APPENDIX B:
Hydrogeological Assessment in Support of Renewable Energy Approval Application for Short-Term, Non-Recurring Water Taking

HYDROGEOLOGICAL ASSESSMENT IN SUPPORT OF RENEWABLE ENERGY APPROVAL APPLICATION FOR SHORT-TERM, NON-RECURRING WATER TAKING

K2 WIND POWER PROJECT

Prepared for:
K2 Wind Ontario Limited Partnership
Suite 105, 100 Simcoe Street
Toronto, ON M5H 3G2

Prepared by:
Stantec Consulting Ltd.
49 Frederick Street
Kitchener, Ontario
N2H 6M7

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Table of Contents

List of Appendices

List of Figures

Appendix A

1.0 Introduction

K2 Wind Ontario Inc., in its capacity as general partner of K2 Wind Ontario Limited Partnership (the Proponent), is proposing to develop, construct and operate the K2 Wind Power Project (the Project) in the Township of Ashfield-Colborne-Wawanosh (Township of ACW) north of Goderich, Ontario (Figure 1). The Proponent is a limited partnership formed under the Limited Partnerships Act (Ontario), with K2 Wind Ontario Inc. as general partner and CP K2 Holdings Inc. (an affiliate of Capital Power Corporation), Samsung Renewable Energy Inc., and Pattern K2 LP Holdings LP (an affiliate of Pattern Renewable Holdings Canada ULC), as limited partners. The Project would supply approximately 270 megawatts (MW) of electricity to the Ontario power grid. The development of the Project would help the province of Ontario meet its goal of increasing the proportion of electricity generated from renewable sources. The Project is subject to Ontario Regulation 359/09 – Renewable Energy Approvals under Part V.0.1 of the Environmental Protection Act (O. Reg. 359/09).

Stantec Consulting Ltd. (Stantec) was retained by the Proponent to complete a desktop-level hydrogeological assessment in support of the Renewable Energy Application (REA) application for the Project. The Project will involve the construction of up to 140 wind turbines and associated infrastructure throughout the General Project Area, which is bounded by Bruce County Road 86 (Amberley Road) to the north, Bluewater Highway (Highway 21) to the west, Shoreline Road to the south, and Halls Hill Line and the lands located roughly between the communities of Dungannon and Nile to the east in the Township of Ashfield-Colborne-Wawanosh (Figure 1). The proposed locations of the wind turbines are shown on Figure 2. The main purpose of the hydrogeological assessment was to evaluate whether the construction of the wind turbines and their associated infrastructure could encounter shallow groundwater conditions throughout the General Project Area and, subsequently, determine if groundwater dewatering may be required as part of these construction activities. Specifically, the objectives of the hydrogeological assessment were as follows:

- Characterize the geological and hydrogeological conditions of the General Project Area, focusing on identifying those areas where the wind turbines and their associated infrastructure foundations could intercept the groundwater table;
- Determine what potential groundwater dewatering efforts may be required in order to support the aforementioned construction activities; and
- Identify measures that can be employed at the construction sites to mitigate potential impacts arising from groundwater dewatering activities.

This report is arranged into seven sections, including this introduction. Section 2 provides background information on the General Project Area and the construction activities that will be associated with the Project. Section 3 provides a description of geological and hydrogeological conditions that characterize the General Project Area, with Section 4 presenting the anticipated groundwater dewatering efforts that will be required as part of the Project. Section 5 identifies the measures that can be employed throughout the General Project Area to mitigate potential impacts arising from groundwater dewatering activities. Section 6 provides the conclusions of the report, with Section 7 providing a listing of cited references. All figures referenced in this report are presented in Appendix A, with Appendix B presenting the Dewatering Calculations. Stratigraphic information provided by Borehole Logs and Ministry of the Environment (MOE) Water Well Records located within the General Project Area are presented in Appendix C.

2.0 Background

2.1 GENERAL PROJECT AREA DESCRIPTION

The boundaries of the General Project Area occupies portions of the former Townships of Ashfield, Colborne, and West Wawanosh in the County of Huron, which has since been amalgamated and is now referred to as the Township of Ashfield-Colborne-Wawanosh (Figure 1). The majority of the General Project Area is situated in Lot 10 of Concessions 10 and 11, Eastern Division; a portion of Lots 10 and 11 in Concession 4, Eastern Division; all of Lot 10 and portions of Lots 11 and 12 in Concession 3, Eastern Division; and all of Lots 10, 11, and 12 in Concessions 1 and 2, Eastern Division within the former Township of Ashfield. In the former Township of Colborne, the General Project Area occupies Lots 1 to 17 in the Lake Road Concession East; Lots 9 to 11 in Concessions 8 and 9, Western Division; Lots 1 to 11 in Concessions 10 to 13, Western Division; and Lots 1 to 3 in Concessions 10 and 11, Eastern Division. In the Township of West Wawanosh Township, the General Project Area includes all of Lot 13, Concession 1; portions of Lots 14 and 15, Concession 1; and portions of Lots 13 and 14, Concession 2. Overall, the General Project Area is roughly bounded by Bruce County Road 86 (Amberley Road) to the north, Bluewater Highway (Highway 21) to the west, Shoreline Road to the south, and Halls Hill Line and the lands located roughly between the communities of Dungannon and Nile to the east (Figure 2).

2.2 PROPOSED CONSTRUCTION ACTIVITIES

Construction activities associated with the Project are anticipated to last for a period of 18 to 24 months, with subsurface excavations being required for the following structures:

- **Wind Turbines**

  A total of up to 140 Siemens SWT-2.3 wind-powered turbines are to be installed throughout the General Project Area. The turbine tower base would be anchored to a reinforced concrete foundation using anchor bolts. The concrete foundation will cover an area approximately 19 m wide by 19 m long, extending up to 3 m below ground surface (BGS). Each turbine will take approximately 14 days to construct, with up to 12 turbines being assembled concurrently over this period.

- **Met Tower**

  The met towers would consist of lattice or monopole structure, approximately 100 m high on a concrete foundation. These towers would either be free standing supported entirely by the foundation or would have guy wires for lateral support. Guy wires would generally be mounted on steel anchors embedded into concrete pads. The concrete foundations would typically be 10 m long by 10 m wide, extending to a depth of approximately 2.5 m BGS.

- **Collection System and Transmission Lines**

  Cabling associated with collector, transmission, and data lines will be placed underground within the road allowances or on privately owned leased lands or above ground on poles or municipal infrastructures as appropriate, over major watercourse crossings or in areas where below grade construction is not possible. Underground cabling will generally be laid in trenches approximately 0.5 m wide by 1.0 m deep according to current practice, and well below cultivation depth.

- **Substation Operation and Maintenance Building and Transformer Station**

  Construction of a single storey concrete slab-on-grade operation and maintenance building that will cover an area approximately 16 m wide by 32 m long, transformer station, and containment pit. AMEC (2006) has suggested that the foundation for the building be set at a depth no deeper than 1.2 m BGS in order to avoid intercepting the groundwater table and, subsequently, requiring the use of a dewatering system.

3.0 Project Area Setting

3.1 PHYSIOGRAPHY

The General Project Area is occupied by two physiographic regions, which Chapman and Putnam (1984) classifies as the Huron Slope and the Horseshoe Moraines (Figure 2). The Huron Slope consists of beveled clay till plain that extends from the shores of Lake Huron to western limits of the Wyoming Moraine, with a section of this moraine being positioned within the eastern portions of the General Project Area. The till plain is occupied by a narrow north-south trending surficial deposit of sand, as well as a ridge of sandy beach deposits that flank the western edge of the moraine, with these soils having been both laid down by the former glacial Lake Warren. The shallow sand deposits are generally characterized by perched groundwater conditions, with wetlands often being present in those sandy areas where topographic depressions exist.

The remainder of the General Project Area lies within the Horseshoe Moraines, a physiographic region that extends northward from Huron County to the toe of the “horseshoe” in Grey County, where the region then extends southward along the edge of the Niagara Escarpment into the Town of Caledon. From the Town of Caledon, the moraines trend west of the Niagara Escarpment and form a belt of moderately hilly relief passing to the east of Acton and Guelph and onward into Cambridge and Paris. In general, the section of the Horseshoe Moraines covering the lands within and to the east of the General Project Area is comprised of irregular stone knobs and ridges, old spillways with broad sand and gravel terraces, and valley floors containing wetlands. Clayey silt till and spillway deposits of sand and gravel associated with the Wyoming Moraine extend into the eastern portions of the General Project Area, terminating at the former shoreline of glacial Lake Warren.

Topographically, lands within the General Project Area slope from east to west, sloping from a high of 300 m AMSL on the Wyoming Moraine to a low of 185 m AMSL along the shores of Lake Huron (Figure 3). The headwaters of several watercourses originate along the western flank of the Wyoming Moraine, draining westward and eventually discharging to Lake Huron.

3.2 GEOLOGY AND HYDROSTRATIGRAPHY

Geological conditions throughout the General Project Area have been documented in investigations completed by Cowan (1974), the Ontario Geological Survey (2003), Waterloo Hydrogeologic, Inc. (WHI) (2004), AMEC Earth and Environmental (2006), Naylor Engineering Associates Ltd. (2007), and the Ausable Bayfield Maitland Valley Source Protection Committee (ABMVSCP, 2011). In summary, the subsurface throughout the region containing the General Project Area is reported to consist of the following key geological formations, with these units being listed from youngest to oldest:

Glaciolacustrine Deposits: Deposits of medium to fine sand and silty fine sand affiliated with the shallow areas of former glacial Lake Warren (i.e., the shoreline), with the areas where the lake was characterized by deeper waters having glaciolacustrine sediments consisting of laminated to varved silt, clay and minor sand (Figure 4, Units 8A and 9);

Glaciofluvial Deposits: Layers of sand and gravel deposited by sediment-laden meltwater streams discharging from the front of receding glaciers (Figure 4, Unit 7);

St. Joseph's Till: Silt to silty clay till forming the Wyoming Moraine and extending westward from this feature to the shoreline of Lake Huron, with this till unit commonly being overlain by outwash sands and gravels and various glaciolacustrine sediments. The till is reported to be in the range of 20 m to 25 m thick throughout the region (Figure 4, Unit 5d)

Catfish Creek Till: Dense, stony, sandy silt to silty sand till with little clay content that is commonly referred to as "hardpan" by many water well drillers due to its stoniness and stiffness. The till is generally less than 6 m in thickness, but can reach up to 12 m thick in some areas (Figure 4, Unit 5b); and,

Bedrock: Grey-brown, highly fossiliferous limestone of the Dundee Formation, forming the bedrock surface beneath the majority of the General Project Area, and limestone of the Detroit River Group (i.e., Amherstburg and Lucas Formations) (Figure 5). The Dundee Formation is reported to be in the range of 35 to 45 m thick, with the thickness of the Detroit River Group being reported to range from 60 m to 90 m.

To better understand regional groundwater conditions throughout southwestern Ontario, WHI (2004), developed a three-dimensional conceptual hydrogeological model for lands located within the jurisdictions of the Ausable Bayfield, Maitland Valley, Essex Region, St. Clair Region, Lower Thames Valley, and Upper Thames Valley Conservation Authorities. The model development involved WHI taking geological formations having similar hydrogeological properties, textural characteristics, and stratigraphic position and grouping them together to form hydrostratigraphic units, which were further categorized into aquifers and aquitards. The results of this exercise are presented below, with the key hydrostratigraphic units being identified as follows:

Aquifer 1 (HU-I):	A shallow unconfined aquifer system consisting of coarse-grained surficial deposits associated with glaciolacustrine and/or outwash sand deposits. Hydraulic conductivities associated with this aquifer system are reported to be in the range of 10^{-4} m/s;
Aquitard 1 (HU-II & HU-IV):	Fine-grained deposits of silt and clay associated with subglacial till sheets (e.g., HU-II – Rannoch, Stratford Till, Wartburg, St. Joseph's and Elma Tills; HU-IV – Tavistock and Port Stanley Tills), glaciolacustrine diamicts, and lacustrine clay plains. HU-II and HU-IV are commonly found to be in direct contact with each other and, consequently, are generally considered to represent one hydrostratigraphic unit. Aquitard 1 is extensive throughout the region, ranging from less than one meter to up to 100 m in thickness. This unit is characterized by low permeability, with reported hydraulic conductivities being in the range of 10^{-6} m/s to 10^{-8} m/s;
Intermediate Aquifer (HU-III):	A confined aquifer system consisting of outwash sands and gravels interbedded within Aquitard 1, with this unit ranging from less than 1 m to 30 m in thickness. This aquifer system is largely found in Middlesex and Elgin Counties and is reported to be absent beneath the General Project Area (ABMVSCP, 2011);
Aquifer 2 (HU-V):	A confined aquifer system consisting of discontinuous deposits of outwash sand and gravel that directly overlie the Catfish Creek Till. The hydrostratigraphic unit is reported to range from less than one meter to 40 m in thickness and is characterized by hydraulic conductivities in the range of 10^{-4} m/s. However, this aquifer system is reported to be absent beneath the General Project Area (ABMVSCP, 2011);
Aquitard 2 (HU-VI):	Dense, stony, sandy silt to silty sand deposits of the Catfish Creek Till and other older over-consolidated tills such as the Canning Till (silt to clay till). The hydrostratigraphic unit is regionally extensive and is found throughout most of Huron County; and,
Bedrock Aquifer (HU-VII/VIII):	A very good water-yielding aquifer system (MOE, 2003) in which a majority of water supply wells in the General Project Area are drilled. Hydraulic conductivities associated with this aquifer system are reported to be in the range of 10^{-5} m/s to 10^{-6} m/s.

Figure 4 presents the surficial geological conditions within the General Project Area and surrounding area as mapped by the OGS (2003) and the locations of Cross Sections A-A' to E-E' (Figures 6 to 10). These cross sections were constructed using borehole information obtained from MOE Water Well Records (WWR) and local geotechnical investigations (AMEC, 2006; NEA, 2007), and regional hydrostratigraphic interpretations presented by WHI (2004). A deposit of clay to silt-textured till covers the majority of the General Project Area, which is interpreted to represent the St. Joseph's Till, which in turn is overlain by glaciolacustrine (sand, silt and clay) and glaciofluvial (sand and gravel) deposits affiliated with the former Lake Warren shoreline and glacial spillways that cut through the Wyoming Moraine, respectively.

In general, the silt and clay deposits encountered across the surface of the General Project Area also appear to be largely present throughout the subsurface, extending from the existing grade to an underlying "hardpan" layer or to the top of the bedrock surface (Figures 6 to 10). These deposits are interpreted to represent a combination of fine-grained glaciolacustrine deposits and the St. Joseph's Till of Aquitard 1 (HU-II). The underlying "hardpan" deposits are interpreted to represent the Catfish Creek Till of Aquitard 2 (HU-VI). Interbedded within Aquitard 1 (HU-II) are discontinuous pockets of sand and gravel that are interpreted to be glaciofluvial in origin, with these deposits being encountered at a median depth of 10 m BGS across the General Project Area (ranging from depths of 2 m BGS to 27 m BGS). These sand pockets do not appear to be affiliated with the Intermediate Aquifer (HU-III), given that this aquifer system is reported to be absent in the area in which the General Project Area is situated (ABMVSCP, 2011). Aquifer 1 (HU-I) is encountered near the northern limits of the General Project Area (Figure 5), corresponding to the surficial deposits of sand and gravel located immediately to the north of the settlement of Lothian (Figure 4). Throughout the till plain of the Huron Fringe, Aquifer 1 (HU-I) is commonly referred to as the Lake Warren Shoreline Aquifer and is reported to be an important source of groundwater discharge to the numerous watercourses that occupy this area of the General Project Area (ABMVSCP, 2011). As shown in Figures 6 to 10, the bedrock surface slopes to the west towards Lake Huron and is encountered at depths ranging from 1 m to 70 m beneath the General Project Area (median depth of 19 m BGS), with the overburden typically being thinnest in those areas where local watercourses have cut deep into the subsurface (e.g., Nine Mile Creek; Figure 8).

3.3 HYDROGEOLOGY

Figure 11 presents the interpreted depth to the groundwater table across the General Project Area, which was largely based on water level measurements recorded in boreholes drilled as part of the geotechnical investigations completed by AMEC (2006) and Naylor Engineering Associates (2007), given that these boreholes provided the most detailed information on local geological and shallow groundwater conditions. Stantec notes that the borehole water levels were recorded at different times of the year under varying seasonal conditions and since groundwater levels throughout southern Ontario are known to fluctuate considerably in response to both seasonal climate changes and longer term precipitation trends, the groundwater depths presented in Figure 11 are to be considered as a representation of average conditions.

In general, the groundwater table throughout the General Project Area appears to be encountered at its highest levels in those areas where shallow deposits of sand and gravel are located at or near ground surface, with these deposits typically being underlain by sediments characterized by low permeability (i.e., glaciolacustrine deposits of silt and clay and/or the St. Joseph's Till). Based on available information, high groundwater conditions (i.e., groundwater table is located within 4 m of ground surface) appear to be concentrated along the western flank of the Wyoming Moraine (Figure 11), corresponding with the ridge of sandy beach deposits affiliated with the former glacial Lake Warren shoreline (Figures 2 and 4). Specifically, these areas of high groundwater are concentrated along Hawkins Road between Lanesville Line and Cransford Line (in vicinity of Turbine 219), around the intersection of Belgrave Road and Lanesville Line (in the vicinity of the Substation and Turbines 229, 233, 236, 237, 239, 256, 259, 262, 267, 269), and immediately to the north of the settlement of Lothian (in the vicinity of Turbines 344 to 347), with other smaller pockets being present in the vicinity of Turbines 300, 306, 307, 308, 311 and 317 (Figure 11). High groundwater conditions may also be encountered in in the vicinity of Turbines 208, 209, 213, 214, 218, 221, 223, 225, 227, 228, 231, 232, 235, 354 and 355, given that surficial deposits of sand and gravel are mapped as occurring in these areas (Figure 4). As shown in Figure 11, the groundwater table becomes progressively deeper moving away from the Wyoming Moraine towards the western limits of the General Project Area, where groundwater depths of up to 15 m BGS are encountered.

Potentiometric surface mapping presented in the Maitland Valley Source Protection Area (SPA) Assessment Report (ABMVSPC, 2011) indicates that groundwater flow beneath the General Project Area through the Bedrock Aquifer (HU-VII / VIII) is to the west and southwest towards Lake Huron, which is interpreted to receive groundwater discharge from this aquifer system. The movement of groundwater through the overburden deposits of the SPA is poorly understood, given that the majority of water supply wells present throughout this area are completed into the Bedrock Aquifer (ABMVSPC, 2011). Assuming that groundwater flow through the overburden aquifer systems beneath the General Project Area are likely controlled by local variations in topography (Figure 3), it is reasonable to conclude that overall flow is to the west towards Lake Huron, with some flow being directed towards local watercourses.

4.0 Predicted Groundwater Dewatering

Applicants for a REA do not require a Permit to Take Water (PTTW) from the Ministry of the Environment (MOE) under the Ontario Water Resources Act and the Water Taking and Transfer Regulation (O. Reg. 387/04) as specified in the MOE (2012) Technical Guide to Renewable Energy Approvals. However, dewatering activities required as part of the wind turbine and associated infrastructure foundation construction will be guided by PTTW protocols. As such, if dewatering volumes are projected to exceed 50,000 L/day throughout the General Project Area, but remain below 400,000 L/day over 30 consecutive days of pumping, the resulting PTTW would be classified as a Category 2 Water Taking, given that this water taking will be short-term and non-recurring.

Preliminary designs for the proposed Siemens SWT-2.3 wind-powered turbines indicate that the footing foundations for the turbines will be constructed to depths up to 3 m with the accompanying building structure foundations (e.g., buildings associated with the Transformer Station and Substation and Operation and Maintenance building), transformer pads, underground collector lines, data cabling and transmission lines remaining above this specified depth. Previous work completed by Naylor Engineering Associates Ltd. (2007) and WHI (2004) indicate that the highest groundwater level observed throughout the General Project Area was in the range of 1.2 m BGS and, subsequently, any potential dewatering activity is likely to be limited to those excavations where meteorological tower or wind turbine footing foundations will be constructed. Given the above information, dewatering activity is not likely to be required during the installation of the collector lines, data cabling and transmission lines.

Overall, dewatering of the foundation excavations may be required to manage the following events:

- Groundwater seepage into the excavation;
- Precipitation within construction area; and
- Accumulated groundwater within the excavation following a prolonged construction delay.

The type and extent of dewatering system to be used at the construction sites will be the responsibility of the Construction Contractor and may include the use of a vacuum well point system, sump/trash pumps located within the excavation, or a similar type system. Dewatering may occur at any time during construction activities, which are tentatively scheduled to occur in the General Project Area from mid-2013 to the winter of 2014.

Dewatering activities are expected to be completed on an as-required basis, with the rate of this dewatering being dictated by the amount of construction activity for the Project that is occurring across the General Project Area at a given time, the type of overburden material and groundwater elevations encountered at the construction sites, and the elevation at which the groundwater table has to be lowered to construct the foundations of the wind turbines and their associated infrastructure. Calculations of the construction dewatering rates that could be required throughout the General Project Area are provided in the sections below, with these rates being largely determined using hydrogeological information provided in studies completed by Naylor Engineering Associates Ltd. (2007) and WHI (2004).

4.1 DEWATERING RATES IN SAND DEPOSITS (AQUIFER 1)

The predicted pumping rates required to lower groundwater elevations within the sand and gravel deposits of Aquifer 1 (HU-I) were calculated using the Dupuit-Forchheimer Flow Equation, which models the rate that groundwater flows into excavations that are completed within an unconfined aquifer system (Powers *et al.*, 2007). Details of the dewatering calculations are presented in Appendix B.

The input parameters required for the Dupuit-Forchheimer Flow Equation include the following: dimensions of the excavation, horizontal hydraulic conductivity of the overburden material, the base elevation of the aquifer system being pumped, the static groundwater elevation, and the targeted groundwater dewatering elevation. Each of aforementioned input parameters that were used to predict dewatering rates are discussed below:

- The proposed foundations for the wind turbines represent the largest structures most likely to intercept the groundwater table and, consequently, the greatest dewatering volumes are expected to be generated at these construction sites. Each wind turbine foundation is expected to cover an area 19 m wide by 19 m long, with the base extending up to a depth of 3 m below ground surface (BGS). For the purpose of the dewatering calculations, Stantec has assumed that the maximum depth at which the foundations will be constructed is 3 m BGS;

- According to WHI (2004), the in-situ horizontal hydraulic conductivity of the sand and gravel deposits of Aquifer 1 (HU-I) are in the range of 1.0×10^{-4} m/s to 6.0×10^{-4} m/s;

- Using hydrostratigraphic information obtained from boreholes drilled by Naylor Engineering Associates Ltd. (2007) and selected MOE Water Well Records (Appendix C), the base of Aquifer 1 (HU-I) was assumed to occur at the contact of the underlying silt and clay deposits of Aquitard 2 (HU-II). The base elevation of Aquifer 1 (HU-I) in those areas of the General Project Area where static groundwater levels were higher than 3 m BGS ranged from 219.4 m AMSL to 238.9 m AMSL. Accompanying static groundwater elevations ranged from 223.3 m AMSL to 244.9 m AMSL. For the purposes of the calculation, Stantec assigned the base elevation of the aquifer to represent the anticipated dewatering elevation minus one (1) meter; and,

- Based on the aforementioned information, groundwater elevations will potentially have to be lowered by 0.9 m to 1.4 m (average drawdown of 1.2 m) for foundation construction to occur within this hydrostratigraphic unit where high groundwater conditions exist.

Based the above range of input parameters, the Dupuit-Forchheimer Flow Equation predicts that the average pumping rate required to remove groundwater seeping into excavations completed into the sand and gravel deposits of Aquifer 1 (HU-I) at an individual construction location could be in the range of 86,880 L/day to 298,140 L/day, with the maximum pumping rate being in the range of 342,790 L/day (Appendix B.1). Based on the tentative construction schedule, dewatering would only occur in up to three (3) excavations at one time across the General Project Area. Assuming that all of these excavations were completed into the deposits of Aquifer 1 (HU-I), the resulting maximum pumping rate required to dewater these excavations would be 1,028,370 L/day, or approximately 714 L/min based on the assumption that the pumping would occur over a 24 hour period. Stantec notes that this maximum day rate is calculated based on the conservative scenario where the sand deposits of Aquifer 1 (HU-I) are characterized by a hydraulic conductivity that is at the higher end of the range of hydraulic conductivities reported for this unit (i.e., 6.0×10^{-4} m/s), with groundwater elevations in each excavation having to be lowered by a maximum of 1.4 m.

In the event that dewatering is expected to exceed the maximum volume of 400,000 L in a given day as allowed under a Category 2 Water Taking, the Construction Contractor will be instructed to manage the dewatering activities in a way that ensures that total water taking across the General Project Area will not exceed this daily permitted volume.

4.2 DEWATERING RATES IN SILT AND CLAY DEPOSITS (AQUITARD 2)

The predicted pumping rates required to lower groundwater elevations within the silt and clay deposits of Aquitard 1 (HU-II) were calculated using the Dupuit-Forchheimer Flow Equation, with the following parameters used in this calculation discussed below. Details pertaining to the dewatering calculations are presented in Appendix B.

- The proposed foundations for the wind turbines represent the largest structures most likely to intercept the groundwater table and, consequently, the greatest dewatering volumes are expected to be generated at these construction sites. Each wind turbine foundation is expected to cover an area 19 m wide by 19 m long, with the base extending to a minimum depth of 3 m below ground surface (BGS). For the purpose of the dewatering calculations, Stantec has assumed that the maximum depth at which the foundations will be constructed is 3 m BGS;

- According to WHI (2004), the in-situ horizontal hydraulic conductivity of the silt and clay deposits of Aquitard 1 (HU-II) are in the range of 1.0×10^{-6} m/s to 6.0×10^{-8} m/s;

- Using hydrostratigraphic information obtained from boreholes drilled by Naylor Engineering Associates Ltd. (2007) and selected MOE Water Well Records (Appendix C), the base of Aquitard 1 (HU-I) was assumed to occur at the elevation where this hydrostratigraphic unit either encounters the bedrock surface or the top of Aquitard 2 (Catfish Creek Till; HU-VI). The base elevation of Aquitard 1 (HU-II) in those areas of the General Project Area where static groundwater levels were higher than 3 m BGS ranged from 200.3 m AMSL to 240.3 m AMSL. Accompanying static groundwater elevations ranged from 222.6 m AMSL to 252.2 m AMSL. For the purposes of the calculation, Stantec assigned the base elevation of the aquifer to represent the anticipated dewatering elevation minus one (1) metre; and

- Based on the aforementioned information, groundwater elevations will potentially have to be lowered by 0.4 m to 1.7 m (average drawdown of 1.1 m) for foundation construction to occur within this hydrostratigraphic unit where high groundwater conditions exist.

Based the above range of input parameters, the Dupuit-Forchheimer Flow Equation predicts that the average pumping rate required to remove groundwater seeping into excavations completed into the silt and clay deposits of Aquitard 1 (HU-II) at a given construction location could be in the range of 775 L/day to 3,520 L/day, with the maximum pumping rate being in the range of 4,390 L/day (Appendix B.2). Based on the tentative construction schedule, dewatering would only occur in up to three (3) excavations at one time across the General Project Area. Assuming that all of these excavations were completed into the deposits of Aquitard 1 (HU-II), the resulting maximum pumping rate required to dewater these excavations would be 13,170 L/day, or approximately 9.1 L/min based on the assumption that the pumping would occur over a 24 hour period.

5.0 Dewatering Mitigation Measures

The key points of concern with the performing of groundwater dewatering activities for the purposes of construction are as follows:

- Groundwater Interference: The potential impact that pumping water from the groundwater system could have on local private and/or municipal water well supplies (quantity and quality) and/or the function of identified groundwater discharge features (e.g., wetlands, watercourses); and
- Management of Pump Water Discharge: The rate, quality of, and location that pumped water is released back into the environment and the impact that this release may have on receiving environmental features (i.e., typically surface water features such as a wetland or watercourse).

Where appropriate, measures that can be employed across the General Project Area to mitigate potential impacts arising from groundwater dewatering activities are discussed in the sections below. Overall, if the recommended mitigation measures are employed in those areas where construction dewatering is required, it is reasonable to conclude that no notable impacts will occur to local groundwater and surface water resources as a result of these dewatering activities.

5.1 PRIVATE WELL INTERFERENCE

- Establishment of a private water well monitoring program that will include:
    - Completion of a door-to-door survey of residences located up to 500 m of the point of dewatering to confirm the location, construction details, integrity, and performance (i.e., quantity and quality) of local private water wells; and
    - Selection of suitable wells for the monitoring of water levels and quality prior to and during the scheduled dewatering period, with these data being used to evaluate whether any changes, if reported, in the quantity and/or quality of well water is attributed to groundwater dewatering activities.
- If it is determined that any changes in local well water quantities and/or quality is attributed to dewatering activities, actions will be taken to make available to those affected: (i) a supply of water equivalent in quantity and quality to their normal takings, or (ii) shall reduce the rate and amount of takings to prevent or alleviate the observed negative impact. In the event that dewatering has permanently impacted a given well water supply, actions will be taken to restore that water supply to those who have been permanently affected.

5.2 SURFACE WATER INTERFERENCE

- Through the completion of a desktop-level analysis, evaluate the potential for proposed dewatering activities to detrimentally impact the hydrogeological form and/or function of nearby groundwater sensitive surface water features (e.g., wetlands and/or watercourses);
- In the event that interference is anticipated, a field program will be designed and implemented to monitor groundwater-surface water interactions of the identified surface water feature prior to, during and following the construction dewatering activity; and
- If monitoring results indicate that dewatering activities are causing potentially detrimental impact to the hydrogeological form and/or function of the surface water feature, actions must be taken to improve the situation with the options of reducing the rate of, or shutting down, the dewatering activity as deemed necessary.

5.3 MANAGEMENT OF DISCHARGE

- During construction dewatering, the main water quality concern is the potential discharging of sediment laden water to surface water receptors. To minimize sediment transport, the following mitigation measures are to be employed as required:
  - If using sump/trash pumps, the inlet pump head for the dewatering system will be wrapped in filter fabric and surrounded with clear stone, or equivalent;
  - Discharged water will be directed through a filter bag or straw bale/filter fabric device or equivalent to reduce suspended solids. The number and size of the sediment control bags or equivalent filter will be dependent on the extent and location of the required dewatering; and
  - An initial settling tank may be used to reduce the suspended solids in the discharge water prior to being released to the surface water receptor, if required.

6.0 Conclusions

Based on the hydrogeological assessment, the following conclusions are provided:

1. The General Project Area is largely underlain by a vertically continuous unit of silt and clay that is interpreted to represent a combination of fine-grained glaciolacustrine deposits and the St. Joseph's Till. This hydrostratigraphic unit is referred to as Aquitard 1 (HU-II), which extends from the existing grade to an underlying "hardpan" layer (i.e., Aquitard 2; HU-VI) or to the top of the bedrock surface. A narrow north-south trending surficial deposit of sand, as well as a ridge of sandy beach deposits that flank the western edge of the Wyoming Moraine, overlie the deposits of Aquitard 1 and are commonly referred to as Aquifer 1 (HU-I);

2. In general, high groundwater conditions (i.e., groundwater table is located within 4 m of ground surface) tend to be encountered within the surficial sand and gravel deposits of Aquifer 1, although such conditions are also found to occur within the silt and clay deposits of Aquitard 1 (HU-II);

3. High groundwater conditions appear to be concentrated along Hawkins Road between Lanesville Line and Cransford Line (in vicinity of proposed Turbine 219), around the intersection of Belgrave Road and Lanesville Line (in the vicinity of the proposed Substation and Turbines 229, 233, 236, 237, 239, 256, 259, 262, 267, 269), and immediately to the north of the settlement of Lothian (in the vicinity of proposed Turbines 344 to 347), with other smaller pockets being present in the vicinity of proposed Turbines 300, 306, 307, 308, 311 and 317). High groundwater conditions may also be encountered in in the vicinity of Turbines 208, 209, 213, 214, 218, 221, 223, 225, 227, 228, 231, 232, 235, 354 and 355, given that surficial deposits of sand and gravel are mapped as occurring in these areas of the General Project Area;

4. The maximum pumping rate required to complete dewatering activities across the General Project Area (i.e., dewatering up to three excavations at one time) is predicted to range from as low as 13,170 L/day (9.1 L/min) to a conservative based estimate of 1,028,370 L/day (714 L/min), with these rates being highly dependent on the hydraulic conductivity of the deposit encountered at each construction site, the accompanying static groundwater elevation, and the desired elevation to which the groundwater table is to be lowered. Overall, in the event that dewatering is anticipated to exceed the maximum volume of 400,000 L in a given day as allowed under a Category 2 Water Taking, the Construction Contractor will be instructed to manage the dewatering activities in a way that ensures that total water taking across the General Project Area will not exceed this daily permitted volume; and

5. Overall, if the dewatering mitigation measures outlined in this report are employed in those areas of the General Project Area where construction dewatering is required, it is reasonable to conclude that no notable long-term impacts to local groundwater and surface water resources will occur as a result of these dewatering activities.

We trust that this report meets your current requirements. If there are any questions or concerns, please do not hesitate to contact the undersigned.

STANTEC CONSULTING LTD.

Grant Whitehead, MES, P.Geo. (Limited)
Hydrogeologist
Tel: (519) 585-7400
Fax: (519) 579-4239
grant.whitehead@stantec.com

Roger Freymond, P.Eng.
Senior Hydrogeologist
Tel: (519) 585-7381
Tel: (519) 579-4239
roger.freymond@stantec.com

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