WASTE MANAGEMENT

Waste Management of Canada Corporation

Environmental Assessment for a New Landfill Footprint at the West Carleton Environmental Centre

GEOLOGY AND HYDROGEOLOGY DETAILED IMPACT ASSESSMENT

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1. Introduction

This report documents the Geology and Hydrogeology impact assessment of the Preferred Alternative Landfill Footprint for the Environmental Assessment (EA) for a new landfill footprint at the West Carleton Environmental Centre (WCEC). In the preceding Alternative Methods phase of the EA, a net effects analysis as well as a comparative evaluation of the four alternative landfill footprint options were carried out in order to identify a Preferred Alternative Landfill Footprint. The Preferred Alternative Landfill Footprint was determined to be Option #2 – the North Footprint Option. The potential environmental effects, mitigation or compensation measures to address the potential adverse environmental effects, and the remaining net effects following the application of the mitigation or compensation measures were identified for the Preferred Alternative Landfill Footprint.

The Preferred Alternative Landfill Footprint was refined based on stakeholder comments received and in order to further avoid or mitigate potential adverse environmental effects, and is illustrated in **Figure 1**.

A Facilities Characteristics Report (FCR) as well as a description of the ancillary facilities associated with the WCEC have been prepared so that potential environmental effects and mitigation or compensation measures identified for the Preferred Alternative Landfill Footprint during the Alternative Methods phase of the EA could be more accurately defined, along with enhancement opportunities and approval requirements.

The discipline-specific work plans developed during the ToR outlined how impacts associated with the Preferred Alternative Landfill Footprint would be assessed. The results of these assessments have been documented in the following 10 stand-alone Detailed Impact Assessment Reports:

- Atmospheric (Air Quality, Noise, Odour, and Landfill Gas)
- Geology and Hydrogeology
- Surface Water
- Biology
- Archaeology
- Cultural Heritage
- Transportation
- Land Use
- Agriculture
- Socio-Economic (including Visual)

Despite being stand-alone documents, there are interrelationships between some of the reports, where the information discussed overlaps between similar disciplines. Examples of this include the following:

- Geology and Hydrogeology, Surface Water, and Biology (Aquatic Environment); and
- Land Use, Agricultural, and Socio-Economic.

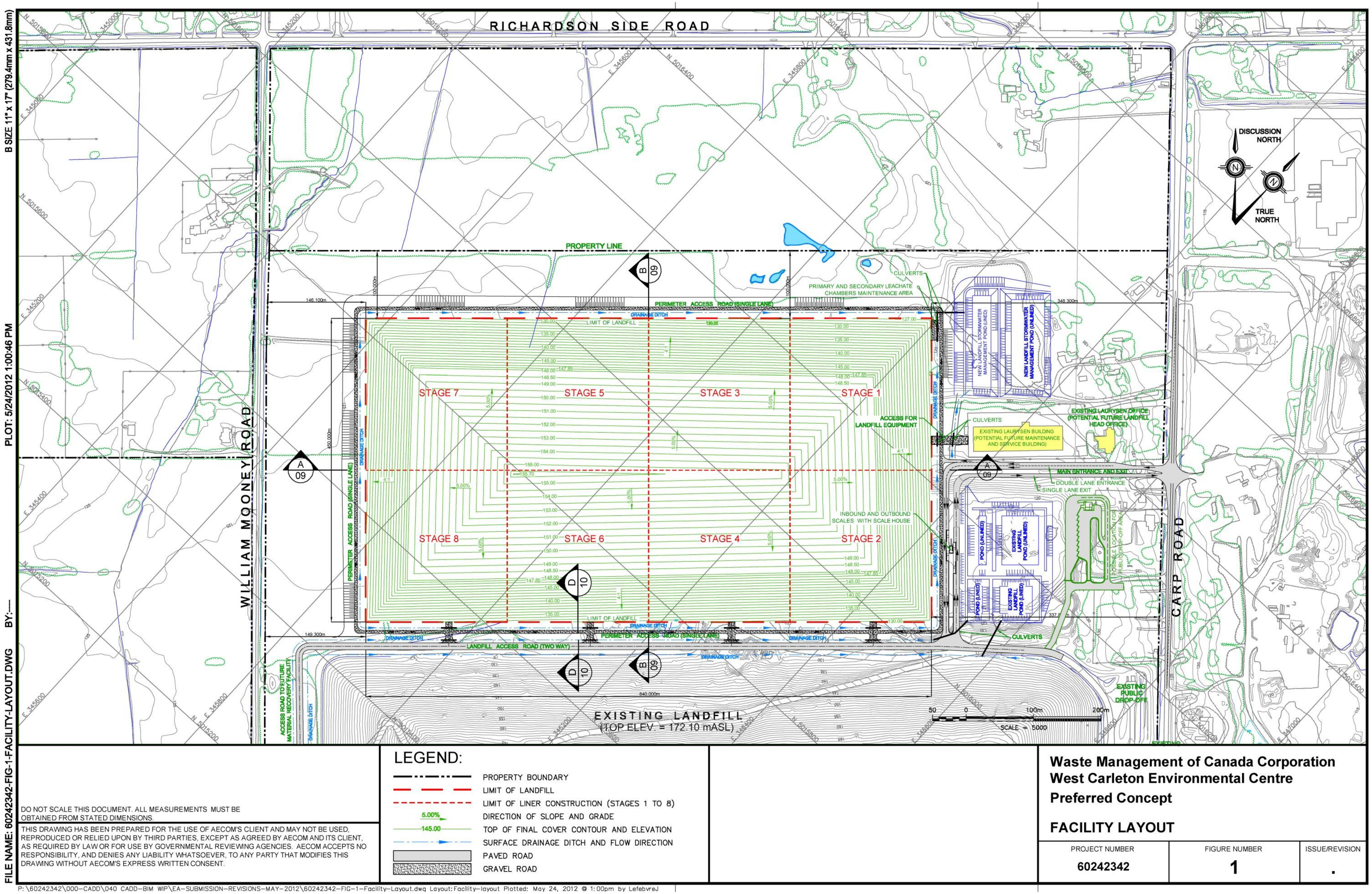


Figure 1. Preferred Alternative Landfill Footprint

1.1 Description of the Preferred Alternative Landfill Footprint

The southern half of the Preferred Alternative Landfill Footprint is on Waste Management (WM) owned lands and the northern half is on lands that WM has options to purchase. A 100 m buffer is maintained between the north limit of the Preferred Footprint and the private lands to the north (e.g., lands which front onto Richardson Side Road) in accordance with Ontario Regulation 232/98, and an approximate 350 m buffer is maintained between the east limit of the footprint and Carp Road. A light industrial building (e.g., the Laurysen building) is situated in the eastern portion of WM optioned lands, which WM anticipates using for equipment storage/maintenance or waste diversion activities in the future. An approximate 45 to 50 m buffer is maintained between the toe of slope of the existing and new landfill footprints, thus allowing sufficient area for a new waste haul road to the new landfill footprint, and for maintenance and monitoring access. The location of the west limit of the Preferred Alternative Landfill Footprint was determined by maintaining the noted buffers and providing the required 6,500,000 m^3 of disposal capacity, while maintaining landfill elevation below 158 mASL (as reported in the CDR) and maintaining side slopes required by Ontario Regulation 232/98 (e.g., varying from 4H to 1V to 5%). This results in an approximate 146 m buffer between the west limit of the Preferred Footprint and William Mooney Road. This buffer preserves a portion of the existing woodlot within the west part of the WM-owned lands.

The final contours of the landfill are shown in **Figure 1** and reflect a rectangular landform with a maximum elevation (top of final cover) of 155.7 mASL. This elevation is approximately 30.7 m above the surrounding existing grade. By comparison, the maximum elevation of the existing Ottawa WMF landfill is approximately 172 mASL or approximately 47 m above the surrounding existing grade. The contours reflect maximum side slopes of 4H to 1V, and a minimum slope of 5%. The total footprint area of the new landfill is 37.8 ha.

1.2 Facilities Characteristics Report

The FCR presents preliminary design and operations information for the Preferred Alternative Landfill Footprint (Option #2) and provides information on all main aspects of landfill design and operations including:

- site layout design;
- surface water management
- leachate management;
- gas management; and,
- landfill development sequence and daily operations.

The FCR also provides estimates of parameters relevant to the detailed impact assessment including estimates of leachate generation, contaminant flux through the liner system, landfill gas generation, and traffic levels associated with waste and construction materials haulage.

1.3 Other WCEC Facilities

In addition to the new landfill footprint, the WCEC will also include other facilities not subject to EA approval. These include:

- A material recycling facility
- A construction and demolition material recycling facility
- An organics processing facility
- Residential diversion facility
- Community lands for parks and recreation
- A landfill-gas-to-energy facility
- Greenhouses

Although these facilities do not require EA approval, it is important to consider environmental impacts from all potential activities at the WCEC, not just the new landfill footprint. As such, the synergistic impacts of these facilities in relation to the Preferred Alternative Landfill Footprint will also be assessed in the EA.

1.4 Geology and Hydrogeology Study Team

The Geology and Hydrogeology study team consisted of WESA Inc. staff. The actual individuals and their specific roles are provided as follows:

- ***David Harding – Project Manager and Senior Engineer***
  Mr. Harding was responsible for undertaking the detailed impact assessment in collaboration with the project team, and for preparing this report on the results of the assessment.

- ***Mike Melaney – Groundwater Modeller***
  Mr. Melaney was responsible for completing the groundwater flow and transport modelling simulations, and for documenting the results of the modelling program.

- ***Francois Richard – Senior Hydrogeologist***
  Mr. Richard developed and supervised the groundwater modelling program and reviewed the simulation results.

2. Study Area

The specific On-Site, Site-Vicinity, and Regional study areas for the Preferred Alternative Landfill Footprint at the WCEC are listed below, and are shown in **Figure 2**:

On-Site .... the lands required for the Preferred Alternative Landfill Footprint. In the Existing Conditions Report and Comparative Evaluation Technical Report, this area is referred to as the North Envelope. The North Envelope lies immediately north of the existing landfill footprint and extends west to William Mooney Road, east to Carp Road and north to the northern boundary of lands under option to Waste Management;

Site-Vicinity...... the lands in the vicinity of the Preferred Alternative Landfill Footprint, extending about 500 metres in all directions, including the licensed area of the existing WM Ottawa Landfill and the Contaminant Attenuation Zones (CAZs); and,

Regional .... the lands within natural hydrogeologic boundaries, including Huntley Creek to the north, Feedmill Creek to the south, and extending to Carp River in the east. The upgradient boundary of the Regional Study Area coincides with the boundary of the Site-Vicinity Study Area.

3. Methodology

The assessment of impacts associated with the Preferred Alternative Landfill Footprint was undertaken through a series of steps that were based, in part, on a number of previously prepared reports (Geology and Hydrogeology Existing Conditions Report, Geology and Hydrogeology Comparative Evaluation Technical Report). The net effects associated with the four Alternative Landfill Footprint Options identified during the Alternative Methods phase of the EA were based on Conceptual Designs. These effects were reviewed within the context of the preliminary design plans developed for the Preferred Alternative Landfill Footprint, as identified in the FCR, to determine the type and extent of any additional investigations required to ensure a comprehensive assessment of net effects. Additional investigations were then carried out, where necessary, in order to augment the previous work undertaken.

With these additional investigations in mind, the potential impact on the Geology and Hydrogeology environment of the Preferred Alternative Landfill Footprint was documented.

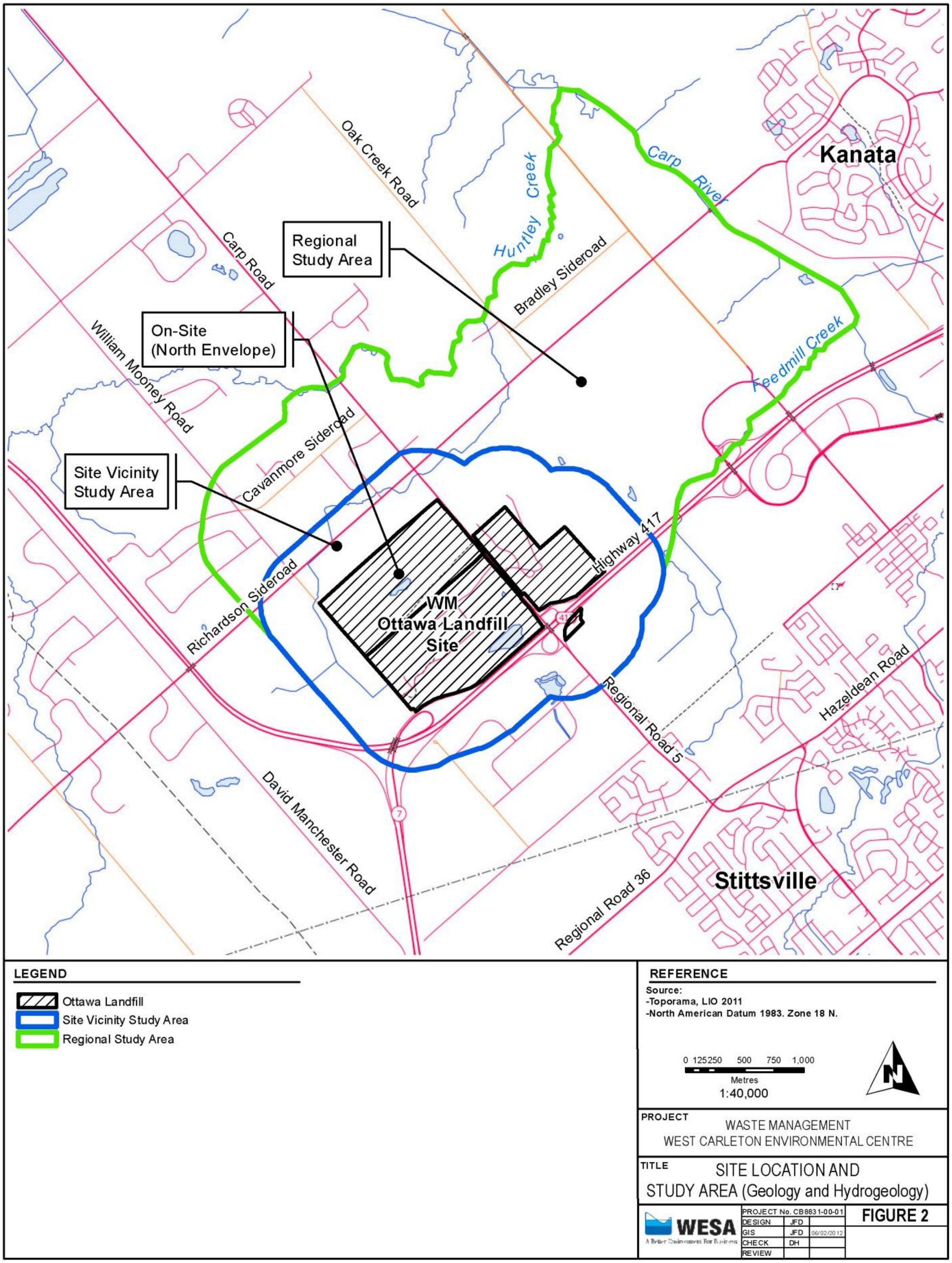


Figure 2. Site Location and Study Area

With a more detailed understanding of the potential impact from the preliminary landfill design on the Geology and Hydrogeology environment, the previously identified potential effects and recommended mitigation or compensation measures associated with the Preferred Alternative Landfill Footprint (documented in the Geology and Hydrogeology Comparative Evaluation Technical Report, September 2011) were reviewed to ensure their accuracy. Based on this review, the potential effects, mitigation or compensation measures, and net effects associated with the Preferred Alternative Landfill Footprint were confirmed and documented. In addition to identifying mitigation or compensation measures, potential enhancement opportunities associated with the preliminary design for the Preferred Alternative Landfill Footprint were also identified, where possible.

Following this confirmatory exercise, the requirement for monitoring in relation to net effects was identified, where appropriate. Finally, any Geology and Hydrogeology approvals required as part of the implementation of the Preferred Alternative Landfill Footprint were identified.

4. Additional Investigations

Upon completion of the preliminary design for the Preferred Alternative Landfill Footprint as documented in the FCR (AECOM, October 2011), the environmental characteristics of the Study Area were reviewed to verify the accuracy of the assessment of net effects from the Preferred Alternative Landfill Footprint. From this review, it was determined that the stormwater management ponds identified in the preliminary design could have potential effects on groundwater flow and contaminant transport within the On-Site and Site-Vicinity Study Area components. Consequently, a detailed groundwater modelling investigation was conducted in order to assess the potential effects on the Geology and Hydrogeology discipline from the preliminary design.

The results from the initial modelling exercise into potential effects led to the development of additional mitigative measures that are predicted to achieve acceptable net effects from the Preferred Alternative Landfill Footprint.

The predicted potential effects, mitigation measures and net effects are described in Section 6 of this document.

5. Detailed Description of the Environment Potentially Affected

In this section, a description of the Geology and Hydrogeology environment is presented. The information is extracted from the Geology and Hydrogeology Existing Conditions Report, and a more detailed description and list of reference sources can be found in that report.

5.1 On-Site Study Area

5.1.1 Topography and Drainage

The On-Site Study Area consists of well-drained sandy areas, representing the upland side of a post-glacial beach ridge. The topography is flat-lying on the western half of the property with an elevation of approximately 125 metres above sea level (mASL), and slopes downward toward the eastern edge of the ridge, reaching approximately 120 mASL. The land surface has been modified by former aggregate extraction activities and landfill operations on the south half of the On-Site Study Area.

Surface drainage on the southern half of the On-Site Study Area is controlled by ditches and a stormwater management pond. Surface flow is from the southwest to northeast across the south half of the property, and the majority of surface water flow in this area collects in shallow ponded areas. On the north half of the On-Site Study Area, surface water flow follows the land contours and agricultural ditches in a northerly orientation. Surface drainage collects in Huntley Creek, which ultimately flows into the Carp River.

5.1.2 Geology

Overburden deposits were found to be relatively homogeneous across the On-Site Study Area, grading from sand-gravel in the eastern portion along the post-glacial beach ridge, to fine sand further west, away from the edge of the ridge. The overburden thickness ranges from approximately 4 to 16 metres. The bedrock surface slopes toward the north and northeast.

The bedrock consists of light to medium grey, fine to medium-grained fossiliferous limestone with some shaly and sandy interbeds. The bedrock is classified as the Bobcaygeon Formation, which is described regionally as a limestone with shaly partings and intermittent sandstone. The bedrock is generally most fractured in the upper few metres, although at the western end of the On-Site Study Area, relatively high fracture frequencies are observed for 5 to 10 metres below the bedrock surface.

5.1.3 Hydrogeology

Shallow groundwater flow on the On-Site Study Area generally follows the trend in bedrock surface topography. Groundwater flows in a northerly orientation on the western half of the On-Site Study Area, and gradually becomes northeasterly across the eastern portion. In the northwest corner of the existing landfill, there is localized groundwater mounding which results in a small component of flow to the northwest in the immediate vicinity of the landfill mound; however, the natural hydraulic gradient, which is oriented north-northeast, controls the direction of flow further away from the landfill mound.

The groundwater elevations in the deep bedrock are similar to the trend in overburden-shallow bedrock, with the regional groundwater flow in the deep bedrock being toward the northeast.

With few exceptions, the water quality parameters from monitoring wells screened in the overburden-shallow bedrock on the western side of the On-Site Study Area are within the expected range of background concentrations.

The southern boundary of the On-Site Study Area lies along the northern edge of the existing landfill. Groundwater monitoring completed as part of the regular environmental monitoring program for the operating landfill site has shown that leachate-impacted groundwater is moving northward away from the landfill, in a direction consistent with the local groundwater flow. Elevated concentrations of dissolved parameters are also seen downgradient of the stormwater management pond, in a former area of biosolids storage.

5.2 Site-Vicinity Study Area

5.2.1 Topography and Drainage

Within the Site-Vicinity Study Area, the natural topography, which has been modified by extraction and waste disposal activities, ranges from an elevation of approximately 131 mASL southwest of the landfill site to less than 110 mASL on the Huntley Quarry property, located east of Carp Road.

North and west of the existing landfill site, surface drainage flows within the Huntley Creek subwatershed. Tributaries of Huntley Creek generally flow northward to Richardson Sideroad, and then eastward past Carp Road. Huntley Creek discharges to Carp River east of Huntmar Road.

From within the boundaries of the existing landfill property, there is minimal direct off-site discharge of surface water. Surface water drainage is primarily contained within the landfill property and is directed to on-site ponds. The exceptions to this are the external slopes of the vegetated site perimeter berms along the east and south boundaries of the landfill property; however, this amount of surface runoff is very minor and is not in contact with operational activities at the landfill. Runoff from the vegetated berms flows into the Carp Road and Highway 417 drainage systems. There is also a small area of drainage from the extreme western end of the site, north of the service entrance, which flows into the ditch along William Mooney Road, and then northward into a tributary of Huntley Creek.

The Highway 417 drainage system controls surface water flow immediately south of the existing landfill property. Surface water drainage south of the landfill property is controlled by ditches, catch basins and culverts along Highway 417 and generally flows from west to east, eventually reaching Feedmill Creek and ultimately Carp River.

Surface water drainage on the quarry property on the east side of Carp Road is influenced by a series of excavated ponds that are used as a recirculation system for on-site aggregate washing and dust control.

5.2.2 Geology

The surficial geology across the Site-Vicinity Study Area reflects the glacial history of the Ottawa region. The unconsolidated deposits observed during subsurface investigations consist principally of sand, silt, gravel and glacial till, and range in thickness from approximately 3 to 17 metres. The surficial deposits are interpreted to be ice-contact stratified drift sediments, consisting of a mixture of poorly to well-sorted, stratified gravels and sands, interbedded with a silty sand-gravel till. The deposits are interpreted to have been submerged during the Champlain Sea encroachment, and therefore show indications of re-working in a subaqueous environment.

The bedrock surface generally slopes toward the northeast across the Site-Vicinity Study Area, ranging between elevations of 125 mASL and 108 mASL. The bedrock surface features two apparent topographic highs: one located near the southwest extremity of the study area, and the other in the western portion of the existing landfill site.

Bedrock consists of light to medium grey, fine to medium-grained fossiliferous limestone with some shaly and sandy interbeds. The bedrock is classified as the Bobcaygeon Formation which is described regionally as a limestone with shaly partings and intermittent sandstone. The bedrock is generally most fractured in its upper few metres, while the frequency of fractures in the bedrock decreases starting at depths of approximately 6 to 8 metres below the bedrock surface.

5.2.3 Hydrogeology

In the higher topographic elevations along Carp Road, the water table in the unconsolidated deposits (i.e., sand, silty sand and silty sand-gravel till) is generally found at over 10 metres depth, indicating that the majority of the unconsolidated deposits are unsaturated. The saturated thickness of these deposits, which represents the water table aquifer, is generally limited to 5 metres or less. In areas where the bedrock is closer to the surface or where the topographic elevations decline, the depth to the water table decreases, however, the saturated thickness remains limited. Groundwater is also found in the weathered bedrock at the overburden-bedrock interface. This part of the unit extends to a depth of approximately 6 to 8 metres below the bedrock surface.

Shallow groundwater flow within the Site-Vicinity Study Area generally follows the bedrock topography, with a water table elevation varying from 128 to 129 mASL in the southwest portion of the landfill property to less than 112 mASL east of Carp Road. The direction of groundwater flow within the overburden-shallow bedrock in the southwest portion of the study area is towards the north-northeast. In the northwest corner of the existing landfill site, the topographic high present in the bedrock appears to influence shallow groundwater flow and induces an area of localized northwesterly flow toward the northwest corner of the site. Across the majority of the study area, the direction of groundwater flow in the overburden-shallow bedrock is towards the northeast.

The regional direction of groundwater flow in the deep bedrock is interpreted to be toward the northeast. Groundwater flow in the deep bedrock is interpreted to be influenced by isolated fracture zones, which do not appear to be well-connected across most of the Site-Vicinity Study Area. However, across the western portion of the Site-Vicinity Study Area, where the bedrock is found at shallower depths, the hydraulic heads in the deep bedrock zone are generally more consistent with those in the overburden-shallow bedrock zone than they are on the eastern portion of the study area. This indicates that there may be more hydraulic connectivity between the shallow and deep hydrostratigraphic units in this area.

The groundwater quality within the Site-Vicinity Study Area is highly variable due to influences on natural groundwater quality from the existing landfill, major transportation corridors, aggregate processing, and local agricultural/commercial/industrial practices. A detailed discussion of groundwater quality in the Site-Vicinity Study Area is presented in the Existing Conditions Report (the Detailed Study Area described in the Existing Conditions Report includes the area designated as the Site-Vicinity in this document). In addition, historical groundwater quality results and interpretations are available in the Annual Reports for the existing landfill.

5.3 Regional Study Area

5.3.1 Topography and Drainage

The Regional Study Area consists of sandy upland areas in the northwest and west to poorly drained swampy areas, clay plains and the Carp River floodplain toward the northeast. The primary natural topographic feature in the area is a northwest-southeast trending sand and gravel ridge, which has historically been exploited for aggregate extraction.

Within the area, the natural topography, which has been modified by extraction and waste disposal activities, ranges from an elevation of approximately 131 mASL southwest of the existing landfill site to less than 100 mASL along Carp River. The dominant man-made topographic features in the study area are the WM Ottawa Landfill, which extends to an elevation of approximately 172 mASL, and the Huntley Quarry, which has been mined to a floor elevation of less than 75 mASL.

The Regional Study Area is situated within the Carp River watershed. The watershed drains approximately 306 km^2 of land in the northwestern portion of the City of Ottawa. Carp River is located approximately four kilometres northeast of the existing landfill (see Figure 2), and discharges to the Ottawa River at Fitzroy Harbour, approximately 20 km northwest of the landfill property. Surface drainage within the Regional Study Area is controlled by the ground surface topography and small tributaries of Carp River, as modified by the surrounding quarry and landfill operations and the Highway 417 drainage system.

5.3.2 Geology

The surficial deposits in the Regional Study Area consist of glacial and related materials from the late Wisconsian glaciation. During this glacial period, thick sequences of sand and gravel were deposited along the Ottawa River valley, followed by deposits of silt and clay during encroachment of the Champlain Sea.

The materials observed in the vicinity of the WM Ottawa Landfill are interpreted to be ice-contact stratified drift sediments, consisting of a mixture of poorly to well-sorted, stratified gravels and sands, interbedded with lenses of silty sand-gravel till. The deposits are interpreted to have been submerged during the Champlain Sea encroachment, and therefore show indications of re-working in a nearshore, subaqueous environment. Closer to Carp River, thick deposits of silt, clay and organic materials (peat and muck) have been deposited in a lower energy, offshore marine environment consistent with the deeper waters of the Champlain Sea. Organic deposits are found on the southeastern portion of the quarry property, east of Carp Road.

The Regional Study Area is underlain by several carbonate rock-types. Throughout the majority of the portion of the Regional Study Area that also encompasses the Site-Vicinity and On-Site, bedrock consists of grey, fine to medium-grained fossiliferous limestone with some shaly or sandy interbeds of the Bobcaygeon Formation, a member of the Middle Ordovician-aged Ottawa Group. Within the Regional Study Area, the Bobcaygeon Formation is in contact with interbedded silty dolostone, limestone, shale and sandstone of the underlying (older) Gull River Formation and overlying (younger) Verulam Formation, which are classified as limestone with shale interbeds. Both formations are also members of the Middle Ordovician-aged Ottawa Group.

The bedrock surface generally slopes at less than 1 degree in a northeasterly direction under the Regional Study Area.

The Paleozoic formations in the Ottawa area are transected by steeply dipping normal faults, three of which are found within the Regional Study Area oriented from northwest to southeast. Carp River follows the orientation of the Hazeldean Fault, which separates the Paleozoic bedrock found within the Regional Study Area from the much older Precambrian rocks that compose the Carp Ridge northeast of the study area. A second line of faults separates the Bobcaygeon and Verulam Formations east of the Huntley Quarry. A third fault has been mapped west of the existing landfill, separating the Gull River and the Bobcaygeon Formations.

5.3.3 Hydrogeology

Groundwater occurs within the unconsolidated overburden units and the Paleozoic bedrock fracture systems found within the Regional Study Area. The general direction of regional groundwater flow is northeast toward Carp River. Water table elevations range from approximately 135 metres southwest of the existing landfill to between 92 and 105 metres along Carp River.

Locally, groundwater recharge occurs along the sand and gravel ridge and upland areas extending north and south of the existing landfill. Overall, the western portion of the Regional Study Area is interpreted as having strong to weak downward gradients, indicating that these areas are considered recharge zones. Closer to Carp River, groundwater discharge zones occur, with upward hydraulic gradients becoming more pronounced in proximity to the river.

Groundwater quality within the Carp River watershed is generally acceptable for potable usage, and is free from recognizable regional-scale groundwater impacts. Non-health related water quality parameters, such as total dissolved solids, hardness, iron, sulphate and chloride commonly exceeded the Ontario Drinking Water Standards, although the concentrations in the groundwater tend to vary considerably with the type of bedrock formation. In general, the regional groundwater quality reflects the characteristics of the limestone bedrock, being dominated by calcium carbonate (hardness) and also containing iron and sulphur compounds (sulphate, hydrogen sulphide) from the shaley interbeds.

6. Geology and Hydrogeology Net Effects

As mentioned, the previously identified potential effects and recommended mitigation or compensation measures associated with the Preferred Alternative Landfill Footprint were reviewed to ensure their accuracy in the context of the preliminary design of the Preferred Alternative Landfill Footprint. Based on the more detailed development of the landfill design components (e.g., stormwater management), additional investigations were completed to further assess the potential effects on the Geology and Hydrogeology environments. With this in mind, the predicted potential effects, mitigation measures, and net effects are summarized in **Table 1** and described in further detail in the sections below.

6.1 Potential Effects on Geology and Hydrogeology

The potential effects on Geology and Hydrogeology from the construction and operation of the proposed landfill presented in the Facility Characteristics Report are described in this section. The environmental criteria used to determine the potential effects are Groundwater Flow and Groundwater Quality, as listed in the approved Terms of Reference.

The potential effects from the Preferred Alternative Landfill Footprint are evaluated in relation to the future baseline conditions that are projected to occur from the existing closed landfill. Computer modelling simulations were used to predict future conditions for groundwater flow and quality in the On-Site and Site Vicinity areas. The simulations were run using chloride as an indicator of contaminant movement, because of its conservative nature in dissolved phase transport. Whether chloride is appropriate to be used as a monitoring indicator and compliance trigger for the site will be determined during the detailed design phase of the landfill and the development of an Environmental Monitoring Plan.

6.1.1 Future Baseline Conditions

The future baseline conditions are defined as the groundwater flow and quality characteristics that are predicted to occur from the existing closed landfill and infrastructure, without the development of a new landfill footprint.

Table 1. Potential Effects, Proposed Mitigation and Compensation Measures, and Resulting Net Effects

ID Number	Potential Effect	Mitigation/ Compensation	Net Effect
Groundwater Flow			
1	• Local groundwater elevations may be lowered as a result of a reduction in the amount of recharge to groundwater below the new landfill footprint. The local and regional groundwater flow directions are not expected to be impacted.	• None required.	• No impacts to off-site groundwater flow.
2	• Infiltration from the SWM Ponds may cause water levels to rise in the vicinity of the ponds. Groundwater flow is expected to be oriented radially away from the ponds, which will affect the orientation of the local flow regime.	• None required.	• No impacts to off-site groundwater flow.
Groundwater Quality			
3	• Surface water that infiltrates to the groundwater table from the SWM Ponds may contain elevated concentrations of contaminants from surface runoff, traffic and landfill operations. These contaminants may migrate with the groundwater flow toward the downgradient property boundary, which is situated approximately 200 metres to the east of the ponds.	• Effluent limits should be established on the concentration of indicator parameters that are discharged to groundwater from the SWM Ponds.	• The effluent limits will restrict the migration of contaminants so that there are no impacts to off-site groundwater quality above acceptable standards.
4	• Radial groundwater flow predicted to occur around the SWM Ponds is expected to intercept the movement of leachate-impacted groundwater from the existing unlined landfill, which may have the effect of re-orienting leachate-impacted groundwater further northward, extending beyond the northern site boundary.	• A series of purge wells may be installed along the northern toe of the existing landfill. The purge wells should be designed to control the migration of leachate-impacted groundwater away from the existing landfill footprint.	• The proposed mitigation measure is considered to provide a reasonable method of reducing the potential effects on groundwater quality. No impacts to off-site groundwater quality are expected above acceptable standards.

6.1.1.1 Groundwater Flow

The future baseline conditions for groundwater flow are predicted to be consistent with the observed conditions seen at the landfill. The full extent of the landfill footprint and site infrastructure have been established, and the site conditions at the time of the groundwater flow model development and calibration are not expected to change significantly in future. The future baseline groundwater head contours for the Regional Study Area and the Site-Vicinity Study Area are shown on **Figures 3 and 4**, respectively.

6.1.1.2 Groundwater Quality

The western two-thirds of the existing landfill footprint is unlined, and leachate generated from the waste can come into contact with the underlying groundwater. The direction of groundwater flow from this area is toward the northeast. As described in the Existing Conditions Report, the concentrations of leachate indicator parameters immediately adjacent to the unlined landfill are elevated above background and indicate migration of leachate away from the toe of the landfill. It is expected that this movement of elevated concentrations of dissolved parameters will continue in future, following the direction of groundwater flow.

The existing purge well system installed along Carp Road to the east of the existing landfill footprint and the closed south cell will continue to be operated in the future. The system provides containment of leachate-impacted groundwater east of the site. As long as the purge wells are operating, groundwater impacts on the Contaminant Attenuation Zone (CAZ) properties are expected to gradually decrease over time.

In order to predict the future orientation and extent of leachate-impacted groundwater from the unlined landfill footprint, computer-based numerical modelling of groundwater flow and dissolved phase transport was completed. The groundwater flow model was calibrated to the observed water levels on the landfill site and to water levels reported in the MOE's Water Well Information System (WWIS). The groundwater flow model simulates the flow system in the study area and is used as the basis for establishing the direction that leachate impacts are expected to migrate away from the landfill. To simulate movement of the leachate-impacted groundwater, source concentration profiles were estimated for the landfill footprint based on observed leachate concentrations, and by fitting an exponential decay curve post-closure. The source concentrations were input to the groundwater flow system model, and allowed to migrate with the groundwater flow according to the principles of advective-diffusive contaminant transport. As noted above in Section 6.1, chloride was used as a modelling parameter to examine plume orientations and trends. This is because of its conservative nature and elevated source concentrations.

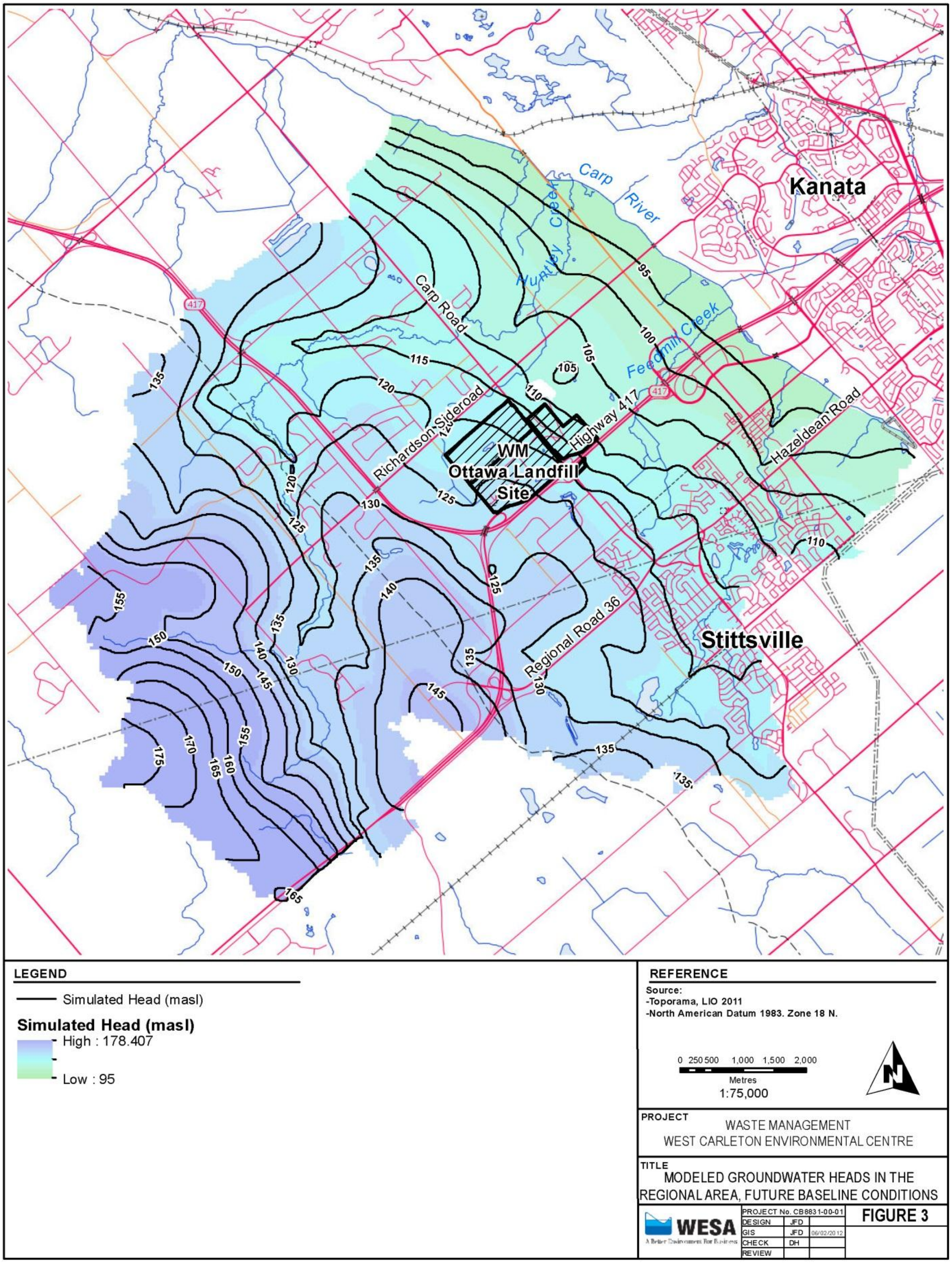


Figure 3. Modelled Groundwater Heads in the Regional Area, Future Baseline Conditions

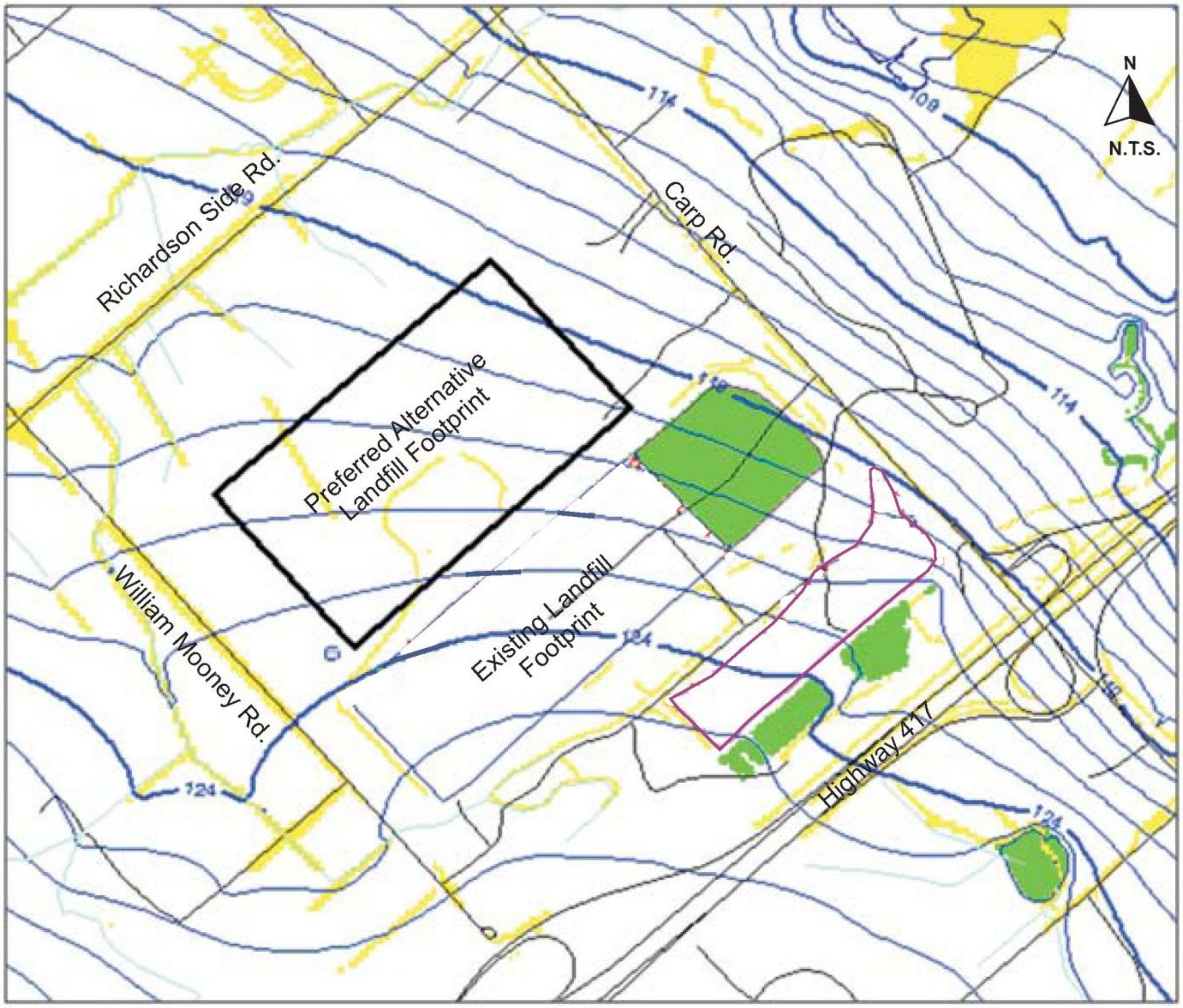


Figure 4:
Modeled Groundwater Head Contours in the Site-Vicinity, Future Baseline Conditions (in metres above sea level).

Figure 4. Modelled Groundwater Head Contours in the Site-Vicinity, Future Baseline Conditions

The results from the future baseline transport modelling indicate that leachate-impacted groundwater is expected to continue to migrate away from the unlined landfill footprint. **Figure 5** illustrates the simulated progression of impacted groundwater. The figure shows the approximate orientation and extent of chloride concentrations that are predicted to exceed 130 mg/L (the Reasonable Use Limit for an aquifer with a background chloride concentration of 10 mg/L). It is seen that the impacted groundwater is predicted to eventually extend beyond the current boundaries of the CAZ properties. This is because the orientation of groundwater flow takes the dissolved constituents north of the existing purge well system, beyond its zone of influence. Measures to control and abate the predicted extent of leachate impacts from the existing unlined landfill are expected to be required.

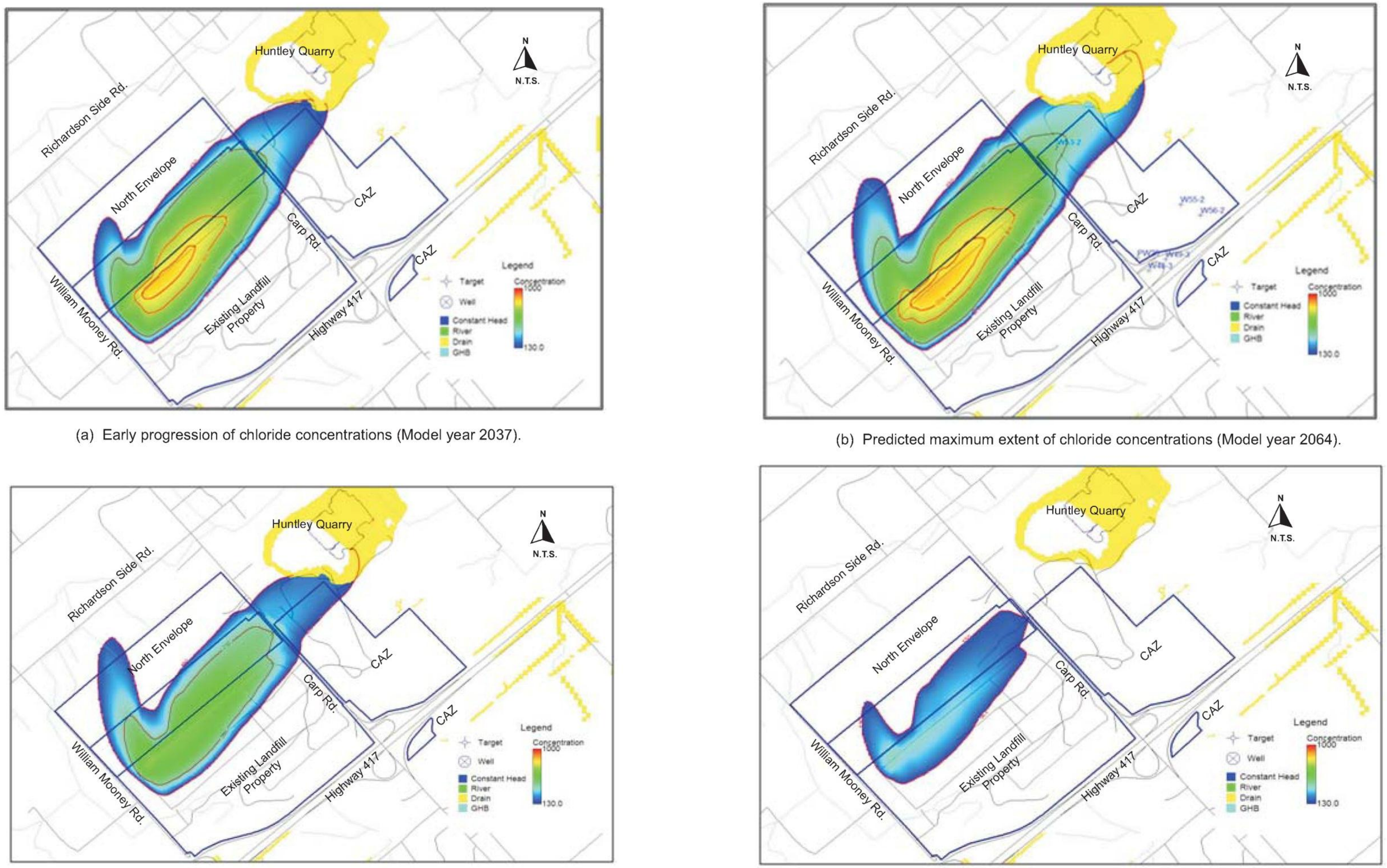
It should be noted that the computer modelling simulations are not considered sufficiently accurate to predict actual groundwater concentrations at specific locations and/or times. Instead, the simulations are used to provide a reasonable projection of future contaminant orientations and trends. Field observations (groundwater elevations and concentration trends) will be necessary to measure actual leachate impacts at specific monitoring well locations.

6.1.2 Potential Effects from the Preferred Alternative Landfill Footprint

The potential effects from the development of a new landfill footprint and stormwater management ponds are described in this section. The design assumptions and preliminary design of the new landfill and stormwater management system are found in the Facility Characteristics Report.

6.1.2.1 Groundwater Flow

The new landfill footprint will include the development of a double-composite leachate collection and containment system. This will have the effect of reducing the amount of recharge to the groundwater within the confines of the landfill footprint. The result is predicted to be a general decrease in the groundwater heads immediately below the landfill. The predicted change in groundwater elevations ranges from approximately 0.49 to 0.62 metres, measured at full landfill development within the footprint. Around the perimeter of the landfill, the groundwater elevations are predicted to decrease between approximately 0.05 and 0.45 metres. However, because the effect of the landfill at reducing the amount of recharge is localized, further from the edges of the landfill the impacts are predicted to be much less noticeable. At the downgradient property boundaries, the decrease in groundwater elevation is predicted to be equal to or less than 0.21 metres. This is much less than the normal seasonal variations in the water table, and is not expected to have negative effects on off-site water supplies.



(a) Early progression of chloride concentrations (Model year 2037).

(b) Predicted maximum extent of chloride concentrations (Model year 2064).

(c) Late stage of chloride concentrations (Model year 2232).

(d) Dissipation of chloride concentrations at very late stage (Model year 2434).

B8831-12-01-FIG5

Figure 5:
Predicted chloride concentrations under Future Baseline Conditions (in mg/L). Note that the dates shown are based on the modeled conditions with Year 1=1975. Actual conditions on specific dates may vary from those shown.

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Figure 5. Predicted Chloride Concentrations under Future Baseline Conditions

The orientations of the local and regional groundwater flow are also not expected to be impacted by the small change in groundwater elevations as a result of the reduced recharge under the landfill.

A more significant effect on the groundwater flow direction within the On-Site and Site-Vicinity Study Areas is predicted to occur from the operation of the stormwater management ponds for the Preferred Alternative Landfill Footprint. As described in the FCR, the three ponds are designed with two stages, a lined stage for settlement and containment, and an unlined stage to permit discharge via groundwater infiltration. Each of the stages is designed to hold the runoff volume from a 1:100 year precipitation event. The estimated amount of infiltration that would occur from each unlined pond stage on an average annual basis is provided in **Table 2**.

Table 2. Infiltration Estimates from Unlined Stormwater Management Pond Stages

Pond	Volume of Runoff (m^3/yr)	Area of Base of Unlined Stage (m^2)	Annual Infiltration Rate (mm/yr)
New Landfill-North Pond	76,048	6,000	12,675
Access Road-SW Pond	21,903	1,200	18,253
Existing Landfill-SE Pond	39,232	3,580	10,958

This amount of infiltration is predicted to cause the groundwater levels to rise on the order of 1.26 to 3.23 metres immediately under the unlined pond stages. The predicted groundwater head contours in the Site-Vicinity Study Area from the development of the new landfill and the stormwater management ponds are shown on **Figure 6**.

The effects of this groundwater mounding diminish with increased distance from the ponds; however, the localized groundwater flow orientations are predicted to be affected, in that radial flow away from the ponds can be expected. Downgradient from Carp Road and north of the north property boundary, the groundwater elevations are not projected to change significantly, and the regional groundwater flow patterns are not expected to be altered. The impacts of this localized effect on groundwater flow are seen in the future projections of groundwater quality, as described in the next section.

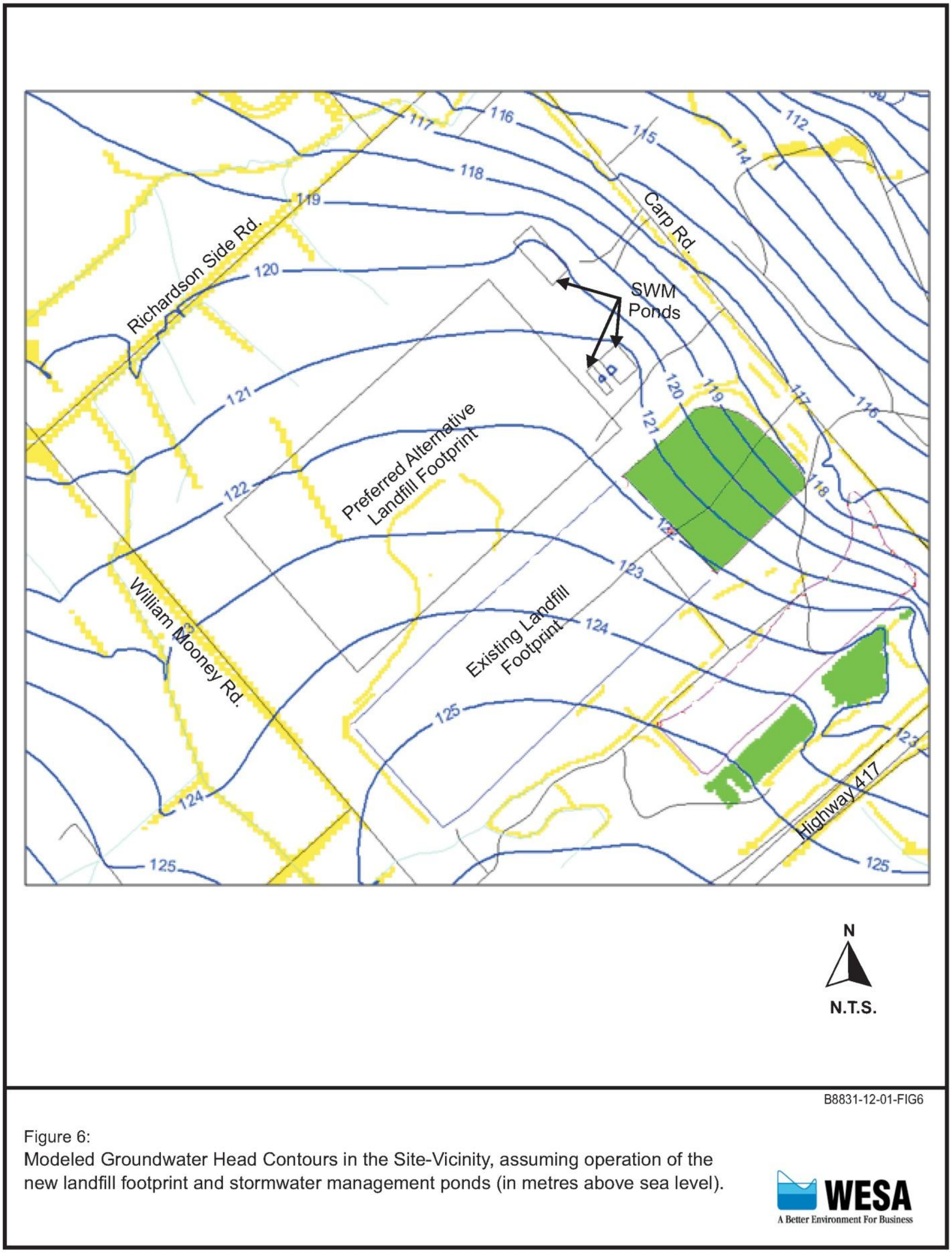


Figure 6. Modelled Groundwater Head Contours in the Site-Vicinity, Assuming Operation of the New Landfill Footprint and Stormwater Management Ponds

In summary, the potential effects on Groundwater Flow from the Preferred Alternative Landfill Footprint (including the stormwater management ponds) are as follows:

1. Recharge to the groundwater is expected to be reduced within the area of the new landfill footprint. This will have the effect of lowering the groundwater elevations immediately below the landfill, but is predicted to have minimal effects away from the footprint. The local and regional groundwater flow directions are not expected to be impacted.
2. Infiltration from the stormwater management ponds is predicted to cause the groundwater levels to rise under the unlined pond stages. The effects of this groundwater mounding diminish with increased distance from the ponds. The groundwater flow will be radially away from the ponds, which is predicted to affect the orientation of the local flow regime and influence groundwater quality in the vicinity.

6.1.2.2 Groundwater Quality

The future baseline conditions of groundwater quality impacts from the existing unlined landfill are described in Section 6.1.1.2. The proposed development of the new landfill footprint and the stormwater management ponds is expected to have the following potential effects on the future baseline conditions for Groundwater Quality:

1. Surface water that infiltrates to the groundwater table from the stormwater management ponds may contain elevated concentrations of contaminants from surface runoff, traffic and landfill operations. These contaminants may migrate with the groundwater flow toward the downgradient property boundary, which is situated approximately 200 metres to the east of the ponds.
2. Radial groundwater flow predicted to occur around the stormwater management ponds (refer to Section 6.1.2.1) is expected to intercept the movement of leachate-impacted groundwater from the existing unlined landfill. This is expected to have the effect of re-orienting leachate-impacted groundwater further northward across the Northern Envelope and extending beyond the northern property boundary. A southern arm of leachate-impacted groundwater is expected to migrate eastward onto the existing CAZ; however, because of the reduced mass of contaminants being transported in this direction, the impacts may not extend as far east as the future baseline scenarios, and may potentially remain within the CAZ boundaries.

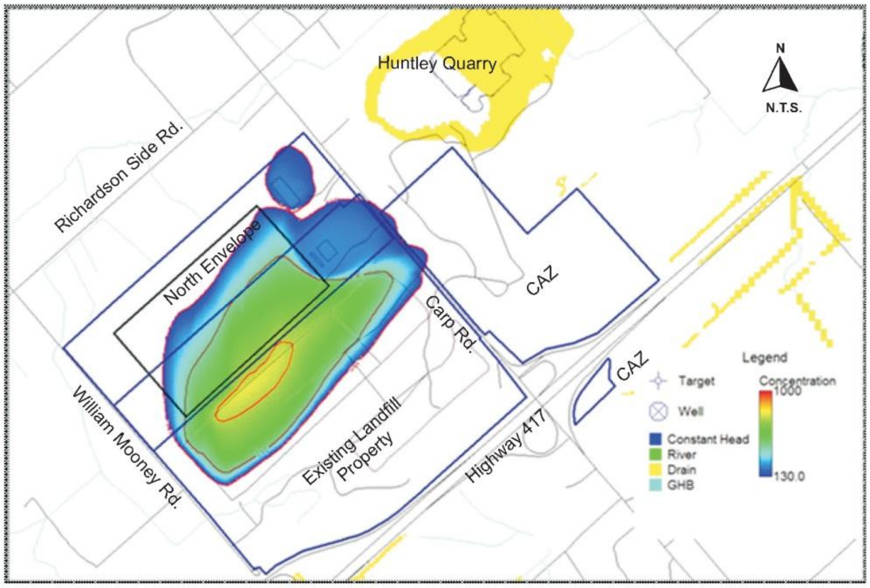
The potential effects from the stormwater management ponds and from the migration of leachate-impacted groundwater from the existing unlined landfill are shown on **Figure 7**. Figure 7(a) shows the maximum predicted extent of chloride concentrations greater than 130 mg/L from the stormwater management ponds. Note that the maximum source concentration of chloride infiltrating from the ponds that was used in the modelling simulations was set at 165 mg/L during landfill operations. This effluent concentration limit restricts the mass of contaminant that is available for transport, as will be discussed further in Section 6.2, Mitigation Measures. Once the landfill site is closed, final cover will be applied and operations traffic reduced. In the simulations, the projected source concentration was linearly reduced to 0 mg/L over five years of post-closure.

Figure 7(b) shows the predicted maximum extent of leachate-impacted groundwater from the existing unlined landfill, as influenced by the new landfill footprint and stormwater management ponds. From the results of the simulations, it is apparent that the leachate-impacted groundwater would be transported further northward than the future baseline scenarios. With no mitigation measures in place, it is predicted that the potential effects to groundwater quality would extend off-site to the north.

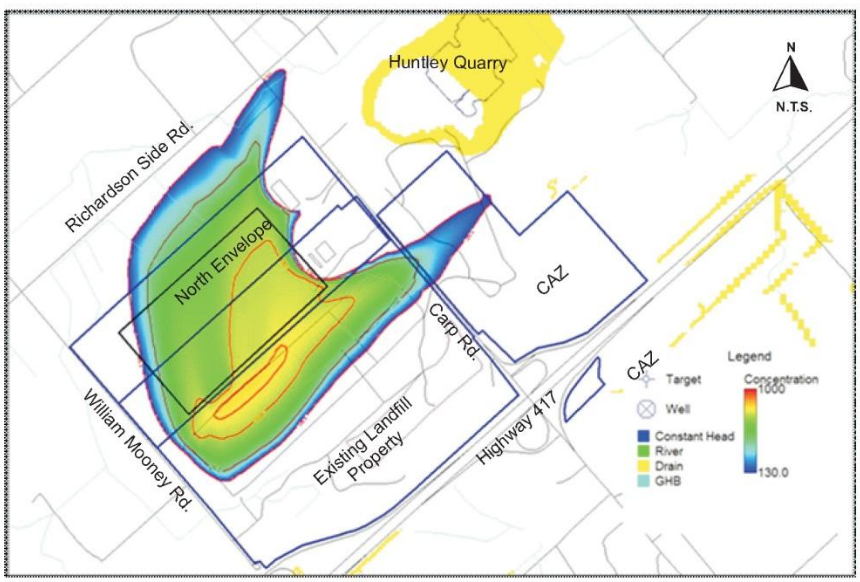
The predicted contaminant flux through the double-composite liner of the new landfill footprint is described in the Facility Characteristics Report. The chloride concentrations predicted to discharge through the base of the attenuation layer of the new landfill were used as source concentration inputs to the groundwater model. Since the mass flux of contaminant through the double-composite liner is very small (transport through the low permeability liner components is dominated by diffusion rather than by advection), the changes in chloride concentrations in the groundwater at the base of the attenuation layer are negligible. This is consistent with the regulatory definition of the Generic Design Option II (G2) liner system, which is designed to provide protection to groundwater quality without reliance on attenuation in the landfill buffer area.

6.2 Mitigation Measures

Mitigation measures will be required to reduce the potential effects of the Preferred Alternative Landfill Footprint on Groundwater Quality to acceptable levels. The proposed mitigation measures are design-based and operational in nature, related to the movement of leachate-impacted groundwater from the existing landfill and effluent from the stormwater management ponds, respectively.



(a) Predicted maximum extent of chloride from the stormwater management ponds, operating with an effluent concentration of 165 mg/L (Model year 2024).



(b) Predicted maximum extent of chloride from the existing landfill (Model year 2072).

B8831-12-01-FIG7

Figure 7:
Predicted chloride concentrations, assuming operation of the new landfill footprint and stormwater management ponds (in mg/L). Note that the dates shown are based on the modeled conditions with Year 1=1975. Actual conditions on specific dates may vary from those shown.

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Figure 7. Predicted Chloride Concentrations, Assuming Operation of the New Landfill Footprint and Stormwater Management Ponds

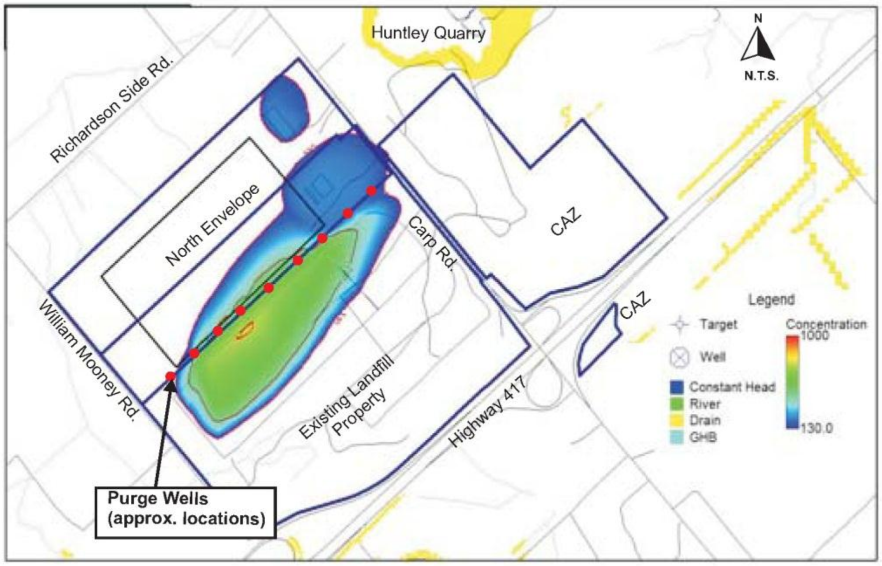
Within the context of the Environmental Assessment, the proposed mitigation measures have been developed to a conceptual design level, using computer-based numerical modelling simulations. This is considered reasonable and sufficient in order to evaluate general trends in flow orientation and contaminant concentrations, and to assess the conceptual feasibility of the proposed measures. A detailed design of the mitigation measures, including additional modelling simulations and field testing, would need to be completed at such time as actual contaminant transport dictates.

6.2.1 Purge Wells

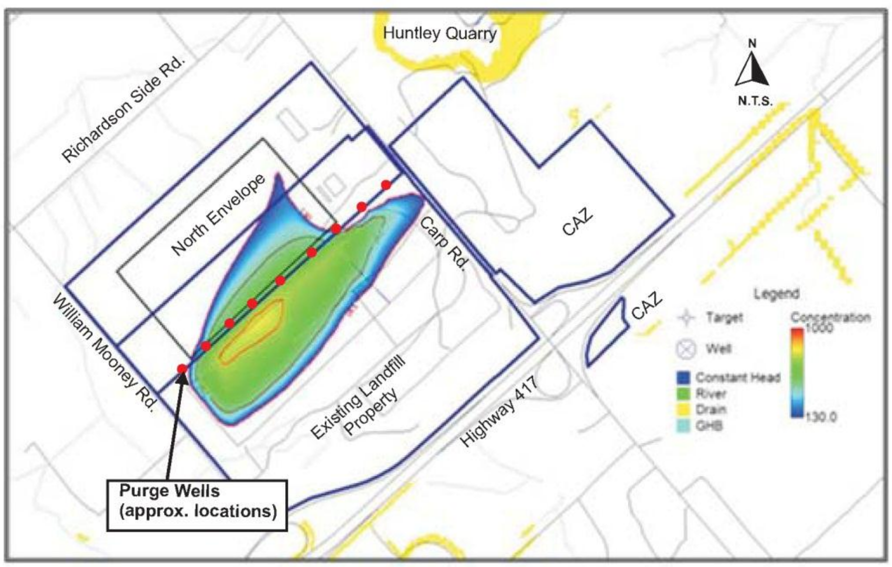
The potential effects of the Preferred Alternative Landfill Footprint and associated operations relative to the future baseline conditions are that contaminant concentrations from leachate-impacted groundwater exceeding acceptable levels (as defined by the Reasonable Use Limits and as modelled using chloride as an indicator parameter) are predicted to extend beyond the northern boundary of the site. The source of the leachate-impacted groundwater is the existing unlined (closed) landfill footprint.

Purge wells are an effective method for controlling leachate migration from landfills in permeable geologic environments. The existing purge wells on the site control the eastward movement of impacted groundwater. A proposed mitigation measure to reduce the potential effects of the Preferred Alternative Landfill Footprint is to install a series of purge wells along the northern toe of the existing landfill, between the landfill and the new footprint. The existing geologic conditions in the area consist of sand to sand-gravel overburden, underlain by fractured limestone bedrock of the Bobcaygeon Formation. The average hydraulic conductivity in the overburden-shallow bedrock zone is on the order of $1.5x10^{-4}$ m/s, which is considered a permeable formation with favourable conditions for hydraulic capture via purge wells. The purge wells would target the saturated overburden and the upper six to eight metres of fractured limestone as the primary pathway for leachate migration.

The concept of purge wells installed as a mitigation measure was simulated using the numerical model of groundwater flow and contaminant transport. The results of the modelling simulations indicate that sufficient capture could be achieved by installing nine purge wells spaced evenly along the toe of the existing landfill, completed in the overburden-shallow bedrock zone. The predicted maximum extent of leachate-impacted groundwater with chloride concentrations greater than 130 mg/L with the operation of the new purge wells is shown in **Figure 8**. Each purge well was simulated to pump 45 m^3/day (31.3 L/min), which is considered to be a reasonable pumping rate for this type of aquifer, and is less than the average pumping rate for the existing purge wells.



(a) Predicted maximum extent of chloride from the stormwater management ponds, operating with an effluent concentration of 165 mg/L and with mitigation measures in-place (Model year 2024).



(b) Predicted maximum extent of chloride from the existing landfill, with mitigation measures in-place (Model year 2064).

B8831-12-01-FIG8

Figure 8:
Predicted chloride concentrations, assuming operation of the new landfill footprint and stormwater management ponds, and with mitigation measures in-place (in mg/L). Note that the dates shown are based on the modeled conditions with Year 1=1975. Actual conditions on specific dates may vary from those shown.

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Figure 8. Predicted Chloride Concentrations, Assuming Operation of the New Landfill Footprint and Stormwater Management Ponds, and with Mitigation Measures In-place

Under this modelling scenario, the predicted distribution of leachate-impacted groundwater exceeding Reasonable Use Limits would not extend beyond the property boundaries of the Preferred Alternative Landfill Footprint. In addition, although there would be drawdown of groundwater levels in the vicinity of the purge wells and changes to the localized groundwater flow directions, it is not expected that there would be any impacts to groundwater levels or flow directions beyond the property boundaries.

The actual number and spacing of purge wells required and the design pumping rates will be determined during the detailed design of the mitigation measures, when required. However, for conceptual design purposes, the proposed mitigation measure is considered to provide a reasonable method of reducing the potential effects on groundwater quality to acceptable levels.

6.2.2 Operational Controls on Stormwater Management Pond Effluent

As described in Section 6.1.2.2, the stormwater management ponds have the potential effect of allowing elevated concentrations of contaminants to infiltrate to the groundwater table. The ponds are designed with two stages: surface runoff first flows into a lined stage and then overflows to an unlined stage. Effluent in the lined stage can be contained in case of a spill of other emergency (refer to the Facility Characteristics Report).

The stormwater management ponds are located relatively close to the downgradient property boundary and beyond the zones of influence of the existing purge well system and the proposed northern purge wells described in the previous section. Because of the pond locations and the types of underlying geologic formations, once in the groundwater there is limited attenuation capacity available to further reduce the effluent concentrations. Therefore, the potential effects on groundwater quality from the operation of the stormwater management ponds should be controlled by establishing limits on the concentration of effluent in the unlined pond stages. These operational effluent limits would restrict the concentrations of dissolved constituents entering the groundwater system such that groundwater quality at the property boundaries would continue to meet acceptable levels.

Several predictive analyses of groundwater quality were completed using maximum effluent concentrations from the ponds ranging from 50 to 300 mg/L. The results of the simulations indicate that a chloride concentration of approximately 165 mg/L would reduce the potential effects from the ponds to acceptable levels. **Figure 8** shows the predicted maximum extent of impacted groundwater with chloride concentrations greater than 130 mg/L, using a maximum effluent concentration of 165 mg/L from the stormwater management ponds. The impacted groundwater in this scenario (i.e., groundwater with chloride concentrations greater than 130 mg/L) does not extend beyond the property boundaries.

Based on this conceptual assessment, the proposed mitigation measure for the potential effects from the stormwater management ponds is to establish concentration limits on the effluent infiltrating to the groundwater from the unlined pond stages. Further evaluation to confirm the final recommended chloride effluent concentration and to determine whether other parameter limits should be established will be completed during the detailed design phase for the landfill.

6.3 Net Effects

The mitigation measures described in Section 6.2 are intended to reduce the potential effects from the Preferred Alternative Landfill Footprint to acceptable levels.

For the Groundwater Flow criterion used to assess the impacts of the proposed undertaking on Geology and Hydrogeology, the potential effects described in Section 6.1.2.1 are acceptable and do not require further mitigation or compensation.

For the Groundwater Quality criterion, mitigation measures have been applied to the potential effects described in Section 6.1.2.2. With the implementation of mitigation measures, the resultant net effects are considered acceptable. A summary of the potential effects, mitigation measures and net effects for each criterion are summarized in Table 1.

7. Impact Analysis of Other WCEC Facilities

As part of the approved Terms of Reference (ToR), WM committed to undertaking an assessment of the cumulative effects of the landfill and other WCEC components/facilities and other non-WCEC activities that are existing, planned and approved or reasonably foreseeable. The additional facilities considered in this assessment of cumulative effects are as follows:

- Material recycling facility (MRF);
- Construction and demolition (C&D) material recycling facility;
- Organics processing facility (restricted to leaf and yard material);
- Community lands for parks and recreation;
- Residential diversion facility;
- Greenhouses; and
- Landfill gas-to-energy facility.

The MRF, C&D and organics processing facilities will be situated in the southwest corner of the existing landfill property in an area currently used for equipment maintenance and storage. The area is already developed with a maintenance garage, gravelled equipment and employee parking areas, and paved and gravelled access roads. A description of the proposed facilities and processes is presented in the Ottawa Transfer and Processing Facility Design & Operations Report (prepared by AECOM, dated June 2011).

Minor changes are expected to occur in the land use at the facility, such as the construction of outdoor concrete slabs for tipping and sorting areas, and changes to the parking areas and roadways. There are predicted to be minor changes in the quantity of runoff; however, the runoff in contact with waste or processed materials will be contained and removed or directed to an existing lined storage pond. Drainage from the concrete pads and gravelled areas will be collected and pumped to the lined storage pond. Drainage from the MRF tipping area will be collected with residue or commercial sorbent and disposed in the landfill.

From this assessment, it is concluded that no measurable effects will occur to the groundwater flow or quality from the proposed MRF, C&D and organics processing facilities, and no cumulative effects are expected on the geology and hydrogeology.

The community lands for parks and recreation will include predominantly passive areas, such as trail systems and open spaces, located in the buffer lands around the perimeter of the WCEC facilities. No negative net effects are expected from the community lands on the geology and hydrogeology. Similarly, no cumulative effects are anticipated from the construction and operation of the residential diversion facility, which will be located east of the new stormwater management ponds.

The greenhouse facility, which will include approximately 2.0 hectares of greenhouses, indoor storage, processing and offices, are to be located south of the existing landfill footprint. The water supply for the greenhouses is not specified as yet; however, it is expected to be sourced from the existing ponds (SWMF #2 or Depression #1 south of the Closed South Cell; refer to Figure FCR-02 of the Facility Characteristics Report) or from a new water supply well. Because of the large separation distance from the potential greenhouse water supplies to the new landfill footprint (greater than 500 metres), it is expected that there will be no cumulative effect on groundwater flow or quality.

The landfill gas-to-energy facility is situated in the southeast corner of the existing landfill property. The facility is already constructed and operational, and has no effect on the geology and hydrogeology on or around the site. There are not expected to be any cumulative effects on the geology and hydrogeology from the continued operations of the landfill gas-to-energy facility.

8. Monitoring and Commitments for the Undertaking

To ensure that the mitigation measures identified in **Section 6** are implemented as envisioned, a strategy and schedule was developed for monitoring environmental effects. With these mitigation measures and monitoring requirements in mind, commitments have also been proposed for ensuring that they are carried out as part of the construction, operation, and maintenance of the landfill.

8.1 Monitoring Strategy and Schedule

As mentioned, a monitoring strategy and schedule was developed based on the Geology and Hydrogeology Impact Assessment carried out for the Preferred Alternative Landfill Footprint to ensure that (1) predicted net negative effects are not exceeded, and (2) unexpected negative effects are addressed.

8.1.1 Environmental Effects Monitoring

The predicted net effects from the design and operation of the Preferred Alternative Landfill Footprint, including the proposed stormwater management facility, are that any negative impacts to groundwater flow and groundwater quality will remain within the site boundaries. Monitoring of groundwater levels and groundwater quality will be required to ensure that the predicted net effects are as expected. Refer to **Table 3** for a list of proposed monitoring requirements for each potential effect identified in the Geology and Hydrogeology Impact Assessment.

Groundwater flow on-site and within the site-vicinity (ID Numbers 1 and 2 in Table 3) will be monitored by measuring water levels in monitoring wells and the stormwater management ponds at a prescribed frequency. The water levels will be measured in selected monitoring wells completed in the overburden-shallow bedrock zone and the deeper bedrock. The water level measurements will be converted to groundwater elevations and will be plotted on a site map to interpret the groundwater flow orientations, hydraulic gradients and average flow velocities. Monitoring wells situated around the stormwater management ponds will be used to observe flow conditions around the ponds, specifically whether localized radial flow occurs as expected.

Table 3. Proposed Monitoring Requirements

ID Number/ Potential Effect	Proposed Monitoring Requirement	Associated Licences, Permits or Authorizations
Groundwater Flow		
1 & 2	• Monitor groundwater elevations in monitoring wells on-site and within the site-vicinity; monitor water levels in the SWM Ponds. • Use the collected data to map and interpret the groundwater flow orientations.	• Development of an approved EMP.
Groundwater Quality		
3 & 4	• Collect groundwater samples from selected monitoring wells located on-site and within the site-vicinity; analyze the samples for an appropriate site-specific indicator list. • Collect effluent samples from the unlined stages of the SWM Ponds to measure water quality in effluent infiltrating to the groundwater table. • Use the collected data to interpret groundwater quality conditions upgradient, between the landfill footprints, and downgradient from the new landfill facilities.	• Development of an approved EMP.

Groundwater quality (ID Numbers 3 and 4 in Table 3) will be monitored by analyzing groundwater chemistry in samples collected from monitoring wells on-site and within the site-vicinity at prescribed frequencies. The required indicator list as specified in Schedule 5 of O. Reg. 232/98 (Landfill Standards) will be used in combination with the monitoring indicator list used in the approved Environmental Monitoring Plan for the current landfill site to develop an appropriate site-specific list of groundwater quality monitoring parameters.

The overall strategy in monitoring groundwater quality is to: i) observe conditions from the existing closed landfill site over time; and ii) observe conditions surrounding the new landfill footprint and the stormwater management ponds. This will be accomplished by monitoring groundwater quality at the following locations:

a) between the two landfill footprints;

b) between the eastern boundary of the new landfill and the western boundary of the stormwater management ponds;

c) effluent from the unlined stages of the stormwater management ponds; and

d) at varying distances downgradient from the stormwater management ponds and the new landfill footprint.

Monitoring wells will also be located at varying distances from the northern edge of the new landfill footprint, and on the upgradient sides of the new landfill footprint. Selected monitoring wells on the existing landfill site currently used for groundwater quality monitoring will continue to be used.

Water samples from the primary and secondary leachate collection systems of the new landfill will be collected and analyzed for the same suite of parameters as the groundwater samples. This will allow for comparison of water quality between the new landfill, the existing closed landfill and groundwater in the vicinity of the two footprints. This information will be used to verify the source of any observed impacts to groundwater quality.

Details of the groundwater monitoring program, including specific sampling locations, physical/chemical parameters, and sampling frequencies, as well as trigger/compliance locations and parameter concentrations, will be developed as part of the Environmental Management Plan (EMP) for the proposed undertaking.

Groundwater monitoring results will be submitted to MOE for review in an annual report for the WCEC landfill facility.

8.1.2 Development of an Environmental Management Plan

An Environmental Management Plan (EMP) will be prepared following approval of the undertaking by the Minister of the Environment and prior to construction. The EMP will include a description of the proposed mitigation measures, commitments, and monitoring.

8.2 Commitments

The following commitments have been proposed for ensuring that the identified mitigation or compensation measures and monitoring requirements are carried out as part of the construction, operation, and maintenance of the undertaking:

a) An EMP for groundwater flow and quality monitoring will be developed as part of the application for approval under the *Environmental Protection Act* for the new WCEC landfill facility;

b) An implementation plan will be prepared for the design and construction of a purge well system (or other approved mitigation measure) in order to control leachate migration from the existing closed landfill site. The implementation plan will be prepared and submitted to MOE concurrent with the application for approval under the *Environmental Protection Act* for the new WCEC landfill facility; and

c) The existing purge well system on the closed landfill site will continue to be operated, maintained and monitored to ensure that groundwater quality impacts from former operations remain within the boundaries of the CAZs. The purge well system will continue to be operated until such time as it can be demonstrated that the system is no longer required in order to maintain groundwater impacts within the CAZs.

9. Hydrogeology Approvals Required for the Undertaking

The following approvals are required for hydrogeology-related components for the proposed undertaking:

a) Approval of an EMP: will be developed as part of an application for approval under Section 27 of the *Environmental Protection Act* for the new WCEC landfill facility, and would be implemented through the terms and conditions of an Environmental Compliance Approval (ECA).

b) Permit to Take Water (Section 34 of the *Ontario Water Resources Act*): An amendment to the existing Permit to Take Water (PTTW) for the current landfill site will be required in order to install and operate the new purge well system. The new wells would be specified as additional sources on the existing PTTW.

c) Industrial Sewage Works (Section 53 of the *Ontario Water Resources Act*): The discharge of effluent to the groundwater from the proposed stormwater management ponds will require approval under the *Ontario Water Resources Act*. The operations and monitoring requirements for the ponds would be specified in the terms and conditions of an ECA for the sewage works.

Report Prepared By:

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Senior Consulting Engineer

10. References

AECOM, 2011:

Ottawa Transfer and Processing Facility, Design & Operations Report. Prepared for Waste Management of Canada Corporation, dated June 2011.

AECOM, 2011:

Draft Facility Characteristics Report, West Carleton Environmental Centre, Landfill Footprint Expansion. Prepared for Waste Management of Canada Corporation, dated June 2011.

WESA Inc., 2011:

Existing Geology and Hydrogeology Conditions, West Carleton Environmental Centre, Ottawa, Ontario. Prepared for Waste Management of Canada Corporation, dated September 2011.

Appendix A

Groundwater Flow and Transport Modeling

INTRODUCTION

The finite-difference model 'MODFLOW-SURFACT ', based on the code, "MODFLOW", which was developed by the United States Geological Survey (USGS), was selected to simulate groundwater flow and mass transport. MODFLOW-SURFACT was selected because of its computational speed, stability and performance. This model is capable of simulating three-dimensional groundwater flow and mass transport in both steady and transient states with various degrees of complexity. Earthfx-ViewLog and Goldensoftware-Surfer were also used in conjunction with Groundwater Vistas (GV) as the pre and post processing tools. In development of the numerical model, multiple data sets were utilized across multiple iterations to combine the conceptual and numerical models. Some of the data used during the model's development are included below:

Referenced regional data:

- Regional topography from the Ontario Ministry of Natural Resources (OMNR);
- Ontario Base Map layers (including streams, lakes, wetlands, drainage lines, bedrock and surficial geology, etc.);
- Domestic well records from the Ontario provincial database, in particular lithologic information, water levels, and specific capacities contained therein;
- Hydrograph data available from the HYDAT monitoring network in the area; and
- Land use information derived from Landsat satellite imagery.

Site-specific data:

- Local survey data (including waste mound topography);
- Physical data, including hydraulic properties of overburden deposits and bedrock;
- Historical hydrograph data, water levels, and water quality data for leachate and groundwater;
- Borehole log data; and
- Purge well system data from within the Waste Management (WM) Ottawa landfill site (PW1 through PW10 and PW20)

MODEL BOUNDARY CONDITIONS

Model boundary conditions and site-specific influential aspects which represent the conceptual understanding of the geological and physical hydrogeological conditions of this site are provided below:

- The extent of the model domain was set to natural hydrogeologic boundaries (Figure 1): Carp River in the northeast and Carp River watershed/subwatershed boundaries were used to define other lateral model limits. Model extents were defined from a combination of topography (DEM), (Figure 2) and refined interpolated water level (WL) information from the MOE Water Well Information System (WWIS) (Figure 3):

- Constant heads were assigned along the Carp River in Layers 1 through 4 ;

- General Head Boundaries were used to represent inferred regional groundwater flow into and out of the model domain, and were assigned along the up-gradient boundary in the southwest in Layers 3 through 5 and to the down-gradient boundary, the Carp River in Layer 5 and;
- All other sides were specified as No-Flow Boundaries (regional groundwater divides).

Further boundary conditions were assigned according to the following rules for surface water and adjusted based on local settings:

- Streams and creeks represented based on Strahler class as Rivers (classes 3 and 4) or Drains (classes 1 and 2), Figure 4;
- Lined portion of the current landfill is represented as a River (allows control of conductance (very low) and stage (leachate head));
- Huntley Quarry: drains with low conductance; and
- Aggregate washwater ponds on quarry property northeast of the landfill represented as Rivers using surveyed water levels (the stage in these ponds is artificially maintained at a relatively constant elevation).

MODEL DISCRETIZATION

The total area of the active model domain is approximately 100 km^2. The model grid ranges from 100 m x 100 m at the periphery to 6.25 m x 6.25 m at the landfill site (Figure 5). Any cells outside of the model boundary were defined as no-flow. The horizontal discretization reflects the density and resolution of the data available (site data and MOE Water Well Records).

The vertical discretization is divided into 5 layers, as shown in Table 1. This layer configuration is based on the site conceptual model which includes geological and physical hydrogeological information.

MODEL CALIBRATION

Model calibration was completed by iteratively adjusting the modeling input parameters of: 1) Hydraulic conductivity of model layers, 2) Reliability factor (RF) of groundwater head levels at site wells (highly reliable) and MOE water wells (low reliability), and 3) Water levels in Carp River.

In order to evaluate adjustments to these parameters the differences between observed and modeled water levels were evaluated. These differences, known as residuals, are aggregated into calibration checks called the Root Mean Squared Error (RMSE) and Normalized Root Mean

Squared Error (NRMSE) (Equation 1 and Equation 2). The O_i and E_i represent the observed and evaluated values, respectively and O_{max} and O_{min} represent the observed maximum and observed minimum, respectively and the n represents the number of target values utilized.

Equation 1 $$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(O_i - E_i)^2}{n}}$$

Equation 2 $$NRMSE = \frac{\sqrt{\sum_{i=1}^{n} \frac{(O_i - E_i)^2}{n}}}{O_{max} - O_{min}}$$

The finalized model had a RMSE and NRMSE of 5.9 m and 7.9%, respectfully, which is acceptable as the NRMSE is less than 10%. Further evaluation of these error calculations reveals that if the residuals were adjusted by the RF, the RMSE and NRMSE reduces to 2.0 m and 2.8 %, respectfully. The scatter plot, Figure 6, presents the observed versus simulated groundwater levels, whereby the 45 degree line indicates a perfect fit. The wells indicated on this figure are segregated into four groups, MOE wells (RF=0.1), site wells (RF=1), site wells partially below model domain (RF=1), and non-pumping purge wells (RF=1). In conjunction with these calibration checks, mass balance checks of inputs and outputs (water entering and leaving the modeling domain) and comparisons to previously developed groundwater contours of the region were conducted to ensure model convergence is achieved within acceptable accuracy. The mass balance of the final calibration was calculated to be 0.5%, as shown in Table 2. The calibrated hydraulic parameters for all active zones are provided in Table 3.

GROUNDWATER FLOW MODELING RESULTS

Baseline Model (Existing Conditions)

The calibrated model simulating the groundwater contours in and around the current landfill site is shown in Figure 7. This figure indicates that general groundwater flow direction within the property limits of the WM landfill site is in a general north to northeast direction with a range of head values from 126 to 116 metres above sea level (mASL).

New Landfill Footprint Model

The incorporation of the new landfill design into the model was accomplished by applying recharge rates across determined hydrogeologically influential zones of the new design. These zones include the new landfill footprint and three stormwater pond footprints that are designed to discharge only to the groundwater. These footprints are plotted to the north of the current landfill as seen in Figure 8. The recharge rates of the new landfill change over time (termed transient) while the rates applied to the stormwater ponds are steady and are listed in Table 4. Figure 8 indicates that mounding of the groundwater table is being simulated in the vicinity of the new landfill and stormwater ponds. This mounding ranges from 1.26 to 3.23 across the three stormwater ponds, as provided in Table 5.

TRANSPORT MODELING RESULTS

Initial Transport Model Set-up and Calibration

The initial set-up for the purpose of calibrating the transport model to the observed conditions simulated mass entering the domain at the closed south cell and the existing landfill between the years 1975 and 2030. The simulation period was subdivided into a pre-current landfill period when only the closed south cell was contributing mass (1975-1999), and a landfilling/post-landfill period when both areas were contributing (1999-2030). The calibration model construction assumptions are described in Table 6. Mass was introduced as a concentration with the recharge rates applied at the landfill footprints.

The transport simulations were calibrated using potassium as the selected leachate indicator. Potassium was used because it is elevated in the leachate, it is found at relatively low concentrations in background groundwater, and there are no other significant sources in the study area. Chloride, which is often used as a parameter in groundwater modeling studies, was not used to calibrate the transport model in this case because of interferences from road salt contamination which would affect the results in the southern area of the landfill site. However, in areas away from the major arterial roads, such as the North Envelope, chloride is an appropriate parameter to use for modeling solute transport and to examine various development scenarios (e.g., future baseline, potential effects, net effects) since it has a Reasonable Use Limit (potassium does not) and is elevated in the leachate relative to background conditions.

Concentration profiles of potassium for the closed south cell and the current landfill that were used for calibration are provided in Figures 9 and 10. A set of sensitivity analyses were completed to examine the best fit with respect to simulated versus observed concentrations of potassium at the source and downgradient. Seven scenarios with a range of dispersivities were used in the analyses as summarized in Table 7. Based on these sensitivity analyses, it was determined that a model having longitudinal, transverse and vertical dispersivities of 20 m, 2 m, and 0.2m, respectively, was the optimal configuration.

Future Baseline Transport Modeling

Once it was calibrated to existing conditions, the groundwater transport model was used to project into simulation periods to the year 3004. These “future baseline” scenarios assumed existing conditions, with no development of the new landfill or stormwater management ponds. Chloride was used to predict the trends in concentration as the plume evolved. The concentration profiles for chloride for the closed south cell and the current landfill are summarized in Table 8 and on Figures 11 and 12, respectively. A progression of simulated concentration plumes were plotted for Model Layer 3 (contact zone bedrock) with contour plots and colour flooding for the years 2005, 2037, 2064, 2232 and 2434 (Figures 13 to 17). The extent of the simulated concentration plume on each of the figures is defined by a contour line having a concentration of 130 mg/L, which is the Reasonable Use Limit (RUL) for an aquifer with a median background concentration of 10 mg/L.

The results of the simulations as represented in Figures 13 to 17 indicate that a concentration plume exceeding the RUL could extend beyond WM property boundaries to the north and northeast, under future baseline conditions. The unlined portion of the current landfill is the major contributor to the predicted groundwater impacts. The maximum extent of the concentration plume was simulated to occur at approximately 2064; the extent of the plume at that date in each of the Model Layers (1 through 5) is shown on Figures 18 to 22, respectively.

Under future baseline conditions, the transport modeling scenarios suggest that groundwater impacts exceeding RUL could extend beyond WM's property boundaries. Consequently, possible mitigative measures were examined to determine an appropriate method of groundwater control. A mitigative measure that controls the extent of the simulated chloride plume is to install purge wells along the north side of the existing landfill. In the model, nine purge wells pumping from Model Layers 2 and 3 were simulated, each extracting 45 m^3/day of impacted groundwater. These wells run parallel to the north toe of the current landfill and are equally spaced 105 metres apart, as shown in Figure 23. The conceptual purge wells were included in the transport model under future baseline conditions, and the simulation results indicate that the concentration plume can be controlled. The resulting maximum extent of the simulated chloride concentration plume is contained within the WM property limits as shown Figures 24 to 28 which present Model Layers 1 through 5 in 2064, respectively.

Transport Modeling with New Landfill Footprint and Stormwater Ponds

Adding the new landfill expansion and stormwater ponds with transient concentration profiles was the next step in the modeling program. This allowed modeling of the potential effects from the proposed undertaking. The transient chloride concentration profile of contaminant flux through the G2 liner for the new landfill footprint was provided by AECOM and presented in the Facility Characteristics Report. Figure 29 shows the concentration profile of chloride through the G2 liner over time. The modeled concentration which fits this curve according to the applied timesteps is also plotted on Figure 29 and summarized in Table 8 (refer to Source 3 in Table 8).

The concentration profile for the stormwater ponds was determined through an iterative process which simulated the concentrations being held constant from 2014 to 2024 (i.e., during landfill operations), with a linear decrease in concentration for five years after closure to 2029. The maximum concentration that was simulated to be discharged from the stormwater ponds was 165 mg/L. At this maximum concentration, the extent of predicted groundwater impacts with concentrations greater than 130 mg/L remains within WM property boundaries. Based on these results, it is apparent that effluent concentration controls should be placed on the operation of the stormwater ponds to ensure groundwater quality is maintained within acceptable limits. The source concentration profile for the stormwater ponds is summarized in Table 8 and presented in

Figure 30. The maximum extent of the simulated chloride concentration created by the stormwater ponds is predicted to occur in 2024 (Figure 31).

The results of the potential effects modeling simulations are presented in Figures 32 to 36. These figures show the predicted maximum extent of chloride concentrations greater than 130 mg/L in Model Layers 1 through 5, in year 2064. The results indicate that the predicted groundwater mounding around the stormwater ponds would have the effect of re-orienting the concentration plume further northward relative to the future baseline conditions. The extent of the plume to the east is expected to diminish. The groundwater quality is predicted to be affected beyond the WM northern property boundary; consequently, mitigation measures would be required.

The final set of simulations involved the evaluation of mitigative measures to achieve acceptable net effects to groundwater quality. The net effects simulations include the existing and proposed new landfills, stormwater ponds and nine simulated pumping wells, as described above. Figures 37 to 41 show the extent of chloride concentrations greater than 130 mg/L in Model Layers 1 through 5, respectively, in year 2064 with mitigation measures in-place. The maximum extent of the chloride concentration plume is predicted to be contained within the WM property boundaries, indicating acceptable net effects.

Figures

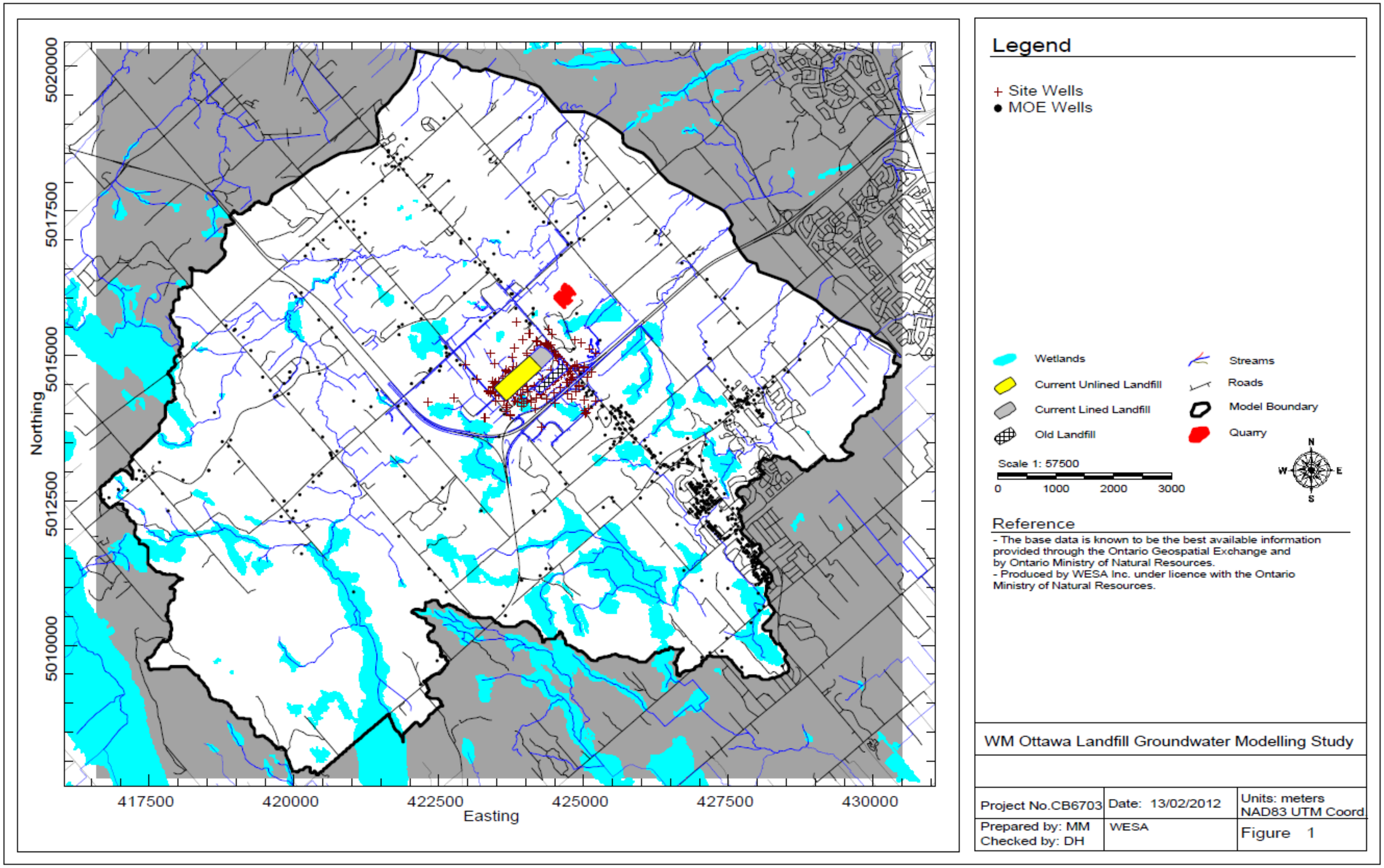

Figure 1: Extent of Groundwater Model Domain

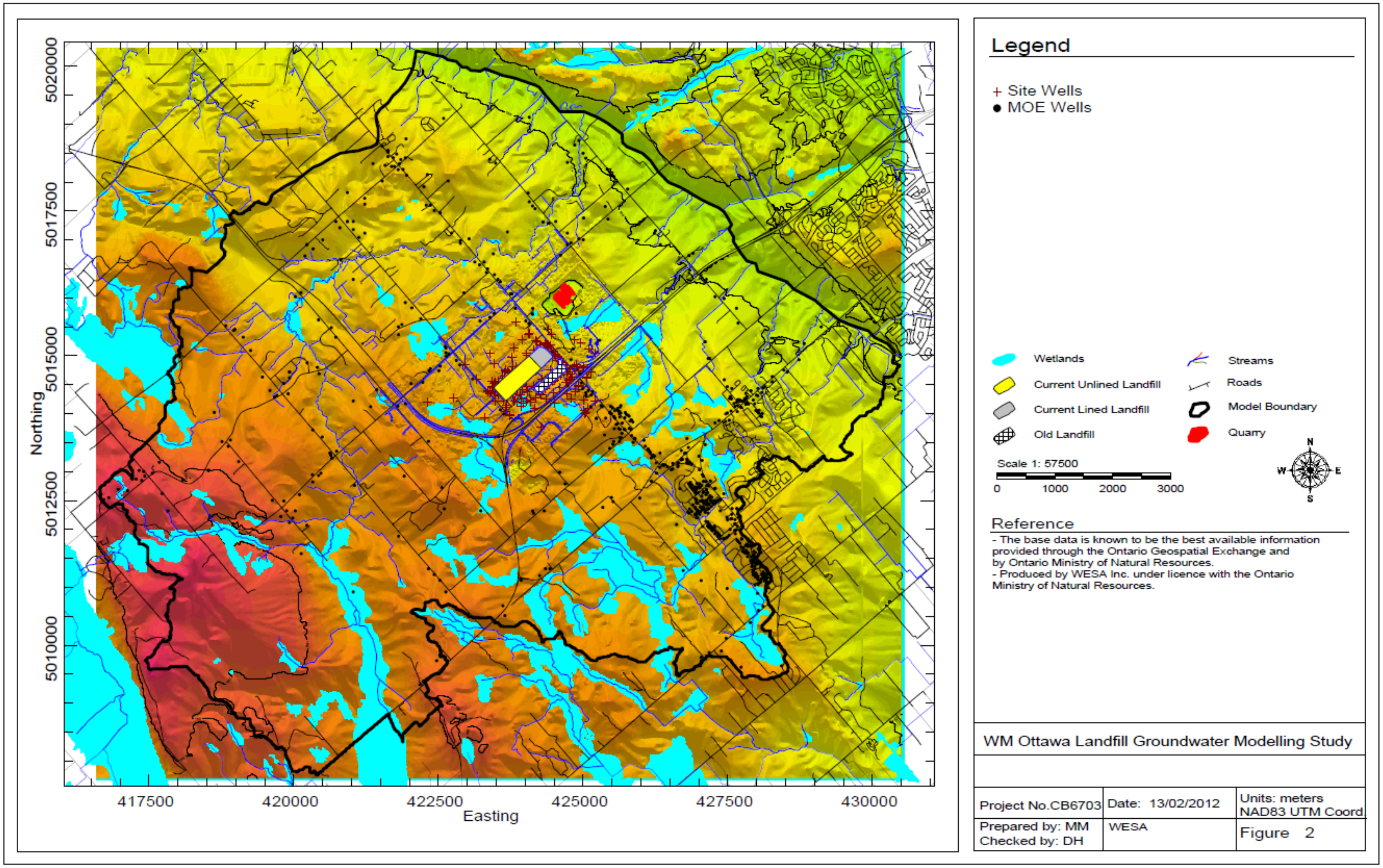

Figure 2: DEM Defining the Topography within the Groundwater Model Domain