FINAL REPORT

Hydrogeology Study for

Proposed Leslie Pit

7731 Fernbank Road, Ottawa, ON

Presented to:

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EXECUTIVE SUMMARY

Morrison Hershfield Limited (MH) was retained by Crains' to assess the hydrogeological impacts of a proposed Pit Above Water on the property at 7731 Fernbank Road, Ottawa, Ontario, in support of license application under the Aggregate Resource Act (ARA) and the a Zoning Amendment by the City of Ottawa.

Crains' previously applied for a Category 2 – Class "A" Quarry Below Water; and Category 3 – Class "A" Pit Above Water license at the property. A complete set of studies for supporting the pit and quarry development were done by McIntosh Perry Consulting Engineers Ltd (McIntosh Perry) including a comprehensive Level 1 and Level 2 Hydrogeological Study in 2016.

A site inspection and a water level monitoring event for the 20 monitoring wells onsite were conducted by MH staff on July 7, 2018. The water level measured varied from 131.77 to 137.32 mASL, and are generally consistent with McIntosh Perry data measured in 2004, 2013 and 2014. The measured water level suggested that there is no significant groundwater in the overburden unit, and the overburden is only wet during the spring. The upper weathered bedrock represents the shallowest aquifer, receiving infiltration through the overburden, feeding deeper regional aquifers, and also discharging at local surface water features.

The pit has been designed such that the established water table is at least 1.5 m below the bedrock surface in all areas of proposed extraction. As such, the proposed development is a "Pit Above Water" in accordance with the Ontario Provincial Standards. No groundwater will be encountered during extraction.

The extraction could potentially result in a slight, and localized lowering of shallow groundwater levels (limited to the site). Despite this, no impact on water quantity or quality in area water wells is expected. The impact of the pit extraction on the King's Park municipal wells are also negligible considering the distance and the depth of the municipal wells. Because of all these factors, neither groundwater level monitoring nor Permit to Take Water, nor well-related contingency plan are required. Existing monitoring wells can be decommissioned.

The water balance calculation results show the pit extraction will cause a reduction in infiltration, and commensurate increase in run-off. The change in water balance is not anticipated to have any impact on the Huntley Wetland during pit operation. The forest and vegetation at the west corner will serve as a natural retention area for storm water management and erosion control. In addition, the natural retention area will also encourage the infiltration and groundwater recharge.

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1. INTRODUCTION

Crains' Construction Limited (Crains') owns the property at 7731 Fernbank Road, Ottawa, Ontario. Crains' previously applied for a Category 2 – Class "A" Quarry Below Water; and Category 3 – Class "A" Pit Above Water license at the property, in accordance with the Aggregate Resources Act (ARA). A complete set of studies supporting the pit and quarry application were done by McIntosh Perry Consulting Engineers Ltd (McIntosh Perry).

Crains' is now only applying for a Category 3 Class "A" Pit (above water, >20,000 tonnes/year). Morrison Hershfield Limited (MH) was retained by Crains' to assess the hydrogeological impacts of this proposed development, and to support a Zoning Amendment along with the ARA License application.

1.1 Study Area

The subject site is located at 7731 Fernbank Road on part of Lot 11, Concession 10 of the Geographic Township of Goulbourn, in the City of Ottawa, Ontario. The site is bordered to the southeast by Fernbank Road, to the northwest by the Trans Canada Trail, and to the northeast and southeast by agriculture properties. The study area is approximately defined by the extents shown on Figure 1 in Appendix A. The study area includes the proposed pit extraction area, as well as the area surrounding the pit including the nearest water wells, wetlands, or other features potentially impacted by the project.

The subject property covers an area of approximately 72.9 hectares and is mainly covered by agricultural land with one on-site former residential dwelling (farm house). The site and the adjacent properties are located on Rural Countryside zoned land. There are several Provincially Significant Wetlands (PSWs) within approximately 1 km of the subject property boundaries. It is also noted that there are several active pits or quarries located within 2 km of the subject site.

1.2 Scope of Work

The scope of work is defined as a hydrogeology study to support the ARA application and City of Ottawa Zoning Amendment.

Regarding the ARA application, it is noted that the Ontario Provincial Standards for Category 3 Class "A" Pit applications do not require a technical report specifically on the topic of groundwater, however they do require the following to be included in the Summary Statement:

- Determine the elevation of the established groundwater table within the site or demonstrate that the final depth of extraction is at least 1.5 metres above the water table.

Regarding the City of Ottawa Zoning Amendment, Section 4.7.5 of the Official Plan sets out the possible need for a groundwater impact assessment "where the City has identified that the lands play a role in the management of the groundwater resource" or “where the proposed use has the potential to negatively impact the groundwater resource”. It is assumed that the City of Ottawa will require a groundwater impact assessment for the currently proposed development. The City “Guide to preparing studies and plans” sets out the requirements for “Groundwater Impact Study” and “Hydrogeological and Terrain Analysis” with reference mainly to MECP guidelines for lot servicing (water supply, ability to accommodate septic systems, etc.).

Considering the above, this hydrogeology study is carried out in accordance with applicable industry standard practices considering the objectives.

1.3 Contents of Report

This section of the report provides information on the context for the study, the scope of work and the layout of the report. Section 2 describes the methods used in the study. Section 3 describes the results including background information, the results of field investigations, and any calculations necessary for the impact assessment. Section 4 describes the assessment of the impacts of the project on all identified potential receptors. Section 5 presents a summary of the results and the potential impacts, describes any recommended monitoring, and contingency plans to be implemented in the event of certain occurrences. Section 6 provides closure notes and signatures of the report authors, and Section 7 presents the limitations and use of this report. References are provided in Section 8. Figures, tables, and supporting documents are provided in the appendices.

2. METHODS

This section describes the methods used in this study. Specifics to the project, including dates, specific data sources and specific details of the chosen methodology are included as part of the results.

2.1 Background Data Review

Background data review was conducted in accordance with industry standard practices using readily available information from federal, provincial, municipal and other sources of information.

The background review included analysis as necessary to develop an overall understanding of the hydrogeological setting and potential impacts of the pit development. In this case, the analysis included the tabulation and plotting of site-specific borehole information; tabulation and use of WWIS water well information to determine depths and available drawdown in area wells; plan view plotting of surface water features such as streams, rivers, lakes and wetlands to assess groundwater and surface water interaction; and plan view plotting of surficial and bedrock geology to determine the likely occurrence of surficial deposits as well as the occurrence and thickness of sedimentary bedrock.

2.2 Site Inspection

Site inspections were carried out primarily to observe geological and hydrogeological conditions on the subject property. During these inspections, the land was inspected for wells, structures, rock outcrops, rock faces including fractures, karst features, seepage, stratigraphy, topographic features, land cover, water courses, wetlands, etc. Photographs were taken of observed features.

2.3 Water Investigation

In hydrogeological studies, especially at a regional scale, it is necessary to understand the interaction of groundwater and surface water. This section describes methods used to assess this.

2.3.1 Groundwater Assessment

McIntosh Perry reported groundwater elevations measured in 2004 (presumably by a previous consultant) and by themselves in 2013 and 2014. To augment this data, a round of water level measurement was conducted by MH personnel for the monitoring wells onsite in July, 2018.

Seven (7) monitoring wells were sampled and analyzed for general chemistry, metals, and nutrients by McIntosh Perry in 2014 as part of the previous Hydrogeological study in support of the Quarry development. As the site condition remains the same as in 2014, and no change in groundwater quality is expected, no groundwater sample was collected and analyzed as part of this study.

2.3.2 Surface Water Inspection

Two surface water samples at the outlet of the site are collected and analyzed by McIntosh Perry in 2014 as part of the previous Hydrogeological. As the site condition remains the same since 2014, and no change in surface water quality is expected, no surface water samples were collected from water bodies in the study area.

The presence of surface water was noted, including observations of water clarity, flow rate, direction, depth, etc.

2.4 Water Balance Calculation

The water balance for the pit was determined on an annual basis, using the Thornthwaite and Mather (1957) water balance method where water surplus is estimated based on the relation between precipitation, evapotranspiration, surface run-off, and infiltration.

$$Water\ Surplus = P - ET = R + I$$

Where

P = Precipitation (mm/year)

ET = Evapotranspiration (mm/year)

R = Runoff (mm/year)

I = Infiltration (mm/year)

The inflow of water from precipitation, P, was estimated by multiplying an estimated catchment area by the average precipitation rate from years 1998 to 2018 from the Environment Canada historical weather data for Appleton station, which is approximately 10 km from the site.

The Potential Evapotranspiration (PET) estimation was obtained for each month, considering a month is 30 days long and there are 12 theoretical sunshine hours per day, applying the following euqation:

$$PET_i = 16 \times \left(\frac{10\bar{T}}{H_i}\right)^{\alpha}$$

where

$$\alpha = 0.49 + 0.0179 \times H_i - 0.0000771 \times H_i^2 + 0.000000675 \times H_i^3$$

where H_i is monthly heat index, calculated as:

$$H_i = \left(\frac{\bar{T}_i}{5}\right)^{1.514}$$

and where $\bar{T}_i$ is the monthly mean temperature. PET values are then multiplied by an adjustment factor (f), after Thornthwaite and Mather (1957), which represents the average number of daylight hours per month at the latitude of the subject property to give the Adjusted Potential Evapotranspiration (PET_{adj}).

The Actual Evapotranspiration (AET), for each month, is then calculated for different precipitation scenarios, as follows:

$$AET_i = \begin{cases} PET_{adj(i)} & if\ P_i - PET_{adj(i)} > 0 \\ P_i + |\Delta S| & if\ P_i - PET_{adj(i)} \leq 0 \end{cases}$$

where ΔS is the change in soil moisture storage for the month, calculated as,

$$\Delta S_i = S_i - S_{i-1} = S_{i-1} * \left(1 - e^{\frac{P_i - PET_{adj(i)}}{S_{mc}}}\right)$$

where S_i is the soil moisture storage for the first dry month *i* has P- PET_{adj} <0 and where S_{mc} is the soil moisture (soil holding capacity) depends on the combination of soil and vegetation (Thornthwaite and Mather, 1957).

Infiltration, I, contributing to the groundwater recharge, was determined by an infiltration factor multiply by the net water surplus in the catchment area. The infiltration factor varies by topography, soil type and land cover, and was provided by the Tier 1 Water Budget and Water Quantity Stress Assessment prepared by Mississippi-Rideau Source Protection Region (MRSPR). The MRSPR estimated the infiltration factor by modifying the Ontario Ministry of the Environment, Conservation and Parks (MECP) infiltration factor (SWM Planning and Design Manual, 2003) specifically for the Mississippi Rideau Region. The MRSPR infiltration factors for different topography, soil type and land cover are summarized in Appendix B Table 3. The reminder of the water surplus is surface run-off, R.

After pit extraction, the evapotranspiration rate from the bare rock surface with fractures and minor vegetation is estimated as the 10% of the original evapotranspiration rate. The net water surplus will be altered due to the reduced evapotranspiration rate. In addition, the infiltration factor will also reduce due to the change in soil type and land cover from pervious overburden material to impervious or semi-impervious bedrock.

Considering all of the above, calculations were made on pre-development, post-extraction, and post-rehabilitation conditions.

2.5 Impact Assessment

Groundwater impacts are generally assessed based on calculated or estimated drawdown of the water table/potentiometric surface, and on calculated or estimated changes in volumetric flow (such as loss of base flow to local streams). The impact assessment is made by considering the impacts of these project-induced calculated or estimated hydrogeological effects on the following potential receptors:

- Wells and Aquifers;
- Surface water;
- Huntley Wetland.

All receptors identified within the study area based on a background data review and site visits.

3. RESULTS

3.1 Background Data Review

The following is a non-exhaustive list of key data sources identified in the background data review:

- Rideau Valley Conservation Authority Reports;
- MECP Water Well Information System (WWIS, 2012);
- Geology Ontario (maps published by the Ontario Geological Survey);
- Google Earth (for quick reference topographic and land use information).
- Hydrogeology Level 1 & 2 Study, McIntosh Perry, 2015
- Hydrogeological Investigation and Modelling Study, Geofirma, 2015
- Water Balance Memo, McIntosh Perry, 2016
- Geotechnical Investigation Memo, McIntosh Perry, 2016
- Water-related objections raised to the previous pit and quarry development proposal.

3.1.1 Geology

Review of the provincial surficial geology mapping (Surficial Geology of Southern Ontario) indicates approximately half of the property area is mapped as “Paleozoic bedrock” with no overburden and the other half of the area is coarse-textured glaciomarine deposits of sand, gravel, minor silt and clay with beach ridges and near shore bars.

An aggregate gradation analysis was completed for the subject property on August 27, 2003 by Morey Houle Chevrier Engineering Ltd. (now GEMTEC Consulting Engineers and Scientists Limited). Based on the results of the analysis, an average of 3.1% of the sample was passed through a 0.075 mm sieve, and 100% of the sample passed through a 150 mm sieve. This defines the aggregate as ‘Granular B Type I’ (Houle Chevrier, 2003). Boreholes were put down by Golder Associates Ltd. in 2004, showing that the subject site is dominated by sand and gravel deposits up to 3.4 m below ground surface (bgs), with some areas of silt (Golder Associates, 2004). Test pits dug by McIntosh Perry support Golder Associates’ 2004 findings, in that loose rock, gravel, and shallow bedrock were identified within the first 1-2 m of overburden at the site It is estimated that 1.3 million m^3 of overburden material exists on site. (McIntosh Perry, 2016).

The bedrock in this area is mapped as the Gull River Formation of Middle Ordovician age. The upper member of the Gull River Formation consists of finely crystalline limestone with shaly partings and the lower member is described as interbedded limestone and silty dolostone with shaly partings

(Williams, 1991). The borehole logs of the monitoring wells drilled in 2013 by Geofirma identified a thin layer of overburden followed by alternating layers of limestone and dolostone up to 35.05 mBGS.

3.1.2 Hydrogeology

For the regional hydrogeology, a comprehensive Watershed Characterization report was completed by the Mississippi-Rideau Source Protection Region (MRSPR, 2008) as part of the requirements for the Source Water Protection initiative through the Province of Ontario and the Clean Water Act. At the study area, the underlying Nepean, March and Oxford formations are considered primary aquifers that supplying adequate groundwater for domestic use. The Gull River formation located above the primary aquifer is considered marginally adequate for domestic consumption.

An upper bedrock aquifer has been identified in the region. This aquifer is not dependent on the lithology of the rock, but it is highly weathered and has a well-developed fracture network that permits a relatively uniform flow pathway. This aquifer is considered to be a domestic supply aquifer based on the typical elevation of domestic water wells in the area.

For the site, McIntosh Perry, 2016 and Geofirma, 2015 indicated that the upper part of the bedrock was weathered, with a measured hydraulic conductivity of 1.4×10^{-5} m/s. The hydraulic conductivity was shown to decrease with depth, be highly variable based on the limited occurrence of factures.

The proposed pit extraction area lies within the Richmond King's Park Wellhead Protection Area (WHPA), where there are two municipal wells supplying drinking water to 520 people in the King's Park subdivision (City of Ottawa, Source Water Protection). The property is within the 25-year capture zone (WHPA-D area), and the provincial vulnerability score for the area is 2. It is further understood that a new municipal well is to be brought into service in the Village of Richmond, and the associated vulnerability scoring would be affected for this area. The two municipal wells are installed at depths of 61 m and 66 m in the Nepean formation aquifer.

Part of the proposed pit extraction area is mapped as a Significant Groundwater Recharge Area (SGRA), where a relatively large percentage of water recharges from the ground surface to an aquifer. Additionally, the property is also mapped as a Highly Vulnerability Area (HVA), which means the aquifer is susceptible to contamination from sources at the surface.

3.1.3 Physiography and Topography

The site is located within Ottawa-St. Lawrence lowland basin in the physiographic region referred to as the Smiths Falls Limestone Plain, which is surrounded to north and east by the Ottawa Valley Clay Plains (Chapman and Putnam, 1984). The Smiths Falls Plain is characterized by shallow soil cover overlying limestone or dolostone bedrock. Topographic relief is minimal, resulting in relatively poor drainage and abundant wetland areas (Geofirma, 2015).

A survey of the site was completed by McIntosh Perry. The local high point (146 mASL) of the site is located in the northeast area part of the property, close to the eastern boundary. The northwest two-thirds of the property generally slopes to the west, and the lowest point is on the west corner of the property at 133 mASL. The southeast one-third of the property slopes to the south towards a topographic elevation of 139 mASL.

3.1.4 Drainage and Surface Water (Hydrology)

The site is located within the Jock River sub-watershed, which lies within the larger Rideau River watershed. The surface runoff from the northwest two-thirds of the site is captured by the Jenkinson Drain catchment area, while the southeast one third of the site is captured by the Hobbs Drain catchment area. North of the drainage boundary of the two catchment areas, the surface runoff flows west into the drainage ditch along the west property boundary, where the water drains towards the west corner of the property and then, exiting the site, flows south to the Jock River via an unnamed tributary. South of the drainage boundary, the surface runoff drains to the south and offsite, and ultimately drained to Hobbs Drain. The drainage ditch along the west property boundary has been observed to be intermittent and tied closely to precipitation evets (Geofirma, 2013).

3.1.5 Water Well Information Record Review

McIntosh Perry conduced a water well record review as part of the hydrogeology study. A search of the MECP well record database was requested, and 19 well records were found within 500 m of the subject property. The depths of the wells ranging from 7 m to 86 mBGS. All wells were completed in bedrock, which was encountered approximately 0 m to 11 m mBGS (McIntosh Perry, 2016). The closest domestic well and the rural subdivision Heritage Corners are located more than 350 m on the east from the proposed extraction area, and are not within the 300 m of zone of influence, traditionally considered by in zoning applications.

3.2 Site Visit and Water Investigations

3.2.1 Site Reconnaissance

A site inspection was conducted by MH staff on July 7, 2018.

The site is currently covered by agriculture land, open field, small forest areas and a two-storey residential dwelling with two sheds. An area of scrap metal and debris was observed surrounding the dwelling.

An estimated two hectare area of exposed bedrock was observed on the east portion of the property. The estimated area is based on the Google Earth Satellite Image and the site inspection observation. The eastern area of the property is dominated by thin soils and coniferous growth. The northwest portion of the property was observed as an open field with shrubs and trees. A large man-made berm extends the southwest property line.

3.2.2 Groundwater Assessment

A total of 20 monitoring wells were identified on site. Three monitoring wells, TW03-1, TW03-2 and TW-03-3, were installed as multi-level piezometers by Geofirma in 2013 and 2014. Water levels were measured in each monitoring well during the site visit on July 7, 2018. The measured water levels with surveyed ground surface elevation, casing top elevation and measured well depth are shown in Appendix B Table 1. The measured water levels varied from 131.77 to 137.32 mASL, and were are generally consistent with previous water levels measured in 2004, 2013 and 2014. The water levels were approximately one metre lower than in previous years, with the exceptions of TW13-2A and TW13-2B. The water levels measured in the both of these deep screens were higher, by approximately five metres, than those measured in spring 2014. This difference results is re-interpretation of the flow directions from the previous assessment, and is the key indicator that the deeper groundwater in the bedrock is below an aquitards and regional in nature.

According to the measured well depths of BH-04-3 and BH-04-5, these two wells are likely installed in the overburden. These were dry or near dry during the 2018 water level monitoring event, and had been found wet only in spring in the monitoring events in previous years.

Separate groundwater piezometric contours are interpreted for the shallow weathered bedrock above and the deeper bedrock below a bedrock aquitard, respectively. The groundwater levels and the piezometric contours are shown in Figure 2 and Figure 3 in Appendix A. Groundwater in the shallow weathered bedrock flows towards the northwest and the southeast, with a divide similar to the topographic divide. This is indicative of an unconfined aquifer. Groundwater in the deeper bedrock flows towards the south, which is consistent with the regional topographic trend, and the direction of groundwater flow inferred from previous particle tracking for the delineation of wellhead protection areas. This is indicative of a confined aquifer, lying below an aquitard. The piezometric surface in shallow weathered bedrock may intersect the top of rock in a few isolated areas, indicating that some groundwater may be present in the parts of the overburden occupying bedrock lows. The piezometric surface in the deeper bedrock is well below the bedrock surface. Together, the groundwater level indicates that the site is a groundwater recharge area.

According to the Ontario Provincial Standards, a Category 3 Class A Pit Above Water should have the final depth of extraction at least 1.5 meters above the established groundwater table. The established groundwater table is defined as top of the saturated zone for unconsolidated surficial deposits. For confined water bearing zones or consolidated bedrock materials, the established groundwater table is defined as the fluid pressure in the water bearing zone and is generally defined by the level to which water will rise in a well.

The overburden sandy deposit at the site was found generally dry with minor wet areas in the spring. Therefore, there is no established groundwater table within the overburden unit.

Although separate groundwater piezometric contours are interpreted for the bedrock above (shallow) and below (deep) the bedrock aquitard, the simplest definition for the purpose of assessing the “established groundwater table” is the water level measured in open hole TW13-04. This water level was approximately 9.5 m below the top of the casing, approximately 8.0 m below the top of the bedrock, and approximately 133.7 mASL, in the center of the site. By this definition, the bottom of the pit, being the top of rock, is well above the established groundwater table. However, at the western corner of the site, the water table in the bedrock is at the approximately the same elevation and is level with the top of the bedrock. To ensure that the bottom of the pit remains 1.5 m above the water table, the extraction area is set back from the western corner. The forest and vegetation at the western corner will function as a natural retention area for storm water management.

3.2.3 Surface Water Inspection

The drainage ditch running parallel to the northwest property boundary has been observed to be ephemeral and closely correlated with precipitation. The ditch was observed either dry or stagnant at many times according to the hydrogeology report prepared by McIntosh Perry, 2016. During the site visit on July 7, 2018, most of the drainage ditch was dry. Additionally, bedrock was noted to be exposed on the southernmost stretches of the streambed.

3.3 Water Balance Calculations

Based on the background information reviewed and the observations obtained from the site inspection, the central portion of the proposed extraction area consists of agriculture land, with an area of exposed bedrock at the southeast area, and an area of forest at the north end of the property. Areas of cultural meadow and mixed woodland exist at the northeast corner. These forest areas will remain outside the extraction area and will be preserved. Thus, they are not included in the calculation

The total proposed extraction area is approximately 38.5 hectares. Berms and rock topography will ensure that all of this area will drain towards the western corner of the extraction area, whereas in the existing condition a small portion(less than five percent) of it drains towards the east. This change in the boundary of on-site drainage basins is considered insignificant in terms of the impact assessment, and is ignored in the following water balance calculations.

The agriculture land, culture meadow and woodland make up the most part of the proposed extraction area, and are considered as pervious. The pervious area will become, for the most part, impervious after the pit extraction, when the overburden is removed and the upper bedrock is exposed. Although the rehabilitation (at a minimum, the spreading of topsoil) will likely be concurrent with the extraction, to be conservative, the calculations assume that the entire extracted area will be impervious.

Based on the historic climate data from Environment Canada for Appleton Station for years 1998 to 2018, the average annual precipitation for the site is estimated to be approximately 880 mm/year. The actual evapotranspiration (AET) rates for site specific soil and vegetation types were calculated based on the method described in section 2.4. The annual evapotranspiration rate for the impervious area (bare bedrock surface) is estimated as 10% of the original evapotranspiration rate, 60 mm/year.

A summary of the calculations are presented in Appendix B Table 2.

3.3.1 Pre-Development Water Balance Calculation

The pre-development water balance calculation is based on conditions as they were observed in 2018.

Based on the site inspection, Google Earth image and the previous Level 1 & 2 Natural Environmental Report, the extraction area was divided into four (4) catchment areas: agriculture land (pervious, 20.8 ha), cultural meadow area (pervious, 15 ha), woodland (pervious, 0.9 ha), and exposed bedrock (impervious, 1.8 ha). According to the surveyed topography contours and site operation plan and cross sections prepared by McIntosh Perry, 2016, the slope across the site ranges from 1.5% to 3%, and, as such, the topographic infiltration rate was assigned as 0.12. The overburden on site is characterized by coarse-textured glaciomarine consists of sand, gravel, minor silt and clay, and the soil type infiltration factor was considered as 0.2 for variable till. A value of 0.1 was used for the land cover infiltration for the areas of agriculture, and cultural meadow and woodland land cover.

The total estimated infiltration amount contributing to the groundwater recharge on the site was 52,000 m^3/year and the total runoff amount was estimated at 82,000 m^3/year for a total net water surplus of 134,000 m^3/year.

A break-down of the pre-development calculation is provided in Table 4a, Appendix B.

3.3.2 Post-Extraction Water Balance Calculation

The post-extraction water balance calculation was based on the theoretical point following extraction of all sand and gravel deposits from the 38.5 ha extraction area, prior to the placement of any rehabilitation materials. In fact, both extraction and rehabilitation will take place in phases, and no more than half of the extraction area will be bare rock at any given time. However, the calculation was carried out this way for a conservative estimate of impacts.

After the pit extraction complete, the entire extraction area was considered as an impervious area, and the evapotranspiration rate of 60 mm/year was used for the whole site to calculate the net water surplus. The net water surplus increased to 316,000 m^3/year due to a smaller evapotranspiration rate from bare rock surface. The site will consist of exposed bedrock during and after the extraction. The slope of the bedrock surface will continue to be between 1.5% and 3%, and therefore the topographic infiltration factor remained unchanged at 0.12. For the exposed bedrock after the pit extraction, a value of 0.02 was assigned for the soil type infiltration factor and 0 was assigned for the land cover infiltration factor prior to rehabilitation. The new infiltration factor was 0.14 under the post-development condition.

The total infiltration amount was estimated at 44,000 m^3/year and the total runoff amount was estimated at 272,000 m^3/year for the post-development. In comparison with the pre-development, the infiltration amount is reduced by 15% and the runoff is increased by 232% due to the pit extraction. The small reduction in infiltration and large increase in runoff are both partly explained by the increase in available water caused by the decrease in ET due to the lack of vegetation on the bare rock surface. The small reduction in infiltration may understate the actual decrease, due to a lack of the equations to accurately capture the sensitivity of the infiltration rate to changes in ground cover (from soil to bare rock). However, considering that the assumptions are conservative in assuming that rehabilitation will not commence until all the overburden has been removed, this lack of precision in the calculations in considered acceptable.

A break-down of the pre-development calculation is provided in Table 4b, Appendix B.

3.3.3 Post-Rehabilitation Water Balance Calculation

The post-rehabilitation water balance calculation was based on the point in time when the entire extraction area has been rehabilitated by spreading of topsoil and planting of crops. In this situation, the entire site is considered as a pervious area. The topography of the rehabilitated agriculture land was assumed to be the same, and a value of 0.12 was used for the topographic infiltration factor. The final rehabilitated land will be covered with topsoil and crops, so a value of 0.15 was assigned to soil type factor and 0.1 was assigned to land cover infiltration factor. The site will have an infiltration factor of 0.37.

The total infiltration amount was estimated at 49,000 m^3/year and the total runoff amount was estimated at 83,000 m^3/year for the rehabilitated agriculture land. This is a 6% infiltration reduction compare to the pre-development conditions, and an increase in runoff of approximately 1%.

A break-down of the pre-development calculation is provided in Table 4c, Appendix B.

The changes of net water surplus, infiltration and runoff for pre-, post- development and post-rehabilitation are summarized in Table 4d, Appendix B.

3.3.4 Huntley Wetland

The vegetation communities of Huntley wetland are surveyed by Golder as part of their Environmental Impact Statement for an ARA license application for the proposed Henderson II Quarry in 2013. According to the wetland survey, the Huntley wetland is dominated by swamp (75%), and the swamp vegetation community is mainly consist of shrubs and deciduous and coniferous trees. These types of vegetation are not sensitive to change in the water table.

Based on the catchment area data gathered from MNRF for Huntley wetland, the wetland has a total catchment area of approximately 2,488 ha. The proposed pit extraction area lies within the south part of the catchment area which drains to the Jock River. The south catchment area has an approximate area of 531 ha, and the site encompasses approximately 35.2 ha (91% of the extraction area) of this catchment area.

A water budget was calculated for the Huntley south catchment area. Based on the Google Earth image, geographic data from MNRF, and surficial geology of the south catchment area, the area generally consists of 4 different land uses and land covers: wooded/wetland area with organic deposits (40%), wooded area with thin soil underlain by Paleozoic bedrock (35%), residential/urban/aggregate land use (15%), and agriculture land with glacial till deposit (10%).

The calculated net surplus for the Huntley Wetland south catchment area is 2,078,000 m^3/year with the infiltration flow of 864,000 m^3/year and runoff of 1,214,000 m^3/year. The infiltration loss due to the pit development was calculated as 8,000 m^3/year which is 0.4% of the net water surplus of the south catchment area. The detailed water budget calculation for the south catchment area of the Huntley Wetland is shown in Appendix B-Table 5.

It is noted that the water balance calculations for the pit operations do not consider that fact that some of the run-off from the pit will actually become groundwater recharge at, or off the property boundary. This will be especially so as the west corner of the site will be retained a natural retention area..

4. IMPACT ASSESSMENT

4.1 Impact on Groundwater and Source Water

Post-Development

The water balance calculation results show about 14% infiltration reduction resulting from the pit extraction. The post-development infiltration reduction could potentially result in a slight, and localized (i.e., restricted to the site only) lowering of shallow groundwater levels. It is not anticipated to have an adverse effects on groundwater levels in the watershed, and specifically in relation to the designation as a Significant Recharge Area (SGRA), and specifically at the closest water wells in the subdivision, approximately 350 m to the south. All precipitation that falls within the watershed will remain within the watershed post-development and ultimately into either the Hobbs or Jenkinson Drains.

The closest domestic wells to the proposed extraction, being for the farm and Heritage Corners rural subdivision, are approximately 350 m from the property proposed to be licensed as a pit. Since the pit extraction will be terminate at least 1.5 m above the water table and since no dewatering or associated groundwater drawdown is expected, no impact on the water quantity in these wells is anticipated. Similarly, no impact is anticipated on the groundwater availability in the two King's Park municipal wells located 13 km from the site and completed in the deep Nepean Aquifer.

None of the proposed activities Pit activities are listed in "Table 2 Potentially Contaminating Activities" of Ontario Regulation 153/04. Generally, the probability of a significant contamination event at the pit is low, and will be mitigated by the spill management practices of the operator. As such, the potential for impact to the quality of the groundwater in the local and regional aquifer is considered low.

Post-Rehabilitation

The hydrogeological conditions of the site will be returned to the predevelopment conditions, as such there will be no impacts on the groundwater and source water in in this region.

4.2 Impact on Surface Water

The impact of the pit development on surface water will be to change the on-site drainage boundary slightly, and increase the size of the hydrograph peaks at the western corner of the site. This impact will be addressed by the natural retention area in the western corner. The natural retention area will reduce the size of the hydrograph peaks, will encourage groundwater recharge, and will retain sediment carried across the pit floor by surface runoff. No significant impact on surface water is anticipated.

4.3 Impact on Huntley Wetland

The Huntley wetland is located northwest of the proposed pit extraction area. The subject property is bound by significant agricultural land to the southwest and northeast, which provides a natural setback from the Huntley wetland of at least 230 m at the closest point. The slight localized lowering in the groundwater level result from the pit development is expected to be contained within the site, and have no impact on the Huntley wetland. Similarly, the temporary (during pit operation) change in water balance, with higher runoff and lower groundwater recharge, is not expected to have any impact on the Huntley Wetland.

In conclusion, and based on calculations, the impact of the loss of infiltration and the increased runoff due to the pit development on the Huntley wetland will be negligible.

5. ENVIRONMENTAL PROTECTION / MITIGATION

5.1 Summary of the Results and Impact Assessment

The extraction area has been chosen such that the established water table measured is deeper than 1.5 m below the bedrock surface (i.e. the proposed pit bottom), and therefore the proposed development is a “Pit Above Water” in accordance with the Ontario Provincial Standards. No groundwater will be encountered during extraction.

The water balance calculation results show the pit extraction will cause up to an approximately 6% reduction in infiltration, with commensurate increase in run-off. This could potentially result in a slight, and localized lowering of shallow groundwater levels (limited to the site). No impact on water quantity or quality in area water wells is expected as a result of the pit development. The impact of the pit extraction on the King’s Park municipal wells are also negligible considering the distance and the depth of the municipal wells.

The change in water balance is not anticipated to have any impact on the Huntley Wetland during pit operation.

Following rehabilitation as agricultural land, there will similarly be no impact on aquifers, wells, surface water, or the Huntley Wetland.

5.2 Recommended Mitigation Measures

Monitoring wells must be maintained in good condition, and, unless they are to be decommissioned, used for their intended purpose. Since no monitoring of groundwater levels is required for the safe operation of the pit, these wells may be decommissioned in accordance with O. Reg. 903.

This assessment identified an increased surface water runoff by 232% under the full extent of pit extraction condition. The surface water runoff of the site would flow to the west corner of the property. The natural retention area at the western corner will be used for storm water management and sediment and erosion control, and is an appropriate mitigation measure.

5.3 Recommended Monitoring Plan

Considering that the proposed development is a pit above the water table, no monitoring of groundwater or surface water is warranted. The regulatory monitoring of the site by MNRF and/or MECP is considered sufficient protection for surface and groundwater resources.

5.4 Recommended Contingency Plan

The impact assessment found that it is highly unlikely that the key receptors (groundwater, water supply wells, surface water and Huntley wetland) will be negatively impacted by the pit development. No contingency plans are needed.

5.5 Permits and Approvals

This assessment has found that no groundwater taking will be required for the safe operation of the pit. As such, no Permit to Take Water is required under Ontario Water Resources Act, Section 34 – 34, 11 and Ontario Regulation 387/04 (Water Taking and Transfer). While no such activities are currently planned, any future taking of more than 50,000 L/day at the site (for aggregate washing, for example), will require such a permit.

The storm water will be drained towards the western corner, and the forest and vegetation at the western corner will serve as a natural retention area for storm water management and erosion control. No sewage works is required for the storm water management and treatment. Therefore, an Environmental Compliance Approval (ECA) is not required.

6. CLOSURE

We trust the above meets with your current requirements. Should you have any comments, questions, or require additional information, please do not hesitate to contact the undersigned.

Respectfully submitted,
Morrison Hershfield Limited

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7. LIMITATIONS AND USE

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The report, which specifically includes all tables, figures and appendices is based on data and information collected during investigations conducted by Morrison Hershfield and is based solely on the conditions of the site at the time of the investigation, supplemented by historical information and data obtained by Morrison Hershfield as described in this report.

Morrison Hershfield has exercised professional judgment in collecting and analyzing the information and formulating recommendations based on the results of the study. The services performed as described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to this study. No other warranty or representation, either expressed or implied, as to the accuracy of the information or recommendations included or intended in this report.

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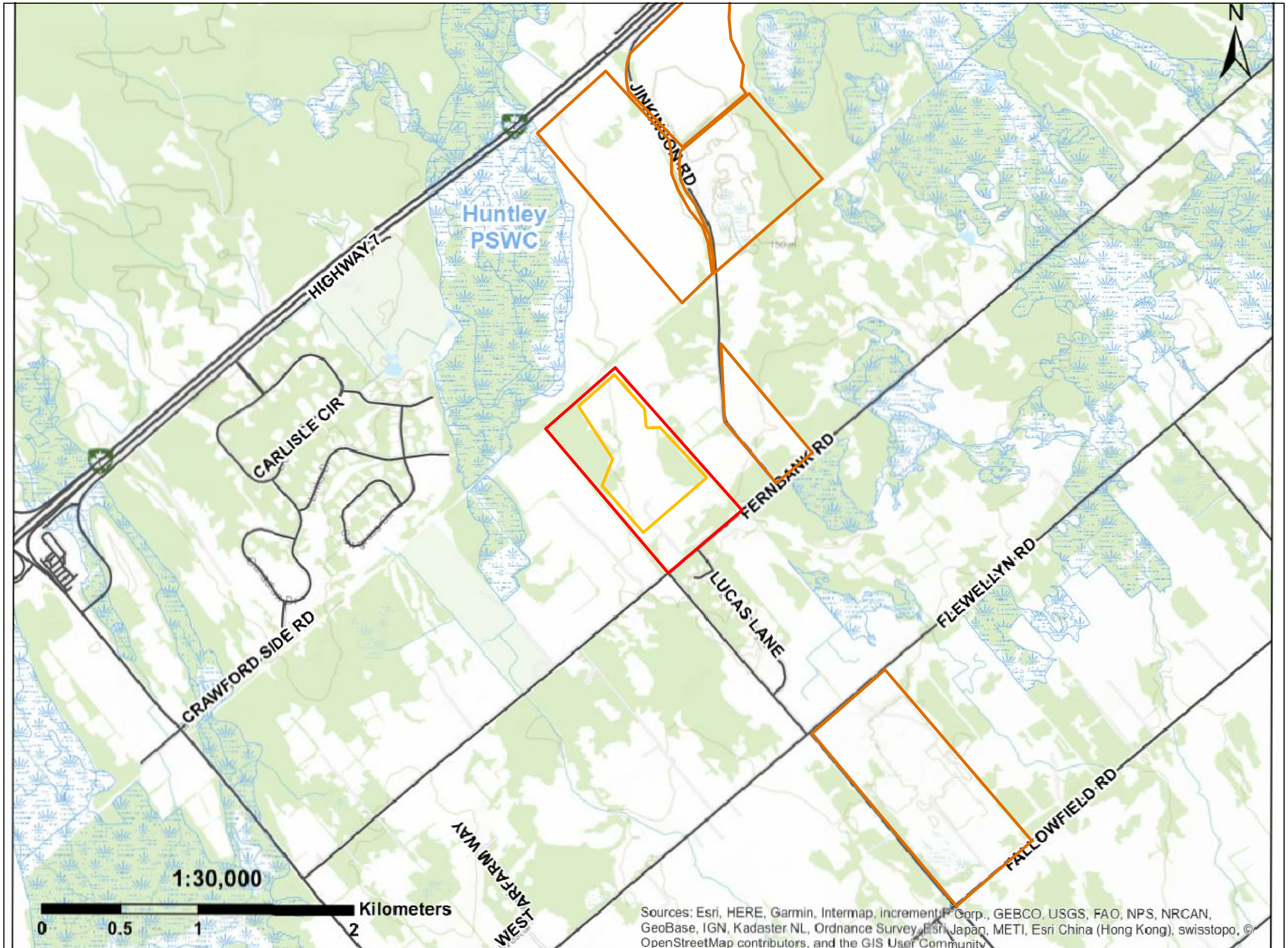
APPENDIX A: Figures



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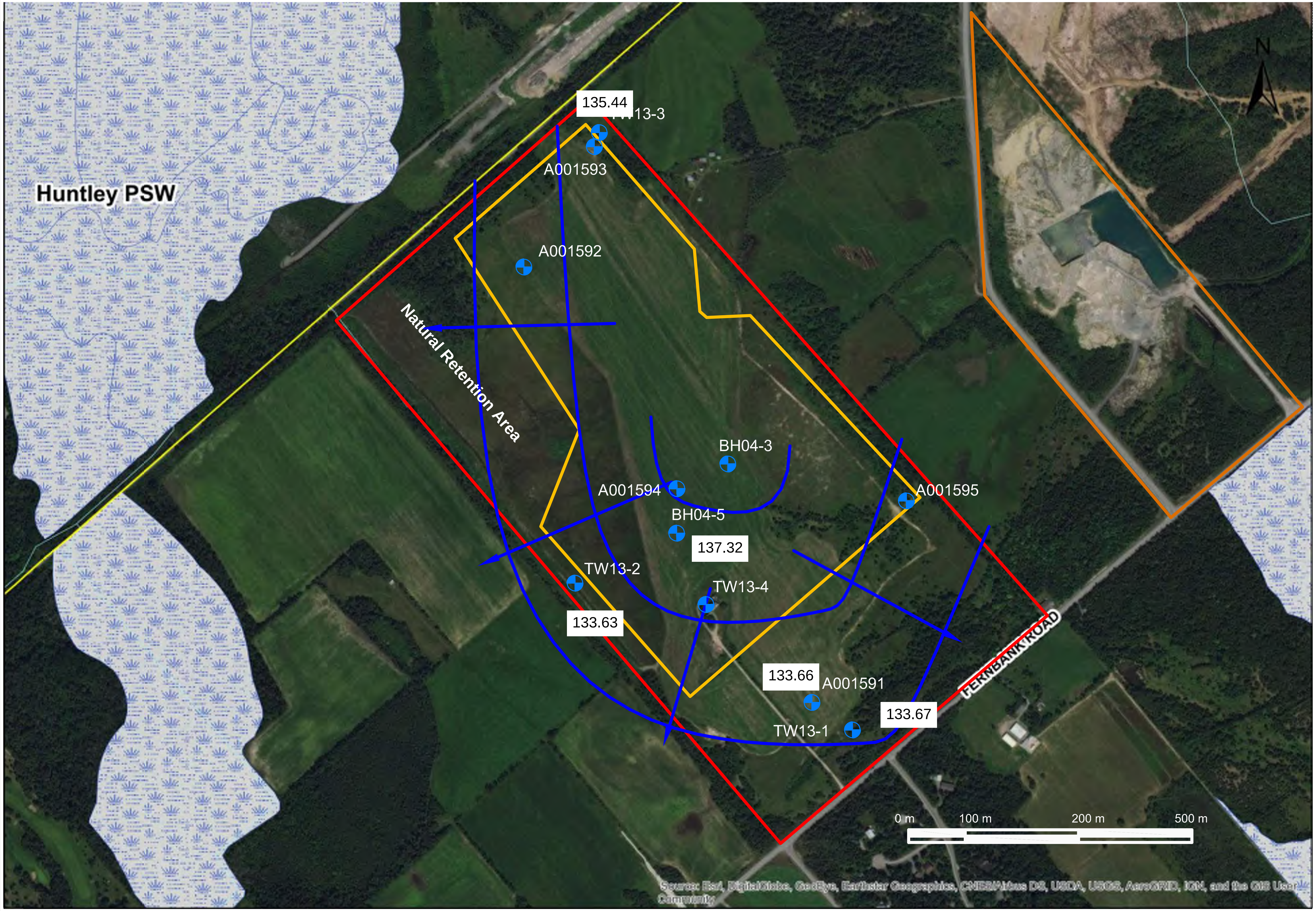
LEGEND

- Property Boundary
- Proposed Extraction Area
- Adjacent Quarry/Pit
- Provincial Significant Wetlands

NOTES

MORRISON HERSHFIELD

PROJECT:	Hydrogeology Study for Proposed Crains' Leslie Pit
PREPARED FOR:	Crains' Construction Ltd.
DESIGNED BY:	C.Z
DRAWN BY:	C.Z
CHECKED BY:	A.W
DATE:	1/3/2019
SCALE:	See Figure
PROJECT NO:	180379100
TITLE:	Location Plan- Hydrogeology Study for Proposed Crains' Leslie Pit
FIGURE NO:	1



LEGEND

- Property Boundary
- Proposed Extraction Area
- Monitoring Well
- Groundwater Equipotential Line
- Groundwater Flow Direction

NOTES

MORRISON HERSHFIELD

PROJECT:	Hydrogeology Study for Proposed Crains' Leslie Pit
PREPARED FOR:	Crains' CONSTRUCTION LTD.
DESIGNED BY:	C.Z
DRAWN BY:	C.Z
CHECKED BY:	A.W
DATE:	1/3/2019
SCALE:	See Figure
PROJECT NO:	180379100
TITLE:	Shallow Groundwater- Hydrogeology Study for Proposed Crains' Leslie Pit
FIGURE NO:	2

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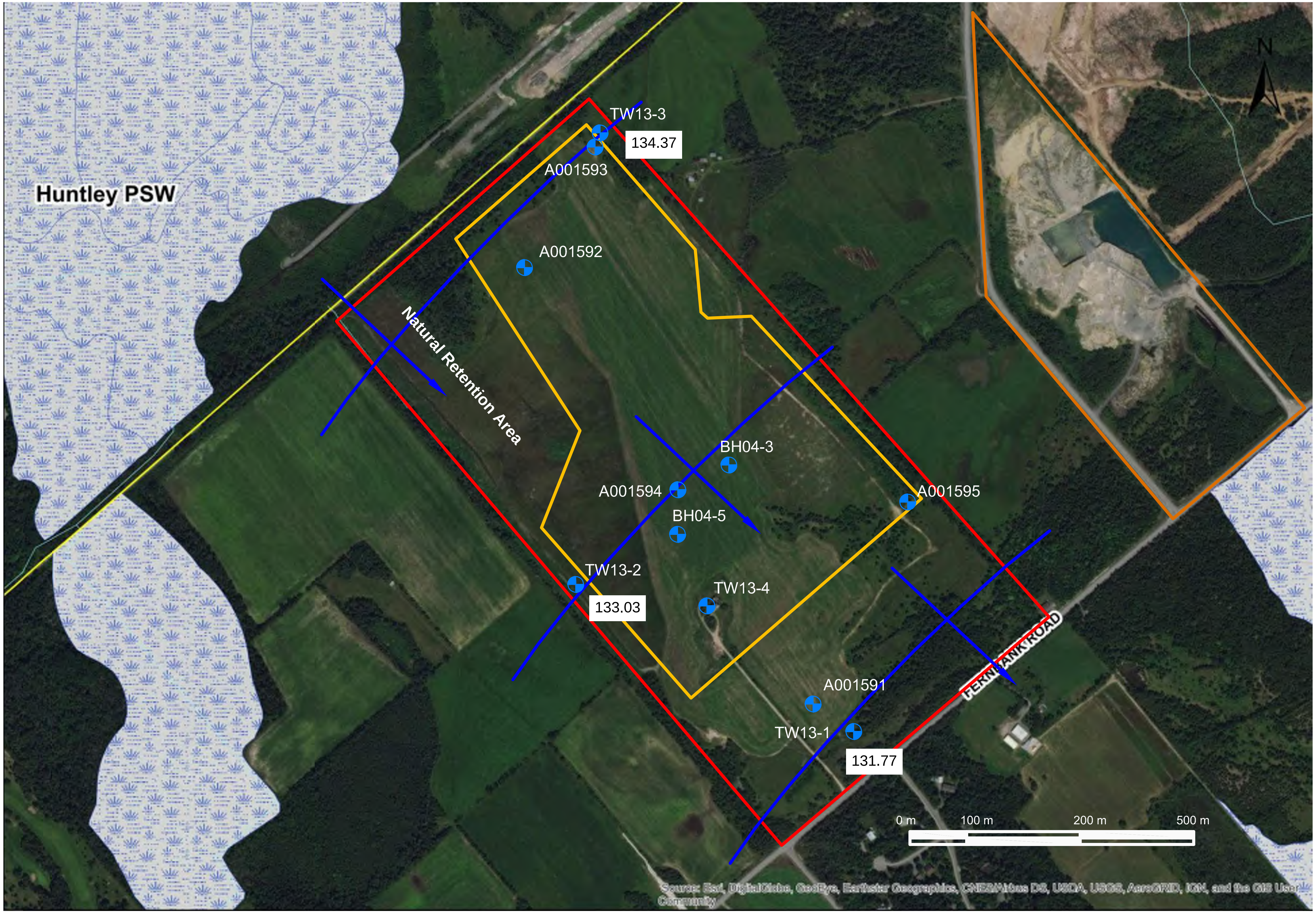

LEGEND

- Property Boundary
- Proposed Extraction Area
- Monitoring Well
- Groundwater Equipotential Line
- Groundwater Flow Direction

NOTES

MORRISON HERSHFIELD

PROJECT: Hydrogeology Study for Proposed Crains' Leslie Pit

PREPARED FOR: Crains' CONSTRUCTION LTD.

DESIGNED BY:	C.Z
DRAWN BY:	C.Z
CHECKED BY:	A.W
DATE:	1/3/2019
SCALE:	See Figure
PROJECT NO:	180379100

TITLE: Deep Groundwater-Hydrogeology Study for Proposed Crains' Leslie Pit

FIGURE NO: 3

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APPENDIX B: Tables

Table 1 Water Levels Measured in July , 2018

MW	Intervel Depth	Top of Casing ELevation (mASL)	Water Level (mASL)	Ground Surface Elevation (mASL)	Well Depth (mBGS)
A001591	shallow	142.82	133.66	141.95	11.53
A001592	Deep	135.97	133.67	135.17	21.58
A001593	shallow	140.28	135.53	139.48	17.50
A001594	shallow	141.04	137.32	140.11	5.55
A001595	shallow	142.66	134.51	141.89	11.03
BH-04-3C	shallow	143.66	Dry	142.94	2.48
BH-04-5E	shallow	141.37	Dry	140.64	1.87
House Well	shallow	143.63	133.67	143.29	14.71
TW13-1A	Deep	140.77	131.77	140.36	34.59
TW13-1B	shallow	140.76	133.32	140.36	27.60
TW13-1C	shallow	140.77	133.65	140.36	19.78
TW13-1D	shallow	140.77	133.67	140.36	11.91
TW13-2A	Deep	135.83	133.03	135.28	23.22
TW13-2B	Deep	135.89	133.09	135.28	21.43
TW13-2C	shallow	135.88	133.63	135.28	15.02
TW13-2D	shallow	135.89	133.63	135.28	7.31
TW13-3A	Deep	139.61	134.37	139.23	34.62
TW13-3B	shallow	139.60	134.45	139.23	23.39
TW13-3C	shallow	139.57	134.39	139.23	19.72
TW13-3D	shallow	139.52	135.44	139.23	11.94
TW13-04	shallow	143.14	133.67	143.10	19.26

Table 2 Site Specific Actual Evapotranspiration (AET) Calculation

Temperatures in C, water-balance terms in mm.													
Month:	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year**
P	55.90	46.13	56.93	72.35	65.39	104.81	81.16	86.05	88.42	81.87	69.12	69.62	**878**
T	-9.32	-7.68	-2.11	6.08	13.74	18.44	20.61	19.79	15.79	8.80	2.37	-5.29	
H_i	0.00	0.00	0.00	1.34	4.62	7.21	8.54	8.02	5.71	2.35	0.32	0.00	**38**
PET	0	0	0	27	66	91	103	98	77	40	9	0	**510**
f	0.80	0.81	1.02	1.13	1.28	1.29	1.31	1.21	1.04	0.94	0.79	0.75	
PETadj	0	0	0	30	84	117	134	119	80	38	8	0	**609**
P - PET	56	46	57	42	-19	-12	-53	-33	9	44	62	70	
						Soil Capacity	**50**						
Soil Storage	50	50	50	50	34	27	9	5	6	14	48	50	
ΔS	0	0	0	0	-16	-7	-18	-4	1	8	34	2	
AET	0	0	0	30	81	112	99	91	80	38	8	0	**538**
						Soil Capacity	**75**						
Soil Storage	75	75	75	75	59	50	24	16	18	32	73	75	
ΔS	0	0	0	0	-16	-9	-25	-9	2	14	41	2	
AET	0	0	0	30	82	114	106	95	80	38	8	0	**552**
						Soil Capacity	**100**						
Soil Storage	100	100	100	100	83	73	43	31	34	53	98	100	
ΔS	0	0	0	0	-17	-10	-30	-12	3	19	45	2	
AET	0	0	0	30	82	114	111	98	80	38	8	0	**561**
						Soil Capacity	**200**						
Soil Storage	200	200	200	200	182	171	131	112	117	145	198	200	
ΔS	0	0	0	0	-18	-11	-40	-20	5	29	52	2	
AET	0	0	0	30	83	116	121	106	80	38	8	0	**581**
						Soil Capacity	**250**						
Soil Storage	250	250	250	250	232	221	179	157	162	194	248	250	
ΔS	0	0	0	0	-18	-11	-42	-22	6	31	54	2	
AET	0	0	0	30	83	116	124	108	80	38	8	0	**586**
						Soil Capacity	**350**						
Soil Storage	350	350	350	350	332	320	275	251	257	292	348	350	
ΔS	0	0	0	0	-18	-11	-45	-24	6	35	56	2	
AET	0	0	0	30	84	116	126	111	80	38	8	0	**592**

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Reviewed by: AW

Table 2 Site Specific Actual Evapotranspiration (AET)

Annual Precipitation (mm)	**880.00**

Soil Type	Soil Moisture			AET (mm)		
	Agriculture	Open Field	Forest	Agriculture	Open Field	Forest
Glaciomarine Sand and Gravel	75	100	250	552	561	586
Organic Soils Underlain by Bedrock	50	200	350	538	581	592
Bedrock with thin Overburden	50	75	100	538	552	561
Impervious Bedrock	0			60		

Created by: CZ
Reviewed by: AW

Table 3: Infiltration Factors

“Tier 1 Water Budget and Water Quantity Stress Assessment”,Mississippi-Rideau Source Protection Region, August 2009

Description of Area	Infiltration Factor
Topography	
Flat Land (<1.5 slope range)	0.172
Rolling land (1.5 – 3% slope range)	0.12
Hilly land (>3% slope range)	0.073
Soil	
Low (clay, silt)	0.1
Low-Medium (till, sand-silt)	0.15
Medium (till, silty sand)	0.2
Medium-High (sands)	0.3
High (gravel, sands, organic deposits)	0.4
Variable (till)	0.2
Variable (fill)	0.4
Variable (sand)	0.35
Variable (bedrock)	
Precambrian Bedrock	0.2
Paleozoic Bedrock	0.05
Land Cover	
Low Infiltration – urban, aggregate	0.05
Medium Infiltration – agriculture, pasture, abandoned fields, wetland	0.1
High Infiltration – forest and plantation	0.2

Table 4a Pre-Development Water Balance Calculations

	Area (ha)	Precipitation	AET	Net Surplus	Infiltrtation Factor		Infiltration	Run-off
Pervious Area-Agriculture Land	208000	183040	114742	68298	**Infiltration Factor**	**0.42**	28685	39613
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.2		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.58**		
Pervious Area-Forest	0	0	0	0	**Infiltration Factor**	**0.47**	0	0
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.15		
					Land Cover Infiltration Factor	0.2		
					Run-off Coefficient	**0.53**		
Pervious Area-Cultural Meadow	150000	132000	84200	47800	**Infiltration Factor**	**0.42**	20076	27724
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.2		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.58**		
Pervious Area-Mixed Wood Land	9000	7920	5052	2868	**Infiltration Factor**	**0.42**	1205	1663
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.2		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.58**		
Impervious Area-Exposed Bedrock	18000	15840	1080	14760	**Infiltration Factor**	**0.14**	2066	12694
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.02		
					Land Cover Infiltration Factor	0		
					Run-off Coefficient	**0.86**		
Total Area	385000	339000	205000	134000			52000	82000

Table 4b Post-Development Water Balance Calculations

	Area (m2)	Precipitation	AET	Net Surplus	Infiltrtation Factor		Infiltration	Run-off
Pervious Area	0	0	0	0	**Infiltration Factor**	**0.42**	0	0
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.2		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.58**		
Impervious Area	385000	338800	23100	315700	**Infiltration Factor**	**0.14**	44198	271502
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.02		
					Land Cover Infiltration Factor	0		
					Run-off Coefficient	**0.86**		
Total Area	385000	339000	23000	316000			44000	272000

Table 4c Post-Rehabilitation Agriculture Land Water Balance Calculations

	Area (m2)	Precipitation	AET	Net Surplus	Infiltrtation Factor		Infiltration	Run-off
Pervious Area	385000	338800	206988	131812	**Infiltration Factor**	**0.37**	48771	83042
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.15		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.63**		
Impervious Area	0	0	0	0	**Infiltration Factor**	**0.14**	0	0
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.02		
					Land Cover Infiltration Factor	0		
					Run-off Coefficient	**0.86**		
Total Area	385000	339000	207000	132000			49000	83000

Table 4d Pre-, Post-Developemt and Post- Rehabilitation Results Summary

Water Input and Output	Pre-Development	Post-Development	Change (%)	Post-Rehabilitation	Change (%)
Input Water Amount					
Precipitation	339000	339000	0	339000	0
Other input	0	0	0	0	0
Total	339000	339000	0	339000	0
Output Water Amount					
ET	205000	23000	-89	207000	1
Infiltration	52000	44000	-15	49000	-6
Runoff	82000	272000	232	83000	1
Total Output	339000	339000	0	339000	0

Table 5 Huntley Wetland Catchment Area Water Balance Calculations

	Area (m2)	Precipitation	AET	Net	Infiltrtation Factor		Infiltration	Run-off
Pervious Area- Organic Deposits	2126216	1871070	1258017	613053	**Infiltration Factor**	**0.62**	380093	232960
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.4		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.38**		
Pervious Area- Bedrock	1860439	1637186	1000916	636270	**Infiltration Factor**	**0.47**	299047	337223
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.15		
					Land Cover Infiltration Factor	0.2		
					Run-off Coefficient	**0.53**		
Pervious Area- Graciomarine	531554	467767	293228	174539	**Infiltration Factor**	**0.42**	73306	101233
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.2		
					Land Cover Infiltration Factor	0.1		
					Run-off Coefficient	**0.58**		
Impervious Area- Anthropogenic (Aggregates and Urban)	797331	701651	47840	653811	**Infiltration Factor**	**0.17**	111148	542663
					Topographic Infiltration Factor	0.12		
					Soil Infiltration Factor	0.05		
					Land Cover Infiltration Factor	0		
					Run-off Coefficient	**0.83**		
Total Area	5315539	4678000	2600000	2078000			864000	1214000

	Area (ha)	Post- Development Infiltration Loss Relative to Wetland Net Water Surplus (%)	Post- Rehabilitation Infiltration Loss Relative to Wetland Net Water Surplus (%)
Proposed Crains' Pit	35.2	0.4	0.1
South Huntley Wetland Catchment Area	531		

Created by: CZ
Reviewed by: AW

APPENDIX C: Site Inspection Photos

Photo 1, Agriculture land and onsite dwelling

Photo 2, Cultural meadow land on the north part of the property

Photo 3, Forest area on the north end of the property

Photo 4, Exposed Bedrock at southeast area of the property

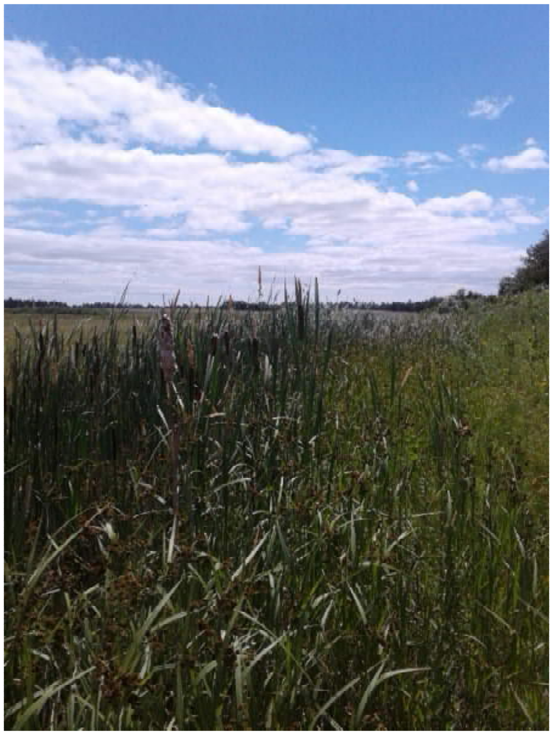

Photo 5, Drainage ditch along the west boundary of the property, was dry on day of inspection

Photo 6, Wetland area of the north corner of the site, was dry on day of inspection

Photo 7, Exposed bedrock in the dry drainage ditch along the west boundary

Photo 8, Location of drainage ditch exiting the site to northwest