REPORT

SITE CONCEPTUAL MODEL UPDATE AND CONTAMINANT ATTENUATION ZONE DELINEATION

Waste Management
Richmond Landfill Site

Submitted to:

WASTE MANAGEMENT OF CANADA CORPORATION
1271 Beechwood Road
RR#6 Napanee, ON K7R 3L1

Submitted by:

BluMetric Environmental Inc.
The Tower – The Woolen Mill
4 Cataraqui St.
Kingston, ON K7K 1Z7

Project Number: C-B12501-00-00

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1. INTRODUCTION

The purpose of this document is to provide the technical information necessary to support Waste Management of Canada Corporation's (WM) upcoming application to amend Environmental Compliance Approval (ECA) No. A371203 for the WM Richmond Landfill (the Site), to incorporate the use of a land parcel as a Contaminant Attenuation Zone (CAZ) to bring the Site into compliance with the Reasonable Use Limits (RULs) in Guideline B-7, and the continued use of the property for general rural purposes.

This report has been updated from the previous version[1] to include additional results from complementary hydrogeological investigations. The additional work was required from settlement agreements between WM and parties as part of the Environmental Review Tribunal (ERT) proceedings, in addition to the requirements of the ERT Order dated July 21, 2015 and amended August 20, 2015 and October 29, 2015. As directed in the ERT Order dated December 24, 2015, an application to amend the Site ECA to establish a CAZ will not be submitted until MOECC determines that the extent of the leachate impacted groundwater has been completely delineated, and the proposed monitoring network is sufficient to monitor potential further migration of impact. As required by the ERT Order dated July 21, 2015, a complementary hydrogeological investigation to delineate the impacted area is currently being conducted on the adjoining property to the east of the southern part of the Site and north of Beechwood Road. The new boreholes will be tested using the same methodology as during previous iterations of this hydrogeological investigation, and results will be documented and interpreted in a separate report to be submitted by April 15, 2015.

In the following sections of this report, a description of the applicant properties and their physical characteristics is provided, the current property usage is outlined, the groundwater and surface water conditions are summarized, and recommendations for the proposed CAZ are presented.

1.1 SITE LOCATION AND DESCRIPTION

The Richmond Landfill is located within Part of Lots 1, 2 and 3, Concession IV, former Township of Richmond now Town of Greater Napanee, County of Lennox and Addington, approximately 1.2 km to the north of Highway 401 and is directly accessible by means of County Road 10 (Deseronto Road). The site location is shown on Figure 1. The WM property is bounded by County Road 10 to the west, County Road 11 (Selby Road) to the north, active agricultural fields and Johnson Road to the east, and Beechwood Road to the south. Only the southerly

[1] *Supporting Document, Application to Amend Environmental Compliance Approval No. A371203, Waste Management Richmond Landfill Site*, prepared by BluMetric Environmental Inc., March 2015.

portion of the property owned by WM is developed for landfill purposes. All works and ancillary buildings and structures associated with the Richmond Landfill, except for a lined emergency leachate storage lagoon and two storm water management ponds, are located to the south of the hydroelectric corridor that bisects the property between Marysville Creek and the waste mound. The landfill site is now closed to further disposal and the current site layout is shown on Figure 2.

The area surrounding the Site is a rural, agricultural-resource based community with a non-farm related component of development. Rural, non-farm related residences are interspersed throughout the study area in a linear manner adjacent to county and local roads. The predominant form of land use is agriculture and farm related uses and activities, while natural areas (woodlots, watercourses and wetlands) occupying much of the remaining land base. Other forms of land use present within three km of the Site include non-farm related residences, recreational open space areas, institutional-commercial-industrial uses and activities, and vacant, undeveloped lands.

The area is traversed by a series of transportation and utility corridors, including the Lennox-Oshawa hydroelectric corridor that includes two rows of high-tension transmission lines that run across the WM landfill property from southwest to northeast, immediately to the north of the existing waste mound (see hydro towers illustrated in Figure 2).

2. CURRENT GROUNDWATER CONDITIONS & UPDATE TO THE SITE CONCEPTUAL MODEL

Several phases of hydrogeologic investigation have been conducted in the area south of the landfill footprint in order to develop a better understanding of groundwater flow and chemistry, and to determine the nature and extent of groundwater impacts from the landfill. The results of the investigations in the area of the proposed CAZ are presented in Appendix A.

In the following sections, the current groundwater conditions south of the landfill are summarized. An updated description of the site conceptual model, based on the additional information gathered during the investigation phases conducted from 2012 to 2015 is also presented.

2.1 CURRENT GROUNDWATER CONDITIONS ON THE PROPOSED CAZ

A brief overview of the results of the detailed hydrogeologic investigation conducted on the proposed CAZ properties south of the landfill is provided below. Further information on the methodology, observations and results from this investigation can be found in Appendix A. The scope of the investigation focused on the intermediate bedrock groundwater flow zone south of the landfill.

2.1.1 Physical Hydrogeology

The hydrogeologic conditions encountered in the proposed CAZ investigation were consistent with the previous interpretations. Limestone bedrock was observed in the new boreholes, with the bedrock surface sloping in a general southerly orientation, similar to the ground surface topography. Bedrock consisted of a light grey fossiliferous limestone with thin undulating shaley partings, stylolites and calcite stringers. Horizontal and sub-horizontal fractures were identified in the boreholes from the geophysical logging profiles, with occasional high-angle fractures also apparent in some boreholes.

The overburden thickness in the boreholes ranged from less than 0.5 to 10 metres, with the thicker sequence of overburden found south of Beechwood Road, north of the abandoned MNR quarry at well locations M173 and M174. The thinnest overburden cover, approximately 0.2 metres, was found to the southeast, at well locations M175, M177 and M179. In the area of the investigations, the overburden to the south and southeast consisted of a grey-brown to brown, silty to sandy clay containing sand and gravel, underlain at some locations by sandy to gravelly till, and brown clay till to the east of the landfill.

Hydraulic conductivity profiles were developed from the boreholes on the proposed CAZ using the results of the straddle-packer testing. Increased bulk rock hydraulic conductivity was associated with zones of sub-horizontal fractures and bedding planes identified on the downhole geophysics logs. The measured bulk hydraulic conductivity in the boreholes located within the area of the proposed CAZ ranged from 3.7×10^{-11} to 2.5×10^{-2} m/s, with a geometric mean of 1.3×10^{-7} m/s. An area of well-connected, hydraulically responsive bedrock fractures, identified in previous investigations and described in more detail in Section 2.2 below, was observed to extend south of Beechwood Road to the area around well locations M167 to M188 and M190. Within this area, groundwater heads are generally similar to one another, which is indicative of an area of well-connected higher permeability fractured rock. Outside of the area to the southwest, south and southeast, for example at M173, M174, M179 and M189, the groundwater heads are lower and the bedrock fractures do not appear to be as well-connected.

Across the area of the proposed CAZ, the groundwater flows in a south-southeasterly orientation (refer to the groundwater contour maps from 2012 to 2015, which are found in Appendix A.6).

2.1.2 Groundwater Quality on the Proposed CAZ

Background groundwater quality in the intermediate bedrock zone is characterized by several monitoring wells around the landfill site, as described in the Environmental Monitoring Plan (EMP) (*Environmental Monitoring Plan, WM Richmond Landfill, Town of Greater Napanee*, Revision No. 04 dated August, 2015). Leachate indicator parameters have been selected for the site based on their elevated concentrations in leachate samples and low concentrations in background groundwater. The primary indicators that are used to delineate impacts from landfill leachate at the site are 1,4 dioxane and alkalinity. The presence of 1,4 dioxane at detectable concentrations (> 0.001 mg/L) indicates the furthest extent of groundwater impacts. In addition, where 1,4 dioxane is detected, alkalinity is generally above 400 mg/L. Other parameters are also used to assist in determining impacts and are included in the routine monitoring program.

The median background concentrations in the intermediate bedrock groundwater flow zone for the indicator parameters are presented in Table 1. Reasonable Use Limits (RULs) have been calculated for parameters that have Ontario Drinking Water Standards (ODWS), and for which concentration limits can be calculated using the procedure outlined in MOE Guideline B-7. A site-specific RUL for 1,4 dioxane was set by the ERT (Order dated December 24, 2015) at 0.001 mg/L and shall be re-calculated in accordance with procedure document B-7-1 should an ODWS be set for 1,4 dioxane.

The groundwater chemistry results within the proposed CAZ investigation area are presented in Table A.4 of Appendix A. A summary of the most recent results for leachate indicators for monitoring wells on the proposed CAZ south of Beechwood Road and selected monitoring wells north of Beechwood Road, and comparisons of the observed concentrations to the RULs are presented in Table 2. Included in Table 2 are the chemistry results from monitoring wells M187 to M191, located to improve the understanding of the area where the furthest extent of groundwater impacts has been observed, and from monitoring well nest M178R installed to replace existing well nest M178, scheduled to be decommissioned in 2016. M178R-2, M178R-3 and M178R-4 were determined from pumping tests to be hydraulically responsive to each other through interconnected fractures in bedrock. These three replacement wells were also determined to be hydraulically responsive to the original wells M178-2 and M178-3, and to other wells within the area of well-connected, hydraulically responsive bedrock (eg, M108, M122, M123, M166, M185-2, M188 and M190).

The groundwater sampling results show that 1,4 dioxane is detected in monitoring wells within the north and central portion of the proposed CAZ at concentrations above the ERT ordered RUL of 0.001 mg/L. RUL exceedances for several other parameters, including alkalinity, chloride, DOC, iron, manganese, sodium and TDS are seen in these areas of the proposed CAZ. With the exception of location M64-2, these monitoring wells have all been determined to be hydraulically responsive to pumping tests. Monitoring well M64-2, where a 1,4 dioxane concentration of 0.0022 mg/L was detected in September and November 2014 and 0.0027 mg/L in November 2015, appears to correspond to the western boundary of the area of higher hydraulic conductivity and shows impact to groundwater quality originating from the landfill. However, other leachate indicator parameters, particularly alkalinity and tritium, are not elevated in this well. Further monitoring is required to confirm the presence of 1,4 dioxane at this location. If real, the presence of 1,4 dioxane in this monitoring well demonstrates that lower hydraulic conductivity monitoring wells, even if non-responsive during pumping tests, are part of the intermediate bedrock flow system and can be utilized to monitor groundwater impacts from the landfill.

Monitoring wells M185-1 and M185-2 were determined to be responsive to pumping at well location M178 in the pumping test conducted in July 2014. Similarly, monitoring wells M178-2, M178-3, M185-2, M188 and M190 responded to pumping at M178R-3 in September 2015. The packer testing profile reveals a lower average bulk rock hydraulic conductivity in borehole M185 relative to well locations M178 and M178R. Based on these data, it is interpreted that well location M185 represents the southern boundary of the area of higher hydraulic conductivity and well-connected bedrock fractures extending south from the landfill. To the east, the boundary of this well-connected zone has been interpreted to lie between well locations M167 and M186.

In several monitoring wells on the proposed CAZ, RUL exceedances are noted, but 1,4 dioxane is not detected. For example, in the most recent results (Table 2), iron, manganese and TDS exceed the RULs at well M180, and chloride, sodium and TDS exceed the RULs at wells M63-2, M176, M183, M186 and M191. Similarly, benzene and/or m+p xylene are detected at concentrations above the RULs at wells M121, M176, M180, M186 and M191. The elevated concentrations of dissolved parameters at these wells are naturally occurring.

Based on the results of the CAZ investigations, the monitoring wells within the proposed CAZ and outside of the extent of impacts include the following:

- M63-2
- M173
- M174
- M176
- M177
- M179
- M181-1
- M181-2
- M182
- M185-1
- M185-2
- M186
- M187
- M188
- M189
- M190
- M191

Evidence of naturally saline groundwater is seen at several well locations, (eg, M63-2, M176, M183, M186 and M191) with sodium, chloride and TDS concentrations much higher than landfill leachate. For example, sodium, chloride and TDS at M191 were 41,000, 15,000 and 73,900 mg/L, respectively, in December 2015, much higher than the highest historical leachate results for these three parameters (3,400, 4,300 and 15,000 mg/L, respectively).

Monitoring well M170 is located along the eastern boundary of the landfill property, southeast of the landfill footprint and approximately 140 metres north of Beechwood Road. 1,4 dioxane was detected at this monitoring well in October 2013, September 2014 and November 2015 at concentrations of 0.00137, 0.00197 and 0.0063 mg/L, respectively. The alkalinity concentration in these samples was 500, 460 and 620 mg/L, respectively. These results indicate the presence of impacts at this monitoring well. It is noted that sodium and chloride are also observed at high concentrations in this well, indicating the presence of naturally saline water as well. It is interpreted that well location M170 has a lower hydraulic conductivity than other hydraulically responsive wells on the landfill property to the west, and represents the northeastern edge of impacts, along the apparent boundary of the higher hydraulic conductivity zone extending south and southeast from the landfill. Boreholes drilled north and east of this location encounter rock with low hydraulic conductivities. 1,4 dioxane has not been observed in samples from wells north of location M170 and closer to the landfill: M47-2, M47-3, M52-1, M52-2 and M52-3.

Dilute impacts may extend beyond well location M170 onto the adjoining property to the east of the southeastern Site boundary; however, the area of potential impact on the property would be limited to the southwest corner, as the groundwater flows south-southeastward across Beechwood Road and onto the proposed CAZ. The concentrations that exceed the RULs are restricted to aesthetic-related parameters alkalinity, DOC, sodium, chloride and TDS (the latter three parameters are believed to be at naturally occurring concentrations), as well as 1,4 dioxane. In the meantime, there is no groundwater use on the property; the residence at 1121 Beechwood Road is on whole-house water supply, and the residence at 1097 Beechwood Road is vacant. Previously, the residences were supplied by shallow dug wells which were sampled and did not exhibit impacts. Further investigations to delineate the impacted area are currently being conducted, with new monitoring wells being installed in the intermediate bedrock groundwater flow zone in the southwestern portion of this property. The new wells will be tested using the same methodology as previous iterations of this hydrogeological investigation, and results will be documented and interpreted in a separate report.

2.2 Update to the Site Conceptual Model

The current Site Conceptual Model used for the WM Richmond Landfill was first presented in the report dated October 2009 entitled *Site Conceptual Model Report, WM Richmond Landfill*. Refinements to the model were developed as part of the Action Plan investigation conducted in 2011 and documented in the October 2012 report entitled *Groundwater Action Plan Investigation Report*. Subsequent phases of investigation beginning in 2012, have focused on properties south of Beechwood Road. The information obtained from these investigations has been used to further refine and extend the Site Conceptual Model, and to establish the extent of the proposed CAZ for the site. The information has also been used to develop the EMP for the landfill[2]. The current Site Conceptual Model for the WM Richmond Landfill and proposed CAZ is summarized below.

2.2.1 Physical Hydrogeology

The Richmond Landfill Site is located within the Napanee Plain which, on a regional scale, is a flat to slightly undulating plain of limestone dipping slightly to the south and typically covered with a relatively thin veneer of overburden. The relatively flat nature of the regional topography is interrupted in places due to the presence of drumlins and major surface drainages such as the Salmon River north of the Site and the Napanee River south of the Site. In the immediate vicinity of the Site, the ground surface slopes approximately 1 m to 3 m per kilometre to the south. A drumlin (Empey Hill) is present on the Site southwest of the landfill. The dominant drainage feature on the Site is Marysville Creek located north of the landfill. Beechwood Ditch provides Site drainage south of the landfill.

The overburden at the Site (including the area of the proposed CAZ) consists of less than 0.5 m to 10 m of clayey silt till. The overburden thickens to approximately 20 m in the area of Empey Hill to the southwest of the landfill. The overburden is underlain by the Verulam Formation which consists of horizontally bedded, medium to coarse crystalline limestone with interbedded shale layers. The Verulam is interpreted to be a few metres thick at the Site and is underlain by the Bobcaygeon Formation which generally consists of horizontally bedded, crystalline limestone with interbedded shale in the upper part and interbedded calcarenite in the lower part. The thickness of the Bobcaygeon Formation beneath the Site varies from approximately 11 m to 15 m. The Bobcaygeon Formation is underlain by the Gull River Formation which consists of horizontally bedded limestone and exhibits a thickness of approximately 75 m beneath the Site.

The active groundwater flow zone at the Site extends to a depth of approximately 30 m below the top of bedrock. The dominant fracture orientation in the upper 30 m of bedrock is parallel to bedding (horizontal to sub-horizontal), which is typical of flat lying limestone formations throughout North America. The horizontal to sub-horizontal fractures are distributed throughout the upper 30 m of bedrock, implying that there are no particular depth horizons exhibiting

[2] Environmental Monitoring Plan, WM Richmond Landfill, Town of Greater Napanee, Ontario, Revision No. 04, August 2015

anomalous amounts of fracturing. Some borings do exhibit a shallow weathered zone, however, in which fracturing is more pronounced. Below approximately five metres from the bedrock surface, the fracture frequency decreases. In addition to the horizontal to sub-horizontal fractures, a moderate amount of vertical to sub-vertical fractures exist providing hydraulic connections between the various horizontal to sub-horizontal fractures.

The bulk rock hydraulic conductivity derived from hydraulic testing on all boreholes at the Site (including the CAZ area as well as the land north of Beechwood Road) ranges from $<1.0x10^{-11}$ to $2.5x10^{-2}$ m/s, with a geometric mean of $5.7x10^{-8}$ m/s. The majority of the conductivity is attributable to the presence of fractures given the low permeability rock matrix. The various hydraulic conductivity measurements indicate that a zone of relatively lower hydraulic conductivity exists north of the landfill. This does not imply that there is no groundwater flow through that portion of bedrock, but rather that the rates of groundwater flow are lower than through portions west, south and east of the landfill. Given that the dominant fracture set is horizontal to sub-horizontal, it follows that the bulk rock hydraulic conductivity exhibits significant anisotropy with greater hydraulic conductivity in the horizontal direction than the vertical direction.

The hydrogeologic characteristics of the area south of the landfill footprint and east of the landfill entrance road are distinguishable from other areas of the site based on hydraulic conductivity, water level variations and the rate of response to recharge events. The area is characterized by interconnected fractures that appear to be well connected to recharge/discharge features, which are likely in direct connection to surface infiltration. The well-connected area has a significant role in the local variation of the potentiometric surface as the water levels vary throughout the year by as much as 4 to 6 m. The results of the recent proposed CAZ investigation, which demonstrated hydraulic connection between monitoring wells north and south of Beechwood Road, have demonstrated that the hydraulically well-connected area extends onto the proposed CAZ properties, as far south and southeast as well locations M188, M190 and M167.

The results of hydraulic conductivity tests conducted in boreholes and monitoring wells within the well-connected area have been compiled, and compared to the results from tests conducted outside of the apparent boundaries of this area. In total, results from 477 tests were evaluated, 249 within the area of hydraulically well-connected borehole locations and 228 outside of the boundaries. The geometric mean of the hydraulic conductivities measured inside the area of well-connected boreholes was slightly higher than the geometric mean of the hydraulic conductivities measured outside the area ($3.52x10^{-7}$ versus $8.71x10^{-8}$ m/s, respectively). Also, the distribution of results showed a much higher proportion of hydraulic conductivities greater than $1x10^{-5}$ m/s within the area of well-connected boreholes (32.5%), relative to the area outside (18.0%). This is illustrated in the histograms on Figure 3. The increased distribution of higher hydraulic conductivities and the observed connections between monitoring wells within this area are consistent with the interpretation that this area consists of a well-connected fracture network through which groundwater can flow at a greater rate than outside of the area.

It is important to emphasize that the area of well-connected bedrock fractures described above interacts hydraulically with other areas of the Site. It is distinct due to its behavioral differences during recharge/discharge time periods, but does not represent a separate flow regime. Furthermore, the zones of lower hydraulic conductivity surrounding the area to the west, south and east do not represent a barrier to flow; rather the rate of groundwater flow is slower within these lower permeability zones within the fractured bedrock. The presence of the less permeable zones is clearly seen by comparison of temporal water level variations inside and outside of the area of well-connected fractures. Flow out of the area is controlled by the lower hydraulic conductivity in the surrounding rock. Infiltrating water recharging into the well-connected area is stored, resulting in the noticeable rise in water levels, which then dissipate as groundwater flow moves through and out of the area. The presence of lower permeability zones within the bedrock is apparent elsewhere at the Site, and is typically accompanied by relatively shallow saline water (e.g., as at well locations M63-2, M106, M186 and M191).

Another area that exhibits a distinct hydraulic behaviour was identified in the southern portion of the proposed CAZ during the most recent round of investigations. Static groundwater elevations in intermediate bedrock zone monitoring wells located within this area (eg, M173, M174, M181, M187 and M189) were observed to be much deeper compared to wells in the area of higher hydraulic conductivity monitoring wells introduced previously. Static water levels at these locations were deep, between 15 and 30 mbgs (100 masl or lower) compared to 2-3 mbgs and rarely deeper than 5 mbgs (115 masl or greater) within the higher conductivity area (see Figure 5(c)). Similarly, groundwater elevations at M176 and M179, while not as deep (3.0 and 7.6 mbgs, respectively), also exhibited static groundwater elevations of 100 masl or lower. While most wells in this group exhibit low permeability across the vertical profile, relatively more permeable fracture zones were identified in some boreholes (eg, M189 and M187). At well location M187, a highly permeable fracture was encountered at a depth of approximately 26 mbgs (~90 masl). Despite the limited drawdown that could be achieved during the pumping test at this location (see Appendix A for details), M187 was confirmed to be hydraulically connected to other wells defining the periphery of the area of responsive monitoring wells (eg, M64-2, M173, M179 and M185).

Another distinguishing feature identified within the proposed CAZ is the presence of a near-surface feature located approximately 50 m southwest of monitoring well M187, where a local surface water course enters into the ground in what appears to be a karstic feature (see Section 2.2.1.1 and Appendix A). This karstic feature is located outside of the area of landfill impacted groundwater defined using the network of wells installed as part of the characterization of the proposed CAZ lands.

2.2.1.1 Shallow Groundwater Zone

The shallow groundwater flow zone comprises overburden, the overburden-bedrock contact, and the first one to two metres of depth into bedrock. Water level monitoring indicates that these three portions of the shallow flow system act in concert and can be treated as a single flow zone. The directions of groundwater flow in the shallow flow zone are strongly influenced by ground surface topography, which is typical throughout northeastern North America where water tables are generally shallow.

Shallow zone flownets are constructed seasonally at the site using water level data from hydraulically responsive wells. Figures 4(a), 4(b) and 4(c) illustrate the shallow groundwater flownets from Fall 2013, Spring 2014 and Fall 2015, respectively. The flownets show that there is a water level high beneath Empey Hill stemming from the elevated topography of this feature. Empey Hill creates a flow divide west of the landfill with shallow groundwater being directed both to the north and the south. The northerly flowing groundwater discharges to Marysville Creek. The southerly flowing groundwater flows towards Beechwood Ditch in the southwest portion of the Site. Shallow groundwater south of the landfill and south of Beechwood Road also flows towards the area of lower water levels in the southwest portion of the Site.

Shallow groundwater east of the landfill is influenced by a local zone of higher water levels in the vicinity of monitoring well M96. Shallow groundwater north of well location M96 flows to the north and ultimately into Marysville Creek while groundwater south of well location M96 flows to the south-southeast. The shallow groundwater flow directions described here do not vary significantly with season despite the fact that water levels at the Site can be up to approximately 2 m higher in the spring months compared to the fall months. The lack of variation of shallow groundwater flow direction with season stems from the fact that the shallow flow system is topographically controlled and indicates that an appropriately located monitoring well network will detect a potential contaminant plume in the shallow zone.

Shallow groundwater discharges into a low-lying area in the central portion of the proposed CAZ area south of Beechwood Road. The land surface rises south of this low-lying area which therefore likely acts as a local divide for the shallow groundwater flow in this part of the CAZ. This shallow groundwater flow system is distinct from that discussed above for the area near the landfill and shown on Figures 4(a) to 4(c), where shallow groundwater converges from local topographic highs towards Marysville Creek and Beechwood Ditch.

2.2.1.2 Intermediate Bedrock Groundwater Zone

The intermediate bedrock groundwater flow zone extends from one to two m below the top of bedrock to a depth of approximately 30 m below the top of bedrock. The 30 m limitation was selected on the basis of the fact that groundwater salinity increases significantly below 30 m depth into bedrock and the fact that fresher groundwater, including leachate, does not have the ability to displace the denser, saline groundwater. In addition, because of the significant anisotropy exerted by the dominance of horizontal to sub-horizontal fractures, the primary groundwater flow direction in bedrock is horizontal. This does not, however, rule out localized occurrences of vertical flow within the intermediate flow zone. The deep groundwater below 30 m depth into bedrock is classified as non-potable according to the Ontario Drinking Water Standards, Objectives and Guidelines. At some well locations, naturally saline waters exist in the intermediate bedrock at depths of less than 30 metres, particularly in areas of lower hydraulic conductivity and slower groundwater flow rates. These waters are distinguishable by elevated sodium, chloride and TDS concentrations, low alkalinity and often the presence of ammonia and BTEX compounds.

As with shallow groundwater, the intermediate zone groundwater will always flow from regions of high hydraulic head to regions of low hydraulic head. The hydraulic testing programs conducted since 2009 have revealed that there is continuity of hydraulically connected fractures in the intermediate flow zone surrounding the landfill to the west, south and southeast. Pumping of individual wells at various depths induced hydraulic responses up to 450 m away, supporting the interpretation that groundwater flow occurs primarily through horizontal and sub-horizontal fractures that are connected to each other by vertical to sub-vertical fractures. The conceptual model for groundwater flow in intermediate bedrock is that a sufficient number of interconnected fractures exist such that flownets can be relied upon to determine the directions of groundwater flow and to delineate the area of landfill impacted groundwater including within the proposed CAZ. Figures 5(a), 5(b) and 5(c) illustrate the intermediate bedrock flownets for Fall 2013, Spring 2014 and Fall 2015, respectively. The near-surface karstic feature identified southwest from monitoring well M187 is located sufficiently far enough downgradient from the well defined area of impacted groundwater such that any potential impacts to groundwater or surface water will be detected using the existing monitoring network and sampling program and by updating the EMP.

Intermediate zone flownets illustrate that groundwater flowing under the landfill generally flows to the west from the western edge of the landfill, to the south-southeast from the southern edge of the landfill, and to the southwest from the southwest corner of the landfill. The hydraulic influence of Empey Hill is seen in the intermediate flow zone in that a relatively stagnant zone (weaker hydraulic gradients) is created southwest of the landfill. Unlike the shallow zone flow system, however, the intermediate zone flow system exhibits greater changing directions of flow with season. This stems from the fact that the intermediate flow system is not as constrained by topographic control as the shallow zone flow system. The regional groundwater flow direction is southward, following the dip of the limestone bedrock as well as the general slope of the topographic surface.

Area South of Landfill

The groundwater contours and orientations of groundwater flow for the intermediate bedrock in the area of well-connected fractures south of the landfill and east of the landfill access road can be distinguished by periods of higher groundwater levels and periods of lower groundwater levels. During periods of high groundwater levels, the groundwater generally flows south-southeast across this area toward Beechwood Road (see Figure 5(b)). Groundwater from the southern edge of the landfill east of the entrance road flows towards the southeast in the direction of well location M105 and continues southeastward toward Beechwood Road.

During periods of lower water levels, groundwater flow is oriented toward the central portion of the well-connected area from the north; west and south (see Figures 5(a) and 5(c)). Flow from the eastern half of the landfill footprint is directed toward the central portion of this area, as is flow from west of the landfill entrance road, as well as flow from properties south of Beechwood Road. Based on the water level contours, groundwater flows eastward south of the landfill, and continues toward the east-southeast. During periods of low water level, the data suggest that a groundwater divide is established south of Beechwood Road, along an approximate orientation from northwest to southeast. This is particularly apparent in on the potentiometric surface for October 2013 (Figure 5(a)), where groundwater north of the divide flows onto the landfill property from the properties south of Beechwood Road, and groundwater south of the divide flows southward. The groundwater divide is present only during periods of low water levels; at other times, the flow is more consistently southeastward.

Flownets derived from the more recent proposed CAZ investigation (Appendix A.6; Figures A.6.1 to A.6.7) indicate that the groundwater flow continues in a southeastward orientation across the properties that are proposed to be used for the CAZ. From the September 2014 water level measurements, it was observed that the monitoring wells outside of the well-connected area exhibited lower water levels than the wells within the area. Monitoring wells within this area had similar water levels to each other, which is indicative of an environment of higher bulk rock hydraulic conductivity and lower hydraulic gradients. As described in Section 2.2.1 above (refer to Figure 3), the area of higher hydraulic conductivity is surrounded by areas of bedrock with lower bulk rock hydraulic conductivity to the west, south and east.

The implication of the changing flow direction seen in the intermediate bedrock is that hydraulically downgradient locations within the intermediate flow zone will vary with season, and that an appropriate monitoring network to assess groundwater quality in the downgradient flow direction will need to comprise a network of monitoring wells at various locations. A corollary to this is that the changing groundwater flow directions in the intermediate flow zone will cause potential leachate plumes to shift in flow direction with season, thereby ensuring that a network of monitoring wells is capable of detecting their presence.

Groundwater from the intermediate bedrock groundwater flow zone is believed to be naturally discharging to ground surface in a wet area located in the central portion of the proposed CAZ. Covering approximately 500 m by 100 m, this area extends between well locations M178/M178R and M173/M187.

Multiple lines of evidence confirm that groundwater discharge is occurring in this area:

- Strong vertical hydraulic connections exist within the intermediate bedrock groundwater flow zone in this area, for example between M178R-4 (screened 4.5 m below bedrock surface) and the deeper wells (M178R-2 and M178R-3, screened 17 and 11 m below bedrock, respectively);
- Artesian conditions exist in several intermediate bedrock monitoring wells in this area (eg, M178, M178R where hydraulic heads have been observed to reach as much as 4.9 m above ground surface, at M178R-2 on May 15, 2015), indicating the presence of strong upward vertical hydraulic gradients;
- Groundwater discharge points have been observed in various locations within this diffuse area, and found to flow intermittently depending on the conditions, including during winter where some discharge points remain flowing and wet at times;
- Areas where groundwater was observed to discharge to surface were sampled and found to be impacted with low 1,4 dioxane concentrations (between 1.5 and 4.0 μg/L in fall 2015, well below the PWQO compliance limit for surface water (20 μg/L)).

Area North and Northwest of Landfill

The area north and northwest of the landfill footprint, between the landfill and Marysville Creek, has been identified through hydraulic testing as an area where relatively lower hydraulic conductivity exists (Site Conceptual Model Report, October 2009). This does not imply that there is zero groundwater flow through this area, but rather that the groundwater flow rate is lower than in other areas around the landfill site.

A further evaluation north of the landfill was completed as part of this update to the site conceptual model. Water levels from 37 monitoring wells located north of the landfill footprint along Marysville Creek were examined. The monitoring wells used for the evaluation are listed in Table 3. The hydrographs from these wells for the past ten years are presented in Figure 6. In proximity to the creek at locations northwest and northeast of the landfill, the vertical hydraulic gradient is generally upward. Immediately north of the landfill, the vertical hydraulic gradient is relatively neutral. This evaluation is consistent with the conceptual model in that the shallow and intermediate bedrock groundwater flow systems are dominated by horizontal components of flow, with upward vertical components of flow near Marysville Creek. The dominant horizontal components of flow stem from the existence of bedding plane fractures in the weathered bedrock which exert significant anisotropy.

Table 3: Monitoring Wells Used for Water Level Evaluation North of Landfill

Monitoring Well			
Shallow Zone		Intermediate Bedrock Zone	
• M35	• M83	• M5-2	• M94-1
• M39	• M84	• M5-3	• OW1
• M55-4	• M85	• M6-3	• OW4
• M65-1	• M86	• M46-2	• OW37-d
• M65-2	• M94-2	• M68-2	• OW55-i
• M66-1	• M103	• M68-3	• OW56-i
• M66-2	• M104	• M75	• OW56-d
• M67-1	• OW5	• M82-1	• PW2
• M67-2	• OW55-s	• M82-2	
• M68-4	• OW56-s		

With reference to the October 2009 Site Conceptual Model Report, comparing the shallow zone flownets to the intermediate zone flownets indicates that the vertical component of the hydraulic gradient between the shallow and intermediate flow zones is relatively neutral to slightly upward to the north and northwest of the landfill in the vicinity of Marysville Creek. This does not imply that the groundwater is always horizontal or upward north of the landfill. The significant anisotropy exerted by the dominance of horizontal to sub-horizontal fractures will result in primarily horizontal flow in bedrock, but some shallow groundwater will be transferred to the intermediate flow zone in areas where a downward component to the hydraulic gradient exists during parts of the year.

Ultimately, Marysville Creek is the primary potential receptor that should continue to be monitored north of the landfill. The extensive amount of monitoring to date, including testing for 1,4 dioxane and other primary leachate indicators, demonstrates that impacts have not been identified in the groundwater adjacent to the creek. Impacts are seen in the groundwater within approximately 50 metres north and west of the unlined Phase 1 portion of the landfill; however, because of the lower hydraulic conductivity and slow rate of groundwater flow, no impacts are observed in groundwater along the creek.

2.2.1.3 Deep Bedrock

The deep bedrock zone is defined as groundwater occurring greater than approximately 30 m below the top of bedrock. The deep groundwater is saline and not suitable for potable use. There is limited hydraulic interaction between the intermediate bedrock flow zone and the deep bedrock because of the differences in groundwater density related to salinity. Deep bedrock groundwater generally flows to the south in a horizontal direction, although vertical components of flow may also exist. Bulk rock hydraulic conductivity is generally lower at depths greater than 30 m below the top of bedrock, and fracture apertures are generally smaller below this depth. It follows that the movement of groundwater in the deep bedrock will be slower than in the shallow and intermediate bedrock flow zones.

2.2.2 Groundwater Quality and Extent of Impacts

Background groundwater quality in the shallow and intermediate bedrock flow zones is characterized by geochemistry in several monitoring wells on the landfill property, as described in the EMP. The monitoring wells exhibit low concentrations of water quality parameters and the groundwater can be classified by the Ca-Mg-HCO_3 facies on a Piper diagram, which is consistent with shallow natural waters obtained from limestone bedrock and overburden.

Naturally saline waters also exist in the intermediate bedrock, particularly in areas of lower hydraulic conductivity and slower groundwater flow rates. These waters are distinguishable by elevated sodium, chloride and TDS concentrations, low alkalinity and often the presence of ammonia and BTEX compounds. Monitoring wells that exhibit naturally saline groundwater in the intermediate bedrock zone include M63-2, M106, M111-1, M111-2 and M112-1 (west of the landfill entrance road), as well as monitoring wells M70-1, M110-2, M176, M183, M186 and M191 (east of the entrance road). Other monitoring wells that exhibit what appears to be a mixture of fresh water and saline water are intermediate bedrock locations M49-1, M49-2, M112-2, M113-1 and M170, and shallow groundwater locations M114-2 and M115-2.

The primary indicators that are used to delineate impacts from landfill leachate at the site are 1,4 dioxane and alkalinity. The presence of 1,4 dioxane at detectable concentrations (> 0.001 mg/L) indicates the furthest extent of impacts. In addition, where 1,4 dioxane is detected, alkalinity is generally above 400 mg/L. Other parameters are also used to assist in determining impacts and are included in the routine monitoring program. A list of the leachate indicators specified in the EMP is provided in Table 4.

Table 4: Groundwater Indicator Parameters Used in Routine Monitoring Program

Primary Leachate Indicator Parameters	
• 1,4 dioxane • Alkalinity	
Other Inorganic and General Indicators	**Volatile Organic Compounds**
• Total dissolved solids • Conductivity • Chloride • Sodium • Dissolved organic carbon • Ammonia • Iron • Manganese	• Benzene • Toluene • Ethylbenzene • Xylenes • 1,1,1-Trichloroethane • 1,1-Dichloroethane • 1,1-Dichloroethylene • Chloroethane

Groundwater sample data collected from on-site monitoring wells indicate that leachate impacted groundwater is flowing from the northwest corner of the unlined Phase 1 footprint of the landfill in the shallow and intermediate bedrock groundwater flow zones.

In the shallow groundwater zone, impacts are evident at monitoring wells M100, M101, M103 and M104 north and west of the Phase 1 landfill cell. These monitoring wells are all in close proximity to the landfill. Further downgradient, in particular along Marysville Creek, no impacts have been observed in the shallow groundwater. Similarly, monitoring well M41, located approximately 25 m south from the landfill footprint, has been impacted by leachate impacts while no impacts have been measured at shallow groundwater monitoring locations farther downgradient (M54-4 or M70-3, located south and southeast of the landfill, respectively). A map showing the historical 1,4 dioxane concentrations in shallow groundwater monitoring wells is presented on Figure 7(a).

In the intermediate bedrock groundwater zone, impacts are evident within 50 metres north of the landfill footprint at monitoring wells M6-3 and OW4. No evidence of impacts is seen further downgradient, closer to Marysville Creek. This is consistent with the hydraulic testing results which show an area of low hydraulic conductivity north and northwest of the landfill.

South of the landfill and onto the area of the proposed CAZ, impacts are evident at several monitoring wells as described in Section 2.1.2. Based on the results of the recent proposed CAZ investigation, it appears that the groundwater impacts extend as far south and southeast as well locations M178/M178R and M167, respectively.

There is no evidence of impacts in any of the monitoring wells located south of the landfill footprint and west of the site entrance road. The concentrations of environmental isotopes are at background levels, and the concentrations of major ions reflect either background groundwater quality or influence from deeper connate water.

Maps showing historical 1,4 dioxane concentrations in intermediate bedrock groundwater monitoring wells are presented in Figure 7(b) and Figure 7(c), for areas north and south of Beechwood Road, respectively.

3. DESCRIPTION OF THE CONTAMINANT ATTENUATION ZONE

The location of the WM Richmond Landfill site in relation to the proposed CAZ is shown on Figure 2. The proposed area for the CAZ is located south of the landfill site, and south of Beechwood Road, as shown on Figure 2. An application to amend the ECA for the Site to incorporate the use of a land parcel as a CAZ, and the continued use of the property for general rural purposes, will be submitted to MOECC at a later date. However the description and recommendations related to the area that is currently proposed as a CAZ are provided here (Sections 3 and 4) for completeness.

There are nine properties included in the area that is proposed to be designated as a CAZ. The individual properties are shown on Figure 8, and include the following registered block and property identification numbers (from west to east):

Block & PIN

- 45083-0098 (owned by Waste Management);
- 45083-0099 (owned by Waste Management);
- 45083-0101 (owned by Waste Management);
- 45083-0100 (owned by Waste Management);
- 45083-0103 (owned by Waste Management);
- 45083-0102 (Crown Land administered by Ministry of Natural Resources);
- 45083-0104 (owned by Waste Management);
- 45083-0105 (owned by Waste Management);
- 45083-0108 (owned by Waste Management).

The properties are located on parts of Lots 2, 3, 4 and 5, Concession III, in the former Township of Richmond, now the Town of Greater Napanee. A copy of the Survey Plans for each property will be provided upon formal submission of a CAZ application to MOECC).

3.1 Current Land Use

The proposed CAZ area is currently zoned as rural (RU), with the following exceptions: i) the property at 1252 Beechwood Road (45083-0100) is the site of a former abattoir, and is zoned as rural industrial (M3-2); and ii) the southern portion of the Crown Land (45083-0102) is zoned extractive industrial (M4). The layout of the properties is shown on Figure 8 and a brief description of the land use is provided below.

The northern area of the proposed CAZ is used mainly for agricultural purposes, including hay production, livestock grazing and unimproved pasture. In this area, the land is mostly cleared of trees except along fencerow boundaries between some of the fields and properties. Further south from Beechwood Road, the area becomes heavily wooded. An abandoned limestone quarry is situated on the southern portion of the Crown Land administered by MNR. The proposed CAZ is transected in a north-south direction by two farm lanes leading to properties further to the south. A pipeline easement crosses the northern portion of the proposed CAZ in a west-to-east orientation, and an overhead power transmission corridor cuts across the southern half of the proposed CAZ, also in a west-to-east orientation.

A livestock abattoir and retail butcher shop formerly operated at 1252 Beechwood Road. The building is now unoccupied. Four residential dwellings are located along the south side of Beechwood Road within the proposed CAZ area. Each dwelling was previously serviced by a private water supply well and in-ground (septic) sewage system. However, three of the dwellings are now unoccupied (1264, 1250 and 1206 Beechwood Road), and the easternmost dwelling is occupied but serviced by a whole-house water system supplied with tanked water from an off-site source (1144 Beechwood Road).

3.2 Physical Setting

3.2.1 Topography and Drainage

The proposed CAZ has low relief with a slope to the south of approximately 1 to 3%. This slope coincides with the regional dip of the underlying limestone bedrock. The ground surface elevation ranges from approximately 129 metres above sea level (masl) in the north to 104 masl in the south. Overland drainage generally follows the local slope of the ground surface. A surface water drainage course cuts across the extreme south east corner of the proposed CAZ, flowing from northeast to southwest, under Highway 401. A local surface water course is also present in the central portion of the MNR property near a wet area where the water table is often observed at ground surface, and drains into the ground in a local topographic depression in the same area of the CAZ.

3.2.2 Site Geology

The overburden beneath the proposed CAZ generally consists of less than 0.5 to 10 m of clayey silt till. In general, the overburden is thicker to the north and thins towards the south and southwest. An area of thicker overburden is found on the MNR property, along the hydro transmission corridor.

The general site area including the landfill property and the proposed CAZ is underlain by Paleozoic rocks of the Simcoe and Basal Groups, including the following formations (from youngest to oldest): Verulam, Bobcaygeon (Upper and Lower Members), Gull River and Shadow Lake. The first three formations are members of the Simcoe Group, and are composed of carbonate rocks, generally consisting of fossiliferous limestone with shaly layers and partings. The Shadow Lake formation is a member of the Basal Group of Paleozoic rocks in the area, and consists of light to dark red shale, siltstone and sandstone.

3.2.3 Physical Hydrogeology

The physical hydrogeology of the WM Richmond Landfill site is divided into three distinct hydrogeologic units, denoted as:

a) the shallow groundwater flow zone;
b) the intermediate bedrock groundwater flow zone; and,
c) the deep bedrock.

These hydrogeologic units are described above in Section 2.2.1. In the area of the proposed CAZ, the unit of interest is the Intermediate Bedrock Groundwater Flow Zone. This unit is described in further detail below.

The intermediate bedrock flow zone extends from two metres below the top of bedrock to a depth of approximately 30 m below the top of bedrock. The 30 m depth was selected on the basis that groundwater salinity increases significantly below 30 m depth into bedrock in the vicinity of the existing landfill, and the fact that fresher water, including leachate, does not have the ability to displace the denser, saline water. In addition, because of the significant anisotropy exerted by the dominance of horizontal and sub-horizontal oriented fractures in bedrock (mostly bedding plane partings), the primary groundwater flow direction in bedrock is horizontal. This does not rule out vertical components of flow in intermediate bedrock, but simply recognizes that the predominant path for groundwater flow is through horizontal and sub-horizontal fractures. The conceptual model for groundwater flow in the intermediate bedrock is that a sufficient number of interconnected, hydraulically active fractures exist such that flownets can be relied upon to determine the directions of groundwater flow. Groundwater in the intermediate bedrock zone flows from areas of high hydraulic head to areas of low hydraulic head through the interconnected system of bedding planes and fractures. On the proposed CAZ south of Beechwood Road, the orientation of groundwater flow in the Intermediate Bedrock is south to southeast.

3.3 Current Groundwater Usage

There is no groundwater usage on the properties covered under this proposed CAZ application. Several monitoring wells are located on the properties for groundwater quality monitoring and water level measurements. The results of water quality investigations have revealed that impacts occur in the north and central portion of the proposed CAZ, extending to well location M178/M178R in the south and well location M167 in the southeast. Beyond these monitoring wells, within the proposed boundaries of the CAZ, impacts have not been observed.

4. RECOMMENDATIONS FOR CONTAMINANT ATTENUATION ZONE

Based on the above information, the land area for the proposed CAZ is shown on Figures 2 and 8.

The following recommendations are offered for the use of the proposed CAZ property:

A. Continued Use of the Land

Section 4.0 of MOE Procedure B-7-1 stipulates that the MOE may support an application for a Contaminant Attenuation Zone when alternate sources of water are available and when the extent of the CAZ is limited.

There is no demand for groundwater use on the applicant property. The continued use of the land for general rural purposes will not impact the proposed CAZ. Residential use can continue; however, any water supplies will need to be serviced by off-site sources and not from on-site wells.

Waste Management is in the process of applying to the Ministry of Natural Resources (MNR) for a Lease of Crown Land to allow the proposed CAZ to be established on the property south of Beechwood Road that is administered by MNR (registered property 045083-0102). The property is shown on Figure 8. Current use of the MNR property will not be affected by the proposed CAZ.

B. Groundwater Monitoring

The recommended Environmental Monitoring Plan (EMP) for the WM Richmond Landfill, including the proposed CAZ, was presented in the report entitled, *Environmental Monitoring Plan, WM Richmond Landfill, Town of Greater Napanee*, and Revision No. 04, dated August, 2015. The EMP was implemented on an interim basis on September 1, 2015 as ordered by the ERT.

The document describes the following components of groundwater monitoring on the proposed CAZ:

- Monitoring well locations (for water level measurements and groundwater sampling);
- Analytical parameters and frequency of testing;
- Trigger well locations;
- Trigger mechanisms to initiate contingency action; and
- Reporting requirements.

The following twenty monitoring well locations will be sampled on the proposed CAZ as part of the EMP:

- M64-2
- M114-1
- M114-2
- M121
- M123
- M167
- M168
- M177
- M178R-1
- M178R-2
- M178R-3
- M178R-4
- M179
- M185-1
- M185-2
- M186
- M187
- M188
- M189
- M190

In addition, as a precautionary measure, domestic water supplies that are serviced by drilled wells along County Road 1 West, south of Highway 401, between Deseronto Road and Oliver Side Road, as well as at 614 and 696 Belleville Road west of Deseronto Road (if these are drilled wells) will be sampled for 1,4 dioxane at two-year intervals for a minimum of 6 years.

Testing results for all sampling completed in accordance with the Environmental Monitoring Plan will be included in the Semi-Annual Reports required under Condition 14.1 of ECA No. A371203.

Respectfully submitted,
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TABLES

Table 1: Summary of Leachate Indicators, Background Concentrations and Reasonable Use Limits

			Intermediate Bedrock Flow Zone		
Parameter[(1)]	**ODWS[(2)]**	**X[(3)]**	**Background Range**	**Median Background**	**RUL**
Primary Leachate Indicators					
1,4-dioxane[(4)]	---	---	< 0.001	< 0.001	0.001
alkalinity	30 - 500	0.5	230 - 430	300	400
Inorganic and General Parameters					
ammonia	---	---	< 0.02 - 3.41	0.17	---
chloride	250	0.5	3 - 63	15	132
conductivity (µS/cm)	---	---	556 - 1070	702	---
DOC	5.0	0.5	< 0.5 - 8.2	1.9	3.5
iron	0.3	0.5	< 0.01 - 2.5	0.05	0.18
manganese	0.05	0.5	< 0.002 - 0.07	0.014	0.032
sodium	200	0.5	< 1 - 123	13	106
TDS	500	0.5	308 - 696	429	465
Volatile Organic Compounds (VOCs)					
1,1,1-trichloroethane	---	---	< 0.0001 - <0.0004	< 0.0001	---
1,1-dichloroethane	---	---	< 0.0001 - <0.0004	< 0.0001	---
1,1-dichloroethylene	0.014	0.25	< 0.0001 - <0.0005	< 0.0001	0.0035
chloroethane	---	---	< 0.0002	< 0.0002	---
benzene	0.005	0.25	< 0.0001 - 0.0009	< 0.0005	0.0014
ethylbenzene	0.0024	0.5	< 0.0001 - < 0.002	< 0.0005	0.0013
m+p-xylene o-xylene	0.3	0.5	< 0.0001 - 0.0017	< 0.0001	0.1500
toluene	0.024	0.5	< 0.0002 - 0.0015	< 0.0005	0.0121

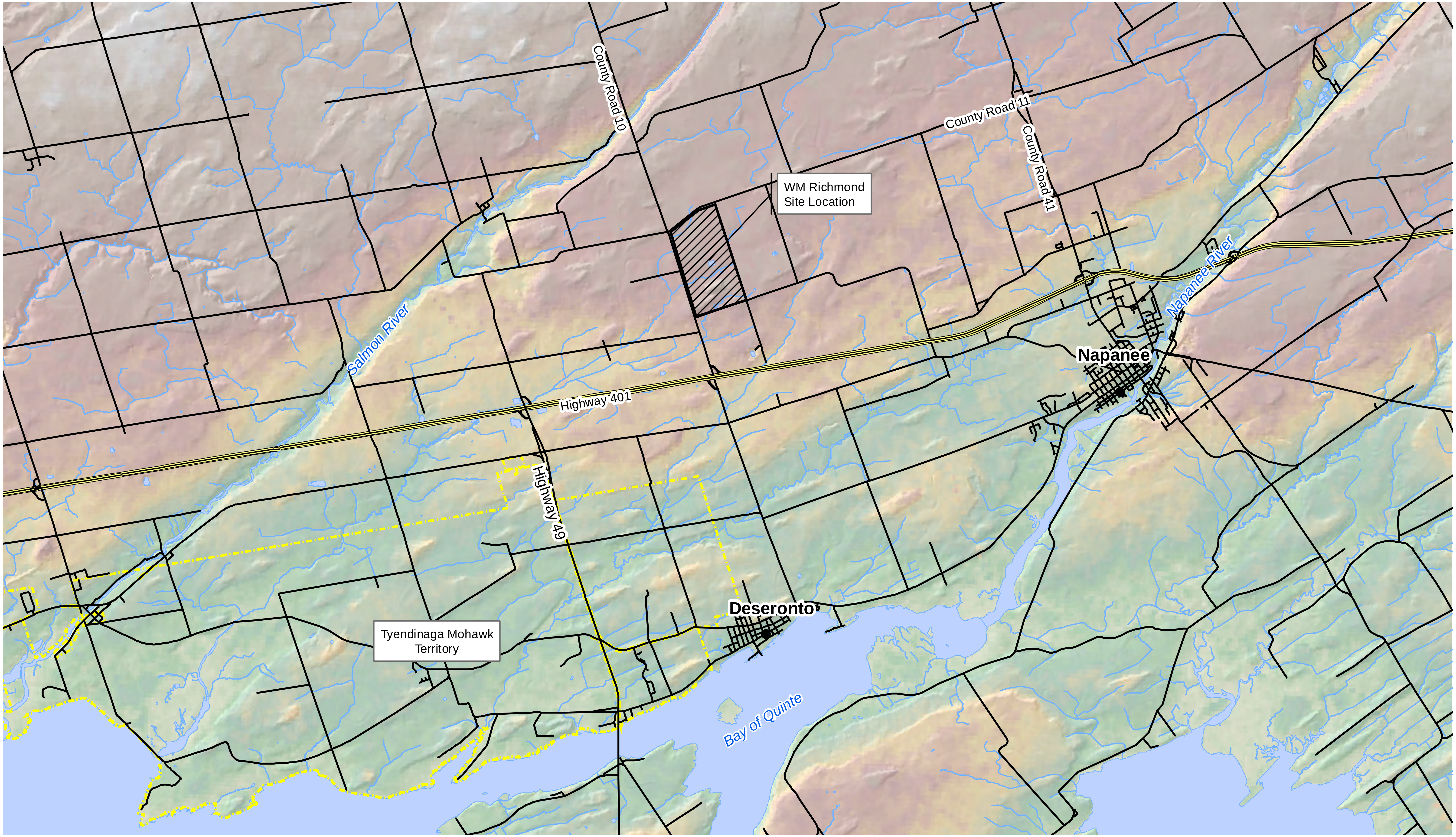
Notes:

1) All units expressed as mg/L, except where noted.
2) ODWS - Ontario Drinking Water Standards, Objectives and Guidelines (MOE, June 2006).
3) X - denotes the factor used in the Reasonable Use calculations:
   - 0.25 for health-related parameters;
   - 0.5 for aesthetic parameters.
4) Site-specific RUL for 1,4 dioxane (0.001 mg/L) set by ERT Order dated December 24, 2015, to be re-calculated in accordance with procedure document B-7-1 should an ODWS standard be set for 1,4 dioxane

Table 2: Most Recent Groundwater Quality Results and Comparison to RULs for Monitoring Wells on Proposed CAZ and Selected Monitoring Wells North of Beechwood Road

Name	Date	1,4-Dioxane mg/L	Alkalinity mg/L	Ammonia mg/L	Chloride mg/L	Dissolved Organic Carbon mg/L	Iron mg/L	Manganese mg/L	Sodium mg/L	Total Dissolved Solids mg/L	1,1,1-Trichloroethane mg/L	1,1-Dichloroethane mg/L	1,1-Dichloroethylene mg/L	Chloroethane mg/L	Benzene mg/L	Ethylbenzene mg/L	Toluene mg/L	m+p-Xylene mg/L	o-Xylene mg/L	Total Xylenes mg/L
RUL (see Table 1)		**0.001**	**400**	**---**	**132**	**3.5**	**0.18**	**0.032**	**106**	**465**	**---**	**---**	**0.0035**	**---**	**0.0014**	**0.0121**	**---**	**0.0013**	**---**	**0.15**
Wells on Proposed CAZ																				
M63-2	20/06/2013		**400**	**1.86**	**300**	**1.3**	< 0.1	**0.016**	**300**	**950**	< 0.0002	< 0.0002	< 0.0002	< 0.0004	0.00051	< 0.0002	< 0.0004	< 0.0002	< 0.0002	< 0.0002
M63-2	12/01/2015	< 0.001	350																	
M64-2	26/11/2015	**0.0027**	290	0.94	110	0.9	< 0.1	0.0085	95	**520**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M114-1	24/11/2015	**0.013**	**580**	0.38	**160**	**7.3**	**14**	**0.69**	100	**942**	< 0.0001	0.00067	0.00034	0.016	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M115-1	09/05/2012	< 0.02	**450**	0.4	100	**6.9**	**16**	**0.73**	66	**630**	0.00012	0.0036	0.00023	0.0067	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M115-1	22/10/2013	**0.0197**																		
M116	04/09/2014	**0.00469**	**420**	0.67	**160**	**3.9**	**9.9**	**0.66**	81	**900**	< 0.0001	0.01	0.00089	0.0051	0.0012	< 0.0001	< 0.0002	0.00088	0.00012	0.001
M117	04/09/2014	**0.00634**	**420**	0.46	100	**4.5**	< 0.1	0.022	58	**642**	< 0.0001	< 0.0001	< 0.0001	0.0015	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M121	24/11/2015	**0.0098**	**510**	1.72	**510**	**4.8**	< 0.1	0.0044	**320**	**1560**	< 0.0005	< 0.0005	< 0.0005	0.0039	**0.045**	0.0011	< 0.001	**0.013**	0.00065	0.014
M122	05/09/2014	**0.00983**	**480**	0.56	96	**4.1**	**2.8**	**0.039**	37	**818**	< 0.0001	< 0.0001	< 0.0001	0.00042	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M123	25/11/2015	**0.0074**	**450**	0.3	75	**4.1**	< 0.1	0.016	51	**582**	< 0.0001	< 0.0001	< 0.0001	0.0037	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M125	04/09/2014	**0.00616**	380	0.31	100	**4.1**	**9.4**	**0.47**	65	**636**	< 0.0001	0.0013	0.00046	0.011	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M166	05/09/2014	**0.0106**	**480**	0.55	91	**4.9**	< 0.1	0.0095	80	**648**	< 0.0001	< 0.0001	< 0.0001	0.0032	0.00018	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M167	26/11/2015	**0.0051**	**420**	1.74	**230**	3.5	< 0.1	0.0027	**180**	**802**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	0.00038	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M168	26/11/2015	**0.0075**	390	1.51	**330**	**3.6**	< 0.1	0.0045	**130**	**1020**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M172	24/11/2015	**0.021**	**580**	0.87	**190**	**8.9**	**27**	**0.91**	**110**	**1020**	< 0.0001	0.0037	0.00028	0.011	0.00013	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M173	05/09/2014	< 0.001	250	0.18	16	2.1	< 0.1	0.01	8.3	434	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M176	04/09/2014	< 0.001	250	1	**400**	2.4	< 0.1	0.019	**210**	**1140**	< 0.00025	< 0.00025	< 0.00025	< 0.0005	**0.022**	0.00042	0.0051	**0.0038**	0.00071	0.0045
M177	25/11/2015	< 0.001	240	0.58	7.6	1.6	< 0.1	0.008	13	304	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M178R-2	30/11/2015	**0.0062**	**430**	0.27	75	**4.6**	**1**	**0.053**	55	**614**	< 0.0001	0.0012	< 0.0001	0.0017	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M178R-3	30/11/2015	**0.0062**	**440**	0.31	87	**4.8**	**0.81**	**0.054**	56	**622**	< 0.0001	0.00097	< 0.0001	0.0022	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M178R-4	30/11/2015	**0.007**	**440**	0.25	83	**4.5**	< 0.1	0.012	53	**626**	< 0.0001	< 0.0001	< 0.0001	0.0014	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M179	25/11/2015	< 0.001	260	0.15	39	**3.7**	**0.95**	0.031	26	420	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M180	04/09/2014	< 0.001	260	< 0.15	120	2.7	**0.66**	**0.27**	74	**494**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	**0.0029**	< 0.0001	< 0.0002	0.00022	< 0.0001	0.00022
M181-1	04/09/2014	< 0.001	210	< 0.15	2	2.5	< 0.1	0.0068	2.1	266	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M181-2	04/09/2014	< 0.001	180	< 0.15	1	3.5	< 0.1	0.012	1.5	240	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M182	04/09/2014	< 0.001	250	< 0.15	17	2.9	< 0.1	< 0.002	9.5	318	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M183	04/09/2014	< 0.001	300	2.36	**190**	1.8	< 0.1	0.01	**230**	**836**	< 0.00025	< 0.00025	< 0.00025	< 0.0005	< 0.00025	< 0.00025	< 0.0005	< 0.00025	< 0.00025	< 0.00025
M185-2	25/11/2015	< 0.001	310	< 0.15	2.6	2.1	< 0.1	0.012	4.5	340	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M186	26/11/2015	< 0.001	300	2.47	**1300**	**3.7**	**1.4**	**0.43**	**770**	**2480**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	0.00065	0.00018	0.0017	**0.0018**	0.00051	0.0023
M187	30/11/2015	< 0.001	260	< 0.15	38	2.1	< 0.1	0.0022	25	**476**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M188	30/11/2015	< 0.001	330	0.71	80	2.1	< 0.1	0.0094	100	**504**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	0.00034	< 0.0001	< 0.0001	< 0.0001
M190	30/11/2015	< 0.001	290	< 0.15	48	**3.6**	< 0.1	0.009	19	448	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M191	01/12/2015	< 0.001	150	10.6	**41000**	**190**	**11**	**2.1**	**15000**	**73900**	< 0.01	< 0.01	< 0.01	< 0.02	**0.15**	< 0.01	0.022	< 0.01	< 0.01	< 0.01
Selected Wells North of Beechwood Road																				
M10-1	04/09/2014	**0.0102**	**510**	0.8	**140**	**6.6**	**19**	**0.75**	73	**856**	< 0.0001	0.0026	0.00025	0.009	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M105	04/09/2014	**0.0184**	**460**	0.75	**250**	**5.7**	< 0.1	0.0083	**120**	**1080**	< 0.00025	< 0.00025	< 0.00025	0.0012	< 0.00025	< 0.00025	< 0.0005	< 0.00025	< 0.00025	< 0.00025
M107	04/09/2014	**0.00819**	**440**	0.18	100	**5.1**	**8**	**0.43**	53	**650**	< 0.0001	0.00076	0.00011	0.0044	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M108	25/11/2015	**0.014**	**560**	1	**140**	**6.3**	**0.8**	**0.082**	97	**820**	< 0.0001	0.00037	< 0.0001	0.0058	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001
M170	26/11/2015	**0.0063**	**620**	1.52	**620**	**5**	< 0.1	< 0.002	**640**	**1750**	< 0.0001	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0002	< 0.0001	< 0.0001	< 0.0001

FIGURES



WASTE MANAGEMENT
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Figure 1
Site Location Map

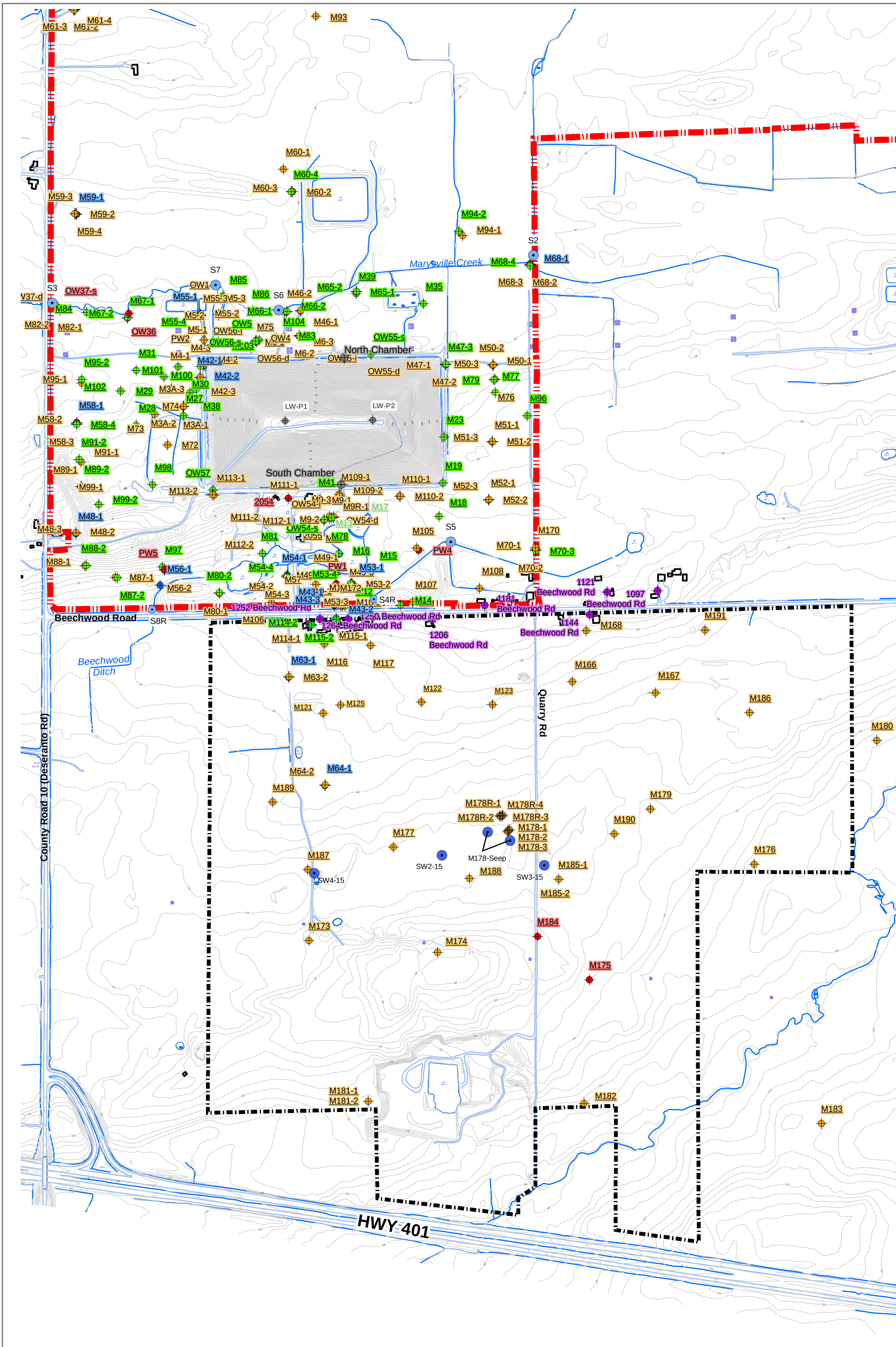
Site Location
Streams
Topography (m)
High : 180
Low : 50

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

1 0.5 0 1
Kilometers

Units:
UTM NAD 83 Zone 18
Scale: 1:75000

BluMetric Environmental



WASTE MANAGEMENT
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Figure 2:
Site Plan

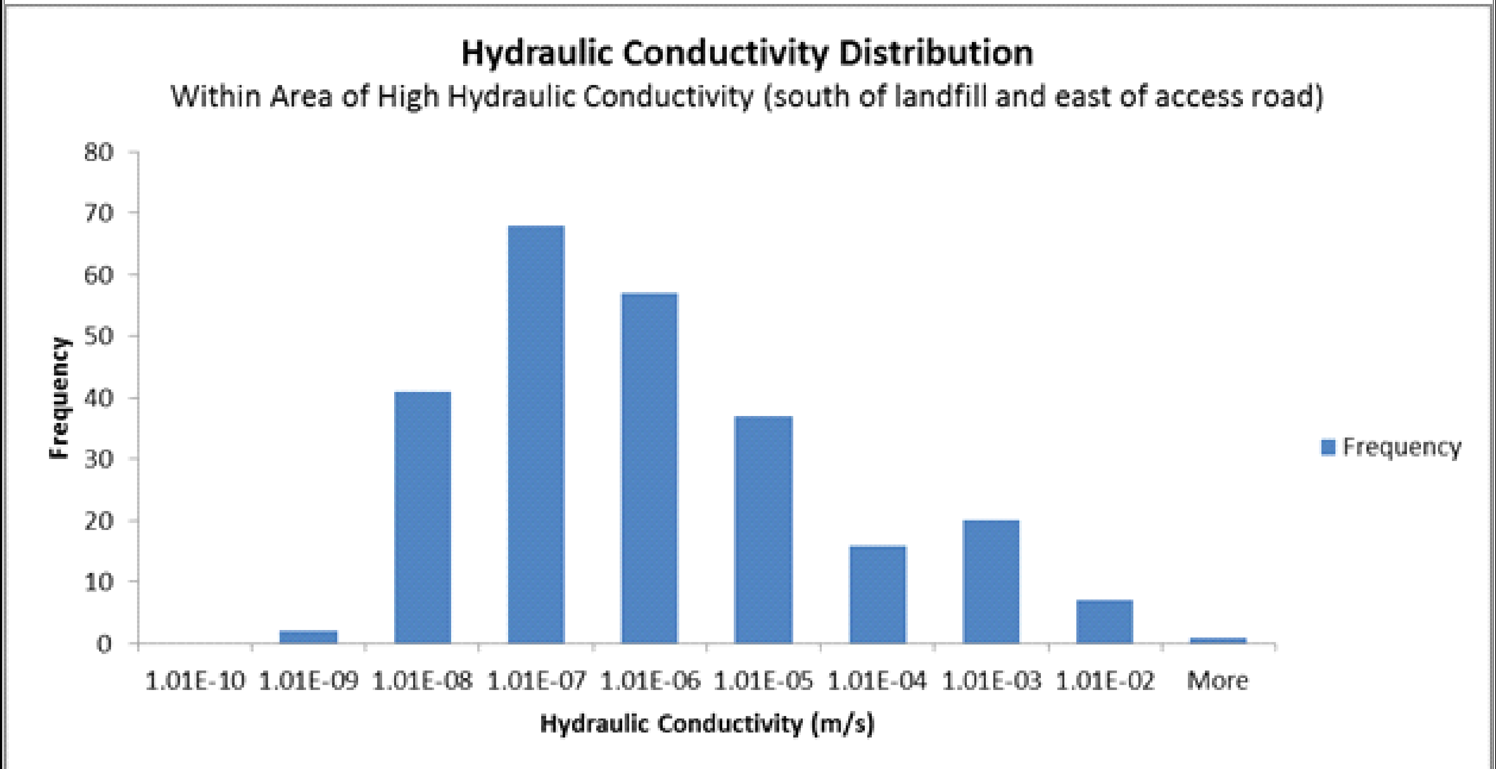
M15	Shallow Monitoring Well
M53-2	Intermediate Bedrock Monitoring Well
M53-1	Deep Bedrock Monitoring Well
PW1	Open Borehole
	Private Water Well (Not Used)
S2	Surface Water Monitoring Location
	Leachate Monitoring Locations
	Proposed CAZ Boundary
	Hydro Tower

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

Units:
UTM NAD 83 Zone 18

Scale: 1:5000

0 12.5 25 50 75 100
Metres



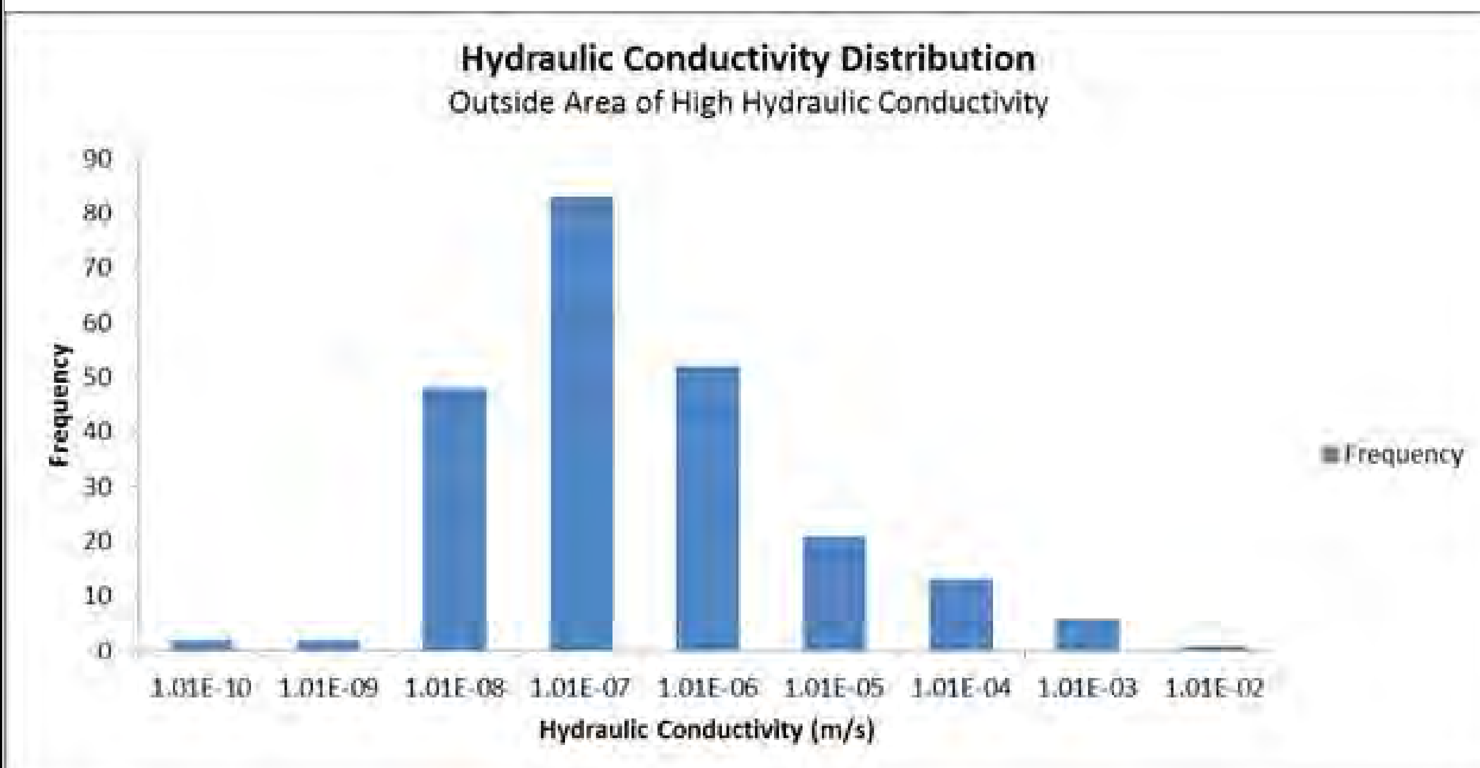


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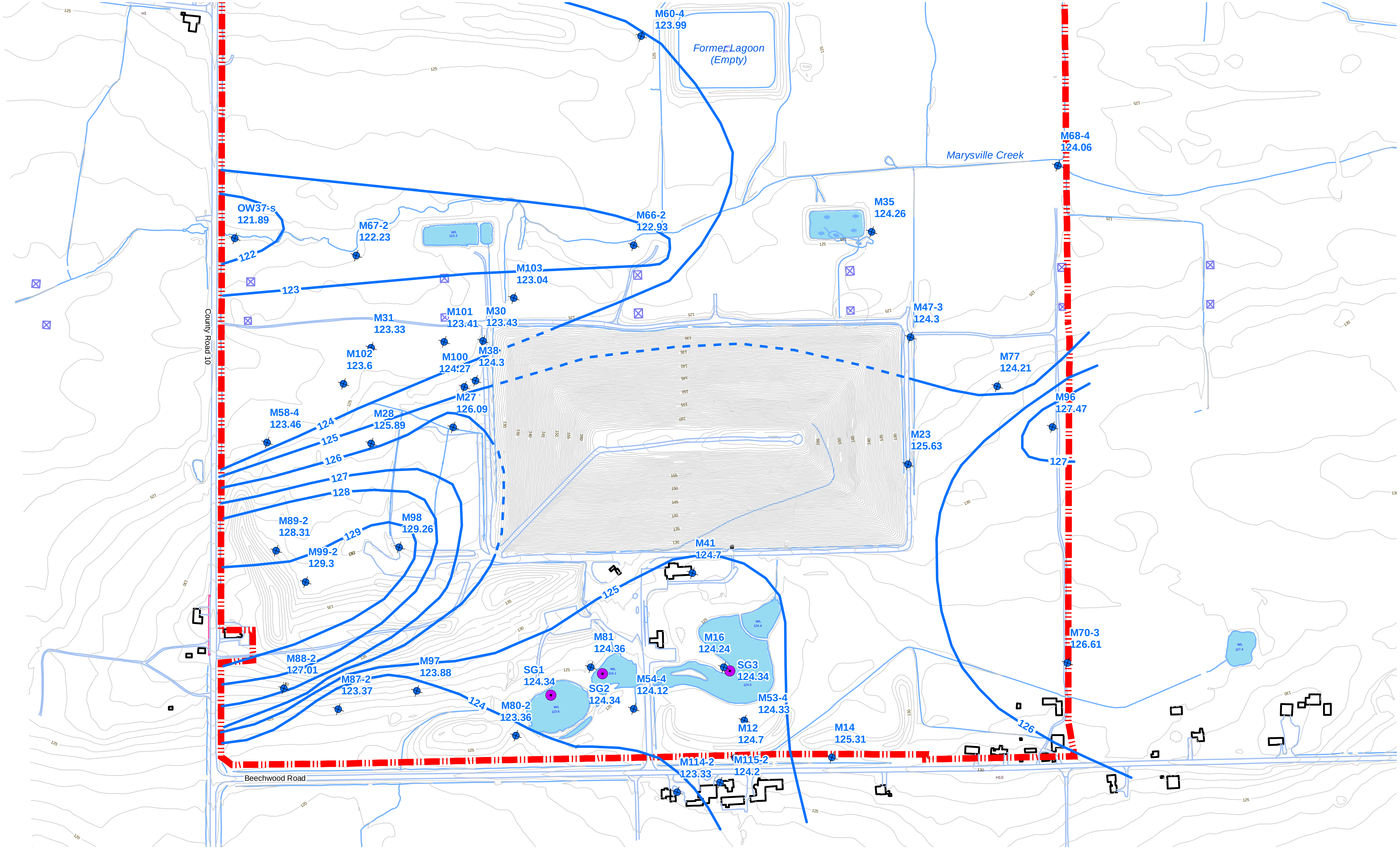
Figure 3:
Distribution of Hydraulic Conductivities

Project : C-B12501-00-00

Data Source: BluMetric Environmental

Date: January 2016



WASTE MANAGEMENT
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Figure 4a:
Shallow Groundwater Flow Zone Potentiometric Surface - October 16, 2013

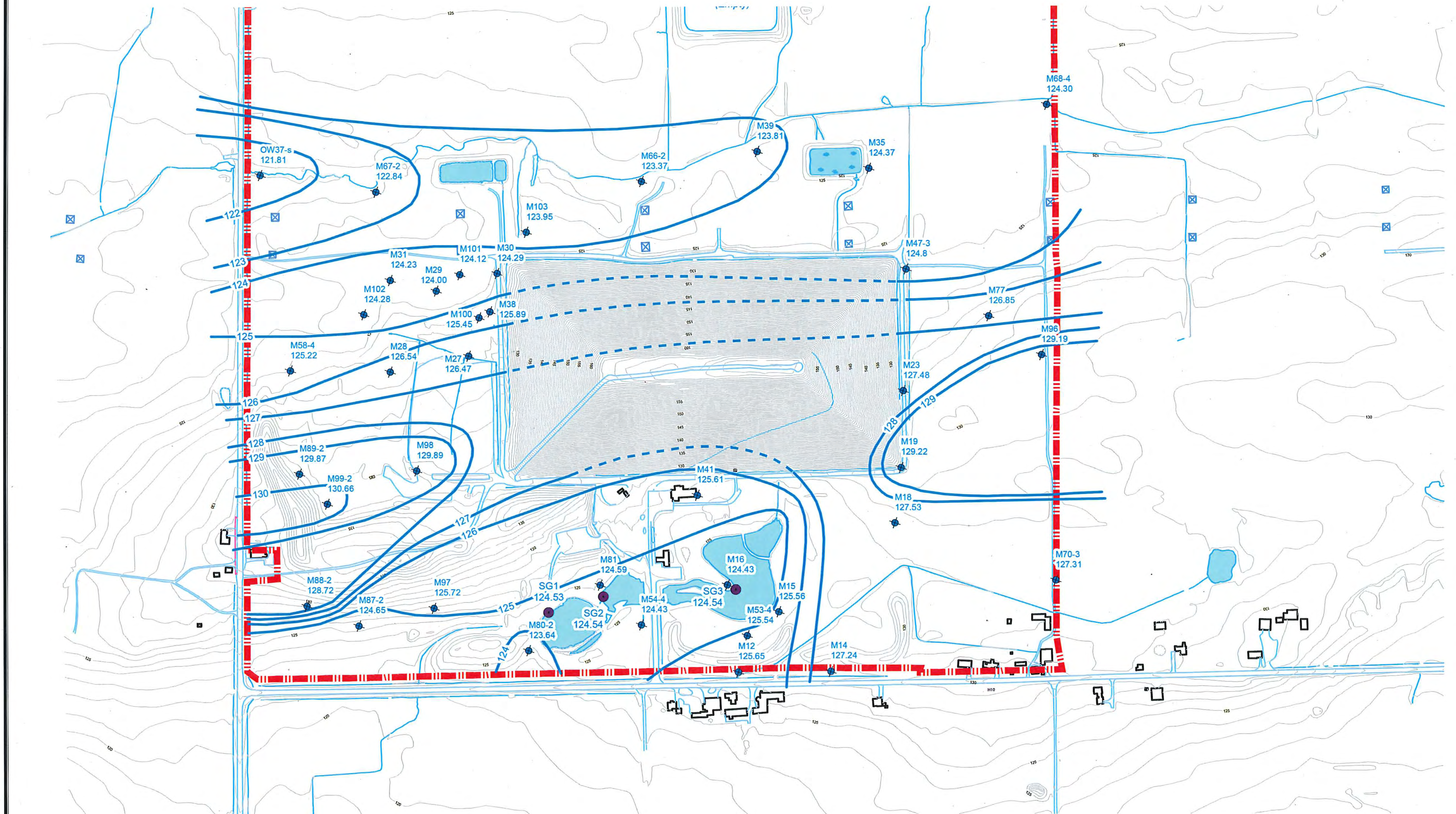
M58-4 Shallow Groundwater Zone Elevation Monitor
SG-1 Staff Gauge Location
Surface Water
Potentiometric Surface (masl)
Property Boundary
Hydro Tower
Topographic Contour Lines

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

Units:
UTM NAD 83 Zone 18

Scale: 1:5000

0 12.5 25 50 75 100
Meters



WASTE MANAGEMENT
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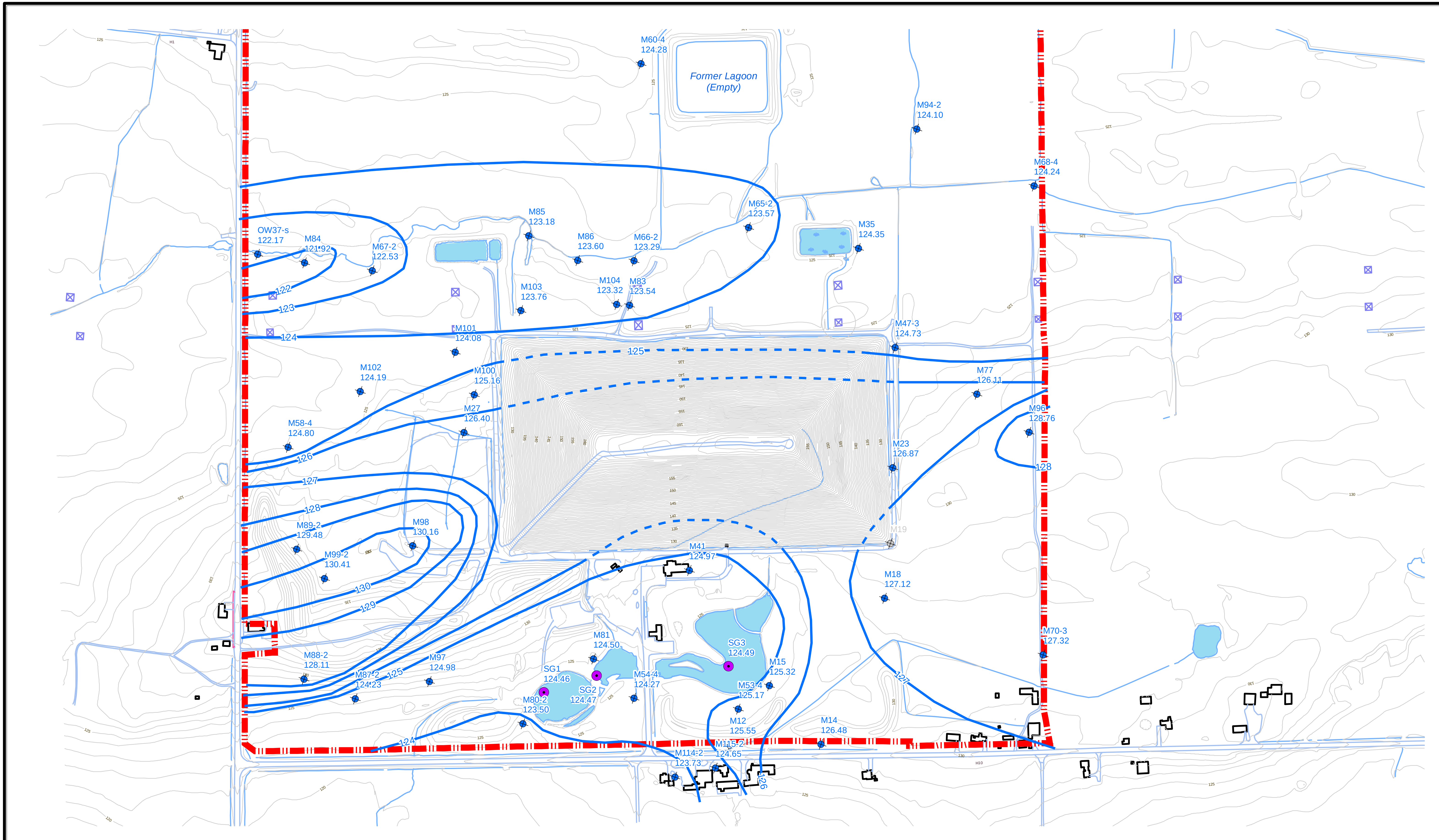
M58-4 Shallow Groundwater Zone Elevation Monitor
Topographic Contour Lines
Surface Water
Hydro Tower
Potentiometric Surface (masl)
Property Boundary
SG-1 Staff Gauge Location

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

Units:
UTM NAD 83 Zone 18
Scale: 1:5000

0 12.5 25 50 75 100
Meters

Figure 4b:
Shallow Groundwater Flow Zone Potentiometric Surface - May 5, 2014



WASTE MANAGEMENT
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Figure 4c:
Shallow Groundwater Flow Zone Potentiometric Surface - November 20, 2015

M58-4 Shallow Groundwater Zone Elevation Monitor
Topographic Contour Lines
Surface Water
Hydro Tower

Potentiometric Surface (masl)
Property Boundary
Note: M77: Not used in contouring

SG-1 Staff Gauge Location
Monitoring Well - No Water Level Measurement

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

0 12.5 25 50 75 100
Meters

Units:
UTM NAD 83 Zone 18

Scale: 1:5000

BluMetric Environmental

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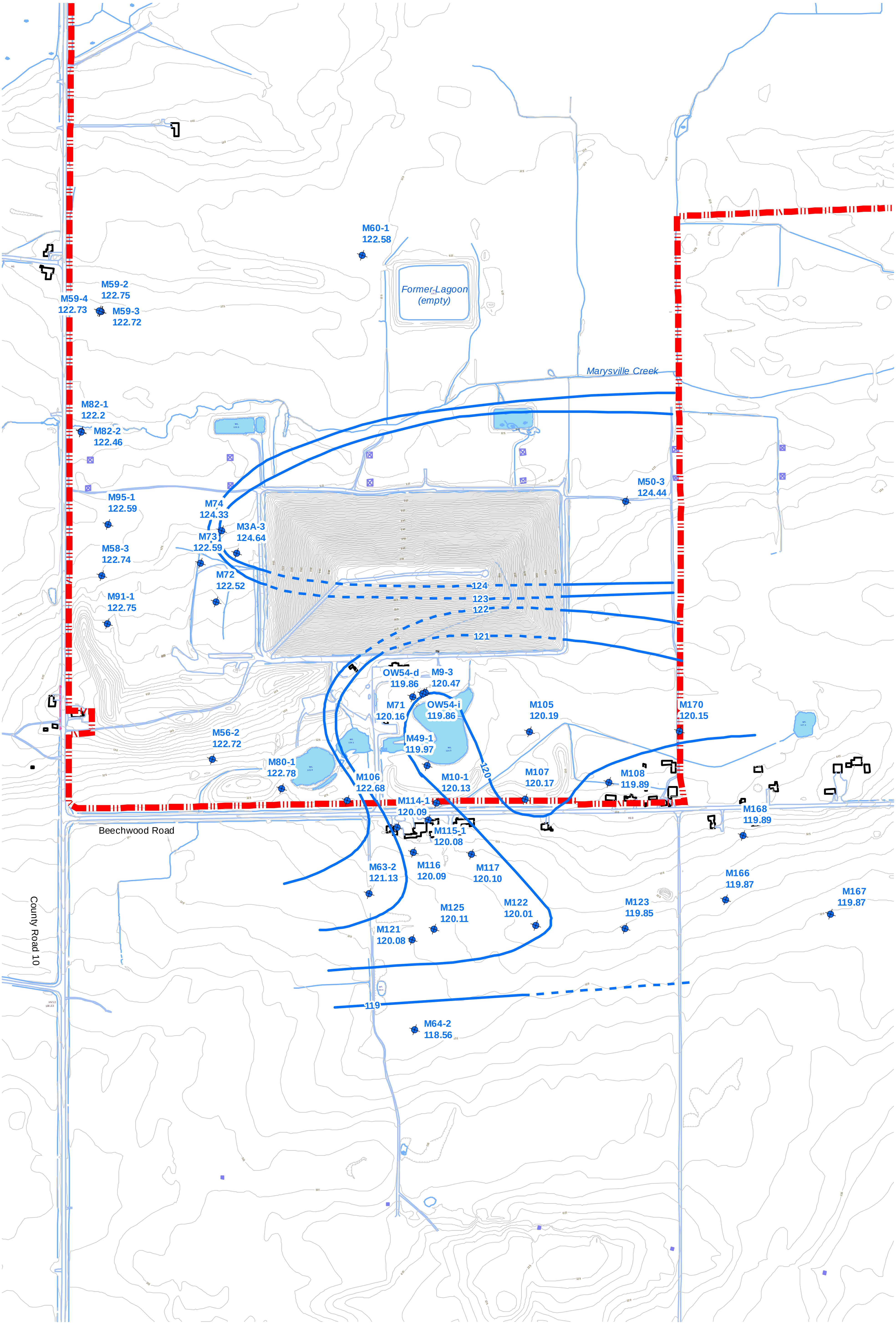

WASTE MANAGEMENT
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M58-3 Intermediate Groundwater Zone Elevation Monitor
Topographic Contour Lines
Potentiometric Surface (masl)

Hydro Tower
Surface Water
Property Boundary

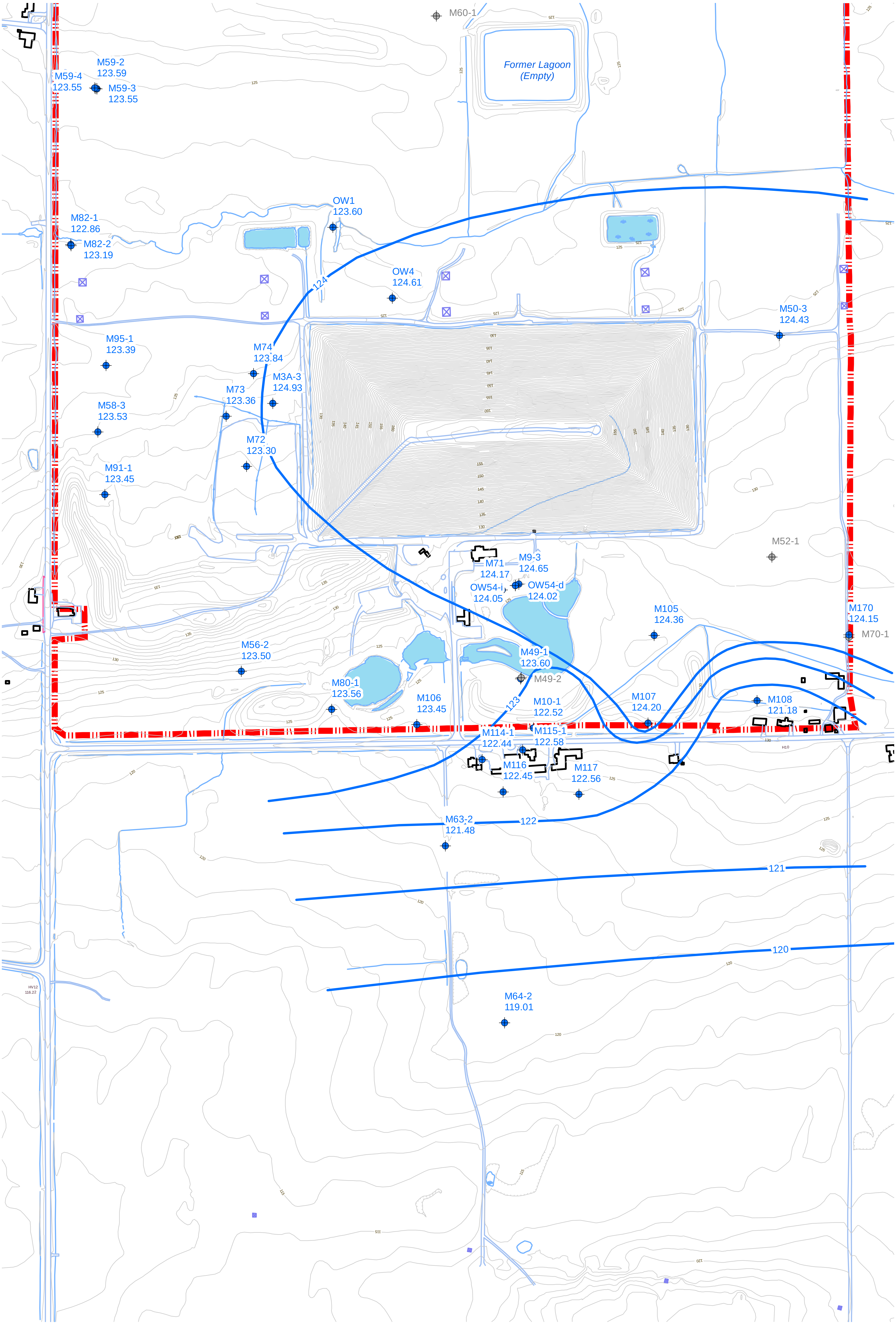
Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

50 25 0 50 100
Meters

Units:
UTM NAD 83 Zone 18

Scale: 1:6500

Figure 5(a):
Intermediate Bedrock Groundwater Flow Zone Potentiometric Surface - October 16, 2013



WASTE MANAGEMENT
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Figure 5(b):
Intermediate Bedrock Groundwater Flow Zone Potentiometric Surface - May 5, 2014

M58-3 Intermediate Groundwater Zone Elevation Monitor
Topographic Contour Lines
Potentiometric Surface (masl)
Hydro Tower
Surface Water
Property Boundary
Monitor Not Used in Contouring

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

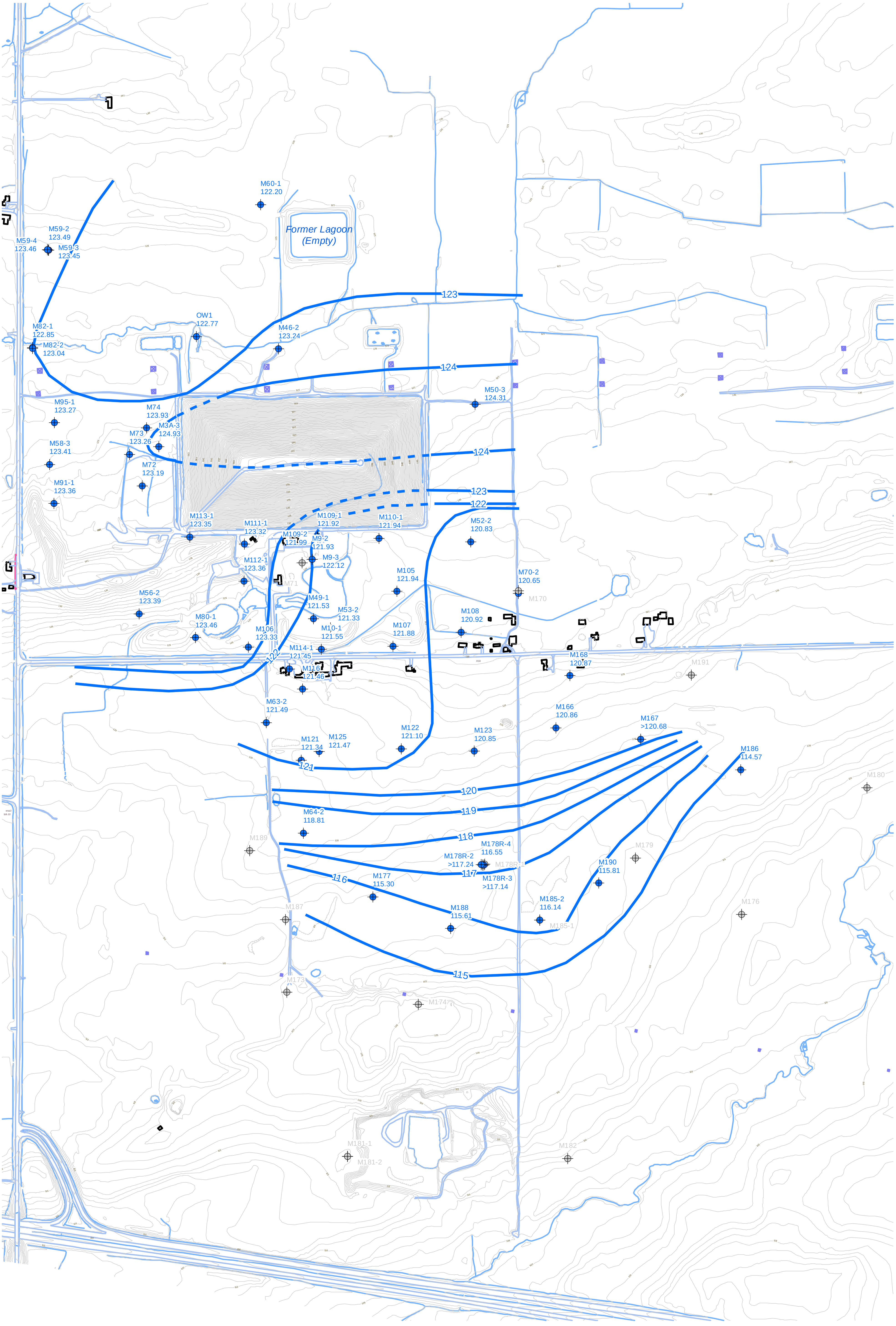
40 20 0 40 80
Meters

Units:
UTM NAD 83 Zone 18

Scale: 1:5000

BluMetric Environmental

WM WASTE MANAGEMENT



WASTE MANAGEMENT
RICHMOND LANDFILL
FALL 2015 SEMI-ANNUAL REPORT

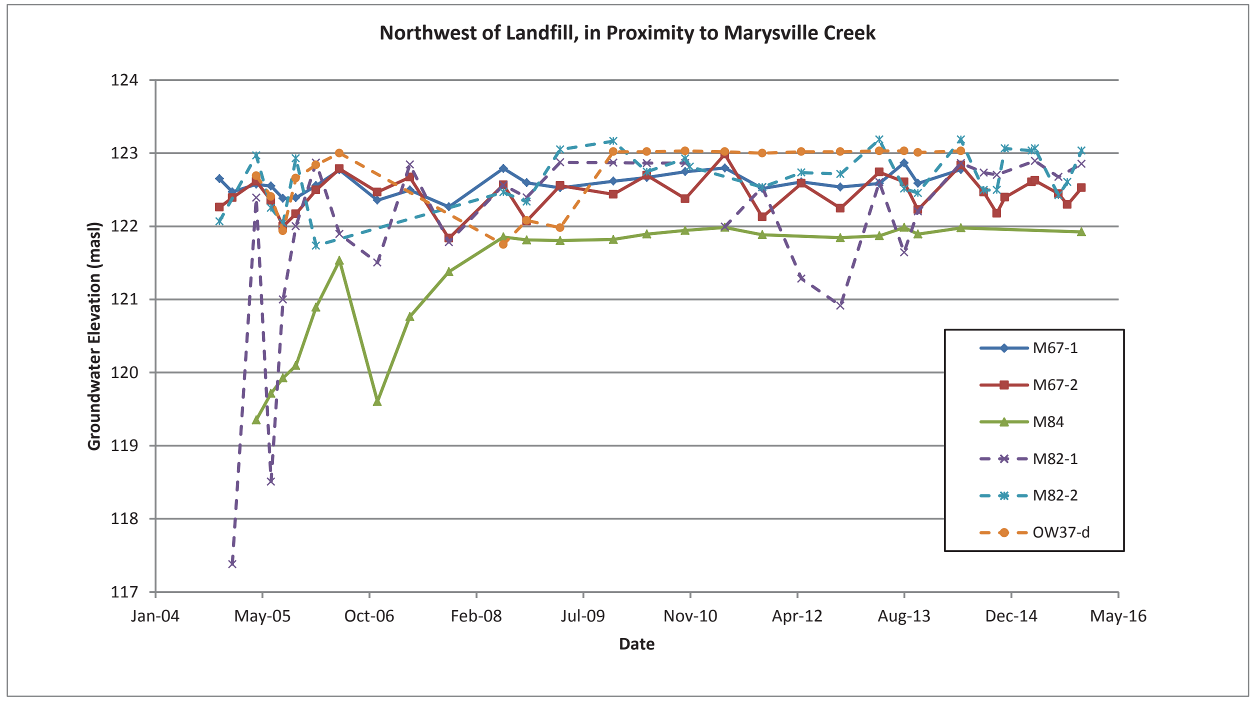
M58-3 Intermediate Groundwater Zone Elevation Monitor
Topographic Contour Lines
Potentiometric Surface (masl)
Monitor Not Used In Contouring
Hydro Tower
Surface Water
Property Boundary

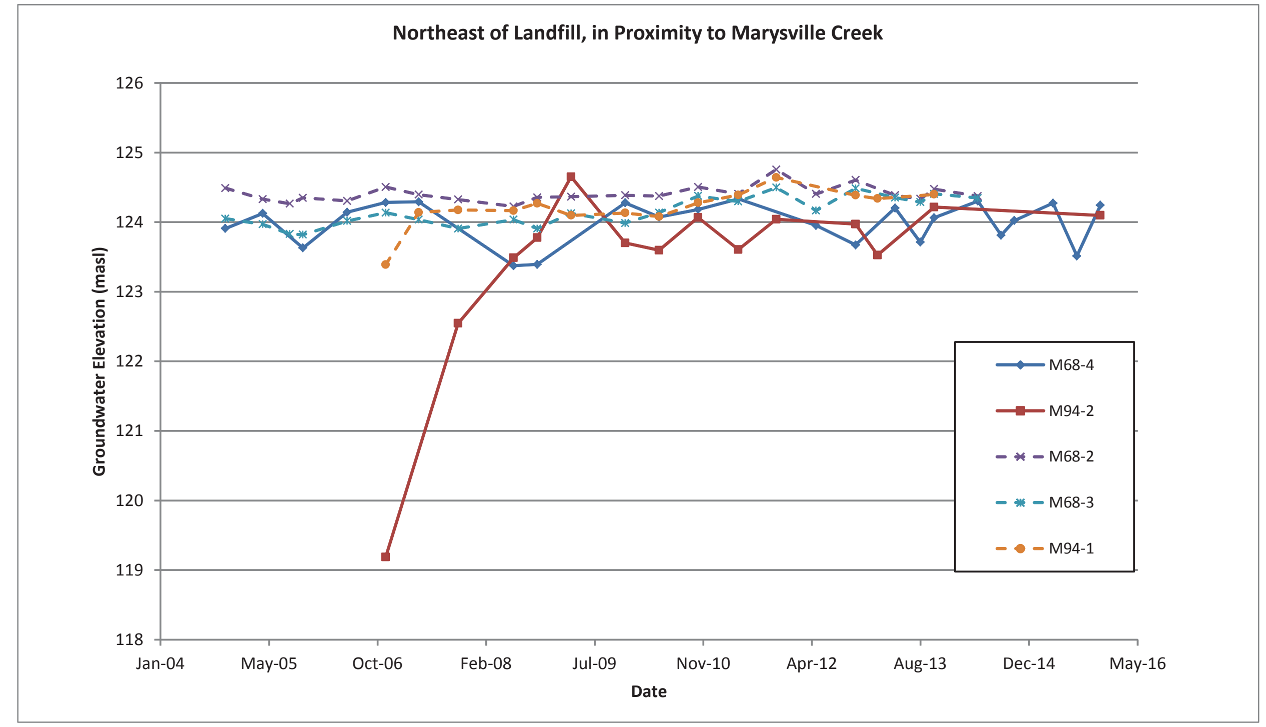
Project : C-B12501
Data Source: WM Canada, WESA, HPA Ltd. Base Mapping 2009
Date: January 2016

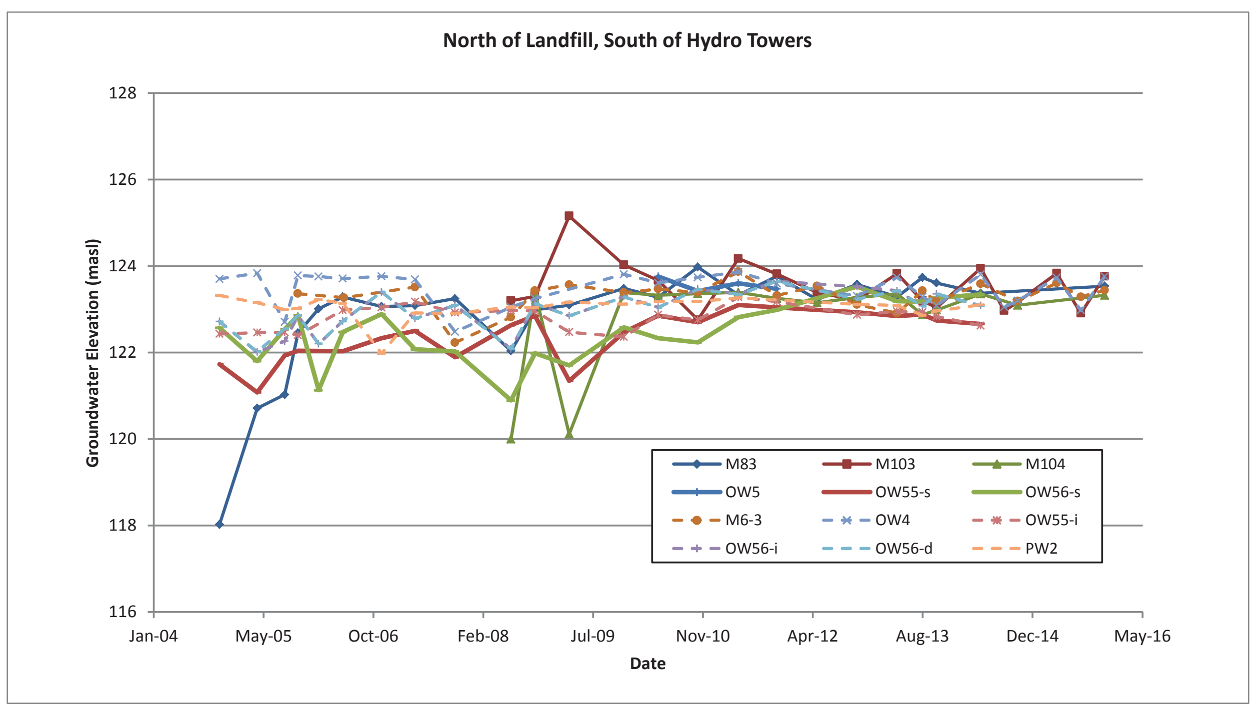
75 37.5 0 75 150
Meters

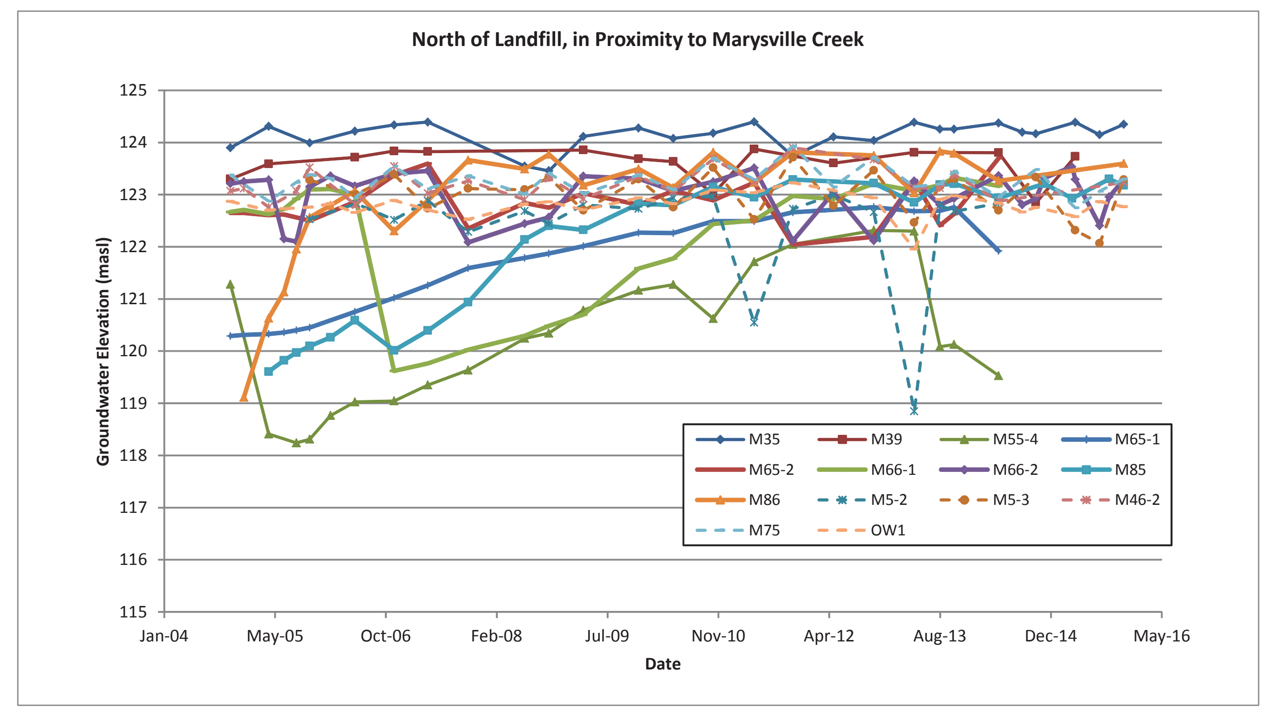
Units:
UTM NAD 83 Zone 18
Scale: 1:8000

Figure 5c:
Intermediate Bedrock Groundwater Flow Zone Potentiometric Surface - November 20, 2015









Note: Dashed lines denote Intermediate Bedrock Zone monitoring wells; solid lines are Shallow Zone monitoring wells

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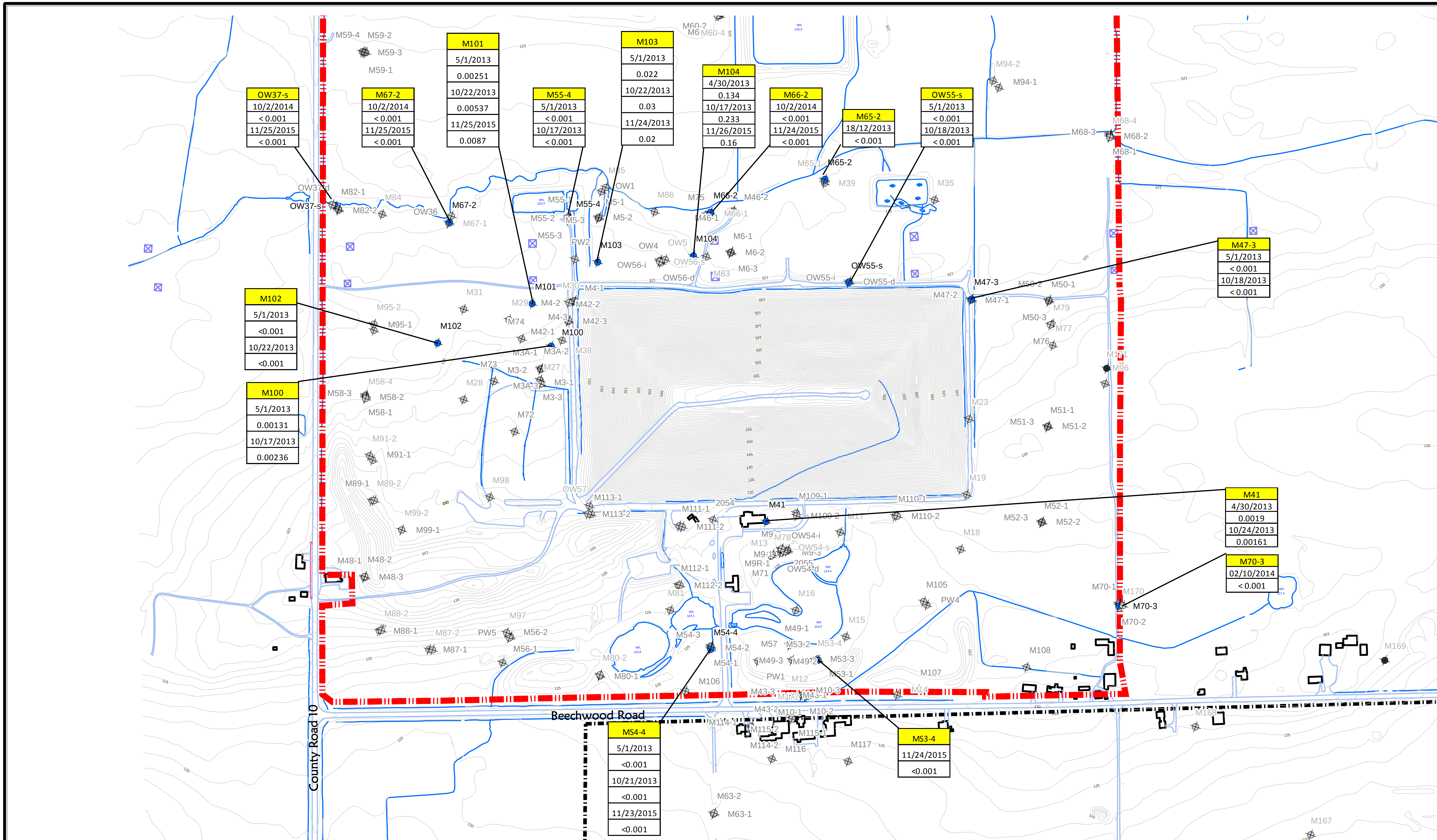
Figure 6:
Hydrographs from Selected Monitoring Wells North of Landfill

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016



WASTE MANAGEMENT
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Figure 7a:
1,4 Dioxane Concentrations in Shallow Bedrock Groundwater

Monitoring Wells
Decommissioned Wells
Monitoring Wells with 1,4 Dioxane Concentrations (in mg/L)
Date of Sample

Property Boundary
Proposed CAZ Boundary

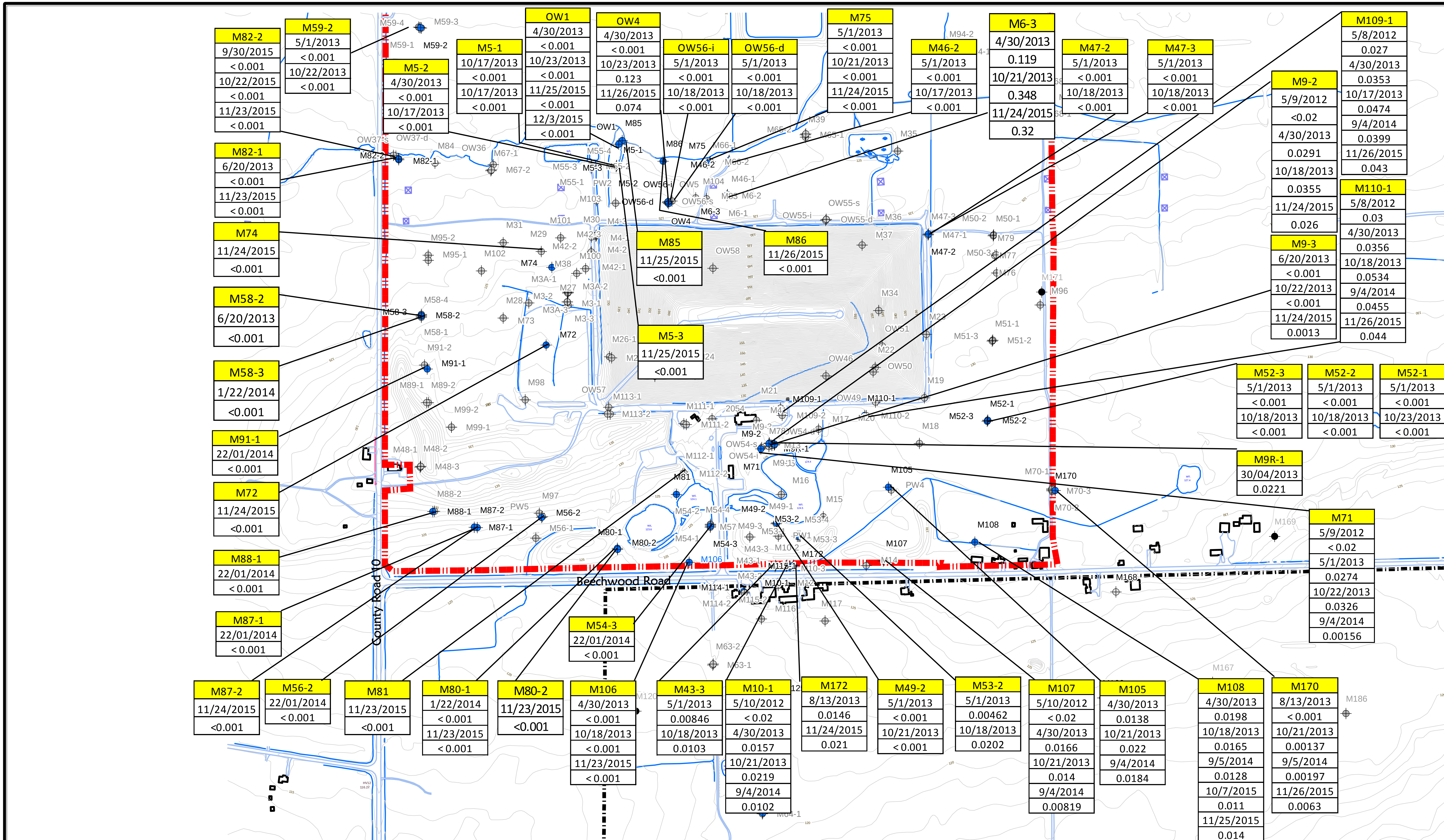
Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

Units:
UTM NAD 83 Zone 18
Scale: 1:5000

0 12.5 25 50 75 100
Meters

BluMetric Environmental

WM WASTE MANAGEMENT



WASTE MANAGEMENT
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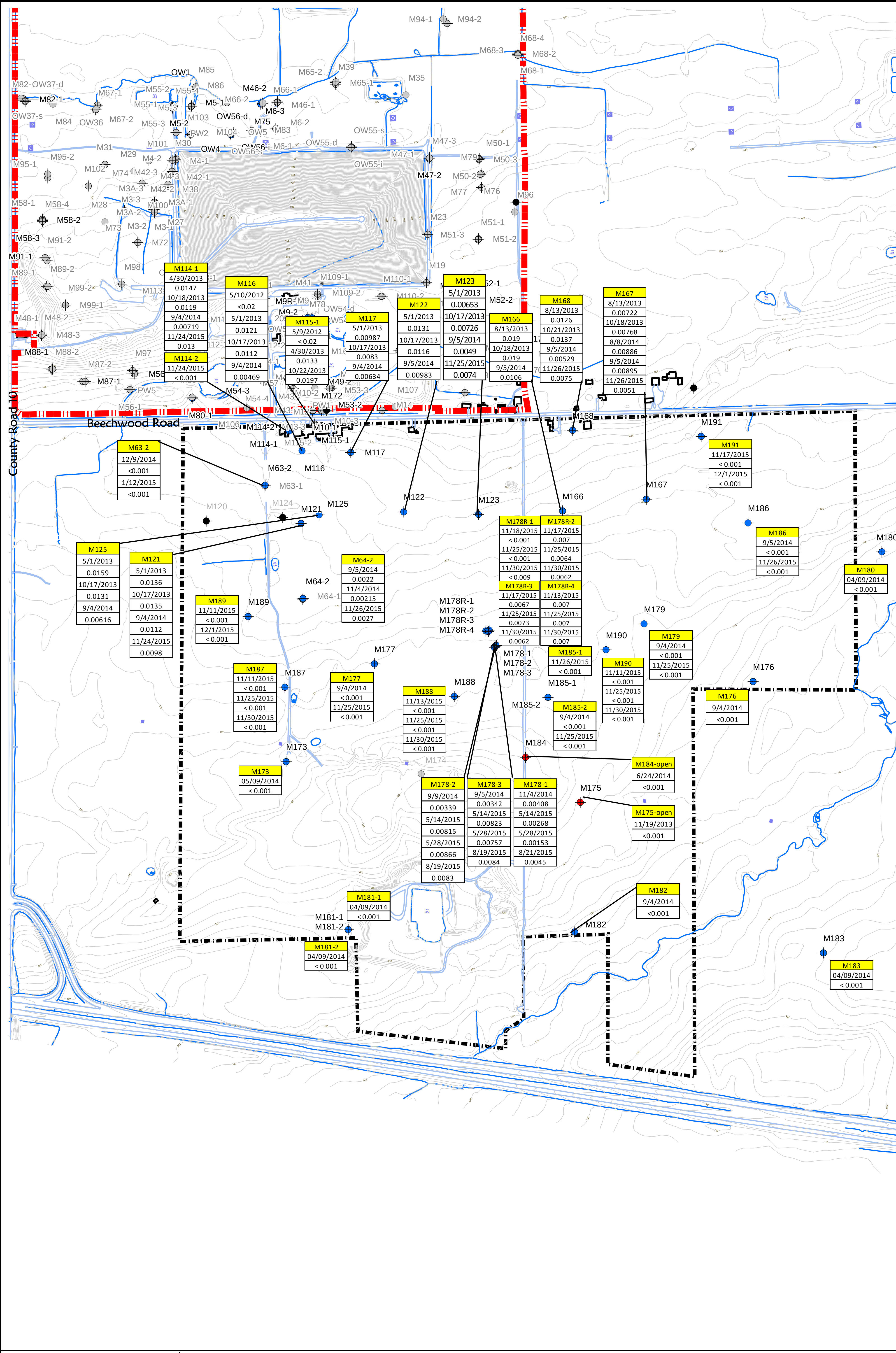
Desommissioned Wells
Monitoring Wells
Monitoring Wells with 1,4 Dioxane Concentrations (in mg/L) Date of Sample
Property Boundary
Proposed CAZ Boundary

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

Units:
UTM NAD 83 Zone 18
Scale: 1:5000

Figure 7b:
1,4 Dioxane Concentrations in the Intermediate Bedrock Groundwater – North of Beechwood Road



WASTE MANAGEMENT
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Figure 7c:
1,4 Dioxane Concentrations in Intermediate Bedrock Groundwater - Proposed CAZ Area

Decommissioned Wells
Monitoring Wells
Monitoring Wells with 1,4 Dioxane Concentrations (in mg/L)
Date of Sample
Open Boreholes (No monitoring wells constructed - results included for reference)
Property Boundary
Proposed CAZ Boundary

Project : C-B12501-00-00
Data Source: WM Canada, WESA, MNRO, NRCAN
Date: January 2016

50 25 0 50 100
Meters

Units:
UTM NAD 83 Zone 18
Scale: 1:8000

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WM WASTE MANAGEMENT

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Figure 8: Properties Included in the Proposed CAZ

LEGEND

Proposed CAZ Boundary

Proepity Block & PIN

Project : C-B12501-00-00

0 70 140 280 Meters

1:8,000

Date: January 2016

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APPENDIX A

Hydrogeologic Investigation in the Area of the Proposed CAZ