Boundary
Secondary Plan Area Boundary
Water Body
Watercourse
Water Table Elevation Contour (2m)
Highway
Road
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Consultant Well
GPW Well
WWIS Well

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

Reference: Da ta pro vided b y the City o f Guelph, Geo Base® and Province of Ontario used under license.

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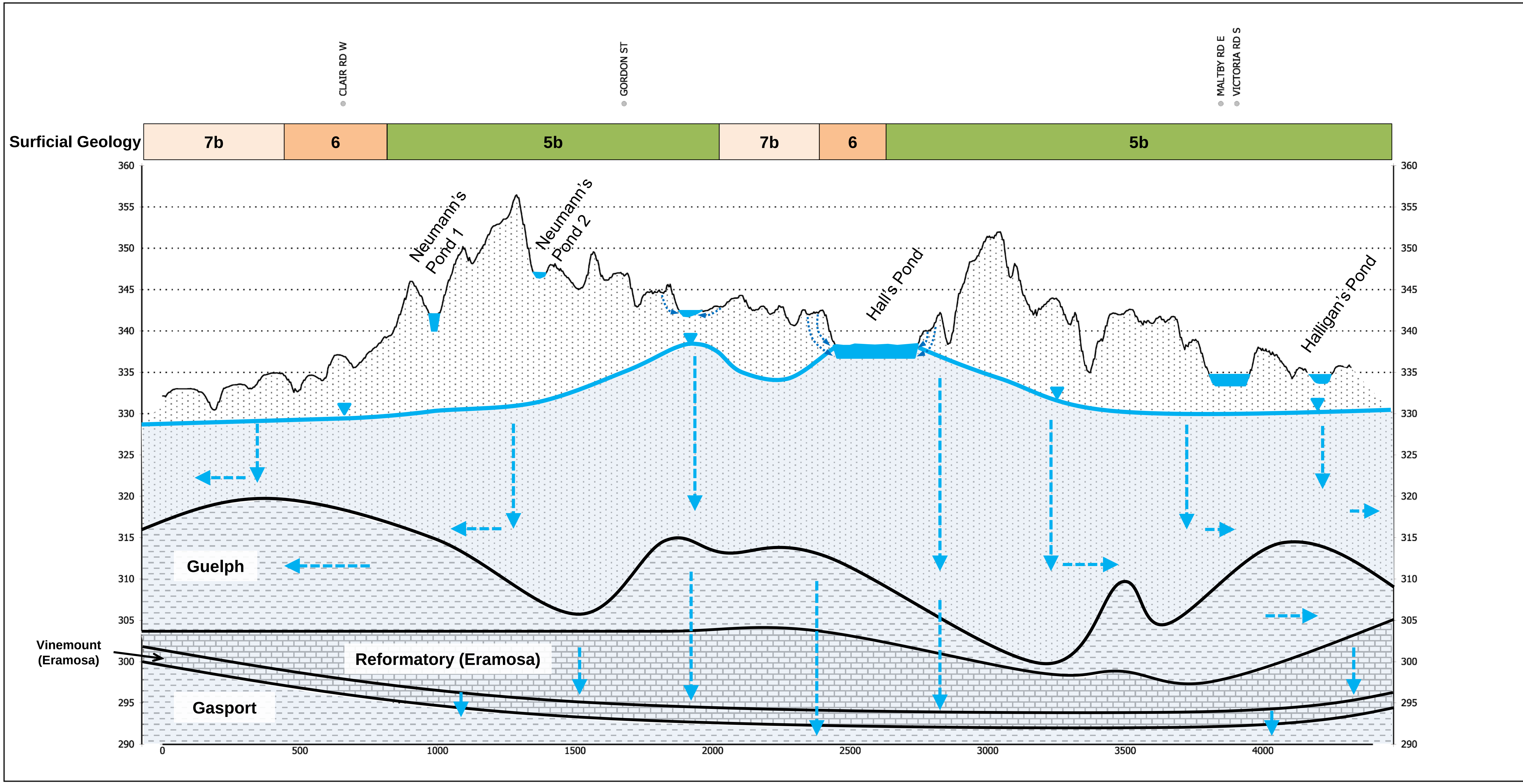
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Water Table Map Observed Data

Date:	Project:	Submitter:	Reviewer:
May, 2018	23089	D. Martin	B. Blackport

Figure
GW-5



Overburden – Silt/Sand/Sand/Gravel Till (minor clay)	5b: Stone-poor, sandy silt to silty sand till (Wentworth Till)
Bedrock – Aquifer unit	6: Ice-contact stratified sand and gravel deposits
Bedrock - Aquitard unit	7b: Glaciofluvial gravel deposits
Saturated zone	Ponded areas

Approximate water table
Interpreted groundwater flow
Local groundwater flow (seasonal)
Approximate geological contact

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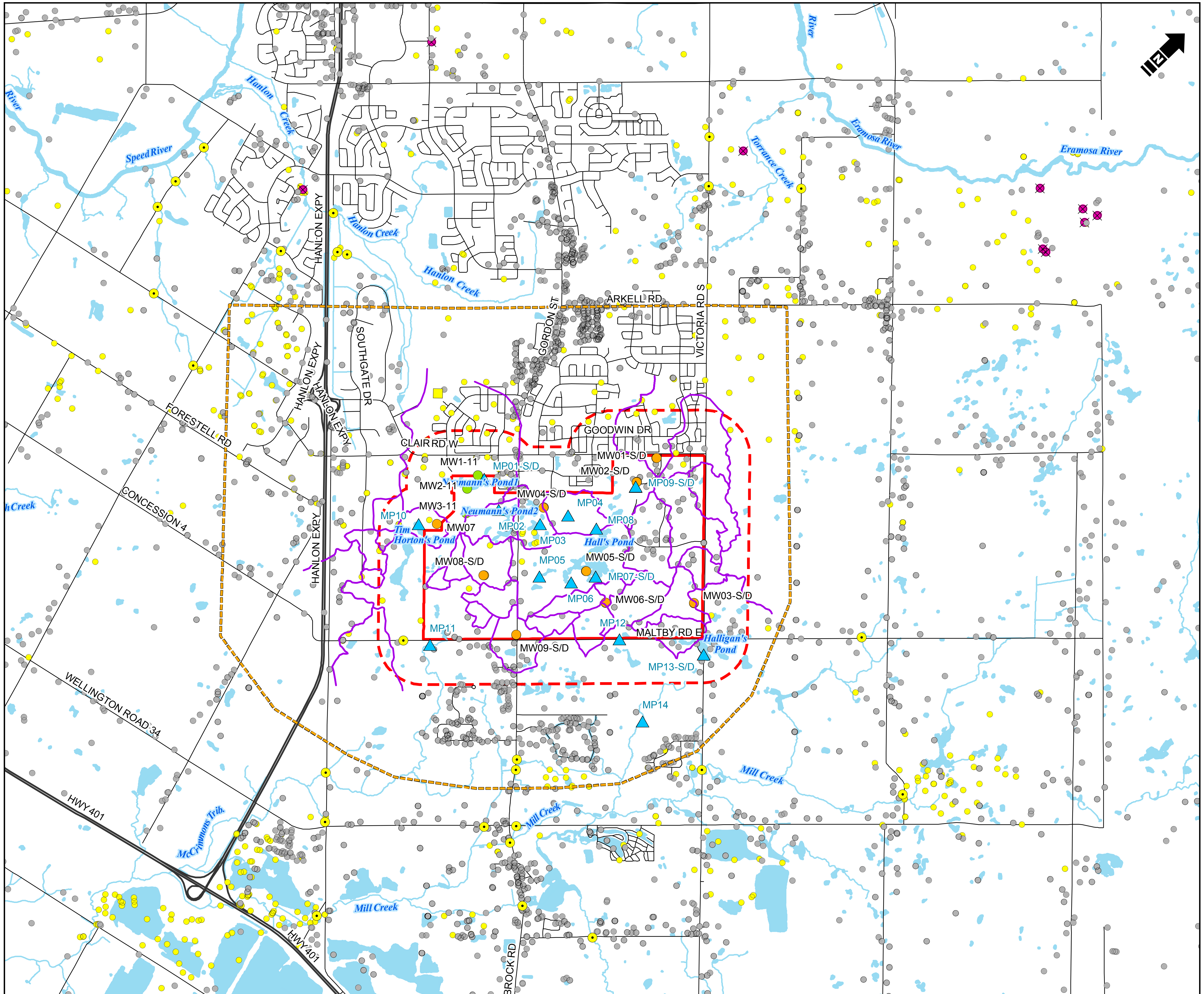
City of Guelph
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Conceptual Groundwater Flow System

Date:	Project:	Submitter:	Reviewer:
Mar 2018	23089	D. Martin	B. Blackport

Figure GW-6



Secondary Plan Area Boundary
Primary Study Area Boundary
MIKE SHE Model Domain
Subcatchment
Water Body
Watercourse
Highway
Road
Mini Piezometer
Spot Flow Location
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Surface Water Flow (Beacon)
Municipal Well
Consultant Well
WWIS Well

1:45,000 metres
475 0 475 950
NAD 1983 UTM Zone 17N

Reference: Data provided by the City of Guelph and GeoBase® used under license.

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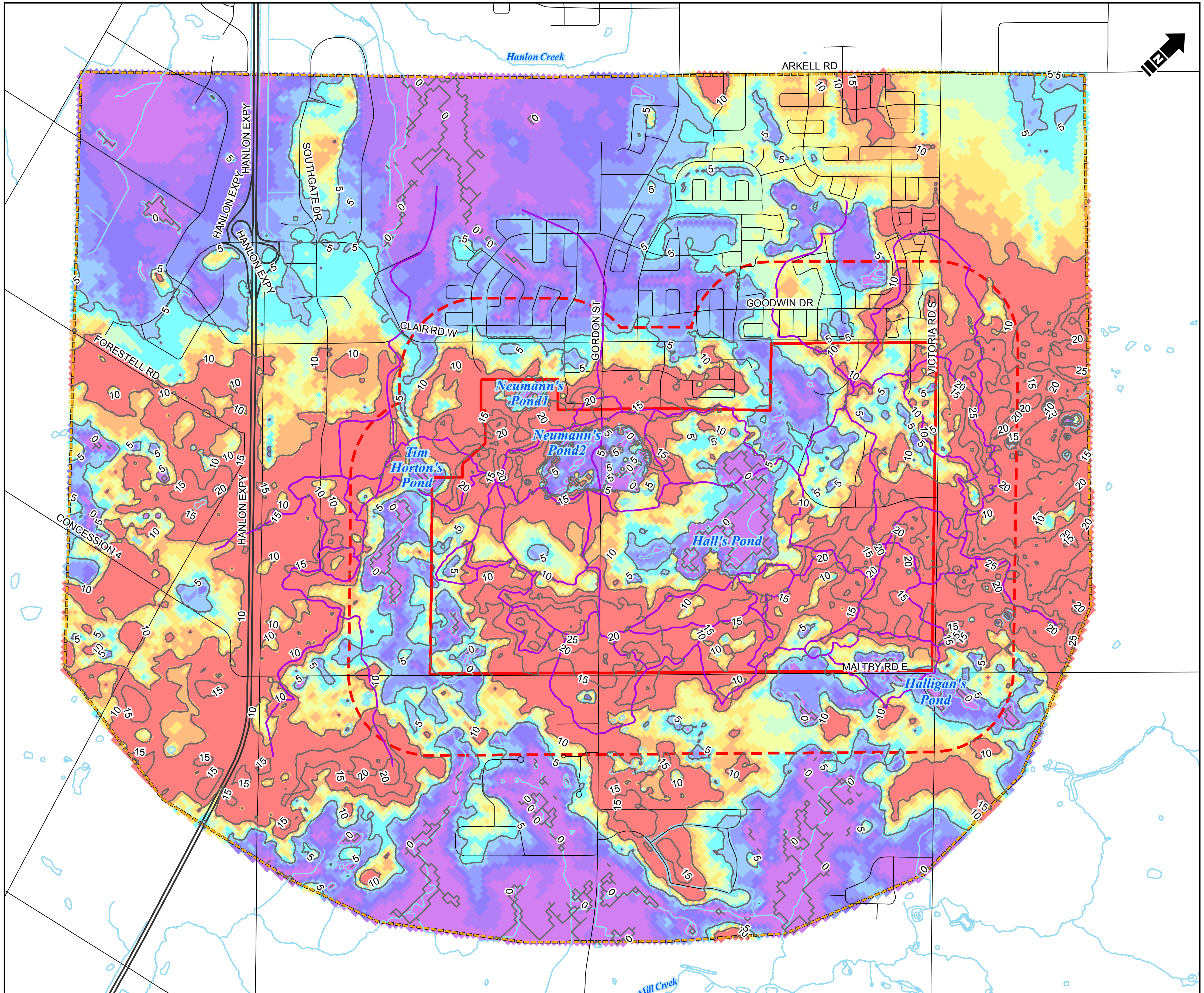
City of Guelph
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Model Domain and Observation Data

Date:	Project:	Submitter:	Reviewer:
August, 2018	23089	D. Martin	B. Blackport

Figure GW-7



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Subcatchment
Water Body
Watercourse
Highway
Road
Average Depth to Water Table Contour (5m)

Simulated Average Depth to Water Table (m)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- > 10

1:25,000
260 0 260 520 metres
NAD 1983 UTM Zone 17N

Reference: Data provided by the City of Guelph, Geo Base® and Province of Ontario used under license.

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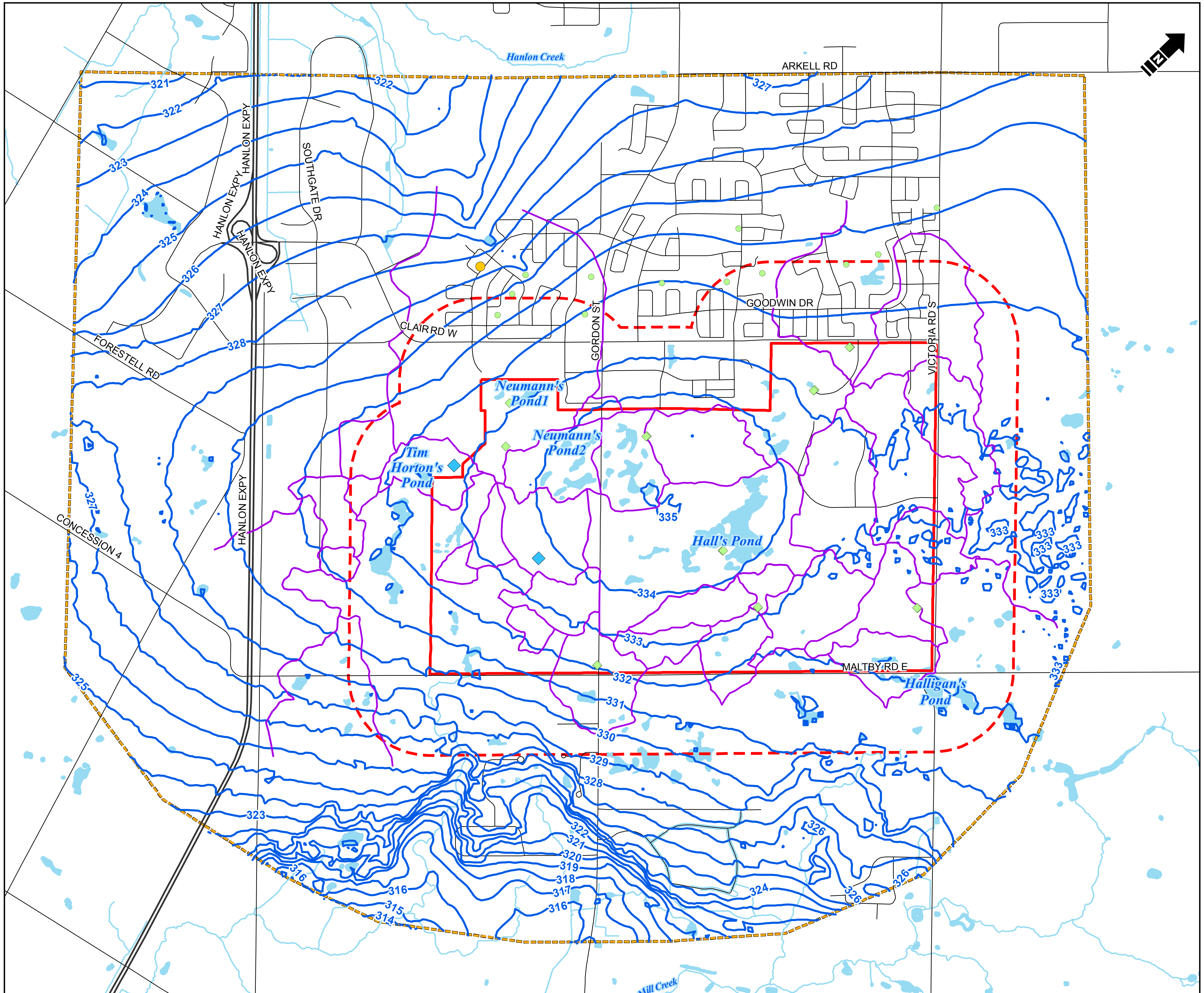
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Simulated Average Depth to Water Table

Date:	Project:	Submitter:	Reviewer:
August, 2018	23089	D. Martin	B. Blackport

Figure GW-8



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Subcatchment
Water Body
Watercourse
Groundwater Contour (1m)
Highway
Road

Groundwater Level Residual (m) - Study Well

- < -5.0
- -5.0 - -2.5
- -2.5 - 2.5
- 2.5 - 5.0
- > 5.0

Groundwater Level Residual (m) - Greenway Well

- < -5.0
- -5.0 - -2.5
- -2.5 - 2.5
- 2.5 - 5.0
- > 5.0

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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City of Guelph
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Simulated Average Groundwater Levels

Date:	Project:	Submitter:	Reviewer:
August, 2018	23089	D. Martin	B. Blackport

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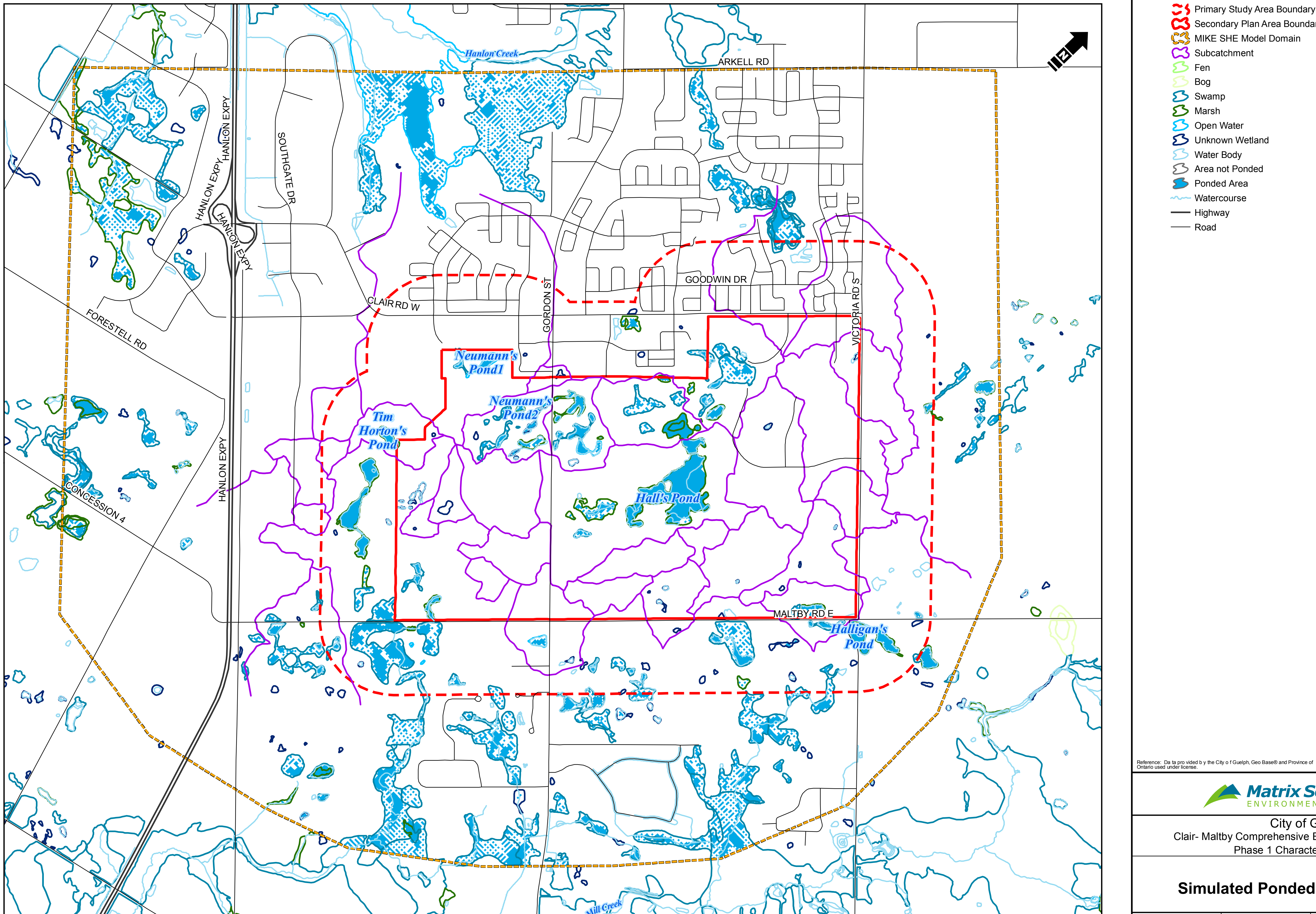
Figure
GW-9



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City of Guelph
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Simulated Ponded Water Locations

Date: August, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

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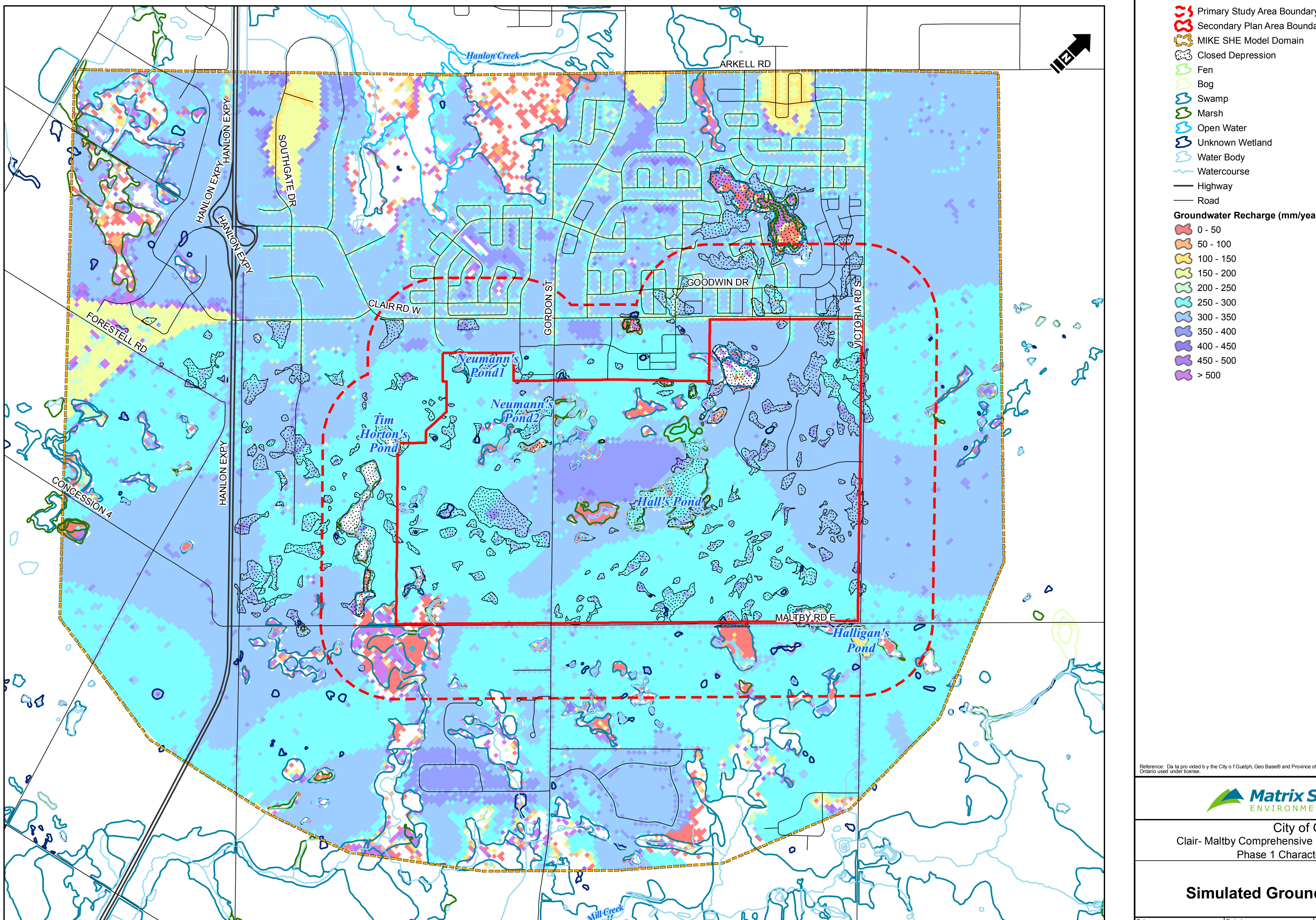
Figure GW-10



1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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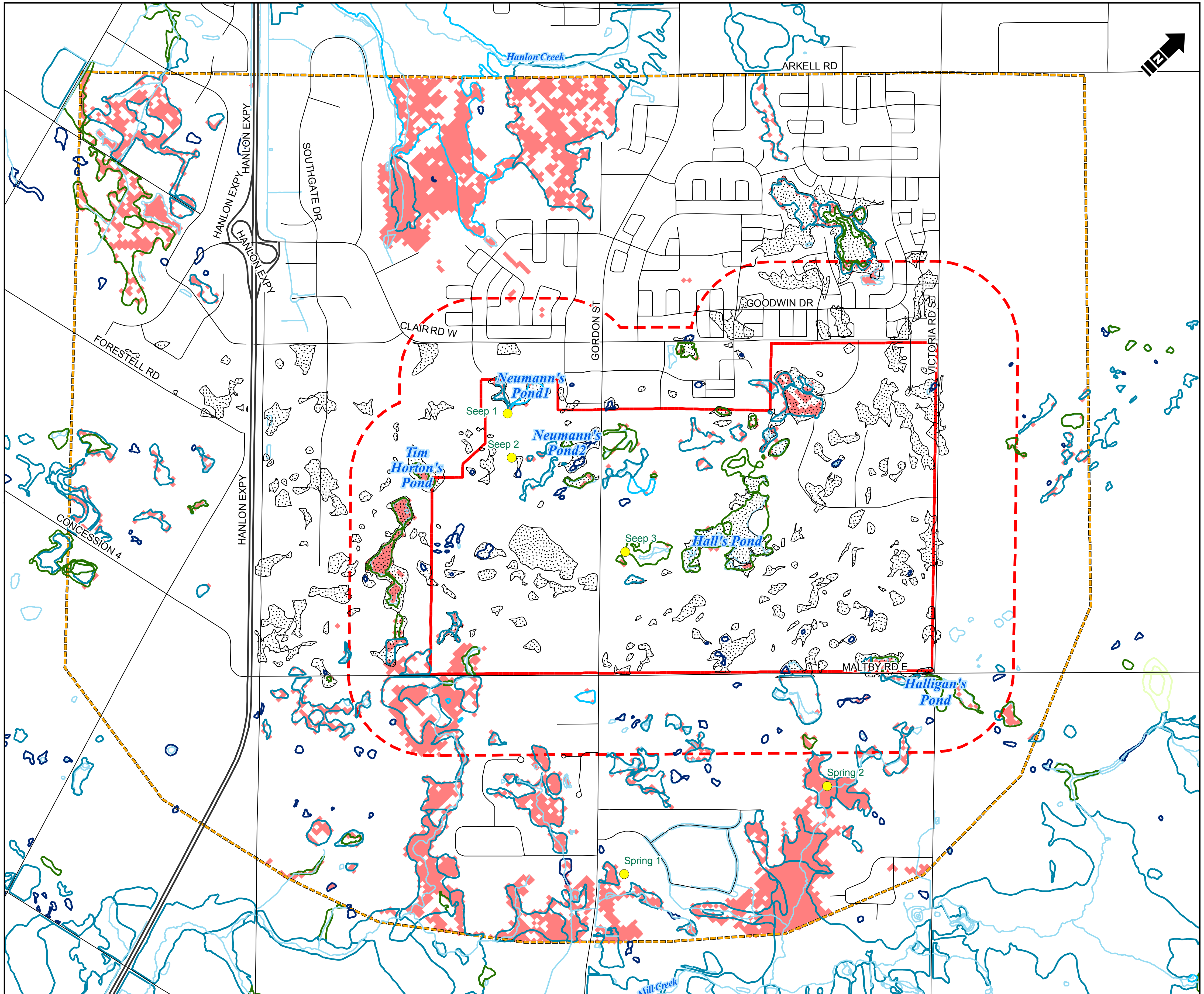
Phase 1 Characterization Report

Simulated Groundwater Recharge

Date:	Project:	Submitter:	Reviewer:
June, 2018	23089	D. Martin	B. Blackport

Figure GW-11



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Phase 1 Characterization Report

Simulated Groundwater Discharge

Date:	Project:	Submitter:	Reviewer:
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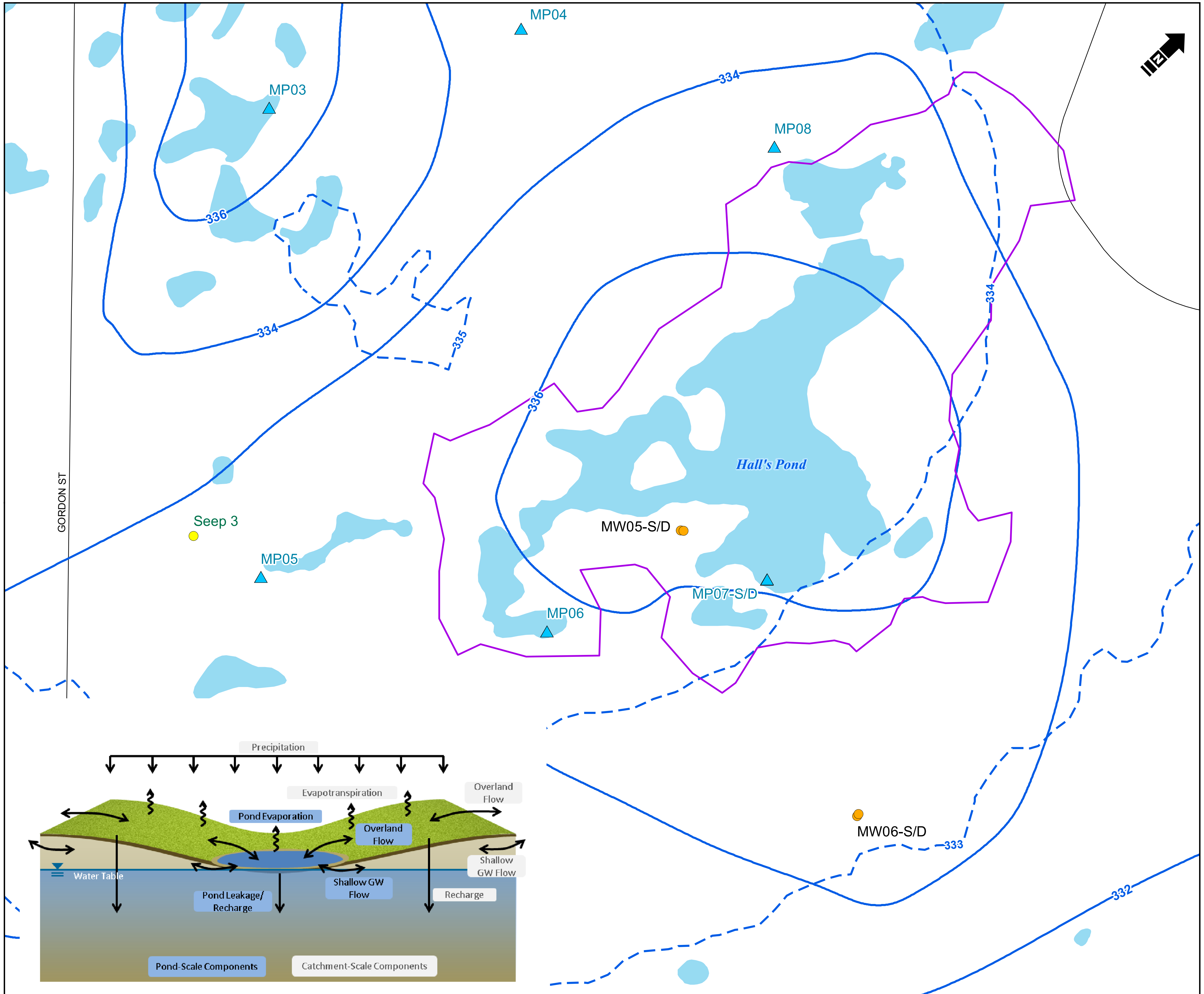
Figure
GW-12



Hall's Pond Subcatchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Hall's Pond Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	509	Evaporation	543
OL_{in}	Overland Flow (In)	3	Overland Flow (In)	71
OL_{out}	Overland Flow (Out)	1	Overland Flow (Out)	52
SGW_{in}	Shallow GW Flow (In)	3	Shallow GW Flow (In)	4
SGW_{out}	Shallow GW Flow (Out)	3	Shallow GW Flow (Out)	1
R	Recharge	299	Recharge	286
S	Storage Change	-5	Storage Change	-6

**All values reported in mm.*

1:5,000 metres
50 0 50 100
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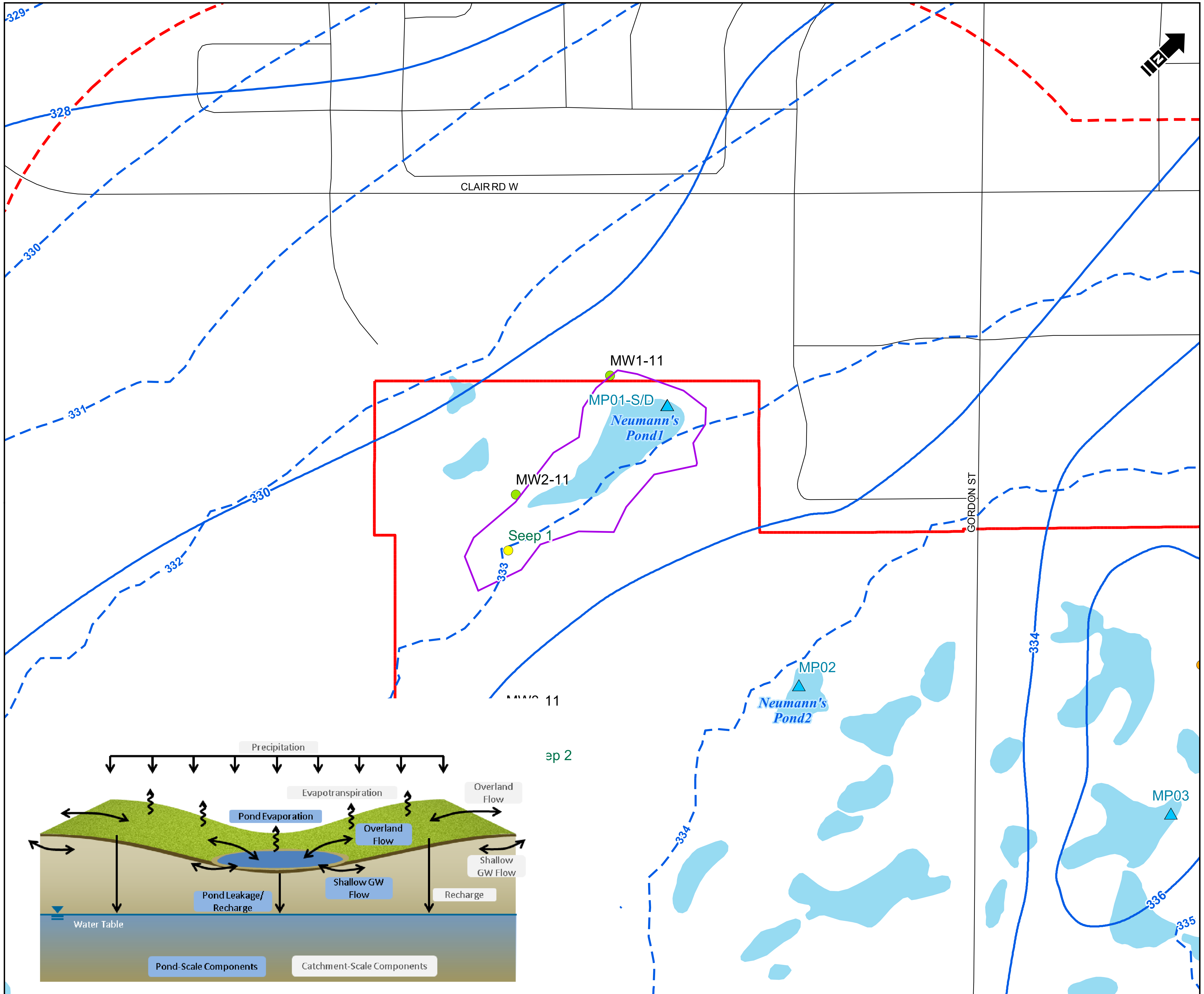
Hall's Pond Groundwater/Surface Water Conditions

Date: June, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

Figure GW-13



- Primary Study Area Boundary
- Secondary Plan Area Boundary
- Neumann Pond Catchment
- Water Body
- Water Table Elevation Contour (2m)
- Simulated Head Contour (1m)
- Road
- Mini Piezometer
- Monitoring Well (Matrix)
- Monitoring Well (132 Clair Rd.)
- Observed Seep and Spring

Neumann's Pond Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	549	Evaporation	675
OL_{in}	Overland Flow (In)	5	Overland Flow (In)	283
OL_{out}	Overland Flow (Out)	1	Overland Flow (Out)	143
SGW_{in}	Shallow GW Flow (In)	11	Shallow GW Flow (In)	11
SGW_{out}	Shallow GW Flow (Out)	7	Shallow GW Flow (Out)	2
R	Recharge	265	Recharge	283
S	Storage Change	-5	Storage Change	-7

*All values reported in mm.

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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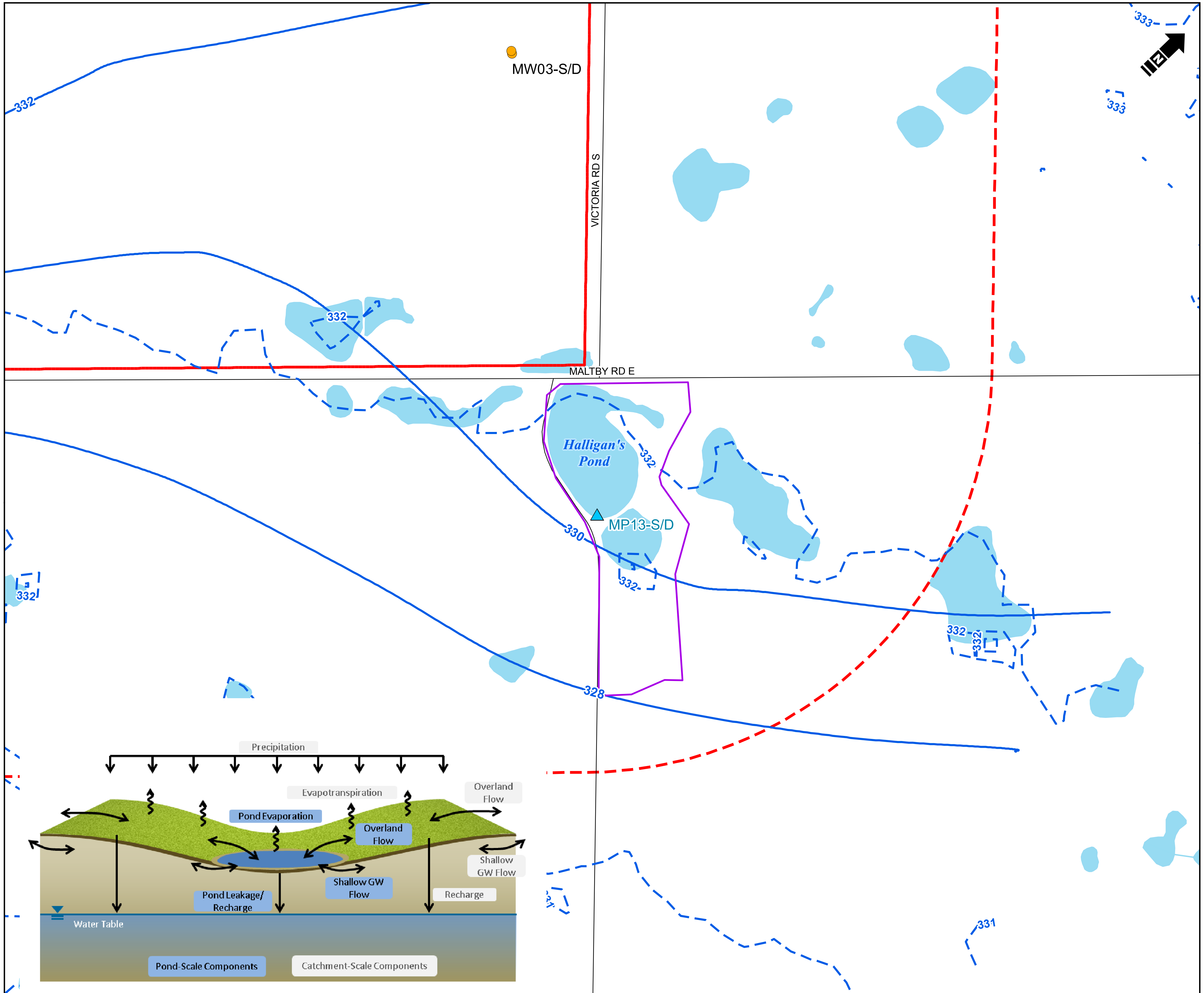
Neumann's Pond Groundwater/Surface Water Conditions

Date: June, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

Figure GW-14



Primary Study Area Boundary
Secondary Plan Area Boundary
Halligan's Pond Subcatchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Halligan's Pond Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	534	Evaporation	570
OL_{in}	Overland Flow (In)	10	Overland Flow (In)	49
OL_{out}	Overland Flow (Out)	4	Overland Flow (Out)	154
SGW_{in}	Shallow GW Flow (In)	3	Shallow GW Flow (In)	5
SGW_{out}	Shallow GW Flow (Out)	2	Shallow GW Flow (Out)	2
R	Recharge	282	Recharge	143
S	Storage Change	-8	Storage Change	-14

*All values reported in mm.

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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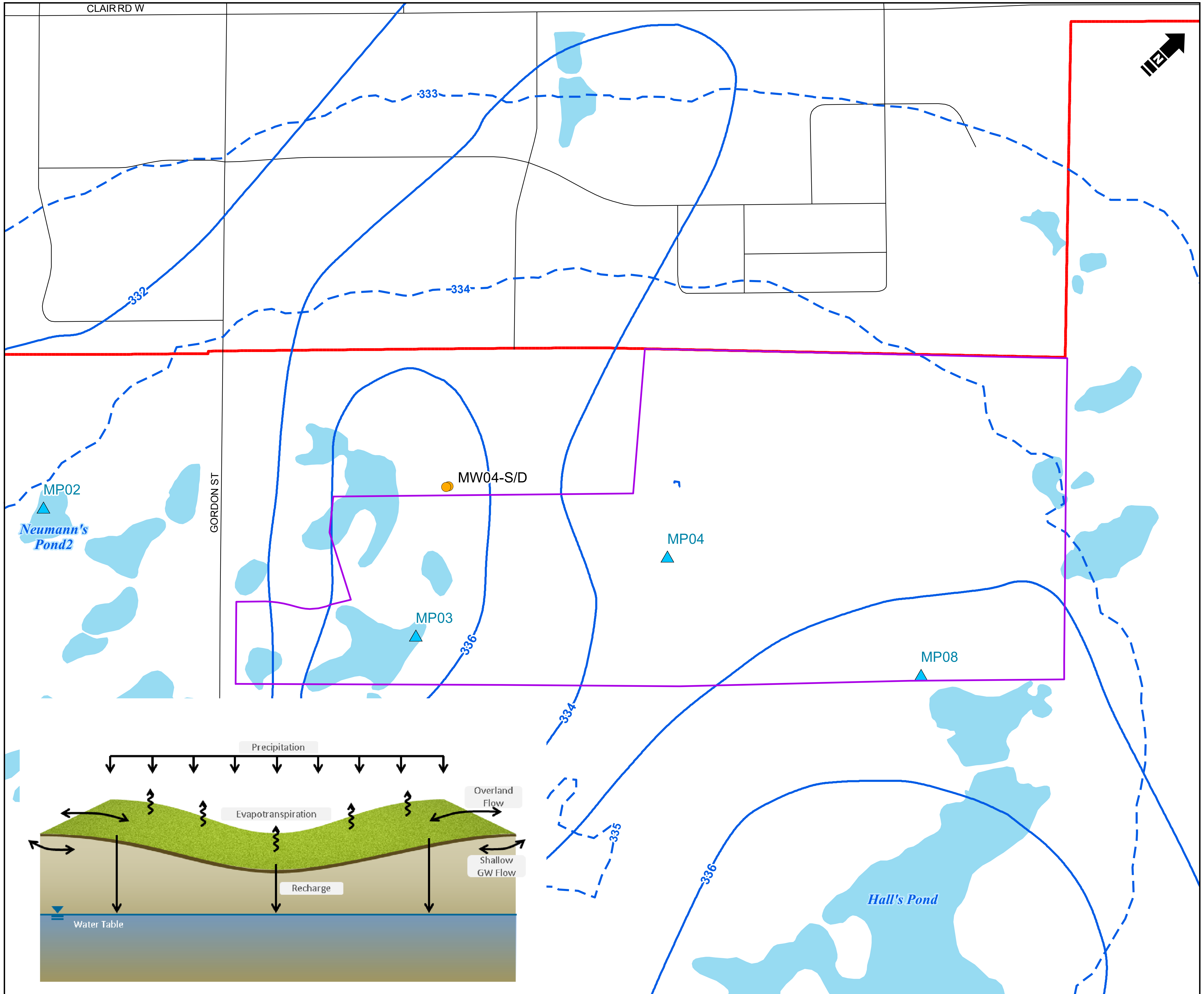
Phase 1 Characterization Report

Halligan's Pond Groundwater/Surface Water Conditions

Date: June, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

Figure GW-15



Secondary Plan Area Boundary
Woodlot Subcatchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

1992 Gordon Street Woodlot
Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Woodlot-Scale	
P	Precipitation	801
ET	Evapotranspiration	503
OL_{in}	Overland Flow (In)	16
OL_{out}	Overland Flow (Out)	18
SGW_{in}	Shallow GW Flow (In)	6
SGW_{out}	Shallow GW Flow (Out)	7
R	Recharge	296
S	Storage Change	-3

**All values reported in mm.*

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

1992 Gordon St. Woodlot Groundwater/Surface Water Conditions

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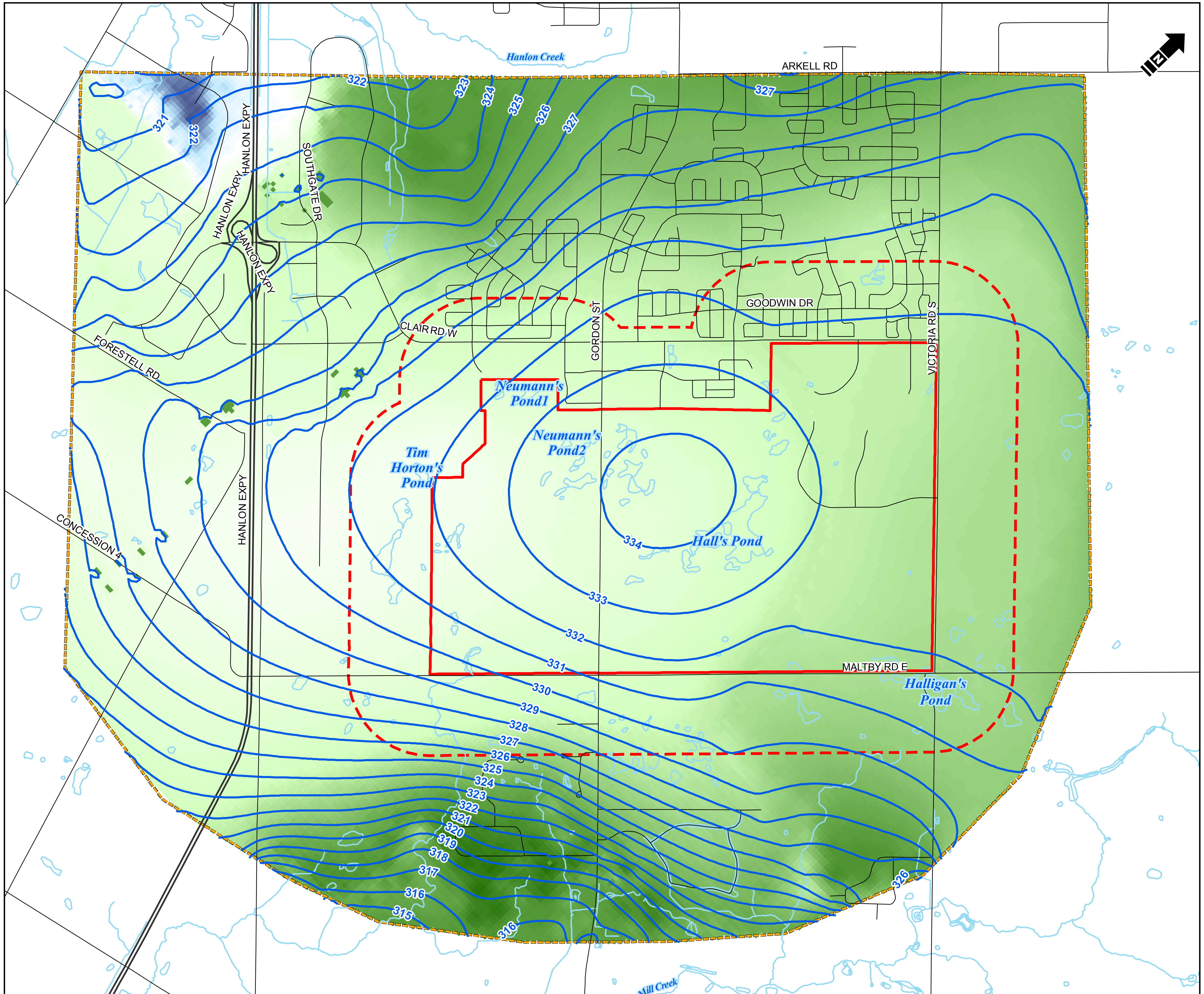
Figure
GW-16



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Highway
Road
Reformatory Quarry Head Contour (1m)

Vertical Flux

Strong Downwards

Strong Upwards

1:25,000 metres

260 0 260 520

NAD 1983 UTM Zone 17N

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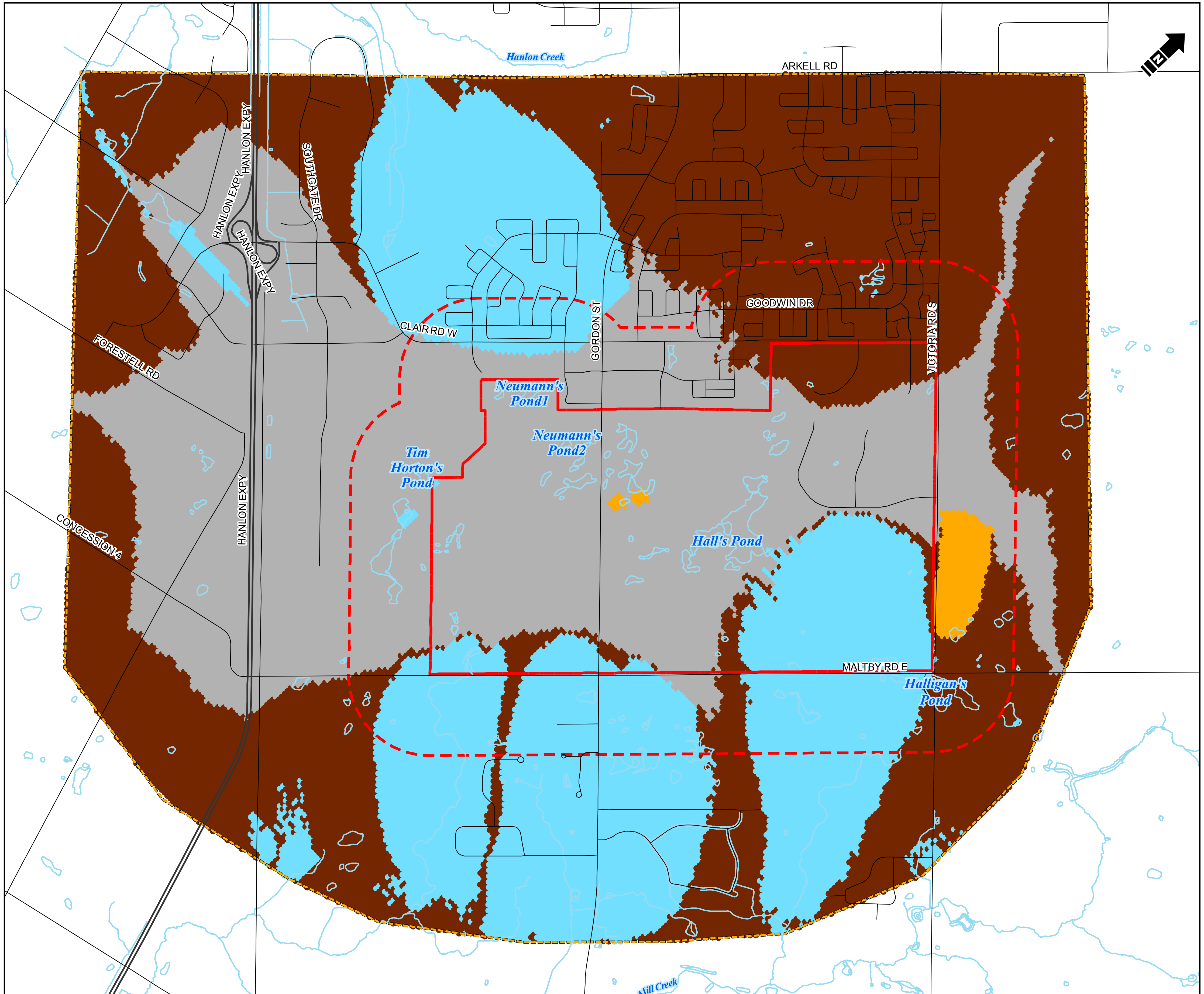
Phase 1 Characterization Report

Simulated Vertical Flux Across the Vinemount

Date:	Project:	Submitter:	Reviewer:
August, 2018	23089	D. Martin	B. Blackport

Figure
GW-17



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Highway
Road

Particle Track

- Vertical Groundwater Flow Out (Across Vinemount Formation)
- Lateral Groundwater Flow Out (Overburden and Bedrock)
- Captured by Pumping Well
- Discharge to Streams and Water Bodies

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1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Particle Tracking Map

Date:	Project:	Submitter:	Reviewer:
August, 2018	23089	D. Martin	B. Blackport

Map
GW-18

DRAFT

TECHNICAL MODELLING REPORT

CLAIR-MALTBY SECONDARY PLAN AND MASTER ENVIRONMENTAL SERVICING PLAN

PHASE 1 EXISTING CONDITIONS CHARACTERIZATION AND INTEGRATION

COMPREHENSIVE ENVIRONMENTAL IMPACT STUDY

Report Prepared for:
CITY OF GUELPH

Prepared by:
MATRIX SOLUTIONS INC. AND BLACKPORT AND ASSOCIATES

Version 0.2
August 2018
Guelph, Ontario

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TECHNICAL MODELLING REPORT

CLAIR-MALTBY SECONDARY PLAN AND MASTER ENVIRONMENTAL SERVICING PLAN

PHASE 1 EXISTING CONDITIONS CHARACTERIZATION AND INTEGRATION COMPREHENSIVE ENVIRONMENTAL IMPACT STUDY

Report prepared for the City of Guelph, August 2018

Steve Murray, M.A.Sc., P.Eng.
Water Resources Engineer

reviewed by
Daron Abbey, M.Sc., P.Geo.
Principal Hydrogeologist

reviewed by
Bill Blackport, M.Sc., P.Geo.
Hydrogeologist, Blackport & Associates

VERSION CONTROL

Version	Date	Issue Type	Filename	Description
V0.1	19-Jul-2018	Draft	23089-528x AppB Modelling R 2018-07-19 draft V0.1.docx	Issued to client for review
V0.2	30-Aug-2018	Draft	23089-528x Modelling R 2018-08-30 draft V0.2.docx	Removed Appendix B from title. Issued to client for review.

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MAPS

B1 INTRODUCTION

The Technical Modelling Memorandum provides additional details regarding model development, processes and calibration to support the summary description of the Integrated Surface and Groundwater Model and results provided in Sections 4.2.6 and 4.2.7 in the Clair-Maltby Secondary Plan and Master Environmental Servicing Plan (CMSP/MESP) Phase 1 Existing Conditions Characterization and Integration Comprehensive Environmental Impact Study (CEIS; Wood 2018).

B1.1 Model Objectives

The catchments of Clair-Maltby represent a complex hydrologic system which includes headwater regions, hummocky terrain and numerous wetlands and ponds. As part of CEIS supporting the Secondary Plan Project an integrated surface water-groundwater model was constructed for an area encompassing the Secondary Study area (SSA), which encompasses the Primary Study Area (PSA) and the Secondary Plan Area (SPA) where development is proposed. The objectives of integrated surface water-groundwater model include the evaluation of the following:

- groundwater recharge and discharge areas and features
- groundwater flow linkages between recharge and discharge areas (groundwater functions)
- spatial and temporal variations in these groundwater functions
- water budget for overall study area and key stream wetland and woodlot features
- PSA role in supporting municipal bedrock aquifers
- constraints and opportunities for future development to maintain groundwater function and support other objectives for stormwater management
- potential impacts of development alternatives on groundwater function in the PSA
- mitigation strategies (e.g. Low Impact Development strategies or Low Impact Developments [LIDs]) to maintain groundwater function and inform overall stormwater management planning

The integrated surface water-groundwater model builds on the Tier Three groundwater flow model developed for the City of Guelph (Matrix, 2017) and represents additional water budget processes, natural heritage feature and land use details.

B1.2 Model Selection

The Conceptual Groundwater Flow System discussion presented in Section 4.2.5 of main report provides a comprehensive discussion of the characteristics and functions of the groundwater system in the SPA and its linkage to adjacent areas.

The relative absence of stream features in the SPA, moderate permeability of overburden materials, and depth to groundwater of greater than 5 m highlights predominance of infiltration. The presence of ponds and wetlands is interpreted from field data to be primarily supported by local runoff and direct precipitation. Groundwater contributions to the ponds and wetlands are estimate to be small to negligible in many areas in the SPA compared to the other inputs. Recharge in the SPA is interpreted to contribute recharge to the municipal bedrock aquifer and discharge to Mill and Hanlon Creeks in the PSA, SSA.

An integrated surface water-groundwater model provides dynamic linking and physical representation of surface and subsurface processes making it the best tool to represent regional and local groundwater flow system and test the conceptual groundwater flow system understanding/hypotheses of existing conditions. Calibration of an integrated model for the SSA using the available field observations and measurements also provides ability to quantitatively assess spatial and temporal variability of the groundwater system under a range of climatic conditions and evaluate potential changes under proposed developed conditions.

MIKE SHE was selected as the numerical modelling software to represent the SPA. MIKE SHE is a three-dimensional, integrated surface water and groundwater model (DHI 2017). MIKE SHE provides a spatially variable, fully dynamic and physically based representation of all the major hydrologic processes and their interactions. The major processes represented include but are not limited to: precipitation, evapotranspiration, surface runoff, channel flow, unsaturated flow, groundwater recharge, groundwater discharge and groundwater flow. The MIKE SHE modelling software provides a quantitative means to address the characterization objectives for this study and includes the ability to represent key physical features (e.g. vegetation, imperviousness, topography), which may be modified through development of the SPA.

B1.3 Model Hydrologic Process Representation

Hydrologic process representations in the MIKE SHE model were selected to satisfy the objectives of the model. They hydrologic processes considered by MIKE SHE are shown on Figure B1. The selected representation of these processes and the primary modelling inputs related to these processes are summarized in Table B1.

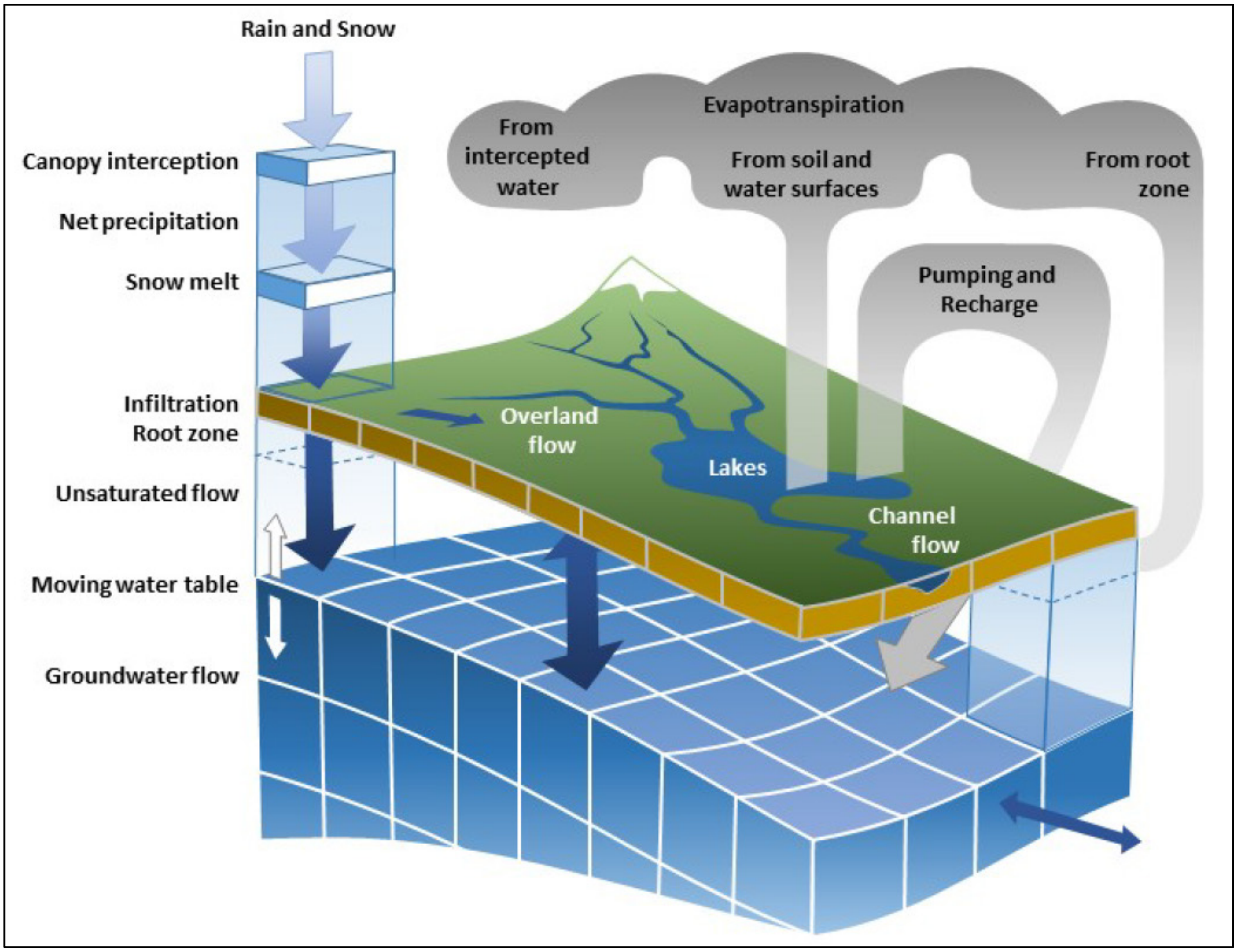

Figure B1 MIKE SHE Hydrologic Process Diagram

Table B1 Modelling Approach

Hydrologic Process	Process Representation	Inputs Related to Process
Overland Flow	2D Finite Difference Diffusive Wave Equation	Topography, Impervious fraction, surface roughness, depression storage,
Channel Flow	Kinematic Routing Method	Channel cross sections (Topography)
Unsaturated Flow	Gravity Flow Model	Vertical hydraulic conductivity, soil water content (saturation point, field capacity, wilting point), pressure-saturation and saturation-conductivity characteristic relationships
Saturated Flow	3D Finite Difference Darcy Equation	Geologic layer elevation, hydraulic conductivity, specific yield and specific storage
Snowmelt Model	Degree-Day Snowmelt Model	Temperature
Evapotranspiration Model	Kristensen and Jensen (1975)	Temperature, rooting depth, leaf area index
Paved Runoff	Abstraction of water fraction in directly connected impervious areas	Impervious Fraction, Surface Roughness, Detention Storage, Topography

B2 MODEL SETUP

A preliminary regional scale model was constructed to evaluate the SSA interaction with the larger regional flow system, the initial parametrization of the model and provide understanding of baseflows at the Grand River Conservation Authority (GRCA) Mill Creek Aberfoyle stream gauge. The preliminary regional scale model was 96 km^2 in area and constructed at a resolution of 100 m × 100 m. This model extended from the headwaters of Mill Creek in the north in to just south of the town of Aberfoyle. The model extended to the Speed River in the west and Mill Creek in the east.

Simulations conducted using the preliminary regional model provided confidence in the model inputs and parameterization. However it was identified that features within the SPA would need increased spatial resolution to be reasonable represented by the model. As a result of this a new smaller model domain was selected to encompass the SPA. and the SSA was constructed and simulates processes at increased spatial resolution. This new model is referred to here as the SSA model and the details of the SSA model structure and set up are summarized in Table B2.

Table B2 Model Structure and Setup

Structural Element	Setup	Rationale/Approach
Simulation and Calibration Period	Time Period: 01/09/1996-31/12/2017 Calibration Period: 2003 to 2017 (15 years) Adaptive time-stepping employed.	Calibration period was selected to provide representative climate for the region. Average annual precipitation is 6% lower than the 30 year average but includes many droughts and high precipitation years. The calibration period was selected considering the land use applied in the model was based on data from 2009-2011 and calibration data is most available for recent years (2016-2017).
Model Extent	East-West Length: 7 km North-South Length: 7 km Area: 30 km^2 Resolution: 25 m × 25 m; Overland Ponding and Infiltration Resolution: 12.5 m × 12.5 m Unsaturated Zone: 48749 cells * (0 to 55 layers depending on saturation, at 0.2 to 0.4 m thickness) Saturated zone: 48749 cells * 7 Layers	The model boundaries allow the examination of the interactions of the SPA with Hanlon, Mill Creek and Torrance Creek. These boundaries also provide sufficient spatial resolution within the SPA to represent the hydrologic processes influencing ponds, wetlands, depressions. Finally the boundaries of the model were designed such that they were sufficiently distant from the SPA so as not to provide undue influence on the PSA.

B2.1 Topography

A high resolution topographic dataset was constructed using 2016 elevation data provided by the City of Guelph for the SSA Model at 5 m × 5 m resolution. The high resolution data was upscaled to be consistent with the model grid cell resolution of 12.5 m × 12.5 m for overland flow processes. Upscaling of the high resolution topographic data maintains the spatial dimensions of the features and the slope of the landscape in and around key pond wetland features. In addition, the upscaling to 25 m × 25 m for all other processes provides sufficient resolution to represent larger scale flow features in the SSA (e.g., groundwater discharge to wetlands, and regional groundwater flow).

B2.2 Climate Data

Climate data provide information on existing and historical spatial and temporal variation in precipitation, temperature and potential evapotranspiration. Understanding study area specific climate conditions is important for identifying future stormwater management options that maintain the function of both the groundwater and surface water systems. Further, the climate data provides inputs for the hydrologic and hydrogeologic/groundwater system models that are used to represent historical and current water budget components and simulate potential future conditions to evaluate potential impacts to the water function. (e.g., runoff, groundwater discharge to Hanlon Creek, Mill Creek, Torrance Creek and Irish Creek Subwatersheds).

B2.2.1 Methods

A climate data set was developed to provide a long-term, 1950-2017, set of observations for the site featuring hourly precipitation and daily temperature records. This data set was constructed using data in close proximity to the site whenever possible and hourly precipitation observations are used throughout the dataset. The assembled observed climatic data set represents temporal variability at hourly to multi-year scales during the period of observations and is suitable for evaluating both short and long-term hydrologic processes, such as infiltration or drought.

Long-term and short-term meteorological data sets were collected as part of this study for use in multi-seasonal, multi-year assessments. Rainfall observations collected as part of the field program were incorporated for the period of 2016-2017.

The climate stations used to develop a continuous set of climate observations for the study are summarized in Table B3.

Table B3 Climate Stations

Data Source	Station ID	Station Name	Latitude	Longitude	Elevation (m ASL)	Period of Record	Observed Data and Frequency
Environment Canada	6143090	Guelph Turfgrass CS	43.55	-80.22	325	1950-2005	Hourly Precipitation, Daily Temperature
Environment Canada	6142286	Elora RCS	43.65	-80.42	376	2003-2015	Hourly Precipitation, Daily Temperature
Environment Canada	6147188	Roseville	43.35	-80.47	328	1972-2017	Hourly Precipitation Daily Temperature
Environment Canada	6149388	Region of Waterloo Airport	43.46	-80.38	321	2002-2011	Daily Precipitation, Daily Temperature
Environment Canada	6144239	Kitchener/Waterloo	43.46	-80.38	322	2010-2017	Daily Precipitation, Daily Temperature
GRCA	N/A	Guelph	43.60	-80.26	361	2004-2015	Hourly Rainfall
GRCA	N/A	Road 32	43.48	-80.28	297	2008-2015	Hourly Rainfall
GRCA	N/A	Cambridge	43.38	-80.29	290	2004-2015	Hourly Rainfall
AMEC Foster Wheeler	N/A	500 Maltby Road	43.50	-80.16	342	2016-2017	15-minute Rainfall
University of Waterloo	N/A	University of Waterloo Climate Station	43.47	80.56	334	1998-2017	15-minute Precipitation

A quality control process was conducted to determine if the climate data selected for numerical modelling was reasonable for the study. Climate data were screened for data gaps, outliers and compared to nearby high quality Environment Canada climate data. For time periods where data were not available for the closest climate stations the data was evaluated annually and seasonally to determine the similarity of observations at a given station to nearby climate stations.

Climate data more proximate to the study area was prioritized over observations further from the site. Where data climate data was identified to likely be erroneous due to significant disagreement with nearby climate stations it was not used and data from the next closest station was used instead.

Through this process a continuous climate data set was compiled from the climate station observations for the period of 1950-2017 featuring hourly precipitation rates and daily temperature observations. The data used for the assembled climate dataset is summarized in Table B4.

Table B4 Climate Data Used

Period	Temperature Data Source	Precipitation Data Source
1950-2005	Guelph Turfgrass - Environment Canada	Guelph Turfgrass - Environment Canada
2006	Guelph Turfgrass CS - Environment Canada	Guelph Lake - GRCA, Roseville, Elora RCS and Region of Waterloo Airport- Environment Canada
2007	Guelph Turfgrass CS - Environment Canada	Roseville, Elora RCS and Region of Waterloo Airport - Environment Canada
2008-2015	Guelph Turfgrass CS - Environment Canada	Road 32 Station, Guelph Lake, Cambridge - GRCA Roseville, Elora RCS, Region of Waterloo Airport, Kitchener/Waterloo - Environment Canada
2016-2017	Guelph Turfgrass CS - Environment Canada	500 Maltby Road Rain gauge - AFW, University of Waterloo Climate Station, Kitchener/Waterloo - Environment Canada

Reference evapotranspiration rates were computed on a daily basis for the study using daily temperature observations and the United Nations Food and Agriculture Organization (FAO) 56 Penman-Monteith method (Allen et al. 1998).

B2.2.2 Analysis

The annual precipitation rates from the assembled climate data for the previous 30 years, 1988-2017, are summarized on Figure B2. For this period the average precipitation rate is 820 mm/year. The wettest year observed occurred in 1992 with 1,127 mm of precipitation and the driest year occurred in 2007 with 530 mm of precipitation.

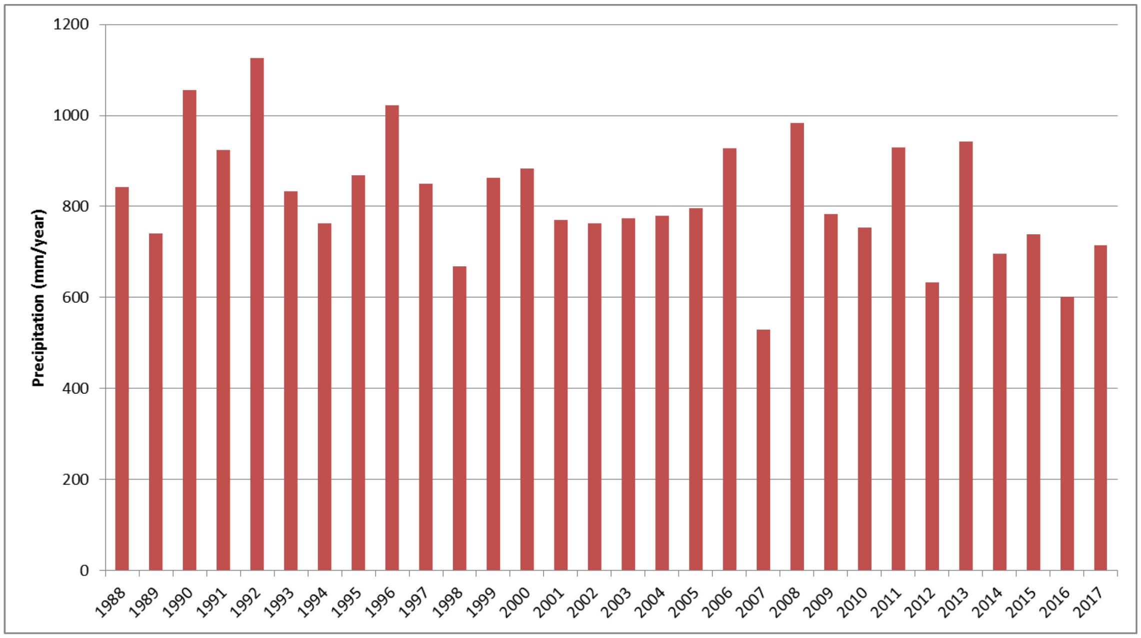

Figure B2 Average Annual Precipitation 1988-2017

The mean monthly, maximum monthly and minimum monthly temperature from the assembled climate data set are presented for the period of 1988-2017 on Figure B3.

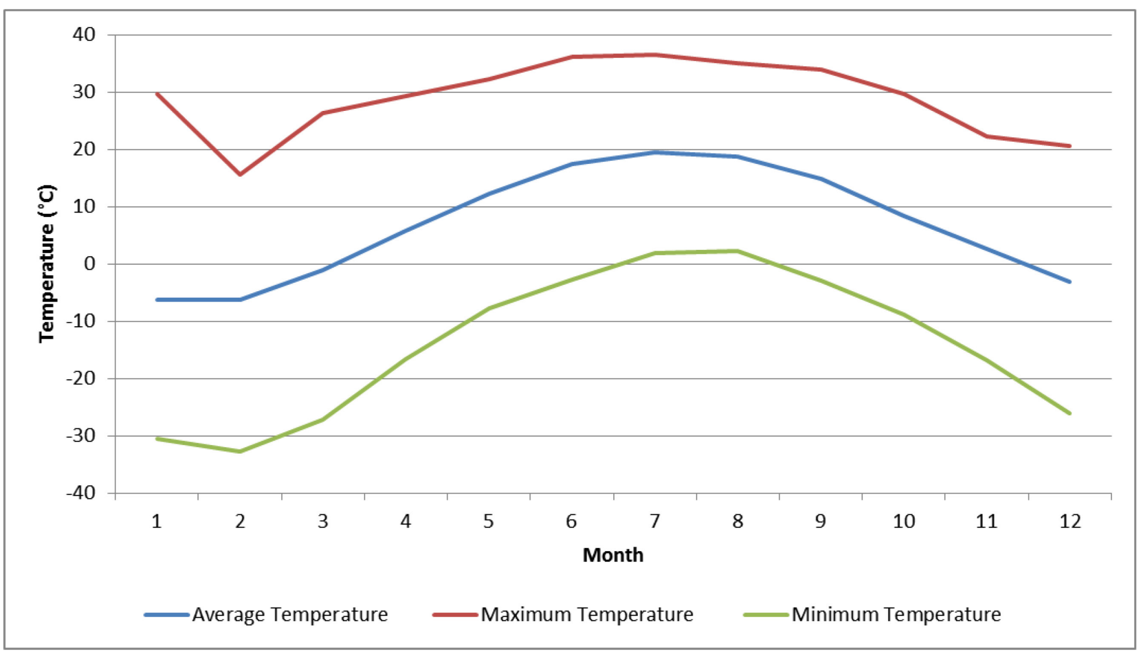

Figure B3 Monthly Temperature Range 1988-2017

The annual reference evapotranspiration rates computed for the period of 1988-2017 are presented on Figure B4. An average annual reference evapotranspiration rate of 830 mm is estimated for this period.

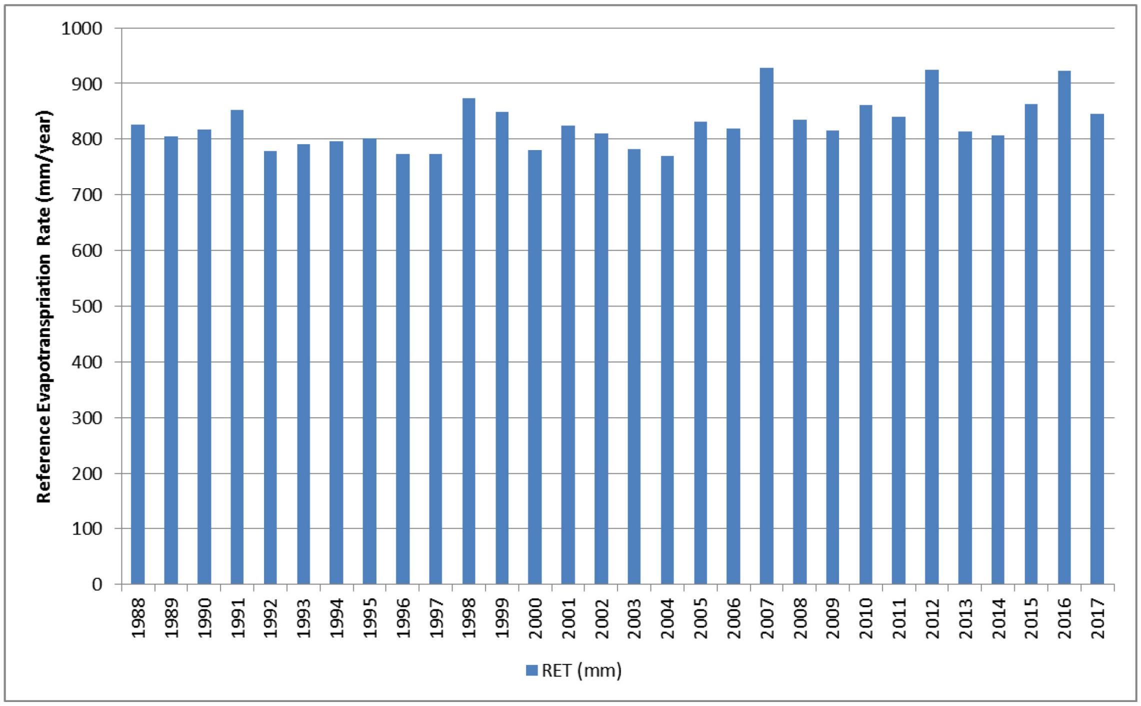

Figure B4 Reference Evapotranspiration Rate 1988-2017

B2.3 Land Use Data and Parameters

Land use data used in the model was based on the Southern Ontario Land Resource Information System (SOLRIS) 2.0 land use dataset. This data provides a land use inventory at 15 m resolution and is based on a land use inventory conducted for 2009-2011. The land use in the model domain is presented on Map B1.

The land use information was used to determine appropriate vegetation characteristics, rooting depth and leaf area index (LAI) for areas in the model. The vegetation parameters assigned to the land use classes are varied temporally to represent the seasonal changes associated with vegetation growth, dormancy, and dieback, which occur between the spring and fall months. The initial values used for rooting depth and LAI for vegetation types was assigned based on literature values (Canadell et al. 1996; Scurlock et al. 2001) and adjusted during the calibration process where necessary.

Similarly land use mapping was used to determine appropriate overland flow characteristics including surface roughness, depression storage and imperviousness for areas in the model. Runoff associated with impervious and urbanized areas is represented in the model by assigning a directly connected impervious fraction to these regions. This fraction represents the portion of precipitation that is conveyed directly to receiving watercourses through storm sewers or other urban drainage systems. The parameters used to describe these overland flow characteristics were assigned initially based on literature values and adjusted during the calibration process where necessary (Brabec et al. 2002; Chin 2006).

A summary of land use classes found within the model and assigned vegetation and overland flow parameters is provided in Table B5.

Table B5 Land Use Characteristics

Land Use	LAI [-]		Root Depth (mm)		Impervious Area - Direct Runoff	Surface Roughness (Manning's Coefficient)		Detention Storage (mm)
	Min	Max	Min	Max	Coefficient [-]	M [m1/3/s]	n [s/m1/3]	
Agriculture	0.4	3.6	300	1,200	0	0.30	3.33	5
Forests	1.75	3.5	1,550	2,500	0	0.56	1.8	7.5
Treed Wetland	1.75	3.5	1,550	2,500	0	0.60	1.67	7.5
Wetland	3.2	6.4	200	600	0	0.60	1.67	10
Developed - Pervious	0.8	2	100	600	0-0.1	0.20	5	2.5
Developed - Impervious	0.8	2	100	600	0.3	0.07	14	2
Roads - Urban	0	0	200	200	0.7	0.03	30	2
Roads - Extra Urban	0	0	200	200	0	0.10	10	2
Open Water	0	0	200	200	0	0.30	3.33	10

B2.4 Watercourse Representation

Watercourses represented in the SSA model were based on a drainage analysis of the topography of the SSA model domain to identify where runoff accumulates during large precipitation events. A small tributary to the wetlands at the headwaters of Hanlon Creek, at the northwest border of the model domain was incorporated into the model as a result of this analysis. This represents an ephemeral feature that may form during heavy precipitation events or during extended seasonal wet periods (e.g. the spring freshet).

In areas where channels were not explicitly modelled any discharge to surface is handled a two dimensional overland flow process (e.g. Mill Creek). In these tributaries spot flow measurements, during baseflow periods were compared to the simulated baseflow, estimated based on depth of overland water and water table depth.

B2.5 Unsaturated Zone Data and Parameters

The spatial distribution of unsaturated zone materials was developed for the model area based on the Ontario Geologic Survey's Surficial Geology of Southern Ontario Dataset (OGS 2010, see Map B2). Materials which were expected to have similar hydraulic properties to one another were aggregated into a common surficial geology class.

The surficial geology classes used in the model and their water content parameters, saturation and residual water content, are presented in Table B6. This table also summarizes the saturated hydraulic conductivity and Van Genuchten fitting parameters which vary in water content and conductivity with pressure. Parameters were selected based on field data, previous studies and literature values. Please refer to Table B7 for a range of observed conductivity values.

Table B6 Unsaturated Flow Parameters

Surficial Geology Class	Saturated Water Content (θs)	Residual Water Content (θr)	Saturated Vertical Hydraulic Conductivity Ks (m/s)	Van Genucten α (1/cm)	n – Van Genucten Fitting Parameter ()	L - Van Genucten Fitting Parameter ()
Outwash Sand and Gravel	0.35	0.05	1.2e-5	0.067	1.446	0.5
Organic Deposits	0.65	0.1	5e-8	0.067	1.446	0.5
Port Stanley Till	0.5	0.1	5E-07	0.027	1.41	0.5
Wentworth Till	0.5	0.1	1e-5	0.027	1.41	0.5

B2.6 Saturated Zone Data and Parameters

The structure of the saturated zone in the SSA model is based on the Guelph Tier Three Finite Element subsurface FLOW (FEFLOW) model as constructed for the Risk Assessment scenarios conducted as part of the Tier Three Project (Matrix 2017). The geologic layer structure found in the SSA model and their parameterization of these layers is summarized in Table B7. The range of hydraulic conductivity (*K*) values observed through the field program and previous investigations in the area informed the conductivity values tested in the model during the calibration process. The table summarizes the final calibrated hydraulic parameter values as well as the range of tested conductivity values. Refer to Sections 4.2.3 and 4.2.4 of the characterization report and Appendix B of the Tier Three Risk Assessment Report (Matrix 2017) for further information regarding observed conductivity values.

Table B7 Model Layer Representation of Hydrogeologic Units

Model Layer No.	Layer Name	Model Thickness Range (m)	Spatial Distribution of Properties	Material Type	Observed Hydraulic Conductivity (Kx) Range (m/s)	Tested Range of *K* (m/s)	Calibrated *K* Values (m/s)	Specific Yield () and Specific Storage (1/m)
1	Surficial Geology (OB1)	3-3	Surficial geology mapping based	Outwash Gravels and Sands	9.40e-8 to 2e-3	Kx = 1e-6 to 1e-4, Kz = 1e-7 to 6e-5	Kx = 1e-4, Kz = 6e-5	Sy = 0.17, Ss = 5e-4
				Wentworth Till	9.40e-8 to 2e-3	Kx = 5e-7 to 5e-5, Kz = 5e-8 to 5e-6	Kx = 5e-5, Kz = 5e-6	Sy = 0.15, Ss = 5e-4
				Port Stanley Till	8e-8 to 6e-7	Kx = 5e-7 to 5e-6, Kz = 5e-8 to 5e-7	Kx = 5e-6, Kz = 5e-7	Sy = 0.15, Ss = 5e-4
				Organic Deposits	No Observed Data	Kx = 1e-7 to 5e-7, Kz = 1e-8 to 5e-8	Kx = 5e-7, Kz = 5 e-8	Sy = 0.32, Ss = 5e-4
				Pond Bottom Organic Deposits	No Observed Data	Kx = 1e-7 to 5e-7, Kz = 1e-8 to 5e-8	Kx = 1e-7, Kz = 1e-8	Sy = 0.32, Ss = 5e-4
2	Wentworth Till (OB2)	1-27	Distributed K, Uniform Storage	Outwash Gravels and Sands	9.40e-8 to 2e-3	Kx = 1e-6 to 1e-4, Kz = 1e-7 to 1e-5	Kx = 1e-4, Kz = 1e-5	Sy = 0.2, Ss = 5e-4
				Wentworth Till	9.40e-8 to 2e-3	Kx = 5e-7 to 1e-5, Kz = 5e-8 to 1e-6	Kx = 1e-5, Kz = 1e-6	
3	Wentworth Till (OB3)	1-37	Uniform K, Uniform Storage	Wentworth Till	9.40e-8 to 2e-3	Kx = 5e-7 to 1e-5, Kz = 5e-8 to 1e-6	Kx = 5e-6, Kz = 5e-7	Sy = 0.2, Ss = 5e-4
4	Contact Zone	2-4	Distributed K, Uniform Storage	General	No Observed Data	Kx = 5e-6 to 5e-4, Kz 5e-7 to 5e-5	Kx = 1e-4, Kz = 1e-5	Sy = 0.03, Ss = 5e-4
				Burke-Carter Valley*	No Observed Data	Kx =5e-5 to 3e-3, Kz = 5e-6 to 3e-3	Kx = 4e-4, Kz = 4e-5	
5	Guelph Formation	1-21	Distributed K, Uniform Storage	General	Kx = 4.0e-7 to 6e-4	Kx = 1e-7 to 5e-6, Kz 1e-8 to 5e-7	Kx = 4e-6, Kz = 4e-7	Sy = 0.01, Ss = 5e-4
				Burke-Carter Valley	No Observed Data	Kx =5e-5 to 3e-3, Kz = 5e-6 to 3e-3	Kx = 2e-4, Kz = 2e-5	

Model Layer No.	Layer Name	Model Thickness Range (m)	Spatial Distribution of Properties	Material Type	Observed Hydraulic Conductivity (Kx) Range (m/s)	Tested Range of *K* (m/s)	Calibrated *K* Values (m/s)	Specific Yield () and Specific Storage (1/m)
6	Eramosa Formation - Reformatory Quarry	1-21	Distributed K, Uniform Storage	General	Kx = 2e-07 to 2e-4	Kx= 6e-8 to 1e-5, Kz= 1.0 e-10 to 1e-7	Kx = 6e-6 to 1e-5, Kz = 1e-8 to 1e-7	Sy = 0.01, Ss = 5e-4
				Burke-Carter Valley	No Observed Data	Kx =5e-5 to 3e-3, Kz = 5e-6 to 3e-3	y Kx = 2e-4, Kz = 2e-5	
7	Eramosa Formation - Vinemount Member	1-4	Distributed K, Uniform Storage	General	Kx = 5e-7 to 3e-5	Kx = 5e-8 to 5e-7, Kz = 5e-10 to 5e-8	Kx = 1e-7, Kz = 1e-9 to 3e-9	Sy = 0.01, Ss = 5e-4

Note:
* Burke-Carter Buried Valley identified in the Tier Three Model (Matrix 2017)

B2.6.1 Saturated Zone Boundary Conditions

The boundary conditions of the model represent the interaction of the regional flow system with the local flow system simulated by the SSA model. Boundary conditions were applied on lateral faces of the model and the bottom of the model to represent this interaction. The boundaries are based on the Tier Three FEFLOW model and as such the calibrated regional flow system as described in Section 4.2.5.1. A summary of the applied saturated zone boundary conditions is provided in Table B8 (Matrix 2017).

Table B8 Saturated Zone Boundary Conditions

Layer	Flow Boundary Condition Features	Flow BC Value Range (m ASL)
All Layers	Type 1 fixed head boundary conditions were applied based on Guelph Tier Three FEFLOW model steady state heads. A seasonal fluctuation of 1 m about the steady state solution was applied to represent fluctuation observed in heads at high quality matrix wells.	313-333
Bottom of Model	Type 1 Fixed Head Boundary conditions were applied based on the Guelph Tier Three FEFLOW model steady State Heads.	314-330

The simulated flux across the bottom boundary of the model represents flow across the Vinemount Member to the deeper bedrock aquifer system (e.g., Goat Island Formation). The change in simulated flux across this boundary will be quantified when completing the impact analysis simulations for the proposed development to assess the potential impacts on flow to deeper aquifer units.

B3 CALIBRATION

This section provides a summary of calibration of the SSA model against observed conditions within the SSA domain. Comparison of observed and simulated conditions provides confidence that model provides a good representation of groundwater conditions suitable for study objectives.

The model was calibrated using study-specific and available historical data and observations, and using input parameter value based on field-measured values or values from literature as described in previous sections. The observations considered during calibration included long-term evapotranspiration rates (water budget), groundwater levels, areas of ponded water levels and spot flows representative of groundwater discharge for the calibration period (2003-2017). The following sections describe the calibration of the SSA model to the observed data.

B3.1 Water Budget

The average annual water budget for the SSA model is presented in Table B9.

Table B9 SSA Model Average Annual Water Budget (2003-2017, mm-year)

	Water Budget Component											
					Lateral Groundwater Flow				Vertical Groundwater Flow			
					Overburden		Bedrock Above Vinemount Formation		Across Vinemount Formation			
Area/Catchment	Precipitation	Evapotranspiration	Overland Flow In	Overland Flow Out	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Pumping[1]	Change in Storage
SSA Model Domain	801	480	0	108	17	44	35	126	0	99	2	-7

Note:
[1] Model Considers Non-Municipal Pumping Above Vinemount Consistent with the Tier Three Model (Matrix, 2017)

The simulated average evapotranspiration rate of 480 mm/year for the period of 2003-2017 is consistent with regional estimates of evapotranspiration. Reference values for evapotranspiration in this area of southern Ontario are predicted to range from 500-600 mm/year on average for the period of 1981-2010 (Wang et al. 2013). While the model predicted evapotranspiration rate are slightly lower than the reference range this result is considered reasonable given the precipitation observed during 2003-2017 is approximately 6% lower than the long-term average from 1988-2017. Further this result is also considered reasonable as 17% of the SSA model domain includes developed/impervious areas, which feature evapotranspiration rates ranging from 380-420 mm/year.

Simulated groundwater flow quantities into out of the SSA model domain provided in Table B9 are consistent with estimates from the Tier Three FEFLOW model (Matrix 2017) in the SSA area.

B3.2 Groundwater Water Levels and Flow Directions

The evaluation of groundwater flow within the SSA used the most recently available groundwater static water levels collected at the wells commissioned for this study, consultant wells, WWIS wells and wells considered in the Tier Three numerical model (Matrix 2017). These observations were compared to the average simulated water levels at the observation locations during the calibration period as well as transient water levels collected in the study monitoring wells (presented in Section B3.3). The calibration statistics for the 609 observation wells are provided in Table B10.

The degree of fit for the entire set of 609 observations wells is considered good and typical for this type of data. The level of fit or error reflects the range in location accuracy, data quality, and range in sampling dates (e.g., wet-year/ dry-year, spring/ summer), grid cell size and model layer thickness.

Table B10 Groundwater Calibration Statistics - Average Water Levels (2003-2017)

Number of Observations	609
Mean Error (m)	1.8
Mean Absolute Error (m)	3.2
Root Mean Squared Error (m)	4.5
Normalized Root Mean Squared Error (NRMS)	9.4%
Maximum Observed Head (m AMSL[1])	346.1
Minimum Observed Head (m AMSL)	298.4

Note:
[1] AMSL – Above Mean Sea Level

The high quality wells commissioned for this study water levels are well represented with a mean error of 0.7 m and root mean squared error of 1.6 m. Considering there is an average variation of plus or minus 1 m in head observed seasonally at the wells the calibration is considered reasonable.

The simulated and observed water levels at the high quality study wells is presented on Figure B5

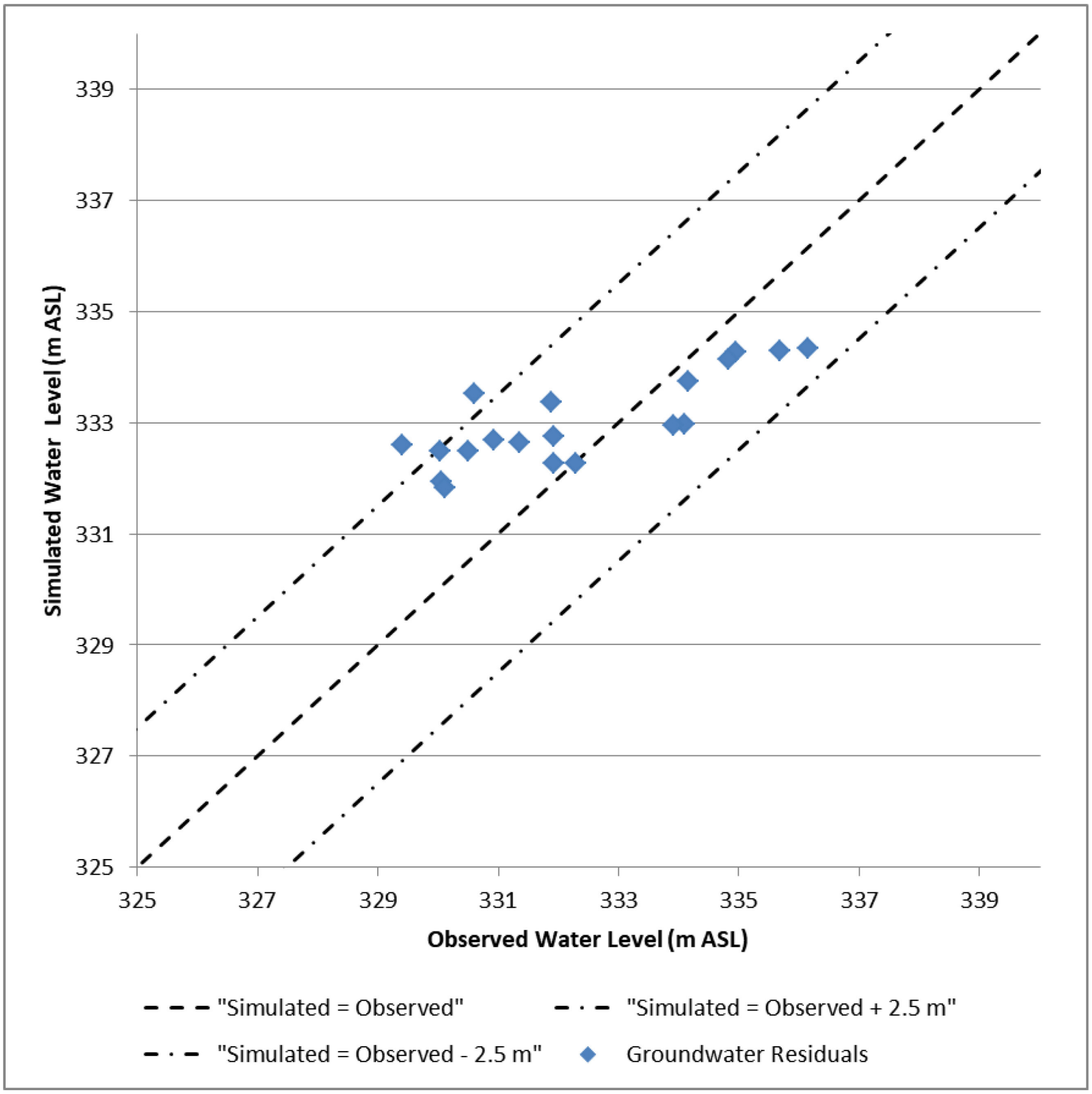

Figure B5 Simulated vs. Observed Water Levels - High Quality Study Wells

Map B3 shows the interpreted and the simulated average water table and shallow groundwater flow directions. This figure also shows groundwater residuals, average error when compared to observed water levels, at the wells commissioned for this study and historic wells found within the Greenways of Clairfields and Westminster Woods for the period of 2003-2017. The consistency of simulated and observed flow directions and depth provides additional confidence that model provides a good representation of groundwater levels and flow directions suitable for study objectives.

B3.3 Natural Heritage System Features Surface Water and Groundwater Linkage

The local conditions observed and simulated at the Natural Heritage System (NHS) features of Hall's Pond, Neumann's Pond, Halligan's Pond and the 1992 Gordon St. Woodlot are presented in Maps B5 to B8. These maps depict the interpreted water table heads contours and the average simulated groundwater head contours for the period of 2003-2017. The subcatchments depicted on the figures represent the area within which overland runoff contributes to a feature (e.g., pond). The maps also incorporate and average annual water budget for the catchment and pond for the period of 2003-2017.

Maps B4 to B7 also illustrate the simulated average annual water budgets of the catchment and ponds or woodlots for the period of 2003-2017. A process diagram illustrates the hydrologic processes that each item in the water budget corresponds to. The components of the water budget are influenced by the characteristics of the subcatchment and pond including but not limited to surface topography, vegetation, hydraulic conductivity of subsurface deposits, and groundwater hydraulic gradients. Water budget analysis presented in indicates that the ponds are primarily supported by direct precipitation with limited contributions from overland runoff and shallow groundwater. Recharge in these water budgets represents leakage from the base of the pond to the underlying groundwater system. These results are consistent with the interpretation of conditions at the NHS features provided by the monitoring data and Conceptual Model of groundwater flow (CM) presented in the Phase 1 Characterization Report (Wood 2018).

The annual water budget for these same NHS features is summarized in Table B11to Table B14.

Table B11 Hall's Pond Annual Water Budget - 2003-2017 (mm/year)

Year	Precipitation	Evapotranspiration	Overland Net	Shallow Groundwater (Layer 1) Net Flow	Recharge	Storage Change
2003	761	-507	4	3	-270	-9
2004	777	-496	5	4	-276	13
2005	796	-544	7	4	-285	-22
2006	942	-523	48	5	-277	196
2007	548	-600	-23	4	-259	-330
2008	989	-533	26	4	-283	204
2009	795	-516	43	5	-257	70
2010	763	-550	3	3	-287	-68
2011	978	-544	127	3	-301	262
2012	656	-588	-14	3	-296	-238
2013	945	-525	24	3	-304	144
2014	696	-526	5	3	-294	-115
2015	761	-551	3	3	-310	-95
2016	769	-595	3	3	-304	-124
2017	831	-546	23	3	-295	17
AVERAGE	**801**	**-543**	**19**	**3**	**-286**	**-6**

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Table B12 Neumann's Pond Annual Water Budget - 2003-2017 (mm/year)

Year	Precipitation	Evapotranspiration	Overland Net	Shallow Groundwater (Layer 1) Net Flow	Recharge	Storage Change
2003	761	-616	114	8	-274	-6
2004	777	-616	93	10	-277	-13
2005	796	-643	150	9	-275	37
2006	942	-670	171	14	-295	162
2007	548	-681	66	11	-276	-333
2008	989	-666	177	6	-270	237
2009	795	-667	138	15	-292	-11
2010	763	-694	123	7	-274	-75
2011	978	-694	435	8	-291	436
2012	656	-760	61	8	-312	-347
2013	945	-663	149	9	-295	145
2014	696	-659	100	10	-287	-141
2015	761	-678	102	7	-273	-82
2016	769	-733	106	8	-275	-125
2017	831	-679	115	11	-275	3
AVERAGE	**801**	**-675**	**140**	**9**	**-283**	**-7**

Table B13 Halligan's Pond Water Budget - 2003-2017 (mm/year)

Year	Precipitation	Evapotranspiration	Overland Net	Shallow Groundwater (Layer 1) Net Flow	Recharge	Storage Change
2003	761	-532	-126	2	-148	-44
2004	777	-522	-122	3	-139	-3
2005	796	-570	-116	3	-147	-34
2006	942	-551	-87	6	-129	181
2007	548	-628	-141	4	-128	-345
2008	989	-560	-99	4	-140	194
2009	795	-543	-81	6	-113	64
2010	763	-578	-131	2	-155	-99
2011	978	-571	110	2	-151	367
2012	656	-618	-144	2	-156	-261
2013	945	-551	-116	2	-156	125
2014	696	-551	-129	2	-148	-129
2015	761	-579	-135	1	-164	-116
2016	769	-624	-133	2	-141	-127
2017	831	-573	-111	3	-133	18
AVERAGE	**801**	**-570**	**-104**	**3**	**-143**	**-14**

Table B14 1992 Gordon Wood Lot Annual Water Balance - 2003-2017 (mm/year)

Year	Precipitation	Evapotranspiration	Overland Net	Shallow Groundwater (Layer 1) Net Flow	Recharge	Storage Change
2003	761	-616	114	8	-251	17
2004	777	-616	93	10	-260	4
2005	796	-643	150	9	-266	46
2006	942	-670	171	14	-312	146
2007	548	-681	66	11	-194	-250
2008	989	-666	177	6	-304	203
2009	795	-667	138	15	-303	-22
2010	763	-694	123	7	-249	-50
2011	978	-694	435	8	-307	420
2012	656	-760	61	8	-308	-343
2013	945	-663	149	9	-282	159
2014	696	-659	100	10	-277	-130
2015	761	-678	102	7	-246	-55
2016	769	-733	106	8	-251	-101
2017	831	-679	115	11	-263	15
AVERAGE	**801**	**-675**	**140**	**9**	**-271**	**4**

The surface water and groundwater conditions for Hall's Pond and the supporting subcatchment are presented on Map B5. The simulated pond water budget indicates that that the primary inflows to the pond are precipitation with overland runoff and shallow groundwater contributing a relatively small proportion of the flows to the pond. The primary outflows from the pond are evapotranspiration and groundwater recharge. These simulated conditions of the pond, primarily providing groundwater recharge or leakage to the subsurface and supported by minor discharge contributions are consistent with the CM interpretation of conditions at Hall's Pond. Groundwater heads observed at the nearby monitoring well pairs of MW5-S and MW5-D and MW6-S MW6-D report water levels in the overburden deposits which underlie the ponds. The average simulated water level, 334 m, in these wells are similar the observed value of 335 m. This representation of average groundwater heads near the pond may be considered reasonable as up to 2 m of seasonal head change has been observed in the transient water levels observed in the monitoring wells for the 2016-2017 monitoring period. This result provides confidence that conditions in Halls pond are being reasonable represented.

The surface water and groundwater conditions for Neumann's pond are presented on Map B6. The simulated water budget indicates that the primary inflows to the pond are precipitation with overland runoff providing a moderate contribution and local shallow groundwater flow providing a minor contribution. The moderate overland runoff contributions are considered to be a result of the steep local topography within the catchment and small travel distance between the edges of the catchment and the pond itself leaving limited opportunity for losses to evapotranspiration or infiltration. The primary outflows from the pond are evapotranspiration groundwater recharge. The simulated conditions of the pond indicate that after losses to evapotranspiration balance of the pond water supports groundwater recharge. Groundwater heads observed at the nearby historic monitoring wells of MW2-11 and MW2 report water levels in the overburden deposits underlying the pond. The average simulated water level, 333 m, in these wells is similar to the observed value of 331 m. This result is considered reasonable given 2 m of seasonal head change observed in monitoring wells and provides confidence that conditions at Neumann's pond are reasonably represented by the model.

The surface water and groundwater conditions for Halligan's Pond are presented on Map B7. The simulated water budget indicates that the primary inflow to the pond is precipitation. The primary outflows of the pond are evapotranspiration and groundwater recharge with overland flow losses contributing a moderate component. Analysis of overland flow from the pond indicates these losses are to the adjacent pond just south east of Halligan's Pond and occur intermittently during high water level periods after large precipitation events. Water budget analysis of Halligan's Pond and the simulated groundwater recharge distribution indicate that Halligan's acts to recharge the groundwater flow system. Groundwater heads observed near the pond are interpreted to be approximately 330 m on average and average simulated groundwater levels are 332 m in the vicinity of the pond. Similar to Hall's and Neumann's pond conditions at Halligans are on average within 2 m of observed conditions on average. Given the seasonal head changes observed in the region this result provides confidence that conditions at the pond are being reasonably represented.

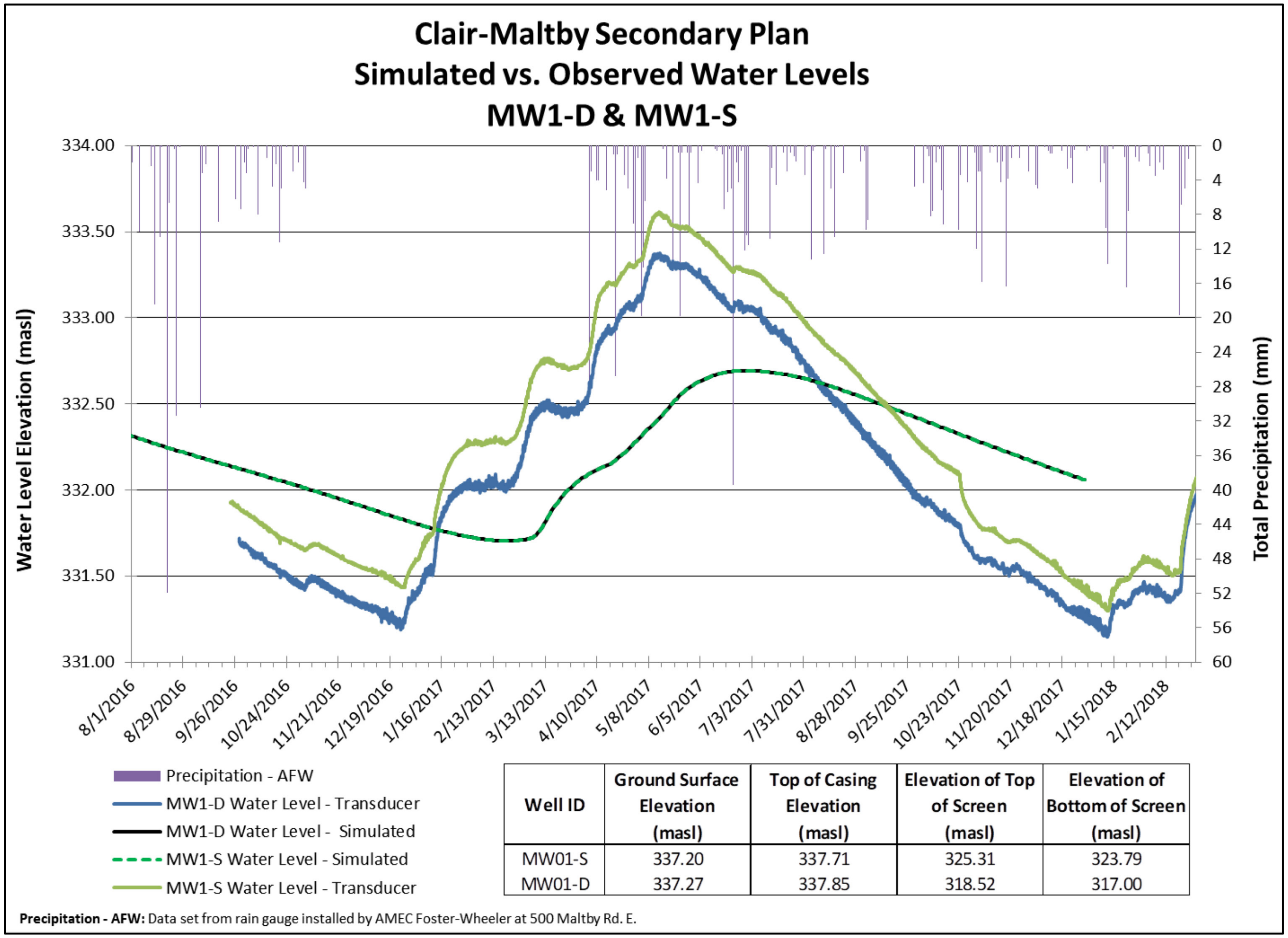
The surface water and groundwater conditions for the 1992 Gordon St. Woodlot are presented on Map B8. The simulated water budget indicates that the principal inflow to this area is precipitation. Shallow groundwater flow and overland flow provide negligible contributions to the area water budget when inflows and outflows are summed. Similar to all the features the primary outflow of the area is evapotranspiration with losses to groundwater recharge comprising the majority of the remaining outflows. Groundwater heads observed adjacent to the woodlot at monitoring wells MW4-S and MW4-D, which monitor head in the overburden deposits the woodlot is situated on, report an average head value of 335.5 m, while simulated heads are 334.3 m. Given the observed seasonal head change of 2 m these results are considered reasonable and build confidence that conditions in the woodlot are reasonably represented.

It is noted that for all catchments and ponds the water budget analysis indicates that conditions within these areas appear relatively stable; the long-term change in storage over the period of analysis, 2003-2017 is small. Years of drought conditions, which result in losses to water storage in the catchments and ponds, are balanced by years of high precipitation, which result in increases in water storage in the ponds and catchments.

B3.4 Transient Water Levels

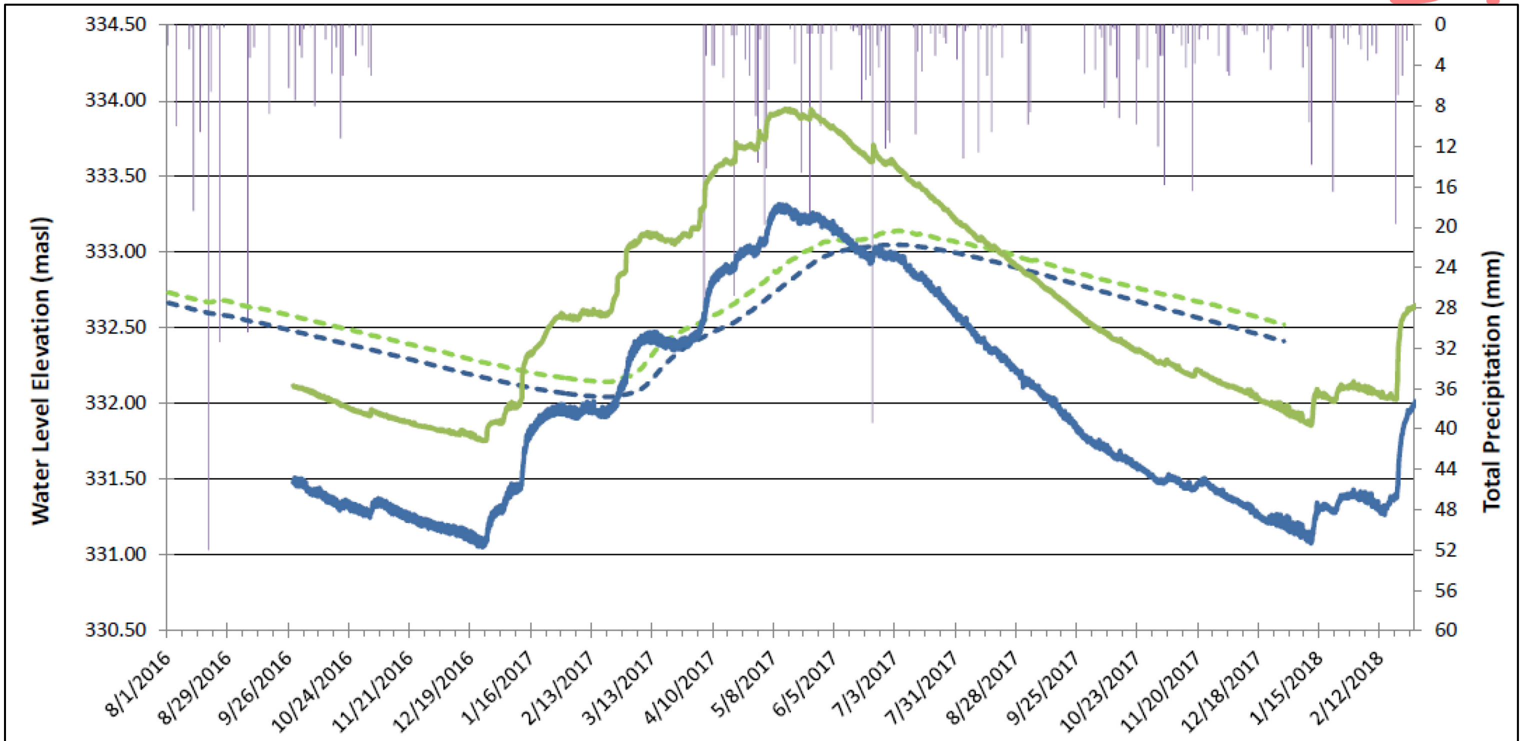
A comparison of the simulated and observed transient water levels for monitoring wells drilled as part of the this study show a good match to average water levels and a good representation of the timing of seasonal and year to year increases and decreases in water levels. The simulated variation in water levels is typically +/- 0.5 m, up to +/- 1 m compared to an observed variation of +/- 0.5 m up to +/- 2 m. The difference in magnitude of the variation of water level is small compared to average depth to water at these wells which is on average approximately 10 m. It is expected that the model is therefore providing a good estimate of average annual and seasonal recharge rates and groundwater levels. The difference in magnitude will be considered when completing the impact assessment and evaluation of stormwater options. However, the calibrated model is considered suitable for representing existing conditions and completing the impact assessment.

The observed and predicted water levels at the monitoring wells are summarized on Figure B6 to Figure B13 below.



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW01-S	337.20	337.71	325.31	323.79
MW01-D	337.27	337.85	318.52	317.00

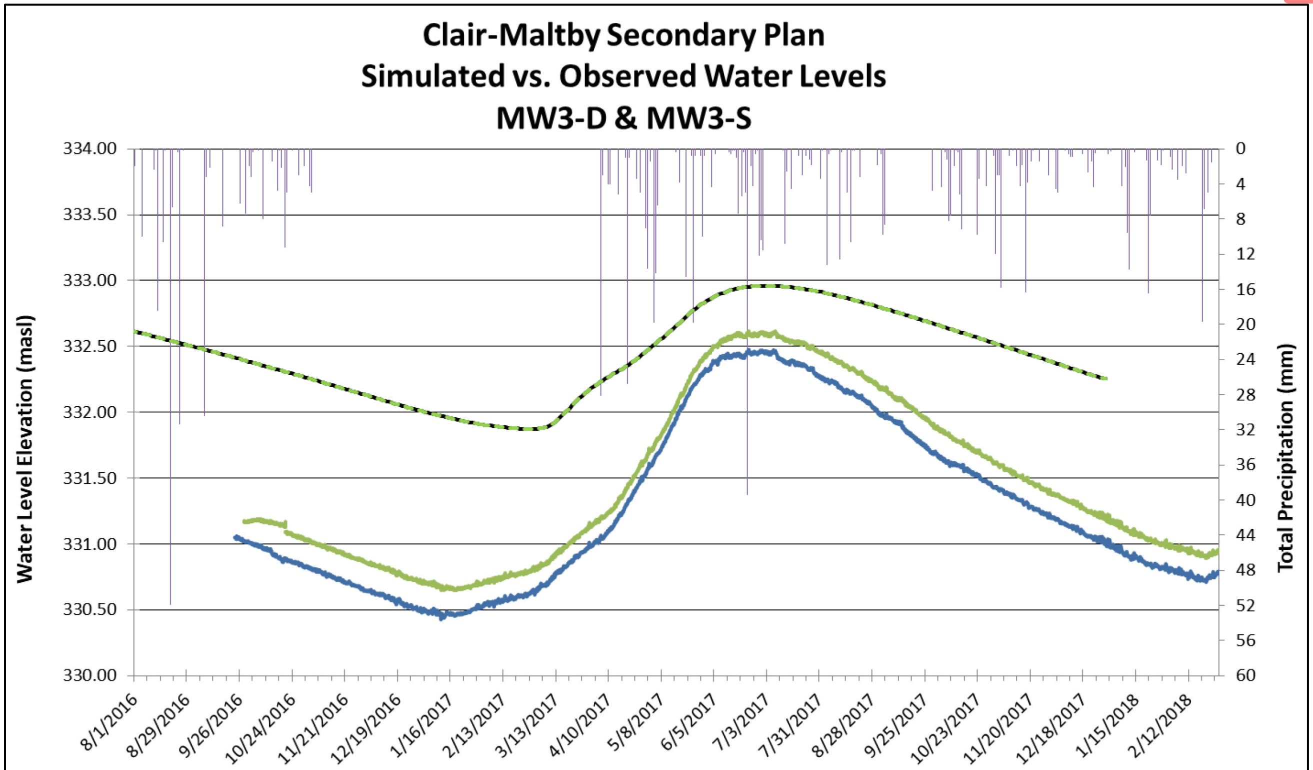
Figure B6 Simulated vs. Observed Water Levels at MW01-S and MW01-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW02-S	335.40	336.36	328.69	327.17
MW02-D	335.29	336.11	316.09	314.56

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

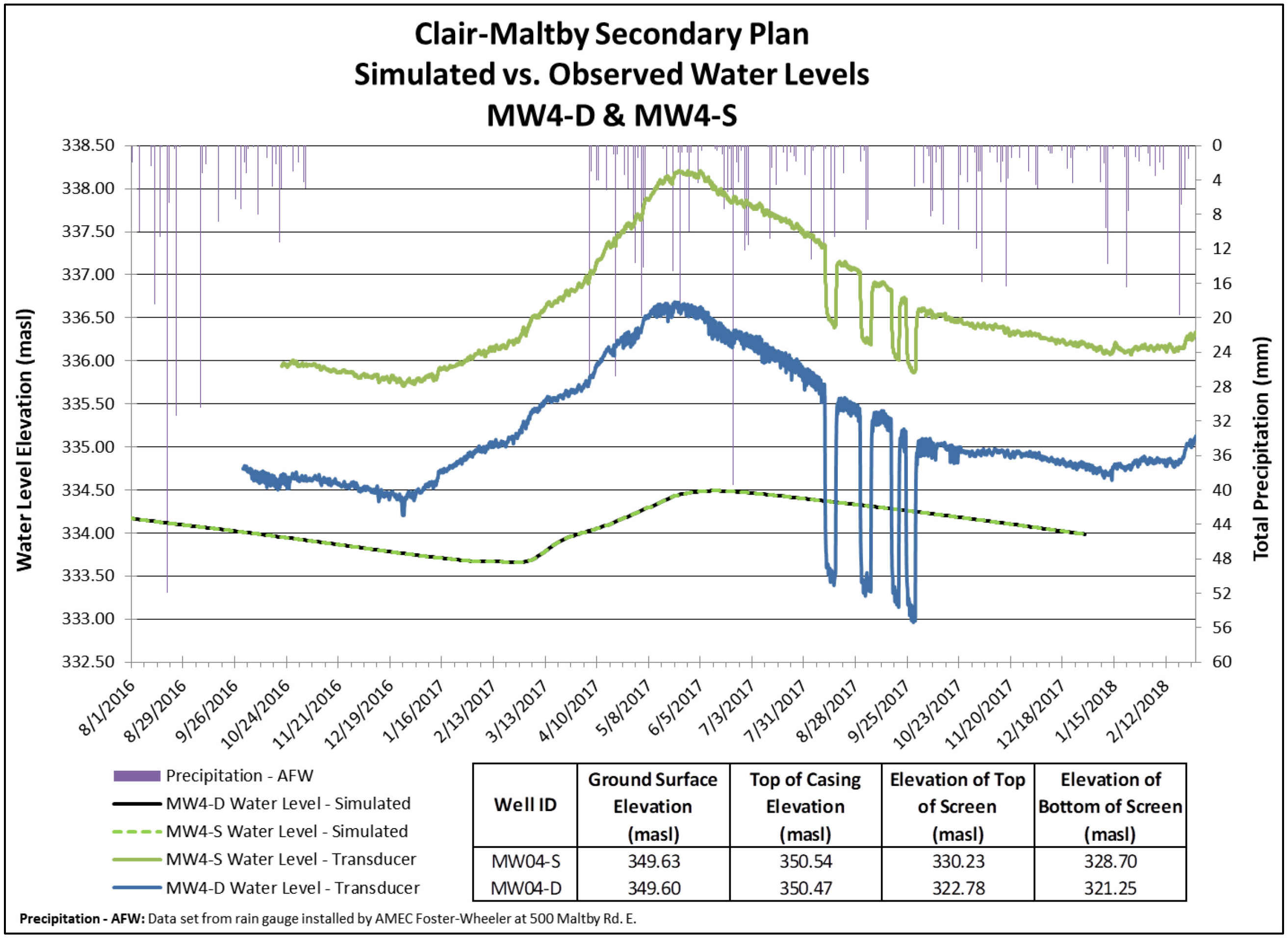
Figure B7 Simulated vs. Observed Water Levels at MW02-S and MW02-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW03-S	349.95	350.70	328.31	326.79
MW03-D	350.05	350.80	317.44	315.91

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

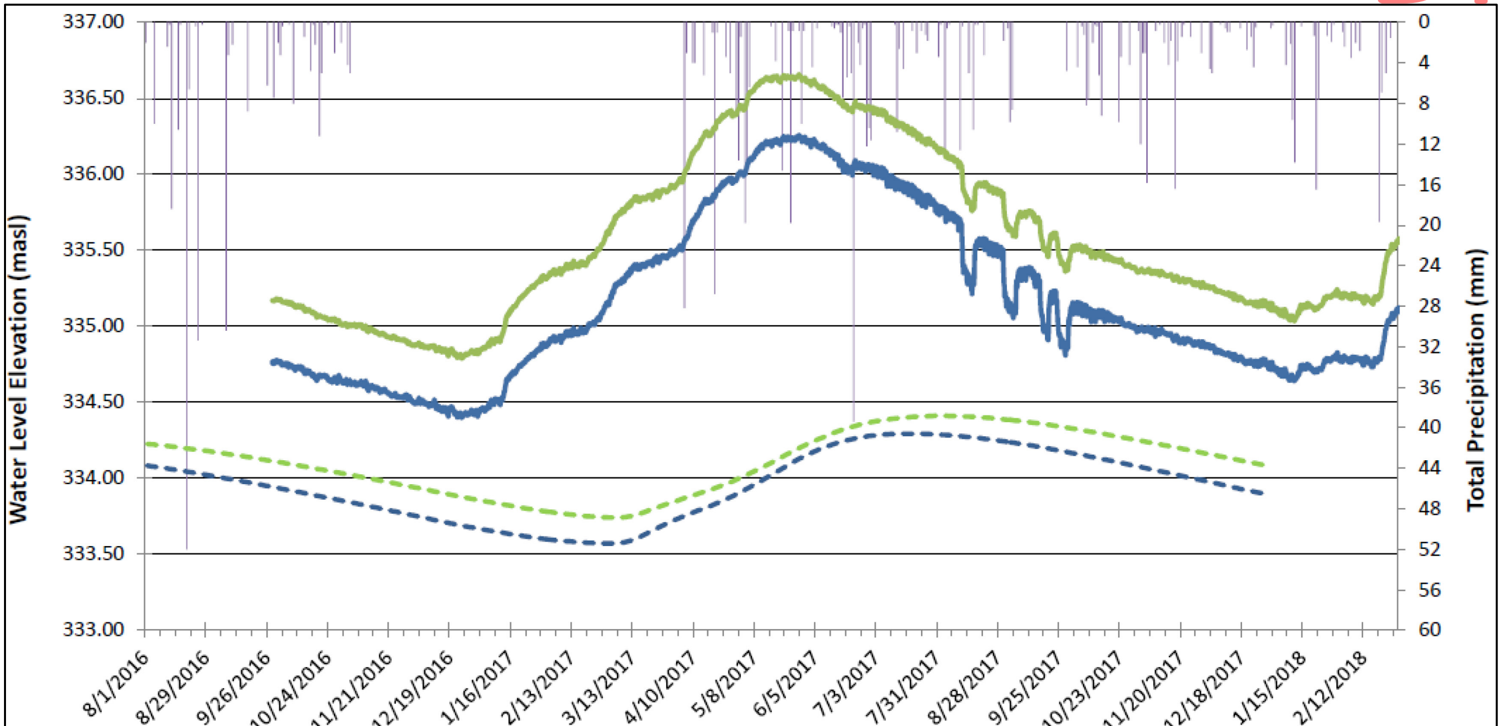
Figure B8 Simulated vs. Observed Water Levels at MW03-S and MW03-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW04-S	349.63	350.54	330.23	328.70
MW04-D	349.60	350.47	322.78	321.25

Figure B9 Simulated vs. Observed Water Levels at MW04-S and MW04-D

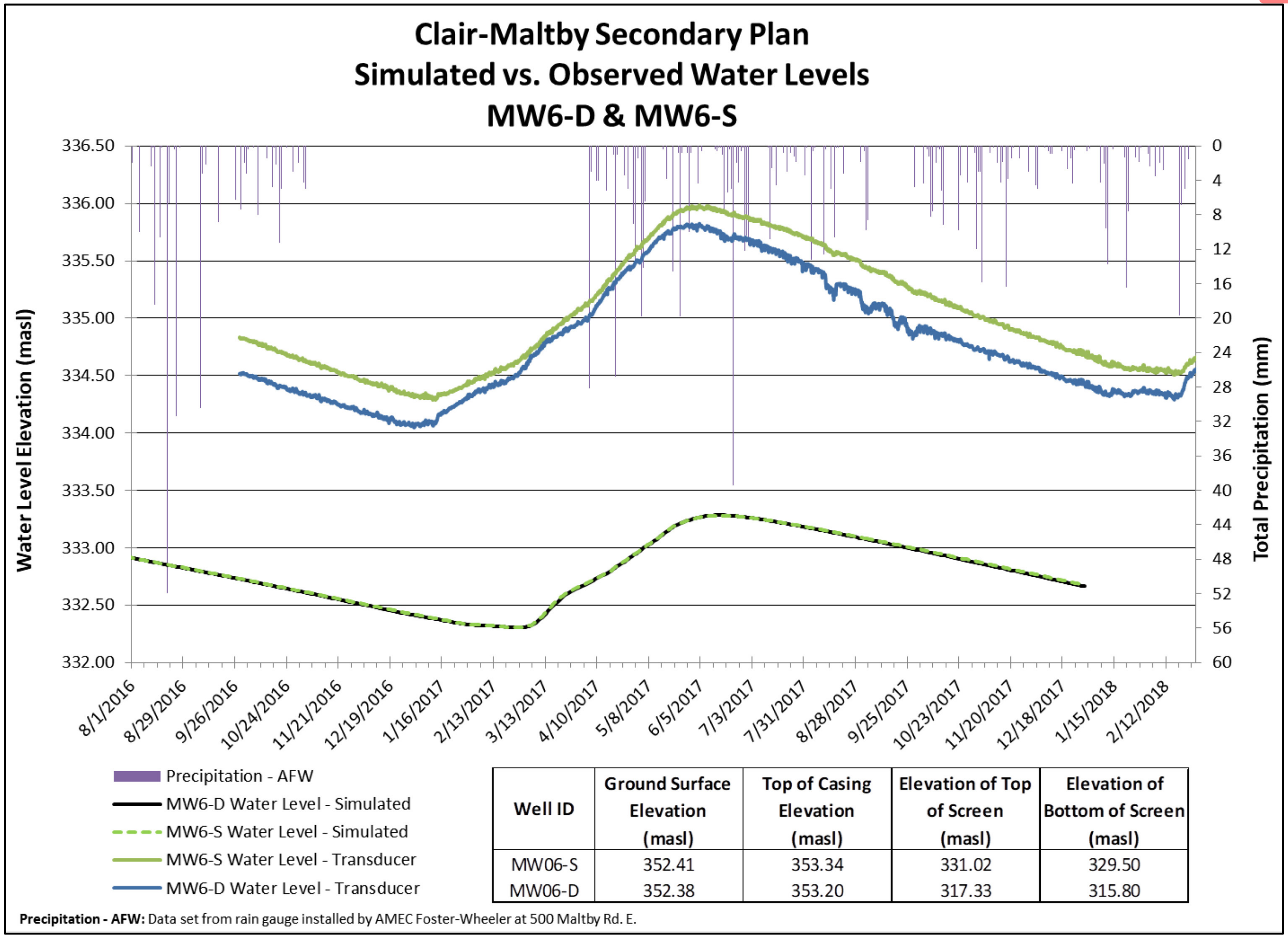
DRAFT



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW05-S	340.16	341.11	324.92	323.40
MW05-D	340.17	341.10	317.61	316.09

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

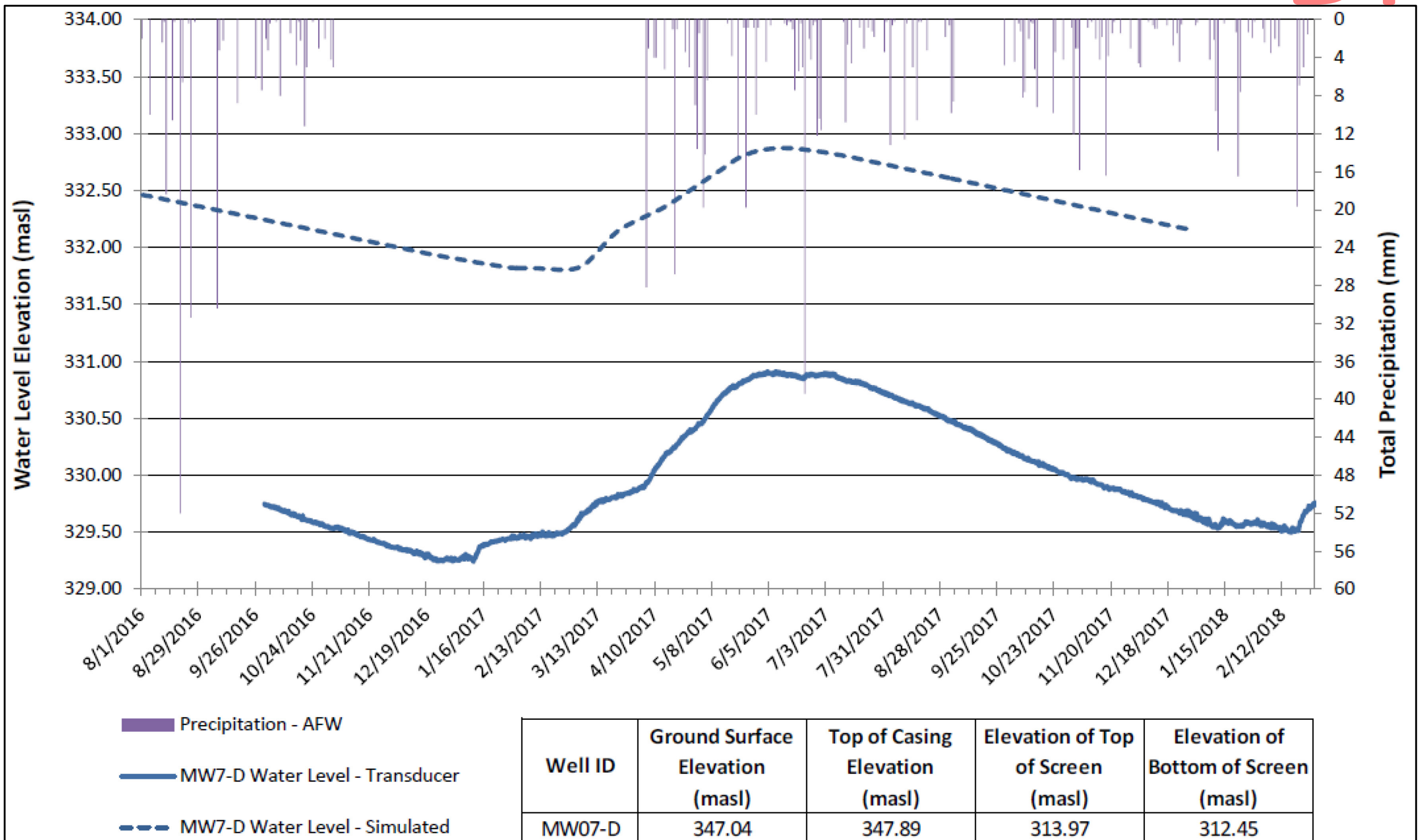
Figure B10 Simulated vs. Observed Water Levels at MW05-S and MW05-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW06-S	352.41	353.34	331.02	329.50
MW06-D	352.38	353.20	317.33	315.80

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

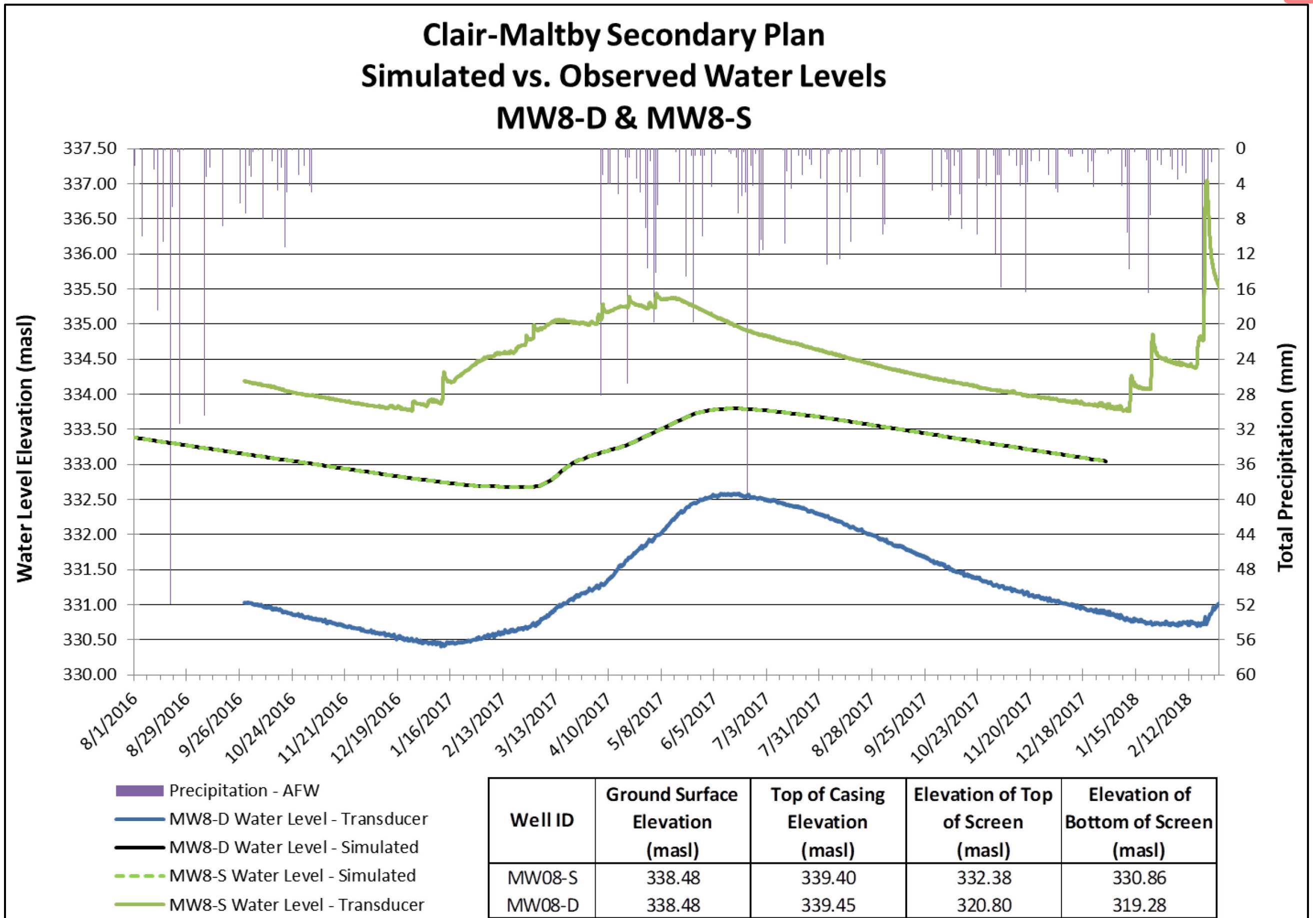
Figure B11 Simulated vs. Observed Water Levels at MW06-S and MW06-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW07-D	347.04	347.89	313.97	312.45

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

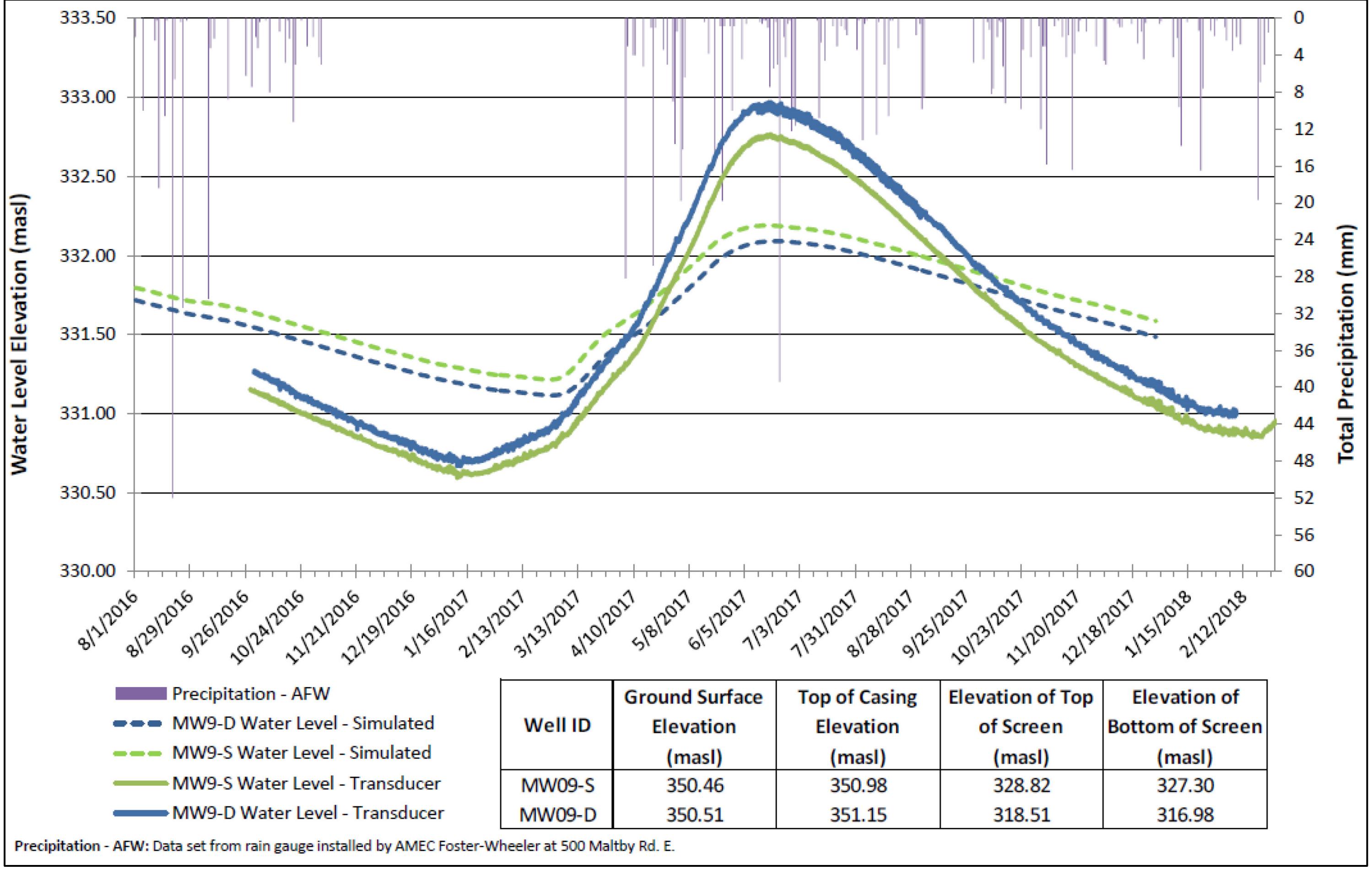
Figure B12 Simulated vs. Observed Water Levels at MW07-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW08-S	338.48	339.40	332.38	330.86
MW08-D	338.48	339.45	320.80	319.28

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

Figure B13 Simulated vs. Observed Water Levels at MW08-S and MW08-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW09-S	350.46	350.98	328.82	327.30
MW09-D	350.51	351.15	318.51	316.98

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

Figure B14 Simulated vs. Observed Water Levels at MW09-S and MW09-D

B3.4.1 Comparison of Simulated and Observed Conditions Local Hydraulic Gradients and Head Differences

The SSA model is intended to evaluate conditions in the SSA at a variety of physical scales as such the structure of the numerical model was designed to represent to the degree possible large and small-scale hydrologic processes in part to evaluate potential impacts on ponds and wetlands. Therefore to meet the modelling objectives the modelling approach applied balances the need for appropriate spatial resolution, temporal resolution, model domain extent and model runtimes to represent large and small-scale processes reasonably.

The piezometers (MP locations) located near key NHS surface water features measure shallow small-scale localized conditions and provide insight on small-scale interaction between groundwater and surface water features. The larger scale function of these features and connections of the surface water features and groundwater system and water budgets are evaluated with the model by comparison of differences and water levels between the surface water, deeper piezometers (MPs) and monitoring wells (MW).

A summary of hydraulic gradients and head differences observed and simulated at the NHS ponds and other features in the SSA is provided in Table B15. For the purposes of discussing head difference magnitudes in the summary table following categorizations used:

- small head difference = 0 to 2 m
- moderate head difference = 2 to 5 m
- large head difference = 5+ m

The hydraulic gradients observed between the shallow subsurface and the deep groundwater system at the NHS ponds are reasonably represented by the model for the period of observation in terms of vertical flow direction and magnitude. The model achieves a reasonable representation of conditions at most of the remaining MP observation locations.

Table B15 Simulated and Observed Local Hydraulic Conditions

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
Neumann's Pond	MP01-S, MP01-D and MW1-11	Small downward.	Small upward.	Large downward.	Large downward.	Large downward.	Large downward.	The gradient simulated in the shallow subsystem opposite in direction than that observed. Evaluation of local head conditions simulated indicates this is a localised condition around the edge of the pond. Further the low conductivity organic material conceptualized at the pond base serves to limit the flux into the pond from the shallow system despite upward gradients. This is confirmed through water budget analysis that indicates minimal contribution of flow from the shallow subsurface to the pond. The gradients observed and simulated are similar from pond to deep system and shallow to deep subsurface systems. Conditions simulated are representative of observed conditions.
Hall's Pond	MP07-S, MP07-D and MW05-D	Small downward.	Varying small downward to small upward.	Moderate downward.	Moderate downward.	Moderate downward.	Moderate downward.	The gradients observed and simulated are similar in the pond to shallow subsurface, pond to deep subsurface and shallow to deep subsurface systems. Conditions simulated are representative of observed conditions. Additional Observations: For the period of July 2017 to October 2017 there is a reversal of vertical gradients indicated by the MP observations where the deep MP shows a discharging condition to the surface water body. This condition likely represents a localized subsurface condition and at a larger scale the gradient between the shallow subsurface and deep groundwater system remains consistent
Halligan's Pond	MP013-S and MP013-D, MW03-D	Small downward.	Neutral gradient.	Moderate downward.	Small downward.	Moderate downward.	Small downward.	The gradients observed and simulated are similar in the pond to shallow system and underestimated in the pond to shallow subsurface and shallow to deep subsurface. The magnitude of the gradient simulated is less than observed which may serve to underestimate leakage from the pond. However the observations at MW03-D, the closest high quality monitoring well, are upwards of 500 m away from the pond and may not be representative of local conditions. Further the CM interpretation of conditions under Halligan's Pond maintains the possibility of sustained saturated conditions being present below the pond. The simulated conditions are more consistent with this interpretation. Conditions simulated are representative of observed interpreted conditions.

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
1992 Gordon St. Woodlot	MP03, MP04, MP08, MW04-D and MW05-D	Neutral to small downward	Small upward to large downward.	Moderate to large downward.	Moderate to large downward.	Large downward.	Small to moderate downward.	The gradients simulated in the pond to shallow subsurface system are overestimated relative to observations. The simulated gradient between the pond system and deep subsurface are similar to observations. The simulated gradient between the shallow subsurface and deep subsurface is underestimated. As a result the model may overestimate leakage from the shallow pond to the shallow subsurface. However this leakage is expected to be relatively limited given the low conductivity organic material conceptualised at the base of the ponds (Kz = 1e-8 m/s). Further the gradient in the pond to deep subsurface system is similar to observations suggesting the larger scale pond to deep subsurface system is represented reasonably. The combination of local MP representation and the reasonable representation of conditions at monitoring wells MW04-S and MW04-D and consistent representation of ponded water extent on mapped ponded areas within the woodlot indicate that conditions simulated are reasonably representative of observed conditions Additional Observations: The seasonal response predicted at the MP locations appears similar in timing but reduced magnitude at the MP locations.
Neumann's Pond 2	MP02 and MW1-11	Small upward.	Small downward to small upward.	Large downward.	Large downward.	Large downward.	Large downward.	The gradients simulated are similar to those observed in all systems. Conclusion: Conditions are representative of observed conditions. Additional Observations: The predicted seasonal response of the MPs simulated is similar to the observed seasonal response.
Marcolongo	MP05 and MW05-D	Small upward or downward.	Moderate downward gradient	Moderate downward.	Moderate downward.	Moderate downward.	Small downward.	The pond to shallow subsurface gradient is overestimated by the model and correspondingly the shallow to deep subsurface gradient is underestimated. This may result in predicted leakage greater than observed by the model. However this leakage is expected to be relatively limited given the low conductivity organic material conceptualised at the base of the ponds (Kz = 1e-8 m/s). Further the gradient in the pond to deep subsurface system is similar to observations suggesting the larger scale pond to deep subsurface system is represented reasonably. Conclusion: Conditions are reasonably representative of observed conditions.

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
Marcolongo	MP06 and MW05-D	Small upward or downward.	Small upward or downward.	Moderate downward.	Moderate downward.	Moderate downward.	Moderate downward.	The gradients simulated are similar to those observed in all systems. Conclusion: Conditions are reasonably representative of observed conditions. Additional Observations: The simulated seasonal response of the shallow subsurface to similar compared to observations in terms of timing but muted in terms of magnitude.
Kilkenny Cul-De-Sac	MP09 and MW02-D	No observations	Moderate downward gradient	No observations	Moderate downward.	Small upward to small downward.	Small downward.	The magnitude of the shallow to deep subsurface gradient observed is at times underestimated by the model which may result in predicted leakage which is less than observed in this location. However the impact of this underestimation on pond leakage is expected to be limited based the low conductivity materials conceptualised at ponds in the area. Conditions are reasonably representative of observed conditions. The simulated response of the shallow subsurface to the spring freshet is very similar to observations in terms of timing.
Tim Horton's	MP10 and MW07-D	Small upward to neutral.	Small upward.	Small downward.	Small upward.	Small downward.	Small upward.	While the simulated pond to shallow subsurface gradients are similar to observed the pond to deep subsurface and shallow to deep subsurface system gradients are the opposite of observed conditions. The issues replicating observed conditions are a result of the deeper water system water levels being too high here. The misfit will cause discharge at this feature rather than leakage.
264 Maltby Road	MP11 and MW09-D	Small upward to neutral.	Ponding not simulated locally.	Moderate downward.	Ponding not simulated locally.	Moderate downward.	Large upward.	The model does not replicate conditions observed at this site. This may be a result of finer scale topography details associated with the road which are not captured by the 25x25 m resolution of the model.
Maltby Right-of-way (ROW)	MP12 and MW06-D	Small upward to small downward.	Large downward.	Moderate upward to moderate downward.	Large downward.	Moderate upward to moderate downward.	Moderate upward from deep system.	The model does not replicate conditions observed at this site. This may be a result of finer scale topography details associated with the road which are not captured by the 25x25 m resolution of the model.
Puslinch Stream	MP14 and MW06-D	No pond observed.	No pond simulated	Neutral to small upward gradient relative to ground surface	Small upward gradient relative to ground surface.	Large upward gradient	large upward gradient	The gradients simulated are similar to those observed in all systems. Conditions are reasonably representative of observed conditions.

B3.5 Spot Flows

Spot flow measurements were made at locations in Mill Creek and Hanlon Creek as part of this study (Map B4). The consistency of with Mill Creek and Hanlon Creek simulated baseflow in the initially larger model was checked against observed spot flows. Spot flows for Hanlon Creek are not within boundaries of the SSA model domain. A summary of spot flow conditions evaluated outside of the SSA is provided Table B16.

Table B16 Initial Regional Model - Observed Vs Simulated Baseflow Conditions

Drainage Area	Location	Observed Flows (L/s)			Simulated Flows (L/s)		
		Min	Max	Average	Min	Max	Average
Hanlon Creek	HC-HR2	0	1	0	0	0	0
Mill Creek	MC-C72	0	10	2	4	39	16.5
Mill Creek	MC-M2	0	3	1	0	0	0
Mill Creek	MC-V2	6	179	48	27	129	61
Mill Creek	MC-GN3	58	209	97	44	142	80

Spot flows observed in smaller headwater drainages are more difficult to represent due to the small drainage area the observation is dependent on. Conversely spot flows collected in locations further downstream which collect more drainage are easier to replicate and can provide a more representative evaluation of baseflow replication by the model given the increased area they represented. In general we observe that simulated flows are in agreement with observed flows.

Simulated discharge conditions for Hanlon and Mill Creek tributaries within the SSA model domain were compared against available observed water levels and mapped ponded water/wetlands see Table B17.

Table B17 SSA Model - Observed Vs Simulated Baseflow Conditions

Drainage Area	Location	Observed Flows (L/s)			Simulated Flows (L/s) or Mapped Discharge Conditions		
		Min	Max	Average	Min	Max	Average
Mill Creek	MC-M3	0	0	0	0	0	0
Mill Creek	MC-GN1	1	5	3	Consistent Discharge Conditions Identified at Location in Discharge Mapping		
Mill Creek	MC-GN2	2	5	3			

This comparison indicates consistent representation of field observations. Combined with the evaluation of spot flows in the larger initial model these simulated values represent the seasonal trends, locations and magnitude of conditions observed in the field and provides confidence the model can be used to represent discharge to Mill Creek.

B4 SIMULATED FLOW SYSTEM

The following sections characterize the hydrologic conditions predicted for flow system for period of 2003-2017. The results include maps that characterize the spatial distribution of hydrologic processes, map of groundwater recharge, as well as water budgets which provide an assessment of the contribution of hydrologic processes, e.g. evapotranspiration, in the SSA model.

The characterization of existing conditions, summarized in the following sections, will be used baseline conditions for comparison with the simulated impact of development alternatives.

Development alternatives will be evaluated for impacts, relative to existing conditions, through changes observed in:

- groundwater recharge and discharge areas and features
- groundwater flow linkages between recharge and discharge areas (groundwater functions)
- spatial and temporal variations in these groundwater functions
- PSA role in supporting municipal bedrock aquifers

The characterization provided by the SSA model of existing conditions will also serve as a basis to address the following model objectives:

- constraints and opportunities for future development to maintain groundwater function and support other objectives for stormwater management
- potential impacts of development alternatives on groundwater function in the PSA
- mitigation strategies (e.g. LIDs) to maintain groundwater function and inform overall stormwater management planning

Land use development alternatives will be assessed using the SSA model and compared against existing conditions to provide understanding of impacts, impact mitigation strategies and selection of a preferred design alternative.

B4.1 Simulated Average Depth to Water Table

A map depicting the spatial distribution of average depth to the groundwater table simulated for the period of 2003-2017 is presented on Map B9. This figure represents the average depth from the ground surface to the water table as simulated by the model.

B4.2 Simulated Ponded Water Locations

A map depicting the spatial distribution of ponded water areas is presented on Map B10. This map represents areas which feature ponded water exceeding 1 cm in depth for at least 10% of the simulation period (2003-2017).

B4.3 Simulated Groundwater Recharge

Water which passes through the unsaturated zone and reaches the water table is known as groundwater recharge. It is the portion of infiltration that is in surplus after meeting evapotranspiration and soil moisture needs above the water table. Evapotranspiration can also occur from below the water table. A map depicting the spatial distribution of average annual groundwater recharge for the period of 2003-2017 is presented on Map B11.

B4.4 Simulated Groundwater Discharge

Groundwater discharge occurs where the water table intersects ground surface typically in areas of topographic lows, locally or regionally. A map which depicts the areas groundwater discharge for the period of 2003-2017 is presented on Map B12.

B4.5 Water Budgets for Model Domain (SSA)

The average annual water budget for the period of 2003-2017 simulated by the MIKE SHE model is presented for model domain and the areas of Mill Creek, Hanlon Creek and Torrance Creek within the model domain in Table B18. The average annual groundwater recharge rates for 2003-2017 are summarized in Table B19.

The inflows of water to the model domain occur through precipitation, overland flow in, lateral groundwater flow through the overburden and bedrock and vertical flow through the underlying municipal aquifer. The outflows of water from the model domain occurs through evapotranspiration, overland flow out (groundwater discharge), lateral flow through the overburden, lateral flow through the bedrock, vertical flow to the underlying municipal aquifer and pumping

Table B20 presents the outflows as a percentage of total inflows. Table B21 presents the outlfows as a percentage of total groundwater inflows approximated as the simulated precipitation, groundwater inflow and change in storage less evapotranspiration.

Table B18 Average Annual Water Budget for SSA (2003-2017, mm/year)

Area/Catchment	Water Budget Component											
					Lateral Groundwater Flow				Vertical Groundwater Flow			
					Overburden		Bedrock Above Vinemount Formation		Across Vinemount Formation			
	Precipitation	Evapotranspiration	Overland Flow In	Overland Flow Out	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Pumping	Change in Storage
SSA Model Domain	801	480	0	108	17	44	35	126	0	99	2	-7
Mill Creek	801	498	1	188	41	36	140	194	1	66	7	-6
Hanlon Creek	801	472	0	86	9	60	42	186	0	64	0	-7
Torrance Creek	801	450	0	60	48	95	233	421	0	58	0	-4

Table B19 Average Annual Groundwater Recharge for SSA (2003-2017)

Area/Catchment	Groundwater Recharge (mm/year)
SSA Model Domain	325
Mill Creek	338
Hanlon Creek	326
Torrance Creek	302

Table B20 Water Budget Outflows as a Percentage of the Total Inflows for the SSA

Area/Catchment	Evapotranspiration	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
SSA Model Domain	56%	13%	5%	15%	12%	0%
Mill Creek	50%	19%	4%	20%	7%	1%
Hanlon Creek	55%	10%	7%	22%	7%	0%
Torrance Creek	41%	6%	9%	39%	5%	0%

Table B21 Water Budget Outflows as a Percentage of Total Groundwater Inflows (Inflows-Evapotranspiration) for the SSA

Area/Catchment	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
SSA Model Domain	28%	12%	33%	26%	1%
Mill Creek	38%	7%	39%	13%	1%
Hanlon Creek	22%	16%	48%	17%	0%
Torrance Creek	9%	15%	66%	9%	0%

B4.6 Secondary Plan Area Water Budgets

The water budgets for the catchments of Mill Creek, Hanlon Creek and Torrance Creek within the SPA are presented in Table B22. These water budgets represent existing conditions and will be used to evaluate water budgets under the development alternatives to help assess the potential impact of alternative development strategies in the SPA.

Table B23 shows the outflows by catchment within the SPA as a percentage of total groundwater inflows (precipitation and storage less evapotranspiration losses). This analysis indicates that approximately 30% to 40% of flow out of these catchments reaches the regional aquifer. This result is generally consistent with the water budget analysis performed on the larger catchment areas found within the SSA.

Table B22 Average Annual Water Budgets for the SPA (2003-2017)

	Water Budget Component											
					Lateral Groundwater Flow				Vertical Groundwater Flow			
					Overburden		Bedrock Above Vinemount Formation		Across Vinemount Formation			
Area/ Catchment	Precipitation	Evapotranspiration	Overland Flow In	Overland Flow Out	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Pumping	Change in Storage
Mill Creek in SPA	801	508	4	9	43	51	326	513	0	102	0	-10
Hanlon Creek in SPA	801	494	1	6	6	32	26	181	0	129	2	-10
Torrance Creek in SPA[1]	801	477	1	22	222	425	1761	1,780	0	88	0	-7

Note:
[1] High discharge rates simulate through lateral bedrock occur in Torrance Creek as a result of a relatively high flow through the bedrock in the Burke-Carter formation associated with the Burke Municipal Well and the relatively small domain area associated with Torrance Creek within the SPA.

Table B23 Water Budget Outflows as a Percentage of Total Groundwater Inflows (Inflows-Evapotranspiration) for the SPA

Area/Catchment	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
Mill Creek in SPA	1%	8%	76%	15%	0%
Hanlon Creek in SPA	2%	9%	52%	37%	1%
Torrance Creek in SPA	1%	18%	77%	4%	0%

B4.7 Natural Heritage System Features - Hydroperiod

A map depicting the simulated hydroperiod of the key NHS pond/wetland features is presented in Map B13. This map illustrates the simulated maximum and minimum extent of the ponds at a 0.25 m threshold depth simulated by the model for the period of 2003-2017. Evaluation of the maximum and minimum extent of the feature against aerial imagery provides a qualitative assessment of the ability of the model to represent the areal extent of the NHS ponds/wetlands, which can be used to approximate the hydroperiod of these features.

B4.8 Particle Tracking

Particle tracking provides a tool that links recharge and discharge areas and provides a means for further understanding the connection between recharge zones and potential receptors. Hypothetical particles were released within the first three layers of the MIKE SHE model and move through the simulated groundwater flow field to their discharge location or where they leave the model domain. The flow conditions observed for the period of 2007-2016 were used as representative conditions and repeated for a 200 year simulation to determine the ultimate fate of particles released in the overburden materials within the study area.

A map depicting the destination or fate of particles released in a given location is presented on Map B14. This map depicts where recharge at a given location in the model leaves the model by groundwater discharge or groundwater outflow.

A quantitative assessment of the particle tracking results is presented in Table B24. The columns have the following meaning:

- Percent of Total Particle Count:
  - Summarizes the destination of a particle based on the count of particles which arrived at a particular destination type as a percentage of the total number of particles released.
- Percent of Total Recharge Volume (Particle*Recharge Rate)

- This represents the multiplication of the recharge predicted on a cell by the cell destination type. In this way the magnitude of recharge associated with particles arriving at each destination type is considered. This number summarizes the fraction of total recharge associated with each particle destination type.

- Water Budget Proportion:
  - This is an approximation of the destination of recharge based on water budget assessment as summarized in Section 4.6.

Table B24 Particle Destination Summary Statistics

Destination Type	Percent of Total Particle Count	Percent of Total Recharge Volume (Particles* Recharge Value)	Water Budget % (Table B20)
Bedrock Vertical Flow Across Vinemount (Regional Aquifer)	31	32	26
Bedrock Lateral Flow Out	*29*	*29*	33
Overburden Lateral Flow Out	*11*	*11*	12
Discharge to Overland	28	27	28
Captured By Pumping Well	1	1	1

In general we observe that the water budget results and the particle tracking results are very similar. Small differences relate to the method used and simulation period for the model and the particle tracking process, 2003-2017 versus 2006-2017, respectively. Particles are only released initially in the particle tracking simulation at the start of the simulation period (January 2007) as opposed to continuously being released in differing flow conditions. We believe the particle tracking provides useful insight and confidence in the model results which agree with the CM interpretation (see 4.2.4).

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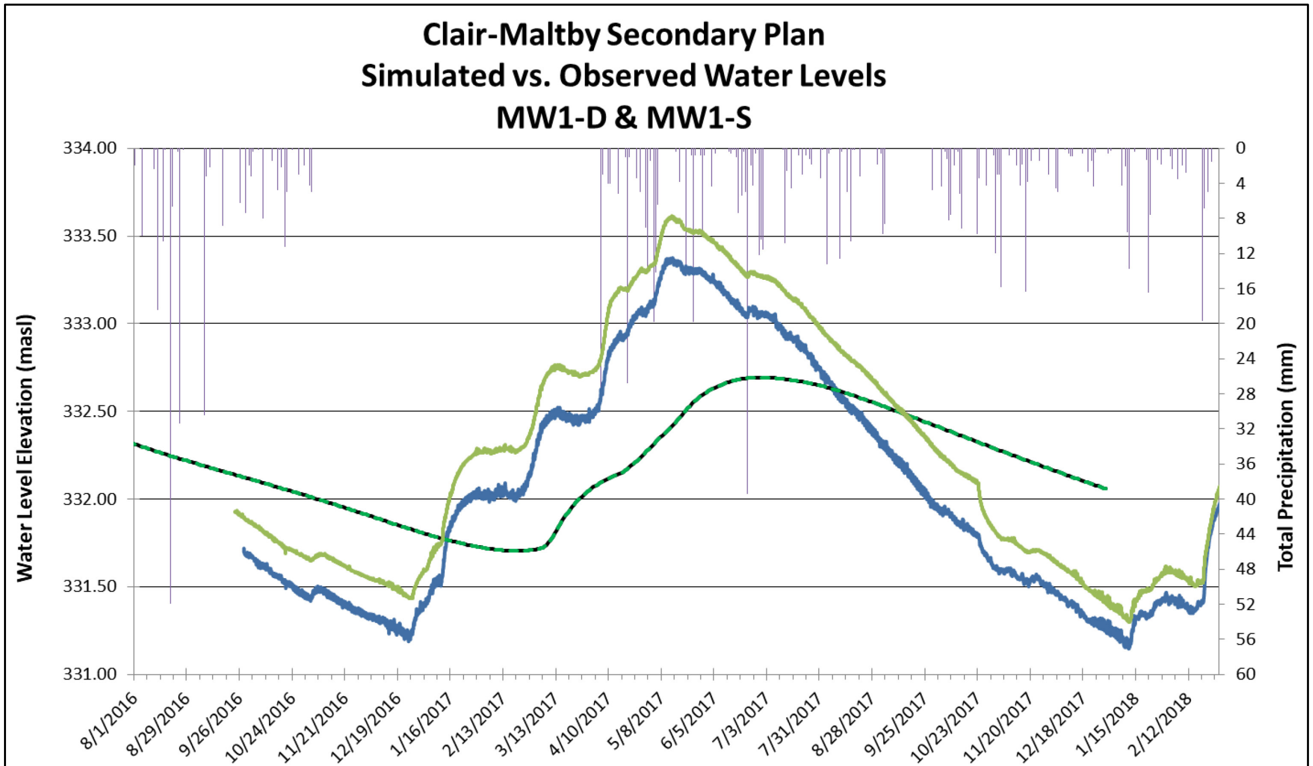
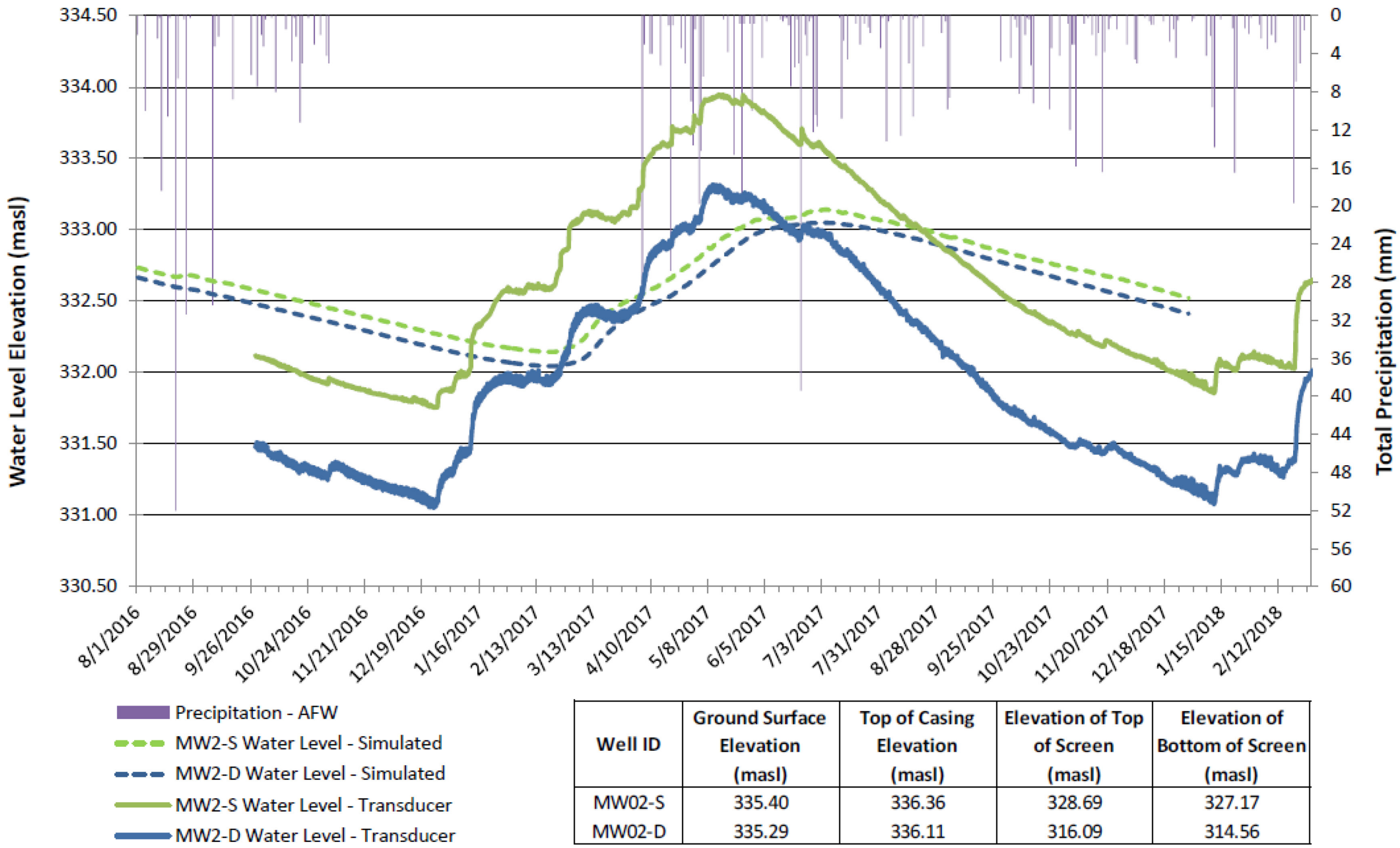


Precipitation - AFW
MW1-D Water Level - Transducer
MW1-D Water Level - Simulated
MW1-S Water Level - Simulated
MW1-S Water Level - Transducer

Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW01-S	337.20	337.71	325.31	323.79
MW01-D	337.27	337.85	318.52	317.00

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

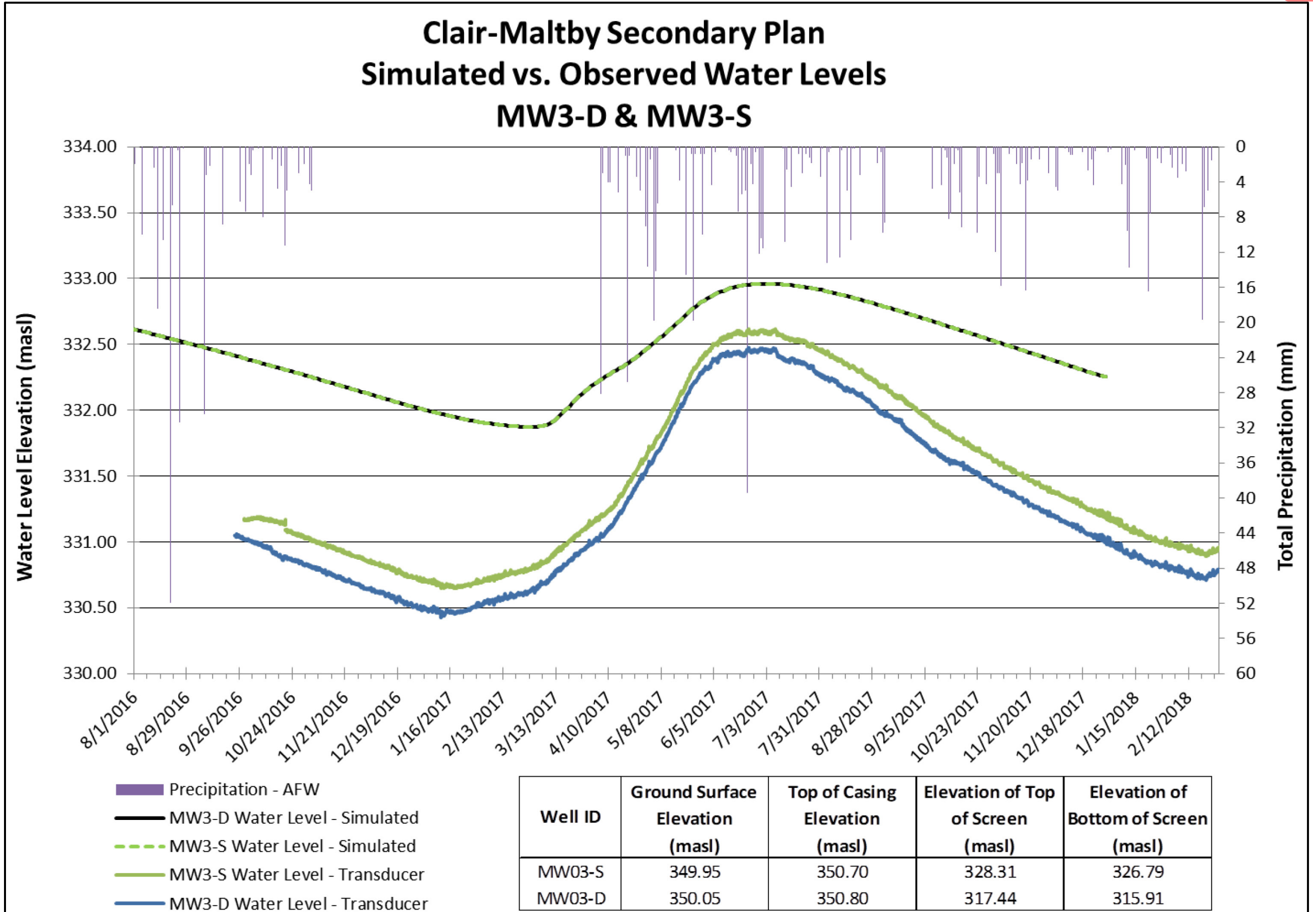
Figure B6 Simulated vs. Observed Water Levels at MW01-S and MW01-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW02-S	335.40	336.36	328.69	327.17
MW02-D	335.29	336.11	316.09	314.56

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

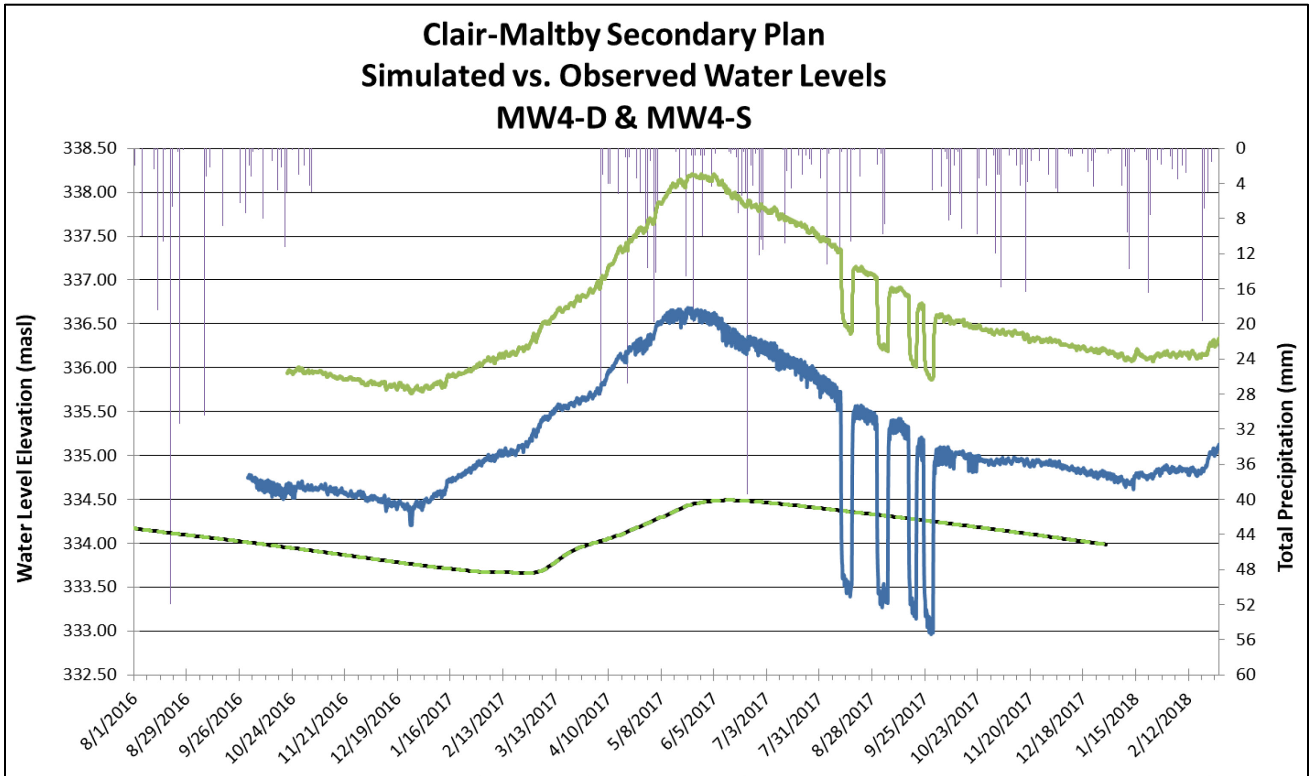
Figure B7 Simulated vs. Observed Water Levels at MW02-S and MW02-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW03-S	349.95	350.70	328.31	326.79
MW03-D	350.05	350.80	317.44	315.91

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

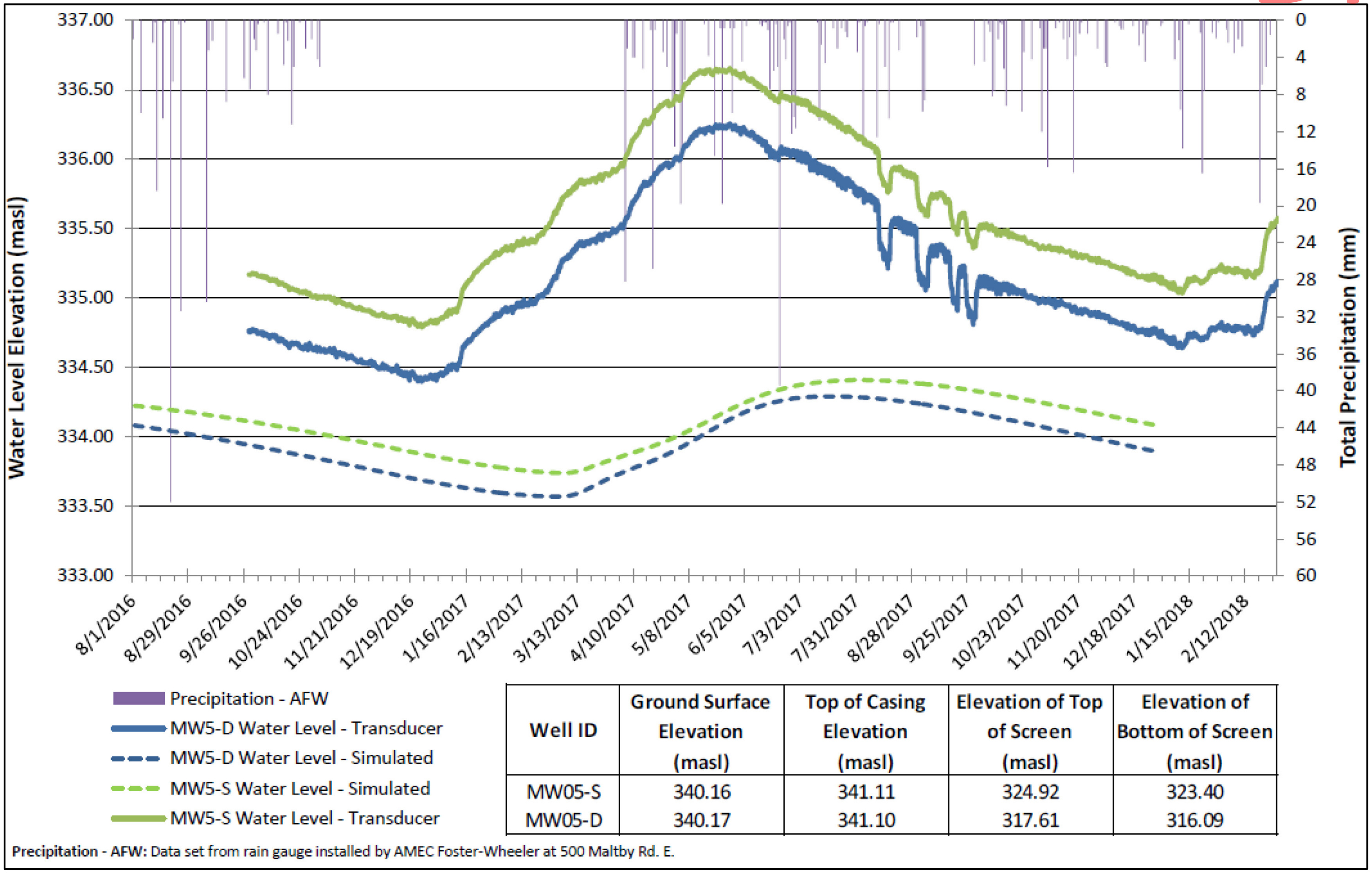
Figure B8 Simulated vs. Observed Water Levels at MW03-S and MW03-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW04-S	349.63	350.54	330.23	328.70
MW04-D	349.60	350.47	322.78	321.25

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

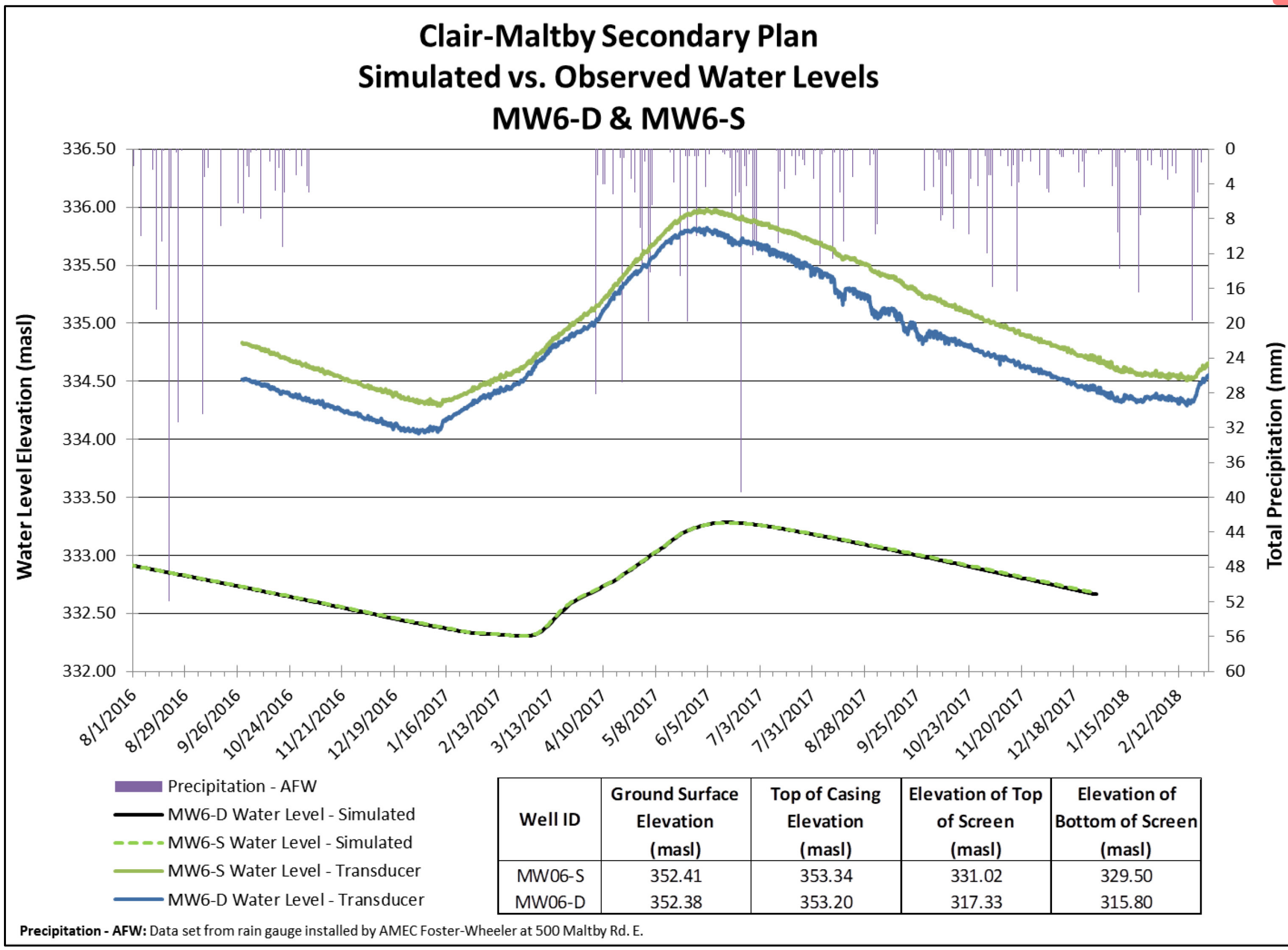
Figure B9 Simulated vs. Observed Water Levels at MW04-S and MW04-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW05-S	340.16	341.11	324.92	323.40
MW05-D	340.17	341.10	317.61	316.09

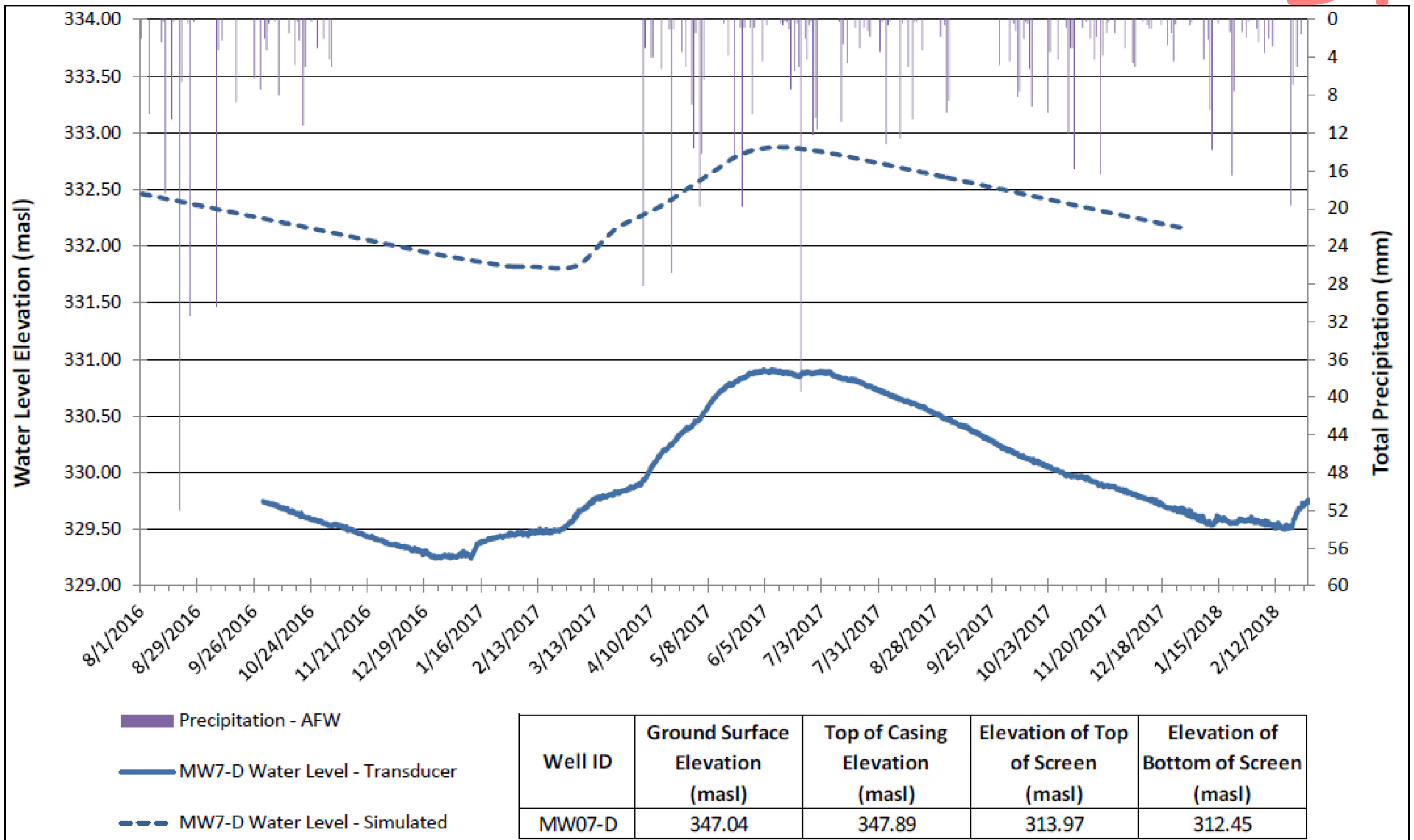
Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

Figure B10 Simulated vs. Observed Water Levels at MW05-S and MW05-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW06-S	352.41	353.34	331.02	329.50
MW06-D	352.38	353.20	317.33	315.80

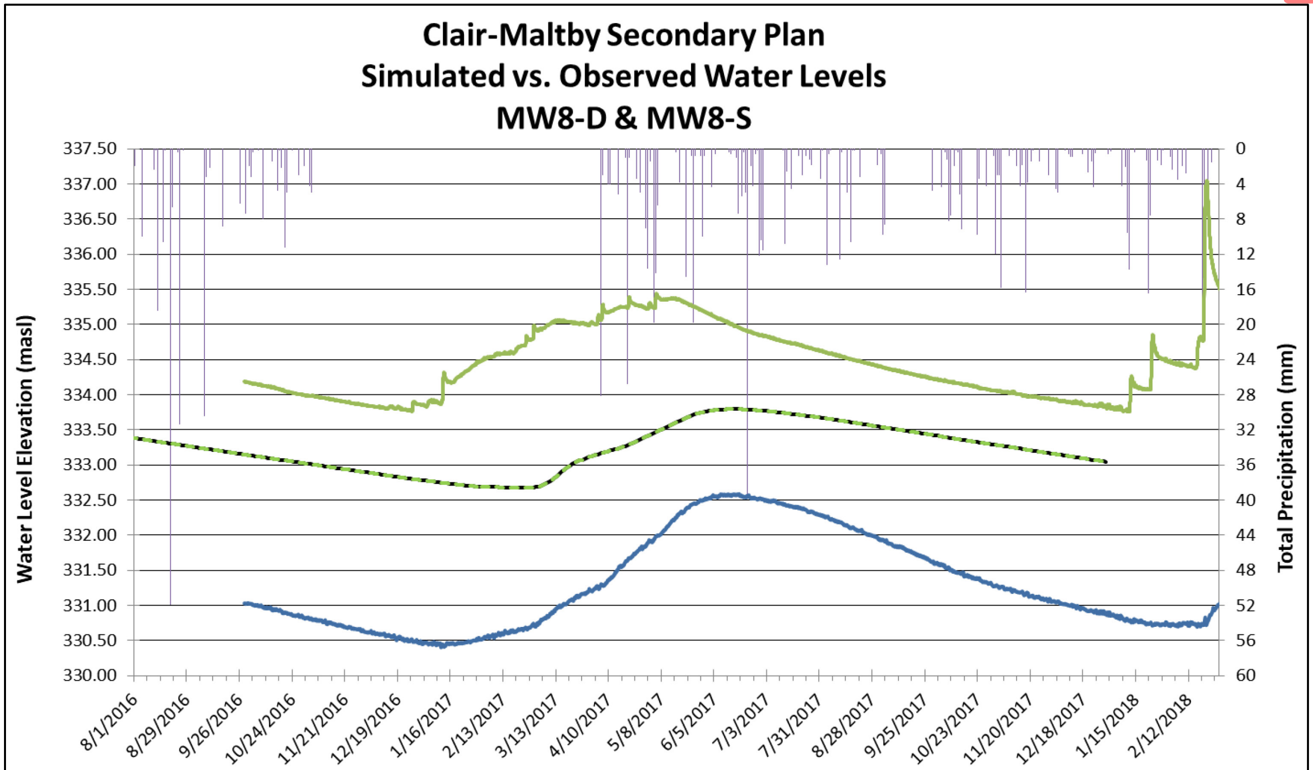
Figure B11 Simulated vs. Observed Water Levels at MW06-S and MW06-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW07-D	347.04	347.89	313.97	312.45

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

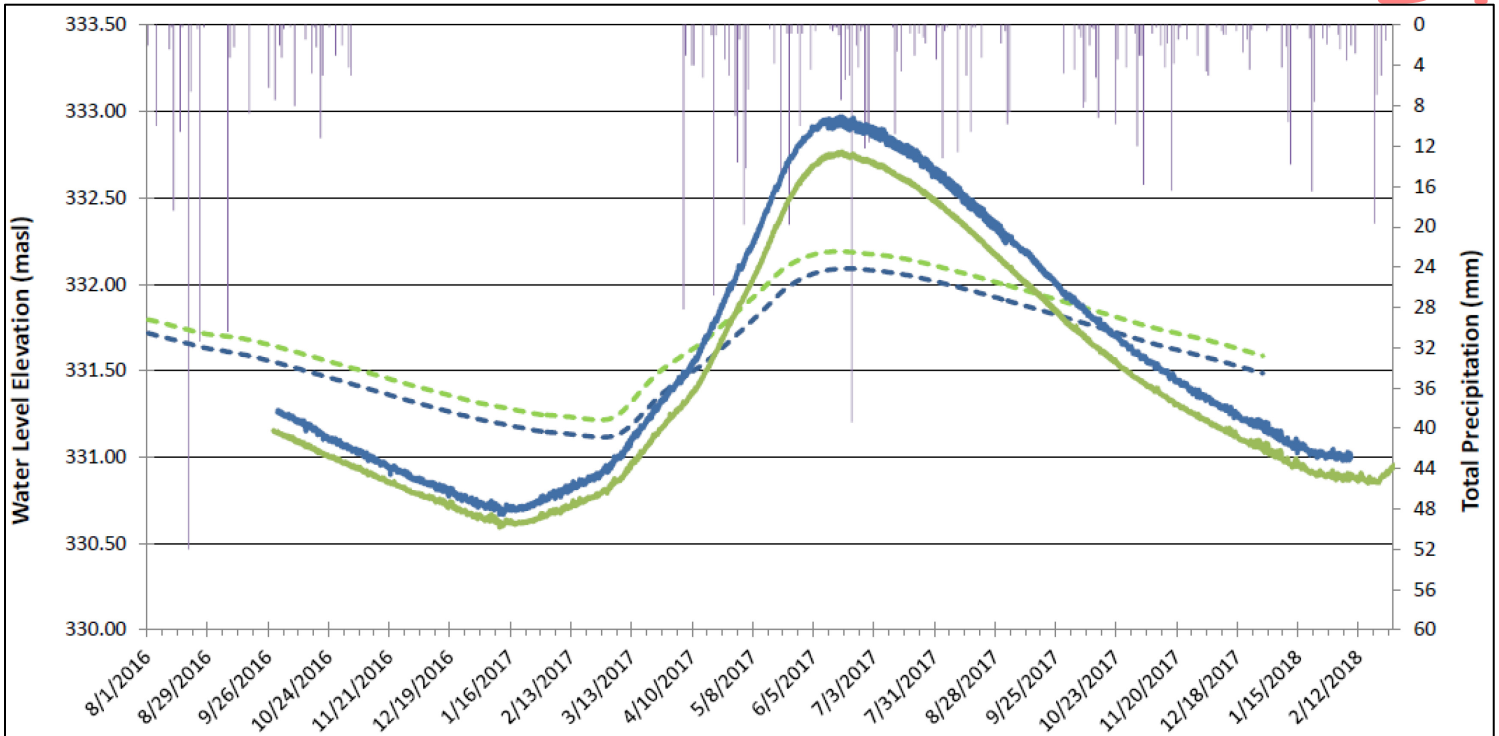
Figure B12 Simulated vs. Observed Water Levels at MW07-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW08-S	338.48	339.40	332.38	330.86
MW08-D	338.48	339.45	320.80	319.28

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

Figure B13 Simulated vs. Observed Water Levels at MW08-S and MW08-D



Well ID	Ground Surface Elevation (masl)	Top of Casing Elevation (masl)	Elevation of Top of Screen (masl)	Elevation of Bottom of Screen (masl)
MW09-S	350.46	350.98	328.82	327.30
MW09-D	350.51	351.15	318.51	316.98

Precipitation - AFW: Data set from rain gauge installed by AMEC Foster-Wheeler at 500 Maltby Rd. E.

Figure B14 Simulated vs. Observed Water Levels at MW09-S and MW09-D

B3.4.1 Comparison of Simulated and Observed Conditions Local Hydraulic Gradients and Head Differences

The SSA model is intended to evaluate conditions in the SSA at a variety of physical scales as such the structure of the numerical model was designed to represent to the degree possible large and small-scale hydrologic processes in part to evaluate potential impacts on ponds and wetlands. Therefore to meet the modelling objectives the modelling approach applied balances the need for appropriate spatial resolution, temporal resolution, model domain extent and model runtimes to represent large and small-scale processes reasonably.

The piezometers (MP locations) located near key NHS surface water features measure shallow small-scale localized conditions and provide insight on small-scale interaction between groundwater and surface water features. The larger scale function of these features and connections of the surface water features and groundwater system and water budgets are evaluated with the model by comparison of differences and water levels between the surface water, deeper piezometers (MPs) and monitoring wells (MW).

A summary of hydraulic gradients and head differences observed and simulated at the NHS ponds and other features in the SSA is provided in Table B15. For the purposes of discussing head difference magnitudes in the summary table following categorizations used:

- small head difference = 0 to 2 m
- moderate head difference = 2 to 5 m
- large head difference = 5+ m

The hydraulic gradients observed between the shallow subsurface and the deep groundwater system at the NHS ponds are reasonably represented by the model for the period of observation in terms of vertical flow direction and magnitude. The model achieves a reasonable representation of conditions at most of the remaining MP observation locations.

Table B15 Simulated and Observed Local Hydraulic Conditions

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
Neumann's Pond	MP01-S, MP01-D and MW1-11	Small downward.	Small upward.	Large downward.	Large downward.	Large downward.	Large downward.	The gradient simulated in the shallow subsystem opposite in direction than that observed. Evaluation of local head conditions simulated indicates this is a localised condition around the edge of the pond. Further the low conductivity organic material conceptualized at the pond base serves to limit the flux into the pond from the shallow system despite upward gradients. This is confirmed through water budget analysis that indicates minimal contribution of flow from the shallow subsurface to the pond. The gradients observed and simulated are similar from pond to deep system and shallow to deep subsurface systems. Conditions simulated are representative of observed conditions.
Hall's Pond	MP07-S, MP07-D and MW05-D	Small downward.	Varying small downward to small upward.	Moderate downward.	Moderate downward.	Moderate downward.	Moderate downward.	The gradients observed and simulated are similar in the pond to shallow subsurface, pond to deep subsurface and shallow to deep subsurface systems. Conditions simulated are representative of observed conditions. Additional Observations: For the period of July 2017 to October 2017 there is a reversal of vertical gradients indicated by the MP observations where the deep MP shows a discharging condition to the surface water body. This condition likely represents a localized subsurface condition and at a larger scale the gradient between the shallow subsurface and deep groundwater system remains consistent
Halligan's Pond	MP013-S and MP013-D, MW03-D	Small downward.	Neutral gradient.	Moderate downward.	Small downward.	Moderate downward.	Small downward.	The gradients observed and simulated are similar in the pond to shallow system and underestimated in the pond to shallow subsurface and shallow to deep subsurface. The magnitude of the gradient simulated is less than observed which may serve to underestimate leakage from the pond. However the observations at MW03-D, the closest high quality monitoring well, are upwards of 500 m away from the pond and may not be representative of local conditions. Further the CM interpretation of conditions under Halligan's Pond maintains the possibility of sustained saturated conditions being present below the pond. The simulated conditions are more consistent with this interpretation. Conditions simulated are representative of observed interpreted conditions.

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
1992 Gordon St. Woodlot	MP03, MP04, MP08, MW04-D and MW05-D	Neutral to small downward	Small upward to large downward.	Moderate to large downward.	Moderate to large downward.	Large downward.	Small to moderate downward.	The gradients simulated in the pond to shallow subsurface system are overestimated relative to observations. The simulated gradient between the pond system and deep subsurface are similar to observations. The simulated gradient between the shallow subsurface and deep subsurface is underestimated. As a result the model may overestimate leakage from the shallow pond to the shallow subsurface. However this leakage is expected to be relatively limited given the low conductivity organic material conceptualised at the base of the ponds (Kz = 1e-8 m/s). Further the gradient in the pond to deep subsurface system is similar to observations suggesting the larger scale pond to deep subsurface system is represented reasonably. The combination of local MP representation and the reasonable representation of conditions at monitoring wells MW04-S and MW04-D and consistent representation of ponded water extent on mapped ponded areas within the woodlot indicate that conditions simulated are reasonably representative of observed conditions Additional Observations: The seasonal response predicted at the MP locations appears similar in timing but reduced magnitude at the MP locations.
Neumann's Pond 2	MP02 and MW1-11	Small upward.	Small downward to small upward.	Large downward.	Large downward.	Large downward.	Large downward.	The gradients simulated are similar to those observed in all systems. Conclusion: Conditions are representative of observed conditions. Additional Observations: The predicted seasonal response of the MPs simulated is similar to the observed seasonal response.
Marcolongo	MP05 and MW05-D	Small upward or downward.	Moderate downward gradient	Moderate downward.	Moderate downward.	Moderate downward.	Small downward.	The pond to shallow subsurface gradient is overestimated by the model and correspondingly the shallow to deep subsurface gradient is underestimated. This may result in predicted leakage greater than observed by the model. However this leakage is expected to be relatively limited given the low conductivity organic material conceptualised at the base of the ponds (Kz = 1e-8 m/s). Further the gradient in the pond to deep subsurface system is similar to observations suggesting the larger scale pond to deep subsurface system is represented reasonably. Conclusion: Conditions are reasonably representative of observed conditions.

Feature	Observation Locations	Vertical Flow Conditions						Interpretation
		Pond to Shallow Subsurface Gradient and Head Difference		Pond to Deep Subsurface Gradient and Head Difference		Shallow Subsurface to Deep Subsurface Gradient and Head Difference		
		Observed	Simulated	Observed	Simulated	Observed	Simulated	
Marcolongo	MP06 and MW05-D	Small upward or downward.	Small upward or downward.	Moderate downward.	Moderate downward.	Moderate downward.	Moderate downward.	The gradients simulated are similar to those observed in all systems. Conclusion: Conditions are reasonably representative of observed conditions. Additional Observations: The simulated seasonal response of the shallow subsurface to similar compared to observations in terms of timing but muted in terms of magnitude.
Kilkenny Cul-De-Sac	MP09 and MW02-D	No observations	Moderate downward gradient	No observations	Moderate downward.	Small upward to small downward.	Small downward.	The magnitude of the shallow to deep subsurface gradient observed is at times underestimated by the model which may result in predicted leakage which is less than observed in this location. However the impact of this underestimation on pond leakage is expected to be limited based the low conductivity materials conceptualised at ponds in the area. Conditions are reasonably representative of observed conditions. The simulated response of the shallow subsurface to the spring freshet is very similar to observations in terms of timing.
Tim Horton's	MP10 and MW07-D	Small upward to neutral.	Small upward.	Small downward.	Small upward.	Small downward.	Small upward.	While the simulated pond to shallow subsurface gradients are similar to observed the pond to deep subsurface and shallow to deep subsurface system gradients are the opposite of observed conditions. The issues replicating observed conditions are a result of the deeper water system water levels being too high here. The misfit will cause discharge at this feature rather than leakage.
264 Maltby Road	MP11 and MW09-D	Small upward to neutral.	Ponding not simulated locally.	Moderate downward.	Ponding not simulated locally.	Moderate downward.	Large upward.	The model does not replicate conditions observed at this site. This may be a result of finer scale topography details associated with the road which are not captured by the 25x25 m resolution of the model.
Maltby Right-of-way (ROW)	MP12 and MW06-D	Small upward to small downward.	Large downward.	Moderate upward to moderate downward.	Large downward.	Moderate upward to moderate downward.	Moderate upward from deep system.	The model does not replicate conditions observed at this site. This may be a result of finer scale topography details associated with the road which are not captured by the 25x25 m resolution of the model.
Puslinch Stream	MP14 and MW06-D	No pond observed.	No pond simulated	Neutral to small upward gradient relative to ground surface	Small upward gradient relative to ground surface.	Large upward gradient	large upward gradient	The gradients simulated are similar to those observed in all systems. Conditions are reasonably representative of observed conditions.

B3.5 Spot Flows

Spot flow measurements were made at locations in Mill Creek and Hanlon Creek as part of this study (Map B4). The consistency of with Mill Creek and Hanlon Creek simulated baseflow in the initially larger model was checked against observed spot flows. Spot flows for Hanlon Creek are not within boundaries of the SSA model domain. A summary of spot flow conditions evaluated outside of the SSA is provided Table B16.

Table B16 Initial Regional Model - Observed Vs Simulated Baseflow Conditions

Drainage Area	Location	Observed Flows (L/s)			Simulated Flows (L/s)		
		Min	Max	Average	Min	Max	Average
Hanlon Creek	HC-HR2	0	1	0	0	0	0
Mill Creek	MC-C72	0	10	2	4	39	16.5
Mill Creek	MC-M2	0	3	1	0	0	0
Mill Creek	MC-V2	6	179	48	27	129	61
Mill Creek	MC-GN3	58	209	97	44	142	80

Spot flows observed in smaller headwater drainages are more difficult to represent due to the small drainage area the observation is dependent on. Conversely spot flows collected in locations further downstream which collect more drainage are easier to replicate and can provide a more representative evaluation of baseflow replication by the model given the increased area they represented. In general we observe that simulated flows are in agreement with observed flows.

Simulated discharge conditions for Hanlon and Mill Creek tributaries within the SSA model domain were compared against available observed water levels and mapped ponded water/wetlands see Table B17.

Table B17 SSA Model - Observed Vs Simulated Baseflow Conditions

Drainage Area	Location	Observed Flows (L/s)			Simulated Flows (L/s) or Mapped Discharge Conditions		
		Min	Max	Average	Min	Max	Average
Mill Creek	MC-M3	0	0	0	0	0	0
Mill Creek	MC-GN1	1	5	3	Consistent Discharge Conditions Identified at Location in Discharge Mapping		
Mill Creek	MC-GN2	2	5	3			

This comparison indicates consistent representation of field observations. Combined with the evaluation of spot flows in the larger initial model these simulated values represent the seasonal trends, locations and magnitude of conditions observed in the field and provides confidence the model can be used to represent discharge to Mill Creek.

B4 SIMULATED FLOW SYSTEM

The following sections characterize the hydrologic conditions predicted for flow system for period of 2003-2017. The results include maps that characterize the spatial distribution of hydrologic processes, map of groundwater recharge, as well as water budgets which provide an assessment of the contribution of hydrologic processes, e.g. evapotranspiration, in the SSA model.

The characterization of existing conditions, summarized in the following sections, will be used baseline conditions for comparison with the simulated impact of development alternatives.

Development alternatives will be evaluated for impacts, relative to existing conditions, through changes observed in:

- groundwater recharge and discharge areas and features
- groundwater flow linkages between recharge and discharge areas (groundwater functions)
- spatial and temporal variations in these groundwater functions
- PSA role in supporting municipal bedrock aquifers

The characterization provided by the SSA model of existing conditions will also serve as a basis to address the following model objectives:

- constraints and opportunities for future development to maintain groundwater function and support other objectives for stormwater management
- potential impacts of development alternatives on groundwater function in the PSA
- mitigation strategies (e.g. LIDs) to maintain groundwater function and inform overall stormwater management planning

Land use development alternatives will be assessed using the SSA model and compared against existing conditions to provide understanding of impacts, impact mitigation strategies and selection of a preferred design alternative.

B4.1 Simulated Average Depth to Water Table

A map depicting the spatial distribution of average depth to the groundwater table simulated for the period of 2003-2017 is presented on Map B9. This figure represents the average depth from the ground surface to the water table as simulated by the model.

B4.2 Simulated Ponded Water Locations

A map depicting the spatial distribution of ponded water areas is presented on Map B10. This map represents areas which feature ponded water exceeding 1 cm in depth for at least 10% of the simulation period (2003-2017).

B4.3 Simulated Groundwater Recharge

Water which passes through the unsaturated zone and reaches the water table is known as groundwater recharge. It is the portion of infiltration that is in surplus after meeting evapotranspiration and soil moisture needs above the water table. Evapotranspiration can also occur from below the water table. A map depicting the spatial distribution of average annual groundwater recharge for the period of 2003-2017 is presented on Map B11.

B4.4 Simulated Groundwater Discharge

Groundwater discharge occurs where the water table intersects ground surface typically in areas of topographic lows, locally or regionally. A map which depicts the areas groundwater discharge for the period of 2003-2017 is presented on Map B12.

B4.5 Water Budgets for Model Domain (SSA)

The average annual water budget for the period of 2003-2017 simulated by the MIKE SHE model is presented for model domain and the areas of Mill Creek, Hanlon Creek and Torrance Creek within the model domain in Table B18. The average annual groundwater recharge rates for 2003-2017 are summarized in Table B19.

The inflows of water to the model domain occur through precipitation, overland flow in, lateral groundwater flow through the overburden and bedrock and vertical flow through the underlying municipal aquifer. The outflows of water from the model domain occurs through evapotranspiration, overland flow out (groundwater discharge), lateral flow through the overburden, lateral flow through the bedrock, vertical flow to the underlying municipal aquifer and pumping

Table B20 presents the outflows as a percentage of total inflows. Table B21 presents the outlfows as a percentage of total groundwater inflows approximated as the simulated precipitation, groundwater inflow and change in storage less evapotranspiration.

Table B18 Average Annual Water Budget for SSA (2003-2017, mm/year)

Area/Catchment	Water Budget Component											
					Lateral Groundwater Flow				Vertical Groundwater Flow			
					Overburden		Bedrock Above Vinemount Formation		Across Vinemount Formation			
	Precipitation	Evapotranspiration	Overland Flow In	Overland Flow Out	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Pumping	Change in Storage
SSA Model Domain	801	480	0	108	17	44	35	126	0	99	2	-7
Mill Creek	801	498	1	188	41	36	140	194	1	66	7	-6
Hanlon Creek	801	472	0	86	9	60	42	186	0	64	0	-7
Torrance Creek	801	450	0	60	48	95	233	421	0	58	0	-4

Table B19 Average Annual Groundwater Recharge for SSA (2003-2017)

Area/Catchment	Groundwater Recharge (mm/year)
SSA Model Domain	325
Mill Creek	338
Hanlon Creek	326
Torrance Creek	302

Table B20 Water Budget Outflows as a Percentage of the Total Inflows for the SSA

Area/Catchment	Evapotranspiration	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
SSA Model Domain	56%	13%	5%	15%	12%	0%
Mill Creek	50%	19%	4%	20%	7%	1%
Hanlon Creek	55%	10%	7%	22%	7%	0%
Torrance Creek	41%	6%	9%	39%	5%	0%

Table B21 Water Budget Outflows as a Percentage of Total Groundwater Inflows (Inflows-Evapotranspiration) for the SSA

Area/Catchment	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
SSA Model Domain	28%	12%	33%	26%	1%
Mill Creek	38%	7%	39%	13%	1%
Hanlon Creek	22%	16%	48%	17%	0%
Torrance Creek	9%	15%	66%	9%	0%

B4.6 Secondary Plan Area Water Budgets

The water budgets for the catchments of Mill Creek, Hanlon Creek and Torrance Creek within the SPA are presented in Table B22. These water budgets represent existing conditions and will be used to evaluate water budgets under the development alternatives to help assess the potential impact of alternative development strategies in the SPA.

Table B23 shows the outflows by catchment within the SPA as a percentage of total groundwater inflows (precipitation and storage less evapotranspiration losses). This analysis indicates that approximately 30% to 40% of flow out of these catchments reaches the regional aquifer. This result is generally consistent with the water budget analysis performed on the larger catchment areas found within the SSA.

Table B22 Average Annual Water Budgets for the SPA (2003-2017)

	Water Budget Component											
					Lateral Groundwater Flow				Vertical Groundwater Flow			
					Overburden		Bedrock Above Vinemount Formation		Across Vinemount Formation			
Area/ Catchment	Precipitation	Evapotranspiration	Overland Flow In	Overland Flow Out	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Pumping	Change in Storage
Mill Creek in SPA	801	508	4	9	43	51	326	513	0	102	0	-10
Hanlon Creek in SPA	801	494	1	6	6	32	26	181	0	129	2	-10
Torrance Creek in SPA[1]	801	477	1	22	222	425	1761	1,780	0	88	0	-7

Note:
[1] High discharge rates simulate through lateral bedrock occur in Torrance Creek as a result of a relatively high flow through the bedrock in the Burke-Carter formation associated with the Burke Municipal Well and the relatively small domain area associated with Torrance Creek within the SPA.

Table B23 Water Budget Outflows as a Percentage of Total Groundwater Inflows (Inflows-Evapotranspiration) for the SPA

Area/Catchment	Estimated Groundwater Discharge to Streams and Water Bodies	Overburden Lateral Flow Out	Bedrock Lateral Flow Out	Bedrock Vertical Flow Out (Across Vinemount Formation)	Pumping
Mill Creek in SPA	1%	8%	76%	15%	0%
Hanlon Creek in SPA	2%	9%	52%	37%	1%
Torrance Creek in SPA	1%	18%	77%	4%	0%

B4.7 Natural Heritage System Features - Hydroperiod

A map depicting the simulated hydroperiod of the key NHS pond/wetland features is presented in Map B13. This map illustrates the simulated maximum and minimum extent of the ponds at a 0.25 m threshold depth simulated by the model for the period of 2003-2017. Evaluation of the maximum and minimum extent of the feature against aerial imagery provides a qualitative assessment of the ability of the model to represent the areal extent of the NHS ponds/wetlands, which can be used to approximate the hydroperiod of these features.

B4.8 Particle Tracking

Particle tracking provides a tool that links recharge and discharge areas and provides a means for further understanding the connection between recharge zones and potential receptors. Hypothetical particles were released within the first three layers of the MIKE SHE model and move through the simulated groundwater flow field to their discharge location or where they leave the model domain. The flow conditions observed for the period of 2007-2016 were used as representative conditions and repeated for a 200 year simulation to determine the ultimate fate of particles released in the overburden materials within the study area.

A map depicting the destination or fate of particles released in a given location is presented on Map B14. This map depicts where recharge at a given location in the model leaves the model by groundwater discharge or groundwater outflow.

A quantitative assessment of the particle tracking results is presented in Table B24. The columns have the following meaning:

- Percent of Total Particle Count:
  - Summarizes the destination of a particle based on the count of particles which arrived at a particular destination type as a percentage of the total number of particles released.
- Percent of Total Recharge Volume (Particle*Recharge Rate)

- This represents the multiplication of the recharge predicted on a cell by the cell destination type. In this way the magnitude of recharge associated with particles arriving at each destination type is considered. This number summarizes the fraction of total recharge associated with each particle destination type.

- Water Budget Proportion:

  - This is an approximation of the destination of recharge based on water budget assessment as summarized in Section 4.6.

Table B24 Particle Destination Summary Statistics

Destination Type	Percent of Total Particle Count	Percent of Total Recharge Volume (Particles* Recharge Value)	Water Budget % (Table B20)
Bedrock Vertical Flow Across Vinemount (Regional Aquifer)	31	32	26
Bedrock Lateral Flow Out	*29*	*29*	33
Overburden Lateral Flow Out	*11*	*11*	12
Discharge to Overland	28	27	28
Captured By Pumping Well	1	1	1

In general we observe that the water budget results and the particle tracking results are very similar. Small differences relate to the method used and simulation period for the model and the particle tracking process, 2003-2017 versus 2006-2017, respectively. Particles are only released initially in the particle tracking simulation at the start of the simulation period (January 2007) as opposed to continuously being released in differing flow conditions. We believe the particle tracking provides useful insight and confidence in the model results which agree with the CM interpretation (see 4.2.4).

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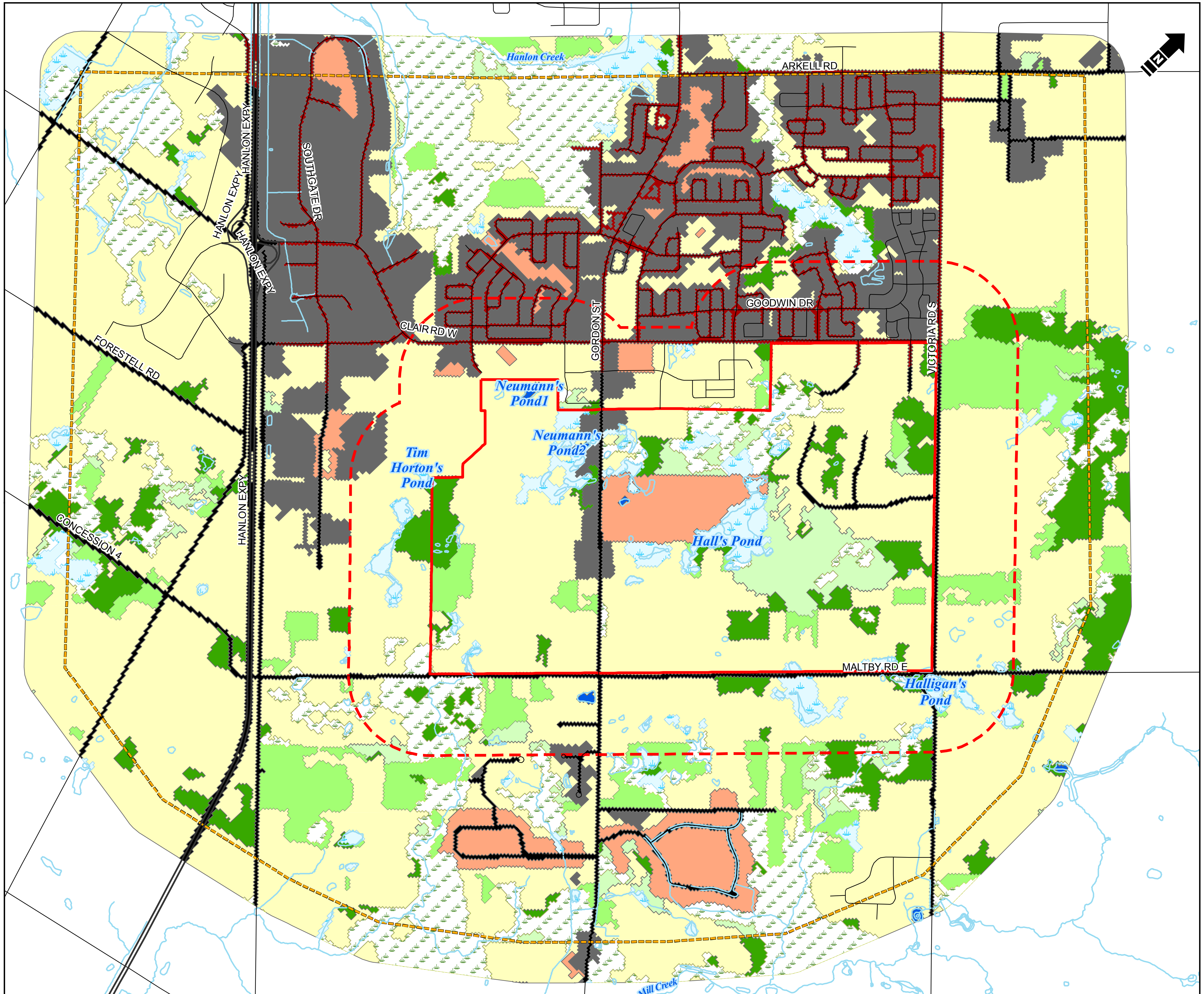

Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Highway
Road

Land Use

Agriculture
Con Forest
Dec Forest
Developed Impervious
Developed Pervious
Mixed Forest
Open Water
Roads - Extra Urban
Roads - Urban
Treed Wetland
Wetland

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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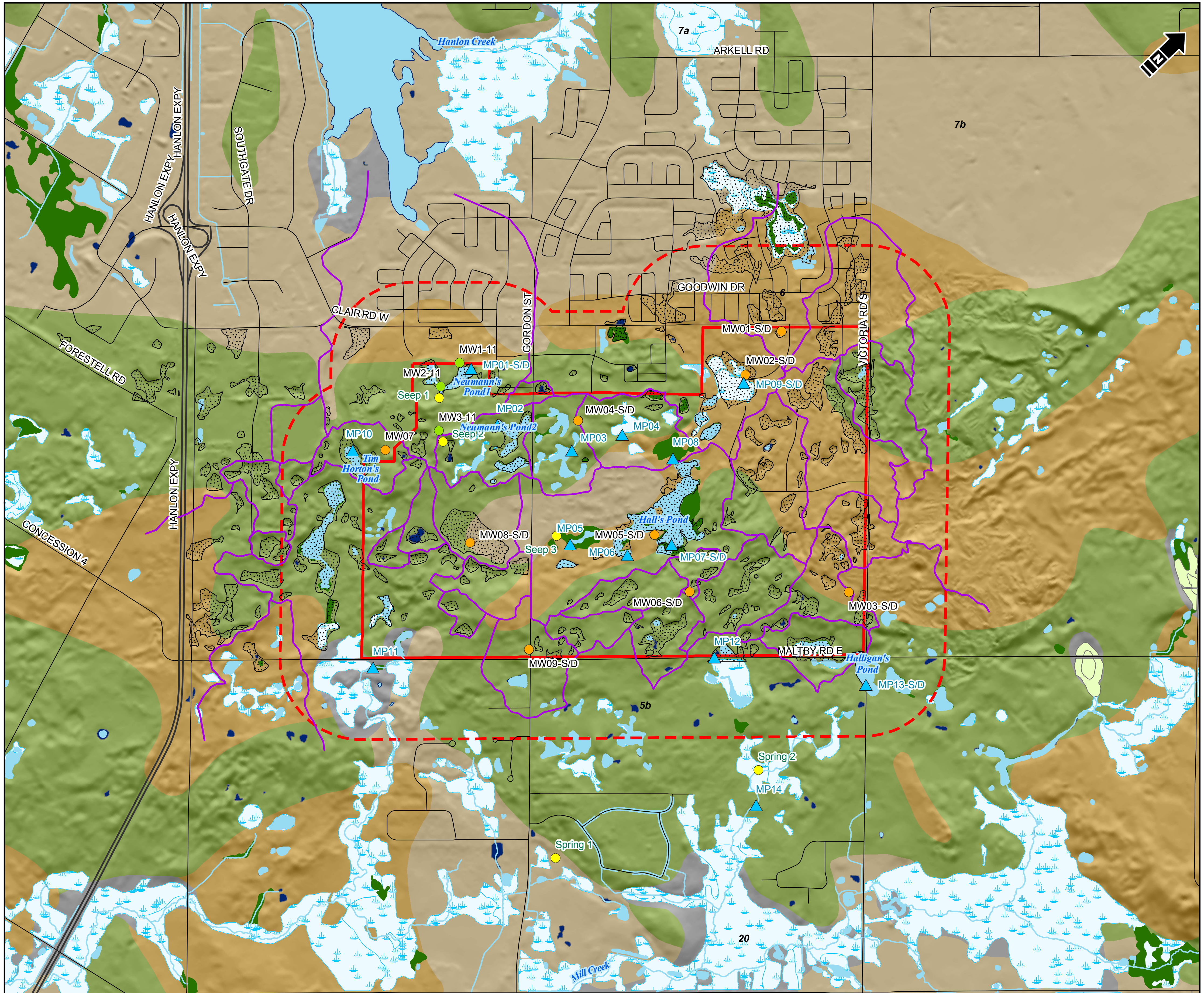
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Model Land Use (Based on SOLRIS 2.0 Data)

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map b1



Primary Study Area Boundary
Secondary Plan Area Boundary
Closed Depression
Subcatchment
Fen
Bog
Swamp
Marsh
Open Water
Unknown Wetland
Water Body
Watercourse
Highway
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Surficial Geology

5b: Stone-poor, sandy silt to silty sand till
6: Ice-contact stratified sand and gravel deposits
7a: Glaciofluvial Sand Deposits
7b: Glaciofluvial Gravel Deposits
20: Organic deposits (e.g., peat, marl)

Reference: Da ta pro vided b y the City o f Guelph, Geo Base® and Province of Ontario used under license.
Ontario Geological Survey 2010. Surficial geology of southern Ontario; Ontario Geological Survey, Miscellaneous Release— Data 128 – Revised.

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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Phase 1 Characterization Report

Hydrogeology Monitoring Locations

Date: July, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

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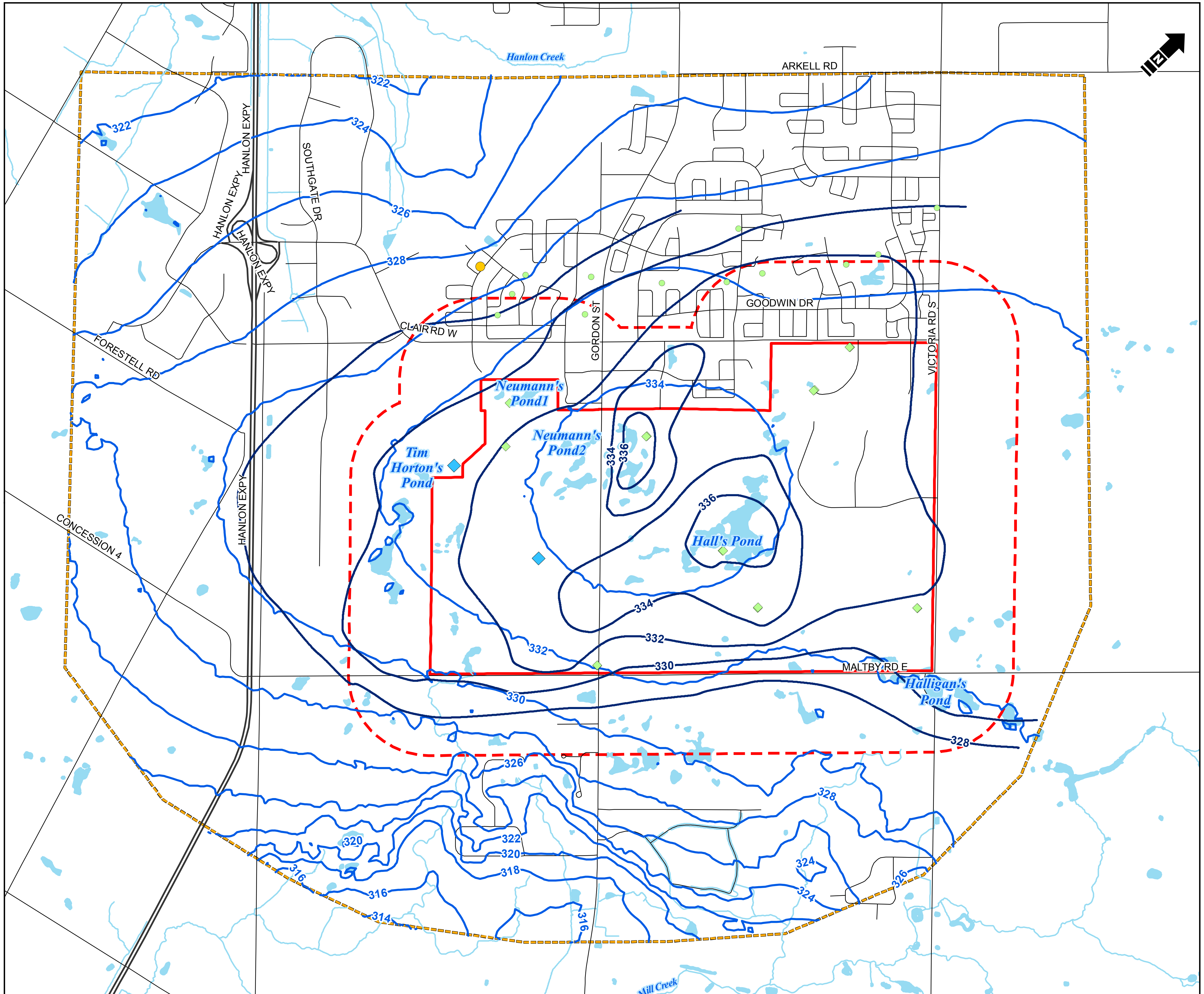
Map b2



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Water Table Elevation Contour (2m)
Simulated Groundwater Contour (2m)
Highway
Road

Groundwater Level Residual (m) - Study Well

- < -5.0
- -5.0 - -2.5
- -2.5 - 2.5
- 2.5 - 5.0
- > 5.0

Groundwater Level Residual (m) - Greenway Well

- < -5.0
- -5.0 - -2.5
- -2.5 - 2.5
- 2.5 - 5.0
- > 5.0

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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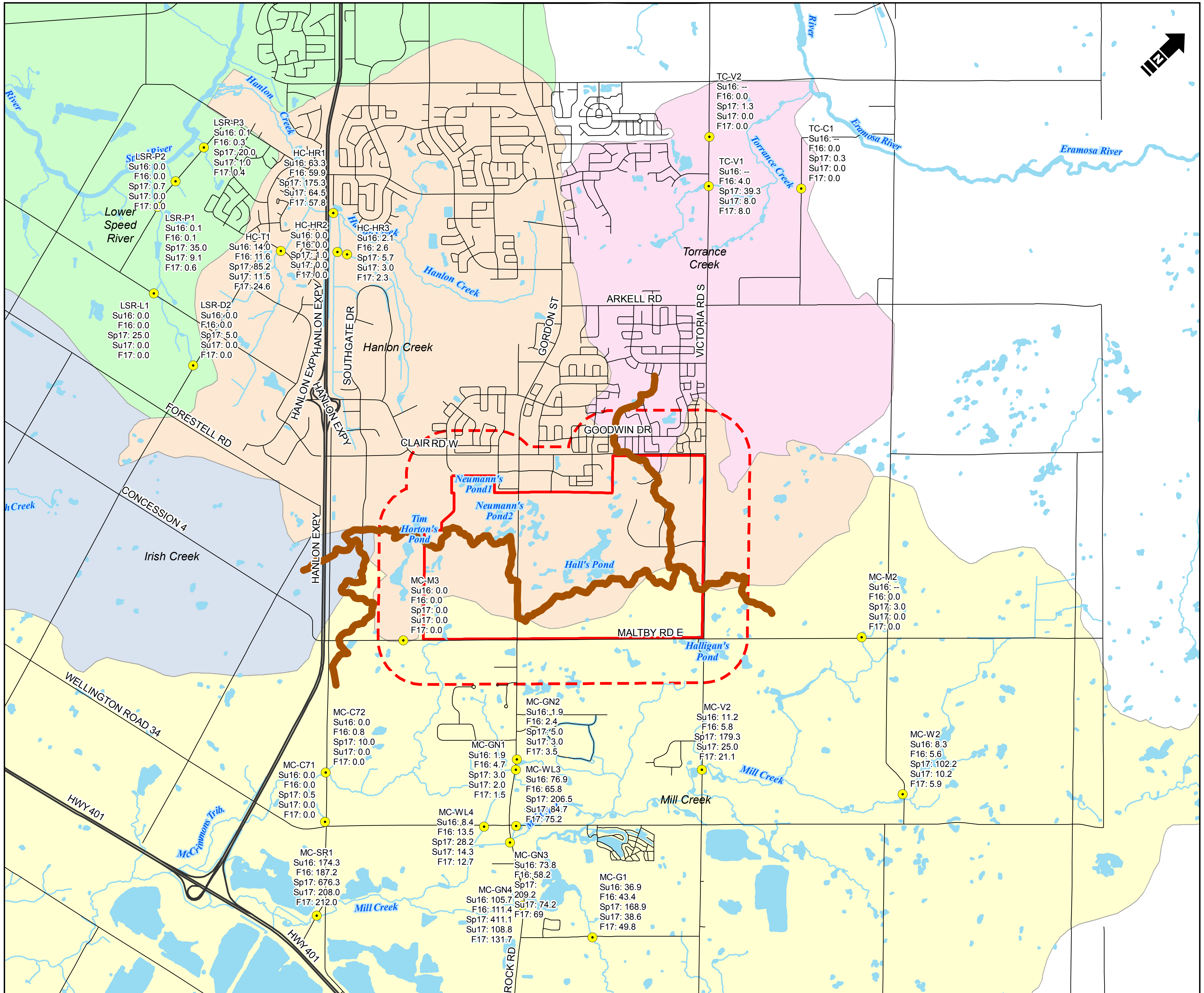
Simulated Average Groundwater Levels

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map
b3



Primary Study Area Boundary
Secondary Plan Area Boundary
Water Body
Watercourse
Updated Subwatershed Boundary (Wood PLC, 2018)
Highway
Road
Spot Flow Location

Subwatershed

Hanlon Creek
Irish Creek
Lower Speed River
Mill Creek
Torrance Creek

HC-D2 Spot Flow Location
Su16:0 Summer 2016 (Aug.30/31,Sept. 1) Flow Rate (L/s)
F16:0 Fall (Nov.9/10) Flow Rate (L/s)
Sp17:0 Spring 2017 (May 10/11) Flow Rate (L/s)
Su17:0 Summer 2017 (Aug.16) Flow Rate (L/s)
F17:0 Fall (Nov. 29) Flow Rate (L/s)

1:45,000 metres
475 0 475 950
NAD 1983 UTM Zone 17N

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Phase 1 Characterization Report

Observation Data Map

Date:	Project:	Submitter:	Reviewer:
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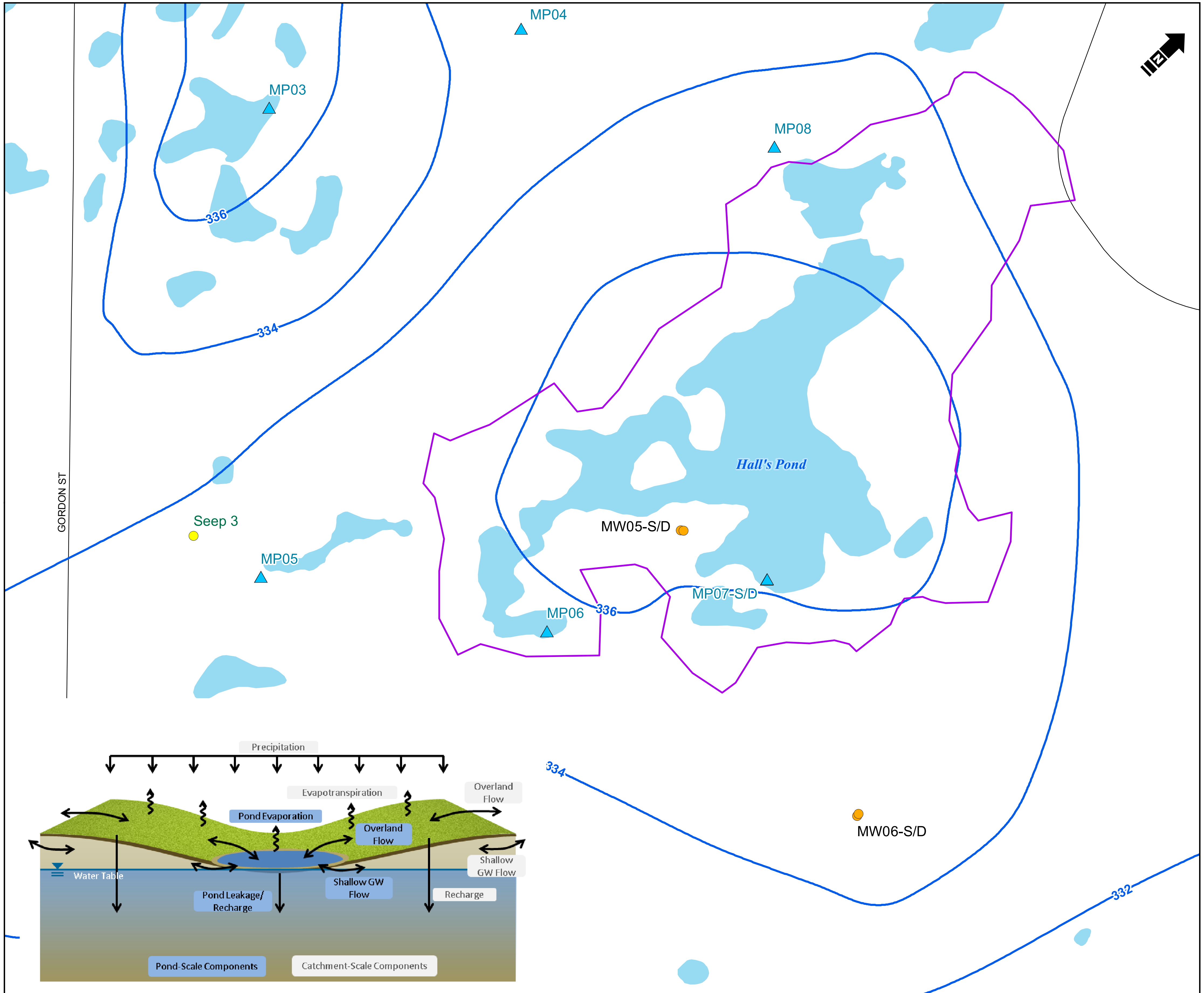
Map b4



DRAFT

- Hall's Pond Subcatchment
- Water Body
- Water Table Elevation Contour (2m)
- Simulated Head Contour (1m)
- Road
- Mini Piezometer
- Monitoring Well (Matrix)
- Monitoring Well (132 Clair Rd.)
- Observed Seep and Spring

Hall's Pond Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	509	Evaporation	543
OL_{in}	Overland Flow (In)	3	Overland Flow (In)	71
OL_{out}	Overland Flow (Out)	1	Overland Flow (Out)	52
SGW_{in}	Shallow GW Flow (In)	3	Shallow GW Flow (In)	4
SGW_{out}	Shallow GW Flow (Out)	3	Shallow GW Flow (Out)	1
R	Recharge	299	Recharge	286
S	Storage Change	-5	Storage Change	-6

All values reported in mm.

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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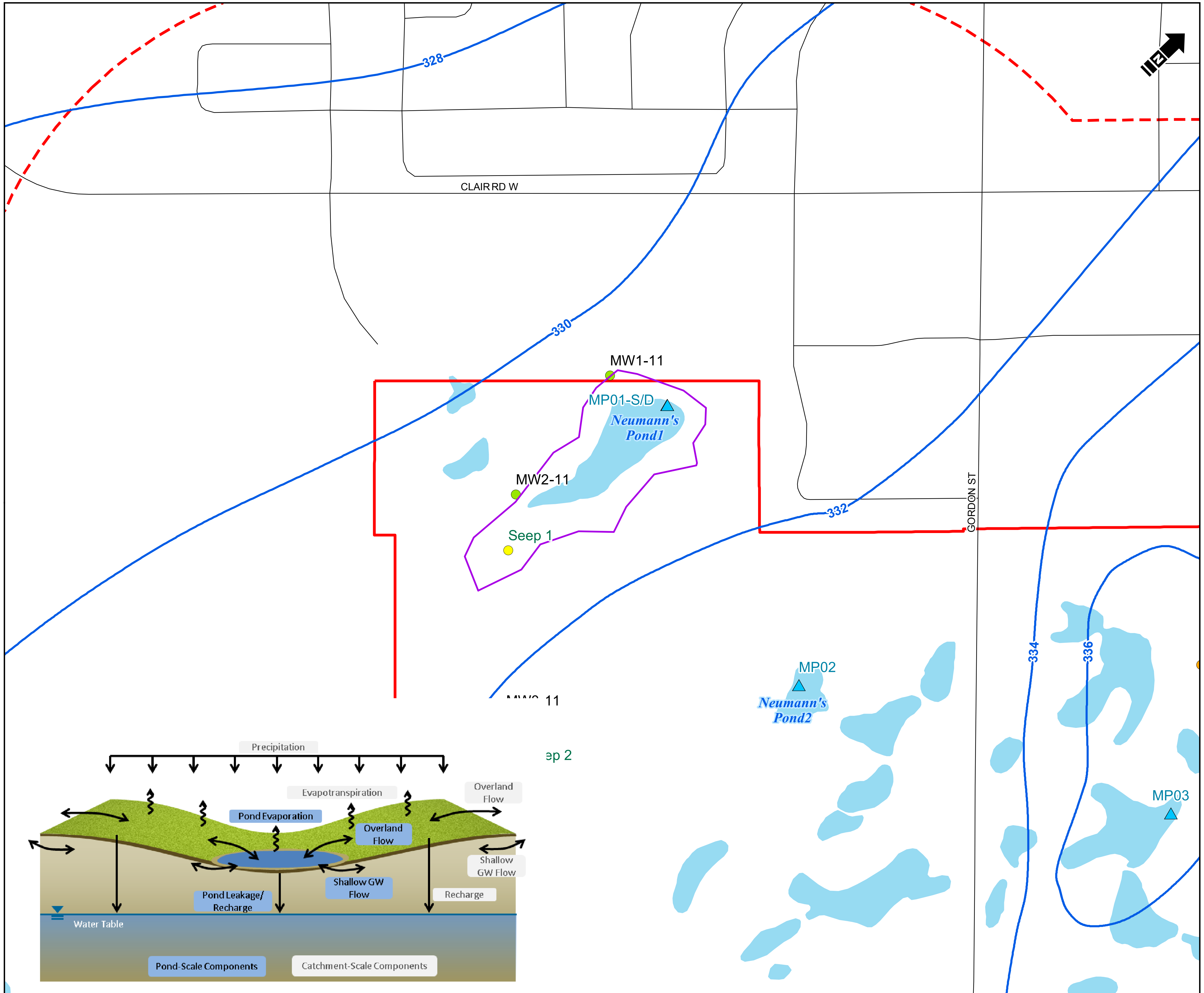
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Hall's Pond Water Budget Map

Date: July, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

Map b5

DRAFT



Primary Study Area Boundary
Secondary Plan Area Boundary
Neumann Pond Catchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Neumann's Pond Average Annual Simulated Water Balance (2003-2017)

$$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	549	Evaporation	675
OL_{in}	Overland Flow (In)	5	Overland Flow (In)	283
OL_{out}	Overland Flow (Out)	1	Overland Flow (Out)	143
SGW_{in}	Shallow GW Flow (In)	11	Shallow GW Flow (In)	11
SGW_{out}	Shallow GW Flow (Out)	7	Shallow GW Flow (Out)	2
R	Recharge	265	Recharge	283
S	Storage Change	-5	Storage Change	-7

*All values reported in mm.

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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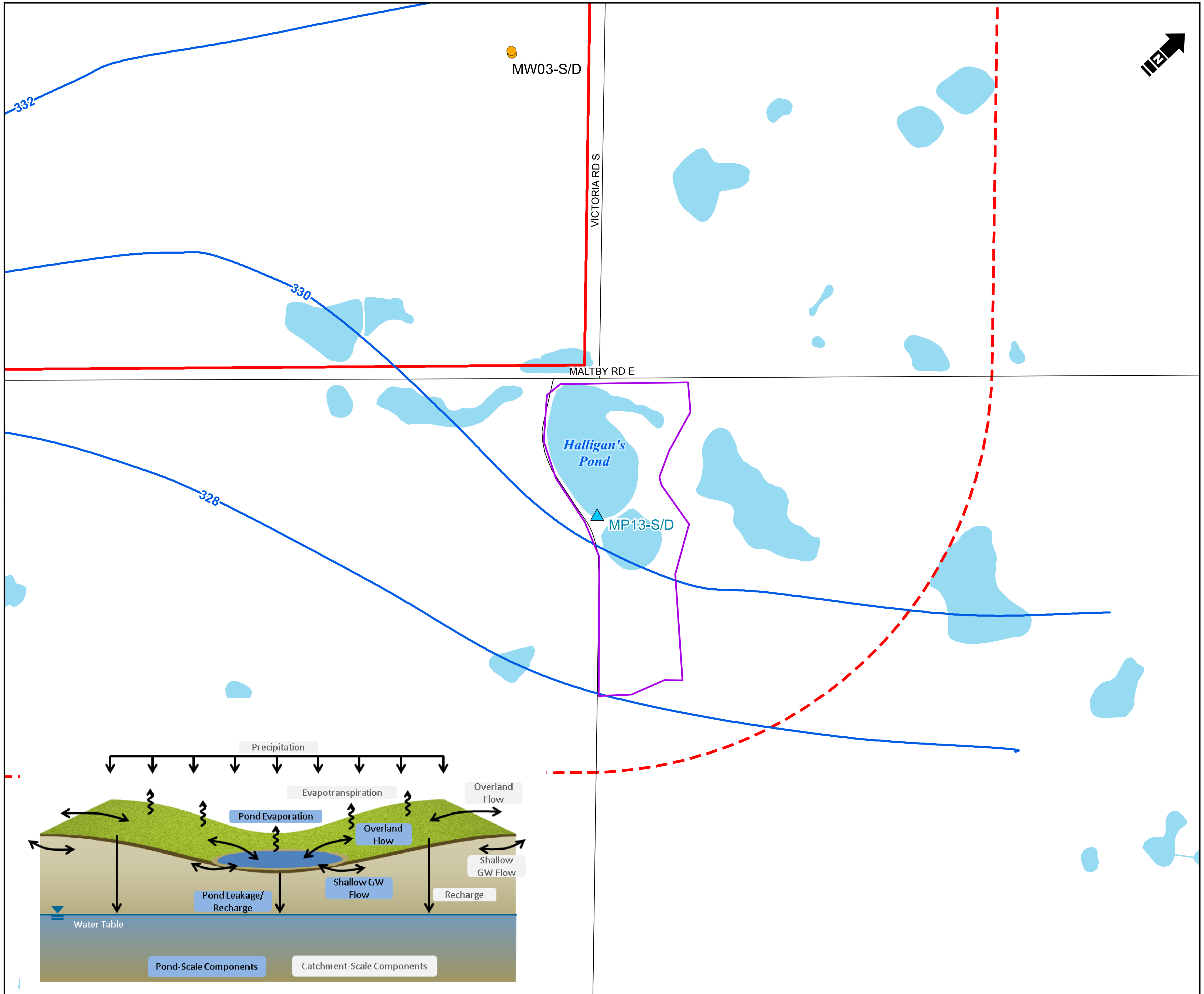
Clair- Maltby Comprehensive Environmental Impact Study
Phase 1 Characterization Report

Neumann's Pond Water Budget Map

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map
b6



Primary Study Area Boundary
Secondary Plan Area Boundary
Halligan's Pond Subcatchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

Halligan's Pond Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Subcatchment-Scale		Pond-Scale	
P	Precipitation	801	Precipitation	801
ET	Evapotranspiration	534	Evaporation	570
OL_{in}	Overland Flow (In)	10	Overland Flow (In)	49
OL_{out}	Overland Flow (Out)	4	Overland Flow (Out)	154
SGW_{in}	Shallow GW Flow (In)	3	Shallow GW Flow (In)	5
SGW_{out}	Shallow GW Flow (Out)	2	Shallow GW Flow (Out)	2
R	Recharge	282	Recharge	143
S	Storage Change	-8	Storage Change	-14

**All values reported in mm.*

1:5,000 metres
50 0 50 100
NAD 1983 UTM Zone 17N

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City of Guelph
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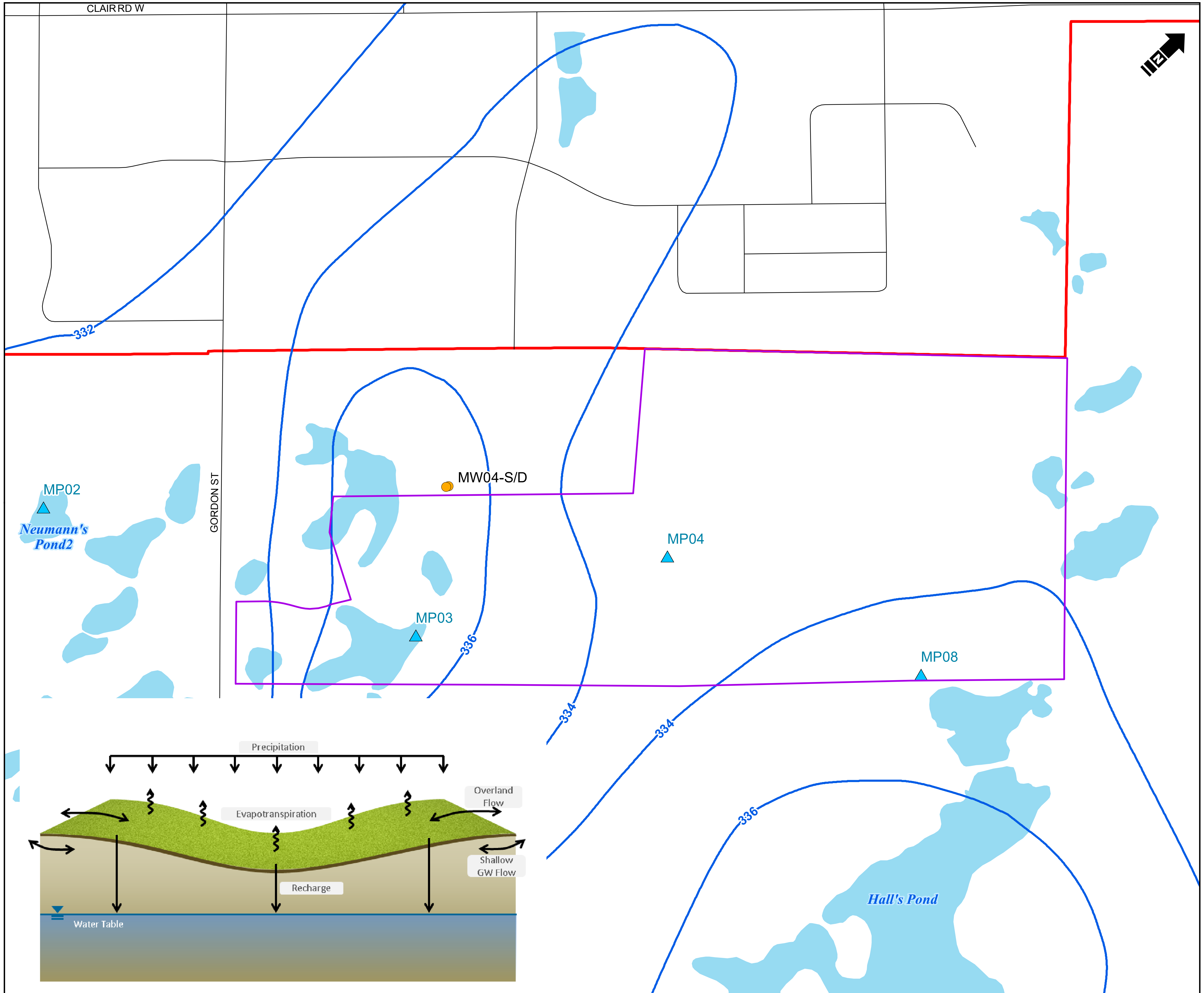
Phase 1 Characterization Report

Halligan's Pond Water Budget Map

Date: July, 2018	Project: 23089	Submitter: D. Martin	Reviewer: B. Blackport

Map b7



Secondary Plan Area Boundary
Woodlot Subcatchment
Water Body
Water Table Elevation Contour (2m)
Simulated Head Contour (1m)
Road
Mini Piezometer
Monitoring Well (Matrix)
Monitoring Well (132 Clair Rd.)
Observed Seep and Spring

1992 Gordon Street Woodlot
Average Annual Simulated Water Balance (2003-2017)

$P - ET + (OL_{in} - OL_{out}) + (SGW_{in} - SGW_{out}) - R = S$

Symbol	Woodlot-Scale	
P	Precipitation	801
ET	Evapotranspiration	503
OL_{in}	Overland Flow (In)	16
OL_{out}	Overland Flow (Out)	18
SGW_{in}	Shallow GW Flow (In)	6
SGW_{out}	Shallow GW Flow (Out)	7
R	Recharge	296
S	Storage Change	-3

All values reported in mm.

1:5,000 metres 50 0 50 100
NAD 1983 UTM Zone 17N

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1992 Gordon St. Woodlot Water Budget Map

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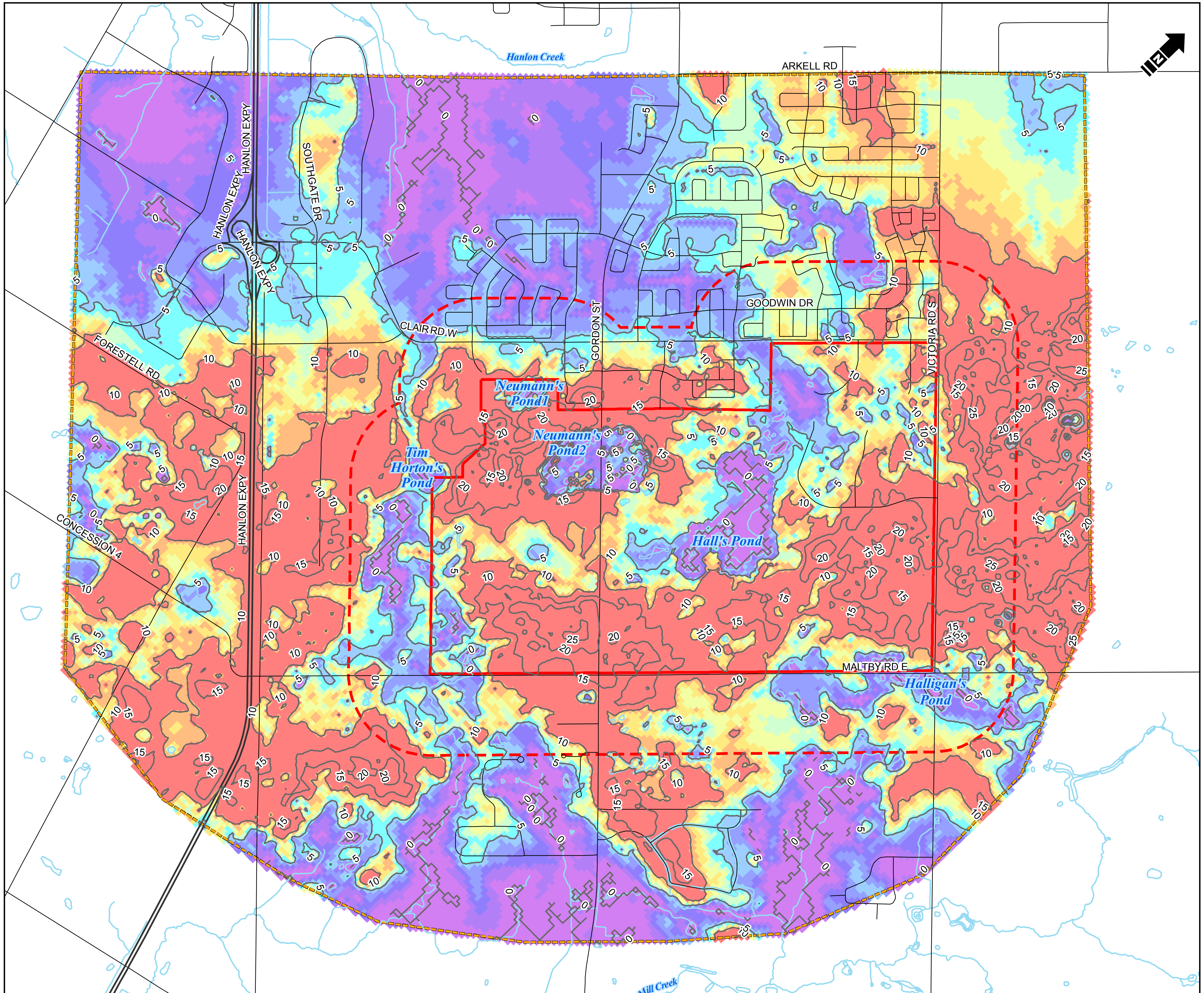
July, 2018	23089	D. Martin	B. Blackport

Map b8



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Highway
Road
Average Depth to Water Table Contour (5m)

Simulated Average Depth to Water Table (m)

- 0 - 1
- 1 - 2
- 2 - 3
- 3 - 4
- 4 - 5
- 5 - 6
- 6 - 7
- 7 - 8
- 8 - 9
- 9 - 10
- > 10

1:25,000
260 0 260 520 metres
NAD 1983 UTM Zone 17N

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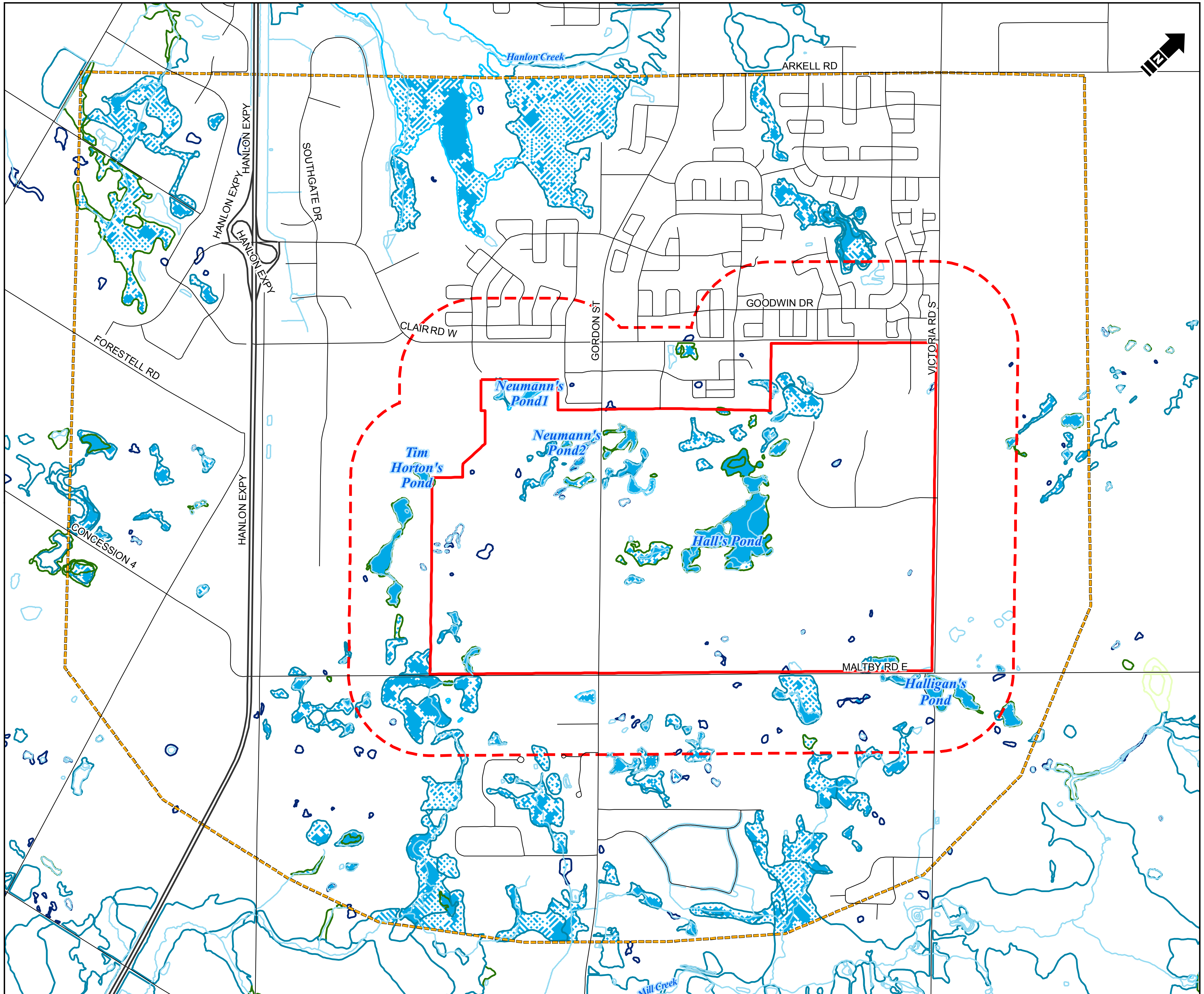
Phase 1 Characterization Report

Simulated Average Depth to Water Table

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map
b9



DRAFT

- Primary Study Area Boundary
- Secondary Plan Area Boundary
- MIKE SHE Model Domain
- Fen
- Bog
- Swamp
- Marsh
- Open Water
- Unknown Wetland
- Water Body
- Area not Ponded
- Ponded Area
- Watercourse
- Highway
- Road

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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Phase 1 Characterization Report

Simulated Ponded Water Locations

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map
b10

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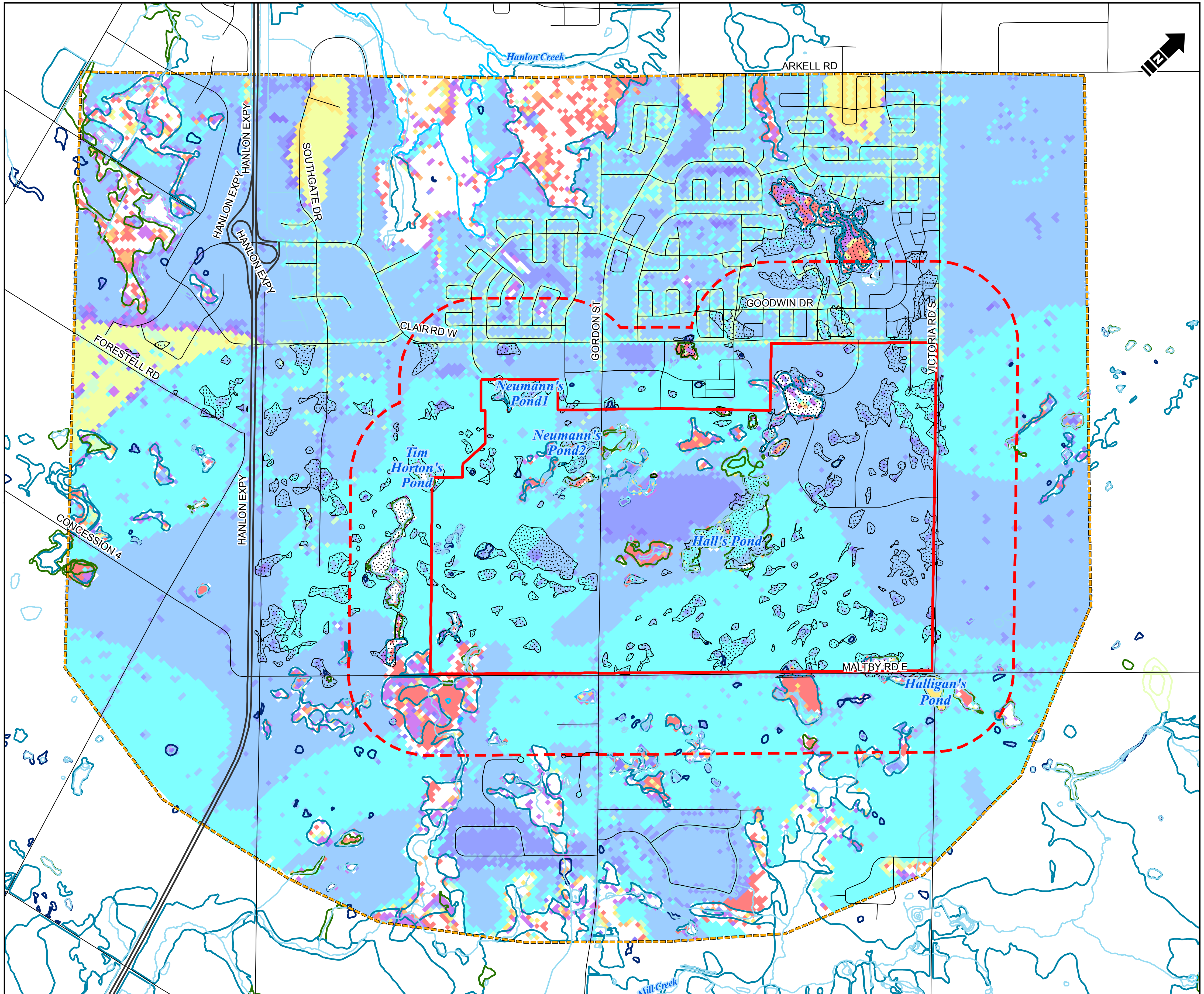

Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Closed Depression
Fen
Bog
Swamp
Marsh
Open Water
Unknown Wetland
Water Body
Watercourse
Highway
Road

Groundwater Recharge (mm/year)

0 - 50
50 - 100
100 - 150
150 - 200
200 - 250
250 - 300
300 - 350
350 - 400
400 - 450
450 - 500
> 500

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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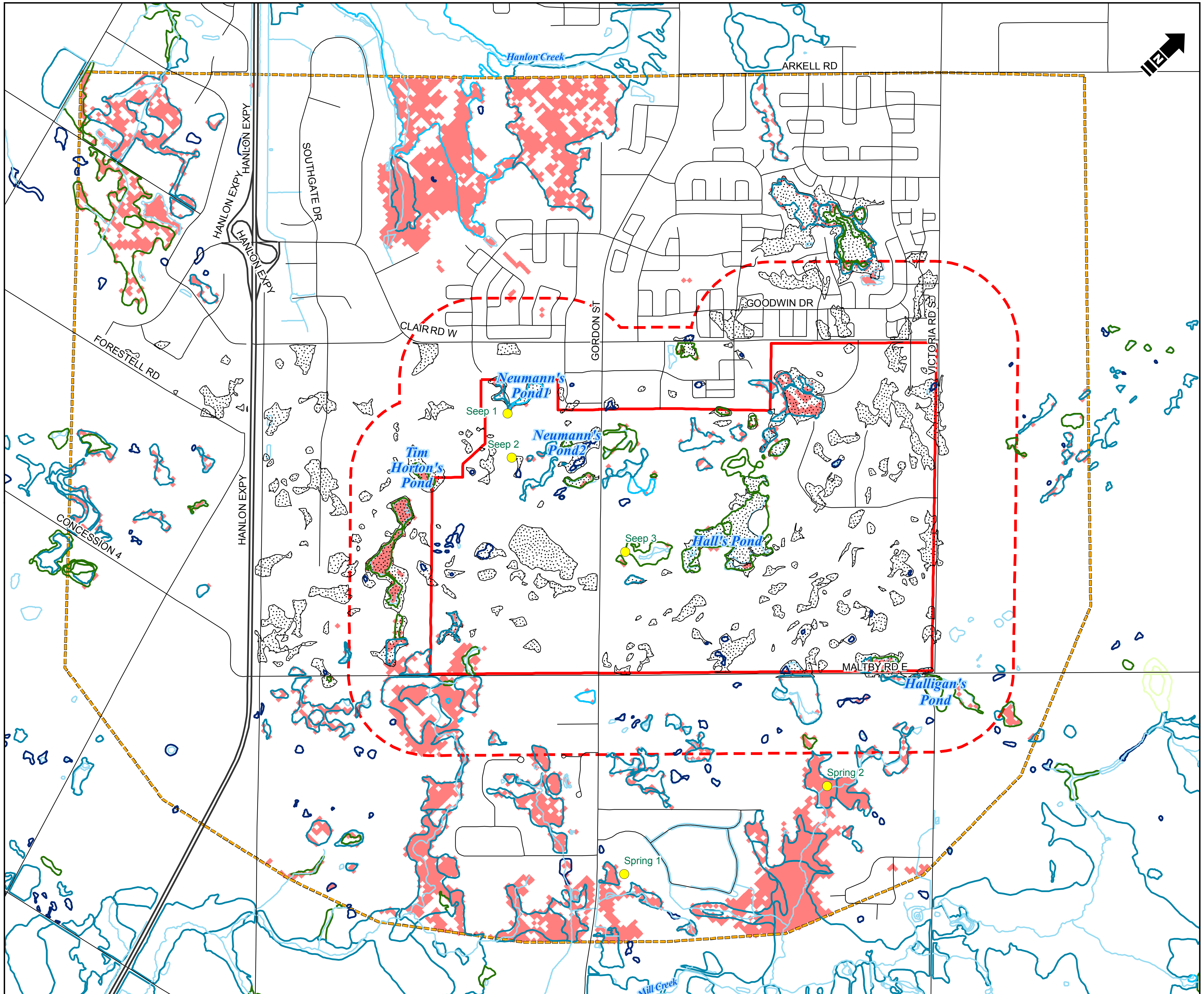
Phase 1 Characterization Report

Simulated Groundwater Recharge

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map
b11



- Primary Study Area Boundary
- Secondary Plan Area Boundary
- MIKE SHE Model Domain
- Closed Depression
- Groundwater Discharge
- Fen
- Bog
- Swamp
- Marsh
- Open Water
- Unknown Wetland
- Water Body
- Watercourse
- Highway
- Road
- Observed Seep and Spring

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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Phase 1 Characterization Report

Simulated Groundwater Discharge

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	D. Martin	B. Blackport

Map b12

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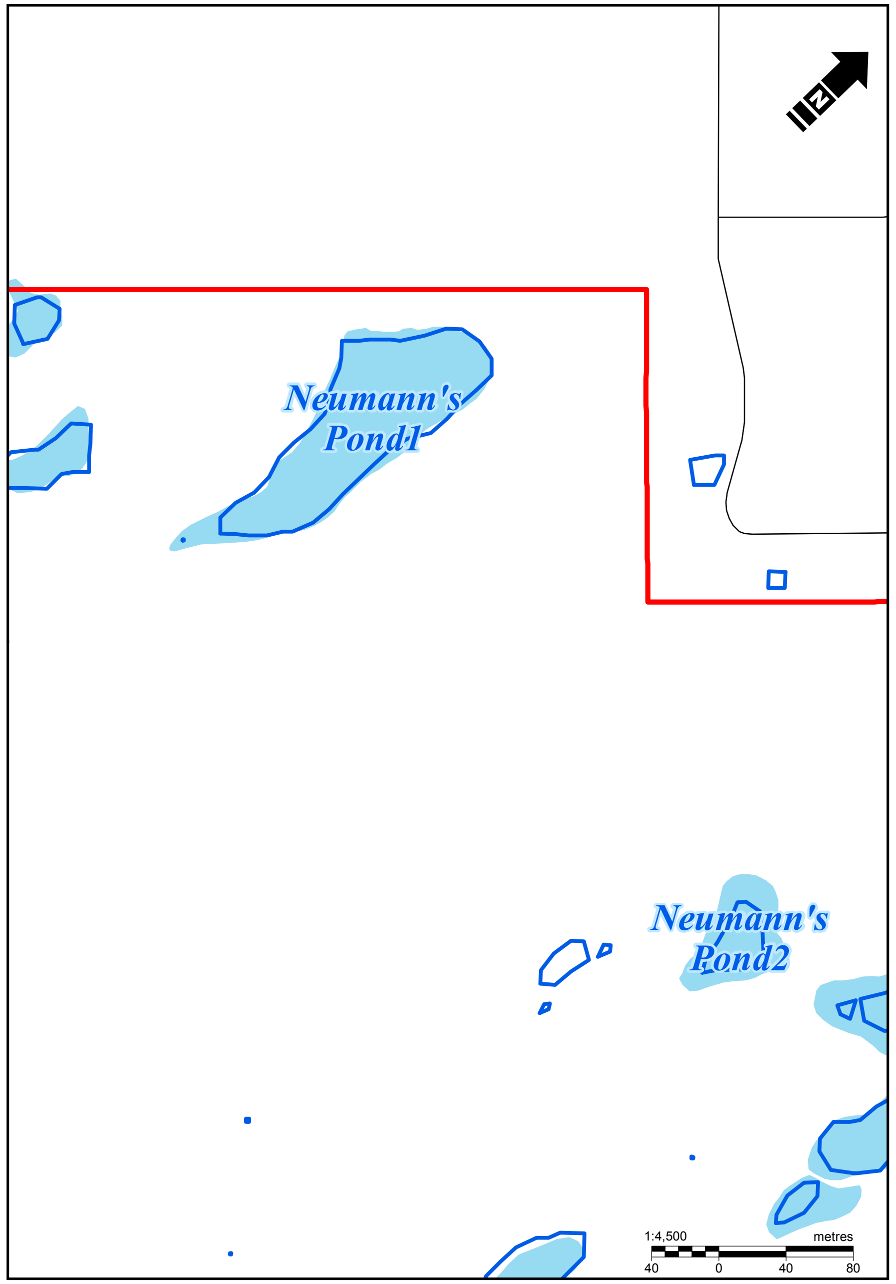
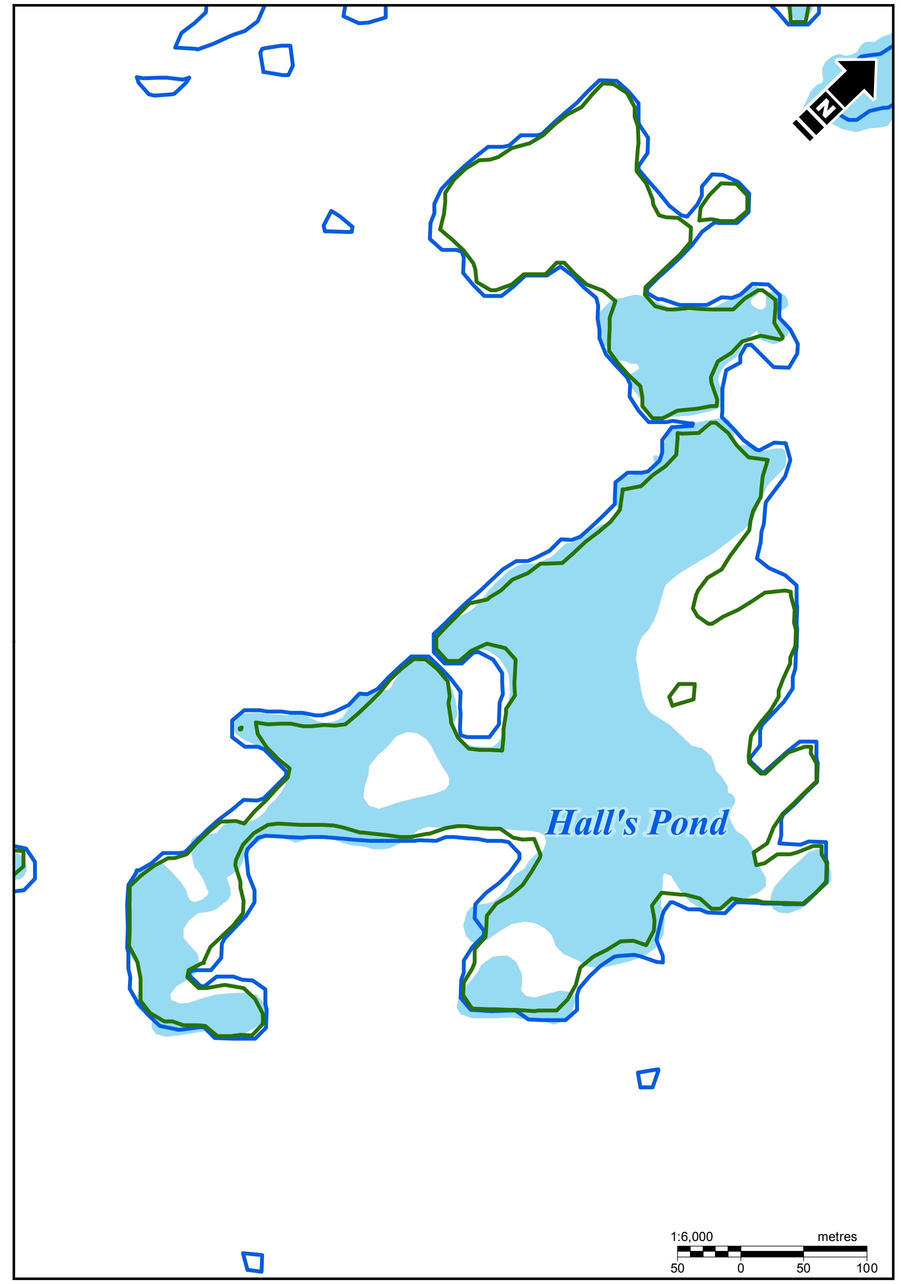
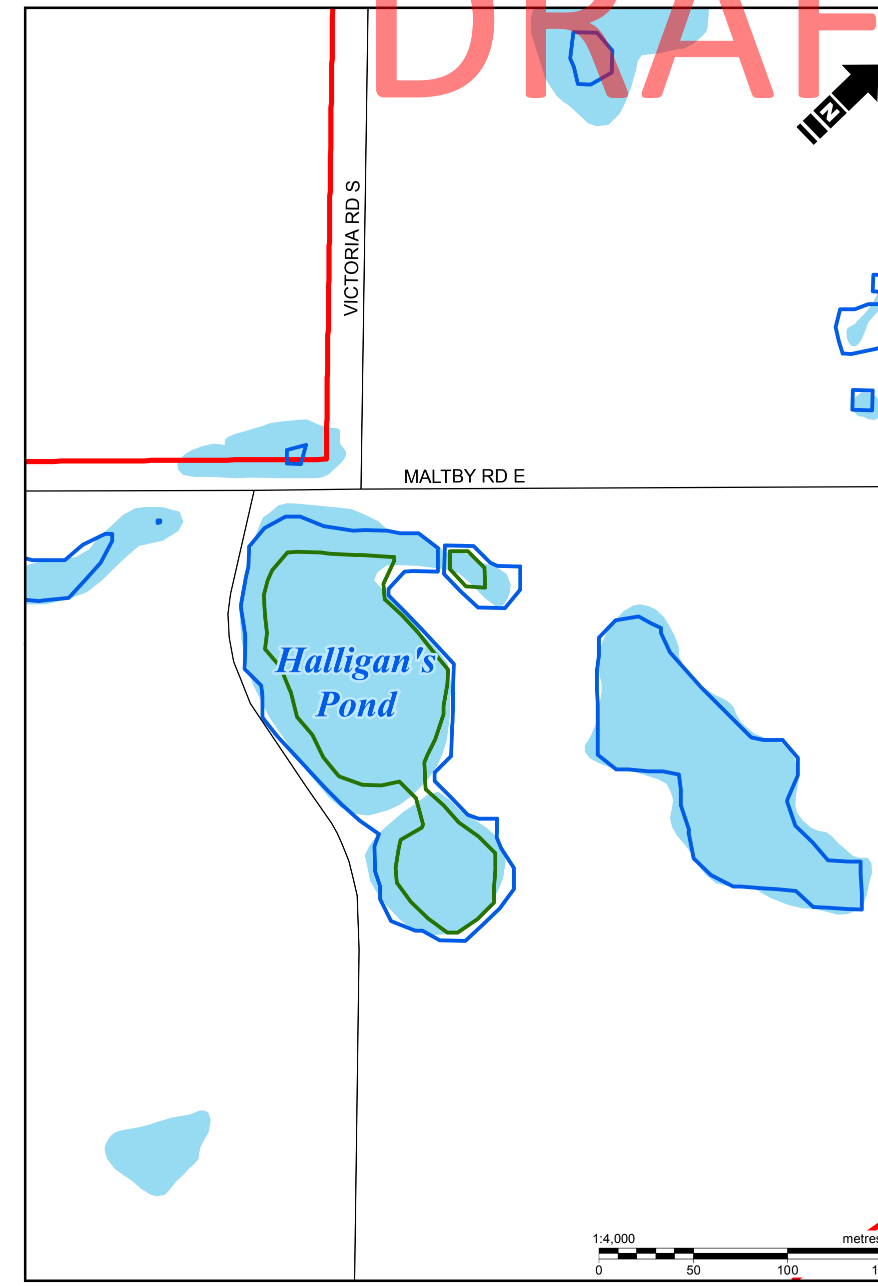


Neumann's Pond



Hall's Pond



Haligan's Pond

- Primary Study Area Boundary
- Secondary Plan Area Boundary
- MIKE SHE Model Domain
- Water Body
- Watercourse
- Simulated Maximum Inundation at 0.25 m depth
- Simulated Minimum Inundation at 0.25 m depth

Reference: Data provided by the City of Guelph, Geo Base® and Province of Ontario used under license.

NAD 1983 UTM Zone 17N

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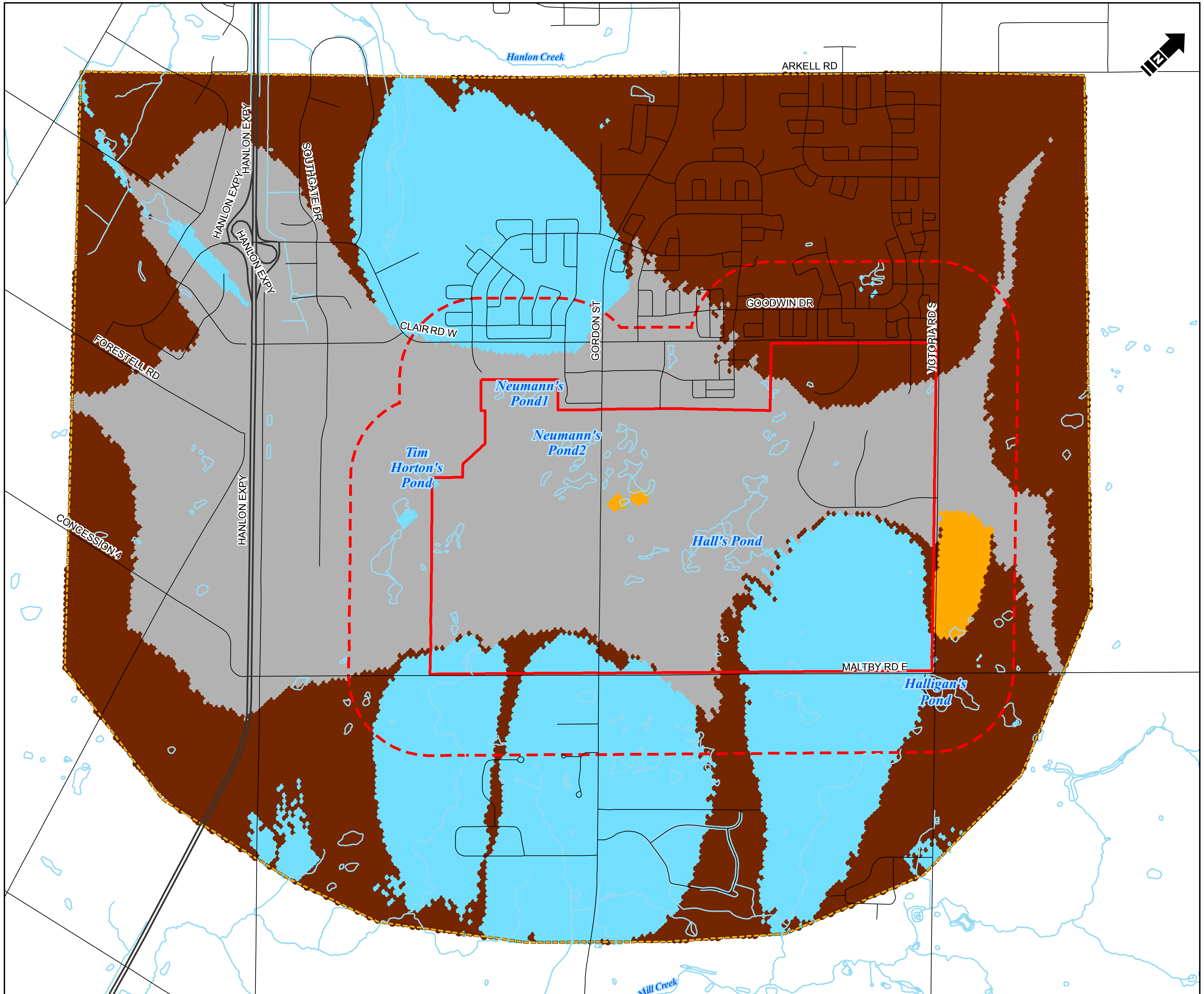
Phase 1 Characterization Report

Simulated Hydroperiod Map

Date:	Project:	Submitter:	Reviewer:
July, 2018	23089	S. Murray	B. Blackport

Map b13

DRAFT



Primary Study Area Boundary
Secondary Plan Area Boundary
MIKE SHE Model Domain
Water Body
Watercourse
Highway
Road

Particle Track

- Vertical Groundwater Flow Out (Across Vinemount Formation)
- Lateral Groundwater Flow Out (Overburden and Bedrock)
- Captured by Pumping Well
- Discharge to Streams and Water Bodies

1:25,000 metres
260 0 260 520
NAD 1983 UTM Zone 17N

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Particle Tracking Map

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Map b14