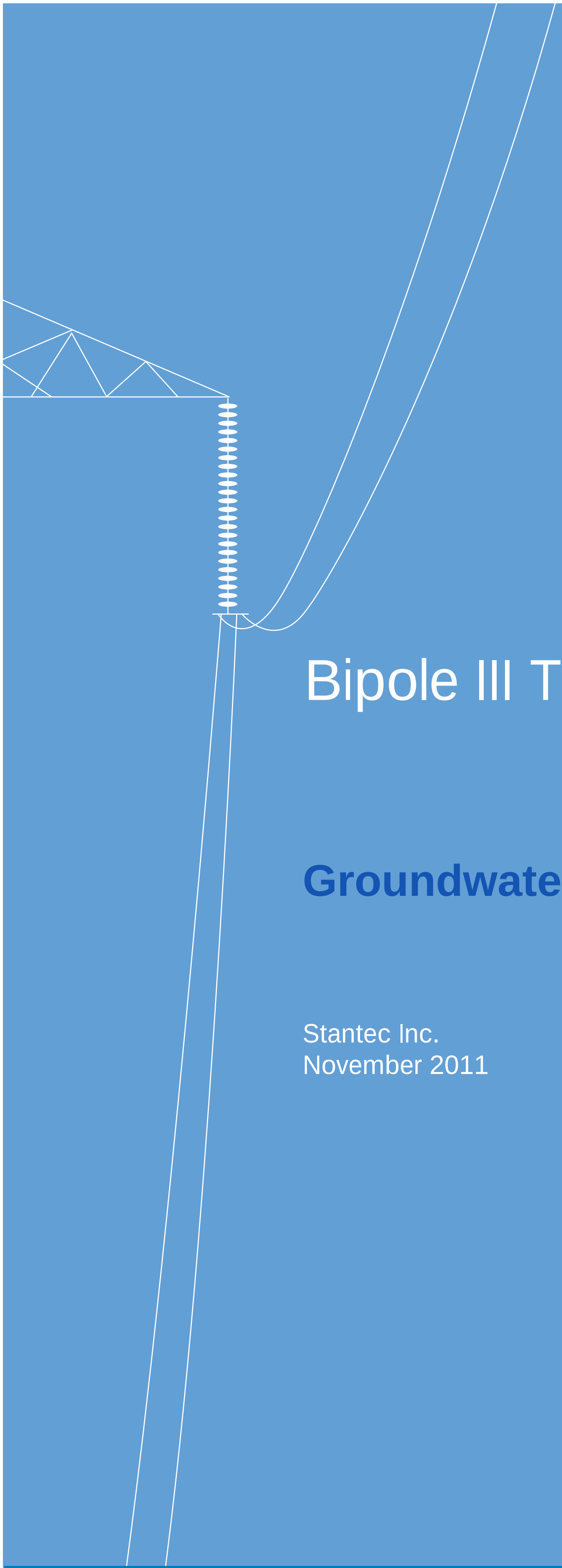

Bipole III Transmission Project

Groundwater Technical Report

Stantec Inc.
November 2011

Manitoba
Hydro

Technical Report on Groundwater - Bipole III Transmission Project

FINAL REPORT

November 2011

Executive Summary

Manitoba Hydro is proposing to construct the Bipole III Transmission Project. Stantec Consulting Ltd. has been retained to conduct the environmental assessment of, and develop an environmental impact statement for, the groundwater environmental component. This Technical Report is developed to conduct a technical assessment of the Project on the groundwater regime by identifying potential effects, assessing them, and recommending mitigation measures to reduce or avoid potential effects. The document will support the overall Environmental Impact Statement being developed for the Bipole III Transmission Project.

The Project consists of a 1,384 km 500 kV HVdc transmission line; a new northern converter station, the Keewatinoow converter station including a construction camp and construction power; a new southern converter station including construction power; new 230 kV transmission lines linking the Keewatinoow converter station to the northern collector system; and new ground electrode sites for each converter station, connected to the station by a low voltage feeder line. Associated components of the Project include access trail construction; marshalling yards establishment and the use of existing and new sources of borrow, as required.

Project activities likely to affect the groundwater environment include pre-construction geotechnical work and foundation excavation/installation. Using heavy equipment, installing anchors and handling/storing hazardous materials have the potential to interact with the groundwater environment if a contingency event occurs (e.g., hazardous materials spill or leak, or accidental interconnection of aquifers).

The proposed Bipole III transmission line preferred linear route will be constructed over the bedrock of the Precambrian Shield and the two large sedimentary basins (specifically the Western Canada Sedimentary Basin in the southwestern part of Manitoba and the Hudson Bay Basin in the northeastern part of Manitoba).

Most of the bedrock is covered by overburden consisting mainly of glacial tills, lacustrine sediments and shallow marine deposits. Thickness is highly variable from thin sediments and outcrops common in the Precambrian Shield to deposits over 100 m thick in locations of infilled bedrock channels and moraines primarily found in southern and western Manitoba. Much of the Precambrian Shield remains unexplored for groundwater resources and aquifers due to sparse population and abundance of surface water sources.

The bedrock of the Western Canada Sedimentary Basin is generally overlain by glacial, lacustrine and deltaic Pleistocene deposits and recent alluvial sediments. Glacial and lacustrine sand and gravel deposits contain extensive freshwater aquifers. A number of regional aquifers also occur in sand that was deposited in pre- and postglacial lakes and rivers.

Shallow marine and continental deposits up to 80 m thick overlie the Paleozoic bedrock of the Hudson Bay Basin. The groundwater supply potential of these deposits is not well explored.

Valued environmental components were identified as part of the environmental effects assessment. Aquifer productivity and aquifer quality were identified as valued environmental components due to their importance in the maintenance of sustainable aquifers for the provision of safe and adequate groundwater resources for multiple uses, including domestic, agriculture and recreation.

Potential direct and indirect effects of the Bipole III Transmission Line Project to aquifer quality are related to pesticide and herbicide application; leachate from required septic lagoon(s) and buried ground electrode coke beds; groundwater withdrawal and construction material usage; however, aquifer quality is not expected to be affected under normal conditions of construction and operation of the proposed Bipole III transmission line and associated infrastructure. Potential direct and indirect effects to aquifer productivity are related to groundwater withdrawal; irrigation of ground electrodes and aquifer disturbance due to unintended discharge.

Residual environmental effects, anticipated to remain after mitigation in some areas, include a depression cone around each proposed supply well and residual groundwater effects should a contingency event occur.

There are potential cumulative effects of future Manitoba Hydro activities (specifically the development of the proposed Conawapa Generating Station) at the northern extent of the study area. These specifically relate to requirements for groundwater withdrawal or contingency event(s) during construction or operation. Both of these actions could have a potential effect (singular or additive) on aquifer quality and aquifer productivity. The potential cumulative effects of either of these actions is considered negative in direction, moderate in both ecological importance, small in magnitude, confined in geographical extent to the local assessment area and reversible.

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1.0 Introduction

Manitoba Hydro is proposing to construct the Bipole III Transmission Project (the Project). This Technical Report consists of a description of the existing geology and hydrogeology of the proposed Project areas, an assessment of potential effects of development on this environment, and an identification of proposed mitigation measures to address these potential effects.

1.1 PROJECT OVERVIEW

The Bipole III Project will consist of an HVdc transmission line, originating at a new converter station to be located near the proposed site of the Conawapa Generating Station and terminating at a second new converter station located at the Riel site immediately east of the Red River Floodway in the Rural Municipality of Springfield (Map 1). Based on recommendations from Fox Lake Cree Nation, the new northern converter station will be named Keewatinoow Converter Station. The southern converter station will be named the Riel Converter Station.

Apart from the HVdc transmission line and new converter stations, the Project will include new 230 kV transmission lines linking the Keewatinoow Converter Station to the northern collector system at the existing 230 kV switchyards at Henday Converter Station and the Long Spruce Switching Station (see Map 1). Each of the new converter stations will also require development of a separate ground electrode, connected to the station by a low voltage overhead line.

Keewatinoow Converter Station will allow power to be exchanged between the northern high voltage ac transmission collector system and the Bipole III high voltage dc transmission system. The dc system is divided into two poles, a positive pole operating at +500 kV, and a negative pole operating at -500 kV with respect to earth (or ground) potential. Both poles will be transmitted on a single transmission line, referred to as the Bipole III HVdc Transmission Line. Riel Converter Station will allow dc power from the HVdc Line to be exchanged with the high voltage southern transmission receiver system.

1.2 SCOPE

As outlined in "*Bipole III Transmission Project: A Major Reliability Improvement Initiative Draft Environmental Assessment Scoping Document*" (Manitoba Hydro 2009), the Environmental Impact Statement will provide general information on groundwater as it relates to the Project including local and regional groundwater characteristics; aquifer charge and recharge areas and rates; sources of potable water and other groundwater uses, and research, observation and potable water well locations. The EIS will provide sufficient level of detail in order to predict, avoid and/or minimize any potential adverse effects on groundwater regime and quality.

The scope of this Technical Report is therefore an assessment of the potential effects of the Bipole III Transmission Project on the groundwater environment beneath the preferred transmission alignment and associated project components, including the northern electrode site, the northern convertor station site, the northern construction power site, the southern Converter Station site and southern electrode site.

The groundwater environment includes the groundwater regime (i.e., aquifer characteristics and recharge) and quality. The assessment focuses on the major hydrogeological features located in the vicinity of the proposed route of the transmission line due to regional extent of the Project, but considers the local groundwater environments near the proposed converter stations, electrode sites and the construction camp.

1.3 PURPOSE

This Technical Report is developed to conduct a technical assessment of the Project on the groundwater regime by identifying potential effects, assessing them, and recommending mitigation measures to reduce or avoid potential effects. The document will support the overall Environmental Impact Statement being developed for the Bipole III Transmission Project.

1.4 REPORT OUTLINE

The following report outlines the assessment area; data sources, assessment method; a description of the existing generalized geology of Manitoba, hydrogeology, and groundwater; Project components and activities likely to affect the groundwater environment; and environmental effects assessment (including mitigation measures) and residual and cumulative effects.

2.0 Study Area

The study area for the assessment was focused on the 66 m transmission line right-of-way and three-mile corridor (Local Study Area) of the preferred linear route from the Riel Converter Station to the Keewatinoow Converter Station (adjacent to the proposed Conawapa Generating Station; see Map 1).

To facilitate the assessment, the transmission line route was divided into sections (from the Riel Converter Station northwards). The section divisions were selected to generally correspond to areas with similar hydrogeology and groundwater use (see Map 1).

3.0 Methods

3.1 DATA SOURCES AND INTEGRATION

The approach taken to understand the current groundwater regime in the vicinity of the proposed Project involved the collection, review, and synthesis of available geological and hydrological information. No field activities were conducted.

The information described in this Technical Report comes from a synthesis of data collected in the area, material from a variety of literature sources, and personal communications with experts who have knowledge of the groundwater in the assessment area.

Bedrock aquifer information and maps for the entire preferred route (see Map 1), maps showing the occurrence of aquifers in the overburden along the route to just north of The Pas (Map 2), and maps of flowing wells and springs (i.e., artesian groundwater conditions) excluding the most northern area of the preferred route (Map 3) were provided by Manitoba Water Stewardship. This same institution also provided a database of licensed wells within the study area (Maps 4A and 4B). Aquifer vulnerability to potential impacts (i.e., from a spill or malfunction) was identified as an ATK concern and was assessed using the map developed by Manitoba Conservation for the assessment of aquifer sensitivity to contamination from underground petroleum tanks (Maps 5A and 5B). For this map, details on ranking parameters and weighting scores can be found in Kirch (1997). This approach can be adopted to assess the vulnerability of groundwater to a spill at the surface. The following parameters were reportedly used by Manitoba Conservation in the development of the aquifer sensitivity map:

- Depth to groundwater table and presence.
- Net recharge.
- Presence and kind of aquifers.
- Vadose zone media.

The combination of Maps 2, 4A and 4B with the provincial database of flowing wells (R. Betcher *pers. comm.* 2011) resulted in Map 6, which shows the environmentally sensitive sites within the Local Study Area.

Map 7 shows the locations of selected boreholes relied upon in this assessment. The borehole logs were provided by Manitoba Hydro (Appendix A).

Map 8, which depicts the hydrogeological conditions in the vicinity of the Riel Converter Station and Ground Electrode Site, is the culmination of information obtained from Manitoba Hydro (1995), MMM Group (2011), the Province of Manitoba, NR Can, Manitoba National Resources and Rutulis (1990).

Additional information sources included outcomes of the Aboriginal Traditional Knowledge (ATK) workshops and public consultation process in relation to the groundwater environment. The ATK information gathered was distributed to Stantec by MMM Group and Manitoba Hydro. This information was analyzed for direct and indirect groundwater terms (see Section 3.3). These terms were compared with information from the literature, maps and other sources of information to complete a holistic examination of the area that could potentially be affected by Bipole III.

It is noted that the large scale resolution of the Local Study Area (see Section 2.0) may mean that some small aquifers were not represented and assessed. Where possible, supplemental information for detailed evaluations (e.g., of Environmentally Sensitive Sites) was obtained as described above. Despite this effort, however, there may still be some unidentified small aquifers in the study area (e.g., in areas where groundwater is not presently relied upon). This is an acknowledged data gap which may require resolution during pre-construction activities.

3.2 ROUTE/SITE SELECTION

Manitoba Hydro transmission projects utilize a Site Selection and Environmental Assessment (SSEA) process to better understand the potential issues and concerns associated with the routing and siting of the transmission line and components, to assess the potential for adverse effects and identify appropriate mitigation measures to manage the overall effect of the proposed project on the environment. This process was undertaken for the Bipole III Transmission Line Project.

Groundwater constraints were reviewed for the proposed alternate transmission line routes throughout the alternate routes evaluation process. Groundwater constraints were considered as part of the Soils, Terrain and Groundwater evaluation. As part of this desktop study and evaluation, the major groundwater constraint to the proposed development was identified as Vulnerable Aquifers. This constraint was rated along with Soil and Terrain constraints according to its relative degree of constraint (i.e., Low, Moderate, or High) to the Project, and used to assign an overall degree rating based on a proportional assessment for each segment of the alternate routes. Weighted constraint scoring was then conducted for each segment based on the relative degree of all constraints and the area (hectares) of the constraint, which allowed for meaningful comparison between all segments regardless of length and the three identified alternate routes (i.e., A, B and C). Final ratings for soil, terrain and groundwater constraints were included as part of the overall biophysical team evaluation of the alternate routes.

It was concluded that alternate route B, which generally corresponds to the selected route, was the overall preferred route from a soil, terrain and groundwater constraint perspective.

Of the three alternate routes, route B had the lowest area and proportional area transecting Vulnerable Aquifers (approximately 6,671 ha or 1.1% of the route), while routes A and C had much higher potential for impacts to these features (approximately 31,418 ha or 4.4% of route A and approximately 32,207 ha or 4.9% of route C).

The reader is referred to "*Bipole III Transmission Line Project: Summary Report for the Evaluation of the Alternative Routes – Soils, Terrain and Groundwater*" (Stantec 2010), for more detail on the alternative route evaluation for groundwater constraints.

3.3 ENVIRONMENTAL EFFECTS ASSESSMENT APPROACH

The environmental assessment has been focused on valued environmental components (VECs) selected for the groundwater environment. Valued environmental components are elements of the environment that are considered to have scientific or cultural importance and therefore should be afforded special consideration. VECs were selected based on literature reviews, previous project experience, professional judgment, as well as consultations with stakeholders, and/or Aboriginal Traditional Knowledge (ATK).

With specific respect to ATK, a few comments were made on direct and indirect effects to surface and groundwater quality. There were concerns noted due to run-off from project construction activities and agricultural activities, including comments made on the concern of potential contamination in drinking water wells and associated health concerns. One comment indicated a concern associated with a potential reduced capacity for the environment to naturally filter water. These comments pertained particularly to unconfined, potable aquifers, or in areas where there is potential for contaminant entry into other potable aquifers preferentially via well casings or other preferential flow paths. Comments suggest a concern that the direct effects of the Project on groundwater may be cumulative with effects of other activities.

ATK comments were also made in relation to water quality and were primarily focused on surface water quality. These included reference to the importance of water bodies for transportation, commercial and recreational fishing, recreational activities and general environmental health. Comments were made concerning run-off from agricultural activities, such as the use of agricultural chemicals and feedlot effluent, and effects from other industrial activities/operations that negatively affect the water supply and degrade water quality.

The interconnectivity between surface water and groundwater systems suggest the potential for concerns to groundwater quality. Comments suggest a concern that the indirect effects of the Project on groundwater may be cumulative with effects of other activities.

Aquifer sustainability is important to provide a safe water supply for multiple uses, including: human consumption, agricultural production, recreational uses, and surface water recharge. The maintenance of productivity and quality of groundwater is important to the sustainability of aquifers. Therefore, aquifer productivity and aquifer quality have been identified as Valued Environmental Components. Aquifer quality can be measured through many physical and chemical parameters of groundwater, such as turbidity, pH, redox conditions, and concentrations of major ions, trace elements, and organic contaminants. Measurable parameters of aquifer productivity include, but are not limited to, groundwater levels, hydraulic conductivity, aquifer extents (size, thickness) and aquifer yield.

The environmental assessment considers all physical works and activities associated with the pre-construction, construction, operation, maintenance and decommissioning of Project components. In general, the assessment of potential effects reviewed the different project components and focused on those components having the potential for direct contact or indirect interaction with the aquifers underlying the study area. In addition, this Technical Report considers residual and cumulative effects. An assessment of greenhouse gas effects relative to the groundwater environment was not included in the scope of the work plan.

Potential interactions between Project activities and environmental groundwater indicators were identified using an environmental interaction matrix. The interaction matrix was the basis for identification and evaluation of Potential Environmental Effects.

Mitigation and environmental protection measures to address the potential environmental effects to the groundwater environment have been proposed based on Stantec’s experience and professional knowledge and on standard and precedent Manitoba Hydro protection measures and best management practices (BMPs).

The significance of residual environmental effects, or environmental effects anticipated to remain after the implementation of mitigation measures, were assessed based on eight assessment factors identified below:

- **Direction:** the difference or trend compared with existing or pre-project conditions, assessed as positive, negligible or negative.
- **Ecological Importance:** the rarity, uniqueness and fragility within the ecosystem and importance to scientific studies, assessed as high, moderate or low.

- **Societal Importance:** the value that individuals and/or communities place on components of the affected socio-economic and biophysical environments that are necessary for economic, social and cultural well-being, assessed as high, moderate or low.
- **Magnitude:** the predicted degree of disturbance the effect has on a component of the biophysical or socio-economic environment, assessed as large, medium or small.
- **Geographic Extent:** the spatial boundary where the residual environmental effect is expected to occur, which was assessed as affecting the regional assessment area, local assessment area or project site/footprint.
- **Duration:** how long the predicted residual environmental effect would last, assessed as long-term, medium-term or short-term.
- **Frequency:** how often the predicted residual environmental effect would occur, assessed as regular or continuous; sporadic or intermittent; or infrequent.
- **Reversibility:** how long it would take for the site to be restored to an acceptable condition, assessed as irreversible or reversible.

MMM Group Limited and Manitoba Hydro Licensing and Environmental Assessment staff in conjunction with Stantec will make the final determination of significance based on the information provided in this assessment and consideration of uncertainty and likelihood of occurrence. The outcome will be reported in the EIS summary volume.

The significance of the identified groundwater effects with respect to other components, such as the aquatic and terrestrial environments, will be assessed by those respective groups, again in conjunction with MMM Group Limited and Manitoba Hydro.

4.0 Existing Environment

4.1 GENERALIZED GEOLOGY OF MANITOBA

4.1.1 Bedrock

The proposed Bipole III transmission line preferred linear route will be constructed over the bedrock of the Precambrian Shield and the two large sedimentary basins defined below (see Map 1).

Precambrian igneous and metamorphic bedrock occupies most of northern Manitoba stretching southeast to Ontario (see Map 1). The Precambrian rock generally consists of granites and gneisses of the Churchill and Superior geological provinces. The Precambrian rocks divide two Phanerozoic sedimentary basins occupying the southwestern and northeastern parts of Manitoba (see Section 4.2.2).

In the southwestern part, bedrock belongs to the Western Canada Sedimentary Basin (WCSB; see Section 4.2.1) and consists of Paleozoic, Mesozoic and Cenozoic deposits. Paleozoic rocks are generally carbonates with minor clastics and evaporites, while Mesozoic rocks are dominantly shales with lesser amounts of sandstones, carbonates and evaporites. Paleozoic and Mesozoic rocks dip gently toward the southwest. Cenozoic rocks are found only in the Turtle Mountain area, which is located far from the proposed project.

In the northeastern part of Manitoba, sediments are primarily Paleozoic carbonates that form the Hudson Bay Basin (HBB; see Section 4.2.3). In this basin, sedimentary units gently dip toward to the northeast.

4.1.2 Overburden

In Manitoba, most of the bedrock is covered by overburden consisting mainly of glacial tills, lacustrine sediments and shallow marine deposits. The thickness of the overburden is highly variable from thin sediments and outcrops common in the Precambrian Shield to deposits over 100 m thick in locations of infilled bedrock channels and moraines primarily found in southern and western Manitoba (Betcher *et al.* 1995). In southern Manitoba, the occurrence of aquifers in the overburden has been mapped (see Map 2; Rutulis 1986). As previously indicated, a similar map is, unfortunately, not available for the northern portion of the preferred route.

4.2 REGIONAL HYDROGEOLOGY AND GROUNDWATER USE

4.2.1 Western Canada Sedimentary Basin

General hydrostratigraphic units of the WCSB were proposed by Simpson *et al.* (1987) and updated by Betcher *et al.* (1995). The hydrostratigraphy of the WCSB from Betcher is shown in Table 1 and can be summarized as follows:

- *Basal Clastic Hydrostratigraphic Unit* includes Cambrian and Ordovician sandstones and shales. The sandstone aquifers in these formations are separated from the overlying rocks by an upper shale.
- *Carbonate-Evaporite Hydrostratigraphic Unit* consists of Paleozoic carbonates with minor shales, sandstones and evaporites.
- *Upper Clastic Unit* includes Mesozoic and Cenozoic predominantly; argillaceous sediments forming a regional aquitard.

Betcher *et al.* (1995) indicated that the Upper Clastic Unit also contains distinct strata forming widespread aquifers confined in between shales, such as the sandstones of the Swan River Formation (see Table 1).

The units of the WCSB contain significant regional aquifers, some of which are extensively used through the Province. Particular aquifers occurring in the Local Study Area are described below.

The bedrock of the WCSB is generally overlain by glacial, lacustrine and deltaic Pleistocene deposits and recent alluvial sediments. Glacial and lacustrine sand and gravel deposits contain extensive freshwater aquifers (e.g., Elie, Winkler, Miami aquifers). A number of regional aquifers also occur in sand that was deposited in pre- and post-glacial lakes and rivers (e.g., Assiniboine Delta, Oak Lake, Glenora and Almasippi).

4.2.2 Precambrian Shield

Groundwater resources of the Precambrian Shield in the study area remains unexplored for water resources and aquifers due to sparse population and abundance of surface water sources. However, groundwater exploration in the southeast of the province can serve as a model for the northern reaches of this geologic unit. Sand deposits encountered in the overburden are not well explored for the same reason as Precambrian bedrock, but the presence of local sand and gravel aquifers is expected in coarse glacial deposits such as eskers and moraines.

4.2.3 Hudson Bay Basin

Limited information is available on the basal sandstone separating the Precambrian metamorphic and igneous rock from the overlying Paleozoic carbonates, which form the Hudson Bay Basin. Betcher *et al.* (1995) suggests that the basal sandstone is regionally connected to the carbonate rock and therefore could be considered as a part of the Carbonate-Evaporate Unit. The Carbonate-Evaporate Unit primarily consists of limestones and dolostones of Silurian and Ordovician age containing karst aquifers nearby. These aquifers provide groundwater supply for the Shamattawa community Betcher *et al* (1995). Shallow marine and continental deposits up to 80 m thick overlie the Paleozoic bedrock of the Hudson Bay Basin. The groundwater supply potential of these deposits is not well explored.

4.3 LOCAL HYDROGEOLOGY AND GROUNDWATER USE

4.3.1 HVdc Transmission Lines

The longest portion of the proposed transmission line will traverse bedrock of the Western Canada Sedimentary Basin. Section 1 is located in the area with bedrock aquifers of the Basal Clastic and Carbonate-Evaporite units of the Western Canada Sedimentary Basin separated by a shale aquitard. These units contain Winnipeg Formation sandstone and carbonate aquifers. These aquifers are continuously recharged from sand and gravel directly overlaying the bedrock east of Winnipeg (see Map 5). They are used as a source of domestic, industrial and irrigation water supply east of the Red River (see Map 4A). West of the river, groundwater in the bedrock aquifers is saline and non-potable (Rutulis 1984). The hydraulics and chemistry of the Winnipeg Formation sandstone and carbonate aquifers are discussed in detail by Ferguson *et al.* (2007) and Render (1970), respectively. In some areas, the carbonate aquifer exhibits artesian groundwater conditions (i.e., free flowing wells, see Map 3). Carbonate bedrock is covered by glacial and lacustrine deposits, which contain lenses of sand- and gravel-forming aquifers (Betcher *et al.* 1995). These aquifers contain potable water and have considerable use along Section 1 (see Map 4A).

Section 2 of the proposed transmission line crosses land underlain by bedrock aquifers that are of limited use because the groundwater is generally saline and non-potable (Rutulis 1984). The bedrock is covered by 10 to 30 m of glacial and lacustrine deposits characterized by low permeability. Within the bedrock aquifers, groundwater generally flows to the east and northeast towards Winnipeg. Sand and gravel aquifers are also sparse in this area (see Map 5) and generally follow the recent alluvial deposits along the rivers. Artesian conditions (free flowing wells) have been reported in the eastern part of this Section.

Section 3 traverses an area containing widespread sand and gravel aquifers, including the most eastern part of the Assiniboine Delta Aquifer (see Map 5). These aquifers are extensively used for irrigation, municipal and domestic water supply (see Map 4A; Render 1987).

Sections 4 and 6 of the proposed transmission line transect land that has limited use of bedrock aquifers due to poor groundwater quality. It is noted, however, that some Jurassic rocks of the Upper Clastic Unit produce freshwater southeast of Dauphin Lake (Betcher *et al.* 1995). Regionally, groundwater flows from the Manitoba Escarpment, acting as a recharge zone, towards the shores of Lake Manitoba and Lake Winnipegosis. Several saline springs are documented along the shores of these lakes (see Map 3; Rutulis 1985). In this area, bedrock is primarily covered with less than 10 m of overburden, which contains lenses of sand and gravel (see Map 5). Good quality water is generally found in the shallow alluvial and beach deposits (Little 1973a).

Section 5 of the route will partially cross the sandstone aquifer of the Swan River Formation, which belongs to the Upper Clastic Unit of the WCSB. There are several hundred wells completed in this aquifer that are used for domestic and farm-water supply regardless that the concentration of Total Dissolved Solids (TDS) is high, often exceeding 3 g/L (Betcher *et al.* 1995). Three communities using the aquifer for municipal water supply rely on desalinization by reverses osmosis. Section 5 also crosses an area with a buried sand and gravel aquifer (see Map 5).

Section 7 of the proposed transmission line will transect Ordovician and Silurian carbonates, which have karst aquifers near the bedrock surface (Little 1973b). These aquifers are used for domestic and municipal supply in The Pas area (see Map 4A). Characteristics of these aquifers are similar to the carbonate aquifer in the vicinity of Section 1 described above. Flowing wells or artesian conditions were documented in the northern part of this section. Shallow sand and gravel aquifers are not well explored in the area (see Map 5).

Section 8 of the transmission line will cross the area occupied by Precambrian igneous and metamorphic rocks (see Map 1). As mentioned above, this area is sparsely populated and abundant in surface water resources. Therefore, exploration of groundwater resources is limited.

Section 9 is located over the sedimentary bedrock of the Hudson Bay Basin (see Map 1). As previously indicated, the bedrock here primarily consists of limestones and dolostones of Silurian and Ordovician age containing karst aquifers nearby (Betcher *et al.* 1995, Stantec 2009). Information has been gathered in relation to the bedrock aquifer (see Section 4.3.2); however, little is known about the groundwater resources contained in the overburden.

4.3.2 Northern Construction Camp

The construction camp will be located within Section 9 and the carbonate rocks of the Hudson Bay Basin. Groundwater investigations in the vicinity of the camp indicate that the carbonate bedrock beneath this area contains a potable aquifer which could serve as the main source of groundwater supply for the construction camp and the Keewatinoow Converter Station. The bedrock aquifer has a high permeability but is also hydraulically connected to the Nelson River (KGS ACRES 2008). Piezometric levels in the aquifer are a few meters above bedrock surface. The bedrock is overlain by a thick (approximately 60 m) layer of overburden with recorded hydraulic conductivities between 10^{-4} m/s (river alluvium) and 10^{-6} m/s (till and lower postglacial sediments; KGS ACRES 2008).

A chain of granular deposits have been explored along the proposed Conawapa Generating Station road (see Map 7). In these deposits, the sand and gravel extends up to approximately 10 m below ground surface and is separated from the carbonate aquifer by a thick layer of till (see Borehole Log OW2 in Appendix C). Data on the groundwater quality of any shallow or perched aquifers within the overburden are not available.

4.3.3 AC Collector Lines and Construction Power Lines

The local conditions at the AC Collector Lines and Construction Power Lines are expected to be similar to conditions at the construction camp site due to proximity of these components of the Project (see Section 4.3.2 and Map 7). The overburden may be thicker because ground elevations along the proposed line routes are higher than ground elevations at the construction camp while bedrock elevations are not expected to change significantly between the two areas. Ongoing investigations along the line routes will confirm expected hydrogeological conditions prior to construction.

4.3.4 Keewatinoow Converter Station and Ground Electrode

Hydrogeological conditions at the Keewatinoow Converter Station and Ground Electrode Site are expected to be similar to conditions at the construction camp site due to proximity and similar geomorphologic setting of these components (see Section 4.3.2). Shallow borehole logs indicate that there are sand deposits in the northeast corner of the electrode site and north of the converter station. Ongoing exploration for the converter station water supply investigations is expected to provide further information regarding the hydrogeological conditions of the aquifer prior to construction.

4.3.5 Riel Converter Station and Ground Electrode

The hydrogeology at the Riel Converter Station and Ground Electrode Site is generally similar to that described for Section 1 of the transmission line (see Section 4.3.1 and Map 8). The Winnipeg Formation sandstone and carbonate aquifers are encountered beneath these sites. The upper carbonate aquifer used for local groundwater supply for domestic and agricultural/livestock supply. The carbonate aquifer is overlain by 10-20 m of clay at the Ground Electrode Site and 20-30 m of clay at the Converter Station Site (Rutulis 1990). Flowing wells have been documented at the Ground Electrode Site indicating the presence of artesian groundwater conditions.

4.4 ENVIRONMENTALLY SENSITIVE SITES

A summary of sensitive groundwater sites/areas (ESSs) is provided in Table 2. As previously indicated, Map 6 provides an overview of the location and extent of these identified areas.

As noted in Section 3.0, aquifer vulnerability was assessed using the map developed by Manitoba Conservation for the assessment of aquifer sensitivity to contamination from underground petroleum tanks (see Maps 5A and 5B). This approach can be adopted to assess the vulnerability of groundwater impacts to a potential contingency event (e.g., a surface spill; an identified ATK concern). It is noted that the results of the vulnerability analysis should be considered with caution, because it is biased by parameter weighting and limited to a regional scale and therefore may not resolve local sand and gravel aquifers up to 5 km long or wide.

The most sensitive areas to potential groundwater impacts are located in Section 1 and most of Section 7 of the preferred transmission line route (see Map 6). The sensitivity in these locations is related to unconfined aquifers. Sections 2, 3 and 4 of the proposed transmission line will go over land that has a moderate sensitivity to aquifer contamination. Moderate and low sensitivity classes can be found along Sections 5 and 6 of the preferred route. The northern portion of the transmission line (Sections 8 and 9), and the Keewatinoow Converter Station, are located in areas of low sensitivity to groundwater contamination.

Other environmentally sensitive areas are related to areas where artesian groundwater or springs have been identified (see Maps 3 and 6). ATK was an additional source of information with respect to small salt lakes with a connecting aquifer. The areas with known saline springs are further considered particularly sensitive due to the potential effect that could result from an unintended discharge of saline groundwater to the surface environment (e.g., Section 6 crosses the area between Red Deer Lake and Dawson Bay where saline springs have been documented [Rutulis 1985]; see Map 3).

5.0 Bipole III Project Description Overview

5.1 PROJECT COMPONENTS

The major components of the Bipole III Project are:

- A 500 kV HVdc transmission line.
- A new northern Converter Station, the Keewatinoow Converter Station, to be located near the proposed site of the Conawapa Generating Station including a construction camp and construction power.
- A new southern Converter Station located at the Riel site in the Rural Municipality of Springfield including construction power.
- New 230 kV transmission lines linking the Keewatinoow Converter Station to the northern collector system at the existing 230 kV switchyards at Henday Converter Station and Long Spruce Generating Stations.
- New ground electrode sites for each Converter Station, connected to the station by a low voltage feeder line.

5.1.1 500 kV HVdc Transmission Line

The Bipole III 500 kV HVdc transmission line will originate at the Keewatinoow Converter Station and terminate at the new southern Converter Station on the Riel site. The overall length of the line is about 1376 km located on a 66 m wide right-of-way.

Two basic tower types will be used for the straight line sections of the transmission line. In northern Manitoba and forested/pasture areas in the south, the line conductors will be suspended from guyed lattice steel towers. In the more densely developed areas of southern Manitoba, self-supporting lattice steel towers will be used to minimize potential effects on farming practice (i.e., to reduce the tower footprint) and to reduce the land acquisition requirement. Typical tower dimensions will be 45 m in height with a 7.8 m square base footprint for self-supporting towers. Towers will be spaced approximately 480 m apart in most areas.

Prior to construction, the right-of-way and required easements will first be surveyed and flagged to establish the line alignment. Clearing and disposal of trees on the proposed right-of-way will be undertaken in advance to facilitate construction activities.

Subsurface disturbance will include pre-construction geotechnical drilling and installation of foundation and piles for the towers. The typical depth of excavated tower footings ranges from 3 to 5 m or up to 10 m if steel tubular towers are used (MMM Group 2011). The deepest concrete pile foundations will be primarily augured and cast-in-place extending up to approximately 45 ft. (13.7 m) below the ground surface. These deeper pile foundations will be predominantly used in southern Manitoba (in the north, bedrock foundation conditions will allow use of reinforced concrete pedestal foundations that will be directly affixed to the rock with steel dowels).

5.1.2 Keewatinoow Converter Station and Ground Electrode Facility

The new Keewatinoow Converter Station will be located about 5 km southwest of the proposed Conawapa Generating Station site on the Nelson River (Map 6). The principal components of the Converter Station are a converter building, a high-voltage ac switchyard and a high voltage dc switchyard required to terminate the 230 kV transmission line connections to the northern collector system, to convert the ac power from the collector system to dc power, and to provide the HVdc switching facilities necessary for termination of the new Bipole III transmission line. The Converter Station site is estimated to require a roughly rectangular site area, approximately 500 x 600 m in dimension for a total area of 24.5 hectares.

Construction activities for the Converter Station development will typically involve site preparation (e.g., removal of existing vegetation and organic topsoil from the site; addition and compaction of inorganic fill material, installation of station surface material) and initial infrastructure development (e.g., installation of station access roads and associated drainage, followed by installation of perimeter fencing and gates). Once general site improvements have been completed, other necessary civil works and systems will be installed (e.g., foundations for building and equipment, grounding arrangements, water supply, oil spill containment, site services and buildings). Station apparatus and equipment installation will follow, including filling of equipment with insulating oil, construction clean-up and commissioning.

The ground electrode required for the Converter Station will be located approximately 10 km south of the Converter Station site on the west side of the Conawapa access road. On the assumption of a shallow land ring electrode (similar to the electrodes used at the existing Henday and Radisson Converter Stations), the electrode will be a buried iron ring approximately 800 m in diameter and will be sited within a planning area in the order of 4 km^2. There will also be an access trail for construction and ongoing maintenance, and a low voltage (12 kV) overhead electrode line between the ground electrode site and the Converter Station. The low voltage line will be supported on guyed single wood poles and routed along an existing right-of-way originally cleared for Conawapa construction power but never used.

A temporary start-up work camp will be established at the proposed Conawapa Generating Station site and a longer-term work camp near the Keewatinoow Converter Station site to house workers involved in the construction of the converter station and ground electrode.

Construction power for the construction camp, Converter Station and electrode site will be provided by extending the existing 138 kV transmission line that runs from Kelsey Generating Station to the Limestone construction power substation about 31 km to a new construction power substation located near the Keewatinoow Converter Station site.

5.1.2.1 Connections to the Northern Collector System

The proposed connections include one 230 kV transmission line about 55 km in length, from the existing 230 kV switchyard at Long Spruce Generating Station to a new 230 kV switchyard to be developed at the site of the new Keewatinoow Converter Station. In addition, four 230 kV transmission lines, each about 27 km in length, will be constructed from the existing 230 kV switchyard at Henday Converter Station to the new 230 kV switchyard at the new Keewatinoow Converter Station. The lines will share a common right-of-way 310 m in width. Guyed lattice steel towers will be used for the collector lines.

5.1.3 Riel Converter Station and Ground Electrode Facility

The new southern Converter Station will include the HVdc switchyard facilities necessary to terminate the new Bipole III transmission line, together with the converters and the ancillary facilities required to convert the dc power from the Bipole III transmission line to ac power at the 230 kV level necessary for injection into the southern receiving system. The southern Converter Station will be located at the existing Riel station site in the RM of Springfield, just east of Winnipeg, which is now under construction for sectionalization purposes. Site development under the sectionalization project will include the portion required for the Converter Station site.

Construction activities for the Converter Station development will involve necessary civil works and installation of systems (e.g., foundations for building and equipment, grounding arrangements, water supply, oil spill containment, site services and buildings). Station apparatus and equipment installation will follow, including filling of equipment with insulating oil, construction clean-up and commissioning.

The ground electrode required for Riel Converter Station will be located approximately 20 km from the station site. On the assumption of a shallow land ring electrode (similar to the electrodes used at the existing Henday and Radisson Converter Stations), the electrode will be a buried iron ring approximately 500 m in diameter and will require a site area in the order of one mile square, together with an access road for construction and ongoing maintenance. There will also be a low voltage line connection between the ground electrode site and the Converter Station. The line will be an overhead line supported by single wooden poles routed on a right-of-way on Manitoba Hydro property or within existing road allowances.

Construction power from the Riel sectionalization portion of the Riel station will be used for the Riel Converter Station and electrode site.

The existing infrastructure at the Riel Station site currently relies on connection to City of Winnipeg water distribution and sewer system.

5.1.3.1 Connections to the Southern Receiver System

The Bipole III transmission line terminates at the Riel Station converter site, where the connections to the southern receiver system occur. The southern receiver system, serving Winnipeg and southern Manitoba, is fed from a network of 230 kV transmission lines originating at Dorsey Station and at a number of existing substations in the Winnipeg area. The Riel Sectionalization project includes sectionalization of several of these existing transmission lines, in order to enable injection of power from the sectionalized D602F at Riel. Although the resultant capacity of the 230 kV connections at Riel facilitates injection of power from Bipole III, additional transmission capacity will be required. The additional capacity will be provided by sectionalization of the existing Ridgeway-Richer 230 kV transmission line R49R at Riel Station.

5.2 PROJECT COMPONENTS LIKELY TO INTERACT WITH THE GROUNDWATER ENVIRONMENT

All of the major components of the Bipole III Transmission Project discussed in the preceding sections were initially considered at the commencement of the groundwater assessment. A number of the Project components were subsequently deemed to have no effect on the groundwater environment due to their surficial or wholly aboveground nature. For example, the existing infrastructure at the Riel Station site currently relies on surface water resources provided by Deacon Reservoir and it is understood that this will not change with the proposed addition of the Converter Station infrastructure at this location. Accordingly, an assessment of the effect of the operation of the proposed Riel Converter Station on groundwater was determined to not be required.

The Project components that were determined to have the potential to directly contact or potentially interact with the groundwater environment included:

- Bipole III transmission line – foundations and vegetation control.
- Keewatinoow Converter Station – groundwater supply and septic lagoon requirements.
- Keewatinoow and Riel Ground Electrode Facilities–electrode maintenance requirements.
- Construction Work Camp - groundwater supply.

Other proposed Project components are generally land-based or surficial in nature and will not contact or interfere with the existing groundwater regime. The only aspect of the other components that could potentially affect the groundwater regime is any excavation for a Project component foundation but based on the Project Description information reviewed (MMM Group 2011); these foundations are shallow and not predicted to interfere with the identified major aquifers.

These Project components became the focus of the assessment and the nature, extent and significance of any potential for physical disturbance of groundwater resources and/or reduction of groundwater quality has been explored in Section 6.0.

5.3 PROJECT ACTIVITIES LIKELY TO INTERACT WITH THE GROUNDWATER ENVIRONMENT

Project activities that have the potential to directly contact or potentially interact with the groundwater environment have also been identified (Table 3). The activities are generally associated with pre-construction geotechnical work and foundation excavation/installation. Activities associated with using heavy equipment (e.g., for clearing, installing anchors and grading) and the handling and storage hazardous materials have the potential to interact with the groundwater environment but only if a contingency event occurs (see Section 6.0).

6.0 Environmental Effects Assessment

The following is a description of potential direct and indirect environmental effects and proposed mitigation measures identified for the Project. The methods applied for the effects assessment are described in Section 3.0.

Sections 5.2 and 5.3 present the Project components and activities likely to interact with the groundwater environment and, as indicated, form the basis for the assessment of potential Project effects (see Table 3). For the further purpose of focusing the environmental effects assessment and mitigation determination, environmental sensitive areas/sites (ESSs) were identified, and are presented in Section 4.4 and Table 2.

An interaction matrix between Project phases and associated activities and groundwater environmental components is provided as Table 4. This interaction matrix was used to identify potential effects and provide mitigation measures, which are summarized in Table 5 and discussed in Section 6.1. It is noted that some of similar activities have the same effect regardless of the stage or component of the Project (e.g., refueling). These common components are discussed together below.

Proposed mitigation and environmental protection measures are provided in sequence with the presentation of potential effects for ease of identifying residual effects (Section 6.3) and follow-up/monitoring requirements (Section 6.4).

6.1 POTENTIAL PROJECT EFFECTS AND MITIGATION

The potential effects of the proposed Bipole III Transmission Line Project can be divided into two categories corresponding to the groundwater VECs as follows:

- Potential effects to aquifer quality.
- Potential effects to aquifer productivity.

Each category includes effects under normal construction and operation and contingency events (see Table 5).

6.1.1 Potential Direct and Indirect Aquifer Quality Effects

In general, aquifer quality is not expected to be affected under normal conditions of construction and operation of the proposed Bipole III transmission line and associated infrastructure. The potential effects on aquifer quality from the Project are discussed below.

6.1.1.1 Pesticide and Herbicide Application

Manitoba Hydro will apply herbicides along the transmission line and at electrode and station sites for vegetation management. Under normal application conditions, most of these chemicals should degrade within the vadose zone (i.e., unsaturated zone above the water table). In the event of a spill or improper application, the potential exists for entry into the aquifer resulting in an indirect effect (groundwater contamination) and exceedances of the stipulated herbicide regulatory guidelines (e.g., CCME 1999).

There are federally approved and registered products specifically designed for right-of-way vegetation control situations. Manitoba Hydro must apply each year to Manitoba Conservation for “Pesticide Use Permits” issued under the Manitoba Environment Act before any herbicide program is implemented. The Province of Manitoba decides which herbicide products can be used in Manitoba and under what conditions they may be used. The Province also sets guidelines for the rates at which products may be used, how and when they may be applied; and where they may not be used, such as environmentally sensitive sites. In areas where herbicides are prohibited, alternate vegetation control measures are implemented (e.g., mechanical methods).

Direct supervisors of herbicide applicators working for Manitoba Hydro on Manitoba Hydro rights-of-way must be trained and licensed by the Province before applying herbicides. Manitoba Hydro must also provide a “Post Seasonal Report” to Manitoba Conservation, providing specific information on the work that was done including the herbicide products used, respective quantities, specific application locations, applicator(s) name and other information as required by the Province. These Regulatory requirements of Canada and Manitoba are in place to ensure only approved herbicides are used safely and properly.

With all the above mitigation measures in place, there are no anticipated residual effects from pesticide and herbicide applications.

6.1.1.2 Leachate from Septic Lagoon

The Project will require the construction of septic lagoons, for the Construction Camp and the Keewatinoow Converter Station, to treat domestic wastewater. The locations of these lagoons are still being investigated and will be the subject of separate licensing. With proper design and normal operation (in compliance with the license), the rates of leachate migration to groundwater should be low, providing protection to the aquifer from pathogens and providing for sufficient time for attenuation and dilution of contaminants (specifically nitrogen and phosphorous).

The main mitigation measures that will be employed to minimize or preclude any potential indirect effects on aquifer quality associated with the septic lagoons will include:

- Siting the lagoons on low permeability soils.
- Designing and operating the lagoons in accordance with the issued licence(s).
- Regular maintenance and inspection of the lagoons.
- Constructing a backup cell to allow repair/overflow of main cell, as required.

Based on the above mitigation measures, there are no anticipated residual effects under normal operation conditions. Potential groundwater contamination with nutrients and bacteria could occur in the event of a contingency event involving a substantial breach of the septic lagoon containment. The residual effect of such an event is discussed in Section 6.2.2.

6.1.1.3 Leachate from Coke Used for Electrode Sites

The metallic electrode will be buried approximately 3-4 m deep (below the normal frost penetration line) and connected to a central terminal house by a system of underground feeder cables (MMM Group 2011). The ring itself is likely to be an iron rod, approximately 4 cm (1.5 in.) in diameter in a high grade coke (relatively pure carbon) bed with a cross section of about 80 cm (2 ft.) square. The surface above the ring will be dished to collect as much rain water as possible.

Ground electrode locations were selected to facilitate adequate soil moisture conditions. They will, however, be equipped with underground irrigation systems fed from wells located on site to facilitate maintenance of adequate moisture conditions during periods of dry soil moisture conditions (see Section 6.1.3). The requirement for the coke beds to be kept saturated may cause any naturally occurring components in this material to leach which could directly affect groundwater quality.

The specific chemical composition of the ground electrode coke was not available at the time of this assessment, nor was any information on the level of leaching from existing ground electrodes (e.g., Henday, Radisson). Therefore information on petrochemical coke and coke leachate was gathered from studies examining the use of petrochemical coke in oil sand wetland remediation. In a leachate study, Puttaswamy *et al.* (2010) observed metal concentrations in leachate substantially lower than maximum acceptable concentrations for drinking water (e.g., Health Canada 2010), however at concentrations that could pose toxicity concerns for aquatic organisms when dilution is not considered. Preliminary estimates indicate that a 10x reduction in the concentration of the contaminants is required to have no significant toxicity effect on *Ceriodaphnia dubia*, based on these studies. Within *in-situ* experiments, metal concentrations were often not found to be significantly elevated however, likely due to the metals being taken up by organic and inorganic constituents (peat, naphthenic acids and other dissolved organic carbon species) (Squires 2005, Baker *et al.* 2007, Baker *et al.* 2008). Minute to no levels of polycyclic aromatic hydrocarbons were found in coke leachate (Squires 2005). It should be noted that these studies looked at the effects of an entire layer of coke under a wetland, as opposed to the relatively discrete use of coke in ground electrodes.

There is limited concern for the entry of contaminants to the potable aquifer at the preferred southern electrode site, due to a 10 to 20 m clay layer that underlies the site and acts as a barrier, and an apparent upward hydraulic gradient the offers further protection against the downward migration of contaminants from the surface to the aquifer (Rutulis 1990).

At the northern electrode site, the potable bedrock aquifer is covered by approximately 60 metres of till overburden, which provides good protection to the underlying bedrock aquifer from downward migration of leachate. There is, however, the potential that leachate will migrate downwards from the surface at this site, reach the low permeability till layer, migrate laterally to the east and seep out on the Nelson river bank, potentially reaching an aquatic receptor. A dilution will occur in this situation, reducing the potential effect to the aquatic environment, however the actual dilution in the subsurface environment will depend on irrigation rates and local groundwater flow under the site, which are currently not well understood.

The following activities will be conducted to minimize or preclude impairment of aquifer quality at the ground electrode sites and associate lines right-of-way:

- Ground electrode irrigation will only be conducted during dry soil conditions and in amounts not exceeding what is required to maintain saturated soil conditions.
- Groundwater quality monitoring will be established at or downgradient from the northeast corner of the preferred northern electrode.

Based on the available data and mitigation measures, there are no anticipated residual effects.

6.1.1.4 Groundwater Withdrawal

Groundwater withdrawal will be required to provide water resources for both the proposed Bipole III construction camp and the Keewatinoow Converter Station (see Section 6.1.2.1). Existing groundwater quality information for the area of the proposed northern work camp and Converter Station were obtained from KGS ACRES (2008; in relation to proposed Conawapa Generating Station). In its investigation, KGS ACRES reported (2008) the following:

- Overall, water quality from the production well during the 72 hour test met most of the Health Canada Guidelines for Canadian Drinking Water Quality, with the exception of:
  - Some aesthetic objective exceedances for hardness, iron and TDS.

  - Turbidity values, which were approximately 2 to 3x the acceptable aesthetic objective and ~10x the maximum acceptable concentration. Turbidity concentrations, however, were expected to decline with further development of the well.

  - Trihalomethane (THM) formation potential, which was approximately 3 to 10x greater than the currently proposed Health Canada total THM maximum acceptable concentration.

- Although the bedrock aquifer and the Nelson River are hydraulically connected, the key groundwater quality parameters (e.g., sodium, chloride, TDS, electrical conductivity, alkalinity, and hardness concentrations) remained basically unchanged and distinct from the Nelson River throughout the 72-hour pumping test. However the wells should be considered groundwater under the direct influence (GUDI) of surface water (KGS ACRES 2008) because they will be used for long term continuous water supply that could draw Nelson River water towards (and into) the well over time. Long-term monitoring of water quality should be required to ensure that any changes at the camp that may be related to the influence of Nelson River water be addressed by the water treatment process (KGS ACRES 2008).

Consistent with KGS ACRES’ recommendations, to ensure potable water is being provided at the construction camp and Converter Station, regular potability testing will be undertaken with results compared to the most current Canadian Guidelines for Drinking Water Quality. Surface water will be prevented from draining into the well by grouting the annulus of the well casing to the surface. The well head will be a minimum of 30 cm above ground, be above the 100 year flood level and be mounded to direct drainage away from the well. Wells will be capped, secured and either sealed or vented. Well(s) will further be marked and protected from vehicle or equipment effects. Based on these mitigation measures, there are no anticipated residual effects.

6.1.1.5 Construction Material Usage

Construction materials for the proposed Project development will generally be sourced locally. Development of the Riel Station and southern portion of the transmission line will use borrow materials transported by the contractor from established and appropriately licensed sources off-site (MMM Group 2011). Excavation of borrow materials, such as sand and gravel, for the other components will be generally limited to the area of the proposed Bipole III construction camp and the Keewatinoow Converter Station. In this area, the major bedrock aquifer is separated from the surface by a thick overburden layer. This cover provides good protection from surficial disturbance even with the proposed borrow excavations. Sand and gravel aquifers are not explored in the area, but small (less than 0.5 km^2) might be associated with the granular deposits. The excavation of borrow materials, however, is unlikely to result in the exposure of any perched water table (KGS ACRES 2008).

For the ground electrodes at the northern and southern Converter Stations, coke will be required. This is the only construction material that appears to have the potential to indirectly affect aquifer quality as already discussed in Section 6.1.1.3.

Based on normal procedures, there are no anticipated residual effects of construction material use on aquifer quality.

Construction activity within the in borrow pits involves frequent machinery use and increases risk of hydrocarbon spills, which are discussed under contingency events in Section 6.1.1.6 and Table 5.

6.1.1.6 Contingency Events

Hazardous waste is handled and generated in the normal course of construction and operation. Wastes that are classified as hazardous present a greater danger to human health and the environment than other waste material as a result of their specific chemical, physical and biological properties. Examples of some common types of hazardous wastes expected to be handled or generated during the construction and operation of the Project include, but are not limited to: fuel, oil, lubricants, solvents, herbicides, pesticides, etc.

As with any project involving construction and long term operation, there is a risk of contingency events such as spills or malfunctions. With respect to the proposed Bipole III Project, there are a number of different stages and components of the Project wherein this risk exists and depending on the nature and magnitude of the contingency event, there is a resulting potential for an indirect effect on aquifer quality.

As discussed in Section 4.4, the most sensitive areas to potential groundwater impacts from any contingency event are located in Section 1 and most of Section 7 of the preferred transmission line route according to the Aquifer Vulnerability to Contamination Maps (i.e., Maps 5A and 5B. The sensitivity in these locations is related to the connection between the potable carbonate aquifer and the overlying shallow sand and gravel aquifers wherein the shallow aquifer is the recharge zone for the deeper aquifer.

Manitoba Conservation’s Hazardous Waste Program administers the regulations pursuant to *The Dangerous Goods Handling and Transportation Act* that sets out requirements pertaining to the handling, generation, transportation and disposal of hazardous waste. The hazardous waste legislation establishes a system of controlling hazardous waste from ‘cradle to grave’ (i.e., from the point at which it is generated to the point at which it is converted into a non-hazardous substance, recycled or otherwise disposed of safely). The management system for hazardous waste involves the registration of hazardous waste generators, and the licensing of hazardous waste carriers and hazardous waste receivers. The hazardous waste movement document/manifest (a special shipping document for hazardous waste that is completed by the generator, carrier and receiver of the waste) provides the means for tracking the movement of hazardous waste.

Mitigation measures that will be in place to minimize or preclude any groundwater effects associated with contingency events can be summarized as follows:

- Fuel, lubricants and other potentially hazardous materials will be stored and handled within dedicated areas at work sites and marshalling yards in full compliance with regulatory requirements.
- Marshalling yards will be located on low permeability soils, where possible.
- Transfer of fuel will be attended at all times.
- An Emergency Preparedness and Spill Response Plan will be developed and an emergency response spill kit will be kept on-site at all times in case of fluid leaks or spills from machinery.
- Hazardous materials, fuel containers and other materials will be removed from the site for proper disposal in accordance with regulatory requirements.

The residual effects of contingency events are anticipated and discussed in Section 6.2.

6.1.1.7 Interconnection of Aquifers

Normal pile construction procedures may intercept an aquifer but are not expected to negatively affect groundwater resources in terms of either flow or quality. In areas with artesian (free flowing) wells or springs (see Maps 3 and 6), however, there is a potential the risk of interconnection (or surface discharge; see Section 6.1.4) via pre-construction (specifically geotechnical drilling) or construction (foundation installations) boreholes if they are not sealed properly or quickly enough. In this situation, groundwater from a more pressurized aquifer will intrude into a less pressurized one resulting in groundwater chemistry changes. Intrusion of saline water into a freshwater aquifer may result in the local loss of groundwater resources. The areas with known saline artesian wells or springs are considered to have a higher risk of such an event (see Map 3).

The following activities will be conducted to minimize or preclude aquifer interconnection (or surface discharge) during drilling and foundation installations in areas of documented springs and artesian groundwater conditions:

- A qualified driller with appropriate experience will be contracted to work in areas affected by artesian conditions.
- Emergency response plans for sealing/grouting and pumping will be implemented as required.
- Follow up inspections of installed foundations will be undertaken to monitor for excess moisture.

The interconnection of aquifers is considered as a contingency event, which may result in a residual effect as discussed in Section 6.2.2.

6.1.2 Potential Direct and Indirect Groundwater Productivity Effects

6.1.2.1 Groundwater Withdrawal

Groundwater withdrawal will be required to provide water resources for both the proposed Bipole III construction camp and the Keewatinoow Converter Station. As previously indicated, engineering designs for the groundwater withdrawal are underway. In the absence of available information/data, the following assumptions have been made to allow a preliminary assessment of Project effects:

- Groundwater will be withdrawn from the bedrock aquifer underlying both proposed sites.
- The proposed Bipole III construction force will consist of a start-up camp and a main camp having capacities 350 and 550 persons, respectively. The camp will be located in the vicinity of the proposed Conawapa Generating Station (MMM Group 2011).
- The expected staff requirement for the Keewatinoow Converter Station is 42 people (MMM Group 2011) and its location has been selected to be about 2.5 km southwest of the camp (see Map 7).
- Approximately 230 L/person/day will be required based (Manitoba Hydro pers. comm. 2011).
- In addition to daily workforce consumption requirements, estimates for groundwater withdrawal should also include fire protection provisions.

The 1992 drilling program and the 2006 Conawapa Generating Station investigation (KGS ACRES 2008) indicated that the confined bedrock aquifer in the area could be the main source of groundwater supply for the proposed Conawapa Generating Station camp, which had a 2500 person estimated workforce (MMM Group 2011). The bedrock aquifer has a high permeability, is hydraulically connected to the Nelson River, and is overlain by a thick (between 60 and 80 m) low permeability confining overburden till layer (see sample borehole logs provided in Appendix A). Accordingly, there are no expected issues of reduced groundwater discharge to local streams (springs) from drawdown due to the till overburden depth. The transmissivity values in the bedrock aquifer range between 12,000 USG/day/ft. to 37,000 USG/day/ft. For the purpose of this assessment, a slightly lower-than-average transmissivity value of 20,000 USG/day/ft. was utilized.

Drawdown curves were estimated based on the rate used in KGS 2008 (even though KGS' rate was developed for a larger workforce). KGS indicated the water supply would be 24 L/s and did their pump test at 28.5 L/s (2,500,000 L/day). On this basis, the drawdown was estimated to range from less than 9 m (in the immediate vicinity of the supply well) to less than 2 m at 150 m distance away from the well. The influence of the cone may be measurable as far away as 2 km, however there are no known groundwater users within this radius (GWDrill 2010). This direct disturbance will persist through the construction stage. In the operation stage, water demand will drop due to decommissioning of construction camp and significant reduction of drawdown cone size. The time to recovery, which was also estimated, indicated that the piezometric head drop at the work camp would recover to original levels within several days of pumping cessation.

The estimated groundwater supply for Keewatinoow Converter Station is 6480 L/day serving approximately 60 people (MMM Group 2011). The groundwater supply investigations are focused on bedrock aquifer. Taking into account results of the aquifer tests (KGS ACRES 2008) for the proposed construction camp and low withdrawal rates relative to the test, measurable changes of groundwater levels is expected only within a few meters from the supply well.

Anticipated residual effects of groundwater withdrawal are discussed in Section 6.2.

6.1.3 Irrigation of Ground Electrodes

The details regarding the ground electrodes are provided in Sections 5.1.3 and 6.1.1.3. The location of ground electrode sites have been selected such that soil moisture conditions are favourable for electrode operation, and, when required, irrigation will only be used to wet the immediate area around the electrode. As such, it is anticipated that irrigation requirements will be minimal. Accordingly, it is anticipated that the quantity of groundwater required for supplemental irrigation of electrodes will be minimal, and the disturbance to the underlying aquifers is not anticipated. No residual environmental effects are anticipated.

6.1.4 Aquifer Disturbance Due to Unintended Discharge

In areas with artesian (free flowing) wells or springs (see Map 3), the potential exists for pre-construction (specifically geotechnical drilling) or construction (foundation installations) disturbance to result in a direct groundwater discharge to the surface or to another aquifer through boreholes. In the event of such an unintended groundwater discharge to the surface, there is a potential for a local drop in the aquifer level and/or an effect on the surficial environment.

In the unlikely event of a substantial drop in groundwater levels, productivity of the aquifer and local groundwater users could be affected. Mitigation measures minimizing the potential for any change in aquifer productivity are identical to the ones described in Section 6.1.1.7. As previously noted, follow up inspections of installed foundations will also be undertaken to monitor for excess moisture. Aquifer disturbance due to an unintended discharge and effects on the surficial environment is considered as a contingency event, which may result in a residual effect as discussed in Section 6.2.2.

6.2 RESIDUAL EFFECTS

An assessment of the significance of anticipated residual effects to the groundwater environment, based on proposed mitigation measures, is presented in Table 6 and discussed below.

6.2.1 Normal Construction and Operation

Following the implementation of the mitigation measures proposed, the residual effects under normal construction and operation appear to be solely related to groundwater withdrawal at the northern construction camp and the Keewatinoow Converter Station. As previously indicated, withdrawal will create a depression cone around each of the proposed supply wells. Due to the larger demand, the greater cone of depression will occur during the operation of the supply well for the construction camp (in comparison with the northern Converter Station). This residual effect is considered to be negative in direction, of low ecological and societal importance, medium term in duration, small in magnitude, confined to the Project site or footprint, occur on a regular/continuous basis, and are reversible during the life of the Project. The residual effect is, therefore, considered to be insignificant.

6.2.2 Contingency Events

Concerns regarding contingency events were raised within the ATK comments received. In the event of a major contingency event, residual groundwater effects (i.e., hydrocarbon or herbicide impacts) may occur depending on the ability for an immediate remedial response.

The directions of these effects are considered to be negative with respect to water quality but expected to be localized due to the Emergency Preparedness and Spill Response Plans that will be in effect. The effect is considered to be medium in magnitude and moderate in both ecological and societal importance. An organic compound groundwater impact is reversible in character due to natural degradation of the contaminants.

Potential groundwater contamination with nutrients and bacteria could also occur in the event of a substantial breach of septic lagoon containment. The residual effect is considered to be negative in direction and be medium magnitude and moderate in both ecological and societal importance. The magnitude of the impact may range from low to medium. The footprint of the impact is localized to the size of the lagoon. The impact assumed to be short-term in duration and sporadic in frequency. Aquifer quality will be eventually restored to the natural conditions and therefore the impact is considered to be reversible.

Lastly, in the event of an interconnection of the aquifers or an unintended groundwater discharge to the surface, the residual effect would be negative in direction and could impact the surface and/or subsurface environments. The surficial discharge may have high ecological and social importance depending on the quality and quantity of the discharging/intruding groundwater and the effect may range from low to high in magnitude. The geographic extent would likely be localized and the impact is considered to be short-term and sporadic. Reversibility of the impact would be dependent on the quality and quantity of the discharging groundwater. Saline groundwater discharges could also directly or indirectly affect other local environments (e.g., terrestrial/soils) and these effects could potentially outlast those to the groundwater or surface water environments. Through the identification of environmental sensitive sites and the adherence to drilling protocols including groundwater monitoring, the likelihood of an unintended discharge is considered low, and therefore the residual effect is not anticipated to be significant.

6.3 FOLLOW-UP/MONITORING

During regular or periodic inspection of the towers and foundations, reporting of visual changes in soil moisture, swamping and spring appearance in areas of artesian aquifers will be conducted. Assuming normal construction and operation of the towers, no other follow-up or monitoring of the existing groundwater regime appears warranted.

Monitoring of bacteria and nutrient (nitrogen and phosphorous species) concentrations in groundwater upstream and downstream of the lagoon will be done for license compliance as well as to ensure any lagoon integrity issues are quickly identified and remedied.

Groundwater level and water quality monitoring will accompany groundwater withdrawal for the construction camp and the Converter Station. KGS ACRES (2008) recommended long-term raw water quality monitoring to ensure that possible changes to aquifer water quality over longer time periods and possible surface water intrusion from the Nelson River to the aquifer during long term (e.g., multi-year) pumping are addressed in the water treatment process stream; particularly during high river staging (e.g., winter ice staging) events. At a minimum, the monitoring program should include the continuous recording of water levels and the regular testing of groundwater quality. The groundwater should be analyzed for routine water chemistry parameters, petroleum hydrocarbons, dissolved metals and trihalomethane.

Follow-up monitoring will be triggered by any contingency events or may be set at the beginning of the Project (e.g., for all designated fuel-storage sites associated with construction [as done during the construction of the Manitoba Floodway Expansion Project]). For any groundwater contamination issues, follow-up monitoring will be focused on the relevant measurable parameters shown in Table 5.

In the case of groundwater rise in the borehole, pumping and grouting procedures will be triggered pursuant to the Emergency Preparedness and Spill Response Plan that will be developed for Project pre-construction, construction and operation. As previously indicated, the nature of this risk means that measures will be primarily reactionary, but will follow the protocols that have been planned in advance. The effects from this event(s) will then be assessed by relevant experts to develop and implement an appropriate remediation and follow-up monitoring strategy(s).

6.4 POTENTIAL CUMULATIVE EFFECTS

Cumulative environmental effects refer to environmental effects which are likely to result from a project in combination with the environmental effects of other past, existing and future actions. For the purposes of this assessment, project, activities (human or project-related) and natural events are considered actions. In addition, this assessment also considered induced actions, or actions which may foreseeably occur if the Project is approved.

This cumulative effects assessment is presented in the following sequence after CEAA (1994) and Hegmann *et al.* (1999):

1. Scoping
2. Analysis of effects
3. Identification of mitigation
4. Evaluation of significance

5. Follow-up

6.4.1 Scoping

The VECs identified in Table 7 form the central focus of this cumulative effects assessment. No groundwater regional issues of concern have been identified.

The spatial boundary selected for the identification of actions that may contribute to a cumulative effect on the groundwater environment is the three-mile study corridor, however, consideration towards activities occurring outside of this spatial boundary has been provided if the actions are expected to affect the same aquifer.

A 20-year before present temporal boundary was selected for the Bipole III Project, to identify past actions that were not considered or accounted for in the baseline for existing environmental components. A future temporal boundary of 20 years was chosen based on typical planning horizons for future actions, such as projects or developments.

The residual environmental effects of the Project, summarized in Section 6.3 and Table 6, relate primarily to groundwater withdrawal in the northern portion of the study area (i.e., for the proposed construction camp and northern Converter Station), but also to major contingency events. There is a potential that other actions (specifically other Manitoba Hydro developments such as the proposed Conawapa Generation Station Project) within the three-mile corridor, or greater region, have the potential to act cumulatively with these residual effects.

6.4.2 Environmental Effects Analysis, Mitigation and Significance

The environmental effects of identified specific and generalized other actions are summarized in Table 7 and described below.

Groundwater Withdrawal:

There is a potential for future Manitoba Hydro activities (specifically the development of the proposed Conawapa Generating Station) at the northern extent of the Project study area to also require groundwater withdrawal to support construction and operation activities (both potable water and fire-suppression requirements). Depending on the timeframe for construction but certainly during operation, this requirement will result in an additive reliance on the aquifer in this area, which may affect productivity or potability because of:

- Overlapping drawdown cones.
- Connectivity between the aquifer and the Nelson River (GUDI effect).
- Both of the above.

The potential additive cumulative effect of groundwater withdrawal in the northern portion of the study area is considered negative in direction, moderate in both ecological and societal importance, small in magnitude, confined in geographical extent to the local assessment area, medium term in terms of duration, regular/continuous in terms of frequency, and reversible.

Contingency Events:

There is also a potential for future Manitoba Hydro activities (specifically the development of the proposed Conawapa Generating Station) at the northern extent of the Project study area to experience a contingency event that results in the contamination of the aquifer. Such an event would have a direct effect on groundwater supply for either (time dependent) the Bipole III construction camp or Keewatinoow Convertor Station. Further, if this event followed an event that occurred during the construction or operation of the Bipole III Project, the effects to the aquifer would be additive.

The cumulative effect of contingency events in the northern portion of the study area is considered to be negative in direction, of low to medium magnitude and moderate in both ecological and societal importance. The footprint of the impact is expected to be localized due to the Emergency Preparedness and Spill Response Plans that would likely be in place. The duration of any impact is assumed to be short-term in duration and sporadic in frequency. Aquifer quality will be eventually restored to the natural conditions and therefore the impact is considered to be reversible.

6.4.3 Effect of Climate Change

The predictions of climate change on groundwater are limited, especially for northern part of the Bipole III route. Climate change related predictions were done for the regional carbonate aquifer in southern Manitoba by Chen and Grasby (2001). They analyzed water-well levels in the aquifer, built an analytical model, and performed simulations to evaluate the effects that long-term climate changes would have on water levels in the freshwater bearing portions of the aquifer (Chen et al. 2002). Some climate scenarios predicted drops in head near the Red River, southeast of Winnipeg resulting in the shifting of the saline/freshwater boundary eastward and causing salinization of water wells. The predicted drops in head also will result in decrease of areas with artesian conditions in Section 1 of the proposed Project. The interaction of the Project with groundwater is limited in this section, therefore climate related-changes in aquifer will not add to cumulative effect of the Project. No available predictions were made for other sections of the Project.

7.0 Conclusions

On the basis of the desktop study assessing groundwater along the preferred transmission line route and in the areas of the associated project components, the following conclusions are drawn:

- There are two categories of potential effects of the proposed Bipole III Transmission Line Project on the groundwater regime, including:
    - Potential effects to aquifer quality.
    - Potential effects to aquifer productivity.
- Mitigation measures can be applied to reduce or preclude the identified potential effects on the groundwater regime, with the exceptions of the cone of depression caused by groundwater withdrawal at the northern work camp and northern Converter Station and major contingency events.
    - The largest effect of groundwater withdrawal on the aquifer is expected at the proposed Bipole III construction camp. This effect is, however, temporary, and the rebound of the piezometric head is expected upon the completion of the construction.
    - The effect of groundwater withdrawal at the northern Converter Station on the groundwater regime appears to be minor, but will be present for the duration of Converter Station operations.
    - The effect of major contingency events on the groundwater regime would be greatest in any of the areas identified as Environmentally Sensitive Sites but is considered reversible provided Emergency Preparedness and Spill Response Plans are enacted quickly.
- Other proposed Project components are generally land-based or surficial in nature and will not contact or interfere with the existing groundwater regime. The only aspect of the other components that could potentially affect the groundwater regime is any excavation for a Project component foundation but, based on the Project Description information reviewed, the foundations are shallow and not predicted to interfere with the identified major aquifers.
- Follow-up/Monitoring will include reporting of visual changes in soil moisture, swamping and spring appearance in areas of artesian aquifers and groundwater monitoring around the proposed septic lagoons at the Keewatinoow Convertor Station and at the construction camp and Converter Station (in association particularly with potable groundwater withdrawal). Follow-up/Monitoring activities will also be triggered by any

contingency event(s) or may be set at the beginning of the Project for specific Project aspects.

There are potential cumulative effects of future Manitoba Hydro activities (specifically the development of the proposed Conawapa Generating Station) at the northern extent of the study area. These specifically relate to requirements for groundwater withdrawal or contingency event(s) during construction or operation. Both of these actions could have a potential effect (singular or additive) on aquifer quality and aquifer productivity. The potential cumulative effects of either of these actions is considered negative in direction, moderate in both ecological importance, small in magnitude, confined in geographical extent to the local assessment area and reversible.

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Tables

ERA	PERIOD		FORMATION (GROUP)	MEMBER	BASIC LITHOLOGY	THICKNESS METRES	HYDROSTRATIGRAPHIC UNITS AQUIFERS AND AQUITARDS	
CENOZOIC	Quat.	Recent			Soil, alluvial deposits, sand dunes, bogs			OVERBURDEN UNIT
		Pleistocene			Glacial deposits	0—260		
	Tertiary	Eocene to Pliocene	Not reported in Manitoba					UPPER CLASTIC UNIT
		Paleocene	Turtle Mountain		Shale, sandstone, lignite	—145+	sandstone aquifer	
MESOZOIC	Cretaceous		Boissevain		Sand and sandstone, greenish grey, kaolinitic shale	30—45		
			Pierre Shale	Coulter	Bentonitic clayey silt	20—55		
				Odanah	Hard grey siliceous shale	—245+	shale aquifer	
				Millwood	Greenish bentonitic shale	15—150		
				Pembina	Non-calc. shale, bentonite beds	2—12		
			Niobrara		Calcareous speckled shale	2—32	shale aquitard	
			Morden Shale		Carbonaceous shale, septarian concretions	15—60		
			Favel		Calc. speckled shale, limestone bands	18—40		
			Ashville	Ashville sand	Non-calc. silty shale; 0-27m sand	37—113		
			Swan River		Sand, sandstone, shale, clay, lignite	0—120		
	Jurassic		Waskada		Varicoloured shale	0—50	sandstone aquifers	
			Melita		Varicoloured shale, calc. shale, limestone	100—145		
			Reston		Argillaceous limestone and shale	0—50		
			Amaranth	Upper evaporite	Anhydrite, gypsum, shale, dolostone	0—50		
				Lower red beds	Dolomitic shale to siltstone, anhydritic	0—42		
	Triassic		Not reported in Manitoba except Permian? Lake St. Martin cryptoexplosion structure					
PALEOZOIC	Permian						evaporite aquitard	CARBONATE - EVAPORITE UNIT
	Pennsylvanian							
	Mississippian		Charles		Dolostone and anhydrite	—37		
			Mission Canyon		Limestone, dolostone, anhydrite; oil production	80—100		
			Lodgepole	Whitewater Lake Virden Scallion Routledge	Limestone, argillaceous and cherty; shale, oil production	145—175	carbonate aquifer	
			Bakken		Black shale and siltstone	3—15		
	Devonian		Qu'Appelle Group	Three Forks	Red dolomitic shale	11—55	shale aquitard	
			Saskatchewan Group	Birdbear	Fossiliferous limestone and dolostone	12—43		
				Duperow	Shaly limestone, dolostone, anhydrite; cyclical	120—195		
			Manitoba Group	Souris River First Red	Limestone, evaporite, shale; cyclical	65—95	carbonate aquifer	
				Dawson Bay Second Red	Limestone, anhydrite, basal red shale	42—67		
			Elk Point Group	Prairie Evaporite	Halite, with potash, anyhdrite, dolostone	0—130		
				Winnipegosis	Dolostone, reef and inter-reef	9—107	evaporite aquitard	
				Elm Point	High-calcium limestone	0—14+		
				Ashern	Dolostone and shale, brick red	2—18		
	Silurian		Interlake Group		Dolostone	53—115		
			Stonewall		Dolostone	9—21		
	Ordovician		Stony Mountain	Gunton	Dolostone, upper part shaly	30—50	carbonate aquifer	
				Penitentiary	Argillaceous dolostone			
				Gunn	Fossiliferous calc. shale; red, grey, green			
			Red River	Fort Garry	Dolostone, minor limestone	53—150		
				Selkirk	Dolomitic limestone, mottled			
				Cat Head	Dolostone, cherty			
				Dog Head	Dolomitic limestone, mottled			
			Winnipeg		Quartzose sand, sandstone; shale	0—67	sandstone aquifer	BASAL CLASTIC UNIT
	Cambrian		Deadwood		Glauconitic sandstone	?		
PRECAMBRIAN								PRECAMBRIAN

Geological formations and hydrostratigraphic units in the WCSB of Manitoba
(Source: Betcher, et al. 1995)

Table 1

Table 2: Bipole III Transmission Project Environmentally Groundwater Sensitive Sites

Source ID	ESS Name	ESS Description	Potential Environmental Effects	Mitigation Measures
1	Aquifers Vulnerable to contamination	1. Sand and gravel aquifers in the western part of Springfield RM 2. Sand and gravel aquifers south-east of Winnipeg 3. Alluvial aquifers in vicinity of Red River Crossing 4. Alluvial aquifers near Mosses River Crossing 5. Alluvial aquifers between Swan and Woody river Crossings 6. Alluvial aquifers near Red Deer River Crossing 7. Alluvial aquifers east of Young Point 8. Sand and gravel aquifers in vicinity Saskatchewan River Crossing 9. Sand and Gravel aquifers south east of Clearwater Lake 10. Sand and Gravel aquifers North east of Hargrave Lake	Potential groundwater contamination from a contingency event (e.g., spill)	• Locating marshalling yards and refueling areas away from these areas, on low permeable soils or areas with greater aquifer protection • Rapid response to contingency events (i.e., detection and clean up)
2	Saline artesian areas	1. Saline aquifers in area between the Rat and River crossings. 2. Saline aquifers in area towns of Osborne and Brunkild. 3. Saline aquifers in area between the Whitemud River and Squirrel Creek crossings. 4. Area north east of Rorketon town 5. Springs on west shore of Dawson Bay 6. Along west shore of the Overflow Bay	• Increase in salinity of soils and surface water in case of potential groundwater discharge to the surface • Wetting the surfical environment (ground saturation); affect on local vegetation	• Monitoring of groundwater level in the drill hole • Sealing the drill hole as soon as possible in case of level rise • Rapid response (containment) to saline water if unable to prevent the seepage to the surface

Table 2 continued.

Source ID	ESS Name	ESS Description	Potential Environmental Effects	Mitigation Measures
3	Freshwater artesian areas	1. Aquifers in eastern/central part of Springfield RM with flowing wells 2. Aquifers in area located between Dufresne and Ste. Anne 3. Aquifers in Randolf area 4. Aquifers in vicinity of Mosses River crossing 5. Aquifers in vicinity of Saskatchewan River crossing	• Wetting the surfical environment near potential discharge from tower foundation drill hole (ground saturation) • Potential level drop in the aquifer	• Monitoring of groundwater level in the drill hole • Sealing the drill hole as soon as possible in case of level rise • Connect the site with ditches to the local drainage system in case of extensive discharge to the surface
4	Artesian areas with uncertain water quality	1. Aquifers around Jarvies Lake 2. Aquifers between of Spence and Dauphin Lakes 3. Aquifers in vicinity of Pine River Crossing 4. Aquifers at the headwaters of the Sinclair River 5. Aquifers at near the residence of Indian Birch	• Potential increase in salinity of soils and surface water in case where aquifer is saline and groundwater discharges to the surface • Wetting the surfical environment (ground saturation)	• Monitoring of groundwater level in the drill hole • Sealing the drill hole as soon as possible in case of level rise • Rapid response to determine water salinity and containment if saline and if unable to prevent the seepage to the surface. Redirection/connection to local drainage if freshwater.

Table 3: Bipole III Transmission Project Activities Likely to Affect Groundwater

Component	Activity
Pre-licensing Activities	• Geotechnical drilling
Construction:	
Transmission Lines	• Refuelling equipment • Installing foundations • Obtaining fill material (borrow sources)
Converter Stations	• Groundwater withdrawal for water supply needs • Using heavy equipment • Filling equipment with insulating oil
Ground Electrode Sites	• Groundwater withdrawal for water supply needs • Refuelling equipment • Installing groundwater supply to maintain coke saturation in the electrode trench
Marshalling Yards and Construction Camp(s)	• Groundwater withdrawal for the Northern Camp water supply needs • Refuelling equipment • Storing hazardous material
Operations and Maintenance:	
Converter Station	• Groundwater withdrawal for water supply needs • Operation of septic lagoon • Re-filling equipment with insulating oil, etc.
Ground Electrode Sites	• Maintaining coke saturation in the electrode trench • Refueling equipment
Transmission Lines	• Applying herbicides for Vegetation Management
Decommissioning:	
Borrow pits, access trails, marshalling yards, construction camp(s)	• Supply well decommissioning • Refuelling equipment during remediation activities

Table 4: Interaction Matrix of Project Activities with Groundwater VEC's

Project phase/Component	**Preconstruction:**	**Construction:**											**Operations and Maintenance:**						**Decommissioning:**	
		T-lines		**Converter Stations**				**Ground Electrode Sites**		**Construction Camp(s) and Marshalling Yards**			**Converter Stations**			**Ground Electrode Sites**		**T-lines**		
Activity	Geotechnical drilling	Refueling equipment	Installing foundations	Groundwater withdrawal for water supply needs	Refueling the equipment	Obtaining/storing fill material (borrow sources)	Filling equipment with insulating oil	Refueling the equipment	Refueling the equipment	Groundwater withdrawal for water supply needs	Refueling the equipment	Storing hazardous material	Groundwater withdrawal for water supply needs	Operation of septic lagoon	Re-filling equipment with insulating oil, etc.	Maintaining coke saturation in the electrode trench	Applying herbicides for Vegetation Management	Applying herbicides for Vegetation Management	Supply well decommissioning	Refueling equipment during remediation activities
Aquifer quality		x			x	x	x	x	x		x	x	x	x	x	x	x	x	x	x
Aquifer productivity	x		x	x						x			x			x				

Note: empty cell - no interaction

x - interaction

Table 5: Summary of the Potential Environmental Effects

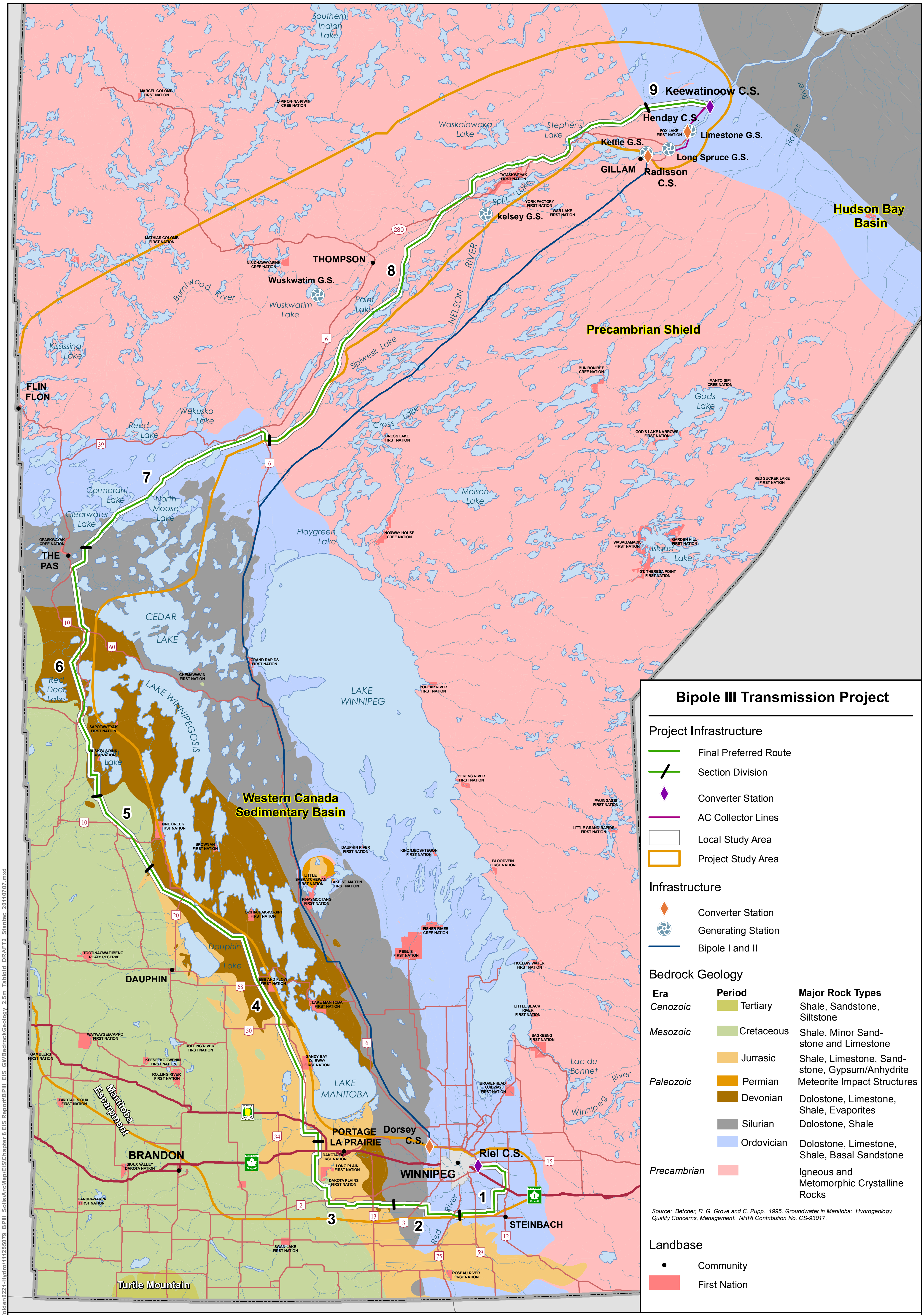
Potential Environmental Effect	Project stage / Activity	VEC	Measurable Parameters	Mitigation Measures	Residual Environmental Effect	Follow-up
Normal operation						
Groundwater impact from herbicide and/or pesticide application	Operation and Maintenance: • Applying herbicides for vegetation management along transmission lines and at electrode sites.	• Aquifer quality	• Concentration of herbicides and/or pesticides in groundwater	• Pesticide use shall be in accordance with the current (Manitoba) Pesticides Regulation. • Herbicide applications will be made by a licensed certified applicator. • Herbicides will be applied according to product label directions.	Negligible	Groundwater quality monitoring
Groundwater impact from leachate from septic lagoon	Operation and Maintenance: • Operation of septic lagoon	• Aquifer quality	• Concentration of bacteria, nutrients (P and N species) in groundwater	• Septic lagoons will be sited on low permeability soils, where possible. • Septic lagoon will be designed and operated in accordance with the *Environment Act* licence that will be required. •	Negligible	Monitoring of groundwater quality
Groundwater impact from leachate from coke	Operation and Maintenance: • Maintaining coke saturation in the electrode trench	• Aquifer quality	• Concentration of trace elements, PAH and other related contaminants in groundwater	• Locating of electrode sites in low permeability soils to minimize infiltration of leachate from electrode trench to the groundwater. • Establish groundwater quality monitoring at the preferred northern electrode. •	Possible at the northern electrode site	Groundwater quality monitoring
Groundwater drawdown at Construction Camp and Keewatinoow Converter Station/electrode site(s)	Construction, Operation and Maintenance: • Using groundwater supply for the northern construction camp and Keewatinoow converter station • Maintaining coke saturation in the electrode trench.	• Aquifer productivity	• Groundwater levels	• No mitigation.	Anticipated residual effects in case of Construction Camp and Convertor Station. None in terms of electrode site(s).	Monitoring of groundwater levels
Contingency events (accidents and malfunction)						
Groundwater impacts as a result of accidental releases of contaminants (hydrocarbons/herbicides or pesticides).	Construction: • Refueling the equipment. • Filling convertor equipment with insulating oil. Operation and maintenance: • Applying herbicides and pesticides for vegetation management along transmission lines and at electrode sites. • Refueling the equipment. • Re-filling equipment with insulating oil, etc. • Storing, Handling, Transport of hazardous material. Decommissioning: • Refueling equipment during remediation activities.	• Aquifer quality	• Concentration of relevant contaminants (BTEX, oil, MOG, herbicides, pesticides) in groundwater	• Fuel, lubricants and other potentially hazardous materials will be stored and handled within dedicated areas at work sites and marshalling yards in full compliance with regulatory requirements. • Marshalling yards will be located on low permeability soils, where possible. • Transfer of fuel must be attended at all times. • An emergency response spill kit will be kept on-site at all times in case of fluid leaks or spills from machinery. • Hazardous materials, fuel containers and other materials will be removed from the site and properly disposed in accordance with regulatory requirements. • Pesticide use shall be in accordance with the current (Manitoba) Pesticides Regulation. • Herbicide applications will be made by a licensed certified applicator. • Herbicides will be applied according to product label directions..	Anticipated residual effects in the event of a major spill.	Remediation and monitoring in accordance with regulatory standards
Groundwater impacts with leachate in case of lagoon breach	Operation and maintenance: • Operation of septic lagoon	• Aquifer quality	• Concentration of bacteria, nutrients (P and N species) in groundwater	• Septic lagoons will be sited on low permeability soils, where possible. • Septic lagoon will be designed and operated in accordance with the *Environment Act* licence that will be required.	Anticipated residual effects	Remediation and monitoring in accordance with regulatory standards

Table 5: Summary of the Potential Environmental Effects						
Potential Environmental Effect	**Project stage / Activity**	**VEC**	**Measurable Parameters**	**Mitigation Measures**	**Residual Environmental Effect**	**Follow-up**
Aquifer interconnection and unintended groundwater discharge to the surface	Pre -Construction: - Geotechnical drilling Construction: - Installing foundations - Obtaining fill material - Installing groundwater supply	- Aquifer quality	- Groundwater levels - Routine groundwater chemistry	- A driller with appropriate experience in dealing with these issues will be contracted to work in areas affected by artesian conditions. - Water levels will be monitored during drilling and foundation installation. - An emergency grouting kit will be kept on-site. - Emergency response plans for sealing/grouting and pumping will be implemented as required.	Anticipated residual effects in the event of prolonged discharge	Remediation and monitoring in accordance with regulatory standards.

Table 6: Residual Environmental Effects Assessment Summary for Groundwater												
VEC	**Project Component**	**Phase**	**Residual Issue**	**Direction**	**Ecological Importance**	**Societal Importance**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Residual Effect**
	Normal Construction and Operation											
Aquifer Quality	HVdc Transmission and AC Collector Lines	Construction	Unintended groundwater discharge	Negative	High	High	Low to High	Project Site/Footprint	Short-term	Sporadic	Reversible	Not Significant
		Operation	No anticipated residual effects									
	Keewatinoow Converter Station	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									
	Riel Converter Station	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									
	Ground Electrodes and Lines	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									
Aquifer Productivity	HVdc Transmission and AC Collector Lines	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									
	Keewatinoow Converter Station	Construction	Ground-water withdrawal	Negative	Low	Low	Small	Local Assessment Area	Medium-Term	Regular / Continuous	Reversible	Not Significant
		Operation		Negative	Low	Low	Small	Local Assessment Area	Medium-Term	Regular / Continuous	Reversible	Not Significant
	Riel Converter Station	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									
	Ground Electrodes and Lines	Construction	No anticipated residual effects									
		Operation	No anticipated residual effects									

Table 7: Bipole III Transmission Project – CEA – Other Actions Summary Table					
Other Actions by Category	**Other Action Description**	**VEC**	**Measureable Parameter/Variable**	**Potential Environmental Effects**	**Comments**
Other Manitoba Hydro Activities (e.g., proposed Conawapa Generating Station)	• Groundwater Withdrawal	• Aquifer productivity • Aquifer quality	• Groundwater levels • Concentration of relevant contaminants pathogens in groundwater	• Decrease in either measureable parameter/variable (overlapping drawdown cones or GUDI effect)	• Nelson River & deep bedrock aquifer hydraulically connected; influence of drawdown cone from camp well estimated to be measureable up to ~2 km away from well but greatest in immediate area.
	Aquifer impacts from contingency events	• Aquifer quality	• Concentration of relevant contaminants pathogens in groundwater	• Decrease/Preclusion of potable groundwater source	• Likelihood low considering depth to bedrock aquifer and overlying confining till protection.

Maps



Bipole III Transmission Project

Project Infrastructure

- Final Preferred Route
- Section Division
- Converter Station
- AC Collector Lines
- Local Study Area
- Project Study Area

Infrastructure

- Converter Station
- Generating Station
- Bipole I and II

Bedrock Geology

Era	Period	Major Rock Types
Cenozoic	Tertiary	Shale, Sandstone, Siltstone
Mesozoic	Cretaceous	Shale, Minor Sandstone and Limestone
	Jurassic	Shale, Limestone, Sandstone, Gypsum/Anhydrite
Paleozoic	Permian	Meteorite Impact Structures
	Devonian	Dolostone, Limestone, Shale, Evaporites
	Silurian	Dolostone, Shale
	Ordovician	Dolostone, Limestone, Shale, Basal Sandstone
Precambrian	🟥	Igneous and Metomorphic Crystalline Rocks

Source: Betcher, R, G. Grove and C. Pupp. 1995. Groundwater in Manitoba: Hydrogeology, Quality Concerns, Management. NHRI Contribution No. CS-93017.

Landbase

- Community
- First Nation

Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, Stantec, ProvMB, NRCAN
Date Created: July 08, 2011

0 25 50 Kilometres
0 25 50 Miles

N

1:2,500,000

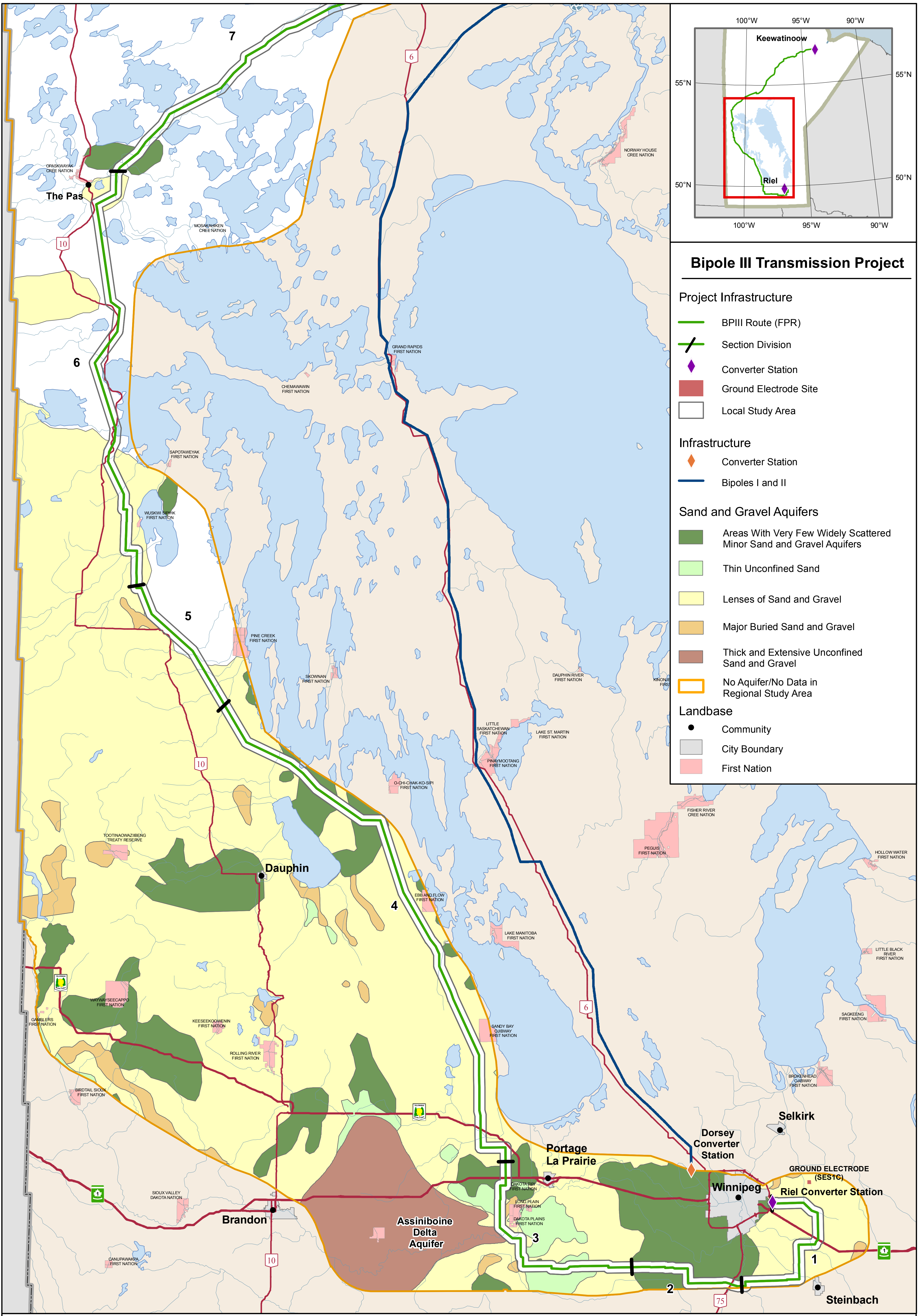
Generalized Bedrock

Geology of Manitoba

Draft: For Discussion Purposes Only

Map 1

File Location: G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWBedrockGeology_2.5m_Tabloid_DRAFT2_Stantec_20110707.mxd



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, Stantec, ProvMB
Date Created: July 8, 2011

N

0 25 50 Kilometres

0 15 30 Miles

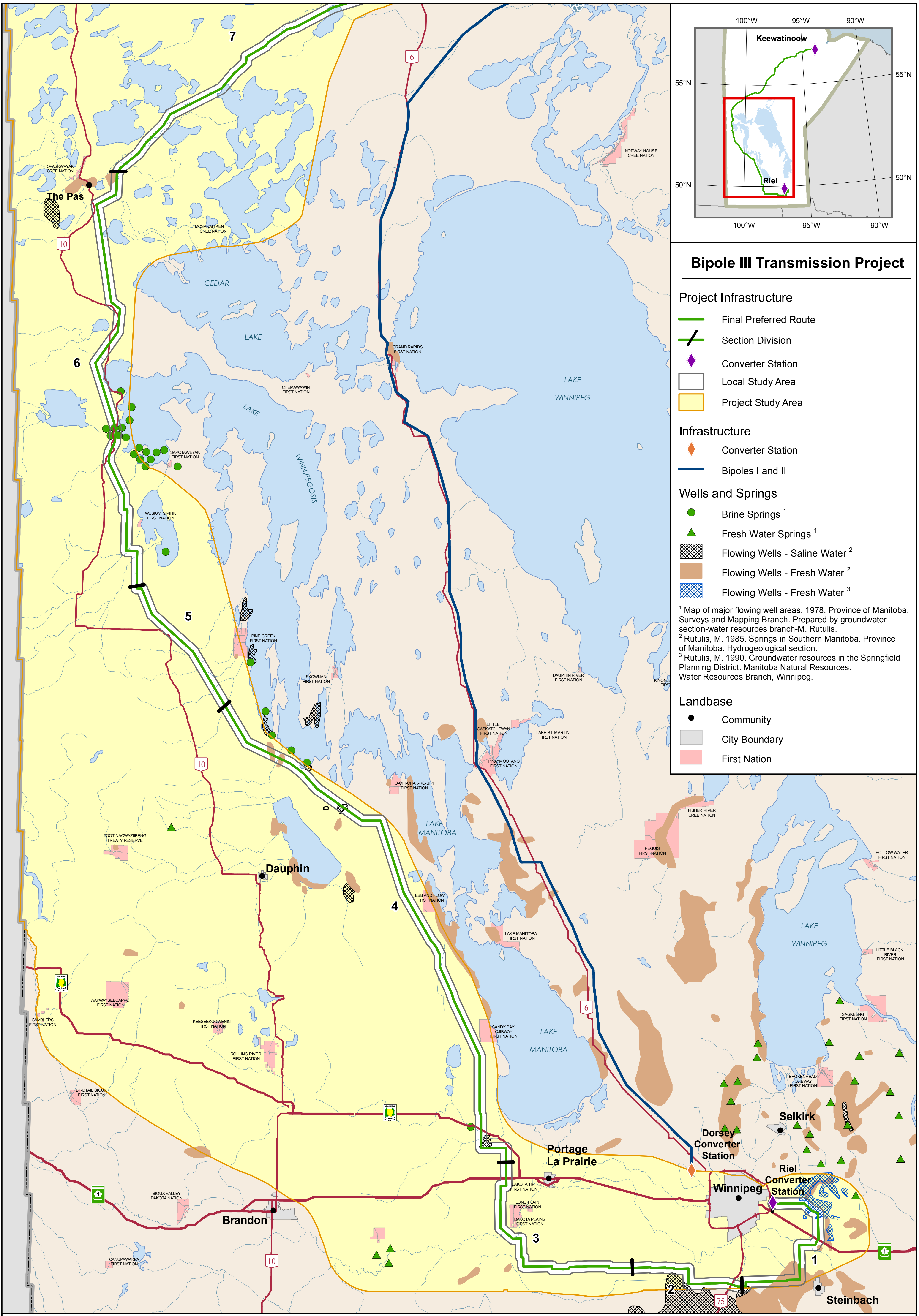
1:1,500,000

Sand and Gravel Aquifers within the Southern Project Study Area

Draft: For Discussion Purposes Only

Map 2

File Location: G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWSandGravelAcquifers_1.5m_Tabloid_DRAFT2_Stantec_20110707.mxd



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, Stantec, ProvMB
Date Created: July 8, 2011

0 25 50 Kilometres

0 15 30 Miles

1:1,500,000

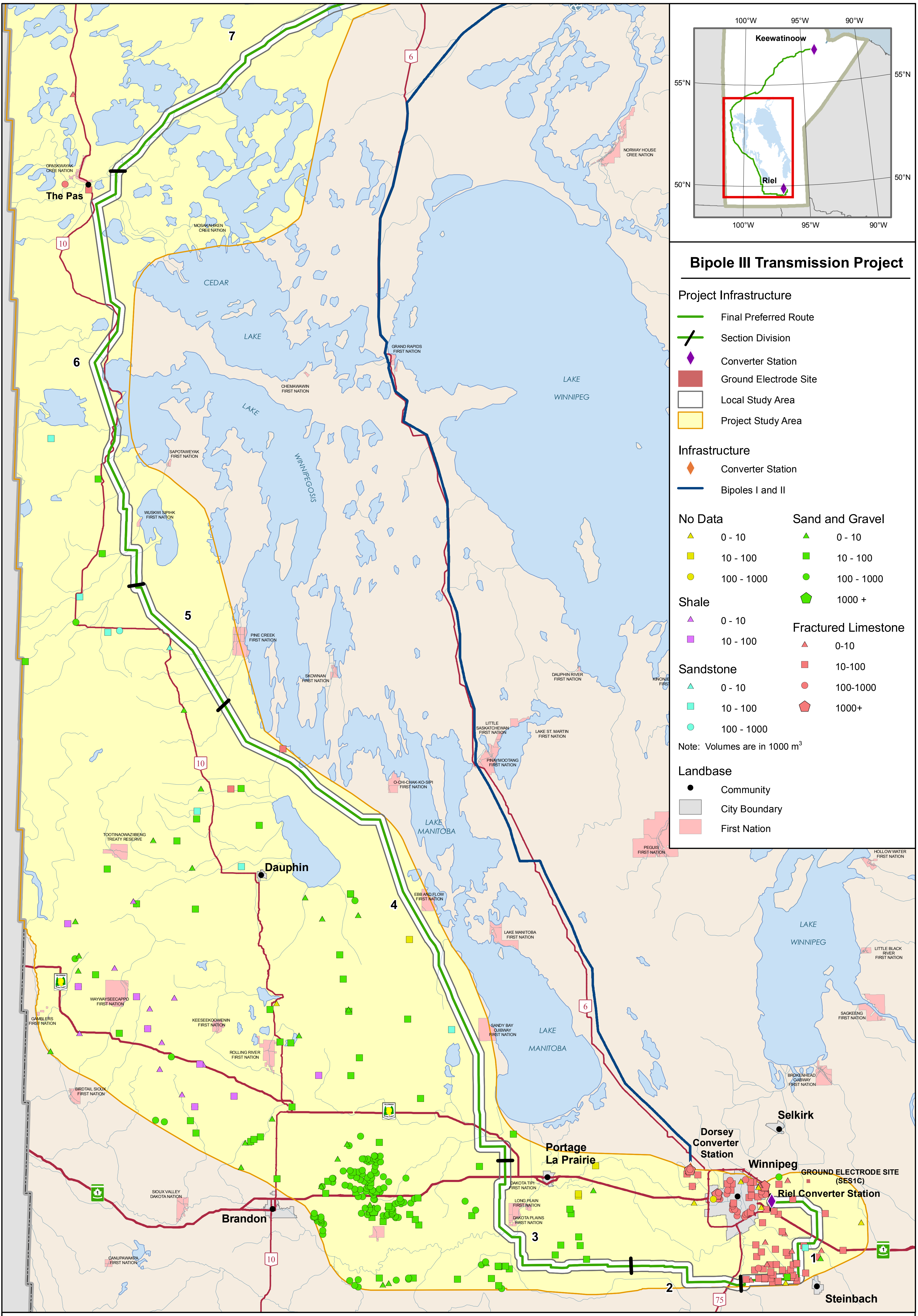
N

Flowing Well Areas and Springs

Draft: For Discussion Purposes Only

Map 3

File Location: G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWFlowingWellAreas_1.5m_Tabloid_DRAFT2_Stantec_20110707.mxd



Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, Stantec, ProvMB
Date Created: July 8, 2011

0 25 50 Kilometres
0 15 30 Miles
1:1,500,000

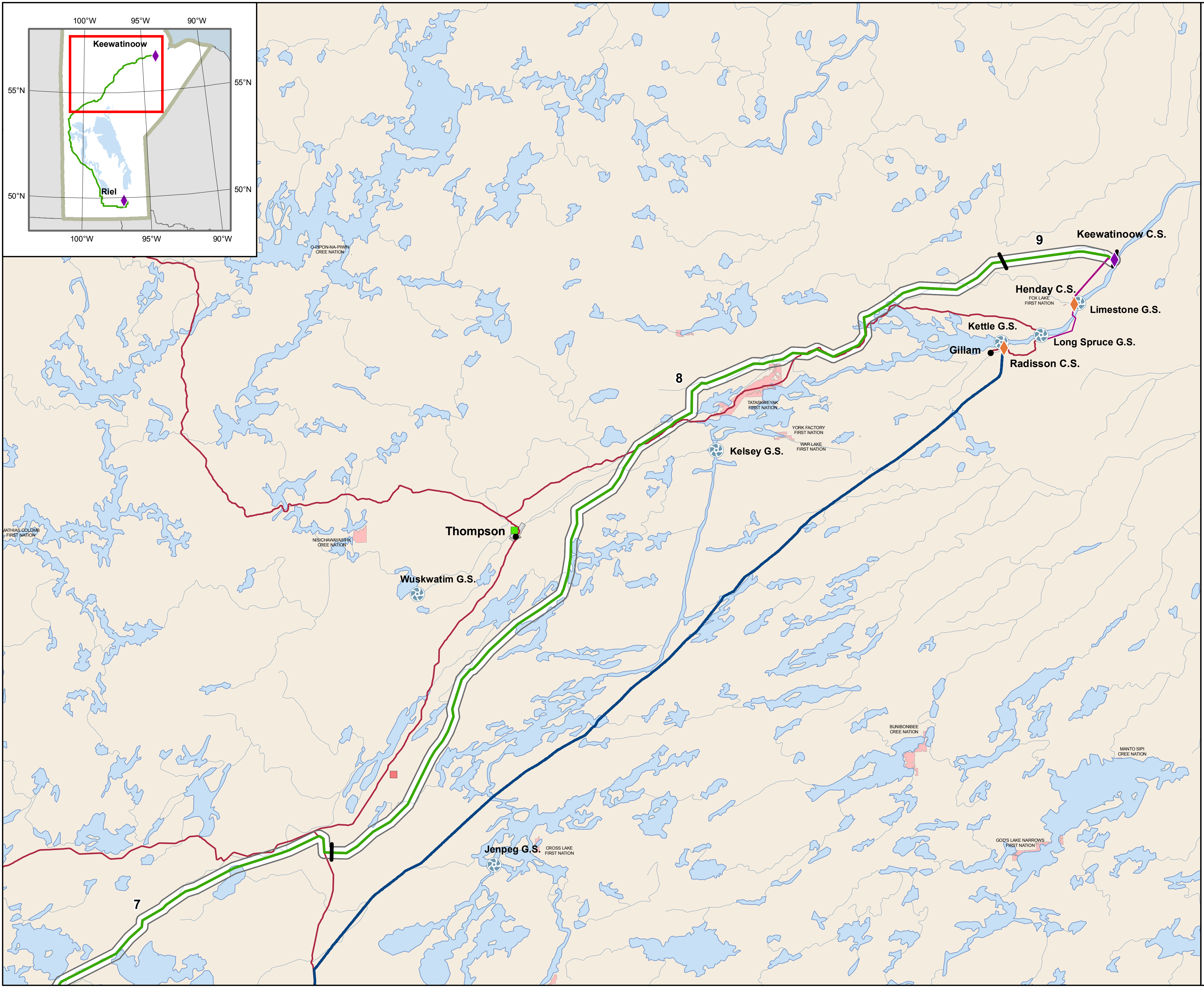
N

Type of aquifer and maximum annual allowed capacity of licensed groundwater supply wells within the project study area

Draft: For Discussion Purposes Only

Map 4A

File Location: G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWLicencedGWSupply_1.5m_Tabloid_DRAFT2_Stantec_20110607_



Manitoba Hydro

Bipole III Transmission Project

Project Infrastructure

- Final Preferred Route
- Section Division
- ◆ Converter Station
- AC Collector Lines
- ☐ Local Study Area

Infrastructure

- ◆ Converter Station
- Generating Station
- Bipoles I and II

No Data

- ▲ 0 - 10
- ■ 10 - 100
- ● 100 - 1000

Shale

- ▲ 0 - 10
- ■ 10 - 100

Sandstone

- △ 0 - 10
- ■ 10 - 100
- ● 100 - 1000

Sand and Gravel

- ▲ 0 - 10
- ■ 10 - 100
- ● 100 - 1000
- ⬟ 1000 +

Fractured Limestone

- ▲ 0-10
- ■ 10-100
- ● 100-1000
- ⬟ 1000+

Note: Volumes are in 1000 m^3

Landbase

- ● Community
- ▨ City Boundary
- 🟥 First Nation

Coordinate System: UTM Zone 14N NAD83
Data Source: MBHydro, MMM, ProvMB
Date Created: July 08, 2011

N

0 25 50 Kilometres
0 15 30 Miles

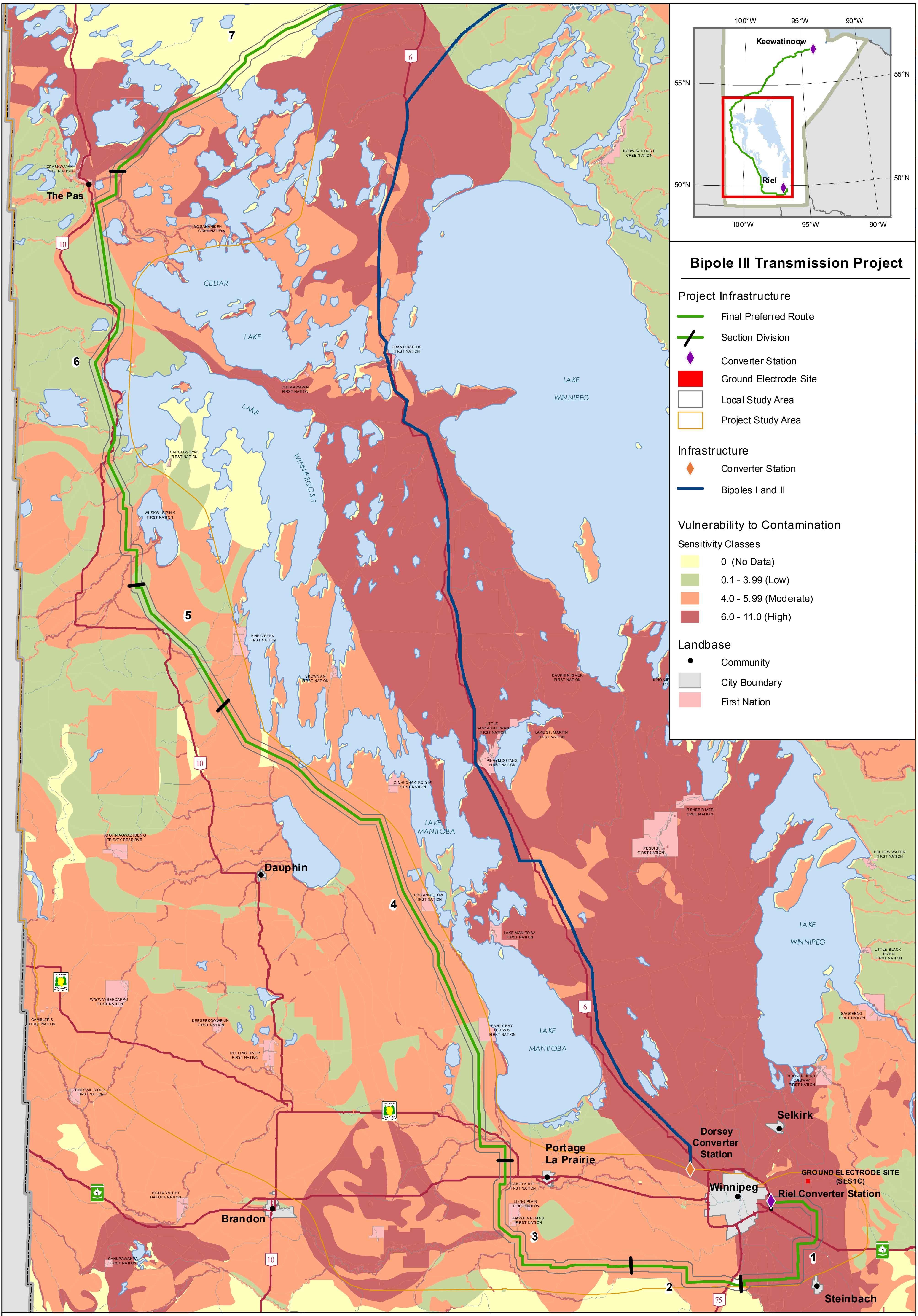
1:1,500,000

Type of aquifer and maximum annual allowed capacity of licensed groundwater supply wells within the project study area

Draft: For Discussion Purposes Only

Map 4B

File Location: G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWLicencedGWSupplyNorth_1.5m_Tabloid_DRAFT2_Stantec_20110607_.mxd



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, Stantec, ProvMB
Date Created: July 22, 2011

0 25 50 Kilometres
0 15 30 Miles

N

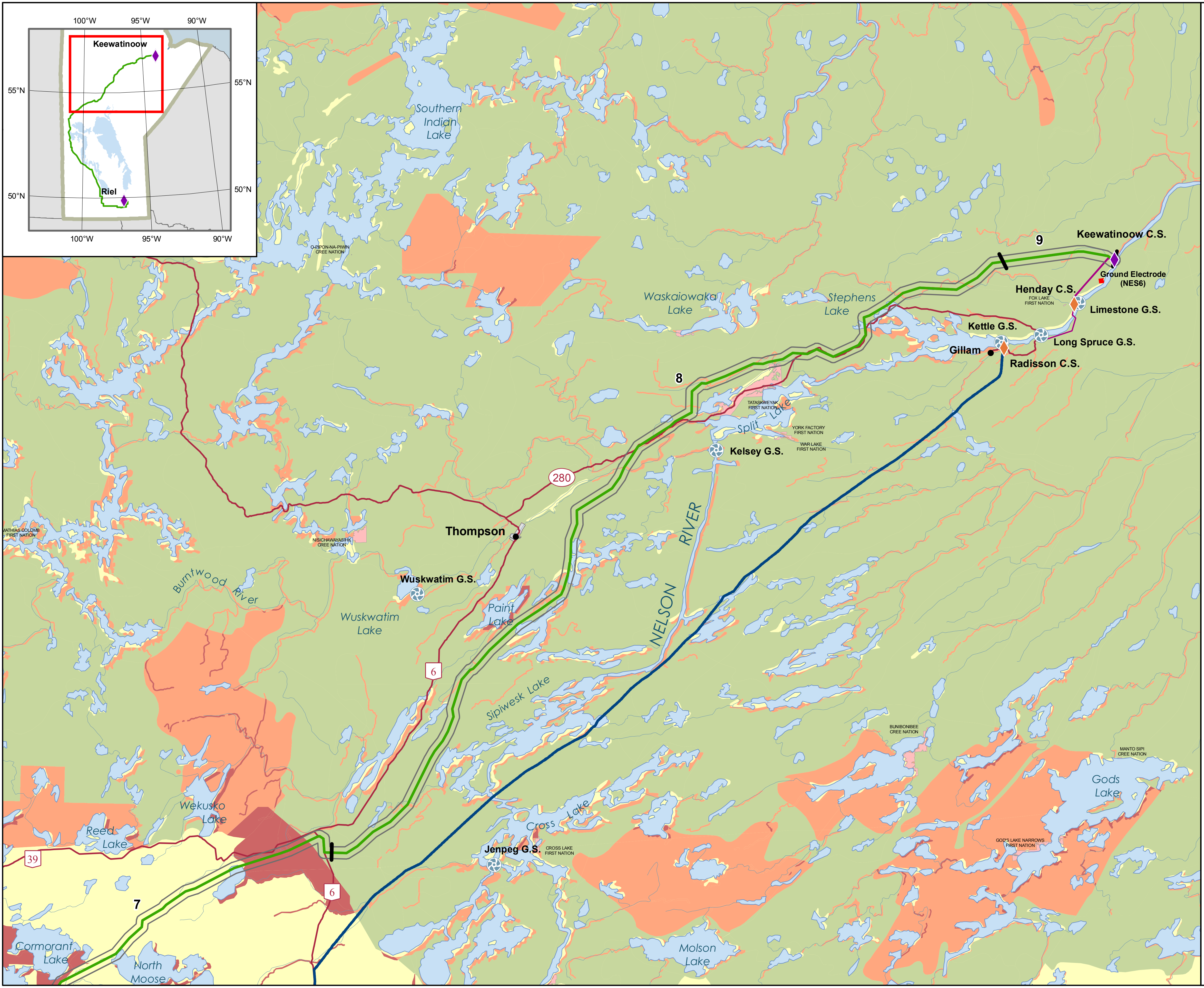
1:1,500,000

Aquifer Vulnerabilty to Contamination

Draft: For Discussion Purposes Only

Map 5A

File Location: G:_GIS_Project_Folder\0221-Hydro\11255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_AcquiferVulnerabilityToContamination_Tabloid_DRAFT2_Stantec_20110722_.mxd



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Manitoba Hydro

Bipole III Transmission Project

Project Infrastructure

- Final Preferred Route
- Section Division
- ◆ Converter Station
- 🟥 Ground Electrode Site
- AC Collector Lines
- ☐ Local Study Area

Infrastructure

- ◆ Converter Station
- Generating Station
- Bipoles I and II

Vulnerability to Contamination

Sensitivity Classes

- 0 (No Data)
- 0.1 - 3.99 (Low)
- 4.0 - 5.99 (Moderate)
- 6.0 - 11.0 (High)

Landbase

- ● Community
- City Boundary
- First Nation

Coordinate System: UTM Zone 14N NAD83
Data Source: MBHydro, MMM, ProvMB
Date Created: July 22, 2011

N

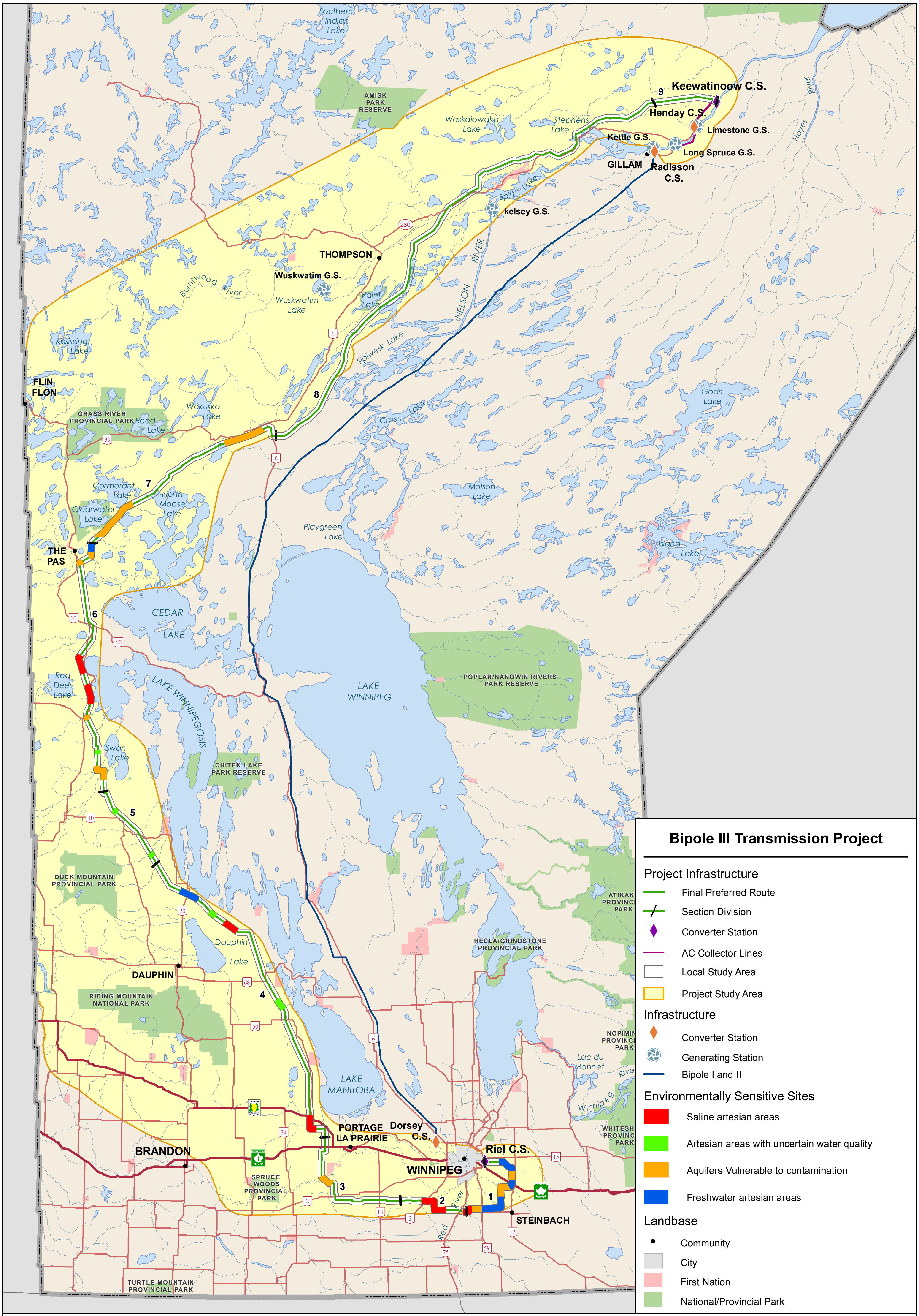
0 25 50 Kilometres
0 15 30 Miles

1:1,500,000

Aquifer Vulnerability To Contamination

Draft: For Discussion Purposes Only

Map 5B



Manitoba Hydro

Coordinate System: UTM Zone 14N NAD83
Data Source: MB Hydro, MMM, ProvMB, NRCAN
Date Created: July 22, 2011

0 50 100 Kilometres
0 25 50 Miles

1:2,500,000

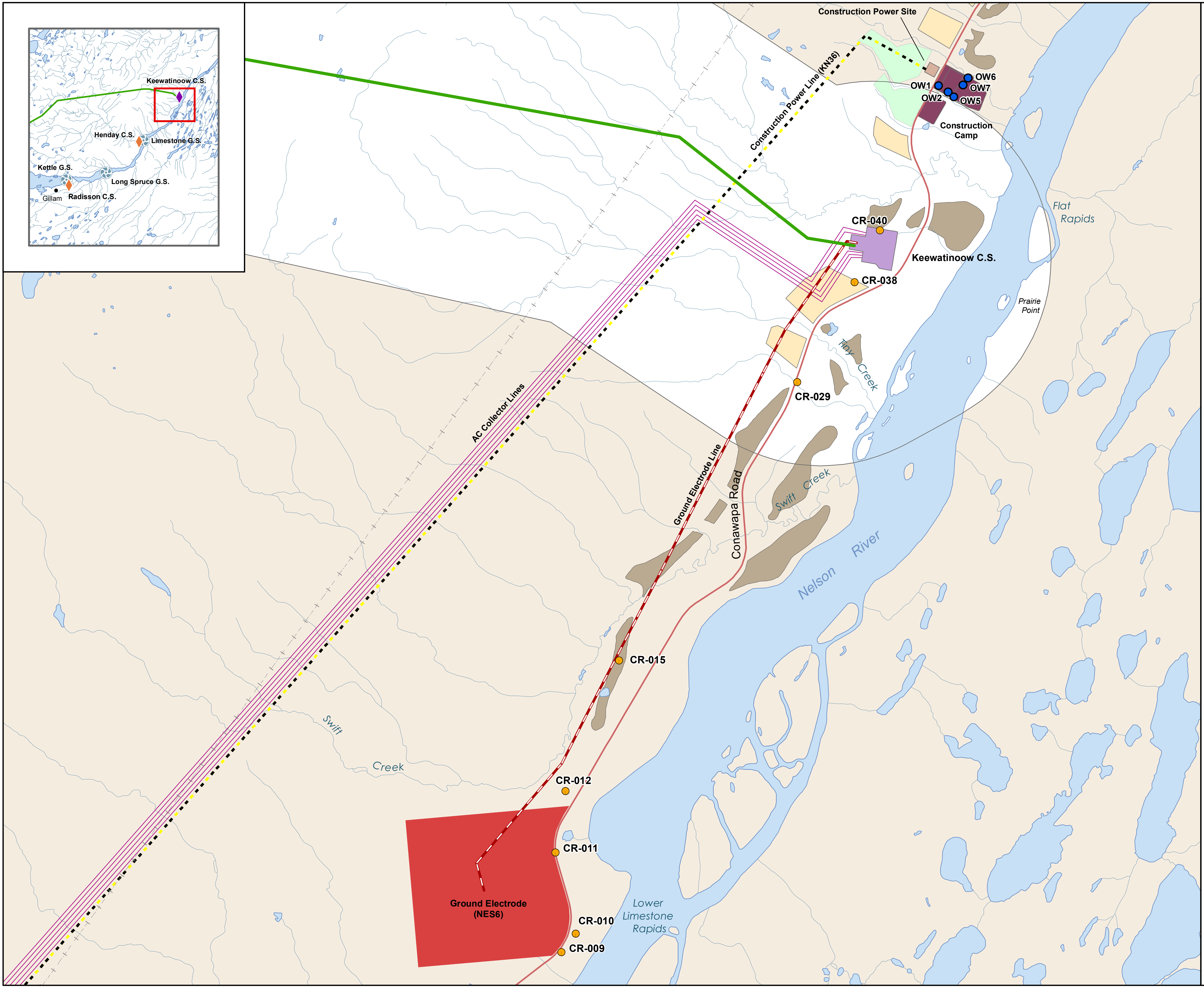
N

Environmentally Sensitive Groundwater Sites

Draft: For Discussion Purposes Only

Map 6

G:_GIS_Project_Folder\0221-Hydro\111255079_BPIII_Soils\ArcMap\EIS\Chapter 6 EIS Report\BPIII_EIS_GWEnvironmentallySensitiveSites_2.5m_Tabloid_DRAFT2_Stantec_20110707.mxt



File Location: G:_GIS_Project_Folder\00_Hydro\111404000_BPIII_EnvPP\ArcMap\BPIII_GEOTECH_EISSelectedBoreholeLocations_Stantec_20110719.mxt

Manitoba Hydro

Bipole III Transmission Project

Project Infrastructure

🟩	Final Preferred Route
🟪	Converter Station Site
—	AC Collector Line
▬	Ground Electrode Line
🟥	Ground Electrode Site
····	Construction Power (KN36)
▨	Construction Power Site
▨	Construction Camp Site
☐	Local Study Area

Geotechnical

●	Selected Borehole (Refer to Appendix C)
●	Well (Refer to Appendix C)
▨	Granular Deposit (Proposed Borehole Area)
▨	Excavated Material Placement Area
▨	Lagoon

Coordinate System: UTM Zone 14N NAD83
Data Source: MBHydro, MMM, Stantec, ProvMB, NRCAN
Date Created: July 22, 2011

N

0 0.5 1 Kilometres

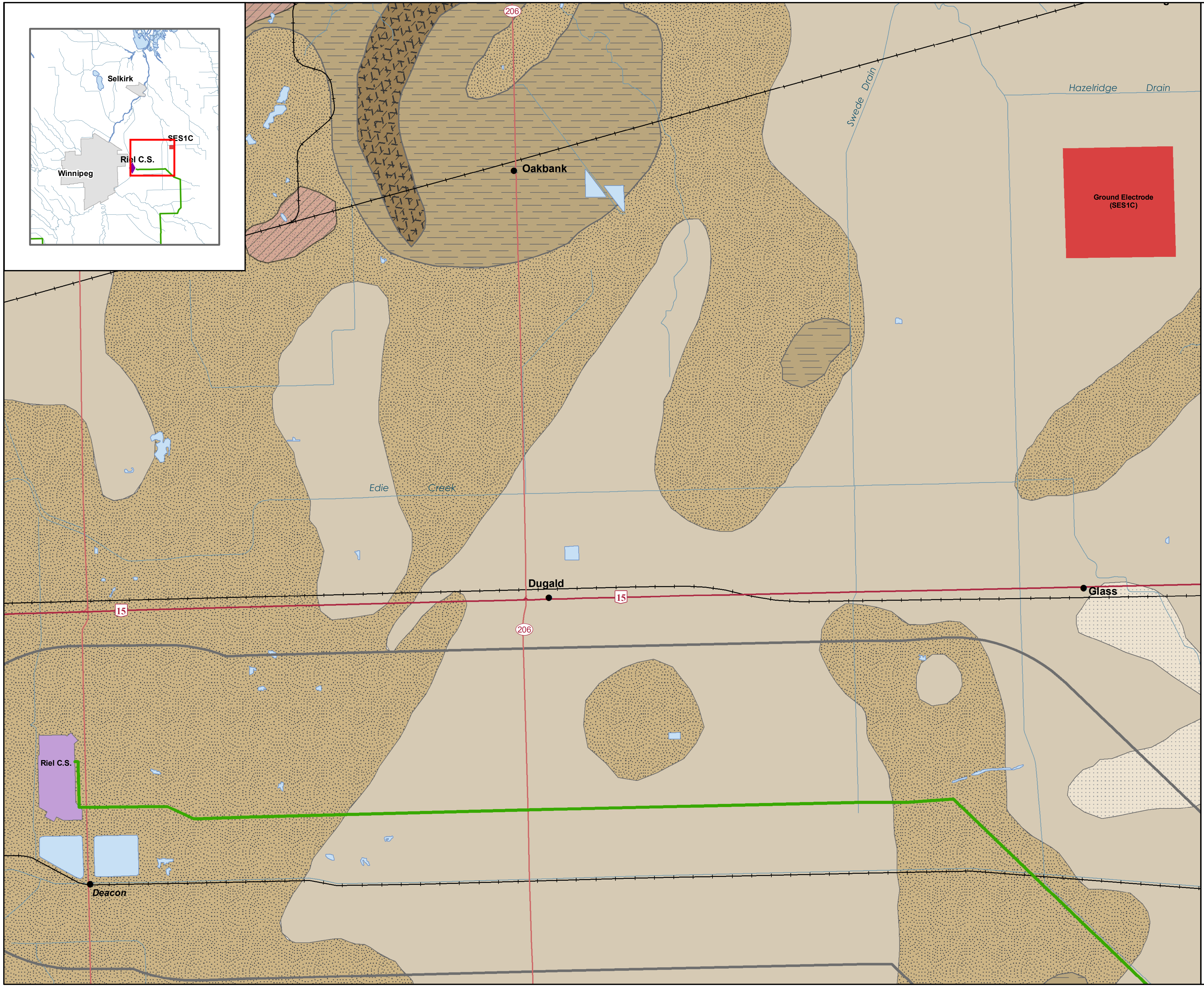
0 0.5 1 Miles

1:50,000

Selected Borehole Locations

Keewatinoow Converter Station

Map 7



Manitoba Hydro

Bipole III Transmission Project

Project Infrastructure

- ▬ Final Preferred Route
- ■ Converter Station Site
- 🟥 Ground Electrode Site
- ☐ Local Study Area

Depth of Bedrock (Metres)

- ▨ 0m - 10m
- ▨ 10m - 20m
- ▨ 20m - 30m
- ▨ 30m - 40m
- ▨ 40m - 50m
- ▨ Areas where shallow sand and gravel aquifers subject to pollution may occur
- ▨ Areas where carbonate rock (limestone and dolostones) is at or near ground surface and pollution of the carbonate rock aquifer is possible

Coordinate System: UTM Zone 14N NAD83
Data Source: MBHydro, MMM, ProvMB, NRCAN, MB Natural Resources, Rutulis, M. 1981
Date Created: July 21, 2011

N

0 0.5 1 Kilometres

0 0.5 1 Miles

1:55,000

Hydrogeological Condition

Riel Converter Station

Map 8

Appendix A

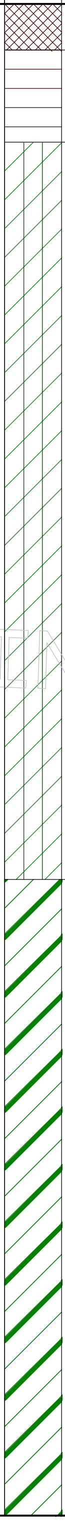
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"
CAMP

LOCATION Conawapa Construction Camp
TERRAIN TYPE
VEGETATION

DEPTH (m) | LAYER DEPTH (ELEV) (m) | SAMPLE NUM. | Moisture PL M.C. LL 20 40 60 80 | Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80 | Unconfined Compression ● Vane Shear Insitu ⊕ Lab ◆ (kPa) 20 40 60 80 | Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80 | GRAPHIC LOG | USCS | DESCRIPTION | INSTRUMENT INSTALLATION



USCS	DESCRIPTION
FILL	(0.00 - 0.31) **SAND AND GRAVEL FILL**
PT	(0.31 - 0.91) **PEAT MOSS** - Black, trace moisture, loose, organics.
CL-ML	(0.91 - 5.79) **SILTY CLAY** - Brown, trace to some moisture, firm, intermediate plasticity, fine to medium grained sand, with fine grained gravel. - Firm to stiff, trace oxidation at 1.22 m. - Grey at 4.27 m.
CI	(5.79 - 10.67) **CLAY** - Grey, trace to some moisture, moderately firm, intermediate plasticity, trace gravel clasts (approx. 2 mm in diameter). - Clay plugs drill bit, hammer not hammering properly.

Depth (m): 1, 2, 3, 4, 5, 6, 7, 8, 9

COORDINATES 6281587.80 N, 448751.60 E
AZIMUTH 0.00°
PLUNGE °
DATUM ELEV 89.66
ROCK ELEV
START DATE 2006 09 07
END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)
CONTRACTOR Friesen Drillers
DATE PRINTED 2008 02 13

HOLE OW1

SHEET 1 OF 10

MATERIALS AND FIELD SERVICES MANITOBA HYDRO

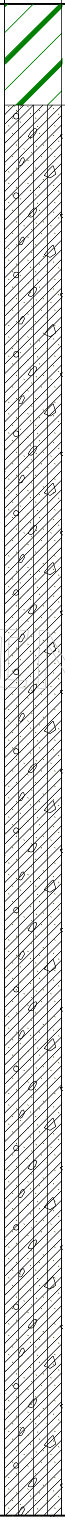
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◇ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
11						TILL	(10.67 - 52.73) **SILTY CLAY TILL (TILL SHEET 1)** - Dark grey, trace to some moisture, dense, with coarse grained sand and fine grained gravel (predominantly limestone gravel lithology).	
12								
13								
14								
15								
16							- Increase in density, till like gravelly zone at 15.85 m.	
							- Increase in fine grained sand content from 16.46 m to 17.07 m.	
17							- Decrease in sand content, increase in clay content at 17.07 m.	
18								
19								



COORDINATES	6281587.80 N, 448751.60 E	AZIMUTH	0.00°	PLUNGE	°	START DATE	2006 09 07
		DATUM ELEV	89.66	ROCK ELEV		END DATE	

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2008 02 13

HOLE OW1

SHEET 2 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

LOCATION Conawapa Construction Camp

TERRAIN TYPE

VEGETATION

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ⌖ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	DESCRIPTION	INSTRUMENT INSTALLATION
21							- Increase in density, downhole hammer is working hard at 21.34 m.	
22								
23								
24								
25								
26								
27								
28								
29								

COORDINATES 6281587.80 N, 448751.60 E

AZIMUTH 0.00° PLUNGE °

DATUM ELEV 89.66 ROCK ELEV

START DATE 2006 09 07

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2008 02 13

HOLE OW1

SHEET 3 OF 10

MATERIALS AND FIELD SERVICES MANITOBA HYDRO

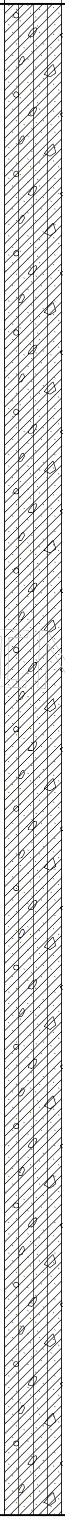
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◇ Lab ◆ (kPa) 20 40 60 80 Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
31								
32							- Drilling more difficult, increased till density and increased coarse gravel content at 32.0 m.	
33								
34								
35								
36								
37								
38								
39							- Decrease in clay content, increase in silt and fine grained sand content at 39.04 m.	



COORDINATES 6281587.80 N, 448751.60 E

AZIMUTH 0.00° PLUNGE °

DATUM ELEV 89.66 ROCK ELEV

START DATE 2006 09 07

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2008 02 13

HOLE OW1

SHEET 4 OF 10

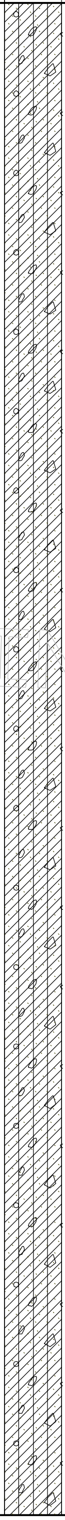
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
41								
42								
43								
44							- Boulder (approx. 20 cm in diameter) at 44.50 m.	
45								
46								
47								
48								
49								



COORDINATES 6281587.80 N, 448751.60 E	AZIMUTH 0.00° DATUM ELEV 89.66	PLUNGE ° ROCK ELEV	START DATE 2006 09 07 END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)	CONTRACTOR Friesen Drillers	DATE PRINTED 2008 02 13	HOLE OW1 SHEET 5 OF 10

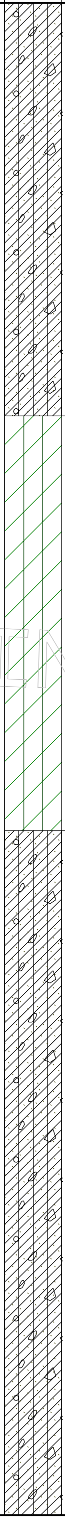
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH / (ELEV) (m)	SAMPLE NUM.	Moisture (PL, M.C., LL) 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ⌖ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
51								
52								
						CL-ML	(52.73 - 55.47) **SILTY CLAY (INTERTILL)** - Grey, moist, moderately firm to soft, trace coarse grained sand.	
53								
54								
55								
						TILL	(55.47 - 62.79) **SILTY CLAY TILL (TILL SHEET 2)** - Grey to dark brown, trace to some moisture, moderately dense, silty clay with coarse grained sand, and trace fine grained gravel.	
56								
57								
58								
59								
▼								



COORDINATES 6281587.80 N, 448751.60 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 89.66

ROCK ELEV

START DATE 2006 09 07

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2008 02 13

HOLE OW1

SHEET 6 OF 10

MATERIALS AND FIELD SERVICES MANITOBA HYDRO

MANITOBA HYDRO

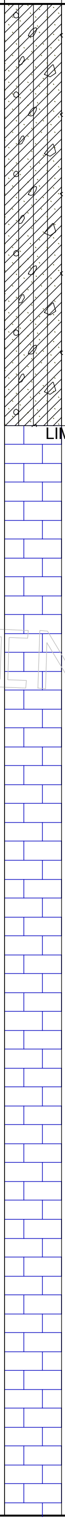
CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"
CAMP

DEPTH (m) | LAYER DEPTH (ELEV) (m) | SAMPLE NUM. | Moisture PL M.C. LL 20 40 60 80 | Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80 | Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 | Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80 | GRAPHIC LOG | USCS | INSTRUMENT INSTALLATION

LOCATION Conawapa Construction Camp
TERRAIN TYPE
VEGETATION

DESCRIPTION



61

- Till is very dense at 61.26 m.

62

LIMESTONE (62.79 - 92.59) **LIMESTONE BEDROCK** - Tan to light brown, clacitic dolomite.

63

64

- Fracture at 64.0 m to 64.21 m.

65

- Drill return indicates limited weathered zone/infill (chert and dolomite pieces, trace weathered limestone) at 65.23 m.

66

67

68

69

COORDINATES 6281587.80 N, 448751.60 E
AZIMUTH 0.00°
PLUNGE °
DATUM ELEV 89.66
ROCK ELEV
START DATE 2006 09 07
END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)
CONTRACTOR Friesen Drillers
DATE PRINTED 2008 02 13

HOLE OW1

SHEET 7 OF 10

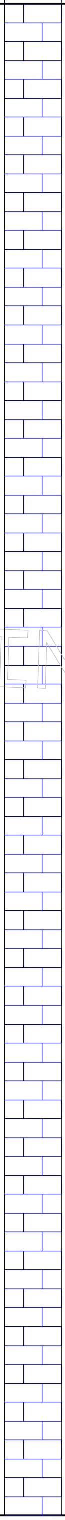
MATERIALS AND FIELD SERVICES MANITOBA HYDRO

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"
CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◇ Lab ◆ (kPa) 20 40 60 80 Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
71								
							- Fracture (approx. 0.15 m wide), lost water circulation, fracture zone infilled with oxidized clay and oxidized dolomite at 71.63 m.	
72								
73								
74							- Difficult to drill between 74.07 m and 81.08 m.	
75								
76								
77								
78								
79							- Difficulty drilling, drill started to bounce on very hard strata while drilling for approximately 0.10 m at 78.94 m depth.	



COORDINATES 6281587.80 N, 448751.60 E
AZIMUTH 0.00°
PLUNGE °
DATUM ELEV 89.66
ROCK ELEV
START DATE 2006 09 07
END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)
CONTRACTOR Friesen Drillers
DATE PRINTED 2008 02 13

HOLE OW1

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ⊕ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
81								
							- Fracture (approx. 50 mm wide) at 81.38 m.	
82								
83								
84								
85								
86								
87								
88								
							- Fracture (approx. 76 mm wide) at 88.39 m.	
89								

COORDINATES 6281587.80 N, 448751.60 E

AZIMUTH 0.00°

PLUNGE °

START DATE 2006 09 07

DATUM ELEV 89.66

ROCK ELEV

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2008 02 13

HOLE OW1

SHEET 9 OF 10

MATERIALS AND FIELD SERVICES MANITOBA HYDRO

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◇ Lab ◆ (kPa) 20 40 60 80 Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
91					▦			
92					▦			

END OF HOLE AT 92.59 m.

Note:
1. Installed 150 mm diameter steel well casing to elevation 25.69 m.
2. Open hole in bedrock (150 mm diameter) below elevation 25.69 m.

93

94

95

96

97

98

99

COORDINATES 6281587.80 N, 448751.60 E
AZIMUTH 0.00°
PLUNGE °
START DATE 2006 09 07
DATUM ELEV 89.66
ROCK ELEV
END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)
CONTRACTOR Friesen Drillers
DATE PRINTED 2008 02 13

HOLE OW1

SHEET 10 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m) | LAYER DEPTH (ELEV) (m) | SAMPLE NUM. | Moisture PL M.C. LL 20 40 60 80 / Standard Penetration Uncorrected Blow Count (N) 20 40 60 80 | Unconfined Compression, Vane Shear Insitu Lab (kPa) 20 40 60 80 / Penetrometer (Lab), Penetrometer (Field) (kPa) 20 40 60 80 | GRAPHIC LOG | USCS

LOCATION Conawapa Construction Camp

TERRAIN TYPE

VEGETATION

INSTRUMENT INSTALLATION

USCS	DESCRIPTION
SP	(0.00 - 7.93) **SILTY SAND** - Brown, damp, loose to moderately dense, fine to medium grained sand, with subrounded to subangular fine grained gravel, poorly graded. - Trace clay, increase in gravel content at 5.18 m.
ML	(7.93 - 10.06) **SILT** - Dark brown, damp to trace moisture, moderately dense, trace fine grained gravel, poorly graded. - Gravel and cobble zone (0.30 m thick) at 9.14 m. - Trace clay at 9.45 m.

COORDINATES 6281494.00 N, 448871.90 E

AZIMUTH 0.00° PLUNGE °

DATUM ELEV 88.74 ROCK ELEV

START DATE 2006 09 10

END DATE

HOLE TYPE (Foremost DR 24)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW2

SHEET 1 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
						TILL	(10.06 - 26.52) **CLAYEY SILT TILL (TILL SHEET 1)** - Dark brown, damp, moderately dense to dense, trace to some sand and fine to medium grained gravel.	
11							- Silty sand and gravel zone, grey, moist, loose, trace clay (approx. 0.41 m thick) at 11.28 m.	
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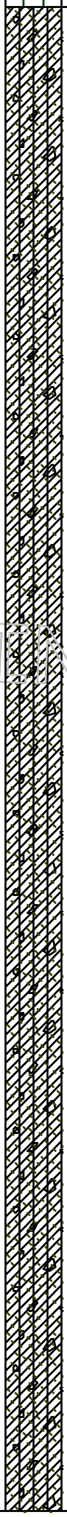

COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)	HOLE OW2
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers	
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 2 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION

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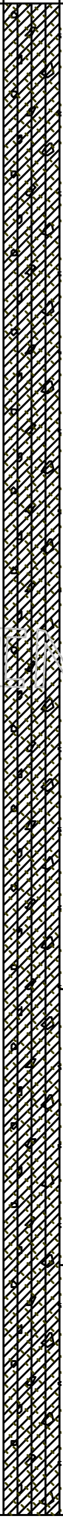

- Clayey silt, dry, dense, trace quartz sand, trace oxidation at 20.12 m.

(26.52 - 28.35) **SANDY SILT TILL** - Dark brown, damp, silt with fine to medium grained sand, and trace fine grained gravel.

- Moist sandy silt zone at 27.74 m. Drill bit plugging.

- Dry to damp at 28.04 m.

(28.35 - 60.05) **CLAYEY SILT TILL** - Dark brown, dry, dense, clayey silt, some fine grained sand, trace fine grained gravel.

- Decrease in clay content with depth.

COORDINATES 6281494.00 N, 448871.90 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 88.74

ROCK ELEV

START DATE 2006 09 10

END DATE

HOLE TYPE (Foremost DR 24)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW2

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture: PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 Penetrometer (Lab) ▼ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
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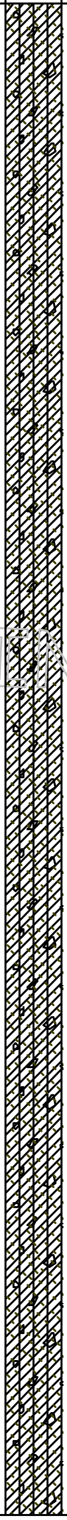
39								



COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)	HOLE
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers	OW2
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 4 OF 10

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression Vane Shear Insitu Lab (kPa) 20 40 60 80 / Penetrometer (Lab) Penetrometer (Field) (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
41								
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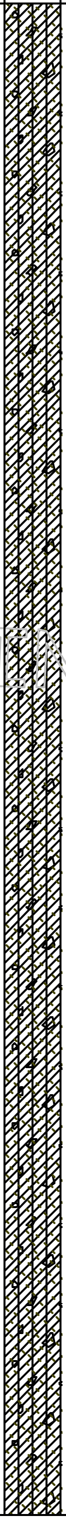
49								



COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)	HOLE OW2
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers	
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 5 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)

LAYER DEPTH (ELEV) (m)

SAMPLE NUM.

Moisture
PL M.C. LL
20 40 60 80

Standard Penetration ✳
Uncorrected Blow Count (N)
20 40 60 80

Unconfined Compression ⬣
Vane Shear Insitu ◈ Lab ◆
(kPa)
20 40 60 80

Penetrometer (Lab) ▽
Penetrometer (Field) ▽
(kPa)
20 40 60 80

GRAPHIC LOG

USCS

LOCATION Conawapa Construction Camp

TERRAIN TYPE

VEGETATION

DESCRIPTION

INSTRUMENT INSTALLATION

51
52
53
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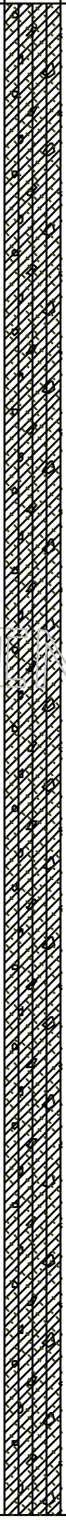
58
59



- Injected water to increase drilling fluid at 50.29 m.

COORDINATES 6281494.00 N, 448871.90 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 88.74

ROCK ELEV

START DATE 2006 09 10

END DATE

HOLE TYPE (Foremost DR 24)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW2

SHEET 6 OF 10

MATERIALS AND FIELD SERVICESMANITOBA HYDRO

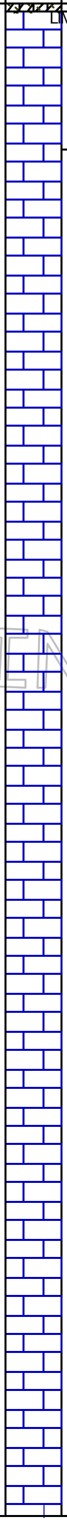
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression Vane Shear Insitu Lab (kPa) 20 40 60 80 Penetrometer (Lab) Penetrometer (Field) (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
▼						LIMESTONE	(60.05 - 60.96) **LIMESTONE BEDROCK** - Tan to buff, upper contact zone is rubble, some clayey silt infill, calcitic dolomite. - Fracture (0.25 m thick) at 60.66 m.	
61							(60.96 - 71.02) **KARSTIC LIMESTONE** - Tan to light grey. Easy drilling infilled weathered bedrock zone. Infill predominantly fine to medium grained silica sand and cherty zones. Broken zone between 60.96 m and 63.70 m. Karstic infilled bedrock.	
62								
63							- Fracture (0.30 m thick) at 62.79 m.	
64							- Hard, competant bedrock (0.30 m thick) at 63.70 m. - Karstic infilled bedrock, infilled with medium grained silica sand, siltstone, chert, dolomite, pink quartz, silt, silty clay. Rubble bedrock zone at 64.01 m.	
65								
66								
67							- Borehole collapsing between 60.93 m and 67.06 m. Casing installed to 65.99 m.	
68								
69								



COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers
				DATE PRINTED 2007 12 18

HOLE OW2

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ⬢ Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
							- Rubble bedrock/broken and karstic infilled bedrock zones continue through to 70.71 m depth.	
71							(71.02 - 97.29) **LIMESTONE BEDROCK** - Tan to buff-yellow, dolomitic, competent, water return is beige in color, trace chert in borehole return.	
72								
73								
74								
75								
76							- 0.10 m thick soft bedrock zone at 76.2 m depth.	
77								
78							- Clay infilled fracture (50 mm thick) at 78.03 m. - Clay infilled fracture (50 mm thick) at 78.33 m. - Weathered bedrock, but not karstic and infilled as zones above. Limestone drills hard, water production has increased marginally. Orange to beige coloured water return, interbedded hard and soft drill zones below 78.64 m.	
79							- Possible fractures, no clay infill observed in wash. Water production has increased between 79.55 m and 81.38 m.	

COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)	HOLE OW2
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers	
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 8 OF 10

MANITOBA
HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

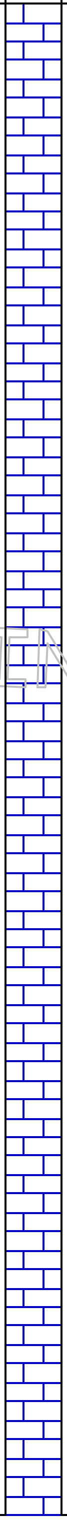
CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	DESCRIPTION	INSTRUMENT INSTALLATION

LOCATION Conawapa Construction Camp

TERRAIN TYPE

VEGETATION



81

82

83

84

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88

89

- 76 mm thick clay infill fracture at 80.16 m.

- 50 mm thick clay infill fracture at 80.52 m.

- 76 mm thick fracture in otherwise solid limestone at 88.09 m.

COORDINATES 6281494.00 N, 448871.90 E

AZIMUTH 0.00°
PLUNGE °

DATUM ELEV 88.74
ROCK ELEV

START DATE 2006 09 10
END DATE

HOLE TYPE (Foremost DR 24)
CONTRACTOR Friesen Drillers
DATE PRINTED 2007 12 18

HOLE OW2

SHEET 9 OF 10

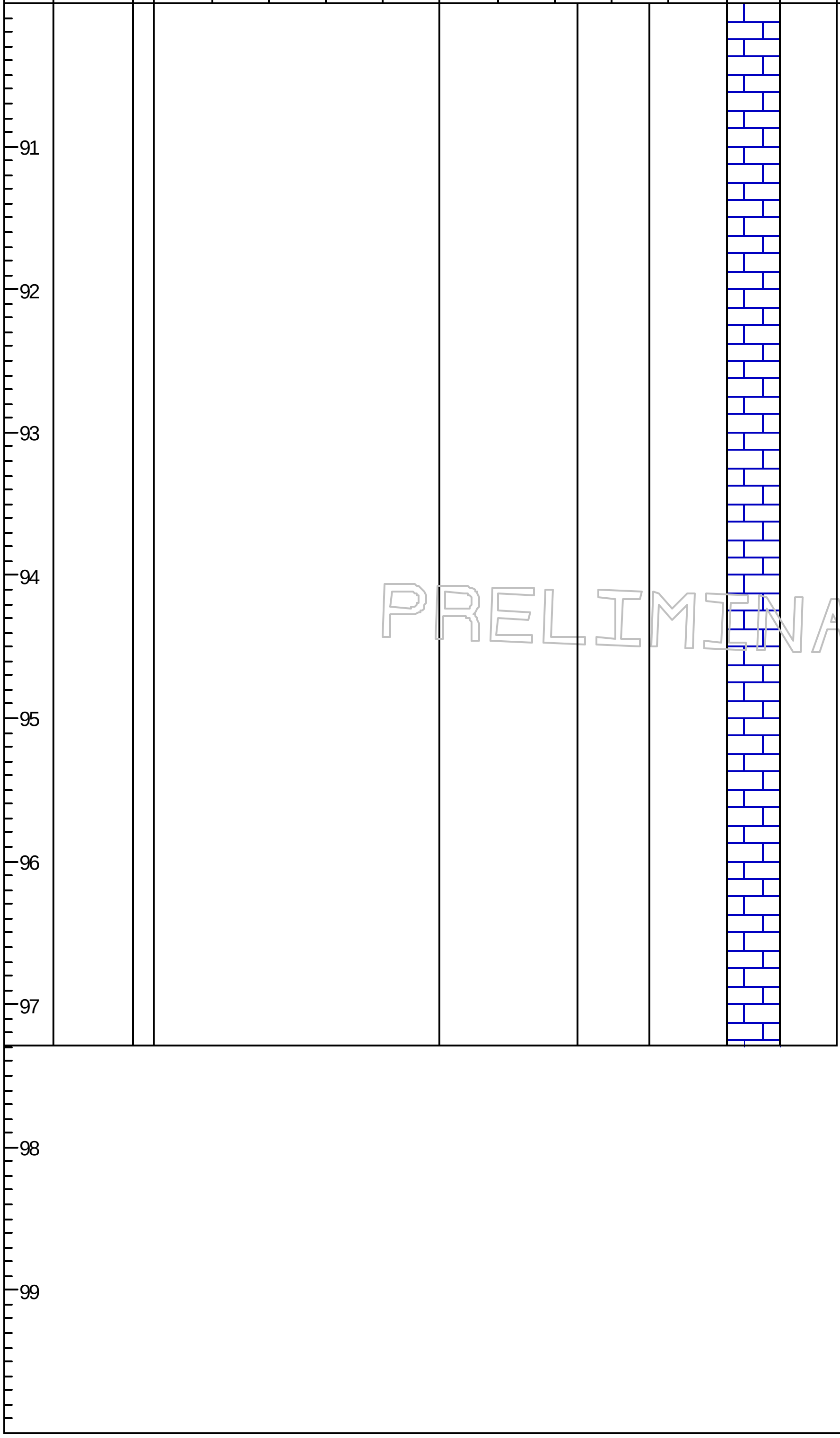
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear (kPa) Insitu ◈ Lab ◆ 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION



- Greyish water return at 91.44 m.

END OF HOLE AT 97.29 m.

Note:
1. During airlift, water is light grey and cloudy.
2. Final well casing installed to elevation 16.84 m.
3. Open hole in bedrock (150 mm diameter) below elevation 16.84 m.

COORDINATES 6281494.00 N, 448871.90 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 10	HOLE TYPE (Foremost DR 24)	HOLE OW2
	DATUM ELEV 88.74	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers	
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 10 OF 10

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"
CAMP

DEPTH (m) | LAYER DEPTH (ELEV) (m) | SAMPLE NUM. | Moisture PL M.C. LL 20 40 60 80 | Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80 | Unconfined Compression Vane Shear Insitu Lab (kPa) 20 40 60 80 | Penetrometer (Lab) Penetrometer (Field) (kPa) 20 40 60 80 | GRAPHIC LOG | USCS | INSTRUMENT INSTALLATION

LOCATION Conawapa Construction Camp
TERRAIN TYPE
VEGETATION

USCS	DESCRIPTION
GM	(0.00 - 6.10) **SILTY SAND AND GRAVEL** - Brown, damp, moderately dense to dense, moderately graded, fine to coarse grained sand, with fine to medium grained gravel, subangular clasts. - Cobble zone between 3.96 m and 4.88 m. - Granite boulder at 4.44 m. - Increase in silt content, trace clay below 4.88 m.
ML	(6.10 - 8.84) **SILT** - Brown, with moisture, dense, poorly graded, trace clay, some fine grained sand, interlayered thin (cm-scale) gravel zones.
TILL	(8.84 - 57.15) **TILL (TILL SHEET 1)** - Grey, trace moisture, dense, low plasticity silty clay, with fine to medium grained sand, with fine grained subangular gravel, moderately graded, hard drilling.

Depth (m): 1 2 3 4 5 6 7 8 9

COORDINATES 6281417.00 N, 448946.00 E
AZIMUTH 0.00°
PLUNGE °
DATUM ELEV 85.36
ROCK ELEV
START DATE 2006 09 09
END DATE
HOLE TYPE (Foremost DR 24 Dual Rotary)
CONTRACTOR Friesen Drillers
DATE PRINTED 2007 12 18

HOLE OW5

SHEET 1 OF 10

MATERIALS AND FIELD SERVICES MANITOBA HYDRO

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
11								
12								
13							- Dark brown, dense, increase in coarse grained gravel content at 13.11 m.	
14								
15								
16								
17								
18								
19								

COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 85.36

ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◆ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▽ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
							- Increase in clay content, cuttings sticking on inside of casing wall at 20.12 m.	
21								
22								
23								
24								
25							- Trace oxidation at 25.60 m.	
26								
27								
28								
29								
							- Decrease in clay content below 29.87 m.	

COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 85.36

ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
31								
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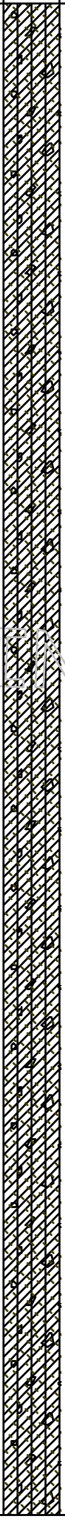

COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 85.36

ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

SHEET 4 OF 10

MATERIALS AND FIELD SERVICESMANITOBA HYDRO

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression / Vane Shear Insitu Lab (kPa) 20 40 60 80 / Penetrometer (Lab) Penetrometer (Field) (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
41								
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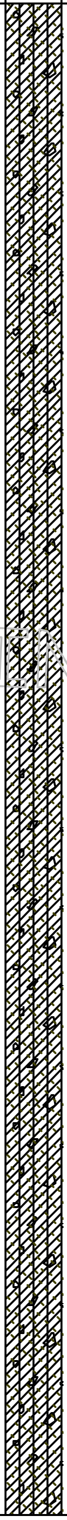
49								



COORDINATES	6281417.00 N, 448946.00 E	AZIMUTH	0.00°	PLUNGE	°	START DATE	2006 09 09	HOLE TYPE (Foremost DR 24 Dual Rotary)
		DATUM ELEV	85.36	ROCK ELEV		END DATE		CONTRACTOR Friesen Drillers
								DATE PRINTED 2007 12 18

HOLE
OW5

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"
CAMP

DEPTH (m)

LAYER DEPTH (ELEV) (m)

SAMPLE NUM.

Moisture: PL, M.C., LL; 20 40 60 80

Standard Penetration ✳ Uncorrected Blow Count (N); 20 40 60 80

Unconfined Compression; Vane Shear Insitu, Lab (kPa); 20 40 60 80

Penetrometer (Lab); Penetrometer (Field) (kPa); 20 40 60 80

GRAPHIC LOG

USCS

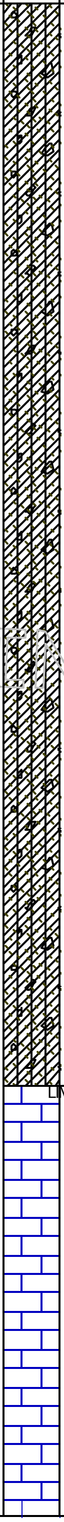
LOCATION Conawapa Construction Camp

TERRAIN TYPE

VEGETATION

DESCRIPTION

INSTRUMENT INSTALLATION



51

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55

- No cuttings returned between 54.86 m and 56.24 m.

56

▼

57

LIMESTONE (57.15 - 64.31) **LIMESTONE BEDROCK** - Tan to light grey to buff, broken calcitic dolomite, trace silty clay infill material, with chert, dolomite, siltstone in the cuttings return.
- Water return is very silty.

58

59

COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00°

PLUNGE °

DATUM ELEV 85.36

ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

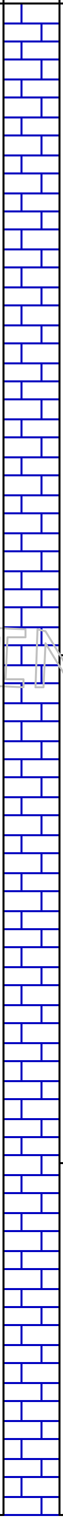
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression Vane Shear Insitu Lab (kPa) 20 40 60 80 Penetrometer (Lab) Penetrometer (Field) (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION



61

- Fracture, small seams/broken zone that the drill falls through (approx. 25 mm to 100 mm intervals) at 60.96 m.

62

63

64

(64.31 - 67.67) **KARSTIC LIMESTONE BEDROCK AND INFILL** - Sandy clay infill is saturated, very soft, no water return from formation, clay, with silty sand, grey, fine to medium grained sand, dense cemented sand nodules in cutting return between 64.31 m and 67.67 m.

65

66

67

(67.67 - 91.20) **LIMESTONE BEDROCK**

68

69

COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00° PLUNGE °

DATUM ELEV 85.36 ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

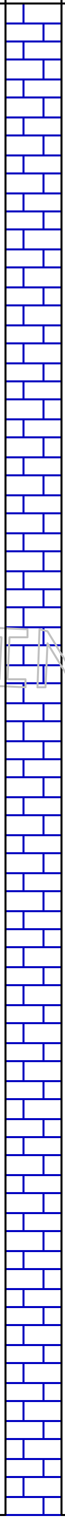
MANITOBA HYDRO

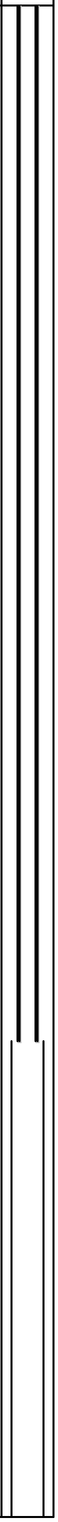
CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▼ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
71							- Soft zone (0.61 m thick), water return very silty, abundant sand in formation return at 70.10 m.	
72								
73								
74								
75							- Competent dolomitic limestone, hard, no fractures, chert infilled vugs in dolomite at 75.59 m.	
76								
77								
78								
79							- Added foam to drilling water at 79.55 m to improve cutting return.	





COORDINATES 6281417.00 N, 448946.00 E

AZIMUTH 0.00° PLUNGE °

DATUM ELEV 85.36 ROCK ELEV

START DATE 2006 09 09

END DATE

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

SHEET 8 OF 10

MATERIALS AND FIELD SERVICESMANITOBA HYDRO

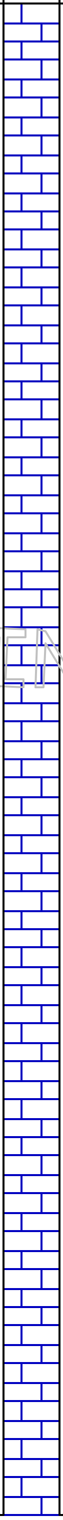
MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◈ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▽ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
81								
82								
83								
84								
85							- Soft 0.30 m zone in bedrock at 85.04 m. - Water return increases at 85.50 m. - Very hard, slow drilling, no cuttings return, added lifting foam to improve cutting return, no water return, unable to identify rock at 85.65 m.	
86								
87								
88								
89								



COORDINATES	6281417.00 N, 448946.00 E	AZIMUTH	0.00°	PLUNGE	°	START DATE	2006 09 09
		DATUM ELEV	85.36	ROCK ELEV		END DATE	

HOLE TYPE (Foremost DR 24 Dual Rotary)

CONTRACTOR Friesen Drillers

DATE PRINTED 2007 12 18

HOLE OW5

SHEET 9 OF 10

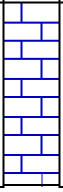
MATERIALS AND FIELD SERVICESMANITOBA HYDRO

MANITOBA HYDRO

CONAWAPA CONSTRUCTION CAMP

CONAWAPA AXIS "B"

CAMP

DEPTH (m)	LAYER DEPTH (ELEV) (m)	SAMPLE NUM.	Moisture PL M.C. LL 20 40 60 80 / Standard Penetration ✳ Uncorrected Blow Count (N) 20 40 60 80	Unconfined Compression ● Vane Shear Insitu ◆ Lab ◆ (kPa) 20 40 60 80 / Penetrometer (Lab) ▼ Penetrometer (Field) ▼ (kPa) 20 40 60 80	GRAPHIC LOG	USCS	LOCATION Conawapa Construction Camp TERRAIN TYPE VEGETATION DESCRIPTION	INSTRUMENT INSTALLATION
91								

END OF HOLE AT 91.22 m.

1. Initial 150 mm diameter steel well casing installed to elevation 28.02 m.
2. 150 mm steel well casing removed, and reinstalled to elevation 8.5 m on September 17, 2007.
3. 150 mm diameter open hole in bedrock below elevation 8.5 m.

92

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COORDINATES 6281417.00 N, 448946.00 E	AZIMUTH 0.00°	PLUNGE °	START DATE 2006 09 09	HOLE TYPE (Foremost DR 24 Dual Rotary)	HOLE OW5	
	DATUM ELEV 85.36	ROCK ELEV	END DATE	CONTRACTOR Friesen Drillers		
MATERIALS AND FIELD SERVICESMANITOBA HYDRO				DATE PRINTED 2007 12 18	SHEET 10	OF 10

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:32 05 Apr 22

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE #4	GRAIN SIZE #200	GRAIN SIZE 0.002mm	POCKET PEN.	SPT N ☐ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
												TYPE OF HOLE *SDH*	
0	(85.57) 1.00											**PEAT, water-logged**	
	(84.57)					0.0						**SILTY CLAY, trace gravel, trace sand, brown**	
	(84.27)											**SAND, coarse, some silt, trace gravel, brown, water bearing**	
	(83.97) 2.80					1.5 4.5					CL	**TILL** **SILTY CLAY, trace gravel, trace sand, grey**	
	(82.77)											**END OF HOLE**	

N 6,270,364.30 E 442,624.97	------ *-90.0*	*81-04-06* *81-04-06*		**HOLE**
LOCATION *Road*	STRIKE DIP	DATE(S) DRILLED		**CR-009**
COMPOSITE LOG	**ACRES WARDROP**		APPROVED	SHEET *1* OF *1*

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:32
05 Apr 22

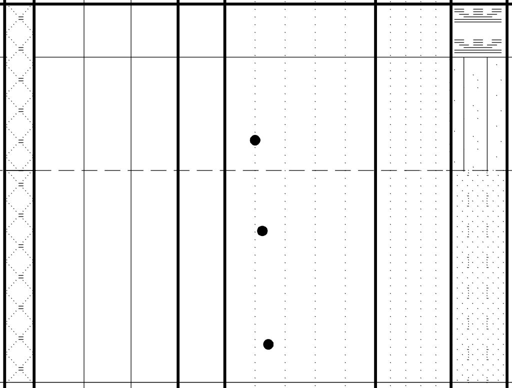
DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE #4	GRAIN SIZE #200	GRAIN SIZE 0.002mm	POCKET PEN.	SPT N □ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
												TYPE OF HOLE *SDH*	
0	(85.53)											**PEAT, water-logged**	
	1.90 (83.63)											**ORGANIC SAND AND GRAVEL**	
	(82.53)					4.5					CL	**SAND, coarse, trace gravel, trace silt, trace clay, brown, water bearing**	
	(82.23)											**TILL** **SILTY CLAY, trace gravel, trace sand, grey**	
5	5.00 (80.53)											**END OF HOLE**	

N 6,270,594.51 E 442,842.54	------ *-90.0*	*81-04-06* *81-04-06*		**HOLE**
LOCATION *Road*	STRIKE DIP	DATE(S) DRILLED		**CR-010**
COMPOSITE LOG	**ACRES WARDROP**		APPROVED	SHEET *1* OF *1*

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:32 05 Apr 22

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE #4	GRAIN SIZE #200	GRAIN SIZE 0.002mm	POCKET PEN.	SPT N ☐ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
												TYPE OF HOLE *SDH*	
0	(89.89) 0.70											**PEAT, water-logged**	
	(89.19) 2.20										ML	**SILT, and fine sand, trace gravel, trace clay, brown, water bearing**	
	(87.69) 5.00										SM	**SAND, fine, and silt, trace gravel, grey, occasional cobble, water bearing**	
5	(84.89)											**END OF HOLE**	



N 6,271,714.72 E 442,662.93	------	*-90.0*	*81-04-06* *81-04-06*	**HOLE**
LOCATION *Road*	STRIKE	DIP	DATE(S) DRILLED	**CR-011**
COMPOSITE LOG		**ACRES WARDROP**	APPROVED	SHEET *1* OF *1*

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:52
05 Jan 28

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	Cu	GRAIN SIZE #4	#10	#40	#200	0.002mm	POCKET PEN.	SPT N □ WP W WL 20 60 (N) 0 20 40%	COMP. TEST OPT.DEN. (kg/m 3)	OMC (%)	LOG	PERMAFROST	USCS	DESCRIPTION	INSTR. LOG
																TYPE OF HOLE *SDH*	
0	(87.94)															**ORGANIC GRAVEL**	
	0.30 (87.64)														SW	**SAND, some gravel (subangular), trace silt, trace clay, moist, brown** 0.50 to 1.50 - trace gravel 1.90 to 2.10 - some silt	
	2.10 (85.84)								2.5						CL-ML	**SILTY CLAY, trace sand, grey**	
5	5.10 (82.84)															**END OF HOLE**	

N 6,272,534.70 E 442,872.71	------ -*90.0*	*81-04-06* *81-04-06*		**HOLE**
LOCATION *Deposit N-3*	STRIKE DIP	DATE(S) DRILLED		**CR-012**
COMPOSITE LOG	**ACRES WARDROP**		APPROVED	SHEET *1* OF *1*

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:52
05 Jan 28

TYPE OF HOLE *SDH*

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	Cu	GRAIN SIZE #4	#10	#40	#200	0.002mm	POCKET PEN.	SPT N □ WP W WL 20 60 (N) 0 20 40%	COMP. TEST OPT.DEN. (kg/m 3)	OMC (%)	LOG	PERMAFROST	USCS	DESCRIPTION	INSTR. LOG
0	(87.68)														PT	**ORGANIC SAND, 0.10 m of surficial peat**	
	0.40 (87.28)														GP	**GRAVEL (subangular), and sand, trace silt, trace clay, moist, brown**	
	1.50 (86.18)								3.5						ML	**SILT, trace sand, trace clay, brown**	
																2.80 to 5.10 - with sand	
5	5.10 (82.58)														SP	**SAND, some gravel (subangular), trace silt, trace clay, moist, brown**	
	5.60 (82.08)								2.3							**SILT, some sand, trace gravel, trace clay, brown**	
	7.20 (80.48)															**SAND, some silt, trace clay, brown** 7.30 to 8.00 - trace gravel, moist	
																8.00 to 9.90 - trace gravel (subangular), trace silt	
	9.90 (77.78)															**END OF HOLE**	

N 6,274,236.92 E 443,751.31

LOCATION *Deposit N-3*

STRIKE ------

DIP *-90.0*

DATE(S) DRILLED *81-04-06* *81-04-06*

COMPOSITE LOG **ACRES WARDROP**

APPROVED

HOLE CR-015

SHEET *1* OF *1*

MANITOBA HYDRO

CONAWAPA GENERATING STATION

PRINTED: 10:32
05 Apr 22

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE			POCKET PEN.	SPT N □ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
			#4	#200	0.002mm								
												TYPE OF HOLE *SDH*	
0	(90.38) 1.30											**PEAT**	
	(89.08) 2.10						●			■		**SILT, and fine sand, trace gravel, brown, frost affected**	
5	(88.28) 5.10		98	87	27	4.5	● ● ●		▨		CL	**TILL** **SILTY CLAY, some sand, trace gravel, grey**	
	(85.28)											**END OF HOLE**	

N 6,277,782.49 E 446,491.09

LOCATION *Road*

STRIKE ------

DIP *-90.0*

DATE(S) DRILLED *81-04-04* *81-04-04*

APPROVED

HOLE
CR-029

SHEET *1* OF *1*

COMPOSITE LOG

ACRES WARDROP

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:32
05 Apr 22

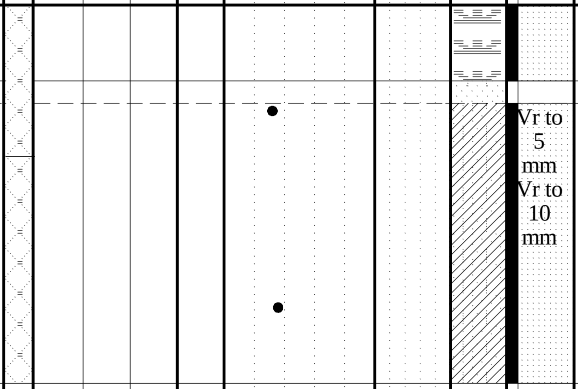
DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE #4	GRAIN SIZE #200	GRAIN SIZE 0.002mm	POCKET PEN.	SPT N ☐ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
												TYPE OF HOLE *SDH*	
0	(91.68)											**PEAT, water-logged**	
	1.40 (90.28)					0.0	●					**SILTY CLAY, trace gravel, trace sand, grey** 1.40 to 2.60 - some sand, probably frost affected	
						3.3					CL	2.60 to 5.10 - till-like	
							●						
5	5.10 (86.58)											**END OF HOLE**	

N 6,279,060.92 E 447,386.42	------ *-90.0*	*81-04-04* *81-04-04*	**HOLE**
LOCATION *Road*	STRIKE DIP	DATE(S) DRILLED	**CR-038**
COMPOSITE LOG **ACRES WARDROP**		APPROVED	SHEET *1* OF *1*

MANITOBA HYDRO **CONAWAPA GENERATING STATION**

PRINTED: 10:32 05 Apr 22

DEPTH	LAYER DEPTH (ELEV) (m)	METHOD	GRAIN SIZE #4	GRAIN SIZE #200	GRAIN SIZE 0.002mm	POCKET PEN.	SPT N ☐ WP W WL 20 60 (N) 0 20 40%	PERM. (m/s) 10-6 10-4	LOG	PERMAFROST TEMP (°C)	USCS	DESCRIPTION	INSTR. LOG
												TYPE OF HOLE *SDH*	
0	(91.85) 1.00											**PEAT, frozen**	
	(90.85)											**SAND, coarse, with silt, trace gravel, moist, grey, trace organic**	
	(90.55)									Vr to 5 mm Vr to 10 mm	CL	**SILTY CLAY, some sand, trace gravel, grey**	
5	5.00 (86.85)											**END OF HOLE**	



N 6,279,734.92 *E 447,788.41*	------ *-90.0*	*81-04-04* *81-04-04*	**HOLE CR-040**
LOCATION *Road*	STRIKE DIP	DATE(S) DRILLED	
COMPOSITE LOG **ACRES WARDROP**		APPROVED	SHEET *1* OF *1*