Grand River Source Protection Area

ASSESSMENT REPORT

Chapter 8: Region of Waterloo

July 29, 2025

CHAPTER 8: REGION OF WATERLOO SECTIONS

Chapter 8 of the Assessment Report, including each municipal well system for the Region of Waterloo, is separated into eight section documents as follows:

CURRENT DOCUMENT:

- **Section 8.1** – Water Quality Risk Assessment

REMAINING DOCUMENTS:

- **Section 8.2** – Waterloo Area Wellfields (Erb Street, William Street, and Waterloo North wells)
- **Section 8.3** – Kitchener Area Wellfields (Mannheim (East, West, ASR and Peaking), Greenbrook, Strange Street, Parkway, Strasburg, Pompeii, Woolner and Wilmot Centre)
- **Section 8.4** – Hidden Valley Intake
- **Section 8.5** – Cambridge Area Wellfields (Hespeler, Pinebush, Blair Road, Clemens Mill, Elgin Street, Middleton Street, Shades Mills, Fountain Street, and Willard)
- **Section 8.6** – Rural Area Wellfields (Ayr, Branchton Meadows, Elmira, Foxboro Green, Heidelberg, Linwood, Maryhill, New Dundee, New Hamburg, Roseville, St. Clements, Wellesley)
- **Section 8.7** – Limitations, Data Gaps and Uncertainty
- **Section 8.8** – Summary

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8.0 REGION OF WATERLOO

The Region of Waterloo operates a total of eighteen municipal drinking water systems with raw water intakes that serve a total population of approximately 647,540 (2022) **(Table 8—1)** . The Integrated Urban System (IUS) is comprised of six municipal drinking water systems. It is an interconnected network of wells and a surface water intake on the Grand River in Kitchener (the Hidden Valley Surface Water Intake) which supplies the Mannheim Water Treatment Plant, reservoirs, and pumping stations. The IUS supplies water to approximately 592,232 people living in the communities of Cambridge, Kitchener, Waterloo, Elmira, New Hamburg, St. Agatha, Conestogo, West Montrose and St. Jacobs as of 2022. Twelve smaller water supply systems currently provide water to settlement areas not connected to the IUS, and which are located in the rural townships (**Table 8—1**). There are two additional wellfields that are currently not active. In all, groundwater is extracted from over 120 wells throughout the Region and one surface water intake. Together these sources are capable of supplying approximately 279,000 cubic metres of water per day.

Table 8—1: Region of Waterloo Municipal Drinking Water Systems

DWS Number[1]	DWS Name (Municipal Wells Included)	Operating Authority	GW or SW	System Classification	Number of Users Served
220000166	Cambridge Wells (G1, G1A, G2, G3, G4, G4A, G6, G7, G8, G9, G14, G15, G16, G17, G18, G19, G38, G39, G40, H3, H3A, H4A, H5, H5A, P9, P10A, P10B, P11, P15, P16, P17, P19)	Region of Waterloo	GW	Large municipal residential	Part of IUS[2]
220003092	Kitchener Wells (K1A, K2A, K4C, K5A, K8, K18, K19, K10A, K11A, K13B, K34, K36, K31, K32, K33, K72, K73, K74, K75, K80, K81, K82)	Region of Waterloo	GW	Large municipal residential	Part of IUS[2]
260002668	Mannheim Village Wells (K23, K24, K26)	Region of Waterloo	GW	Large municipal residential	Part of IUS[2]
220006981	Mannheim bracket (Kitchener) WTP, (ASR1, ASR2, ASR3, ASR4, ASR5, RCW2, RCW3, RCW4, K21,	Region of Waterloo	SW/ GW	Large municipal residential	Part of IUS[2]

DWS Number[1]	DWS Name (Municipal Wells Included)	Operating Authority	GW or SW	System Classification	Number of Users Served
	K21A, K25, K29, K91, K92, K93, K94)				
260002707	Shingletown Wells or Wilmot Centre (K50, K51, K52)	Region of Waterloo	GW	Large municipal residential	Part of IUS[2]
220000157	Waterloo Wells (W5, W5A, W25, W6C, W6B, W7, W8, W10, W1B, W1C, W2B, W2C, W3A)	Region of Waterloo	GW	Large municipal residential	Part of IUS[2]
220004199	Ayr Wells and Distribution bracket (A1, A2, A3) bracket	Region of Waterloo	GW	Large municipal residential	5,391
260002538	Branchton Wells and Distribution (BM1, BM2, BM3)	Region of Waterloo	GW	Small municipal residential	121
220007301	Roseville Wells and Distribution (R5, R6)	Region of Waterloo	GW	Small municipal residential	290
220007310	Heidelberg Drinking Water System (HD1, HD2)	Region of Waterloo	GW	Large municipal residential	1,013
220000102	Linwood Drinking Water System (L1A, L2)	Region of Waterloo	GW	Large municipal residential	781
220005811	St. Clements Wells and Distribution (SC2, SC3, SC4)	Region of Waterloo	GW	Large municipal residential	1,267
220004215	Wellesley Wells and Distribution (WY1, WY5, WY6)	Region of Waterloo	G W	Large municipal residential	3,472
220009210	Foxboro Wells (FG1, FG2A, FG4)	Region of Waterloo	G W	Large municipal residential	410
220004180	New Dundee Wells (ND4, ND5)	Region of Waterloo	G W	Large municipal residential	1,049
220000111	New Hamburg Wells (NH3, NH4)	Region of Waterloo	G W	Large municipal residential	13,974
220004171	Maryhill Wells (MH1, MH2)	Region of Waterloo	G W	Small municipal residential	141

DWS Number[1]	DWS Name (Municipal Wells Included)	Operating Authority	GW or SW	System Classification	Number of Users Served
260007413	Maryhill Heights Wells (MH5, MH4A)	Region of Waterloo	G W	Small municipal residential	143
	Elmira[3] (E10)	Region of Waterloo	G W	Not applicable	Not applicable
	Pompeii[3] bracket (K72, K73, K74, K75) bracket	Region of Waterloo	G W	Not applicable	Not applicable

[1] As defined by Ontario Regulation 170/03 (Drinking Water Systems) made under the *Safe Drinking Water Act, 2002.*

[2] The Integrated Urban System (IUS) distributes treated water to approximately 592,232 users.

[3] These wells are not associated with a drinking water system but are part of the Region's approved Long Term Water Supply Strategy for the Integrated Urban System and are not currently being used.

A description of each of these systems is included in the separate municipal wellfield **Sections 8.2** to **8.5**. Monthly and annual average pumping rates for each well in the Region of Waterloo during 2017 are provided in **Table 8—2.**

In January 2018, Regional Council approved the following resolution:

"That the Regional Municipality of Waterloo approve decommissioning wells K70, K71, K41, K42A, K22A in Kitchener, P6 in Cambridge, the wells supplying West Montrose (WM1, WM2, WM3, WM4) and the wells supplying Conestogo (C3, C4, C5, C6) and direct staff to submit application to revoke related licenses, approvals and permits within five years after the day of this resolution."

The aforementioned wells in Kitchener and Cambridge were deemed unnecessary by the Updated Water Supply Master Plan (Stantec 2015), have been decommissioned and/or removed from the Drinking Water Licences and have been removed from **Table 8—1**. Class Environmental Assessment studies completed for West Montrose (Aecon 2013) and for Conestogo Plains (CIMA 2015) recommended replacement of the local municipal water supply sources for these communities with water from the Integrated Urban System through a connection at St. Jacobs. The West Montrose and Conestogo wells have been decommissioned and the Drinking Water Works Permit cancelled.

The following sections outline the common methodology that was used to delineate wellhead protection areas and intake protection zones, assess vulnerability and threats, and evaluate issues and uncertainty for each of the aforementioned supply systems.

Table 8—2: 2017 Average Monthly Pumping Rates for Region of Waterloo Production Wells in m^3/d (*)

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
Woolwich													
HD1	5.6	1.1	87.1	106.1	1.1	0.8	0.9	152.4	11.9	0.9	1.1	0.8	30.8
HD2	162.3	164.3	70.9	66.0	195.6	214.2	203.8	21.4	174.2	164.5	151.2	179.7	147.3
MH1	0.1	0.1	24.8	20.8	66.0	26.4	0.2	23.6	68.8	33.5	0.2	0.1	22.0
MH2	62.8	63.9	43.5	41.3	0.4	30.1	59.4	45.0	1.9	33.8	62.5	64.1	42.4
MH3	1.1	0.9	0.7	0.7	1.2	0.8	0.7	2.4	10.0	0.8	0.9	27.7	4.0
MH4A	26.1	25.7	25.0	42.0	31.1	31.0	31.6	30.6	34.4	26.9	29.8	3.8	28.2
E10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wilmot													
FG1	96.2	91.5	93.5	104.3	108.5	118.4	104.8	106.9	104.8	105.5	86.0	106.6	102.2
FG2A	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	
FG4	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	12.1	0.6	1.3
ND4	122.9	137.6	148.8	144.0	137.9	148.4	143.8	142.3	148.6	108.9	107.2	122.0	134.4
ND5	94.6	79.0	57.3	65.3	62.9	76.3	61.5	46.0	49.1	72.7	62.9	56.9	65.4
NH3	983.8	358.9	1200.8	1326.3	1182.5	1643.4	1298.6	1533.6	1692.7	1593.8	1485.8	1512.4	1317.7
Wellesley													
L1A	208.0	209.3	215.2	186.7	185.5	266.0	223.5	220.3	231.5	229.9	229.2	219.2	218.7
L2	0.7	0.8	1.0	52.7	60.1	0.9	0.8	0.9	0.7	0.7	1.0	0.8	10.1
SC2	2.5	43.0	86.5	1.7	13.4	3.4	2.5	111.5	38.3	1.9	140.1	35.5	40.0
SC3	192.2	150.6	80.9	5.5	34.5	2.8	53.2	97.3	197.3	204.9	11.4	1.9	86.0
SC4	0.0	0.0	11.0	94.5	84.5	118.1	84.4	1.4	0.9	0.9	23.2	87.8	

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
WY1	1.8	2.1	2.7	162.5	2.2	2.0	2.3	1.9	1.8	1.7	2.3	2.2	15.5
WY5	2.2	2.4	3.3	82.7	138.3	307.5	591.1	489.9	506.7	621.7	563.0	591.2	325.0
WY6	549.7	549.8	527.3	329.3	449.8	314.8	2.6	69.5	77.6	1.9	2.7	2.0	239.7
North Dumfries													
A1	316.4	2010.5	577.2	1063.3	1037.2	1023.4	916.6	943.5	975.3	853.5	876.8	841.2	952.9
A2	4.3	4.4	536.1	1073.1	1093.8	1156.9	1010.1	854.9	1010.5	880.5	905.5	874.4	783.7
A3	1715.9	121.5	1015.6	4.0	13.7	19.4	8.4	5.0	3.4	7.0	4.2	4.6	243.6
BM1	24.2	23.3	6.2	0.2	0.2	8.0	4.6	0.4	0.2	0.2	0.2	0.2	5.6
BM2	0.2	0.1	17.2	25.0	30.1	24.3	21.6	34.6	30.5	24.3	26.4	29.3	22.0
R5	54.1	53.4	53.2	57.3	62.3	89.1	90.9	91.3	90.1	67.9	62.3	61.9	69.5
R6	0.4	0.5	0.5	0.4	0.4	0.6	0.4	0.5	0.4	0.6	0.5	0.4	0.5
Waterloo													
W1B	1951.6	2489.2	2756.4	2667.4	2637.6	2495.3	2520.8	2592.8	2631.3	2593.3	2702.9	2583.8	2551.9
W1C	96.7	163.9	214.5	77.8	398.5	368.9	352.9	334.7	210.4	318.3	231.9	213.1	248.5
W2	1523.6	1719.4	1761.2	2074.5	2064.9	1910.4	1941.9	1969.5	1991.8	1953.1	2014.0	1966.7	1907.6
W3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W6A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
W6B	1656.0	1633.1	1587.7	0.0	1305.0	1641.0	1661.8	1651.8	1636.5	1627.9	1683.7	1638.4	1476.9
W7	7698.8	7516.4	7492.4	7668.4	7608.6	7621.0	7632.0	7617.5	7614.5	7529.7	7626.2	7547.3	7597.7
W8	1453.7	2126.5	2058.6	1937.0	1844.4	1600.6	1523.2	1534.0	1384.7	787.7	0.0	1952.5	1516.9
W10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
Cambridge													
G1	5364.5	5296.7	5197.9	5921.4	5855.2	6311.4	6186.7	5971.3	6400.0	4882.9	4101.9	3239.4	5394.1
G1A	1361.7	1303.4	1352.1	1740.0	2027.8	1895.9	1763.8	2164.6	2652.3	2334.7	361.4	1310.2	1689.0
G2	248.0	113.0	157.5	134.6	503.7	86.3	97.7	213.6	100.4	174.3	1756.4	82.8	305.7
G3	7648.5	7642.8	7662.5	7734.3	7567.6	7684.2	7632.0	7620.4	7743.7	7532.8	7669.2	7491.5	7635.8
G14	56.3	19.3	49.3	52.6	179.2	39.6	84.9	66.5	281.3	927.4	2627.5	49.3	369.4
G15	3654.6	3888.3	3753.7	3548.3	3369.3	3573.3	3436.6	3227.0	2682.9	730.5	0.0	3593.5	2954.8
G4	0.0	0.0	0.0	0.0	0.0	1187.7	1590.0	417.6	0.0	0.0	0.0	697.8	324.4
G4A	1467.6	1563.3	1536.2	1341.1	338.7	0.0	0.0	879.1	1568.1	1572.9	707.6	432.0	950.6
G5	1971.4	2179.9	2035.3	2105.6	2151.2	2152.1	2084.7	2069.7	2161.5	2157.1	31.1	1344.8	1870.4
G5A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
G6	1256.9	1117.0	1278.0	1014.2	1229.5	1262.0	1260.4	1257.6	1270.8	1371.6	1342.9	1345.8	1250.6
G7	1488.8	1558.9	1669.2	1892.1	1861.3	2031.8	1700.3	1939.9	1671.7	1727.3	1984.5	1515.5	1753.4
G8	1105.9	1160.6	1238.0	1403.2	1371.2	1528.8	1338.2	1443.9	1174.3	1306.3	1516.0	1158.5	1312.1
G38	858.7	886.3	824.6	878.8	983.6	1034.0	717.3	729.7	264.6	811.7	459.3	561.7	750.9
G39	2.9	0.8	0.0	0.0	0.0	0.0	0.0	0.0	18.6	437.8	869.9	869.4	183.3
G9	0.4	0.0	0.0	0.0	0.0	0.6	0.1	0.0	0.1	0.0	0.0	0.0	0.1
G16	701.0	753.6	677.8	917.2	927.0	1115.1	1124.1	1190.2	1185.1	1391.5	1396.2	1158.7	1044.8
G17	1042.0	1087.5	1017.1	1368.3	1382.3	1584.9	1274.2	140.8	1583.5	2156.5	2092.2	1727.0	1371.4
G18	514.2	581.8	655.8	662.7	596.3	847.8	668.7	1194.8	981.4	968.5	1354.7	1190.2	851.4
G19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H3A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
H4A	1436.7	1382.6	879.9	326.9	1440.4	1374.8	1485.3	1510.8	1361.3	18.9	1302.1	1268.3	1149.0
H5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H5A	0.0	0.0	0.0	0.0	3.5	0.9	198.9	845.3	811.2	847.9	824.0	844.5	
P16	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P9	1281.1	1361.8	1345.5	1322.9	1319.4	1335.2	1304.5	1293.8	1208.7	1059.9	1345.6	1327.1	1292.1
P15	493.0	753.1	815.7	679.8	660.7	614.3	624.2	610.3	647.3	914.6	785.2	739.0	694.8
P10	2446.0	1934.7	2300.7	2413.8	2338.5	2653.8	2086.4	2299.3	2541.7	2692.2	2593.1	2379.6	2390.0
P10A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P10B	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
P11	425.5	198.6	549.9	621.7	633.4	468.8	1.2	42.1	142.6	181.3	79.7	208.2	296.1
P17	0.0	0.0	1.9	1.3	1.0	107.0	679.3	516.5	206.7	95.5	258.0	190.4	171.5
P19	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Kitchener													
K1A	2693.3	2741.9	2511.2	753.6	2079.7	2516.9	2832.8	2759.2	2045.3	1873.3	2955.1	861.6	2218.7
K2A	133.0	6.4	4.6	9.6	1.2	4.3	15.1	3.9	3.9	318.8	1308.1	6.5	151.3
K4B	2306.7	2331.2	2253.7	2880.4	2657.6	2801.1	2750.0	2731.9	2258.2	1408.5	865.8	941.5	2182.2
K5A	2793.6	2825.0	2600.7	2796.8	2551.0	2648.6	2645.7	2543.9	2100.1	1761.9	2739.4	975.2	2415.2
K8	137.6	184.5	159.1	5.7	17.1	41.8	54.3	36.5	29.9	133.4	468.6	39.2	109.0
K10A	897.4	911.8	709.7	490.2	432.9	374.1	298.9	97.8	314.3	881.9	640.8	656.9	558.9
K11A	2014.1	2038.3	1927.4	2623.7	2269.2	2173.0	2160.9	2233.8	2185.0	2381.7	2034.3	2412.1	2204.5
K13/ K13A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K18	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.1	0.0	0.0	0.0	0.0

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
K19	0.0	0.0	0.0	0.0	87.0	570.4	445.7	228.5	416.3	7.6	0.0	0.0	146.3
K21	2795.6	2756.1	2820.4	2826.7	2866.5	2864.0	2842.7	2772.6	2725.9	2634.4	2631.9	1936.0	2706.1
K23	2308.1	2266.4	2300.5	2308.9	2296.5	2287.2	2174.7	2024.0	2063.9	1929.8	1973.6	1894.9	2152.4
K24	2896.6	2834.2	2872.6	2703.7	2767.1	2784.6	2869.9	2865.1	2870.8	2842.7	2869.3	2800.5	2831.4
K25	4621.5	4538.3	4805.5	4811.2	4823.4	4820.0	4715.0	4806.7	4806.0	4590.9	4589.7	3401.4	4610.8
K26	7433.8	7119.2	7527.0	7187.9	7495.7	7394.9	7433.9	7002.2	7555.9	7289.9	7268.0	7326.4	7336.2
K29	4272.0	4275.2	3269.3	3240.9	3258.9	3246.2	3230.9	3235.0	3212.3	2985.3	2990.5	2231.9	3287.4
K31	0.0	723.3	742.7	717.1	1421.6	1946.1	1558.9	1992.4	2341.0	1978.4	1344.4	2297.7	1422.0
K32	1238.6	666.3	697.7	668.8	1628.9	2037.7	2032.4	697.5	0.2	0.0	617.8	1368.1	971.2
K33	1201.1	1411.5	1457.0	1029.7	1110.2	1505.1	1209.7	1659.5	1993.6	1624.5	753.1	1644.6	1383.3
K34	2206.5	1656.2	1766.9	2128.6	2231.0	2194.1	2164.3	2056.6	1943.1	1522.9	2151.0	2041.1	2005.2
K36	1146.7	852.9	910.5	1113.9	1162.5	1153.0	1131.7	1078.3	1105.9	1154.8	1118.3	1027.8	1079.7
K50	5268.7	5037.5	5040.1	5118.1	5204.3	5177.8	5284.4	5236.8	5222.5	5295.5	5267.9	5246.2	5200.0
K51	4597.4	4579.5	4375.9	4397.0	4587.5	4542.6	4792.0	4815.8	4663.6	4509.5	4531.7	4712.7	4592.1
K72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K73	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K74	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K80	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K81	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
K91	1011.6	873.7	290.3	321.2	863.7	1096.0	798.1	398.5	1511.7	827.6	880.9	1216.6	840.8
K92	1387.3	1093.1	355.9	248.3	1315.6	1451.6	1051.8	505.2	2131.5	1045.4	1362.4	1617.4	1130.5

Well ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Average Monthly Rate
K93	1148.3	945.4	328.7	370.4	934.8	1197.2	812.7	354.7	1397.9	760.1	850.7	1339.9	870.1
K94	1265.9	967.0	326.9	225.0	1159.9	1314.3	1009.7	416.1	1885.0	909.3	1128.0	1423.9	1002.6
Aquifer Storage and Recovery (ASR)													
ASR1	226.8	351.1	131.8	33.1	309.5	534.9	435.9	651.3	827.6	240.5	76.0	63.0	323.5
ASR2	268.0	422.5	40.2	82.8	310.1	439.9	509.9	631.9	142.6	20.7	106.7	73.1	254.0
ASR3	14.7	184.5	31.4	47.8	186.4	311.9	216.1	357.4	79.9	33.4	24.1	17.4	125.4
ASR4	383.7	562.3	125.1	104.3	370.9	790.3	733.1	693.0	71.2	304.6	136.7	138.2	367.8
ASR5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RCW1	613.3	788.0	196.8	136.0	712.6	931.8	949.2	1516.5	1907.6	597.1	236.6	401.5	748.9
RCW2	588.6	878.7	191.5	129.5	687.1	957.8	931.3	1496.5	1941.8	561.9	226.1	386.2	748.1
RCW3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RCW4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Surface Water Intake													
Hidden Valley Intake	25243	31011	31789	31638	24222	29553	27015	27408	31743	29451	28065	26374	28626

Notes: (*) The pumping rates shown in this table are not the modeled pumping rates.

8.1 Water Quality Risk Assessment

8.1.1 Region of Waterloo Groundwater Models

A groundwater model was developed for the entire geographical extent of the Region of Waterloo (Region) to delineate Wellhead Protection Areas (WHPAs) for the Grand River Source Protection Assessment Report (LESPC, 2015). Subsequently, the groundwater model was updated to meet Clean Water Act water quantity assessment requirements through the Tier 3 Water Budget and Local Area Risk Assessment. The updates included results from numerous detailed hydrogeologic characterization studies completed at well fields to improve the geological understanding of the local areas with high quality borehole data. To refine the numerical discretization of the model in the areas of interest, two distinct models were created. The Waterloo Moraine Model (Moraine Model) encompasses the entire Region of Waterloo with detailed layering of the overburden stratigraphy that supplies most of the water to Kitchener and Waterloo. The Cambridge Model encompasses the well systems of Cambridge with a geographical extent that is limited to the Cambridge area and includes more refinement in the bedrock stratigraphy that supplies water to the majority of wells in this area.

A summary description of the conceptual model for the Region of Waterloo including physiography, geology, hydrogeology, hydrostratigraphy, and groundwater flow is provided in Section 20 of the report entitled Region of Waterloo Tier 3 Water Budget and Risk Assessment. Details regarding the numerical model calibration can be found in Tier Three Water Budget and Local Area Risk Assessment, Model Calibration and Water Budget Report (Matrix and SSPA, 2014a).

Following the completion of the Tier 3 assessment, several updates were made to the Cambridge model. First, the model was updated to reflect the results of pumping tests that were undertaken following the drilling of three new wells in Hespeler (H3A in 2009, H4A in 2012 and H5A in 2012) and an additional test conducted in the Pinebush Well Field in October 2011. A summary of these updates is provided in *Regional and Cambridge Model Updates following the Region of Waterloo Tier Three Water Budget and Local Area Risk Assessment* (Matrix, 2015). The Cambridge model was then updated based on two extensive hydrogeologic assessments undertaken as part of the Cambridge East Class Environmental Assessment (EA) and the Regional Water System Upgrades in Cambridge and North Dumfries Class EA. A summary description of the model and changes implemented for the Cambridge East EA can be found in *Appendix A Cambridge East Water Supply Class EA Hydrogeological and Natural Environment Report* (Golder, 2017c). A summary of changes made in the Blair Road Well Field area can be found in Appendix B Blair Road Well Field Hydrogeologic Assessment of the Cambridge and North Dumfries EA (Golder, 2020c).

The Moraine Model was updated in the area of the William Street Well Field following the completion of the William Street and Strange Street Water Supply Systems Class EA (XCG, 2016). The EA identified a solution to combine treatment from William and Strange Street Well Fields to maximize groundwater taking from both well fields. Following the EA, new wells W2B, W2C and W3A were drilled as replacements for wells W2, W2A and W3. Since a WHPA did not exist for well W3, and anticipated flow rates for the new overburden production wells were planned to increase, the Moraine Model was utilized to generate updated WHPAs (Matrix, 2024).

Mannheim Aquifer Storage and Recovery MODFLOW Model

ASR Model Setup

The Mannheim Aquifer Storage and Recovery wells (ASR) were modeled using a MODFLOW groundwater model originally created by CH2M, and recently refined by Golder (CH2M, 1993; CH2M Hill, 2003; Golder, 2017b; Golder, 2018b). The Mannheim ASR system was intended to operate by temporarily injecting treated but un-chlorinated water, originating from the Grand River, into Aquifer 1 at the Mannheim Water Treatment Plant during wetter conditions (over as much as an 8-month period). This water would then be stored in the aquifer and recovered during periods of increased water demand. The Mannheim ASR model included all existing supply wells in the Mannheim East and Peaking areas (K21 to K26, K29 and K91 to K94), four (4) ASR wells (ASR1, ASR2, ASR3, and ASR4) and two (2) recovery wells (RCW1 and RCW2). It also included six test wells that were installed on the Treatment Plant property and the reservoir property to the north of the plant that were drilled as part of the proposed expansion of the ASR. The ASR wells are used for both injection and recovery while RCW wells are used only for recovery.

ASR Model Calibration

The Mannheim model was calibrated to both steady-state and transient conditions from data collected between September 2006 and July 2010 that represented static conditions and early use of the ASR system. The overall water balance error for the calibrated model (i.e., the difference between total inflow and outflow), was less than one percent. Simulated groundwater elevations were typically within 1 meter of the measured values at steady state. The Normalized Root Mean Squared error of the steady-state calibration for the Mannheim model was 8.9% with about a 12-meter range of observed hydraulic head values in the model area. Calibration resulted in an assigned recharge rate of 219 mm/year or 26% of the annual precipitation across most of the study area, with the exception of a few pre-existing gravel pits within the model domain. Infiltration through the gravel pits was expected to be elevated and was assigned a recharge rate of 1000 mm/year. All of the calibrated values determined during model calibration were considered to be reasonable when compared to the estimated ranges for the locations under consideration.

Following the steady-state calibration, a transient model calibration was completed. The transient calibration consisted of simulation of the operational startup period from November 2005 to December 2006, and a 30-day performance test of the ASR system in June-July 2010. Similar to the steady-state calibration, simulated and observed hydraulic heads were compared to evaluate the agreement between the two data sets, thereby indicating the degree of model calibration. The modeled groundwater elevations at monitoring well locations generally matched the elevations observed during the time interval quite well. Given the results, the model was considered well calibrated to transient conditions. The calibrated model was then used to complete the capture zone assessment.

Further information on the Mannheim ASR model can be found in “Aquifer Storage and Recovery (ASR) Stage 2 Expansion Project: Phase 1 Hydrogeology Report” (Golder, 2017b) and “Mannheim ASR Project, Stage 1 – Conceptual Design Report” (Golder, 2017a).

8.1.2 Wellhead Protection Area Delineation

The two FEFLOW® groundwater flow models developed and refined during the Tier 3 Risk Assessment and a third ASR MODFLOW model, were utilized to develop updated WHPAs for the municipal supply wells in the Region. The Regional FEFLOW® model encompasses the entire Region of Waterloo and was modified from a pre-existing groundwater flow model with a focus on the overburden groundwater flow systems. The Cambridge FEFLOW® Model was developed during the Tier 3 Assessment and focussed on the bedrock stratigraphy in the Cambridge area. The model utilized to generate capture zones at each wellfield was selected based on which best represented the local conditions. Capture zones for all wells besides the ASR wells were completed using steady-state model conditions. The WHPAs for the ASR wells were delineated using a MODFLOW model run in transient state to simulate the cyclical nature of water injection and withdrawal of this system.

The input parameters applied in the Regional and Cambridge Models contain a level of uncertainty, including uncertainty in the subsurface structure, parameter values, boundary conditions, and observed values. All -these factors contribute to the non-uniqueness of a model and the input parameter values. As a result, many combinations of parameter values can produce an equally good fit to the observed data. In the context of a single conceptual model, numeric uncertainty can be analyzed by making small perturbations to parameter values and evaluating the fit to the observed data. Exploring these minor changes provides insight into parameter-specific numeric uncertainty. However, to examine the uncertainty in the overall flow system, alternative conceptual models with various parameter value combinations provide even more insight into the uncertainty associated with the overall groundwater flow system, and the potential impact on model predictions.

Three unique uncertainty realizations were developed and calibrated in the Regional and Cambridge Models to test the uncertainties in the conceptual model of the Kitchener-Waterloo and Cambridge areas. Each alternative is considered statistically calibrated to a level that is as good (or better) than the original base case model The uncertainty case realizations can be briefly summarized as:

- Uncertainty Case 1 involved calibration to long-term, time varying groundwater level elevations across the Region, rather than steady-state water levels, which resulted in a different set of hydraulic conductivity and recharge values that varied across the models.
- Uncertainty Case 2 involved increasing the hydraulic conductivity values of the aquitard layers to the upper range of our conceptual understanding of the range of property values, and this often led to a commensurate decrease in conductivity values of the intervening aquifers to produce a statistically calibrated model.

- Uncertainty Case 3 in the Moraine Model involved increasing the hydraulic conductivity values of the Salina Formation bedrock beneath the Waterloo Moraine to the upper range of our conceptual understanding. In the Cambridge area, Uncertainty Case 3 involved adding model layers representing the Guelph Formation to simulate vertical variability within the formation.

Results of forward and backward particle tracking was completed for each of the base and uncertainty cases and were combined and an “envelope” was created around all of the particle tracking simulations. For the wells in the Moraine Model, forward and backward particle traces for all three uncertainty cases plus the base case were used for the delineation of protection areas with the exception of wells W5 and W25 as the original Tier 3 model did not include these wells and the uncertainty scenarios were not run for these wells. Similarly, for some wells in the Cambridge Model forward and backward particle traces were used for all four cases; however; for many of the wells, particle traces from one or more uncertainty cases produced unacceptable results and so were excluded in the delineation of well head protection areas. This occurred for the Blair (G4), Clemens Mill (G6, G16, G17, G18, G19), Hespeler (H3, H3A, H4A, H5, H5A), Middleton (G1, G1A, G2, G3, G14), and Pinebush (P10A, P10B, P11, P17, P19) well fields. Once delineated, the protection area envelopes were then carried forward into the vulnerability assessment and scoring process.

Time of travel WHPAs (WHPA-B, WHPA-C and WHPA-D) were generated using both forward and reverse particle tracking. WHPA-A’s represent the area within an outer boundary identified by a radius of 100 meter from each well. Forward particles were released near ground surface in only the base case model using a 100 meter grid spacing across the model area and tracked forward in time until the particles reached a municipal well or another boundary condition. Forward particle traces that stopped within a 50 meter radius of a municipal well were considered to be captured by the well, and the time-of-travel for the particle trace was recorded. Backward particle tracking was also undertaken to confirm and supplement the forward particle tracking. Backward tracking particles were released within a 10 meter radius around the well screen at the top, mid-point and bottom of each screened interval or open hole and tracked backward in time. Particles were released in this manner to capture the flow field toward each municipal production well screen. These backward tracking particles were released in the base case models, as well as the uncertainty realizations for the Regional and Cambridge Models.

Modeled pumping rates used to generate the WHPAs were established in consideration of future (2031) Allocated Rates applied in the Tier 3 Assessment and the planned rates (to 2051) in the Water Supply Master Plan. In the Tier 3 Assessment, the Moraine Model and Cambridge Model were run to predict changes in drawdown within each respective well while pumping at the 2031 Allocated Rates. However, several of the existing operating water supply wells were not included in the Tier 3 Assessment as they were not needed to meet the 2031 demands as documented in the 2015 Water Supply Master Plan (Stantec 2015). Also, the wells in Cambridge, Kitchener and Waterloo are part of the Integrated Urban System whereby the wells can be operated at different rates to meet the demands, maintenance and/or treatment upgrades across this entire area. Further, the results of the Tier 3 Assessment identified that withdrawal of water from wells in one area interferes with and changes where water flows to adjacent and/or up gradient wells resulting in wellhead protection areas that change with changes in pumping. Pumping rates were established to address these issues.

To help quantify this, a series of iterative groundwater flow modelling scenarios were undertaken to simulate the potential takings from various well fields within the IUS in the event that a large wellfield or treatment plant becomes temporarily unavailable due to treatment upgrades or some catastrophic failure. Pumping scenarios were run to assess the ability of the wells and aquifers to sustain pumping for up to a two-year period while the wellfield or treatment system is repaired or replaced. These short-term rates served as an upper limit for the derivations of long-term pumping rates that were used for wellhead protection delineation.

Based upon Regional Council's resolution to decommission well K70 and K71, a subsequent study made modifications to the Pompeii Wellfield (K72 to K75) WHPAs and generated new WHPAs for Elgin Street Wellfield (G9) (Matrix, 2018c). The WHPAs for these wells were delineated or re-delineated due to changes in the Region's long term servicing plans for these water supply wells. Specifically, K70 and K71 were removed from the long-term plan and scheduled for decommissioning and G9's service life was extended.

As noted previously, the Cambridge East EA utilized the Tier 3 Cambridge model that was subsequently updated with the testing completed as part of the EA. The wellhead protection areas delineated as part of the Cambridge East EA used the "base case" Tier 3 Cambridge model and followed the same process as for the other wells in the Region as outlined above.

Blair Road and William Street WHPA Updates

The WHPAs at Blair Road and at William Street Well Fields were updated in 2018 and 2024 utilizing the Cambridge Model and the Moraine Model, respectively. In each case, the models were updated to reflect new hydrogeological information that had become available. A new WHPA was required at the Blair Road Well Field due to the planned increase in water taking at the G4A well (original WHPA-E delineation remains unchanged). The re-delineation of WHPAs at Blair Road and William Street Well Fields used the "base case" versions of the Cambridge and Moraine models, respectively, and completed a backward particle tracking analysis.

The Moraine Model was updated in the area of the William Street Well Field following the completion of the William Street and Strange Street Water Supply Systems Class EA (XCG, 2016). The EA identified a solution to combine treatment from William and Strange Street Well Fields to maximize groundwater taking from both well fields. Following the EA, new wells W2B, W2C and W3A were drilled as replacements for wells W2, W2A and W3. Since a WHPA did not previously exist for well W3, and anticipated flow rates for the new overburden production wells were planned to increase, the Moraine Model was utilized to generate new WHPAs (Matrix, 2024).

Mannheim ASR WHPA Delineation

WHPAs for the ASR and RCW wells could not be delineated using typical groundwater flow methods since the ASR system is intended to be water-balance neutral. A transient annual pumping schedule was developed consisting of a 95-day pause period in which all pumping/injection ceases, followed by a 60-day injection period, a 180-day second pause period and a 30-day pumping period (Golder, 2018b). A two-year transient model simulation was run where reverse and forward particle tracking was applied to the transient flow results. An area of capture was delineated that encompassed the forward and reverse particle simulations. The resulting area was increased an additional 20% and the regional flow direction was adjusted by +/- 5 degrees to account for model uncertainty for the delineation of the final WHPA-B. Only WHPA-A and WHPA-B areas were delineated for the ASR and RCW wells, since the capture zones for the ASR wells and the other wells in the Mannheim Wellfield overlap.

Reports

Complete descriptions of the methodologies and the results of the capture zone delineation studies are provided in the reports entitled:

(1) Region of Waterloo Wellhead Protection Area Delineation Study (Matrix, 2017a);
(2) Updates to the Wellhead Protection Area Delineation, Vulnerability Scoring, and Transport Pathways for Wells K72 to K75 and Well G9 (Matrix, 2018c); and,
(3) Updated Wellhead Protection Area Delineation and Vulnerability Scoring Mannheim Aquifer Storage and Recovery Wells (Golder, 2018b).
(4) WHPA Delineation for the Cambridge East Well Fields in Support of the Cambridge East Environmental Assessment (Matrix, 2017).
(5) Updates to Wellhead Protection Areas, Vulnerability Scoring, Percent Managed Lands, Livestock Density, and Impervious Cover for Parkway and Pinebush Well Fields: Data Transfer Letter Report, (Matrix, 2018f)
(6) WHPA Delineation for the Cambridge East Well Fields in Support of the Cambridge East Environmental Assessment (Matrix, 2017)
(7) Updates to Pinebush Wellhead Protection Areas in Support of the Cambridge East Environmental Assessment, (Matrix, 2020)
(8) Updated Well Head Protection Area Delineation and Vulnerability Scoring Mannheim Aquifer Storage and Recovery Wells (Golder, 2020b).
(9) Updated Source Water Protection Mapping for the Blair Road Well Field (Golder, 2022).
(10) William Street Wellfield Wellhead Protection Areas Delineation and Vulnerability Update (Matrix, 2024)

8.1.3 Intake Protection Zone Delineations

The Region of Waterloo's Hidden Valley intake is located on the Grand River immediately upstream of a small overflow weir. The intake is considered a Type C river intake due to the fact that the area upstream of the weir maintains riverine characteristics. There is constant flow in the downstream direction hence the direction of flow does not change. The weir creates a backwater area approximately 3 to 4 m deep and serves to maintain a relatively constant head over the intake structure and pumps. The weir works by reducing the velocity of the stream in the vicinity of the weir. The change in velocity is small enough that it does not significantly influence the flow characteristics of the river nor is the weir large enough to create a significant impoundment or reservoir which would behave more like a lake.

This is supported by dye tracer and hydraulic modeling work carried out as part of background studies to delineate the IPZ-2 (Stantec 2009b). These studies demonstrated that the weir has a small effect on hydraulics upstream of the intake. The river flow direction is not changed by the weir and water moves continuously in a downstream direction. In addition, the weir has a small impact on the time of travel. Based on the dye tracer study, the weir has the effect of increasing the time of travel in the backwater area by approximately 1 to 2 hours at low flow conditions; this effect would be much smaller under high flow conditions. Under high flow conditions (i.e. the conditions under which IPZ-2 was delineated), hydraulic modeling suggests that the effect of the weir would be to reduce the average channel velocity by approximately 0.2 m/s, which increases the time of travel by less than 10 to 15 minutes.

For these reasons, a request was made under Technical Rule 55.1 to have this intake classified as Type C. The request was granted by the Director in a letter dated November 26th, 2010 and is included in **Appendix B.**

IPZ-1, -2, and -3 were delineated for the Hidden Valley Surface Water Intake as part of Source Water Protection studies in the Region of Waterloo.

The IPZ-1 was initially delineated to include an on-land setback based on the GRCA Regulation Limit, or 120 m, whichever was greater. This was modified on the east side of the river where the IPZ-1 boundary now follows a drainage divide found within both the regulated limit and the 120 meter setback. Water to the east of this drainage divide is conveyed to an outlet approximately 70 meter downstream of the intake.

The majority of field work and analysis was completed in support of the IPZ-2 delineation since the IPZ-1 uses a distance-based delineation and the IPZ-3 was delineated using the GRCA's watershed and sub-watershed delineations. The IPZ-2 delineation work was primarily focused on deriving the design flow rate of concern, the water velocities associated with this flow rate, and the travel distance that such flows could cover in 2-hours. The 2-hour time of travel was used for the IPZ-2 delineation in accordance with Technical Rule 66:

> "66. For the purposes of sub rules 65(1) and 65(2), where the time that is sufficient to allow the operator of the system to respond to an adverse condition in the quality of the surface water is less than two hours, the time of travel to the surface water body intake shall be deemed to be two hours."

Given that an operator would be able to respond to adverse conditions in the Hidden Valley Intake and Groundwater Under Direct Influence (GUDI) WHPA-E capture zones within 2-hours, rule 66 was deemed applicable. The IPZ-2, 2-hour time of travel delineation utilized information from a variety of sources including the following:

- An in-situ dye tracer study using Rhodamine WT;
- Mixing zone modeling using CORMIX;
- Detailed bathymetric and velocity survey work;
- Low-flow hydraulic analysis and parameter derivation using HEC-RAS;
- Hydraulic analysis through a range of flow regimes using HEC-RAS;
- Spreadsheet and graphical analysis on the timing of historical hydrograph events;
- A spreadsheet statistical analysis of in-river flows; and
- Examination of the flow-turbidity relationships of the river, specifically with regards to the operational protocols of the intake.

Through these extensive analyses, a channel-bankfull design flow rate of 80 m^3/s was determined to be appropriate for the IPZ-2 delineation. With an associated average maximum water velocity of 0.82 m/s, the 2-hour travel distance up the river from the intake was estimated at 5,880 m.

Additional hydraulic analysis was completed for tributaries and anthropogenic features within the IPZ-2. The primary tributaries which were identified include: Idlewood Creek, Randall Drain, Freeport Creek, Hofstetter Creek, and the outlet from the Hidden Valley ESPA located immediately upstream of the intake. Numerous other unnamed tributaries and drains, as well as storm sewer outfalls, were identified and included within the IPZ-2 delineation as appropriate. The following design criteria were used to delineate the IPZ-2:

- Travel times in the sewersheds were calculated using a storm velocity of 2 m/s.
- Intake protection areas were limited to a 120 meter setback from the river/creek or the GRCA shoreline Regulation Limit, whichever was greater.

Owing to the number of conservative assumptions incorporated in the IPZ-2 delineation, it was concluded that the IPZ-2 delineation is conservative.

8.1.4 WHPA-E Delineations

WHPA-E capture zones were delineated and scored for wells classified as GUDI in the Region of Waterloo using similar methods as that used to delineate the IPZ-2 for the Hidden Valley intake. The delineation and scoring of a WHPA-F is only necessary where a drinking water quality Issue is identified in the well according to the Rules.

WHPA-E and WHPA-F capture zones were not delineated for the Middleton Wellfield. Under Technical Rule 49: A WHPA-E and WHPA-F is required where *the interaction between surface water and groundwater has the effect of decreasing the time of travel of water to the well when compared to the time it would take water to travel to the well if the raw water supply for the well was not under the direct influence of surface water.* At the Middleton Street wellfield, the interaction between the Grand River and groundwater does not appear to influence the travel time of water to the wells, therefore delineation of a WHPA-E was not required for this wellfield. Considerable work has been completed in study of the potential influence of surface water to the Middleton Street wellfield, relating to the designation of the Middleton Street wells as Groundwater Under Direct Influence of surface water with effective filtration (GUDI-EF) (Stantec, 2007; Stantec, 2009c). The hydrogeologic study including detailed monitoring of water quality and water levels in the shallow and deep groundwater and in the Grand River indicate that, in the area close to the wellfield, there is no direct connection between the River and the municipal aquifer and further, in the area of the wellfield the shallow groundwater discharges to the River even under municipal pumping conditions. Regionally, there is recharge to the deeper municipal aquifer from shallow groundwater, and this is likely the source of surface water indicator parameters in the raw water at Middleton Street wellfield, and the reason the wellfield is designated GUDI-EF; in other words the municipal wells may be under the influence of shallow groundwater but apparently not directly the Grand River.

A numeric modelling analysis (AquaResource, 2010) suggested that 8% of the municipal extraction originated from the Grand River, and “a window in the bedrock aquitard to the north of the production wells is simulated to allow surface water to travel downward from the Grand River to the bedrock aquifer. The contribution from the Grand River to the Middleton Street Wellfield is simulated to have a minimum travel time of approximately 0.75-years.” While this connection has been included in the numeric model, a direct hydraulic connection between the river and the deeper aquifer in the area close to the wellfield has not been identified in the studies to date and was added in the numeric model to facilitate the overall water balance. This analysis and the field study results, suggest that limited recharge from surface water reaches the municipal aquifer near the Middleton wellfield; however, this recharge from the river does not “short circuit” to the wells, and does not decrease overall the time of travel of recharge water to the wells.

Given the above discussion, in accordance with Technical Rule 49, a WHPA-E was not designated for the Middleton Street wellfield. It is noted that the hydrogeologic setting (a relatively vulnerable fractured bedrock aquifer) and large extraction rates from the Middleton Street wellfield have resulted in large and vulnerable WHPAs for the wellfield. The additional protection of a WHPA-E vulnerable area for the Middleton wellfield would likely not serve a significant purpose given the large vulnerable areas already delineated and that the WHPA-E for the Cambridge well G15, located approximately 1 kilometre to the south, overlies a considerable portion of these vulnerable areas.

A variety of approaches consisting of both fieldwork and desktop analysis were used to delineate the 2-hour travel distances and associated WHPA-E upstream limits. This work included the completion of the following studies:

- Dye tracer studies;
- Statistical analysis of historical flow characteristics;
- Hydraulic modeling of the primary watercourse systems and select secondary transport pathways; and
- Data/results obtained from previous studies.

In total, three well systems identified as GUDI and requiring WHPA-E delineations were selected for in-situ dye tracer studies, namely the Greenbrook, Mannheim West and

Shades Mills Wellfields. The results of the dye tracer studies were used to calibrate the associated hydraulic models and to help determine travel times and distances in the various watercourse systems at design flow rates. Specific rationale for the selection or omission of a given site for dye tracer work was as follows:

- Greenbrook was selected as it is an urban, channelized system where travel times were expected to be quite rapid and no previous field work assessed in-situ velocities.
- Mannheim West was selected since Alder Creek has many associated branches and wetlands and dye tracing can provide a reliable travel time estimate in this type of system.
- Shades Mills was selected as the hydrodynamic characteristics of the reservoir were largely unknown.
- The Clair Creek system at Waterloo North was not included as the hydraulics of the primary reaches are generally well understood and the well receives only a small fraction of its water from surface water sources.
- In-situ dye tracing was not completed at Willard since flow records were not available for Moffat Creek which joins the Grand River upstream of Willard.

The field components of the dye tracer studies were undertaken in conjunction with elevated flow conditions in the spring, on March 20 and April 4, 2009. In most instances, bankfull or near bankfull conditions were observed, minimizing the need for extensive analytical interpretation of results or extrapolation to estimate design flow conditions. A summary of the selected design flow rates and subsequent 2-hour travel distances is provided in **Table 8.1—3** for each GUDI system. Flow rates in four of the wellfields are based upon the findings of the dye tracer studies outlined above.

A GUDI study undertaken in 2011 to investigate the GUDI condition of the reconstructed G4 well determined the well to be GUDI-EF (Burnside, 2011). A concurrent study completed during the construction of G4A also determined G4A to be GUDI-EF (Burnside, 2010). The WHPA-E delineation at this wellfield – similar to the above WHPA-E delineations – was focused on identifying the upstream points within Devil's Creek which, under bankfull or 2-year peak flow conditions, lie at the two-hour time of travel distance from the shallow overburden zone of influence for G4/G4A.

To determine the travel time, the GRCA's one-dimensional United States Army Corps of Engineers (USACE) HEC-RAS hydraulic model of Devil's Creek was reviewed. Based on this review, it was confirmed that the existing model extents were limited to the portion of Devil's Creek between the Grand River confluence and the pond adjacent to Kent Street, located approximately 3.2 kilometers upstream. Based on a simulation of the two-year return period bankfull flow, the upstream extent of the existing model equated to a travel time of approximately 45 minutes from the existing WHPA-A delineation for G4/G4A (Golder, 2018a). The upstream extent of the Devil Creek watershed was determined to approximately equate to, or be lower than, a two-hour travel distance for G4/G4A. Based on this assumption, the entire surface water catchment of Devil's Creek was included in the WHPA-E capture area.

Table 8.1—3: WHPA-E Delineation Design Flow Rates - Testing Results

		Dye Tracing Study					Historical Flow Analysis	Selected Design Flow (m^3/s)	2 Hour Travel Distance at Design Flows /Velocities (km)
GUDI Well/ Wellfield	Primary Watercourse	Date	Flow (m^3/s)	Distance Traveled (m)	Time to Peak (min)	Average Velocity (m/s)	Q95 (m^3/s)		
Forwell/ Pompeii	Grand River	n/a					n/a	93.5	7.24
Woolner	Grand River	n/a					n/a	93.5	8.83
Waterloo North (W10)	Clair Creek	n/a					0.98	1.0	3.60
Mannheim West Wellfield	Alder Creek	Apr 3, 2010	0.66	2,920	153	0.32	0.57	0.66	4.28
				4,270	210	0.34			
				5,590	300	0.31			
Greenbrook Wellfield	Borden Creek	Apr 3, 2010	0.46	580	16	0.60	n/a	2.0	1.81
				2,175	213	0.17			
	Voisin Greenway	n/a					n/a	3.0	3.40 (plus Laurentian Wetland)
Shades Mills Wellfield	Mill Creek	Mar 23, 2009	1.6	1,420	NA	n/a	1.6/2.7*	n/a	Shades Mills

		Dye Tracing Study					Historical Flow Analysis	Selected Design Flow (m^3/s)	2 Hour Travel Distance at Design Flows /Velocities (km)
GUDI Well/ Wellfield	Primary Watercourse	Date	Flow (m^3/s)	Distance Traveled (m)	Time to Peak (min)	Average Velocity (m/s)	Q95 (m^3/s)		
		Apr 1, 2009	1.3	500	371	0.03			Reservoir**
Willard	Grand River	n/a					134.5	134.5	4.78
Blair Road	Devil's Creek	n/a					n/a	n/a	Entire catchment

* Historical flow analysis for Mill Creek was conducted on two distinct data sets, as obtained from the Water Survey of Canada (WSC) and the Grand River Conservation Authority (GRCA).

** The results of the dye tracing study indicate that the Reservoir provides more than 2 hours of travel time, therefore the WHPA-E encompasses the reservoir, and no specific travel distance is required.

8.1.5 IPZ and WHPA-E Vulnerability Scoring

IPZ and GUDI wells were assigned vulnerability scores which were created by multiplying an area vulnerability factor (Vfa) by a source vulnerability factor (Vfs). The source vulnerability factor reflects those aspects of the intake/well that can impact its relative vulnerability to contamination from the associated watercourse. The area vulnerability factor is related primarily to those physical characteristics of the zone that impact how fast a potential contaminant may be transported to the inlet. Given the above, it is inherent that the zones closest to the intake will have the highest degree of vulnerability.

Factors which affect the weighting and final Vfa score include:

- the area of the WHPA-E that is composed of land;
- the land cover, soil type, permeability of the land and the slope of any setbacks; and,
- the hydrogeological and hydrological conditions in the area that contribute water through transport pathways.

These factors are generally related to either the runoff generation potential of the protection area (percent of land cover, slopes, soil types, and permeability) or the relative efficiency of runoff transport at conveying the runoff from its source to the receiving systems and its intake.

The Vfs is applied to the location of the intake, with those systems on inland lakes and rivers generally considered to be more vulnerable than their Great Lakes counterparts, corresponding to a higher Vfs. In recognition of the variation in water source and intake systems, a range of Vfs can be considered, with selection of the most appropriate value chosen at the local level and based on local conditions and professional judgment.

Factors influencing the weighting of the Vfs include the physical characteristics of the intake system such as depth from surface and distance from shoreline, and the history of water quality concerns, particularly those indicating exceedance of Provincial water quality standards or objectives. While the impact of physical intake characteristics on Vfs are more significant on Great Lakes intakes, these aspects can and should be considered in inland river intakes where appropriate, especially given the general lack of depth or ability to provide a significant distance from the shoreline. However, the range of acceptable Vfs that can be applied to inland rivers systems is limited, as illustrated on **Table 8.1—4**.

Table 8.1—4: Guidelines for Determining Vulnerability Scores for Type C (Inland River) Drinking Water Intakes using Surface Water Sources

Area Vulnerability Factor (Vfa)			Source Vulnerability Factor (Vfs)	Range of Vulnerability Scores		
IPZ-1	IPZ-2	IPZ-3		IPZ-1	IPZ-2	IPZ-3
10	7 to 9	1 to 9	0.9 to 1	9 to 10	6.3 to 9	0.9 to 9

Vulnerability Scoring for the Hidden Valley Intake Protection Zone

The assessed vulnerability scores for the Hidden Valley IPZ-1 and IPZ-2 are summarized in the sections below. Some explanatory notes describing the determination of the assigned values are as follows:

- The Vfa for IPZ-1 is fixed at 10, as required.
- The Vfa for IPZ-2 is assigned a moderate value of 8 in recognition of the extent of transport pathways that exist within the zone. The minimum permitted value of 7 was deemed unsuitable given the 15 natural or anthropogenic pathways located within the IPZ-2. The rationale for not selecting the highest possible value (9) for IPZ-2 is that, with the exception of the headwaters of the Freeport Creek system, the entire Woolwich / Cambridge half of the River largely remains in a generally undeveloped condition.
- A value of 0.9 has been assigned for Vfs, recognizing both the physical characteristics of the intake, including the inherent protection provided by the raw water storage reservoirs, and the observed hydraulic characteristics of the River. The location of the intake below water surface provides an element of protection against contaminants of lower density than the River water itself, such as oils, greases, and other floatables. Further, the location of the intake along the north shoreline of the River provides an additional benefit given the preferred River flow path in the centre of the channel at this location, as observed during the dye tracer work. A final rationale for the selection of the lowest permitted value is the lack of significant water quality issues recorded at the intake historically.

The contribution of contaminants to an intake from the IPZ-3 can vary significantly due to many factors including the size, hydrology and geology of the watershed, amount and type of drinking water threats within the watershed; and the amount and type of contaminants that contribute to chronic loadings. Due to the variation in the level of vulnerability within the IPZ-3, the area vulnerability factor can range from low to high ($1 \le Vfa \le 9$). The selection of appropriate area vulnerability is dependent on those factors influencing the potential for runoff generation such as:

- Rainfall;
- Land use;
- Impervious coverage;
- Soil type;
- Slope; and
- Proximity to outlet.

A higher potential for runoff generation implies a higher inherent vulnerability and, conversely, a lack of available transport pathways or a significant distance from the source to intake translates into a lower vulnerability.

WHPA-E Vulnerability Scoring

GUDI wells, by virtue of their physical separation from the watercourse and the associated additional time of travel required for contaminants to travel to the well, are inherently less vulnerable than surface water intakes to short-term adverse conditions such as spills or other events that may impair the quality of the water. The range of possible scores for the source vulnerability factor for Type C intakes or GUDI wells is limited to values of either 0.9 or 1.0. GUDI wells do not warrant a factor of 1.0, as this would imply that they represent vulnerabilities similar to a surface water intake. For this reason, all GUDI wells except the Shades Mills wells were assigned a source vulnerability factor of 0.9 in the WHPA-E. The Shades Mills wells were assigned a different vulnerability as they are currently classified as Type D intakes or GUDI wells and, as such, are limited to values of 0.8 to 1.0. Investigation has shown that Shades Mills has low source vulnerability and, as such, these wells have been assigned a source vulnerability factor of 0.8.

The area vulnerability factor was assigned to GUDI systems using knowledge of site-specific system characteristics, including hydrology, hydraulics, and historic water quality information. Each assessment inherently involved some unknowns and assumptions; as such a degree of professional judgment was incorporated into the analysis. The following provides a summary of how the key characteristics of each GUDI system affected the final vulnerability scores:

- Contributing drainage areas identified as rural were considered to have a reduced potential for generating runoff versus urbanized catchments. Therefore a WHPA-E zone comprised primarily of rural areas weights the area vulnerability factor lower.
- The velocities of runoff associated with rural drainage areas (natural transport pathways) are slower and include more filtration potential than that of urbanized catchments (anthropogenic transport pathways). Therefore, a higher incidence of anthropogenic transport pathways upstream of the intake results in a higher area vulnerability factor.

Table 8.1—5 provides Wellfield specific details regarding the assigned area vulnerability factors.

Table 8.1—5: WHPA-E Area Vulnerability Scores

Well	Area Vulnerability Factor (B)	Key Characteristics
Pompeii	8	• Significant portion of the WHPA-E is urbanized • Multiple natural or anthropogenic transport pathways existing on west side of River; north/east side of the River remains largely undeveloped.
Woolner	8	• Significant portion of the WHPA-E is urbanized • Multiple natural or anthropogenic transport pathways existing on west side of River; north/east side of the River remains largely undeveloped.

Well	Area Vulnerability Factor (B)	Key Characteristics
Waterloo North (W10)	9	• Contributing drainage area highly developed at typical urbanized impervious coverage levels. • Drainage network generally composed of anthropogenic storm water conveyance systems.
Greenbrook	9	• Contributing drainage area highly developed at typical urbanized impervious coverage levels. • Drainage network generally composed of anthropogenic storm water conveyance systems.
Mannheim	7	• Contributing area is predominantly rural and undeveloped, with the exception of a small urbanized area immediately northeast • Only one major road crossing the River within the WHPA-E • Limited anthropogenic inputs via secondary transport pathways
Willard	9	• Contributing drainage area is highly developed at typical urbanized impervious coverage levels. • Drainage network generally composed of anthropogenic storm water conveyance systems. • Numerous road crossings of primary and secondary watercourses carrying substantial traffic in the WHPA-E
Shades Mills	7	• The WHPA-E lies almost entirely within a protected conservation area with no associated transport pathways.
Blair Road	9	• Significant portion of the WHPA-E is urbanized • Drainage network generally composed of anthropogenic storm water conveyance systems. • Numerous road crossings of watercourses in the WHPA-E

Transport Pathways for IPZ and WHPA-E Zones

In accordance with the delineation guidelines, the following were considered when defining the IPZ-1, IPZ-2 (or WHPA-E) and IPZ-3 (or WHPA-F) zones:

- Perennial and intermittent streams upstream of the river/creek intakes/wells within the limits of the main watercourse protection zone which act as vectors for contaminants.
- Anthropogenic threats with direct discharge to the watercourses upstream of the intakes were considered, including:

- storm sewer outfalls,
- lands drained by tile drains,
- drainage / outfalls of industrial units, etc.

The Technical Rules include an option for the inclusion of drainage areas that contribute water to the WHPA-F/IPZ-3 through a transport pathway. However, unlike the inclusion of such features within the WHPA-E/IPZ-2 delineations, the WHPA-F/IPZ-3 protection zone does not reflect a dynamic condition in its delineation, such as a 2-hour travel distance upstream of the intake. Rather, the WHPA-F/IPZ-3 delineation extends upstream of the WHPA-E/IPZ-2 to the limits of the watercourse systems as contained within the most appropriate GIS database. Given the sheer size of upstream catchment areas to most of the subject systems and the limited importance of including additional transport pathways in addition to the known surface watercourse systems, it was deemed reasonable to not include an assessment of transport pathways within the WHPA-F/IPZ-3 delineation. While WHPA-Fs have been delineated and scored as part of the technical studies, they are not included in the Assessment Report as no locations were identified where Issues were found to originate outside of the other WHPA areas, as per Technical Rule 50 (MOE, 2009b).

The Hidden Valley IPZ-3 vulnerability scoring also took into consideration the inherent detention and dilution benefits provided by reservoirs found in the watershed (Belwood Lake formed by Shand Dam and Conestoga Lake formed by Conestoga Dam), which significantly increase the travel time between contaminant contribution locations and the intake.

A complete description of the methodology and results of the IPZ delineation and scoring at Hidden Valley are provided in the report entitled "*Intake Protection Zones Delineation Study – Grand River Hidden Valley Intake, City of Kitchener"* by Stantec Consulting (2010a). Studies detailing the methodology and results of WHPA-E delineation and scoring are:

(1) Delineation of Wellhead Protection Area 'E' for GUDI Wells, (Stantec, 2009d);

(2) Wellhead Protection Area "E" Delineation and Vulnerability Scoring Municipal Supply Well G15, (Stantec, 2010b); and

(3) Well G4-G4A WHPA-E Delineation (Golder, 2018a).

8.1.6 Groundwater Vulnerability Mapping

Aquifer vulnerability mapping in the Region of Waterloo was originally completed in 2009 to assess the intrinsic susceptibility of municipal aquifers in the Region (AquaResource, 2009). This assessment produced maps of four aquifers of interest utilized by municipal wells throughout the Region of Waterloo.

Subsequent to the original approved Assessment Report, groundwater flow models of the Region were refined during the Tier 3 Assessment (Matrix and SSPA 2014a, 2014b). Following the Tier 3 Assessment, additional refinements were made to the model layers and input parameters in five urban wellfield areas to incorporate field data that was collected after the model characterization portion of the project was complete (Matrix, 2015). The five wellfield areas included Strange Street, Fountain Street and

Waterloo North in the Moraine Model, and Hespeler and Pinebush in the Cambridge Model.

Updated analyses of the intrinsic vulnerability and WHPAs were warranted to utilize the additional geological understanding obtained during the Tier 3 Assessment. An updated groundwater vulnerability assessment was completed by Matrix Solutions Inc. to incorporate additional information gained during model calibration and additional borehole data obtained since the previous assessment (Matrix, 2017). This same vulnerability mapping was utilized for the updates to the Assessment Report at ASR and Cambridge East wells, as well as recent updates to Blair and William Street Well Fields.

Intrinsic Susceptibility Analysis

The Intrinsic Susceptibility Index (ISI) value is intended to reflect the intrinsic degree of protection an aquifer has based upon the thickness and properties of the materials overlying the aquifer. In general terms, this is analogous to the time it would take a contaminant to reach a given aquifer. The ISI technique is one of several techniques specified in the Technical Rules (MOECC, 2015) that can be utilized to develop a vulnerability assessment of aquifer systems over a broad area. Specifically, the approach used for the ISI technique follows the guidance outlined in the MOE Guidance Module 3 (MOE, 2006). Traditionally, ISI values are calculated at discrete well locations on wells that are screened above or within an aquifer of interest. The ISI ranking value is calculated using the following formula;

$$ISI = \sum b \times K_f$$

where b is the thickness of a given geological unit overlying an aquifer, and Kf is a dimensionless number called the K-factor. The K-factor identifies the degree of protection offered by the geologic materials overlying an aquifer of interest.

Updated aquifer vulnerability mapping in the Region of Waterloo was completed using a modified ISI methodology. ISI values were calculated at points across the Regional and Cambridge model domains using the hydrostratigraphic layers and vertical hydraulic conductivity values applied in the models. Using the model layers and conductivity values capitalizes on the conceptual understanding built into the models, accounts for the interpreted continuity of aquifers and aquitards between boreholes, and does not rely on discrete wells or clustered points, which are common downfalls of the traditional ISI method.

The conceptualized stratigraphy in the numerical models was consistent with Ontario Geological Survey (OGS) publications of the Region of Waterloo area (Bajc and Shirota, 2007; Brunton, 2008; Brunton, 2009). Stratigraphic nomenclature referred to in this report for sediments and bedrock formations are described further in the OGS publications and in Section 20 of the report entitled Region of Waterloo Tier 3 Water Budget and Risk Assessment.

ISI values were also calculated using the traditional ISI approach for the higher quality logs as a secondary verification. This additional step was undertaken to identify areas within the WHPA-Ds where the intrinsic susceptibility rating, adjacent to boreholes with high data quality, differed from that calculated on a broader wellfield scale using the modified ISI method described above. ISI values at discrete borehole locations were calculated and overlain on the intrinsic susceptibility rating zone maps (i.e., zones of high, moderate, low) and, where warranted, the ISI layers were updated to reflect the high quality borehole data.

ISI values were calculated using the modified ISI approach from ground surface to the top of each of the following municipal production aquifers:

- Outwash Deposits (primarily Grand River Outwash; AFA2)
- Upper Waterloo Moraine Sands and Equivalents (AFB1)
- Middle Waterloo Moraine Sands and Equivalents (AFB2)
- Lower Waterloo Moraine Sands and Equivalents (AFB3)
- Pre-Catfish Creek Sands and Equivalents (AFD1)
- Contact Zone/Upper Bedrock Surface Aquifer

The ISI results produced as part of the Region of Waterloo's Source Water Protection studies are consistent with the Region's understanding of the thickness and properties of materials overlying the municipal aquifers. For instance, the results for AFB1 and AFB2 indicate lower susceptibility along the core of the Waterloo Moraine, reflecting the considerable thickness of unsaturated sediments along the core and the Upper Maryhill Till clay cap that extends from Erb Street to just north of Mannheim along the western boundary of the Cities of Waterloo and Kitchener. This susceptibility increases to medium and high east and west of the Moraine core where the Maryhill Till cap thins or is not present. The areas of greatest susceptibility are located in low-lying areas where protective surficial tills units have been eroded (e.g., along the Grand and Speed Rivers).

The intrinsic susceptibility ratings for the lower overburden aquifers (Lower Waterloo Moraine Sands [AFB3] and Pre-Catfish Creek Aquifer [AFD1]) in the Waterloo Moraine area were mapped as predominately low, with lesser areas of moderate and high where the Grand, Speed rivers have locally eroded overlying sediments. There are also isolated patches at Elmira and at the Greenbrook wellfield, where the susceptibility increases to medium or high. This ISI result is largely consistent with the understanding of the surficial geology and depositional environment, indicating low susceptibility in areas where the Maryhill, Mornington, Tavistock, and Port Stanley Tills are present; elsewhere the susceptibility increases to medium and high.

The intrinsic susceptibility ratings for the Contact Zone bedrock aquifer ranged from low to high across the Cambridge area, due to the variable thicknesses and properties of the overburden in this area. Bedrock outcrops at surface and overburden thins in Cambridge along the Grand and Speed rivers and in the southeastern reaches of the Region in the Township of North Dumfries. Within the Cambridge area, the intrinsic susceptibility ratings of the Contact Zone bedrock aquifer were low where the Port Stanley and Catfish Creek Tills are thick and act as confining units for the underlying bedrock aquifer.

Table 8.1—6 below provides a list of all the wellfields in the Region of Waterloo and identifies the production wells and the uppermost aquifer that the wells draw water from.

It also identifies the shallow aquifers from the list of 6 key aquifer units noted above, which are found above the municipal aquifer.

A complete description of the methodology and the results of the ISI mapping are provided in the report entitled *Groundwater Vulnerability Assessment for the Region of Waterloo Using a Modified Intrinsic Susceptibility Approach* (Matrix, 2017a).

Table 8.1—6: Aquifers Applicable to Wellfields for ISI Mapping

Wellfield	Production Wells	Screened Aquifer for ISI Mapping	Overlying Aquifer
Waterloo Area Wellfields			
Erb Street	W6C, W6B, W7, W8	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
William Street	W1B, W1C, W2B, W2C, W3A	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
Waterloo North	W5A, W25 (Laurel Tank)	Pre-Catfish Creek Aquifer (AFD1)	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)
Waterloo North	W10[a]	Upper Waterloo Moraine Sands (AFB1)	n/a
Kitchener Area Wellfields			
Strange Street	K10A, K11A, K13/K13B, K18, K19	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
Mannheim ASR	ASR1, ASR2, ASR3, ASR4, ASR5, RCW2, RCW3, RCW4	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
Mannheim East	K21, K21A, K25, K29	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
Mannheim West	K23, K24, K26	Upper Waterloo Moraine Sands (AFB1)	n/a
Mannheim Peaking	K91, K92, K93, K94	Middle Waterloo Moraine Sands (AFB2)	Upper Waterloo Moraine Sands (AFB1)
Greenbrook	K1A[a], K2A[a], K4B[a]/K4C[a], K5A[a], K8[a]	Pre-Catfish Creek Aquifer (AFD1)	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)
Parkway	K31, K32, K33	Pre-Catfish Creek Aquifer (AFD1)	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)

Wellfield	Production Wells	Screened Aquifer for ISI Mapping	Overlying Aquifer
Strasburg	K34, K36	Pre-Catfish Creek Aquifer (AFD1)	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)
Pompeii	K72[b], K73[b], K74[b], K75[b]	Pre-Catfish Creek Aquifer (AFD1)	n/a
Woolner	K80[a], K81[a], K82[a]	Pre-Catfish Creek Aquifer (AFD1)	n/a
Wilmot Centre	K50, K51, K52	Upper Waterloo Moraine Sands (AFB1)	n/a
Cambridge Area Wellfields			
Fountain Street	P16, P18 (Maple Grove)	Pre-Catfish Creek Aquifer (AFD1)	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)
Hespeler	H3, H3A, H4A, H5, H5A	Contact Zone	Middle Waterloo Moraine Sands (AFB2)
Pinebush	G5, G5A, P9, P10A, P10B, P11, P15A, P17, P19	Contact Zone	n/a
Blair Rd	G4[a], G4A[a]	Contact Zone	n/a
Clemens Mill	G6, G16, G17, G18, G19	Contact Zone	n/a
Shades Mills	G7, G8, G38[a], G39[a], G40[a]	Grand River Outwash Sediments Aquifer (AFA2)	n/a
Elgin Street	G9	Contact Zone	n/a
Middleton	G1[a], G1A[a], G2[a], G3[a], G14[a]	Contact Zone	n/a
Willard	G15 [a]	Contact Zone	n/a

Wellfield	Production Wells	Screened Aquifer for ISI Mapping	Overlying Aquifer
Rural Wellfields			
Ayr	A1, A2, A3	Pre-Catfish Creek Aquifer (AFD1)	Middle Waterloo Moraine Sands (AFB2)
Branchton Meadows	BM1, BM2, BM3	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)	Pre-Catfish Creek Aquifer (AFD1)
Elmira	E10	Pre-Catfish Creek Aquifer (AFD1)	Middle Waterloo Moraine Sands (AFB2)
Foxboro Green	FG1, FG2A, FG4	Pre-Catfish Creek Aquifer (AFD1)	Middle Waterloo Moraine Sands (AFB2)Pre-Catfish Creek Aquifer (AFD1)
Heidelberg	HD1, HD2	Pre-Catfish Creek Aquifer (AFD1)	Middle Waterloo Moraine Sands (AFB2)
Linwood	L1A, L2	Contact Zone	Middle Waterloo Moraine Sands (AFB2)
Maryhill	MH1, MH2, MH5, MH4A	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)	Middle Waterloo Moraine Sands (AFB2)
New Dundee	ND4, ND5	Upper Waterloo Moraine Sands (AFB1)	n/a
New Hamburg	NH3, NH4	Contact Zone	Pre-Catfish Creek Aquifer (AFD1)
Roseville	R5, R6	Lower Waterloo Moraine or Catfish Creek Till Outwash Aquifer (AFB3)	Middle Waterloo Moraine Sands (AFB2)
St. Clements	SC2, SC3, SC4	Upper Waterloo Moraine Sands (AFB1)	n/a
Wellesley	WY1, WY5, WY6	Pre-Catfish Creek Aquifer (AFD1)	Middle Waterloo Moraine Sands (AFB2)

n/a denotes no significant aquifers other than the unit screened are intersected by the production wells a – Wells are Groundwater Under Direct Influence of Surface Water (GUDI) with Effective Filtration

b – Wells are considered GUDI with Effective Filtration, but are without Formal Designation

c - Replacement well drilled on same property as original well but the newer well is not yet connected to the municipal supply system

Transport Pathways and Adjustments to Aquifer Vulnerability

A transport pathway is an anthropogenic feature that could reduce the transport time of a contaminant to a water supply source by circumventing the natural protection provided to an aquifer by the overlying sediments. An inventory and analysis of transport pathways, and vulnerability scoring within WHPAs was undertaken by Matrix Solutions Ltd. (Matrix, 2017b). Subsequent updates to this work were completed in 2018 at Wells G9 and K70 to K75 (Matrix, 2018c), at Mannheim ASR wells (Golder, 2018b), at Pinebush & Clemens Mill (Golder, 2020a), the Blair Road Well Field (Golder, 2022) and at William Street Well Field (Matrix, 2024). To assess and identify the location of these transport pathways, a thorough review of a variety of data sources was conducted. The possible transport pathways considered in this investigation and the data sources are provided in **Table 8.1—7** below.

Table 8.1—7: Data Sources Used to Identify Transport Pathways

Transport Pathway	Data Source
Monitoring Wells and Boreholes (current, unused and abandoned)	WRAS+ (2017)[1] Consultant Reports[2] The Ontario Ministry of the Environment and Climate Change (MOECC) Water Well Information System Database (MOECC, 2017) Oil and gas petroleum well data (OGSR 2016)
Municipal Underground Services	Underground services GIS data from the Region (RMOW, 2017)
Pits, Quarries and Mines	MNR (2009)[3] Personal communication (Schweir 2017, Pers. Comm. 2017)
Septic Systems	Region of Waterloo's Assessment Parcel Shape file (2017) Wastewater Services Areas GIS data (RMOW, 2017) Aerial imagery from the Region (RMOW 2016b) Building footprints GIS data from the Region (RMOW, 2016a)

Transport Pathway	Data Source
Stormwater Infiltration Systems	Stormwater infiltration systems GIS data from the Region (RMOW 2017b) Stantec Transport Pathways Geodatabase (Stantec, 2011b)
Deep Excavations, Construction Activities, Underground Parking Structures	Assessment parcels GIS data from the Region (RMOW 2017b) Building footprints GIS file from the Region (RMOW 2016a) Personal communication (Domaratzki 2017, Pers. Comm.; Durnford 2017, Pers. Comm.; Adams 2017, Pers. Comm.)[4] City of Kitchener underground parking structures GIS file (City of Kitchener 2017) Satellite imagery and 3-D map data (Google Maps 2017) Stantec Consulting Inc. Transport Pathways Geodatabase (Stantec 2011b)

[1] Water Resources Analysis System (WRAS). Obtained from the Region of Waterloo, 2017.

[2] Various consultant reports provided by the Region of Waterloo.

[3] Aggregate license data from the Ontario Ministry of Natural Resources and Forestry (2016)

[4] Locations of deep excavation/ deep underground parking based on personal communication.

In accordance with the Technical Rules, an increase in the underlying vulnerability (i.e., aquifer ISI) was evaluated in situations where transport pathways had the potential to increase the vulnerability of drinking water sources to contamination. The Region of Waterloo's approach to transport pathway adjustments included the following:

- All pathways were considered discrete with the exception of licensed aggregate areas and deep excavations;
- If three discrete pathways were found within a 50 meter radius, the 50 meter buffer around each triggered an increase in ISI by one level (i.e., low to medium or medium to high);
- The relative risk of any aggregate extraction areas intersecting overburden aquifers were automatically assigned as "high" with the exception of AFB3 (Lower Waterloo Moraine sediments) and AFD1 (Pre-Catfish Creek deposits), where they were considered to be high risk pathways only if they were licensed for extraction below the water table. For the Contact Zone aquifer, aggregate

extraction areas were considered as low risk pathways unless the bottom of the pathway intersected the aquifer and was within 2 meter of the water table.

- For deep excavations, the increase in ISI was treated similar to clusters, with a single level ISI adjustment made (i.e., low to medium, or medium to high); and,
- If an area was identified as an ISI adjustment area, but the current classification of the ISI was already "high", no adjustment was made to the ISI layer.

WHPA Vulnerability Scoring

After the adjustments were made to the ISI layers, each WHPA was overlain on the ISI map for the corresponding production aquifer identified in **Table 8.1—6**. Vulnerability scores were assigned to the WHPAs according to the Technical Rules, Part VII.3, sub rule 83 (MOECC, 2015). The resulting scores are provided on a wellfield basis in **Sections 8.2** to **8.6**.

The complete methodology and results of the transport pathways assessment and vulnerability scoring are provided in the reports:

(1) Transport Pathways Assessment and Vulnerability Scoring for an Updated Assessment Report in the Region of Waterloo (Matrix, 2017c);
(2) Updates to the Wellhead Protection Area Delineation, Vulnerability Scoring, and Transport Pathways for Wells K72 to K75 and Well G9 Region of Waterloo (Matrix, 2018c);
(3) Updates to Transport Pathways and Vulnerability Scoring for Woolner Wellfield (Wells K80 to K82), (Matrix, 2018e);
(4) Updated Wellhead Protection Area Delineation and Vulnerability Scoring Mannheim Aquifer Storage and Recovery Wells (Golder, 2018b); and,
(5) Vulnerability Scoring, Managed Lands, Livestock Density and Percent Impervious Surfaces Evaluation for Pinebush and Clemens Mill Well Fields – Cambridge East Environmental Assessment New Well Scenarios (Golder, 2020a).
(6) Updated Source Water Protection Mapping for the Blair Road Well Field (Golder, 2022).
(7) William Street Wellfield Wellhead Protection Areas Delineation and Vulnerability Update (Matrix, 2024)

8.1.7 Percent Managed Lands and Livestock Density

An assessment of managed lands and livestock density was completed within the updated WHPAs by Matrix Solutions Inc. (2018d). Subsequent updates to this work were completed in 2018 at Mannheim ASR wells (Golder, 2018b), at Pinebush & Clemens Mill (Golder, 2020a), the Blair Road Well Field (Golder, 2022) and at William Street Well Field (Matrix, 2024). The methodology used was consistent with the *Technical Bulletin: Proposed Methodology for Calculating Percentage of Managed Lands and Livestock Density of Land Application of Agricultural Source Material*, *Non-Agricultural Source Material and Commercial Fertilizers* (MOE, 2009c). Managed lands are defined as land to which fertilizers and/or nutrient units are applied as per the Technical Rules, and livestock density indicates the number of nutrient units over a given area. Data compiled as part of this assessment were used to indicate areas of intensive agriculture and other land management activities during the threats assessment process. Details regarding their calculation are summarized below.

Delineation of Agricultural and Non-Agricultural Managed Lands

Managed Lands were identified by reviewing the property codes, where available, in the MPAC dataset and identifying those where nutrients had the potential to be applied. The parcels identified as agricultural were classified as Agriculturally Managed Lands. Non-Agricultural Managed Lands consisted of Municipal Parks, common land, golf courses, ski resorts, schools, cemeteries, recreational sports clubs (commercial and non-commercial), and exhibition grounds.

Some WHPAs extended outside the Region of Waterloo borders. In these areas, MPAC parcels were obtained from Perth and Wellington Counties. Since property codes were unavailable in these areas, MNRF identified wooded and wetland areas, impervious surfaces (roads, parking lots etc.) and additional wooded areas, aggregate pits, and large residential areas noted in satellite imagery were classified as not managed lands. For the remaining lands, satellite imagery was reviewed to classify individual parcels into Agricultural and Non-Agricultural Managed Lands.

Residential lawns were not included as part of the non-agricultural managed land because they likely do not represent a significant nutrient loading to municipal aquifers.

Where a parcel crossed a protection area boundary, the entire land parcel was factored into the calculations of percent managed land and livestock density rather than just the portion of land that falls within the protection zone. Where a property lies on the border between several protection zones, the category for the protection zone closer to the well or intake (i.e., WHPA-B rather than WHPA-C for example) was assigned to the property (the same procedure was applied to the salt loading potential mapping).

The percent managed land was calculated for each of the approximately 300 protection zones (all WHPA-A, B, C, D, E and IPZ-1 and IPZ-2) regardless of vulnerability. There is a full range of percent managed land categories within various protection zones within the Region of Waterloo, with a relatively equal distribution between the three categories (0-<40%, 40-80% and >80%). Results for each Wellfield are provided in subsequent sections.

Livestock Density

Livestock Density was calculated based on MPAC Parcel data categories or a detailed assessment of existing information (municipal property codes, air photo mapping of land use and farm structures). The resulting livestock density values were mostly in the <0.5 NU/acre category within the urban areas with some higher density categories mostly in rural areas. In many cases, assumptions were made as to the number of livestock and type of livestock at particular parcels. Some WHPA zones included only one or two livestock nutrient sources and were particularly dependent on imagery interpretation and the conservative assumptions of livestock presence and type. Should a more accurate estimate of livestock density be required, additional data collection would be needed including field visits and information from landowners, such as that collected as part of the development of nutrient management plans.

8.1.8 Calculation of Percent Impervious Surfaces

Impervious surface area mapping is used in the scoring and assessment of threats relating to road salt application. Total impervious surface area is defined in the Technical Rules as the surface area of all highways and other impervious land surfaces used for vehicular traffic and parking, and all pedestrian paths that could receive road salt. A recent assessment of impervious surface areas was completed and details are reported in the *Percent Managed Lands, Livestock Density, and Impervious Cover Within Wellhead Protection Areas* (Matrix, 2018d). Subsequent updates to this work were completed in 2018 at Mannheim ASR wells (Golder, 2018b), at Pinebush & Clemens Mill (Golder, 2020a), the Blair Road Well Field (Golder, 2022) and at William Street Well Field (Matrix, 2024).

The key information used to complete the impervious surface area mapping for the Region of Waterloo included detailed air photo analysis and digital mapping for roads and large buildings. The percentage of total impervious surface area was originally calculated for the entire Region of Waterloo over a square kilometre grid (Golder, 2011a). The majority of the Region of Waterloo fell in areas of 1–8% and 8–80% impervious with no areas in the 80–100% category indicating that there are no locations in the Region of Waterloo where a Quantity Score of 10 (indicating a high potential for road salt to be applied at a quantity sufficient to affect source water) would be assigned. Therefore, the approach prescribed under the Technical Rules would result in no significant road salt application threats in the Region of Waterloo. This is inconsistent with the fact that a number of wellfields are known to be impacted by road salt. Recent MOE guidance (November 2009) addressed this by providing that "*any SPC wanting to apply a local method to quantify this Activity can request approval of their method through the Director. This approach allows for local considerations when determining whether road salt is a Threat to drinking water.*"

An alternative method was proposed by the Region of Waterloo (Golder, 2011b), which provides an improved assessment of the Salt Loading Potential and appropriate Quantity Scores for WHPA and IPZ areas. This approach is referred to as the Salt Loading Potential in the following sections and is a surrogate measure of percent impervious surfaces. The Salt Loading Approach was used for all WHPAs and IPZs within the Region of Waterloo with the exception of the IPZ-3 for Hidden Vally Intake, where the moving window average method was used as described in Chapter 3, Water Quality Threat Assessment Methodology, of the Assessment Report.

The Salt Loading Potential approach follows the relationship between *Quantity Score*, *Hazard Score* and *MOE Circumstance ID* as defined by the MOE and was considered to be an appropriate approach for assessing road salt threats in the Region of Waterloo for the following reasons:

- The approach takes into account technical data already available for the Region of Waterloo regarding road types and relative salt application rates. The use of this information in the calculations provides an improved understanding of the distribution of potential salt loading on the roads within the Region of Waterloo's protection zones;

- The approach incorporates technical data on salt application rates for parking lots and other impervious areas collected from the commercial/private sector. This provides an improved understanding of the distribution of salt loading potential on parking lots and other impervious areas;
- The approach was verified against the Region of Waterloo's extensive geochemical database of impacted groundwater. This verification evaluated whether Wellfields with identified Drinking Water Quality Issues related to road salt application were assigned a Quantity Score of 10 since it is already known that there is a high potential for road salt to be applied at sufficient quantity to affect source water in these areas;
- The approach can be integrated with the Region of Waterloo's more detailed mass balance modelling studies which take into account additional information such as tracking of salt application rates on specific roads and estimation of historical salt application rates; and,
- The approach calculates an average value for each WHPA or IPZ (protection zone). The majority of the protection zones in the Region of Waterloo are small (<1 km^2) and as such a value calculated for the footprint of the protection zone is more relevant for these wells/intake.

The Salt Loading Potential method requires that a salt loading potential factor be calculated prior to assigning a Quantity Score. The following bullets describe how the salt loading potential factor is calculated:

Salt Loading Potential = 2**P** + 1**S** + 0.075**IMP**

Where;

- **P = Primary roads -** these include highways, regional roads, and key city roads that need a high level of winter maintenance including salting and plowing. The lengths of primary roads per square kilometre of WHPA or IPZ zone was calculated with the road length expressed as kilometres of two lane road. A weighting factor of 2 is applied to these roads since previous studies have shown that Primary roads generally have about twice the quantity of salt applied relative to Secondary roads (Stantec, 2005; Stantec, 2002).
- **S = Secondary roads -** these include most of the city streets and township roads that are maintained in the winter. This does not include the local roads that only receive road salt under adverse winter conditions such as an ice storm. The length of Secondary roads per square kilometre of WHPA or IPZ was calculated with the road lengths expressed as kilometres of two lane road. A weighting factor of 1 is applied to Secondary roads.
- **IMP = Percent impervious area of parking lots, sidewalks and other impervious areas –** to account for potential road salt application on areas other than roads, the impervious mapping is used with the road areas removed. This is done to calculate a percent impervious of non-road areas in each WHPA or IPZ zone. A weighting factor of 0.075 is applied to these impervious percentage values. This weighting factor is used to normalize the

percent impervious to an equivalent road value, which is also expressed as kilometres of two lane road per square kilometre of WHPA or IPZ zone. This weighting factor was set so that the Salt Loading Potential from these non-road areas accounts for 30% of the total Salt Loading Potential across the Region. Environment Canada (1999) estimated that commercial/private salt use represented approximately 10% of the total winter salt application. However, more recent studies in the United States have shown that commercial/private winter salt application may often account for a greater proportion, representing as much as about 50% of the total salt loadings in some watersheds (Trowbridge et al., 2010; Sassan & Kahl, 2007; City of Madison, Wisconsin, 2006). An intermediate value of 30%, within the range of estimates mentioned above, was selected for this study.

The Salt Loading Potential is expressed in units of 2 lane km/km^2 of WHPA or IPZ. Salt Loading Potential values can be related to Quantity Scores and percent impervious surrogate categories as shown in **Table 8.1—8** below.

The majority of wellfields with road salt-related Issues have a Salt Loading Potential value of greater than 9 and are assigned the highest Quantity score of 10. The Quantity Scores assigned to other values of Salt Loading Potential are shown in **Table 8.1—8**.

Table 8.1—8: MECP Quantity and Hazard Scores for Categories of Salt Loading Potential

Salt Loading Potential (2 lane km/km^2)	Number of WHPA/IPZ Zones	Quantity Score	Hazard Score	MOE Circumstance ID	Corresponding Percent Impervious Surface
0 to 1	17	4	5.9 (gw) 6.7 (sw)	88 (chloride) 89 (sodium)	<1%
1 to <5	64	6	6.7 (gw) 7.5 (sw)	90 (chloride) 91 (sodium)	1 to <8%
5 to <9	48	8	7.5 (gw) 8.3 (sw)	92 (chloride) 93 (sodium)	8 to <80%
≥9	49	10	8.3 (gw) 9.1 (sw)	94 (chloride) 95 (sodium)	≥ 80 %

Note: gw = groundwater, sw = surface water

The relationship of Salt Loading Potential to Quantity Score is analogous to the relationship of Percent Impervious Area to Quantity Score and therefore the existing road salt application circumstances in the MOE Tables of Drinking Water Threats would apply to this alternate method (i.e., no changes are proposed to the existing relationship between Quantity Score, Hazard Score and MOE Circumstance ID). More detailed results for the Salt Loading Potential for each wellfield are presented in the Municipal Systems section below.

8.1.9 Drinking Water Quality Threats Assessment

The Ontario Clean Water Act, 2006, defines a Drinking Water Threat as “an activity or condition that adversely affects or has the potential to adversely affect the quality or quantity of any water that is or may be used as a source of drinking water, and includes an activity or condition that is prescribed by the regulation as a drinking water threat.”

Threat Identification Approach

The original threats risk assessment process was undertaken to determine Significant, Moderate, and Low Threats (Golder, 2010d; Golder, 2010e; Golder, 2011a), and documented in the 2015 Grand River Source Protection Area Approved Assessment Report. An intensive approach was selected to reduce data uncertainty given the potential implications to property owners of being ranked significant and the approximately 20,000 properties that needed to be assessed for the municipal systems. Accordingly, a Threat Inventory and Circumstances Survey (“Census”) was undertaken in 2009 to gather activity and circumstance information from individual properties to enable a more accurate risk assessment. Further verification studies were conducted in 2010 to supplement and verify selected census data.

The key features of the census were as follows:

- The census was customized for five categories of land uses: industrial/commercial; institutional/municipal; agriculture; rural residential; and parkland/vacant. These categories covered the range of regulated threat activities.
- The census was sent to both property owners and tenants, where applicable.
- The initial distribution was based on a preliminary delineation of vulnerable areas (WHPAs, IPZs). The vulnerable areas were later updated and the census distribution therefore did not include several areas that were not delineated at the time of initiation. Unfortunately time constraints did not permit a subsequent census to be undertaken and still meet the legislated reporting requirements. The census was created to be primarily completed on the internet by property owners and tenants, with information transmitted directly to a database. Threat scores were calculated for each reported threat and circumstance using the Tables provided with the MECP Technical Rules.
- Several pieces of communication were provided to property owners/tenants in advance of and during the census to provide information on its purpose, provide census access codes, and provide information about where additional support could be obtained during completion of the census.
- Following the initiation of the census, telephone calls were made to each property owner and tenant to encourage their participation. Greater follow-up efforts including on-site reminders were undertaken in areas of higher vulnerability or for threats with the highest threat scores because of the implications for mandatory risk management.
- Consultation and/or meetings were undertaken directly with local municipal staff, the Grand River Conservation Authority, and local school boards due to

the large number of properties included in the assessment. Follow-up information notices and Public Information Centres were held for the general public.

As it was anticipated that not all property owners and tenants would complete the census, an assumption-based approach was also developed to assess risk for properties without census information. This approach was also used for properties that did not receive a census because of incorrect address information, where the vulnerability mapping was not completed at the time the census was initiated and in cases where the circumstances for the threats were changed by the MECP following initiation. Existing information such as records of environmental soil and water quality, MOE permits, previous threat inventories completed by Water Services staff, and municipal land use tax codes were used as sources of data for this assessment approach. Threat scoring was completed by assigning assumed threat and circumstances hazard scores, from the MECP tables, to each category of existing information.

The assumption-based threats approach work was initiated in January 2010 and updated in October 2010 and January 2011 to incorporate recently provided information, new provincial guidance, and to improve the threat scoring process. Details provided in Golder Associates (2010d: 2010e; 2011) associated with this work are provided in three reports entitled: *Region of Waterloo Threat Inventory and Circumstances Survey – Final Report* (Golder, 2010d), *Updated Threat Assessment – Region of Waterloo Threat Inventory and Circumstances Survey (TICs) Project* (Golder, 2010e) and *Region of Waterloo Threat Inventory and Circumstance Survey: Threat Assessment Update Report* (Golder, 2011a). Examples of the assumption-based approach are provided below:

- For the Threat “Sewage System or Sewage Works-Septic System”, information used to calculate threat scores included GIS mapping of properties located outside of municipally-serviced areas, air photo confirmation for residences location within a WHPA-A, municipal property code information (residential, commercial, etc.) and assumptions regarding the type and size of septic systems present;
- For the Threat “The Handling and Storage of DNAPL”, information used to calculate threat scores included the MOE Hazardous Waste Information Network database. This database contains a list of properties licensed to generate waste derived from DNAPL chemicals and uses the assumption that chemicals are handled and stored partially below grade; and,
- For the Threat “The Handling and Storage of Fuel”, the information used to calculate threat scores included municipal property code listings of gas stations, fuel depots, etc. and assumptions regarding the size and location of the storage tanks were made using the property code.
- For the Threat “Sewage System or Sewage Works – Discharge of Untreated Stormwater from a Stormwater Retention Facility”, it is important to note that the information used to calculate threat scores was based only on Region and area municipal mapping of storm water management facilities and did not include the

related storm sewer distribution piping even though some of these associated distribution networks such as ditches, unlined trenches or sub-system structures in facilities retrofitted in built-up urban areas likely existed and could be considered drinking water threats.

The verification studies completed in 2010 focused on evaluating and verifying data collected in seven selected wellfields: Cambridge (Middleton, Shades Mills, Willard); Kitchener (Parkway, Mannheim); and Wilmot Township (Baden, Wilmot Centre). Approximately 25 properties were visited by a Region of Waterloo inspector in the Middleton Street Wellfield to verify information from a selection of completed Censuses, collect missing information, and to assess the reliability of threat ranking assumptions used when no Census data was available.

Data was also collected in Baden, Wilmot Centre and Mannheim through the completion of additional Censuses by property owners, generally assisted by technical consultants working on behalf of the Region of Waterloo. Data verification was done at approximately 128 rural residential or agricultural properties in the Baden, Wilmot Centre and Mannheim Wellfields through in person or verbal communication with the property owners. More details are available in the *Verification of Threat Inventory and Circumstances Survey Wilmot Centre and Baden Wellfields – Preliminary Draft Report* prepared by WESA (2011) and the *Verification of Threats Inventory and Circumstances Study Results – Mannheim West Wellfield* report prepared by Stantec (2011).

Activities continue to be verified through on-going processes related to the implementation of Source Protection Plan policies, such as correspondences with property owners, site verifications, and air photo analysis. The updated activity data is tracked and managed within the Region of Waterloo's Threats and Policies (TAPS) database.

Significant Threats were enumerated using the activity records within the TAPS database and supplemented with new activity records in only those areas where WHPAs have expanded from the original Assessment Report mapping, and limited to the activities that could be Significant. More details on this process are available in the Significant Threat Enumeration Methodology Technical Memorandum prepared by the Region of Waterloo (2018).

Activities enumerated in expanded WHPA areas were completed by utilizing an assumption-based approach and combined available datasets with analysis of air photos. Examples include:

- For agricultural activities specifically related to nutrient application, including Threats "Application of Agricultural Source Material to Land" and "Application of Commercial Fertilizer" air photos were used to determine whether any cropping areas were present. If so, it was assumed these activities are occurring;
- For agricultural activities specifically related to the storage of nutrients, including "Storage of Agricultural Source Material" and "Storage of Commercial Fertilizer" air photos were used to identify the storage features. Activities were enumerated if the activity was visible;

- For the Threat "Sewage System or Sewage Works-Septic System", information used to enumerate the activities included GIS mapping of properties located outside of municipally-serviced areas, air photo confirmation for residences, and assumptions regarding the type and size of septic systems present;
- For the Threat "The Handling and Storage of DNAPL", information used to enumerate activities included the MOE Hazardous Waste Information Network database;
- For the Threat "The Handling and Storage of Fuel", the information used to enumerate activities included GIS mapping of properties not serviced by gas pipelines, air photo confirmation, and assumptions regarding the size and location of the storage tank;
- For the Threat "Sewage System or Sewage Works – Discharge of Untreated Storm Water from a Storm Water Retention Facility", enumeration of new activities utilized the same approach as the original activity enumeration, which was based only on Region and area municipal mapping of storm water management facilities;
- For the Threat "Application of Road Salt", information used to enumerate new activities included GIS mapping of properties located within new WHPA areas, municipal property code information (non-low density residential), air photo confirmation, and the assumption that chloride-based salt is applied on all properties where paved areas/parking lots are present.

To enumerate Significant Threats in the expanded WHPA areas it was assumed that, in the absence of confirmed activity details, the individual circumstances of the activity were calculated such that they presented the highest hazard score rating (i.e., chemical storage below grade above the highest quantity threshold). This approach was taken so that activities enumerated as Significant Threats would be investigated as resources allow, and accurate activity details could be collected and used to update the database. As such, if an activity intersected a WHPA vulnerability score area equal to or lower than the minimum hazard score at which the activity could be significant, the activity was enumerated as a Significant Threat. Activities exported from the TAPS database, which included activities created by outside users of the system, were enumerated as Significant Threats if the calculated hazard score associated with the activity multiplied by the highest intersecting WHPA vulnerability score equaled or was greater than 80.

8.1.10 Drinking Water Quality Issues Evaluation

The Clean Water Act process allows water quality Issues to be identified for intakes and wells. The objective of the Issues evaluation is to identify drinking water Issues where the existing or trending concentration of a parameter or pathogen at an intake, well or monitoring well would result in the deterioration of the quality of water for use as a source of drinking water. The parameter or pathogen must be listed in Schedule 1, 2 or 3 of the Ontario Drinking Water Quality Standards (ODWQS) or Table 4 of the Technical Support Document for Ontario Drinking Water Standards, Objectives and Guidelines (Technical Rules XI.1 (114 – 117)). An Issues evaluation was completed as part of the

Region of Waterloo's Threats assessment. More details are provided in a report by the Region of Waterloo (2018).

The Technical Rules and MOE guidance on drinking water Issues provides considerable flexibility in the approach that may be taken to define Issues. Considering the information available and the details of the Region of Waterloo's municipal drinking water systems, the following rationale was adopted.

The assessment considered water quality data from production wells and the Grand River Intake. This includes both current and historical chemical and biological test results of raw water with a dataset starting prior to 1990 in many cases. Generally, the chemical dataset included at least annual tests of raw water for general inorganic ("basic chemistry") parameters, common metals, volatile organic compounds, and selected other organic compounds. The dataset also includes results of testing required under the Safe Drinking Water Act (e.g., Ontario Drinking Water Standards parameters that are tested generally every three years as per Regulation 170/03). The assessment considered available water quality data from monitoring wells, only as supporting information for decision-making. No Issues were defined based solely on monitoring well data.

The Issues analysis was completed only for municipal water sources (municipal supply wells and the Grand River intake). This analysis did not attempt to identify Issues in groundwater sources not affecting the Region of Waterloo's municipal supply and did not include noting naturally occurring Issues (e.g., naturally occurring iron, manganese, or hardness).

In the case of raw water sources showing an increasing concentration trend of salt (chloride) or nitrate but where the concentrations were not currently over the relevant criteria: a simple trend analysis was completed, and an Issue was defined if the trend analysis indicated concentrations at the intake/well would likely rise over the criteria within 10 years (by 2029). In the case of raw water sources showing an elevated concentration of organic contaminants with low drinking water standards, an *Issue* was defined if the elevated concentrations were close to the drinking water standard such that the quality of the water as a source of drinking water is deteriorated as per Technical Rule 114 (1) a. Issues are discussed in more detail in **Section 8.2 – Waterloo Area Wellfields**. One parameter was found to be present in Region of Waterloo raw water sources under this circumstance: trichloroethylene which has a drinking water standard of 5 µg/L.

Judgment was used to designate Issues at individual production wells within wellfields in cases where different production wells contained differing raw water quality. In most cases, Issues were designated at all production wells within a wellfield, even for production wells showing lower concentration trends of the parameter of concern. Factors considered in defining Issues in these situations included: the tendency for increases in concentration at a well if the other wells in the wellfield were not operating (i.e. contaminant drawn toward the nearest operating well), the screened interval of the various production wells in a wellfield (i.e. are the production wells tapping the same aquifer), mixing of production waters in the distribution system or reservoir (i.e. is mixing with lower concentration water an impact management option for Issues).

The Issue Contributing Area was selected on a case-by-case basis taking into account the following considerations: potential for multiple sources of contamination to complicate or prevent adequate management/mitigation of the contamination at the intake/well, potential for natural attenuation of the specific contaminant within the aquifer, potential effectiveness of mitigation/prevention programs over the Issue Contributing Area, the contaminant distribution in the aquifer, and the specifics of the wellfield hydrogeological system including groundwater-surface water interaction. If an Issue is identified for an intake, all activity threats within the Issue Contributing Area that can potentially release the same chemical or pathogen are automatically considered significant threats, regardless of the vulnerability.

In all cases, the Issue Contributing Area was delineated as the WHPA-D boundary for the supply well. As noted previously, the well head protection area boundaries for wells in the IUS were delineated using pumping rates that were higher than needed to meet future demand. These rates were established to ensure protection areas were delineated for wells that were not used in the Tier 3 Assessment, to account for increased pumping rates at some wells to offset extended shut down periods for treatment upgrades, and to account for changes in protection areas resulting from the extended shutdowns. Accordingly, these pumping rates best reflect the long term operation of the wells, improve the likelihood that adequate number of non-point properties can be mitigated to reduce the impact to water quality, that future activities approved through development and building permit applications can also be mitigated through implementation of risk management plans and recognized that pumping rates will be higher by the time all risk management plans in Issue Continuing Areas can be negotiated. The Region of Waterloo has several supply wells containing the man-made organic compound 1,4-dioxane. Most impacted wells contain 1,4-dioxane at low or trace concentrations however the Greenbrook supply wells contain 1,4-dioxane contamination at significant levels and a water treatment plant is in operation to reduce the concentrations to acceptable levels in drinking water. The occurrence of 1,4-dioxane has not been included as an Issue at this time because: the compound does not have an Ontario Drinking Water Standard and 1,4-dioxane sources cannot at this time be designated as a Condition. Work is ongoing to mitigate the impact from 1,4--dioxane including treatment and source investigations. The Region of Waterloo's Issues assessment is documented in an updated technical report completed by the Region of Waterloo in 2018.

An Activity Threat is related to an Issue if the Threat is deemed to be a potential source of the contaminant identified in the Issue. Issue-related Activity Threats become Significant Threats if they are located within the Issue Contributing Areas, as per the Technical Rules. **Table 8.1—9** lists the Activity Threats related to the Sodium, Chloride, Nitrate, and Trichloroethylene Issues identified for the Region of Waterloo (Golder, 2011a).

Table 8.1—9: Activities That Become Significant Drinking Water Threats as a Result of an Issue

Chemical of Concern	Issue Related Threat Subcategory
	Application of Road Salt

Chemical of Concern	Issue Related Threat Subcategory
Salt (chloride/ sodium)	Sewage System Or Sewage Works - Discharge Of Untreated Storm water From A Storm water Retention Pond
	Sewage System Or Sewage Works - Industrial Effluent Discharges
	Storage Of Road Salt
	Storage Of Snow
	Waste Disposal Site - Landfilling (Municipal Waste)
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)
Nitrate	Application Of Agricultural Source Material (ASM) To Land
	Application Of Commercial Fertilizer To Land
	Application Of Non-Agricultural Source Material (NASM) To Land (Including Treated Septage)
	Application Of Untreated Septage To Land
	The use of land as livestock grazing or pasturing land, an outdoor confinement area or farm animal yard
	Sewage System Or Sewage Works - Combined Sewer discharge from a storm water outlet to surface water
	Sewage System Or Sewage Works - Discharge Of Untreated Storm water From A Storm water Retention Pond
	Sewage System Or Sewage Works - Industrial Effluent Discharges
	Sewage System Or Sewage Works - Sanitary Sewers and related pipes
	Sewage System Or Sewage Works - Septic System
	Sewage System Or Sewage Works - Septic System Holding Tank
	Sewage System Or Sewage Works - Sewage treatment plant bypass discharge to surface water
	Sewage System Or Sewage Works - Sewage Treatment Plant Effluent Discharges (Includes Lagoons)
	Sewage System Or Sewage Works - Storage Of Sewage (E.G. Treatment Plant Tanks)
	Storage Of Agricultural Source Material (ASM)
	Storage Of Commercial Fertilizer
	Storage of Non-Agricultural Source Material (NASM)
	Storage Of Snow
	Storage, Treatment And Discharge Of Tailings From Mines
	Waste Disposal Site - Landfilling (Municipal Waste)
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)
Trichloroethylene	Sewage System Or Sewage Works - Combined Sewer discharge from a storm water outlet to surface water
	Sewage System Or Sewage Works - Industrial Effluent Discharges

Chemical of Concern	Issue Related Threat Subcategory
	Sewage System Or Sewage Works - Sewage treatment plant bypass discharge to surface water
	Sewage System Or Sewage Works - Storage Of Sewage (E.G. Treatment Plant Tanks)
	Handling and Storage of a DNAPL
	Waste Disposal Site - Landfilling (Municipal Waste)
	Waste Disposal Site - Landfilling (Solid Non Hazardous Industrial or Commercial)
	Waste Disposal Site - Liquid Industrial Waste Injection into a well

8.1.11 Conditions Resulting from Past Activities

Conditions are locations that could affect the quality of drinking water sources due to existing contamination associated with a past activity at the site. Technical Rule 126 (MOECC, March 2017) defines conditions as follows:

- The presence of a non-aqueous phase liquid in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or wellhead protection area.
- The presence of a single mass of more than 100 litres of one or more dense non-aqueous phase liquids in surface water in a surface water intake protection zone.
- The presence of a contaminant in groundwater in a highly vulnerable aquifer, significant groundwater recharge area or a wellhead protection area, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, is present at a concentration that exceeds the potable groundwater standard set out for the contaminant in that Table, and the presence of the contaminant in groundwater could result in the deterioration of the groundwater for use as a source of drinking water.
- The presence of a contaminant in surface soil in a surface water intake protection zone if, the contaminant is listed in Table 4 of the Soil, Ground Water and Sediment Standards is present at a concentration that exceeds the surface soil standard for industrial/commercial/community property use set out for the contaminant in that Table and the presence of the contaminant in surface soil could result in the deterioration of the surface water for use as a source of drinking water.
- The presence of a contaminant in sediment in an intake protection zone, if the contaminant is listed in Table 1 of the Soil, Ground Water and Sediment Standards and is present at a concentration that exceeds the sediment standard set out for the contaminant in that Table, and the presence of the contaminant in sediment could result in the deterioration of the surface water for use as a source of drinking water.
- The presence of a contaminant in groundwater that is discharging into an intake protection zone, if the contaminant is listed in Table 2 of the Soil, Ground Water and Sediment Standards, the concentration of the contaminant exceeds the

potable groundwater standard set out for that contaminant in the Table, and the presence of the contaminant in groundwater could result in the deterioration of the surface water for use as a source of drinking water.

The assessment completed for the Region of Waterloo identified Significant Condition threats meeting the above criteria under the criteria listed in bullets 1 (NAPL), and 3 (groundwater contamination). There were no Significant Conditions identified within a surface water intake protection zone (IPZ) therefore the criteria 2 and 4 above did not apply.

The assessment of conditions within Region of Waterloo WHPAs and IPZs was carried out using the following data sources:

- Information self-reported through the Census (2009) and verified by follow-up communication or file information;
- Information on contamination of land or water already held in Region of Waterloo files, gathered historically for various source water protection initiatives (the majority of the information used came from these files); and
- Historical file information provided by the Ministry of the Environment Guelph District office (2008), on environmental approvals and contaminated sites within 500 metres of most drinking water intakes.
- Comments and opinion provided by Ministry of the Environment Guelph District office staff through a review of the Grand River Proposed and Proposed Amended Assessment Report.

Site information was assessed according to the specific criteria in the Technical Rules and sites were classified into “Conditions”, “not Conditions”, or “Insufficient information”. Subsequently the Conditions were classified as significant, moderate, low, or “score <= 40”, according to Technical Rules 138 through 143. As per the Technical Rules, the threat score depends on the vulnerability score of the property where the contamination exists, whether the contamination was assessed to extend off the property (“off-site”) and the relationship to any Issue Contributing Areas.

The Condition hazard score is addressed under Technical Rule 139 which specifies a hazard score of 6 unless contamination was assessed to extend off the property (“off-site”), or if the condition is on the same property as a well, intake, or system-related monitoring well, in which case the hazard score is 10. Technical Rule 139 states “if there is evidence that the condition is causing off site contamination, the hazard rating is 10”. In the case of Issue-related conditions, Technical Rule 141(4) states “Despite anything else in these rules a condition that results from a past activity is or would be a significant drinking water threat if there is evidence that the condition is or may be causing off-site contamination.” Therefore, one of the key information requirements for scoring Conditions is whether or not the condition is or may be causing off-site contamination of groundwater.

Whether a contaminant source area is or may be causing off-site contamination was subject to a hydrogeological assessment, including scientific decision making as to (a) what constitutes “off-site” (with respect to property boundaries, roadways, multiple parcel properties, etc.) and (b) the probability that offsite contamination is “caused” by the condition. The Region of Waterloo Conditions assessment used a science-based approach using the available technical data on groundwater conditions, groundwater flow regime, property/parcel mapping, and other relevant information, and following the general principles outlined in this document and in Golder Associates (2010, 2011). The most recent information available to the Region on off-site impacts was considered. A number of sites are classed as “insufficient information” to determine if there were off-site impacts, and as a result as per the Technical Rules these sites were not classified as Significant Conditions regardless of the severity of the contamination or location of the site.

Another factor in the Conditions assessment is the approach to assessment of multiple contaminated sites located near to each other, where the resulting groundwater contamination apparently forms co-mingled plumes (i.e., overlapping or combined areas of groundwater contamination). The Region of Waterloo Conditions assessment used a science-based approach which identified sites with groundwater contamination source areas. Each source area site was assessed to be a separate Condition. (Note that the circumstance of one property parcel containing multiple and distinct source areas was not encountered, but the circumstance of one source area spanning multiple parcels was encountered). Sites without source areas, but which had groundwater impacts from an off-site source, were not assessed to be Conditions. This approach was found to be compatible with technical hydrogeological principles of groundwater contamination, and compatible with the implementation of Source Protection Plan policies - which generally must be implemented on a property or owner basis.

The Conditions assessment for the purposes of the Assessment Report was focused on identification of Significant and Moderate Conditions because the Source Protection Plan includes, at this time, only policies for Significant Threats, and due to limited time and resources to gather information on other, lower-scoring Conditions.

The complete methodology and results of the original Threats assessment are provided in *Region of Waterloo Threat Inventory and Circumstances Survey – Final Report* (Golder, 2010d) and *Updated Threat Assessment – Region of Waterloo Threat Inventory and Circumstances Survey (TICs) Project* (Golder, 2010e) and *Region of Waterloo Threat Inventory and Circumstance Survey: Threat Assessment Update Report* (Golder, 2011a).