6111 91 Street
Edmonton, AB T6E 6V6
tel: 780.496.9048
fax: 780.496.9049

Suite 325, 1925 18 Avenue NE
Calgary, AB T2E 7T8
tel: 403.592.6180
fax: 403.283.2647

#106, 10920 84 Avenue
Grande Prairie, AB T8X 6H2
tel: 780.357.5500
fax: 780.357.5501

toll free: 888.722.2563
www.mems.ca

Lindbergh SAGD Expansion Project
Hydrogeology

Prepared for:
Pengrowth Energy Corporation

Prepared by:
Millennium EMS Solutions Ltd.
6111 – 91 Street
Edmonton, Alberta
T6E 6V6

December 2013
File 11-033

Table of Contents

List of Appendices

1.0 INTRODUCTION

Pengrowth Energy Corporation (Pengrowth) is proposing to expand their steam assisted gravity drainage (SAGD) operations in the Lindbergh area of Alberta, approximately 24 km southeast of Bonnyville within St. Paul County No. 19 and the Municipal District of Bonnyville No. 87. Pengrowth currently operates the Lindbergh SAGD Pilot Project in Section 13, Township 058, Range 05, West of the Fourth Meridian and is proposing to develop the Lindbergh SAGD Expansion Project (the Project), which will expand bitumen production of the approved Lindbergh SAGD Project (Phase 1) from 1,987 m^3/day (12,500 barrels per day (bpd)) to 4,770 m^3/day (30,000 bpd). The Project footprint is shown in Figure 1. The central processing facility (CPF) for the Project is located in 25-058-05 W4M.

This report summarizes baseline hydrogeological data that have been collected within the hydrogeological study area and evaluates the potential effects the Project may have on groundwater resources.

The Project's SAGD wells will be completed within the Lloydminster Sand of the Mannville Group and two approved and existing disposal wells are planned to be used to dispose of waste into the Cambrian Basal Sandstone Formation. Water for the operation of the SAGD facilities will be obtained from Pengrowth's existing North Saskatchewan River Pump Station located in 10-23-056-05 W4M, authorized under *Water Act* Licence No. 00029768-00-00, as amended. No groundwater will be used as part of the Project.

For the purposes of this report, tables will be presented in Appendix A and figures will be presented in Appendix B.

2.0 ASSESSMENT APPROACH

2.1 Terms of Reference

The final Terms of Reference were issued by Alberta Environment and Sustainable Resource Development (ESRD) on December 13, 2013. Requirements relating to hydrogeology are identified in Section 3.2 of the Terms of Reference. A concordance table is included as Table 1 in Appendix A.

2.2 Regulatory Considerations

Key government regulations or guidelines applicable to the Project and relating to hydrogeology include:

- Alberta *Environmental Protection and Enhancement Act* (EPEA) as amended (Alberta Government, 2000);
- *Water Conservation and Allocation Guideline for Oilfield Injection* (Alberta Government, 2006);

- Alberta Energy Regulator Draft Directive 023: Oil Sands Project Applications (AER, 2013);
- Lower Athabasca Region Groundwater Management Framework (Alberta Government, 2012); and
- Lower Athabasca Region Groundwater Management Framework Supporting Document for the Cold Lake- Beaver River (CLBR) Area (Alberta Government, 2013).

2.3 Study Areas

The hydrogeology local study area (HLSA) was defined as a 1.6 km buffer around the EIA Project Area and the hydrogeology regional study area (HRSA) was defined as an 8 km buffer around the HLSA (Figure 1). The HRSA was selected to satisfy the requirements presented in Section 7.3 of Draft Directive 023 (AER, 2013). It is expected that the HLSA will include the extent of all groundwater impacts related to the Project and that any residual effects with the potential to cumulatively interact with the residual effects of other projects will be within the HRSA.

2.4 Impacts and Assessment Criteria

Components of the Project that have the potential to impact groundwater resources include:

- the operation of surface facilities; and
- steaming and production.

The potential impact to groundwater resources are evaluated in terms of the following criteria for residual effects:

- magnitude;
- geographic extent;
- duration;
- reversibility;
- frequency;
- project contribution;
- confidence rating; and
- probability of occurrence.

ESRD and the Canadian Environmental Assessment Agency (CEAA) provide additional guidance regarding the criteria which is included in Part C of the Application (Pengrowth, 2013).

The **magnitude** is classified as follows: negligible (residual effect is not detectable), low (residual effect is detectable but well within environmental standards), moderate (residual effect is approaching environmental standards), and high (residual effect exceeds environmental standards).

The **geographic extent** is defined as local (within the HLSA), regional (within the HRSA) or provincial (outside of the HRSA). Effects associated with the operation of surface facilities, steaming and production are anticipated to be only local in extent.

The **duration** of impact is determined to be short-term (less than one year), medium-term (less than the Project duration which is expected to be 25 years), long-term (up to 10 years past the Project decommissioning) or residual (more than 10 years past the Project decommissioning).

The **reversibility** of an impact is determined to be short-term (effects diminish upon cessation of activities), long-term (effects remain after cessation of activities but diminish with time) or irreversible (effects do not diminish).

The **frequency** is determined to be continuous (occurs continually over the assessment period), isolated (effects are confined to a specified period), periodic (occurs intermittently but repeatedly), or occasional (occurs intermittently and sporadically).

The **project contribution** is classified as, positive (net benefit), negative (net loss) or neutral (no net benefit or loss).

The **confidence rating** is defined as low if the impact is based on an incomplete understanding of cause-effect relationships and incomplete data, moderate if based on a good understanding of the relationships using data from elsewhere or incompletely understood relationships using data pertinent to the study area or it is rated as high if the impact is based on a good understanding of the relationships and data pertinent to the study is used.

The **probability of occurrence** can be considered low (unlikely), medium (possible or probable) or high (certain).

2.5 Valued Environmental Components

The valued environmental components (VECs) focused on for this assessment included non-saline aquifers, surface water bodies and wetland areas. It was determined that the quality of these VECs could be impacted by the operation of surface facilities, as well as steaming and production activities. Pengrowth does not currently plan to use groundwater for steam generation; therefore, the quantity of water associated with the VECs will not be impacted and has not been assessed. Impacts to

vegetation, wildlife and aquatic resources as a result of groundwater and surface water interactions were also considered.

3.0 METHODOLOGY

3.1 Information Sources

The baseline study was completed based on a literature review and field investigations. Initially a desktop review of available information was completed and data gaps were identified. A field program was then initiated to obtain site specific information. The drilling programs targeted permeable units given that these represent groundwater resources; therefore information for low permeability units is limited. Key information sources included the following:

- published regional geological and hydrogeological maps and reports from the Alberta Geological Survey and Alberta Research Council;
- field investigations within the HLSA;
- a review of water well records in the ESRD Water Well Information Database;
- a review of groundwater and surface water licenses issued by ESRD; and
- a review of geophysical logs.

Field investigations which have provided information relevant to this report include the following:

- Drilling activities conducted in 2002, 2005, 2010 and 2012 resulted in the installation of 22 shallow monitoring wells near former facilities and on the Pilot Project plant site. Of the 22 monitoring wells installed, 19 remain. One of these wells is completed within the Grand Centre Formation, one is completed within the Marie Creek Formation and 17 are completed in the Sand River Formation equivalent.
- Drilling and installation of ten monitoring wells at four locations in 2011 near the Pilot Project SAGD well pad to establish baseline conditions. Of these, five were completed within the Sand River Formation equivalent, four were completed within the Ethel Lake Formation and one was completed straddling the Lea Park Formation and the overlying Bonnyville Formation Unit 1.
- Drilling and installation of nine monitoring wells in 2013; two in the vicinity of the Pilot Project SAGD well pad to confirm aquifer characteristics and seven within the HLSA to collect baseline data for the Project. Of these, one is completed within the Sand River Formation equivalent, two are completed within the Ethel Lake Formation, one is completed within the Bonnyville Formation, one is completed within the Muriel Lake Formation and four are completed within the Lea Park Formation. Based on the desktop review prior to drilling in

2013, it was determined that using the sonic drilling method for the 2013 program would produce the best results for interpretation of the till units.

- Hydraulic conductivity testing that has been completed on most of the monitoring wells.
- Groundwater monitoring results collected up to fall 2013, which included monitoring physical characteristics of the groundwater, as well as the collection of samples for chemical analysis.
- Field verified surveys that were conducted in January and June 2012 and in June, July and October 2013 in an effort to confirm groundwater and surface water users within the HLSA. MEMS personnel attempted to establish contact with landowners in person. Each attempt to contact a landowner was documented and a Field Verification Survey questionnaire was either completed or a letter outlining the purpose of the survey and how to participate was left at the residence.

3.2 Established Targets and Thresholds

As part of the approved groundwater monitoring program for the Pilot Project, *target* and *threshold* values for the hydrostratigraphic units were established. The results of ongoing operational monitoring were then compared to the established limits on an annual basis and exceedences of the *targets* and/or *threshold* values will indicate that attention to the parameter is required or the groundwater response plan may be triggered.

Groundwater monitoring wells that were installed in the vicinity of the Pilot Project SAGD well pad in 2011 were sampled five times prior to steaming (before February 2012) and the results of these chemical analyses were considered to be representative of the background groundwater quality. Historical monitoring wells located upgradient of the operations were also used to enhance the background dataset. Both *target* and *threshold* values were established for the hydrostratigraphic units of completion using ESRD-approved methods outlined in the Annual Groundwater Monitoring Plan (MEMS, 2011a) and the statistical methods presented in the 2011 Groundwater Monitoring report (MEMS, 2012a). *Targets* were defined as the 95th percentile of the background data for an upper *target* and the 5th percentile for a lower *target*. Upper *threshold* limits were defined as the most stringent guideline value according to the Alberta Tier 1 Soil and Groundwater Remediation Guideline (Alberta Environment, 2010) or as the highest value measured prior to full plant start-up if the background results exceed the Tier 1 Guidelines. The approved *targets* and *thresholds* are included in Table 2.

No monitoring wells representative of background conditions were completed in the Grand Centre or Marie Creek formations and no baseline sampling events were completed prior to steaming or historical operations. Background concentrations of chemical constituents from these formations could not be determined and chemical analysis results have been compared against the *targets* and *thresholds* established for the Sand River Formation equivalent.

Baseline monitoring data from one well (MW11-20-74) drilled near the Pilot Project SAGD well pad before steaming began was used to determine *target* and *threshold* values for the Lea Park Formation. It is understood that using monitoring data from MW11-20-74 is not exclusively representative of background conditions within the Lea Park Formation since the monitoring well is completed partially within the overlying Bonnyville Formation. However, since no other monitoring wells were completed within the Lea Park Formation before steaming began, MW11-20-74 was considered to provide the best representation of background for this formation. Moving forward, MW11-20-74 will be considered to be more representative of the hydrogeologic conditions of the Bonnyville Formation since the Bonnyville is the more permeable unit of the two within which the monitoring well is completed.

4.0 BASELINE SETTING

4.1 Physiography and Climate

The Project is located within the Eastern Alberta Plains physiographic region, and is situated over a surface water divide between the Beaver River basin and the North Saskatchewan River basin (Parks *et al.*, 2005). The area is characterized by relatively high relief, with ridged to hummocky rolling terrain. The Project is located on Crown and private land, with both anthropogenic and natural cover (Pengrowth, 2010). Surrounding land is primarily used for cattle grazing, although some hay cropping is also practiced. There are also several oilfield producers and industrial service providers in the immediate vicinity of the site (Pengrowth, 2010).

The ground surface in the vicinity of the Project varies between 570 and 720 m above sea level (asl) (Figure 2). Over the HLSA, the topography generally slopes towards topographical lows such as lakes and creeks. Several unnamed surface water bodies lie within the HLSA in addition to two larger named lakes: Garnier and Bluet. Portions of Muriel Lake and Reita Lake and the majority of Cushing Lake are within the HLSA boundary (Figure 1). Muriel Lake, Garnier Lake and Bluet Lake are within a valley and are at lower elevations than Reita and Cushing Lakes. The valley slopes to the northwest towards Muriel Lake.

Mean monthly temperatures are typically below zero from November to March with mean annual precipitation of 442 mm (Environment Canada, Climate ID 3012280). Average monthly precipitation is less than 50 mm for the majority of the year with the exception of June to August (inclusive) when nearly half of the annual precipitation occurs. The highest average monthly precipitation occurs in July.

4.2 Geology

The Project is in east-central Alberta, and is underlain by Quaternary, Cretaceous, Devonian and Cambrian deposits (Figure 3). The uppermost Devonian units are expected to include the Cooking Lake Formation of the Woodbend Group and the underlying Beaverhill Lake and Elk Point groups. Overlying the Devonian units are the Cretaceous Mannville Group including the McLaren Member, Upper Grand Rapids, Lower Grand Rapids, Clearwater and McMurray formations, and the Colorado Group which includes the Lea Park Formation, 2nd White Specks Sandstone, LaBiche Formation, Viking Formation, and Joli Fou Formation (Pengrowth, 2011). The Quaternary deposits include the Grand Centre, Sand River equivalent, Marie Creek, Ethel Lake, Bonnyville, Muriel Lake, Bronson Lake and the Empress Unit 3 formations.

The stratigraphy and hydrostratigraphy, adapted from Bachu *et al.* (1993) is illustrated in Figure 3 and cross sections illustrating the Quaternary geology within the HLSA and the corresponding line of section map are included as Figures 4, 5 and 6. A discussion of the geological units is provided in the following sections.

4.2.1 Bedrock

4.2.1.1 Cambrian

In the HRSA, the Cambrian deposits are the lowermost deposits of interest for the purposes of this study. The Cambrian deposits lie beneath Devonian deposits and unconformably overlie the Precambrian basement (Figure 3). The top of the Cambrian is expected to be at approximately 750 m asl and can be up to 200 m thick (Hitchon *et al.*, 1989; Hitchon *et al.*, 1996). The Cambrian deposits are divided into the Upper Cambrian (Deadwood Formation), the Middle Cambrian (Earlie Formation and Basal Sandstone Formation), and the Lower Cambrian, which is absent in the HRSA (Hitchon *et al.*, 1989). The Deadwood Formation consists of interbedded shale and siltstone and the Earlie Formation consists of interbedded siltstone, sandstone and shale (Slind *et al.*, 1994). The underlying Basal Sandstone Formation is described as a coarse-grained sandstone unit and is not known to contain hydrocarbons (Slind *et al.*, 1994). Pengrowth plans to utilize two approved and existing disposal wells (ERCB Approval No. 12088A), which are both completed within the Cambrian as part of their expansion operations.

4.2.1.2 Devonian

Devonian deposits overlie the Cambrian units and include the Elk Point, Beaverhill Lake and Woodbend groups. The stratigraphy and hydrostratigraphy of the Elk Point Group is described in Hitchon *et al.* (1989), and is summarized in Figure 3. The Elk Point Group consists of depositional sequences, each composed of "*marginal clastics, redbeds, anhydritic carbonates and fossiliferous carbonates*" (Meijer Drees, 1994). Extensive evaporites are also recognized in some sequences (Meijer Drees, 1994).

The elevation of the Elk Point Group top is approximately -300 m asl and can be up to 200 m thick (Hitchon *et al.*,1996).

The Beaverhill Lake Group overlies the Elk Point Group and is expected to be present throughout the HRSA. The Beaverhill Lake Group is generally up to 200 m thick beneath the HRSA and includes: the Waterways Formation which is an alternating succession of carbonates and calcareous shales, the limestone-dominated Slave Point Formation, and the anhydrite-dominated Fort Vermillion Formation (Bachu *et al.*, 1993; Hitchon *et al.*, 1989).

The Cooking Lake Formation of the Woodbend Group overlies the Beaverhill Lake Group and is primarily composed of limestone. The Cooking Lake Formation may be absent within the HRSA based on regional mapping (Hitchon *et al.*, 1989).

4.2.1.3 Cretaceous

The Cretaceous Mannville Group overlies the Devonian deposits in the HRSA, is expected to be up to 200 m thick and includes the McMurray, Clearwater and Grand Rapids formations. The Mannville Group is primarily composed of alternating sequences of sand and shale and its deposition was influenced by the topography of the Devonian deposits, which rises gently northwards (Pengrowth, 2011). The Lloydminster Sand of the lower Grand Rapids Formation is the focus of Pengrowth's SAGD development.

The Colorado Group overlies the Mannville Group and includes the Lea Park Formation, the 2nd White Specks Sandstone, the LaBiche Formation, the Viking Formation and the Joli Fou Formation (Figure 3). The Lea Park, LaBiche, and Joli Fou formations consist of marine shales, while the Viking Formation is a fine to medium-grained marine sandstone (Bachu *et al.*, 1993; Currie and Zacharko, 1976).

Across the HRSA, the upper bedrock is the Lea Park Formation which is described as a dark grey marine shale (Andriashek and Fenton, 1989). The thickness of the Lea Park Formation is expected to be greater than 125 m in the HRSA (Andriashek and Fenton, 1989).

4.2.1.4 Post-Cretaceous Bedrock Channels

Regional mapping of bedrock topography indicates that the Holyoke Channel is present within the HRSA (Figure 7). The extent of this glacial channel has not been determined but is predicted to run from beneath Muriel Lake towards the southeast (Township 059, Range 05, W4M towards Township 058, Range 03 W4M) and could merge with the preglacial Vermillion Valley beneath Frog Lake in Township 056, Range 02, W4M (Andriashek and Fenton, 1989). The Holyoke Channel is estimated to be between one and two kilometres wide and 115 to 120 m deep; the gradient of the Holyoke Channel is uncertain (Andriashek and Fenton, 1989).

The regionally-mapped Bronson Lake channel is also present at the northeastern edge of the HRSA (Figure 7). The Bronson Lake Channel is estimated to be 1.5 to 3 km wide and 30 to 40 m deep; the gradient of the Channel is 1.3 m/km to the northwest (Andriashek and Fenton, 1989).

Other significant bedrock channels outside the HRSA are shown on Figure 7 (Pawlowicz and Fenton, 1995).

4.2.2 Quaternary

Regional information indicates that up to 60 m of Quaternary sediments are present above the bedrock in the HRSA (Atkinson and Lyster, 2010a). Hydrogeological drilling activities within the HLSA encountered up to 95 m of unconsolidated deposits above the bedrock surface that were predominantly till deposits with layers of sand that correspond to formations discussed in the following subsections.

4.2.2.1 Empress Formation

The Empress Formation is divided into three units. Unit 1 is described as pre-glacial sands and gravels. The overlying Unit 2 is of glacial origin and is primarily composed of clay and silt, and Unit 3 is a glacial unit composed of sand, gravel, silt and clay. Within the HRSA, only Unit 3 of the Empress Formation is expected to be present and its extent is restricted to the Bronson Lake Channel and the southeastern portion of the Holyoke Channel (Figure 8).

The Empress Formation Unit 3 is primarily sand and gravel composed of igneous and metamorphic clasts from the Canadian Shield (Andriashek and Fenton, 1989). Small amounts of silt and clay may also be present locally within the sand and gravel deposits. Typically, Unit 3 contains fine to coarse grains and the deposits are described as soft and loose. The Unit is expected to be up to 20 m thick within the Channels (Andriashek and Fenton, 1989). The Empress Formation Unit 3 is likely composed of glaciofluvial sediment (Andriashek and Fenton, 1989).

4.2.2.2 Bronson Lake Formation

The Bronson Lake Formation is present within the Holyoke and Bronson Lake channels and overlies the Empress Formation Unit 3 (Figure 9). This formation was deposited during the Cherry Grove Glaciation and is described as a relatively clast free clay till unit with an average thickness of less than 10 m (Andriashek and Fenton, 1989). The contact between the Bronson Lake Formation and the underlying Empress Formation is generally recognized as sharp, whereas the contact between the Bronson Lake Formation and the overlying Muriel Lake Formation is more gradual (Andriashek and Fenton, 1989).

4.2.2.3 Muriel Lake Formation

The Muriel Lake Formation overlies the Bronson Lake Formation and is present within and in close proximity to the Holyoke and Bronson Lake channels in the HRSA (Figure 10). The Muriel Lake Formation consists of silt, sand, and sand and gravel deposits, with minor occurrences of silt and clay beds (Andriashek and Fenton, 1989). The sand in the Muriel Lake Formation is typically described as medium grained and well sorted. Clay deposits near the base of the Muriel Lake Formation are considered to be glaciolacustrine in origin and the overlying sand and gravel deposits with minor clay components are interpreted to be glaciofluvial deposits (Andriashek and Fenton, 1989).

The Muriel Lake Formation was encountered during the drilling of MW13-27-90 in 01-20-059-04 W4M. Medium- to coarse-grained sand, with some fine- to coarse-grained gravels, and clay materials were encountered during drilling through the Muriel Lake Formation. The deposit was described as humid to wet and the clay component was described as very stiff.

4.2.2.4 Bonnyville Formation

The Bonnyville Formation is sub-divided into two units, Unit 1 and Unit 2, both believed to consist of glacial deposits from the Fort Kent Glaciation (Andriashek and Fenton, 1989). Unit 1 is located at the bottom of the Formation and is primarily composed of clay till, and the overlying Unit 2 is characterized as a sandy glacial till. In some areas, sand and gravel deposits are present between the units; these sediments are considered to be fluvial in origin and are believed to have been deposited between two glacial advances that deposited Units 1 and 2. The fluvial sand and gravel deposits are considered to be part of Unit 1 (Andriashek and Fenton, 1989).

In some areas, the Bonnyville Formation Unit 1 can contain an abundance of sand and gravel (Andriashek and Fenton, 1989). In the southeast of the HRSA, in the vicinity of the Holyoke Channel trace, it is expected that the Bonnyville Formation Unit 1 sands and gravels will be present (Figure 11).

The Bonnyville Formation Unit 2 is present throughout the HRSA (Figure 12). This unit is approximately 10 m thick over most of the HRSA but can be up to 30 m in the east. The Unit is also rich in very coarse-grained sands and pebbles, and cobbles are commonly found (Andriashek and Fenton, 1989). The regional mapping presented in Figure 12 indicates that the Bonnyville Formation Unit 2 is up to 30 m higher in elevation than the local hydrogeological drilling indicates.

Both units of the Bonnyville Formation were encountered during hydrogeological drilling activities within the HLSA. Bonnyville Formation Unit 1 sand and gravel deposits are discontinuous over the HLSA and only one monitoring well (MW13-19-82) was completed within the Unit. The Bonnyville

Formation was found to be up to 30 m thick, and the sands observed were described as fine to coarse grained and generally increasing in coarseness with depth.

4.2.2.5 Ethel Lake Formation

The Ethel Lake Formation consists of stratified silt and clay, with some sand and gravel (Alberta Government, 2013). The sand and gravel materials are considered to be glaciofluvial in origin and the silt and clay deposits are considered to be of glaciolacustrine origin deposited from proglacial lakes (Andriashek and Fenton, 1989). The sand component of the Formation is considered to be well sorted, and has been found to be both fine and coarse grained (Andriashek and Fenton, 1989). A sharp contact is observed where the sand and gravel of the Ethel Lake Formation overlies the Bonnyville Formation till, whereas the contact is more gradational between the Ethel Lake Formation and the overlying Marie Creek Formation (Andriashek and Fenton, 1989). Figure 13 shows the distribution of the Ethel Lake Formation in the HRSA and the elevation of the top of the Formation based on regional data. The regional surface is approximately 10 m higher than the top of the Formation based on drilling data within the HLSA. The Ethel Lake Formation is approximately 10 m thick and is considered to be widespread but not continuous (Andriashek and Fenton, 1989).

During drilling in the HLSA, the Ethel Lake Formation was recognized based on the sand and gravel content of the material. The sand content of the Formation was typically light brown, medium to fine grained and moderately to well sorted. The sand and gravel content was described as coarse and poorly sorted and was found to be greater within the HLSA than the regional data suggests.

4.2.2.6 Marie Creek Formation

The Marie Creek Formation is a glacial till unit with local occurrences of very coarse sand rich in carbonate fragments deposited during the Ardmore Glaciation (Andriashek and Fenton, 1989). This formation is subdivided into two units: Unit 1 and Unit 2. Unit 1 is absent over most of the HRSA and is only regionally mapped near the eastern boundary whereas Unit 2 is present throughout; both Units are described as sandy diamictons (Andriashek and Fenton, 1989). Calcareous materials are present in the coarse sand fraction of the Marie Creek Formation Unit 2 as well as in the silt-clay fraction. The proportion of calcareous material within Unit 2 is considered to be a distinguishing feature of the unit.

The Marie Creek Formation is present throughout the HLSA (Figure 14) and was typically described during hydrogeological drilling as a dark grey, gravelly clay deposit. The mapping based on regional data presented in Figure 14 is generally consistent with the results of hydrogeological drilling within the HLSA but is up to 20 m higher than the surface observed during drilling in some locations. Based on the 2013 drilling program, the Marie Creek Formation is expected to be between 30 and 40 m thick (Figures 5 and 6).

4.2.2.7 Sand River Formation Equivalent

Regional mapping indicates that the Sand River Formation is present inside the northern boundary of the HRSA but is absent beneath the HLSA, however, a facies of similar geological characteristics and stratigraphic position was reported present during drilling in the vicinity of the Pilot Project footprint (MEMS, 2011b). For the purposes of this report, this facies is referred to as the Sand River Formation equivalent (informally named) within the HLSA. The Sand River Formation is composed of stratified sand and gravelly sand, with some silt and clay and the sand is described as well sorted and is classified as fine to medium-grained (Andriashek and Fenton, 1989). This description is similar to the descriptions noted during the drilling of boreholes in the vicinity of the Pilot Project.

During the 2013 drilling program, the previously identified Sand River Formation equivalent as described above was only encountered at one location (01-20-059-04 W4M). The revised interpretation is that the Sand River Formation equivalent is present as isolated sands with limited extent within the HLSA.

4.2.2.8 Grand Centre Formation

The Grand Centre Formation is primarily composed of glacial till with sandy-clay texture deposited during the Cold Lake Glaciation (Andriashek and Fenton, 1989). The Formation is subdivided into four glacial till members that were deposited from different Lobes of the Laurentide Ice Sheet: Vilna, Kehiwin, Reita Lake, and Hilda Lake (Andriashek and Fenton, 1989). The Grand Centre Formation is widespread and expected to be present throughout the HRSA (Figure 15). The very coarse-grained sand content is typically high in igneous and metamorphic material which differentiates the Formation from the other till formations in the HRSA (Andriashek and Fenton, 1989).

The Grand Centre Formation encountered during drilling within the HLSA was typically 15 to 25 m thick depending on the topography, which generally aligns with the regional mapping. Observations during drilling indicated that the Formation is primarily a silty clay with some gravels and local occurrences of sand and gravel seams. The sands encountered were generally coarse grained and the clays were typically firm.

4.3 Hydrogeology

Aquifers within the Quaternary deposits in the HLSA are identified within the Sand River equivalent, Ethel Lake, Bonnyville, Muriel Lake, and Empress formations. Regional bedrock aquifers in the area include the Viking Formation, the upper Mannville Group, and the McMurray Formation (Ozoray *et al.*, 1980). The elevation of the base of groundwater protection in this area is shown in Figure 16, and the uppermost protected units are the Quaternary deposits (Alberta Energy Regulator, Ground Water Protection). Groundwater from bedrock aquifers is expected to be saline.

The hydrogeology of Cambrian, Devonian and Cretaceous units are summarized in the following sections; hydrogeological characteristics of the Quaternary units and the Lea Park Formation are described in greater detail. Monitoring well installation programs within the Project area focused on the more permeable units encountered during drilling, therefore, often limited information is available regarding aquitards. The locations of the groundwater monitoring wells are shown on Figures 17a and 17b and monitoring well details are in Table 3.

4.3.1 Bedrock

4.3.1.1 Cambrian

The only aquifer unit that is part of the Cambrian deposits in the HRSA is the Basal Sandstone Formation (Middle Cambrian). The overlying Earlie and Deadwood Formations are both considered to be aquitards (Bachu *et al*., 1993). Pengrowth plans to use two existing and approved disposal wells completed in the Basal Sandstone Formation as part of the Project.

The Basal Sandstone Formation is considered to be a laterally continuous sand unit of varying thickness in Alberta. The Formation is upwards of 80 m thick in the Project area and is overlain by the lower Deadwood shales that act as the caprock with respect to the disposal wells. Precambrian shield is present below the Formation (Pengrowth, 2013). Drilling sample descriptions indicate that the Basal Sandstone Formation appears to be very uniform from top to bottom and consist of coarse, rounded, very well sorted, unconsolidated quartz sand. The average porosity of the Formation is 20% with good permeability based on petrophysical analysis.

Regional data indicate that the Basal Cambrian aquifer is expected to have a hydraulic conductivity of 5×10^{-7} m/s and have total dissolved solids (TDS) concentrations between 240,000 and 310,000 mg.L (Bachu *et al.*, 1989). Swab samples collected by Pengrowth from 05-13-058-05 W4M indicate TDS concentrations up to 251,000 mg/L from the Basal Sandstone Formation. The swab sample chemical analysis results also indicate that the formation water from the Basal Sandstone Formation is sodium-chloride type water.

4.3.1.2 Devonian

The Devonian Elk Point Group includes formations that are characterized as aquifers, aquicludes and aquitards. The Elk Point Group includes the Lower Elk Point aquitard-aquiclude system, the Contact Rapids-Winnipegosis aquifer system and the lower part of the Prairie-Watt Mountain aquiclude system (Bachu *et al*., 1993). The hydrostratigraphy of the Elk Point Formation is summarized in Figure 3. The salinity of the groundwater in the Contact Rapids-Winnipegosis aquifer system can be up to 100,000 mg/L and the general groundwater flow direction is to the northwest (Bachu *et al*., 1993).

The Beaverhill Lake Group overlies the Elk Point Group and includes the Fort Vermillion Formation, an aquiclude, the Slave Point Formation, an aquifer, and the Waterways Formation, an aquifer – aquitard. The Fort Vermillion Formation aquiclude is part of the Prairie – Watt Mountain aquiclude system, and the Waterways and Slave Point Formations are part of the Beaverhill Lake – Cooking Lake aquifer system. The overlying Cooking Lake Formation of the Woodbend Group is also considered to be an aquifer unit and is part of the Beaverhill Lake – Cooking Lake aquifer system.

4.3.1.3 Cretaceous

In the HRSA, the Cretaceous McMurray aquifer system includes the McMurray Formation of the Mannville Group and is likely hydraulically connected to the underlying Beaverhill Lake – Cooking Lake aquifer system. Overlying the McMurray aquifer system is the Clearwater Aquitard and the Grand Rapids aquifer system; both are part of the Mannville Group. The Grand Rapids Formation is characterized as an aquifer unit that also contains intervals of silt and shale (MEMS, 2012b). The Lloydminster Sand is the lowermost unit within the Grand Rapids Formation and is the target for bitumen production for the Project.

In 2012, Pengrowth began investigating saline groundwater sources in the vicinity of the Pilot Project to determine if a potential saline groundwater source exists that could be used for the operations. The findings of the desktop investigation determined that the Waseca Sand, Sparky Sand and General Petroleum Sand of the Grand Rapids Formation have the best potential of supplying Pengrowth's operations. It was found that the TDS concentration in groundwater from the Grand Rapids Formation varied between 4,000 mg/L and 45,000 mg/L.

The Colorado aquitard system is expected to have a thickness of greater than 150 m and separates the overlying Quaternary sand aquifers from the underlying Cretaceous aquifers. The Joli Fou Formation is part of the Colorado aquitard system and is a relatively strong aquitard (Bachu *et al.*, 1993). The Viking Formation is a sandstone unit that overlies the Joli Fou Formation and is the only unit characterized as an aquifer within the Colorado aquitard system.

The Lea Park Formation of the Colorado Group is the upper bedrock in the HRSA and accounts for close to half of the thickness of the Group (Andriashek and Fenton, 1989; Hitchon *et al.*, 1989). The Formation is interpreted as an aquitard based on the predominance of fine-grained materials that compose the unit. Localised permeable zones within the formation that consist of minor amounts of bentonitic sandstone material may also be present (HCL, 1998). Increased permeability within the Lea Park Formation could also be an indication of a weathered contact surface.

There are four monitoring wells completed in the Lea Park Formation within the HLSA. Hydraulic conductivity testing of the monitoring wells completed within the Lea Park Formation resulted in hydraulic conductivities of 3.3×10^{-9} and 2.0×10^{-9} m/s. Of the four monitoring wells completed

within the Lea Park Formation, only two appear to have reached static water levels following drilling in June 2013; therefore, an interpretation of groundwater flow rate and direction within the Lea Park Formation is unable to be determined at this time (Figure 18).

The groundwater from the Lea Park Formation is sodium bicarbonate type water or calcium type water with no dominant cation (Figure 19) and the TDS concentration primarily ranges between 900 and 1,900 mg/L (Table 4). The Alberta Energy Regulator reports that the top of the Lea Park Formation represents the base of groundwater protection in the HRSA (Figure 16) and although the chemical analyses indicate that the groundwater from the upper Lea Park Formation is non-saline, given the thickness of the Lea Park Formation, it is expected that the groundwater becomes saline within the Formation.

4.3.2 Quaternary Deposits

4.3.2.1 Empress Formation Unit 3

The Empress Formation Unit 3 is expected to be present at the base of the Holyoke Channel and the Bronson Lake Channel within the HRSA and is typically characterized as an aquifer as it is primarily composed of stratified sand and gravel (Andriashek and Fenton, 1989).

A drilling program within the HRSA is planned for early 2014 and the Empress Formation Unit 3 may be encountered. If a high permeability interval is encountered within the Empress Formation Unit 3, a monitoring well will be installed and will be added to the monitoring well network.

4.3.2.2 Bronson Lake Formation

The Bronson Lake Formation is expected to be present within the Holyoke and Bronson Lake channels in the HRSA and is typically characterized as an aquitard as it is primarily a glacial till unit. Based on limited regional data, the geometric mean vertical hydraulic conductivity for the Bronson Lake Formation is reported as 2.2×10^{-8} m/s (Hitchon *et al.*, 1996).

A drilling program in the HRSA is planned for early 2014 and the Bronson Lake Formation may be encountered. It is not expected that a high permeability interval will be encountered within the Bronson Lake Formation; however, if one is present, a monitoring well will be installed and will be added to the monitoring well network.

4.3.2.3 Muriel Lake Formation

The Muriel Lake Formation is present within the Holyoke Channel and the Bronson Lake Channel in the northeastern portion of the HRSA and overlies either the Bronson Lake Formation or the Lea Park Formation. The Muriel Lake Formation is primarily composed of sand and gravel deposits with some

clay and is characterized as an aquifer (Alberta Government, 2013). Within the HRSA, the Muriel Lake Formation is expected to be between five and ten metres thick but locally it can be up to 20 m thick. Only one monitoring well encountered the Muriel Lake Formation within the HLSA (MW13-27-90). The monitoring well is completed within sand and gravel materials, and testing indicates a hydraulic conductivity of 2.2 x 10^{-5} m/s. Regional data indicate a geomean hydraulic conductivity of 6.8 x 10^{-5} m/s (Hitchon *et al.*, 1996).

The water level measured in MW13-27-90 is 596.2 m asl. The horizontal hydraulic gradient and groundwater flow cannot be determined at this time as only one monitoring well is completed in the Muriel Lake Formation. Since the Muriel Lake Formation is only expected to be present in relation to the Holyoke and Bronson Lake channels, it may not be practical to install a sufficient number of monitoring wells to determine the local flow characteristics of this formation. However, if the Muriel Lake Formation is encountered during hydrogeological drilling, monitoring wells will be installed in the unit. Regional data indicate that groundwater flow within the Muriel Lake Formation is to the north in the Beaver River basin (Parks *et al.*, 2005). The Muriel Lake Formation can be underlain by the Bronson Lake Formation and the Lea Park Formation, both of which are expected to be aquitards and would therefore separate the Muriel Lake Formation from underlying aquifer units.

The groundwater from the Muriel Lake Formation is a sodium type water with no dominant anion and an average TDS concentration of approximately 1,350 mg/L (Figure 19 and Table 4). The local hydrogeologic characteristics of the Muriel Lake Formation are currently based on only one monitoring well. Data collected from additional monitoring wells completed within the Muriel Lake Formation in future will be used to verify and supplement the current evaluation.

4.3.2.4 Bonnyville Formation

The Bonnyville Formation overlies either the Muriel Lake Formation in the Holyoke and Bronson Lake channels or the Lea Park Formation where the channels are not present. The majority of the Bonnyville Formation is characterized as an aquitard due to the clay till content of the Formation, however, a discontinuous sand and gravel aquifer between the Units may also be locally present. The Bonnyville Formation is therefore characterized as an aquifer-aquitard.

MW11-20-74 is partially completed in the Bonnyville Formation Unit 1 and partially in the underlying Lea Park Formation. Although this monitoring well was previously used to characterize the Lea Park Formation, it is now considered to be more representative of the hydrogeologic conditions of the Bonnyville Formation.

Testing of MW13-19-82 completed within the Bonnyville Formation Unit 1 sands resulted in a hydraulic conductivity of 8.0 x 10^{-5} m/s. MW13-19-82 is completed within a more permeable zone in the Formation so the hydraulic conductivity is not considered representative of the entire Unit.

Where the Bonnyville Formation overlies the Muriel Lake Formation, the two formations may be hydraulically connected (Alberta Government, 2013). Due to the low permeability of the Lea Park Formation a low degree of hydraulic connection is expected between the Bonnyville Formation and the upper bedrock. Since there is only one monitoring well completed within the Bonnyville Formation Unit 1 sands, the hydraulic gradient and groundwater flow direction and velocity are unable to be determined. It may be impractical to install a sufficient number of monitoring wells to determine local groundwater flow characteristics within the Bonnyville Formation Unit 1 sands due to the discontinuous occurrence of the Unit in the HLSA. However, if the Bonnyville Formation Unit 1 sands are encountered during hydrogeological drilling, monitoring wells will be installed.

The groundwater from the Bonnyville Formation is sodium bicarbonate type water (Figure 19).

4.3.2.5 Ethel Lake Formation

The Ethel Lake Formation underlies the Marie Creek Formation and overlies the Bonnyville Formation in the HRSA. This formation is interpreted as a glacially-derived aquifer that could supply water for domestic use (Alberta Government, 2013). Six groundwater monitoring wells are completed within the Ethel Lake Formation that were drilled and completed in 2011 and 2013 (Table 3). Hydraulic conductivity testing resulted in values that range from 5.7×10^{-6} to 1.6×10^{-3} m/s with a geometric mean of 2.1×10^{-4} m/s. These hydraulic conductivity values are generally consistent with limited regional data for the Ethel Lake Formation. Hitchon *et al.* (1996) reported that the hydraulic conductivity for the Ethel Lake Formation in the Cold Lake area ranged from 1.2×10^{-5} to 3.7×10^{-2} m/s with a geometric mean of 3.6×10^{-4} m/s.

Regional groundwater flow in the Ethel Lake Formation is expected to be to the north within the Beaver River basin (Parks *et al.*, 2005). Since there is only one monitoring well completed within the Ethel Lake Formation in the Beaver River basin, no further groundwater flow characteristics can be determined, including the hydraulic gradient. Additional hydrogeological drilling will be completed in order to determine the groundwater flow within the Ethel Lake Formation in this basin.

The groundwater flow within the Ethel Lake Formation in the North Saskatchewan River basin appears be to the south based on the difference in hydraulic head measurements (Figure 20). An approximate flow rate of 220 m per year within the Ethel Lake Formation in the North Saskatchewan River basin was calculated using the geometric mean hydraulic conductivity for the formation (2.1×10^{-4} m/s), the hydraulic gradient (approximately 0.01 m/m) and an assumed effective porosity of 30%. The hydraulic gradient within the Formation is based on very limited data and could be greater than expected for these high permeability deposits. Further investigation is planned and should help to determine an accurate hydraulic gradient and evaluation of the expected flow rate within the Ethel Lake Formation.

The Ethel Lake Formation may be hydraulically connected to the underlying Bonnyville Formation where the sands and gravels of the Ethel Lake Formation overlie coarse grained material in the Bonnyville Formation. This configuration is not expected to be common in the HLSA.

The groundwater from the Ethel Lake Formation is typically bicarbonate type water with no dominant cation (Figure 19). Three monitoring wells were drilled near the Pilot Project SAGD well pad to establish background groundwater chemistry for the Ethel Lake Formation before steaming began. Chemical analysis results from the Ethel Lake Formation have been compared to the *targets* and *thresholds* in 2011 and 2012. The concentration of arsenic has not exceeded the established limits over the two years of operational groundwater monitoring (MEMS, 2013).

The chemical analysis results for groundwater collected from MW11-19-67 have been compared to established well-specific *targets* and *thresholds*. The concentration of arsenic in MW11-19-67 exceeded the threshold limit of 0.013 mg/L by 0.001 mg/L during the first monitoring event in June 2011 but returned to below the limit by the next sampling event and has not exceeded since (Table 5).

4.3.2.6 Marie Creek Formation

The Marie Creek Formation is present throughout the HRSA, and is primarily composed of fine-grained materials and characterized as an aquitard. This formation is expected to be approximately 30 m thick and underlies the Sand River Formation equivalent where present or the Grand Centre Formation where the Sand River Formation equivalent is absent. One monitoring well is completed within the Marie Creek Formation (P02-5) and it is completed within sandy clay and clay silt materials with a hydraulic conductivity of 3.0×10^{-7} m/s. The average water level measured in P02-5 is 650 m asl.

The most recent groundwater sampled from the Marie Creek Formation indicates that the water is bicarbonate type water with no dominant cation (Figure 19). No monitoring wells representative of background conditions were completed in the Marie Creek Formation prior to steaming as part of the Pilot Project so background concentrations of chemical constituents were unable to be determined. Chemical analysis results from the Marie Creek Formation have been compared against the *targets* and *thresholds* established for the Sand River Formation equivalent. Between 2002 and 2012, the concentrations of arsenic and TDS in groundwater from P02-5 have been below the established limits. The concentration of chloride exceeded the *threshold* limit in 2011 but decreased to below the limits by fall of 2012.

4.3.2.7 Sand River Formation Equivalent

The Sand River Formation equivalent is present locally in the vicinity of the Pilot Project, underlying the Grand Centre Formation and overlying the Marie Creek Formation. The Sand River Formation

equivalent is expected to be up to 15 m thick and is considered to be an aquifer as it primarily consists of sand and silt. There are 23 monitoring wells completed in the formation. Testing of the monitoring wells resulted in hydraulic conductivities between $1.1x10^{-3}$ and 1.1×10^{-6} m/s and a geomean hydraulic conductivity of 3.5×10^{-5} m/s. The monitoring wells are reportedly completed within materials that range in size from silty clay to sandy gravel (Table 3).

Water level measurements indicate that the groundwater flow within the Sand River Formation equivalent is generally to the southwest in the vicinity of the Pilot Project (Figure 21). The groundwater elevations in the monitoring wells located near the Pilot Project CPF (13-058-05 W4M) are considered to be less representative of natural conditions due to development of the site including re-grading and changes to the surface materials. An approximate flow rate of 40 m per year within the Sand River Formation equivalent was calculated using the geometric mean hydraulic conductivity for this formation (3.5×10^{-5} m/s), the hydraulic gradient (approximately 0.01 m/m) and an assumed effective porosity of 30%.

Groundwater from the Sand River Formation equivalent is determined to be primarily calcium-bicarbonate type water or bicarbonate type water with no dominant cation (Figure 22). Salinity and hydrocarbon impacts to groundwater have been identified in the Sand River Formation equivalent in the vicinity of the Pilot Project CPF that were the result of historical operations (MEMS, 2013). Five monitoring wells completed in the Sand River Formation equivalent are located in the area of the Pilot Project SAGD well pad and are considered to be representative of baseline conditions. The baseline monitoring wells were completed prior to the Pilot Project start up but the baseline results would include any residual impacts from the former operations if present. *Targets* and *thresholds* for chemical constituents were established for the Sand River Formation equivalent and the groundwater monitoring results from the monitoring wells completed within the Formation have been compared against the limits (MEMS, 2013).

4.3.2.8 Grand Centre Formation

The Grand Centre Formation is the uppermost till unit in the HRSA and is interpreted as an aquitard based on the predominance of fine-grained, low permeability materials. One groundwater monitoring well is completed in the Grand Centre Formation (P10-12A) which is completed in clay and silty clay till. Monitoring well P10-12A has an average water level of 649.2 m asl and a hydraulic conductivity of 8.5×10^{-7} m/s.

Groundwater from the Grand Centre Formation is determined to be bicarbonate type water with no dominant cation and have a TDS concentration of between 580 and 710 mg/L (Figure 19, Table 4). No monitoring wells representative of background conditions were completed in the Grand Centre Formation prior to steaming as part of the Pilot Project, therefore, background concentrations of

chemical constituents were not determined. Chemical analysis results from the Grand Centre Formation have been compared against the *targets* and *thresholds* established for the Sand River Formation equivalent, and between 2010 and 2012, the TDS, chloride and arsenic concentrations in groundwater from P10-12A have been below the established limits (MEMS, 2013).

4.3.3 Groundwater Flow System

Groundwater flow within Quaternary deposits is expected to be driven by physiography, with recharge in upland areas and flow towards topographic lows. Regional groundwater flow within the Beaver River basin is north from the HLSA towards Beaver River (Parks *et al.*, 2005). The Beaver River is located approximately 25 km north of the HLSA. Based on limited datasets, groundwater flow within the North Saskatchewan River basin appears to be generally to the south as demonstrated by the groundwater levels in the Pengrowth monitoring wells (Figures 20 and 21). There are no records in the ESRD Water Well Information Database related to springs or flowing shot holes within the HLSA which would indicate areas of groundwater discharge or artesian conditions. Only one spring which is located near the east shore of Muriel Lake was identified and sampled during a field verified survey conducted in October 2013. The spring represents an area of groundwater discharge.

ESRD has monitored Observation Water Well (Obs WW) No. 243 in 16-32-058-03 W4M near Cushing Lake as part of their Groundwater Observation Well Network (GOWN) since 1987. Obs WW No. 243 was interpreted by ESRD as being completed within sands in surficial deposits to a depth of 39 m bgl. Based on a surface elevation of 640 m asl, it is likely that the water well is completed within the Ethel Lake Formation. Between 2002 and 2012, the peak water levels measured in Obs WW No. 243 typically occurred in July indicating that most of the recharge to shallow surficial deposits likely happens in the spring.

Within the North Saskatchewan River basin, there is an overall upward hydraulic gradient observed in nested wells completed within the upper bedrock and Quaternary deposits to the west of Garnier Lake in sections 12 and 13-058-05 W4M (Figure 5). The nested wells in 01-20-059-04 W4M in the Beaver River basin show an overall downward hydraulic gradient within the Quaternary deposits (Figure 5).

Since it is expected that the shallow surficial deposits over most of the HLSA are the clay tills of the Grand Centre Formation, the recharge potential is expected to be relatively low as precipitation will not be able to penetrate the low permeability materials as easily as they would infiltrate higher permeability materials such as sand and gravel. The recharge potential to Quaternary and bedrock aquifers will be particularly low in areas where the Sand River Formation equivalent is absent within the HLSA as the thickness of low permeability clay till is greater when the Grand Centre Formation

directly overlies the clay tills of the Marie Creek Formation in the absence of substantial topographic lows.

The low permeability Lea Park Formation which is part of the Colorado aquitard system directly underlies the Quaternary deposits in the HRSA and separates the Quaternary deposits from underlying Cretaceous aquifer systems. Over one thousand vertical metres of material separate the Cambrian Basal Sandstone Formation from the Quaternary aquifers including several aquitards and the Clearwater aquitard system which effectively separate the proposed disposal zone from non-saline aquifers (Figure 3).

4.3.4 Groundwater-Surface Water Interactions

Within the HLSA, several unnamed lakes and creeks exist along with five main named lakes: Muriel Lake, Garnier Lake, Bluet Lake, Reita Lake and Cushing Lake.

Under natural conditions, groundwater flows into Muriel Lake (Alberta Government, 2013). Muriel Lake is expected to be up to 10 m deep and is in contact with the Ethel Lake and Bonnyville formations (Alberta Environment, 2008a; University of Alberta, 1990; Parks *et al.*, 2005). The hydrology of Muriel Lake was reviewed by Millennium EMS Solutions Ltd. and Northwest Hydraulic Consultants Ltd. in 2012 (MEMS and NHC, 2012). The review determined that Muriel Lake received groundwater from the Grand Centre, Marie Creek and Ethel Lake formations and groundwater from the Bonnyville and Muriel Lake formations is moving downwards and northwards. Hydrogeological drilling in 01-20-059-04 W4M indicates that there also may be upward flow from the Bonnyville Formation and the Muriel Lake Formation towards Muriel Lake based on a lake level of 555.8 m asl measured in July 2013 (Environment Canada, Station ID 06AC007) and the groundwater elevation in the Muriel Lake Formation, which is over 595 m asl (Figure 5 and Table 3).

Garnier Lake and Bluet Lake are south of Muriel Lake and are situated within a deep valley. Surface water flows from southeast to northwest along the valley towards Muriel Lake. The valley walls on either side of the lakes impact the amount of precipitation available to contribute to lakes. Precipitation that falls outside of the valley walls runs away from the lakes leaving only the portion of the total precipitation that falls within the valley walls to contribute to the lakes by overland flow. This situation typically results in groundwater discharging into lakes in valley bottoms. The lake level measured in Garnier Lake in 2004 was 602.84 m asl, which is lower than the water levels measured in nearby monitoring wells completed in the Ethel Lake, Bonnyville and Lea Park formations. An upward hydraulic gradient is also observed in nested monitoring wells adjacent to the valley within the HLSA suggesting that groundwater is contributing to the lakes in the valley bottom. The maximum depth of Garnier Lake is 9.5 m and the maximum depth of Bluet Lake is over

6.5 m (Alberta Lake Management Society, 2005a and 2005b) suggesting that the lakes are likely receiving groundwater from the Ethel Lake Formation.

Reita Lake and Cushing Lake are at higher elevations than Muriel, Garnier and Bluet lakes. Reita and Cushing lakes are also expected to be shallower than the lakes situated in the valley. Reita Lake is approximately four metres deep (Alberta Environment, 2008b). Nested water wells in 01-20-059-04 W4M indicate a downward hydraulic gradient and along with the limited lake depths it is expected that the primary source of water for Reita and Cushing Lakes is precipitation. If groundwater contributes to these lakes at all, it is expected that it would be from the shallow Grand Centre Formation and the contribution would be minor. It is more likely that the water from Reita Lake and Cushing Lake are recharging the underlying groundwater units.

Groundwater is expected to be recharged by precipitation over most of the HLSA, except in the areas of Muriel Lake and the valley containing Garnier and Bluet lakes where groundwater is expected to discharge into the surface water system.

4.3.5 Groundwater and Surface Water Use

Water well records in the ESRD Water Well Information Database were reviewed within the HLSA (ESRD, 2013). One hundred forty-one records were identified within the search radius (65 domestic use, 12 domestic and stock use, six stock watering use, 38 industrial use, three monitoring or observation use, 16 unknown use, and one record for an "old well"). Sixteen records indicate that the feature is abandoned or was a dry hole. The nearest domestic water well record located downgradient of the Project CPF is approximately four kilometres southwest in 04-15-058-05 W4M (Well ID 289206). This water well is completed from 28.04 to 29.57 m below ground level (bgl) within Quaternary deposits.

A map showing the location of the water well records and a summary of the well details are included as Figure C-1 and Table C1 in Appendix C.

During the 2012 and 2013 field surveys, 162 residences were visited. Of the 162 residences, MEMS confirmed 39 water sources (12 for domestic, 11 for stock, nine for domestic and stock, one for landscape maintenance and two used for unknown purposes and four that are not in use). During the field survey, 26 groundwater samples and 13 surface water samples were collected. The water samples were submitted to ALS Environmental for total and dissolved metals analyses and routine potability analysis. A map and table summarizing the field survey (Figure D-1and Table D-1) are included in Appendix D.

4.3.6 Licensed Groundwater and Surface Water Use

There are two licensed and six registered groundwater users within the HLSA. Based on the depths drilled and area water well lithologies, both of the licensed water wells are likely completed within Quaternary deposits. No information associated with the licenses or any corresponding water well records are available to confirm this interpretation. One of the licensed water wells is in SE 13-058-05 W4M and is identified as being used for "camps" (*i.e.*, domestic purposes) by Pengrowth; the other is in SE 35-059-04 W4M and was licensed for stock watering purposes. The total annual quantity of licensed groundwater is 3,427 m^3 (9.4 m^3/day).

There are 179 registered surface water diversions within the HLSA, and 159 of the applicants are listed as "Public Land Management".

Figure C-2 and Table C-2 in Appendix C summarize the licensed water well and surface water locations records.

5.0 ENVIRONMENTAL ASSESSMENT

Quaternary non-saline aquifers, surface water bodies and wetland areas have been identified as VECs related to the Project (Section 2.5). Potential impacts to VECs include the effects of operating surface facilities as well as production and injection wells on the quality of water resources in the area. The potential impacts to VECs are assessed in the following sections.

5.1 Potential Effects of the Surface Facilities on Groundwater

5.1.1 Description of Potential Impacts

As a result of the best management practices and the material handling methods outlined in the Project Description (Pengrowth, 2013), there should be a low possibility of potential effects to shallow groundwater quality, except through upset conditions, (*i.e.*, accidental spills or leaks). Accidental releases may allow fluids to seep into the ground where they could alter shallow groundwater quality. The impact to groundwater quality will depend on the volume and type of fluids released, the characteristics of the surface materials at the release location, and the underlying groundwater conditions. Fluids handled at the Project CPF include produced emulsion, produced vapours, diluent, dilbit, produced water and small volumes of various process related organic chemicals such as glycol or lubricants (Pengrowth, 2013).

5.1.2 Impact Assessment

The Project is located in an area which is underlain by approximately 95 m of unconsolidated glacial deposits. The Quaternary formations that are expected to underlie the Project CPF include the Grand Centre Formation, possibly the Sand River Formation equivalent, the Marie Creek Formation, Ethel

Lake Formation and Bonnyville Formation. Groundwater flow rates are expected to be generally slow within the clay-rich deposits of the Grand Centre Formation—which is expected to form the uppermost deposits at the CPF. The Sand River Formation equivalent is interpreted as an isolated sand unit that is discontinuous through the HLSA. Over the majority of this area, it is expected that the Sand River Formation equivalent will be absent and the Grand Centre Formation directly overlies the Marie Creek Formation. Where the Sand River Formation equivalent is absent, up to 80 m of clay till material can be present.

No impacts to surface water receptors, terrestrial or riparian vegetation, wildlife or aquatic resources including wetlands are expected. The potential impact to groundwater from surface facilities, will be local in extent, can occur during the operation of the facilities, may occur occasionally, will diminish over time and may exceed background concentrations but will likely be within threshold limits. The overall impact rating is determined to be low.

5.1.3 Monitoring

A groundwater monitoring program will be implemented to detect any impacts on the shallow groundwater quality resulting from spills or leaks from surface facilities. In the event that an impact on groundwater quality is detected, a groundwater response plan will be implemented. The response plan would include determining the magnitude of the impact and the mitigation measures required. The response plan will serve to mitigate impacts to groundwater quality and prevent impacted groundwater from reaching domestic water wells and/or surface water bodies. The groundwater monitoring network will be expanded as facilities are added, to ensure that the Project is adequately monitored.

5.1.4 Mitigation

Mitigation measures for minimizing or preventing adverse impacts on shallow groundwater quality due to spills or leaks include industry-standard operating practices, preparedness for upset conditions and the appropriate management of upset conditions. Industry best practices employed by Pengrowth include double walled storage tanks, secondary protection, leak detection and good housekeeping practices that will minimize the occurrence of product leaks from tanks and prevent any significant impacts to groundwater resources. Groundwater monitoring for the Pilot Project is established and reviewed annually and groundwater monitoring for the Project CPF will also be established (see Appendix E). If there is a verified change in groundwater chemistry, the groundwater response plan will be implemented. The groundwater response plan will be effective in mitigating impacts to groundwater.

5.2 Potential Effects of Production/Injection Wells on Groundwater Quality

5.2.1 Description of Potential Impacts

The main areas of concern with respect to the SAGD production/injection wells include:

- the potential for casing failure to allow well bore fluids to be introduced into non-saline aquifers; and
- thermal effects adjacent to the well bore of the injection wells that could cause mobilization of metals within groundwater.

The planned drilling, completion and operational details for the production and injection wells are included in Part B of Pengrowth's Lindbergh SAGD Expansion Project application (Pengrowth, 2013) and are summarized briefly in the following:

- the surface casing for the production and injection wells will be set below the base of groundwater protection at approximately 150 m bgl;
- the intermediate casing for the production and injection wells will be installed to near the base of the lower Grand Rapids Formation (Lloydminster Sand reservoir), approximately 500 m bgl. The casing will be high-grade material with premium connections, and will be cemented with thermal cement from the casing shoe to the ground surface;
- the liner for the production and injection wells will run approximately 800 m horizontally from the intermediate casing shoe to the well total depth; and
- during operations, well pressures and steam flow rates will be continuously monitored and recorded to verify casing integrity.

Thermal changes along the well bore of the injection wells have the potential to locally alter groundwater chemistry in non-saline aquifers due to the response of geologic materials to heating along the well bore. This has been observed in other SAGD operations in the Cold Lake area. Numerous studies have been completed (Canadian Natural Resources Limited (CNRL), 2006; CNRL, 2009; Imperial Oil Limited, 2009; Fennell, 2008; Alberta Health and Wellness, 2000; Andriashek, 2000; Andriashek, 2003, Lemay *et al.*, 2005 and Moncur *et al.*, 2011) which have demonstrated the following:

- naturally occurring arsenic in the glacial deposits can be mobilized from minerals to water by temperature increases caused by in situ steam processes;
- concentrations of arsenic within the tills in the Cold Lake area are typically up to 20 mg/kg;
- arsenic moves within the groundwater flow, but with a retardation factor of approximately 1.6 (*i.e.*, 60% of the distance that groundwater would move in the same time) due to sorption and mineral precipitation reactions;

- arsenic concentrations are attenuated to background values downgradient as the thermal regime returns to ambient temperature; and
- velocity of groundwater flow is a major factor in the downgradient distance of arsenic movement, however the ultimate control lies with the temperature.

5.2.2 Impact Assessment

The design features and operational factors that Pengrowth has committed to are expected to ensure that the production and injection wells will not have any effect on the chemical quality of the groundwater in non-saline aquifers or surface water bodies due to failure of the well casing integrity. Operational monitoring has been designed to identify any upset conditions, at which time a groundwater response plan could be implemented if potential risks to non-saline aquifers were identified.

The changes in temperature along the well bore are expected to be localized, as would any changes in groundwater chemistry due to the potential dissolution of minerals (*e.g.*, arsenic). Of concern is the proximity of the production wells to surface water bodies, surface water users, and groundwater wells, as there is the potential to alter water chemistry.

Drilling activities conducted in the HLSA indicate that the naturally occurring arsenic concentrations in the soil ranged between 1.1 mg/kg and 24.4 mg/kg (Table 7), which is comparable to the concentrations measured in the Cold Lake tills (Andriashek, 2000; Andriashek, 2003). Baseline groundwater concentrations of arsenic have been measured within three Quaternary units beneath the Project: the Sand River Formation equivalent, the Ethel Lake Formation and the Muriel Lake Formation (Table 5). Laboratory results indicate that baseline arsenic concentrations in groundwater from Quaternary deposits in the HLSA typically exceed the freshwater aquatic and human consumption guidelines of 0.005 and 0.01 mg/L, respectively.

The lifetime of each well pair is anticipated to be seven years, following which, temperature conditions would return to baseline. During the operational life of the well pairs, there is potential for elevated arsenic concentrations to occur within non-saline aquifers underlying the Project. Of the Quaternary aquifer units, the highest rate of groundwater flow appears to be within the Ethel Lake Formation. Potential impacts have been assessed based on the estimated flow velocity within the Ethel Lake Formation taking into account a 60% retardation factor. Other factors that may contribute to, prevent or restrict the mobility or concentration of arsenic in groundwater were not considered.

There are five main named lakes within the HLSA, three of which are likely receiving groundwater from the Ethel Lake Formation. Groundwater is likely discharging into Muriel Lake from the Grand Centre, Marie Creek and Ethel Lake formations, however, Muriel Lake is not downgradient from any

of the well pad locations and the closest proposed well pads as part of the Project are approximately 4.9 km south and over 5 km east of Muriel Lake. Based on the distance between Muriel Lake and the closest well pad locations, the groundwater flow directions and the maximum distance elevated arsenic concentrations could travel, it is not expected that Muriel Lake will be negatively impacted by the Project.

Garnier Lake and Bluet Lake may also be in contact with the Ethel Lake Formation and are likely receiving groundwater from the Ethel Lake Formation. The closest well pad to Garnier Lake is 500 m northeast and the closest well pad to Bluet Lake is 1.7 km northwest. Based on the distance between Garnier Lake and the closest well pad locations, the groundwater flow direction and the maximum distance elevated arsenic concentrations could travel, groundwater discharging into Garnier Lake could be altered by the development of thermal plumes, however, many other processes and factors such as adsorption and mineral precipitation will contribute to the possibility that undesirable concentrations of dissolved arsenic will actually discharge into the lake (Stollenwerk, 2003). It is not expected that groundwater containing high concentrations of arsenic will travel the 1.7 km distance to reach Bluet Lake before the formation temperature decreases and the arsenic precipitates out of solution.

It is unlikely that groundwater is discharging into Reita Lake. There are several well pads proposed in the vicinity of the lake, the closest of which is approximately 100 m southwest. It is not expected that any impacted groundwater will discharge into Reita Lake. The water level in the lake is expected to be at a higher elevation than the water levels in underlying units which would result in a downward hydraulic gradient. However, due to the close proximity of the proposed well pads to Reita Lake, groundwater monitoring will be recommended.

It is also unlikely that groundwater is discharging into Cushing Lake. The closest well pad to Cushing Lake is approximately 5.3 km northwest and a downward hydraulic gradient is expected. The distance between the Lake and the nearest well pad, the expected shallow depth of the lake, along with the expected groundwater flow direction indicate that that Cushing Lake will not be impacted by changes in groundwater chemistry as a result of the Project.

Records from the ESRD Water Well Information Database for domestic use, stock use and domestic and stock use water wells indicate that water wells may be located in close proximity to proposed well pads in the southwest and the northeast areas of the HLSA. Water wells were field verified in the southwest and groundwater monitoring to ensure the protection of the groundwater resource in that area will be proposed. No water wells were field verified in the northeast due to restricted access. Groundwater monitoring downgradient of the well pads in the northeast will also be proposed.

The groundwater response plan will be effective at avoiding undesirable effects to groundwater. No impacts to surface water receptors, terrestrial or riparian vegetation, wildlife or aquatic resources including wetlands are expected.

The potential impact to groundwater due to steaming activities, will be local in extent, can occur during operations, may occur during steaming, will diminish over time and may exceed background concentrations but will be well within established limits. The overall impact rating is determined to be low.

5.2.3 Monitoring

Ongoing groundwater monitoring of the Quaternary deposits is being conducted for the Pilot Project, which will determine the propensity of minerals to mobilize from the soils into the groundwater under the changing thermal regime. Detailed monitoring of the Pilot SAGD well pad is ongoing and includes four nested monitoring locations with monitoring wells completed within the Sand River Formation equivalent, Ethel Lake Formation and Bonnyville Formation. Monitoring data from 2011 and 2012, since steaming began, have been reviewed annually and do not indicate elevated arsenic concentrations or elevated temperatures in any of the Quaternary formations. Many of the newly installed groundwater monitoring wells have limited chemical quality data available at this point. Therefore, based on continued groundwater monitoring results, additional groundwater wells may be drilled in areas downgradient of the proposed well pads, so that sufficient monitoring of the Quaternary deposits can be accomplished.

The proposed groundwater monitoring program for the Project is included in Appendix E.

5.2.4 Mitigation

Design features, operational factors, operational monitoring and industry best practices are expected to ensure that the production and injection wells will not have any effect on the chemical quality of the groundwater in non-saline aquifers due to well casing failure. In the event of upset conditions, a groundwater response plan can be implemented if it is identified that non-saline aquifers or surface water bodies may be at risk.

5.3 Environmental Impact Assessment Summary

Possible Project impacts are summarized as follows:

- potential spills or leaks of bitumen, produced water or process-related chemicals at the surface facilities are assessed to have a low impact on the chemical quality of non-saline aquifers, surface water bodies and wetlands; and

- the construction and operation of the production and injection wells are assessed to have a low impact on the chemical quality of non-saline aquifers, surface water bodies and wetlands.

The impact assessment is also summarized in Table 8.

5.4 Cumulative Effects Assessment

Groundwater effects associated with surface facilities and injection and production wells have low impact ratings and are local in extent. Oil sands facilities are located north of the HRSA in the vicinity of Cold Lake, approximately 60 km from the Project. The nearest industrial facility to the Project is the Canadian Salt Company Lindbergh Facility located 16 km south.

There will be no cumulative effects related to groundwater associated with the Project.

5.5 Groundwater Monitoring Program

The groundwater monitoring program developed for the Project will have the following main purposes:

- to detect any impacts on the shallow groundwater quality resulting from spills or leaks from surface facilities at the plant site; and
- to identify any changes in groundwater chemistry in the non-saline groundwater zones associated with steam injection.

Below is a brief overview of the proposed groundwater monitoring program for the Project; a detailed description is included in Appendix E

Areas that will be monitored will include:

- the Project CPF; and
- downgradient of well pads and upgradient of VECs such as domestic and stock water wells, Muriel Lake, Garnier Lake and Reita Lake.

Groundwater monitoring wells for the Project will target aquifer units that have the potential to transmit groundwater to receptors. Monitoring near the Project CPF will be focused on the shallowest aquifer unit or water table if no aquifer is within the upper 15 m whereas monitoring of the Project area away from the Project CPF will target all permeable units present. High-permeability Quaternary formations that will be targeted include the Sand River Formation equivalent, Ethel Lake Formation, Bonnyville Formation Unit 1, Muriel Lake Formation and the Empress Formation Unit 3.

The monitoring program will include biannual sampling with more frequent sampling during the baseline data collection period. Water-measurements in monitoring wells not planned for operational monitoring will continue to be collected following the baseline data collection period. Annual reporting will be completed describing the information collected, an interpretation of results and recommendations to improve the monitoring program. The annual report will be submitted to AER.

6.0 REFERENCES

Alberta Energy Regulator. Base of Ground Water Protection Tool. Accessed at https://www3.eub.gov.ab.ca/Eub/COM/BGP/UI/BGP-Main.aspx on September 20, 2013.

Alberta Energy Regulator. 2013. Draft Directive 023: Oil Sands Project Applications. May 2013.

Alberta Environment. 2008a. Muriel Lake, Alberta – Bathymetry (GIS data, line features). Digital Data 2008-0648. Alberta Geological Survey.

Alberta Environment. 2008b. Reita Lake, Alberta – Bathymetry (GIS data, line features). Digital Data 2008-0663. Alberta Geological Survey.

Alberta Environment. 2010. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Government of Alberta. December 2010.

Alberta Environment and Sustainable Resource Development (ESRD). 2013. Alberta Water Well Information Database. Accessed at http://groundwater.alberta.ca/WaterWells/ on July 24, 2013.

Alberta Government. 2000.Environmental Protection and Enhancement Act. Revised Statutes of Alberta 2000. Chapter E-12.

Alberta Government. 2006. Water Conservation and Allocation Guideline 2006.

Alberta Government. 2012. Lower Athabasca Region Groundwater Management Framework. Alberta Environment and Sustainable Resource Development. August 2012.

Alberta Government. 2013. Lower Athabasca Region Groundwater Management Framework. Supporting Document for the Cold Lake – Beaver River (CLBR) Area. Alberta Environment and Sustainable Resource Development. June 2013.

Alberta Health and Wellness. 2000. Arsenic in Groundwater from Domestic Wells in Three Areas of Northern Alberta. Health Surveillance. October 2000.

Alberta Lake Management Society. 2005a. Lakewatch. The Alberta Lake Management Society Volunteer Lake Monitoring Program. Garnier Lake. 2005 Report.

Alberta Lake Management Society. 2005b. Lakewatch. The Alberta Lake Management Society Volunteer Lake Monitoring Program. Bluet (Garnier South) Lake. 2005 Report.

Andriashek, L.D. 2000. Geochemistry of Selected Glacial and Bedrock Geologic Units, Cold Lake Area, Alberta. Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2000-10.

Andriashek, L.D. 2003. Quaternary Geological Setting of the Athabasca Oil Sand (In Situ) Area, Northeast Alberta. Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2002-03.Andriashek, L.D. 2001. Quaternary Stratigraphy of the Buried Birch and Willow Bedrock Channels, NE Alberta. EUB/AGS Earth Sciences Report 2000-15

Andriashek L.D. and M.M. Fenton. 1989. Quaternary Stratigraphy and Surficial Geology of the Sand River Area 73L. Alberta Research Council. Bulletin No. 57.

Atkinson, N. and S. Lyster. 2010a. Thickness of Quaternary and Neogene Sediment in Alberta, Canada. Map No. 551.

Atkinson, N. and S. Lyster. 2010b. Bedrock Topography of Alberta, Canada. Energy Resources Conservation Board, ERCB/AGS. Map No. 500.

Bachu, S., E.H. Perkins, B. Hitchon, A.T. Lytviak and J.R. Undershultz. 1989. Evaluation of Effects of Deep Waste Injection in the Cold Lake Area, Alberta. Alberta Research Council. Bulletin No. 60.

Bachu, S., J.R. Underschultz, Brian Hitchon and D. Cotterill. 1993. Regional-Scale Subsurface Hydrogeology in Northeast Alberta. Alberta Research Council. Bulletin No. 61.

Canadian Natural Resources Limited (CNRL). 2006. Primrose In Situ Oil Sands Project, Primrose East Expansion, Application for Approval. Volume 4: Aquatic Resources, Appendix II Hydrogeology Baseline Report. Submitted to Alberta Energy and Utilities Board and Alberta Environment. January 2006.

Canadian Natural Resources Limited (CNRL). 2009. Primrose, Wolf Lake and Burnt Lake Annual Presentation to the ERCB. February 6, 2009. Presentation to the Energy Resources and Conservation Board. 57 pp.

Currie, D.V., N. Zacharko. 1976. Hydrogeology of the Vermillion area, Alberta. Alberta Research Council. Report 75-5.

Environment Canada. Canadian Climate Normals 1971–2000. Elk Point Station (3012280). Accessed at http://climate.weather.gc.ca/climate_normals/results_e.html?stnID=1876&lang=e&dCode=0&province=&provBut=Go&month1=0&month2=12 on July 24, 2013.

Environment Canada. Hydrometric Data. Muriel Lake at Gurneyville (06AC007). Accessed at http://www.wateroffice.ec.gc.ca/graph/graph_e.html?stn=06AC007&prm1=3&prm2=-1&mode=text&smo=7&sday=1&syr=2013&emo=7&eday=31&eyr=2013&y1min=&y1max=&y2min=&y2max= on October 10, 2013.

Fennell, J. W. 2008. Effects of Aquifer Heating on Groundwater Chemistry with a Review of Arsenic and its Mobility; A thesis submitted to the faculty of graduate studies in partial fulfillment of the requirements for the degree of Doctor of Philosophy; Department of Geoscience, University of Calgary, Calgary, AB, March, 330 pages.

Hitchon, B., S. Bachu, C.M. Sauveplane, A. Ing, A.T. Lytviak and J.R. Underschultz. 1989. Hydrogeological and geothermal regimes in the Phanerozoic succession, Cold Lake area, Alberta and Saskatchewan. Alberta Research Council. Bulletin No. 59.

Hitchon, B., A.T. Lytviak, S. Bachu, L.D. Andriashek, C.M. Sauveplane, H.R. Hudson and S.C. O'Connell. 1996. Hydrogeology of the Cold Lake Study Area. Alberta, Canada. Basin Analysis Group, Alberta Geological Survey, Alberta Research Council. Open File Report 1996-01.

Hydrogeological Consultants Ltd. (HCL). 1998. County of St. Paul No. 19, Part of the North Saskatchewan River Basin, Parts of Tp 055 to 062, R03 to 13, W4M, Regional Groundwater Assessment.

Imperial Oil Limited. 2009. Cold Lake Annual Performance Review. Presentation to the Energy Resources and Conservation Board. November 24, 2009.

Lemay, T., K. Parks, L.D. Andriashek, K. Michael, G. Jean, E. Kempin and S. Stewart. 2005. Regional Groundwater Quality Appraisal, Cold Lake-Beaver River Drainage Basin, Alberta. Alberta Energy and Utilities Board and Alberta Geological Survey. Special Report 73. February 2005.

Meijer Drees, N.C. 1994. Devonian Elk Point Group of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetsen (comp.), Canadian Society of Petroleum Geologists and Alberta Research Council. http://www.ags.gov.ab.ca/publications/wcsb_atlas/atlas.html, November 12, 2013.

Millennium EMS Solutions Ltd. (MEMS). 2011a. Lindbergh Enhanced Recovery Heavy Oil Processing Plant, 06-13-058-05 W4M, Annual Groundwater Monitoring Plan. File No. 10-131. November 2011.

Millennium EMS Solutions Ltd. (MEMS). 2011b. Pengrowth Lindbergh SAGD Project. Hydrogeology. December 2011.

Millennium EMS Solutions Ltd. (MEMS). 2012a. Lindbergh Enhanced Recovery In-Situ Oil Sands Processing Plant, 06-13-058-05 W4M, 2011 Groundwater Monitoring Program Summary Report. File No. 10-131. March 2012.

Millennium EMS Solutions Ltd. (MEMS). 2012b. Regional Saline Groundwater Source Review. Lindbergh SAGD Project. File No. 10-131. August 2012.

Millennium EMS Solutions Ltd. (MEMS). 2013. 2012 Groundwater Monitoring Program Summary Report. Lindbergh Enhanced Recovery In-Situ Oil Sands Processing Plant. 13-058-05 W4M. March 2013.

Millennium EMS Solutions Ltd. (MEMS). and Northwest Hydraulic Consultants Ltd. (NHC). 2012. Review of Muriel Lake Hydrology. April 2012.

Moncur, M.C., D. Paktunc, Y. Thibault, S.J. Birks, M. Weiser. 2011. Uranium and Arsenic Sources in Shallow Groundwater Near Bonnyville, Alberta: A Mineralogy Study. Water for Life. Alberta Innovates-Technology Futures, Alberta Environment and Water. March 2011.

Osum Oil Sands Corp. 2009. Application for Approval of the Taiga Project. Submitted to: Alberta Energy Resources Conservation Board and Alberta Environment. December 2009.

Ozoray, G., E.I. Wallick, A.T. Lytviak. 1980. Hydrogeology of the Sand River Area, Alberta. Alberta Research Council. Earth Science Report 79-1.

Parks, K., L.D. Andriashek, K. Michael, T. Lemay, S. Stewart, G. Jean and E. Kempin. 2005. Regional Groundwater Resource Appraisal, Cold Lake – Beaver River Drainage Basin, Alberta. Alberta Energy and Utilities Board and Alberta Geological Survey. Special Report 74. February 2005.

Pawlowicz, J.G. and M.M. Fenton. 1995. Bedrock Topography of Alberta. Map No. 226.

Pengrowth Corporation. 2010. Project Update and Supplemental Information Responses for Lindbergh SAGD Pilot Project. (Submitted to Alberta Environment). December 2010.

Pengrowth Energy Corporation. 2011. Lindbergh SAGD Project Application for Amendment (Submitted to ERCB). December 2011.

Pengrowth Energy Corporation. 2013. Lindbergh SAGD Expansion Project Application (Submitted to ERCB). December 2013.

Slind, O.L., G.D. Andrews, D.L. Murray, B.S. Norford, D.F. Paterson, C.J. Salas and E.E. Tawadros. 1994. Middle Cambrian to Lower Ordovician Strata of the Western Canada Sedimentary Basin; *in* Geological Atlas of the Western Canada Sedimentary Basin, G.D. Mossop and I. Shetsen (comp.), Canadian Society of Petroleum Geologists and Alberta Research Council. http://www.ags.gov.ab.ca/publications/wcsb_atlas/atlas.html, October 29, 2013.

Stollenwerk, K.G. 2003. Geochemical Processes Controlling Transport of Arsenic in Groundwater: A Review of Adsorption In A.H. Welch and K.G. Stollenwerk (Eds.), Arsenic in Ground Water (pp. 67-100). Springer US.

University of Alberta. 1990. Atlas of Alberta Lakes. Edited by P. Mitchell and E.E. Prepas.

APPENDIX A: TABLES

List of Tables

Table 1: Terms of Reference Concordance Table

Section	Condition	Location in Document; Comment
3.2.1 [A]	Provide an overview of the existing geologic and hydrogeologic setting from the ground surface down to, and including, the oil producing zones and disposal zones.	Sections 4.2 and 4.3
3.2.1 [A] a)	Present regional and Project Area geology to illustrate depth, thickness and spatial extent of lithology, stratigraphic units and structural features.	Section 4.2 Figures 3 and 5-15
3.2.1 [A] b)	Present regional and Project Area hydrogeology describing:	Section 4.3
3.2.1 [A] b) i)	The major aquifers, aquitards and aquicludes (Quaternary and bedrock), their spatial distribution, properties, hydraulic connections between aquifers, hydraulic heads, gradients, groundwater flow directions and velocities. Include maps and cross sections.	Sections 4.3.1, 4.3.2 and 4.3.3 Figures 3, 5, 6, 8-15 and 18-21 Table 3
3.2.1 [A] b) ii)	The chemistry of groundwater aquifers including baseline concentrations of major ions, metals and hydrocarbon indicators.	Tables 2, 4, 5 and 6
3.2.1 [A] b) iii)	The potential discharge zones, potential recharge zones and sources, areas of groundwater-surface water interaction and areas of Quaternary aquifer-bedrock groundwater interaction.	Sections 4.3.3 and 4.3.4
3.2.1 [A] b) iv)	Water well development and groundwater use, including an inventory of groundwater users.	Sections 4.3.5 and 4.3.6 Appendix C and D
3.2.1 [A] b) v)	The recharge potential for Quaternary aquifers.	Section 4.3.3
3.2.1 [A] b) vi)	Potential hydraulic connection between bitumen production zones, deep disposal formations and other aquifers resulting from Project operations.	Sections 4.3.1 and 4.3.3 Figure 3
3.2.1 [A] b) vii)	The characterization of formations chosen for deep well disposal, including chemical compatibility and containment potential, injection capacity, hydrodynamic flow regime, and water quality assessments.	Sections 4.2.1.1 and 4.3.1.1
3.2.1 [A] b) viii)	The locations of major facilities associated with the Project including facilities for waste storage, treatment and disposal (*e.g.*, deep well disposal) and describe site-specific aquifer and shallow groundwater conditions beneath these proposed facilities. Provide supporting geological information.	Sections 1.0, 5.1.2 Figures 1, 5, 6, 8-15
3.2.2 [A]	Describe Project components and activities that have the potential to affect groundwater resource quantity and quality at all stages of the Project.	Section 5.0
3.2.2 [B]	Describe the nature and significance of the potential Project impacts on groundwater with respect to:	Section 5.0
3.2.2 [B] a)	Inter-relationship between groundwater and surface water in terms of both groundwater and surface water quantity and quality.	Section 4.3.4, 5.2
3.2.2 [B] b)	Implications for terrestrial or riparian vegetation, wildlife and aquatic resources including wetlands.	Sections 5.1.2 and 5.2.2
3.2.2 [B] c)	Changes in groundwater quality, quantity and flow.	Sections 5.1.2 and 5.2.2
3.2.2 [B] d)	Conflicts with other groundwater users, and proposed resolutions to these conflicts.	N/A
3.2.2 [B] e)	Potential implications of seasonal variations.	N/A
3.2.2 [B] f)	Groundwater withdrawal for Project operations, including any expected alterations in the groundwater flow regime during and following Project operations.	N/A

N/A – Not Applicable

Table 2: Targets and Thresholds

Analytical Parameter	General Chemistry					Major Ions and Ion Balance									
	pH	Electrical Conductivity	Total Dissolved Solids	Total Alkalinity	Hardness	Bicarbonate	Carbonate	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate - N	Nitrite - N
Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Alberta Environment Tier 1	8.5	-	500	-	-	-	-	-	-	200	-	100	500	13	0.06
CLBR Area - Sand River	-	-	500	-	-	-	-	-	-	-	-	25	-	2	-
CLBR Area - Ethel Lake	-	-	500	-	-	-	-	-	-	-	-	25	-	0.5	-
CLBR Area - Bonnyville	-	-	500	-	-	-	-	-	-	-	-	125	-	0.2	-
Target															
Grand Centre *	9.83	1,325	836	756	612	922	7.85	148	93	124	11	28	163	0.32	0.04
Sand River	9.83	1,325	836	756	612	922	7.85	148	93	124	11	28	163	0.32	0.04
Marie Creek *	9.83	1,325	836	756	612	922	7.85	148	93	124	11	28	163	0.32	0.04
Ethel Lake	9.91	1,654	1,055	668	567	815	7.88	144	51	226	6	23	267	0.18	0.10
Bonnyville	8.28	1,724	1,160	560	433	683	6.00	111	38	297	5	12	447	0.11	0.36
Lea Park	8.28	1,560	964	579	292	706	6.00	73	26	260	5	57	208	0.25	0.25
Threshold															
Grand Centre *	9.83	-	836	-	-	-	-	-	-	200	-	100	500	13	0.06
Sand River	9.83	-	836	-	-	-	-	-	-	200	-	100	500	13	0.06
Marie Creek *	9.83	-	836	-	-	-	-	-	-	200	-	100	500	13	0.06
Ethel Lake	9.91	-	1,055	-	-	-	-	-	-	226	-	100	500	13	0.10
Bonnyville	8.50	-	1,160	-	-	-	-	-	-	297	-	100	500	13	0.45
Lea Park	8.50	-	964	-	-	-	-	-	-	260	-	100	500	13	0.25

Notes:

* Used values established for Sand River Formation equivalent

Red Text - Primary groundwater quality indicator parameter

Blue Text - Secondary groundwater quality indicator parameter

Table 2: Targets and Thresholds

Analytical Parameter	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Phosphorus	Selenium	Silicon	Silver	Strontium	Sulphur	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc	Zirconium
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Alberta Environment Tier 1	**0.005**	**0.006**	**0.005**	**1**	**-**	**-**	**0.5**	**0.000097**	**0.0089**	**-**	**0.004**	**0.3**	**0.007**	**-**	**0.05**	**0.0001**	**-**	**0.15**	**-**	**0.001**	**-**	**0.0001**	**-**	**-**	**-**	**-**	**-**	**0.01**	**-**	**0.03**	**-**
CLBR Area - Sand River	-	-	**0.003**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CLBR Area - Ethel Lake	-	-	**0.003**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CLBR Area - Bonnyville	-	-	**0.003**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Target																															
Grand Centre *	0.101	0.005	0.038	0.352	0.025	0.001	0.5	0.000207	0.0138	0.0026	0.006	1.3	0.002	0.171	0.90	0.0001	0.022	0.02	-	0.002	13.0	0.0001	1.2	52.4	0.000	0.002	0.007	0.02	0.008	0.02	-
Sand River	0.101	0.005	0.038	0.352	0.025	0.001	0.5	0.000207	0.0138	0.0026	0.006	1.3	0.002	0.171	0.90	0.0001	0.022	0.02	-	0.002	13.0	0.0001	1.2	52.4	0.000	0.002	0.007	0.02	0.008	0.02	-
Marie Creek *	0.101	0.005	0.038	0.352	0.025	0.001	0.5	0.000207	0.0138	0.0026	0.006	1.3	0.002	0.171	0.90	0.0001	0.022	0.02	-	0.002	13.0	0.0001	1.2	52.4	0.000	0.002	0.007	0.02	0.008	0.02	-
Ethel Lake	0.013	0.010	0.007	0.077	0.016	0.001	0.3	0.000101	0.0163	0.0040	0.017	0.1	0.012	0.093	1.48	0.0001	0.010	0.01	-	0.008	11.1	0.0002	0.9	71.6	0.000	0.017	0.020	0.02	0.018	0.04	-
Bonnyville	0.047	0.001	0.013	0.050	0.001	0.001	0.2	0.000060	0.0015	0.0010	0.006	0.1	0.001	0.087	0.25	0.0001	0.026	0.00	-	0.003	8.5	0.0001	0.7	160.0	0.000	0.001	0.015	0.01	0.003	0.03	-
Lea Park	0.018	0.001	0.019	0.102	0.001	0.001	0.4	0.000064	0.0036	0.0010	0.005	0.4	0.001	0.079	0.17	0.0001	0.014	0.00	-	0.001	9.9	0.0001	0.8	65.4	0.000	0.002	0.007	0.00	0.005	0.02	-
Threshold																															
Grand Centre *	0.101	0.006	0.038	1	-	-	0.5	0.000207	0.0138	-	0.006	1.3	0.007	-	0.90	0.0001	-	0.15	-	0.002	-	0.0001	-	-	-	-	-	0.02	-	0.03	-
Sand River	0.101	0.006	0.038	1	-	-	0.5	0.000207	0.0138	-	0.006	1.3	0.007	-	0.90	0.0001	-	0.15	-	0.002	-	0.0001	-	-	-	-	-	0.02	-	0.03	-
Marie Creek *	0.101	0.006	0.038	1	-	-	0.5	0.000207	0.0138	-	0.006	1.3	0.007	-	0.90	0.0001	-	0.15	-	0.002	-	0.0001	-	-	-	-	-	0.02	-	0.03	-
Ethel Lake	0.013	0.099	0.007	1	-	-	0.5	0.000100	0.0163	-	0.017	0.3	0.012	-	1.48	0.0001	-	0.15	-	0.008	-	0.0002	-	-	-	-	-	0.02	-	0.04	-
Bonnyville	0.047	0.006	0.013	1	-	-	0.5	0.000097	0.0089	-	0.006	0.3	0.007	-	0.25	0.0001	-	0.15	-	0.003	-	0.0001	-	-	-	-	-	0.01	-	0.03	-
Lea Park	0.018	0.006	0.019	1	-	-	0.5	0.000097	0.0089	-	0.005	0.4	0.007	-	0.17	0.0001	-	0.15	-	0.001	-	0.0001	-	-	-	-	-	0.01	-	0.03	-

Notes:
* Used values established for Sand River Formation equivalent
Red Text - Primary groundwater quality indicator parameter
Blue Text - Secondary groundwater quality indicator parameter

Table 2: Targets and Thresholds

Analytical Parameter	Benzene	Toluene	Ethylbenzene	Xylene	F1 (C6-C10) - BTEX	F2 (C10-C16 Hydrocarbons)	Naphthenic Acid	Phenols
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/mL	mg/L
Alberta Environment Tier 1	**0.005**	**0.024**	**0.0024**	**0.3**	**0.81**	**1.1**	**-**	**0.004**
CLBR Area - Sand River	**-**	**-**	**-**	**-**	**0.2**	**-**	**-**	**0.009**
CLBR Area - Ethel Lake	**-**	**-**	**-**	**-**	**0.2**	**-**	**-**	**0.009**
CLBR Area - Bonnyville	**-**	**-**	**-**	**-**	**0.4**	**-**	**-**	**0.009**
Target								
Grand Centre *	0.0019	0.0024	0.0019	0.0019	0.3850	0.1225	0.9100	0.0092
Sand River	0.0019	0.0024	0.0019	0.0019	0.3850	0.1225	0.9100	0.0092
Marie Creek *	0.0019	0.0024	0.0019	0.0019	0.3850	0.1225	0.9100	0.0092
Ethel Lake	0.0072	0.0027	0.0019	0.0019	0.3882	0.1225	0.2000	0.0078
Bonnyville	0.0010	0.0010	0.0010	0.0010	0.2000	0.1000	0.2000	0.0028
Lea Park	0.0010	0.0010	0.0010	0.0010	0.2000	0.1000	0.2000	0.0044
Threshold								
Grand Centre *	0.0050	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0092
Sand River	0.0050	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0092
Marie Creek *	0.0050	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0092
Ethel Lake	0.0072	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0078
Bonnyville	0.0050	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0040
Lea Park	0.0050	0.0240	0.0024	0.3000	0.8100	1.1000	-	0.0050

Notes: * Used values established for Sand River Formation equivalent

Red Text - Primary groundwater quality indicator parameter

Table 3: Monitoring Well Completion Details and Hydraulic Conductivities

Well ID	Location (W4M)	UTM Northing	UTM Easting	Ground Elevation (m asl)	Stickup (m)	Screen Interval (m bgl)	Hydraulic Conductivity (m/s)	Completion Lithology	Completion Formation	Most Recent Water Level (m asl)	Water-Level Measurement Date
P02-1	07-13-058-05	5984920	525525	655.82	0.70	5.0-8.0	4.0E-05	sand/silty clay	Sand River equiv. Fm.	649.32	18/10/2013
P02-2 (Decommissioned)	07-13-058-05	5984861	525666	655.45	0.60	4.6-7.6	5.7E-06	silty clay/sand & gravel	Sand River equiv. Fm.	649.34	23/05/2008
P02-3 (Decommissioned)	07-13-058-05	5984916	525633	655.73	0.65	4.6-7.6	1.1E-05	silty clay/sand	Sand River equiv. Fm.	649.47	23/05/2008
P02-4	07-13-058-05	5984922	525598	656.40	0.60	5.3-8.3	1.9E-05	sand	Sand River equiv. Fm.	649.38	18/10/2013
P02-5	07-13-058-05	5984980	525674	656.17	0.60	6.8-9.8	3.0E-07	sandy clay/clay silt	Marie Creek Fm.	650.14	18/10/2013
P02-6	07-13-058-05	5984838	525747	654.29	0.65	3.4-6.4	3.2E-05	silty clay/sand	Sand River equiv. Fm.	649.54	10/10/2013
P02-7	10-13-058-05	5985087	525732	659.82	0.55	7.0-10.0	>5.0E-05	sand	Sand River equiv. Fm.	651.67	10/10/2013
P02-8	09-13-058-05	5985449	525950	663.83	0.59	9.6-12.6	>5.0E-05	sand	Sand River equiv. Fm.	652.26	10/10/2013
P05-10A (Decommissioned)	09-13-058-05	5985440	525915	664.56	0.96	7.5-10.5	-	clay till/sand	Sand River equiv. Fm.	Dry	-
P05-9A	09-13-058-05	5985453	525886	665.13	0.96	10.6-13.6	-	clay till/sand	Sand River equiv. Fm.	652.03	13/06/2012
P10-11A	06-13-058-05	5984752	525133	649.63	1.14	3.8-6.8	>1.0E-05	silty clay till/gravelly sand	Sand River equiv. Fm.	646.76	10/10/2013
P10-12A	01-13-058-05	5984358	526091	651.44	1.15	3.4-6.5	8.5E-07	silty clay till/clay	Grand Centre Fm.	648.23	10/10/2013
P10-13A	07-13-058-05	5985026	525707	660.11	1.13	6.4-9.4	6.1E-05	sand	Sand River equiv. Fm.	652.09	10/10/2013
P10-14A	07-13-058-05	5984881	525793	658.16	1.20	5.7-8.85	>1.0E-05	sand	Sand River equiv. Fm.	651.25	10/10/2013
P10-15A	07-13-058-05	5984846	525603	654.97	1.18	4.1-7.1	6.2E-06	silty clay till/sand	Sand River equiv. Fm.	650.11	18/10/2013
P10-16A	07-13-058-05	5984816	525657	654.65	1.20	3.3-6.3	>1.0E-05	silty clay till/gravelly sand	Sand River equiv. Fm.	650.41	18/10/2013
P10-17A	09-13-058-05	5985421	525920	666.01	1.01	13.7-16.7	4.3E-06	sand/clay	Sand River equiv. Fm.	653.15	10/10/2013
P10-18A	14-13-058-05	5985715	525405	661.76	1.18	7.15-10.1	1.1E-06	sand/gravelly sand	Sand River equiv. Fm.	653.01	18/10/2013
MW11-19-12	11-13-058-05	5985407	525187	654.31	0.68	10.1-11.6	7.5E-04	sand	Sand River equiv. Fm.	652.32	17/10/2013
MW11-19-24	11-13-058-05	5985405	525193	654.33	0.52	20.7-22.8	-	medium grained sand	Sand River equiv. Fm.	652.35	17/10/2013
MW11-19-67	11-13-058-05	5985409	525193	654.30	0.70	64.3-67.4	1.1E-04	sand	Ethel Lake Fm.	651.29	17/10/2013
MW11-20-53	06-13-058-05	5984975	525206	651.16	0.82	49.8-53.0	6.2E-04	coarse to very coarse sand	Ethel Lake Fm.	651.28	09/10/2013
MW11-20-7	06-13-058-05	5984976	525202	651.12	0.94	5.4-6.8	2.0E-05	coarse grained sand to gravel	Sand River equiv. Fm.	647.79	18/10/2013
MW11-20-74	06-13-058-05	5984979	525206	651.15	0.97	72.6-74.0	-	sand/shale	Bonnyville Unit 1 Fm.	651.27	09/10/2013
MW11-21-11	06-13-058-05	5985050	525085	651.49	0.72	7.6-10.8	-	medium grained sand	Sand River equiv. Fm.	647.36	18/10/2013
MW11-21-54	06-13-058-05	5985048	525083	651.45	0.77	52.5-54.0	1.6E-03	sand & gravel	Ethel Lake Fm.	651.28	09/10/2013
MW11-22-54	11-13-058-05	5985123	525340	654.46	0.80	51.0-54.2	3.0E-04	medium to coarse sand	Ethel Lake Fm.	651.28	10/10/2013
MW11-22-9	11-13-058-05	5985122	525345	654.88	0.65	6.2-9.2	-	fine to medium grained sand	Sand River equiv. Fm.	650.22	18/10/2013
MW12-23-14	09-13-058-05	5985433	525897	664.48	0.76	12.0-13.5	1.5E-04	medium sand	Sand River equiv. Fm.	652.41	17/10/2013
MW12-24-8	07-13-058-05	5984860	525660	655.71	0.85	6.3-7.8	2.7E-04	medium sand	Sand River equiv. Fm.	649.52	18/10/2013
MW12-25-8	07-13-058-05	5984896	525612	655.57	0.90	6.0-7.5	2.7E-04	clayey, sandy gravel	Sand River equiv. Fm.	649.83	18/10/2013
MW12-26-8	07-13-058-05	5984810	525609	652.43	0.90	6.0-7.5	2.0E-04	clayey sand	Sand River equiv. Fm.	648.66	18/10/2013
MW13-19-82	11-13-058-05	5985403	525177	654.32	0.90	78.6-81.6	8.0E-05	clay/silt/sand & gravel	Bonnyville Unit 1 Fm.	651.30	08/10/2013
MW13-19-96	11-13-058-05	5985403	525174	654.31	0.90	93.0-96.0	3.3E-09	shale	Lea Park Fm.	651.38*	15/10/2013
MW13-23-50	09-12-058-05	5983694	525940	645.76	0.95	47.0-50.0	4.7E-04	sand	Ethel Lake Fm.	631.75	09/10/2013
MW13-23-81	09-12-058-05	5983696	525940	645.88	0.97	77.8-80.8	2.0E-09	shale	Lea Park Fm.	634.12	16/10/2013
MW13-24-94	03-32-058-04	5989409	528453	656.04	0.97	90.5-93.5	-	shale	Lea Park Fm.	625.43	09/10/2013
MW13-25-29	14-36-058-05	5990442	525317	610.17	0.93	26.0-29.0	-	shale	Lea Park Fm.	606.21*	10/10/2013
MW13-27-23	01-20-059-04	5995839	528981	619.31	0.83	20.1-23.2	1.1E-03	sand & gravel/gravelly clay, sand	Sand River equiv. Fm.	613.77	08/10/2013
MW13-27-55	01-20-059-04	5995840	528977	619.38	0.96	51.5-54.5	5.7E-06	sand/silt	Ethel Lake Fm.	606.17	08/10/2013
MW13-27-90	01-20-059-04	5995840	528979	619.37	0.96	86.9-89.9	2.2E-05	clay, sand & gravel	Muriel Lake Fm.	596.17	08/10/2013
Alberta Enviroment Groundwater Observation Well Network											
Muriel Lake 07-2 0944	02-01-060-06	6000420	515453	567.84	-	5.8-7.3	-	sand & gravel	*Surficial*	560.74	04/12/2012
Cushing Lake 2411E 0243	16-32-058-03	5990470	538726	646.12	-	37.8-39.01	2.1E-05	sand & gravel	*Surficial*	634.59	06/12/2012
Cushing Lake 2412E East 0244	16-32-058-03	5990620	538922	640.00	-	125.88-131.06	-	sand & gravel	*Muriel Lake Fm.*	605.61	19/11/2009
Cushing Lake 2406E West 0242	16-32-058-03	5990615	539001	645.79	-	187.45-194.16	-	sand & gravel	*Empress Fm. Unit 1*	611.23	16/05/2012

Notes: Coordinates are inferred, not surveyed

Alberta Envirmonment Interpretation

* water level has not stabilized

Table 4: Groundwater Chemistry – General and Major Ion Parameters

Well ID	Sampling Date	General Chemistry					Major Ions and Ion Balance										
		pH	Electrical Conductivity	Total Dissolved Solids	Total Alkalinity	Hardness	Bicarbonate	Carbonate	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate N	Nitrite N	Ion Balance
	Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
Grand Centre Formation																	
P10-12A	05-Oct-11	8.00	1,170	707	618	608	754	<6	129.0	69.5	47.6	5.2	7.3	78	0.04	<0.005	101
	12-Jun-12	7.76	1,020	709	662	639	808	<6	120.0	82.6	37.3	3.9	6.7	61	0.36	-	99
	02-Oct-12	7.55	1,170	581	660	650	805	<6	132.0	77.8	39.8	5.2	6.6	71	0.18	-	100
Sand River Formation																	
P02-1	05-Oct-11	7.83	1,150	660	632	647	771	<6	147.0	67.9	14.3	4.4	9.8	37	2.74	<0.005	99
	12-Jun-12	7.48	1,080	725	694	712	846	<6	159.0	76.4	13.6	4.6	14.1	41	1.44	-	98
	02-Oct-12	7.33	1,300	769	741	777	903	<6	178.0	80.7	12.8	4.5	15.6	33	1.58	-	101
P02-4	05-Oct-11	7.88	1,100	624	632	634	770	<6	137.0	71.0	10.9	5.1	13.5	8	1.81	<0.005	100
	12-Jun-12	7.62	835	595	603	586	735	<6	126.0	65.8	10.1	4.9	20.1	7	0.38	-	96
	02-Oct-12	7.57	1,060	619	618	635	753	<6	136.0	72.0	10.3	4.9	18.6	7	0.53	-	102
P02-6	05-Oct-11	7.86	1,120	630	584	612	712	<6	148.0	58.8	15.1	6.4	33.1	18	0.72	<0.005	100
	12-Jun-12	7.60	1,060	697	606	662	738	<6	152.0	68.7	14.7	3.6	51.2	43	0.45	-	97
	01-Oct-12	7.42	1,090	645	589	638	718	<6	152.0	63.1	11.6	4.3	38.9	22	0.52	-	100
P02-7	05-Oct-11	7.66	4,540	2,300	472	1,480	576	<6	345.0	151.0	231.0	9.1	1270.0	15	0.22	<0.05	88
	12-Jun-12	7.60	1,920	1,150	504	944	615	<6	223.0	94.1	97.5	8.6	413.0	16	0.15	-	106
	01-Oct-12	7.33	3,370	1,950	515	1,440	628	<6	342.0	143.0	193.0	8.6	936.0	18	0.31	-	101
P02-8	05-Oct-11	7.76	1,480	808	614	770	748	<6	168.0	85.5	21.9	7.0	138.0	19	0.57	<0.005	100
	12-Jun-12	7.59	1,310	808	642	765	783	<6	166.0	84.9	21.4	7.3	126.0	17	0.25	-	98
	02-Oct-12	7.45	1,430	812	653	782	796	<6	169.0	87.5	22.2	6.8	118.0	17	0.37	-	100
P05-9A	05-Oct-11	7.96	1,270	716	586	690	715	<6	139.0	83.3	16.4	6.5	85.9	33	0.62	<0.005	99
	12-Jun-12	7.83	1,150	723	573	669	699	<6	139.0	78.0	20.4	7.2	95.4	39	0.26	-	97
P10-11A	05-Oct-11	7.76	1,190	670	534	607	651	<6	135.0	65.8	31.4	4.5	76.6	36	0.40	<0.005	100
	12-Jun-12	7.60	1,080	695	554	586	676	<6	132.0	62.3	35.2	4.1	81.6	47	0.42	-	93
	03-Oct-12	7.60	992	586	506	553	617	<6	122.0	59.9	27.3	4.4	37.1	31	0.39	-	105
P10-13A	05-Oct-11	7.73	991	1,290	558	85	680	<6	26.0	4.8	450.0	2.9	20.2	451	1.78	<0.005	100
	12-Jun-12	7.59	866	567	567	521	691	<6	121.0	53.2	17.4	7.0	10.9	17	0.13	-	95
	01-Oct-12	7.42	957	581	575	555	701	<6	129.0	56.4	17.3	6.8	10.1	16	0.21	-	99
P10-14A	05-Oct-11	7.68	1,090	617	578	634	704	<6	169.0	51.2	6.2	6.3	19.8	18	6.24	<0.005	102
	12-Jun-12	7.37	817	689	465	974	567	<6	244.0	88.8	9.4	9.0	20.5	38	2.96	-	185
	02-Oct-12	7.24	1,300	758	604	742	736	<6	178.0	72.4	10.3	8.1	95.9	31	1.05	-	100
P10-15A	05-Oct-11	7.83	1,020	594	604	559	736	<6	123.0	61.1	20.6	6.1	2.7	18	<0.01	-	98
	12-Jun-12	7.59	524	599	561	646	684	<6	145.0	69.1	20.3	6.1	5.7	17	0.12	<0.003	119
	02-Oct-12	7.25	948	556	561	517	684	<6	114.0	56.6	20.3	5.6	5.0	18	0.02	-	97
P10-16A	05-Oct-11	7.52	2,140	1,170	707	913	862	<6	224.0	85.9	80.4	7.5	328.0	18	<0.05	-	92
	12-Jun-12	7.30	1,590	1,030	752	897	916	<6	223.0	82.6	41.9	5.4	201.0	27	<0.01	0.004	94
	02-Oct-12	7.20	1,460	880	788	803	960	<6	199.0	74.6	35.6	5.2	62.3	31	<0.01	-	98
P10-17A	05-Oct-11	7.86	1,170	666	534	626	651	<6	140.0	67.3	18.9	6.5	71.6	41	0.66	-	100
	12-Jun-12	7.65	1,140	726	576	695	702	<6	154.0	75.4	21.6	7.3	92.1	31	0.47	0.014	102
	02-Oct-12	7.54	1,170	668	550	638	671	<6	141.0	69.4	18.7	6.1	69.0	34	0.34	-	101
P10-18A	05-Oct-11	7.89	1,040	598	469	564	572	<6	118.0	65.8	15.9	6.4	39.7	69	1.53	-	101
	12-Jun-12	7.70	728	466	435	446	530	<6	91.9	52.5	16.9	6.3	21.8	16	0.27	<0.015	102
	02-Oct-12	7.75	848	487	439	461	535	<6	93.3	55.3	20.4	5.7	20.2	29	0.34	-	100
MW11-19-12	23-Jun-11	8.20	859	501	503	466	614	<5	103.0	50.8	20.4	8.3	1.0	15	<0.113	<0.015	100
	27-Jul-11	8.10	861	481	502	422	612	<5	94.3	45.2	18.2	5.1	1.0	15	<0.113	<0.005	91
	25-Aug-11	7.83	901	507	514	469	626	<6	103.0	51.4	18.5	5.1	7.5	13	<0.01	<0.005	96
	5-Oct-11	7.85	862	497	504	470	615	<6	103.0	51.6	19.2	5.2	0.5	15	<0.01	<0.005	100
	2-Nov-11	7.97	864	503	514	471	626	<6	102.0	52.3	19.2	5.5	0.4	15	<0.01	-	98
	12-Jun-12	7.73	788	510	527	467	643	<6	103.0	51.2	19.4	5.2	<0.4	15	<0.01	0.113	95
	2-Oct-12	7.56	897	532	539	506	657	<6	110.0	56.2	20.2	5.5	0.8	16	<0.01	-	100
MW11-19-24	23-Jun-11	8.20	1,020	634	480	403	586	<5	102.0	36.0	86.1	6.0	5.0	110	<0.113	<0.015	100
	27-Jul-11	8.20	1,040	632	510	403	622	<5	101.0	36.7	77.4	6.2	4.0	100	<0.113	<0.005	94
	25-Aug-11	7.89	1,080	648	537	455	655	<6	112.0	42.8	70.9	6.5	6.5	87	<0.01	<0.005	97
	05-Oct-11	7.92	1,070	672	557	477	679	<6	118.0	44.6	74.2	6.7	3.0	92	<0.001	<0.005	99
	02-Nov-11	8.05	1,100	684	568	488	692	<6	120.0	45.7	73.9	6.8	2.4	95	<0.01	-	98
	12-Jun-12	7.88	1,040	709	612	514	746	<6	128.0	47.1	73.4	6.9	2.4	85	<0.01	<0.015	97
	02-Oct-12	7.78	1,120	730	609	556	743	<6	138.0	51.2	74.9	6.4	2.3	91	<0.01	-	103
MW11-20-7	23-Jun-11	8.10	902	536	405	493	494	<5	121.0	46.3	16.2	4.8	30.0	73	0.41	<0.015	102
	26-Jul-11	8.10	849	484	387	413	473	<5	103.0	37.8	12.9	3.9	23.0	69	0.41	<0.005	91
	25-Aug-11	7.94	888	499	387	446	472	<6	108.0	42.4	16.9	4.9	31.2	63	0.10	<0.005	98
	05-Oct-11	7.87	895	527	414	479	505	<6	117.0	45.1	16.2	4.5	29.5	66	0.30	<0.005	99
	02-Nov-11	7.86	875	530	415	485	506	<6	118.0	46.4	16.9	4.8	31.2	65	0.25	-	100
	12-Jun-12	7.73	753	509	434	452	529	<6	110.0	42.7	17.0	4.4	21.1	53	0.23	<0.015	95
	03-Oct-12	7.63	884	534	433	492	528	<6	120.0	46.9	18.8	4.5	23.5	60	0.33	-	102
MW11-21-11	24-Jun-11	8.00	986	583	538	497	657	<5	93.5	64.0	43.7	4.9	6.0	48	<0.113	<0.015	101
	26-Jul-11	8.10	1,000	579	550	471	671	<5	87.9	61.1	40.8	4.6	5.0	49	<0.113	<0.005	94
	25-Aug-11	7.78	1,060	598	564	506	688	<6	91.4	67.4	41.2	4.5	7.3	47	<0.01	<0.005	97
	05-Oct-11	7.99	1,040	612	561	526	684	<6	96.2	69.4	44.4	4.5	6.5	54	<0.01	<0.005	100
	02-Nov-11	8.04	1,020	605	568	504	693	<6	91.6	66.9	41.3	4.0	6.3	53	<0.01	-	95
	12-Jun-12	7.85	942	619	571	509	696	<6	93.0	67.3	45.0	4.6	7.3	60	0.02	<0.015	96
	03-Oct-12	7.69	1,060	663	588	582	716	<6	104.0	78.3	48.5	4.7	7.5	67	<0.005	-	104
MW11-22-9	23-Jun-11	8.20	876	520	501	453	611	<5	109.0	43.8	34.8	8.0	2.0	22	<0.113	<0.015	103
	26-Jul-11	8.20	883	518	504	410	615	<5	103.0	37.1	47.0	5.4	2.0	21	<0.113	<0.005	98
	25-Aug-11	8.00	924	515	511	441	623	<6	108.0	41.7	32.8	6.3	0.9	19	<0.01	<0.005	98
	04-Oct-11	8.07	900	537	523	449	637	<6	112.0	41.3	38.3	7.3	1.1	23	<0.01	<0.005	99
	02-Nov-11	8.07	891	531	525	447	640	<6	110.0	41.8	34.9	6.1	0.9	22	<0.01	-	97
	12-Jun-12	7.87	838	530	523	443	638	<6	110.0	40.7	35.7	6.0	1.3	21	<0.01	-	97
	03-Oct-12	7.89	909	560	539	489	657	<6	121.0	45.6	38.8	6.4	1.2	24	<0.01	-	103
MW12-23-14	12-Jun-12	7.74	1,220	774	450	719	548	<6	141.0	89.4	14.2	6.1	131.0	123	0.64	-	99
	02-Oct-12	7.61	1,180	696	535	674	653	<6	129.0	85.9	17.1	6.0	52.4	85	0.40	-	103
MW12-24-8	12-Jun-12	7.78	993	638	588	583	717	<6	135.0	62.1	21.6	5.0	44.8	16	0.02	-	97
	02-Oct-12	7.18	1,920	1,080	656	916	799	<6	214.0	92.7	68.6	6.9	286.0	18	0.02	-	100
MW12-25-8	12-Jun-12	7.65	1,120	711	590	634	720	<6	147.0	64.8	48.0	7.6	76.4	13	1.10	-	105
	02-Oct-12	7.36	1,170	675	577	553	703	<6	129.0	56.1	56.5	7.7	65.6	14	0.66	-	100

Table 4: Groundwater Chemistry – General and Major Ion Parameters

Well ID	Sampling Date	General Chemistry					Major Ions and Ion Balance										
		pH	Electrical Conductivity	Total Dissolved Solids	Total Alkalinity	Hardness	Bicarbonate	Carbonate	Calcium	Magnesium	Sodium	Potassium	Chloride	Sulphate	Nitrate N	Nitrite N	Ion Balance
	Units		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	%
MW12-26-8	12-Jun-12	7.75	898	573	555	542	677	<6	127.0	54.7	20.4	5.5	16.4	16	0.04	-	100
	02-Oct-12	7.61	1,020	589	578	556	705	<6	129.0	56.7	20.8	5.5	13.5	17	0.03	-	99
MW13-27-23	16-Jun-13	8.01	941	553	567	526	692	<5	127.0	50.6	19.4	6.0	0.7	9	<0.050	<0.050	100
	09-Oct-13	7.88	958	596	620	520	756	<6	126.0	50.2	25.8	6.6	1.5	14	<0.01	<0.005	92
Marie Creek Formation																	
P02-5	05-Oct-11	7.79	1,510	807	568	767	693	<6	155.0	92.1	25.9	6.0	173.0	14	0.79	0.018	100
	12-Jun-12	7.71	1,060	688	616	640	751	<6	122.0	81.3	29.5	5.6	61.7	18	0.41	-	98
	01-Oct-12	7.53	1,050	632	628	594	765	<6	112.0	76.2	26.2	5.4	16.4	19	0.64	-	98
Ethel Lake Formation																	
MW11-19-67	24-Jun-11	8.20	1,280	824	568	453	693	<5	116.0	39.6	142.0	4.6	10.0	171	<0.113	<0.015	101
	27-Jul-11	8.30	1,460	921	529	355	645	<5	91.2	31.0	204.0	5.0	10.0	261	<0.113	0.448	99
	25-Aug-11	8.18	1,300	792	459	272	560	<6	69.4	23.9	186.0	4.6	12.6	220	0.02	0.014	97
	04-Oct-11	8.05	1,290	845	462	268	563	<6	68.7	23.5	212.0	4.5	8.8	251	0.01	<0.005	100
	02-Nov-11	8.18	1,790	1,220	502	276	612	<6	68.8	25.4	318.0	4.6	7.6	493	<0.01	<0.005	95
	12-Jun-12	7.85	916	616	543	408	662	<6	99.6	38.6	81.7	4.4	1.9	64	<0.01	<0.005	97
	02-Oct-12	7.79	987	602	548	424	668	<6	102.0	40.8	67.8	4.9	2.2	55	<0.01	<0.005	95
MW11-20-53	24-Jun-11	8.20	1,320	854	514	356	627	<5	91.2	31.2	183.0	4.3	18.0	218	<0.113	<0.015	100
	26-Jul-11	8.30	1,280	791	506	307	618	<5	78.2	27.1	178.0	4.8	17.0	182	<0.113	<0.015	98
	25-Aug-11	8.05	1,310	801	502	318	612	<6	80.7	28.4	177.0	4.4	17.3	192	<0.01	0.112	98
	05-Oct-11	8.03	1,270	818	497	330	606	<6	79.5	31.9	183.0	4.6	17.1	203	0.06	0.221	100
	02-Nov-11	7.97	1,330	874	558	402	680	<6	101.0	36.4	172.0	4.8	18.2	207	<0.01	<0.005	98
	12-Jun-12	7.86	1,220	882	582	409	709	<6	104.0	36.2	169.0	4.2	17.2	202	<0.01	<0.005	96
	03-Oct-12	7.96	1,370	953	588	459	717	<6	116.0	40.8	188.0	4.5	17.2	233	<0.01	<0.005	102
MW11-21-54	24-Jun-11	8.30	1,370	890	556	406	679	<5	102.0	36.8	180.0	5.2	16.0	216	<0.113	<0.015	101
	26-Jul-11	8.20	1,360	870	564	400	688	<5	101.0	35.8	163.0	4.7	15.0	212	<0.113	<0.015	96
	25-Aug-11	7.97	1,430	875	568	419	693	<6	105.0	38.1	168.0	4.6	15.6	203	0.04	<0.005	99
	04-Oct-11	7.96	1,380	884	572	430	698	<6	108.0	38.9	169.0	4.3	14.3	207	<0.01	<0.005	99
	02-Nov-11	8.12	1,340	851	570	414	695	<6	103.0	37.9	151.0	3.9	13.5	199	<0.01	<0.005	94
	12-Jun-12	7.89	1,230	892	602	428	734	<6	107.0	38.8	163.0	4.1	14.7	203	0.04	<0.005	94
	03-Oct-12	7.88	1,380	954	593	471	723	<6	118.0	42.8	180.0	4.4	14.7	238	<0.01	<0.005	101
MW11-22-54	24-Jun-11	8.20	1,340	866	556	441	679	<5	113.0	38.5	161.0	3.8	15.0	201	<0.113	<0.015	102
	26-Jul-11	8.10	1,410	907	551	350	672	<5	91.7	29.3	196.0	4.5	15.0	240	<0.113	<0.015	96
	25-Aug-11	7.92	1,420	882	556	380	678	<6	99.0	32.2	185.0	4.3	14.9	213	<0.01	<0.005	99
	04-Oct-11	7.97	1,360	880	554	388	675	<6	100.0	33.3	183.0	4.3	14.0	213	0.01	<0.005	100
	02-Nov-11	8.00	1,330	876	558	386	680	<6	98.4	34.0	176.0	4.1	13.5	215	<0.01	<0.005	97
	12-Jun-12	7.91	1,250	864	574	382	700	<6	98.2	33.2	170.0	4.3	13.7	200	<0.01	<0.005	95
	03-Oct-12	7.87	1,370	909	583	428	711	<6	109.0	38.0	180.0	4.0	13.8	215	<0.01	<0.005	100
MW13-23-50	10-Jun-13	8.05	1,110	730	626	581	763	<5	149.0	50.6	59.8	6.1	1.8	87	<0.050	<0.050	100
	09-Oct-13	12.2	2,840	804	719	664	<5	295	266.0	<0.2	72.4	10.1	1.5	23	<0.05	<0.02	112
MW13-27-55	16-Jun-13	8.15	1,260	814	610	471	744	<5	118.0	42.5	137.0	6.5	1.5	142	<0.050	<0.050	102
	08-Oct-13	8.04	1,290	857	676	457	824	<6	114.0	42.1	142.0	6.5	1.6	146	<0.01	<0.005	93
Bonnyville Formation																	
MW11-20-74	24-Jun-11	8.20	1,520	962	559	293	682	<5	73.5	26.5	258.0	5.0	57.0	206	<0.113	<0.015	101
	26-Jul-11	8.30	1,510	937	561	241	672	<5	60.9	21.6	249.0	5.2	55.0	208	<0.113	<0.015	94
	25-Aug-11	8.03	1,570	937	564	265	687	<6	66.4	24.0	255.0	5.1	56.3	192	0.02	0.247	98
	04-Oct-11	8.11	1,510	949	568	271	692	<6	68.0	24.5	260.0	5.0	51.9	199	0.26	0.226	99
	02-Nov-11	8.10	1,510	965	582	286	710	<6	71.8	26.0	250.0	5.4	55.8	206	<0.01	<0.005	96
	12-Jun-12	7.93	728	522	302	164	368	<6	41.8	14.6	143.0	3.4	26.5	111	0.23	0.048	105
	03-Oct-12	7.86	1,540	1,040	599	336	731	<6	84.6	30.2	281.0	5.3	56.3	227	<0.01	<0.005	104
MW13-19-82	10-Jun-13	8.24	1,370	879	546	337	666	<5	86.9	29.2	212.0	5.3	29.0	189	<0.050	<0.050	103
	08-Oct-13	8.08	1,390	904	596	321	726	<6	82.0	28.3	210.0	4.6	28.6	193	<0.01	<0.005	94
Muriel Lake Formation																	
MW13-27-90	16-Jun-13	8.21	2,890	1,850	617	300	753	<5.0	72.7	28.8	590.0	4.4	214.0	573	<0.50	<0.50	105
	08-Oct-13	8.23	2,870	1,920	667	279	813	<6	69.5	25.5	594.0	4.6	233.0	594	<0.05	<0.02	98
Lea Park Formation																	
MW13-19-96	10-Jun-13	11.2	1,960	959	552	-	<5	271	5.6	4.3	367.0	24.5	219.0	7	<0.050	<0.050	99
	17-Oct-13	11.5	2,120	898	487	73	<5	174	23.1	3.7	345.0	21.5	198.0	14	<0.05	<0.02	109
MW13-23-81	10-Jun-13	12.5	11,400	3,150	2,690	-	<5	78.70	438.0	2.5	705.0	256.0	95.7	43	<0.50	<0.50	103
	16-Oct-13	12.4	6,640	1,920	1,500	1,010	<5	66.0	406.0	<1	346.0	70.3	144.0	54	<0.1	<0.05	106
MW13-24-94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW13-25-29	10-Jun-13	8.35	1,480	991	352	109	424	<5	24.8	11.5	330.0	13.4	42.5	348	1.96	-	109
	11-Oct-13	8.27	1,930	1,320	774	413	944	<6	108.0	34.9	351.0	8.1	93.7	264	0.06	<0.005	101

Table 5: Groundwater Chemistry – Dissolved Metals Parameters

Well ID	Sampling Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silicon	Silver	Strontium	Sulphur	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Grand Centre Formation																														
P10-12A	05-Oct-11	0.00	0.000	0.0007	0.108	<0.0001	<0.0005	0.087	0.00006	0.0028	0.0002	0.001	-	<0.0001	0.110	-	<0.0001	0.002	0.0013	0.0012	10.40	<0.00001	0.492	26.0	<0.00005	<0.001	0.0015	0.0266	0.0076	0.001
	12-Jun-12	1.10	<0.0002	0.0013	0.200	0.0004	<0.0005	0.048	0.00016	0.0034	0.0030	0.007	1.20	0.0063	0.082	0.430	<0.0001	0.001	0.0054	0.0073	10.70	0.00002	0.489	20.4	<0.00005	<0.001	0.0103	0.0184	0.0083	0.014
	02-Oct-12	<0.002	<0.0002	0.0005	0.125	<0.0001	<0.0005	0.088	0.00001	0.0019	<0.0001	0.002	<0.01	<0.0001	0.132	<0.005	<0.0001	0.002	<0.0005	0.0029	10.40	<0.00001	0.510	23.8	<0.00005	<0.001	0.0007	0.0240	0.0053	0.001
Sand River Formation																														
P02-1	05-Oct-11	0.00	<0.0002	0.0004	0.217	<0.0001	<0.0005	0.063	0.00002	0.0022	<0.0001	<0.001	-	<0.0001	0.060	-	<0.0001	<0.001	<0.0005	0.0010	-	<0.00001	0.456	12.4	<0.00005	<0.001	0.0010	0.0066	0.0060	<0.001
	12-Jun-12	0.14	<0.0002	0.0006	0.252	<0.0001	<0.0005	0.062	0.00007	0.0035	0.0006	0.004	0.26	0.0004	0.064	0.050	<0.0001	<0.001	0.0017	0.0018	10.00	0.00001	0.510	13.6	<0.00005	<0.001	0.0068	0.0071	0.0064	0.001
	02-Oct-12	<0.002	<0.0002	0.0003	0.270	<0.0001	<0.0005	0.060	0.00004	0.0019	<0.0001	0.002	<0.01	<0.0001	0.073	<0.005	<0.0001	<0.001	<0.0005	0.0013	11.10	<0.00001	0.542	11.1	<0.00005	<0.001	<0.0005	0.0067	0.0050	0.002
P02-4	05-Oct-11	<0.002	<0.0002	0.0004	0.423	<0.0001	<0.0005	0.043	0.00001	0.0035	<0.0001	<0.001	-	<0.0001	0.052	-	<0.0001	<0.001	<0.0005	0.0012	-	<0.00001	0.444	2.8	<0.00005	<0.001	<0.0005	0.0085	0.0069	<0.001
	12-Jun-12	0.06	<0.0002	0.0005	0.403	<0.0001	<0.0005	0.051	0.00003	0.0020	0.0003	0.004	0.20	<0.0001	0.062	0.025	<0.0001	<0.001	0.0010	0.0011	9.24	<0.00001	0.456	2.2	<0.00005	<0.001	0.0038	0.0074	0.0054	0.006
	02-Oct-12	<0.002	<0.0002	0.0004	0.423	<0.0001	<0.0005	0.046	0.00003	0.0019	<0.0001	0.002	<0.01	<0.0001	0.063	0.038	<0.0001	<0.001	<0.0005	0.0013	9.95	<0.00001	0.466	2.3	<0.00005	<0.001	<0.0005	0.0088	0.0038	0.001
P02-6	12-Jun-12	<0.002	<0.0002	0.0004	0.280	<0.0001	<0.0005	0.040	0.00002	0.0012	<0.0001	0.003	<0.01	<0.0001	0.061	<0.005	<0.0001	<0.001	<0.0005	0.0006	10.30	<0.00001	0.344	14.5	<0.00005	<0.001	<0.0005	0.0034	0.0042	0.003
	01-Oct-12	0.00	<0.0002	0.0003	0.334	<0.0001	<0.0005	0.046	0.00001	0.0016	<0.0001	0.002	0.01	<0.0001	0.059	<0.005	<0.0001	0.001	<0.0005	<0.0002	12.00	<0.00001	0.344	7.3	<0.00005	<0.001	<0.0005	0.0039	0.0040	0.001
P02-7	05-Oct-11	0.00	<0.0002	<0.0002	0.016	<0.0001	<0.0005	0.035	<0.00001	<0.0005	0.0001	<0.001	-	<0.0001	0.028	-	<0.0001	<0.001	0.0007	<0.0002	-	<0.00001	0.164	5.0	<0.00005	<0.001	0.0007	0.0028	0.0006	0.002
	12-Jun-12	0.01	<0.0004	<0.0004	0.376	<0.0002	<0.001	0.059	0.00033	<0.001	0.0007	0.006	<0.02	0.0010	0.040	0.041	<0.0001	<0.002	0.0094	<0.0004	10.10	0.00003	0.390	5.4	<0.0001	0.002	<0.001	0.0040	0.0020	0.009
	01-Oct-12	0.00	<0.0004	<0.0004	0.551	<0.0002	<0.001	0.060	0.00043	0.0100	0.0008	0.006	0.03	0.0002	0.041	<0.01	<0.0001	<0.002	0.0170	<0.0004	9.92	<0.00002	0.524	5.9	<0.0001	<0.002	<0.001	0.0038	0.0025	0.004
P02-8	05-Oct-11	<0.002	<0.0002	0.0007	0.240	<0.0001	<0.0005	0.075	0.00010	0.0014	<0.0001	<0.001	-	<0.0001	0.073	-	<0.0001	0.001	<0.0005	<0.0002	10.90	<0.00001	0.692	6.4	<0.00005	<0.001	0.0008	0.0106	0.0059	0.001
	12-Jun-12	0.08	<0.0002	0.0007	0.253	<0.0001	<0.0005	0.081	0.00003	<0.0005	<0.0001	0.004	0.09	<0.0001	0.074	0.007	<0.0001	<0.001	<0.0005	<0.0002	11.10	<0.00001	0.711	5.6	<0.00005	<0.001	0.0044	0.0099	0.0046	0.006
	02-Oct-12	<0.002	<0.0002	0.0005	0.250	<0.0001	<0.0005	0.079	0.00002	<0.0005	<0.0001	0.001	<0.01	<0.0001	0.078	<0.005	<0.0001	<0.001	<0.0005	<0.0002	11.30	<0.00001	0.710	5.7	<0.00005	<0.001	<0.0005	0.0111	0.0032	0.002
P05-9A	05-Oct-11	<0.002	<0.0002	0.0005	0.270	<0.0001	<0.0005	0.066	0.00003	0.0014	<0.0001	<0.001	-	<0.0001	0.080	-	<0.0001	0.001	<0.0005	0.0018	10.50	<0.00001	0.581	11.1	<0.00005	<0.001	0.0009	0.0105	0.0054	<0.001
P10-11A	05-Oct-11	0.00	<0.0002	0.0003	0.237	<0.0001	<0.0005	0.079	0.00004	0.0024	<0.0001	<0.001	-	<0.0001	0.061	-	<0.0001	0.002	<0.0005	0.0007	10.20	<0.00001	0.500	12.1	<0.00005	<0.001	0.0010	0.0066	0.0062	<0.001
	12-Jun-12	0.05	<0.0002	0.0003	0.199	<0.0001	<0.0005	0.084	0.00004	0.0015	0.0001	0.003	0.06	<0.0001	0.059	<0.005	<0.0001	0.001	0.0022	0.0009	9.30	<0.00001	0.479	15.7	<0.00005	<0.001	0.0029	0.0058	0.0042	0.005
	03-Oct-12	<0.002	<0.0002	0.0004	0.185	<0.0001	<0.0005	0.096	0.00004	0.0013	<0.0001	0.002	<0.01	<0.0001	0.068	<0.005	<0.0001	0.001	<0.0005	0.0009	10.60	<0.00001	0.448	10.3	<0.00005	<0.001	<0.0005	0.0053	0.0032	0.002
P10-13A	05-Oct-11	0.03	0.002	0.0088	0.130	<0.0005	<0.002	2.040	0.00010	0.0300	0.0007	0.010	-	<0.0005	0.628	-	<0.0001	0.040	<0.002	0.0072	4.70	<0.00005	1.860	150.0	<0.0002	<0.005	0.0360	0.0220	0.0420	0.050
	12-Jun-12	<0.002	<0.0002	0.0008	0.282	<0.0001	<0.0005	0.072	0.00005	0.0019	<0.0001	0.002	-	<0.0001	0.043	0.027	<0.0001	<0.001	<0.0005	0.0003	9.04	0.00002	0.321	5.8	<0.00005	<0.001	<0.0005	0.0048	0.0045	0.003
	01-Oct-12	<0.002	<0.0002	0.0005	0.291	<0.0001	<0.0005	0.076	0.00002	0.0013	<0.0001	0.001	0.01	<0.0001	0.051	<0.005	<0.0001	<0.001	<0.0005	<0.0002	9.53	<0.00001	0.328	5.4	<0.00005	<0.001	<0.0005	0.0047	0.0040	0.001
P10-14A	05-Oct-11	<0.002	<0.0002	0.0008	0.328	<0.0001	<0.0005	0.033	0.00003	0.0025	<0.0001	0.001	-	<0.0001	0.024	-	<0.0001	<0.001	<0.0005	<0.0002	10.40	<0.00001	0.202	-	<0.00005	<0.001	0.0006	0.0017	0.0069	0.001
	12-Jun-12	4.14	<0.0002	0.0024	0.700	0.0014	<0.0005	0.031	0.00114	0.0071	0.0133	0.024	2.93	0.0084	0.019	1.060	<0.0001	<0.001	0.0289	0.0004	11.80	0.00008	0.189	12.7	<0.00005	<0.001	0.0144	0.0042	0.0167	0.033
	02-Oct-12	0.00	<0.0002	0.0006	0.338	<0.0001	<0.0005	0.030	0.00030	0.0010	<0.0001	0.002	<0.01	<0.0001	0.021	<0.005	<0.0001	<0.001	<0.0005	<0.0002	9.80	<0.00001	0.141	10.5	<0.00005	<0.001	0.0005	0.0012	0.0042	0.002
P10-15A	05-Oct-11	<0.002	<0.0002	0.0008	0.354	<0.0001	<0.0005	0.100	0.00006	0.0023	0.0008	<0.001	-	<0.0001	0.067	-	<0.0001	0.004	0.0030	<0.0002	-	<0.00001	0.490	6.0	<0.00005	<0.001	<0.0005	0.0050	0.0056	<0.001
	12-Jun-12	1.96	<0.0002	0.0101	0.910	0.0005	<0.0005	0.089	0.00040	0.0050	0.0057	0.008	18.00	0.0027	0.055	2.530	<0.0001	<0.001	0.0154	<0.0002	15.70	0.00004	0.486	5.7	<0.00005	<0.001	0.0125	0.0069	0.0068	0.022
	02-Oct-12	<0.002	<0.0002	0.0014	0.294	<0.0001	<0.0005	0.095	0.00003	0.0008	0.0009	<0.001	<0.01	<0.0001	0.065	1.180	<0.0001	0.004	0.0018	<0.0002	11.20	<0.00001	0.497	6.1	<0.00005	<0.001	<0.0005	0.0041	0.0025	<0.001
P10-16A	05-Oct-11	0.01	<0.0004	0.0038	1.600	<0.0002	<0.001	0.091	0.00020	0.0030	0.0428	<0.002	-	<0.0002	0.046	-	<0.0001	0.009	0.0404	<0.0004	12.30	<0.00002	0.545	5.9	<0.0001	<0.002	0.0020	0.0037	0.0037	0.003
	12-Jun-12	0.02	<0.0002	0.0076	1.160	<0.0001	<0.0005	0.065	0.00016	<0.0005	0.0371	0.002	16.40	<0.0001	0.040	3.520	<0.0001	0.007	0.0381	<0.0002	14.20	<0.00001	0.457	9.0	0.00006	<0.001	0.0010	0.0044	0.0075	0.006
	02-Oct-12	<0.002	<0.0002	0.0022	1.230	<0.0001	<0.0005	0.097	0.00006	0.0020	0.0277	<0.001	4.12	<0.0001	0.048	2.790	<0.0001	0.008	0.0348	<0.0002	14.80	<0.00001	0.452	10.4	0.00005	<0.001	0.0008	0.0041	0.0061	0.003
P10-17A	05-Oct-11	<0.002	<0.0002	0.0012	0.216	<0.0001	<0.0005	0.060	0.00005	0.0013	<0.0001	0.001	-	<0.0001	0.001	-	<0.0001	0.001	0.0008	<0.0002	9.89	<0.00001	0.496	13.7	<0.00005	<0.001	0.0010	0.0086	0.0055	<0.001
	12-Jun-12	0.02	<0.0002	0.0016	0.217	<0.0001	<0.0005	0.068	0.00004	0.0025	0.0002	0.004	0.02	<0.0001	0.069	0.025	<0.0001	0.001	0.0037	0.0027	10.10	<0.000001	0.565	10.2	<0.00005	<0.001	0.0018	0.0078	0.0095	0.006
	02-Oct-12	<0.002	<0.0002	0.0004	0.216	<0.0001	<0.0005	0.069	0.00003	0.0006	<0.0001	0.002	<0.01	<0.0001	0.066	<0.005	<0.0001	0.001	0.0005	0.0016	10.20	<0.00001	0.527	11.3	<0.00005	<0.001	<0.0005	0.0079	0.0030	0.002
P10-18A	05-Oct-11	<0.002	<0.0002	0.0010	0.212	<0.0001	<0.0005	0.038	<0.00001	0.0010	0.0002	<0.001	-	<0.0001	0.059	-	<0.0001	0.003	0.0007	0.0023	10.10	<0.00001	0.472	23.1	<0.00005	<0.001	0.0013	0.0084	0.0029	<0.001
	12-Jun-12	0.71	<0.0002	0.0084	0.290	0.0001	<0.0005	0.046	0.00011	0.0035	0.0041	0.006	4.60	0.0005	0.057	0.517	<0.0001	<0.001	0.0096	0.0007	10.90	0.00002	0.378	5.2	<0.00005	<0.001	0.0181	0.0056	0.0047	0.010
	02-Oct-12	<0.002	<0.0002	0.0010	0.167	<0.0001	<0.0005	0.058	<0.00001	0.0008	0.0002	0.002	<0.01	<0.0001	0.063	<0.005	<0.0001	0.003	<0.0005	0.0008	9.98	<0.00001	0.369	9.6	<0.00005	<0.001	<0.0005	0.0057	0.0019	0.001
MW11-19-12	23-Jun-11	0.02	<0.001	0.0090	0.014	<0.001	-	0.100	0.00004	<0.001	<0.001	<0.002	0.20	<0.001	0.064	0.241	-	<0.003	<0.003	<0.001	9.80	<0.0001	0.516	-	<0.0001	<0.0001	<0.001	0.0070	<0.001	0.005
	27-Jul-11	<0.002	<0.001	0.0090	0.130	<0.001	-	0.090	0.00003	<0.001	<0.001	<0.002	0.50	<0.001	0.057	0.266	-	0.003	0.0030	<0.001	9.81	<0.0001	0.475	-	<0.0001	0.000	<0.001	0.0070	<0.001	0.005
	25-Aug-11	<0.002	<0.0002	0.0136	0.137	-	-	0.098	<0.00001	0.0012	-	<0.001	-	<0.0001	-	-	<0.0001	-	<0.0005	<0.0002	-	<0.00001	-	-	-	-	-	0.0068	-	0.002
	4-Oct-11	<0.002	<0.0002	0.0102	0.129	<0.0001	<0.0005	0.106	0.00001	0.0019	0.0005	<0.001	-	<0.0001	0.072	-	<0.0001	0.004	<0.0005	<0.0002	10.30	<0.00001	0.491	5.0	<0.00005	<0.001	<0.0005	0.0064	0.0062	0.002
	2-Nov-11	0.00	<0.0002	0.0150	0.138	<0.0001	<0.0005	0.097	0.00001	0.0008	0.0006	0.002	-	<0.0001	0.063	-	<0.0001	0.004	0.0010	0.0003	-	<0.00001	0.485	5.0	<0.00005	<0.001	0.0006	0.0061	0.0019	0.006
	12-Jun-12	0.00	<0.0002	0.0176	0.128	<0.0001	<0.0005	0.108	0.00001	0.0013	0.0003	0.003	1.97	<0.0001	0.069	0.172	<0.0001	0.004	0.0014	<0.0002	10.30	<0.00001	0.491	5.0	<0.00005	<0.001	<0.0005	0.0065	0.0038	0.005
	2-Oct-12	<0.002	<0.0002	0.0102	0.125	<0.0001	<0.0005	0.105	<0.00001	0.0011	0.0002	<0.001	<0.01	<0.0001	0.071	0.167	<0.0001	0.004	<0.0005	<0.0002	11.00	<0.00001	0.506	5.3	<0.00005	<0.001	<0.0005	0.0061	0.0029	0.003
MW11-19-24	23-Jun-11	0.10	<0.001	0.0140	0.070	<0.001	-	0.260	0.00006	0.0610	<0.001	0.003	0.50	<0.001	0.069	0.204	-	0.010	0.0600	<0.001	7.78	<0.0001	0.601	-	<0.0001	<0.0001	0.0030	0.0070	<0.001	0.013
	27-Jul-11	<0.002	<0.001	0.0060	0.100	<0.001	-	0.250	0.00004	<0.001	<0.001	0.003	<0.1	<0.001	0.065	0.174	-	0.009	0.0040	<0.001	7.78	<0.0001	0.593	-	<0.0001	0.000	<0.001	0.0080	<0.001	<0.003
	25-Aug-11	0.03	0.000	0.0156	0.099	-	-	0.258	0.00001	0.0012	-	0.001	-	0.0001	-	-	<0.0001	-	<0.0005	<0.0002	-	<0.00001	-	-	-	-	-	0.0076	-	0.007
	04-Oct-11	<0.002	<0.0002	0.0089	0.096	<0.0001	<0.0005	0.284	0.00001	0.0021	0.0003	<0.001	-	<0.0001	0.079	-	<0.0001	0.010	<0.0005	<0.0002	8.37	<0.00001	0.636	30.6	<0.00005	<0.001	0.0016	0.0070	0.0067	0.008
	02-Nov-11	0.00	<0.0002	0.0142	0.096	<0.0001	<0.0005	0.281	0.00002	0.0008	0.0004	0.004	-	<0.0001	0.074	-	<0.0001	0.010	0.0012	0.0004	8.58	<0.00001	0.687	31.7	<0.00005	<0.001	0.0038	0.0072	0.0016	0.008
	12-Jun-12	0.16	<0.0002	0.0216	0.106	<0.0001	<0.0005	0.322	0.00003	0.0018	0.0006	0.004	0.69	0.0003	0.083	0.250	<0.0001	0.010	0.0016	<0.0002	8.66	<0.00001	0.724	28.2	<0.00005	<0.001	0.0084	0.0074	0.0053	0.008
	02-Oct-12	<0.002	<0.0002	0.0135	0.093	<0.0001	<0.0005	0.328	<0.00001	0.0005	0.0003	<0.001	<0.01	<0.0001	0.089	0.257	<0.0001	0.011	<0.0005	<0.0002	9.27	<0.00001	0.758	30.4	<0.00005	<0.001	0.0008	0.0068	0.0020	0.002
MW11-20-7	23-Jun-11	0.02	0.023	<0.001	0.170	<0.001	-	0.040	0.00067	<0.001	<0.001	0.004	<0.1	<0.001	0.029	0.388	-	0.003	0.0050	0.0020	8.46	<0.0001	0.304	-	<0.0001	0.000	<0.001	0.0060	<0.001	0.019
	26-Jul-11	<0.002	<0.001	<0.001	0.180	<0.001	-	0.030	0.00004	<0.001	<0.001	<0.002	<0.1	<0.001	0.022	0.441	-	<0.003	0.0050	<0.001	8.32	<0.0001	0.252	-	<0.0001	0.000	<0.001	0.0060	<0.001	0.004
	25-Aug-11	0.00	<0.0002	0.0006	0.206	-	-	0.040	0.00003	0.0009	-	0.001	-	<0.0001	-	-	<0.0001	-	0.0022	0.0008	-	0.00001	-	-	-	-	-	0.0005	-	0.001
	04-Oct-11	<0.002	<0.0002	0.0006	0.180	<0.0001	<0.0005	0.053	0.00004	0.0011	0.0002	<0.001	-	<0.0001	0.034	-	<0.0001	0.003	<0.0005	0.0003	9.15	<0.00001	0.289	21.9	<0.00005	<0.001	0.0012	0.0072	0.0041	0.001
	02-Nov-11	0.03	<0.0002	0.0012	0.208	<0.0001	<0.0005	0.050	0.00003	0.0015	0.0004	0.002	-	<0.0001	0.030	-	<0.0001	0.002	0.0014	0.0016	9.68	<0.00001	0.281	-	<0.00005	<0.001	0.0043	0.0069	0.0015	0.002
	12-Jun-12	<0.002	<0.0002	0.0006	0.157	<0.0001	<0.0005	0.052	0.00002	0.0007	0.0001	0.002	<0.01	<0.0001	0.034	0.246	<0.0001	0.002	0.0012	0.0006	8.16	<0.00001	0.252	17.6	<0.00005	<0.001	0.0005	0.0063	0.0027	0.005
	03-Oct-12	<0.002	<0.0002	0.0005	0.177	<0.0001	<0.0005	0.057	0.00003	<0.0005	0.0001	<0.001	<0.01	<0.0001	0.033	0.399	<0.0001	0.002	<0.0005	0.0005	9.87	<0.00001	0.271	20.1	<0.00005	<0.001	0.0005	0.0060	0.0008	<0.001

Table 5: Groundwater Chemistry – Dissolved Metals Parameters

Well ID	Sampling Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silicon	Silver	Strontium	Sulphur	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
MW11-21-11	24-Jun-11	0.13	<0.001	0.0170	<0.05	<0.001	-	0.160	0.00005	0.0110	0.0010	0.003	0.90	<0.001	0.082	0.315	-	0.007	0.0140	<0.001	9.78	<0.0001	0.548	-	<0.0001	<0.0001	0.0030	0.0140	0.0010	0.013
	26-Jul-11	0.10	<0.001	0.0190	0.070	<0.001	-	0.150	0.00024	0.0050	0.0020	0.003	1.50	<0.001	0.079	0.005	-	0.005	0.0080	<0.001	9.46	<0.0001	0.528	-	0.00030	0.000	0.0050	0.0140	0.0020	0.014
	25-Aug-11	0.11	<0.0002	0.0248	0.081	-	-	0.168	0.00002	0.0015	-	0.002	-	0.0002	-	-	<0.0001	-	<0.0005	0.0012	-	<0.00001	-	-	-	-	-	0.0149	-	0.006
	04-Oct-11	0.00	<0.0002	0.0162	0.078	<0.0001	<0.0005	0.192	0.00002	0.0021	0.0005	<0.001	-	<0.0001	0.104	-	<0.0001	0.006	<0.0005	<0.0002	9.57	<0.00001	0.564	18.0	<0.00005	<0.001	0.0012	0.0152	0.0068	0.002
	02-Nov-11	0.01	<0.0002	0.0217	0.082	<0.0001	<0.0005	0.169	<0.00001	0.0010	0.0006	0.002	-	0.0002	0.094	-	<0.0001	0.006	0.0011	<0.0002	9.14	<0.00001	0.561	17.8	<0.00005	<0.001	0.0028	0.0138	0.0010	0.006
	12-Jun-12	0.01	<0.0002	0.0224	0.082	<0.0001	<0.0005	0.164	0.00001	0.0012	0.0006	0.002	1.36	<0.0001	0.086	0.301	<0.0001	0.006	0.0016	<0.0002	9.12	<0.00001	0.572	19.8	<0.00005	<0.001	0.0009	0.0146	0.0035	0.007
	03-Oct-12	0.00	<0.0002	0.0135	0.082	<0.0001	<0.0005	0.182	<0.00001	0.0009	0.0006	<0.001	0.02	<0.0001	0.099	0.302	<0.0001	0.006	<0.0005	<0.0002	10.40	<0.00001	0.579	22.4	<0.00005	<0.001	0.0008	0.0149	0.0025	0.001
MW11-22-9	23-Jun-11	0.01	<0.001	0.0070	<0.05	<0.001	-	0.160	0.00007	<0.001	0.0010	0.003	<0.1	<0.001	0.084	0.469	-	0.012	0.0040	<0.001	7.58	<0.0001	0.545	-	<0.0001	0.000	<0.0001	0.0100	0.0010	0.014
	26-Jul-11	0.01	<0.001	0.0110	0.120	<0.001	-	0.190	0.00003	<0.001	<0.001	<0.002	<0.1	<0.001	0.074	0.305	-	0.011	0.0050	<0.001	7.83	<0.0001	0.565	-	<0.0001	0.000	<0.001	0.0090	0.0010	<0.003
	25-Aug-11	<0.002	<0.0002	0.0193	0.132	-	-	0.190	0.00002	0.0031	-	0.001	-	<0.0001	-	-	<0.0001	-	0.0013	0.0006	-	<0.00001	-	-	-	-	-	0.0068	-	0.001
	04-Oct-11	<0.0001	0.003	0.0002	0.005	0.1460	<0.0005	0.225	0.00003	0.0017	0.0005	<0.001	-	<0.0001	0.096	-	<0.0001	0.014	<0.0005	<0.0002	7.36	<0.00001	0.602	7.8	<0.00005	<0.001	0.0010	0.0079	0.0060	<0.001
	02-Nov-11	0.17	<0.0002	0.0342	0.133	<0.0001	<0.0005	0.185	0.00004	0.0011	0.0012	0.003	-	0.0003	0.081	-	<0.0001	0.010	0.0032	0.0002	9.57	<0.00001	<0.00005	7.4	<0.00005	<0.001	0.0097	0.0055	0.0018	0.008
	12-Jun-12	0.01	<0.0002	0.0285	0.130	<0.0001	<0.0005	0.184	0.00002	0.0008	0.0006	0.003	0.02	<0.0001	0.080	0.434	<0.0001	0.011	0.0020	<0.0002	8.43	<0.00001	0.599	7.1	<0.00005	<0.001	0.0006	0.0052	0.0035	0.005
	03-Oct-12	<0.0001	<0.002	0.0145	0.145	<0.0001	<0.0005	0.213	0.00002	0.0007	0.0008	0.001	<0.01	<0.0001	0.089	0.510	<0.0001	0.012	<0.0005	0.0004	9.06	<0.00001	0.641	8.0	<0.00005	<0.001	<0.0005	0.0056	0.0034	0.001
MW12-23-14	12-Jun-12	0.01	<0.0002	0.0008	0.221	<0.0001	<0.0005	0.045	0.00008	<0.0005	0.0004	0.002	<0.01	<0.0001	0.062	0.084	<0.0001	0.002	0.0038	0.0005	9.76	<0.00001	0.579	70.9	<0.00005	<0.001	0.0012	0.0086	0.0031	0.005
	02-Oct-12	0.00	<0.0002	0.0004	0.198	<0.0001	<0.0005	0.063	0.00005	0.0011	<0.0001	0.003	<0.01	<0.0001	0.080	0.015	<0.0001	0.002	0.0056	0.0017	11.00	<0.00001	0.533	28.3	<0.00005	<0.001	0.0007	0.0091	0.0034	0.003
MW12-24-8	12-Jun-12	0.08	<0.0002	0.0020	0.204	<0.0001	<0.0005	0.078	0.00004	0.0020	0.0012	0.001	0.14	<0.0001	0.058	0.851	<0.0001	0.002	0.0031	<0.0002	9.59	<0.00001	0.459	5.5	<0.00005	<0.001	0.0046	0.0073	0.0053	0.002
	02-Oct-12	<0.002	<0.0002	0.0011	0.325	<0.0001	<0.0005	0.088	0.00022	<0.0005	0.0007	0.002	<0.01	<0.0001	0.070	1.500	<0.0001	0.002	0.0151	<0.0002	11.30	<0.00001	0.714	6.1	<0.00005	<0.001	0.0005	0.0082	0.0046	0.003
MW12-25-8	12-Jun-12	0.62	<0.0002	0.0007	0.284	<0.0001	<0.0005	0.109	0.00022	0.0033	0.0036	0.006	0.76	0.0032	0.053	0.188	<0.0001	<0.001	0.0103	<0.0002	10.30	0.00002	0.366	4.5	<0.00005	<0.001	0.0131	0.0048	0.0071	0.013
	02-Oct-12	<0.002	<0.0002	0.0004	0.238	<0.0001	<0.0005	0.122	0.00007	0.0011	<0.0001	0.002	<0.01	<0.0001	0.050	0.007	<0.0001	0.001	0.0010	0.0002	10.40	<0.00001	0.362	4.8	<0.00005	<0.001	<0.0005	0.0044	0.0037	0.002
MW12-26-8	12-Jun-12	0.39	<0.0002	0.0004	0.218	<0.0001	<0.0005	0.085	0.00006	0.0010	0.0023	0.005	1.78	0.0017	0.058	0.632	<0.0001	<0.001	0.0042	<0.0002	11.10	0.00002	0.447	5.4	<0.00005	<0.001	0.0134	0.0043	0.0021	0.009
	02-Oct-12	<0.002	<0.0002	<0.0002	0.176	<0.0001	<0.0005	0.094	<0.00001	0.0013	<0.0001	0.001	<0.01	<0.0001	0.058	0.023	<0.0001	<0.001	<0.0005	<0.0002	11.00	<0.00001	0.461	5.6	<0.00005	<0.001	<0.0005	0.0045	0.0038	0.001
MW13-27-23	16-Jun-13	<0.0050	0.000	0.0281	0.239	-	-	0.084	<0.00010	<0.0050	-	<0.0010	1.55	<0.00010	-	0.151	<0.00010	-	0.0030	<0.00040	-	<0.00010	-	-	-	-	-	0.0057	-	0.004
	09-Oct-13	0.00	0.000	0.0053	0.222	<0.0001	<0.0005	0.089	<0.00001	<0.0005	0.0005	<0.001	6.21	<0.0001	0.052	-	<0.0001	0.016	0.0013	<0.0002	8.73	<0.00001	0.713	4.8	<0.00005	<0.001	<0.0005	0.0016	0.0002	0.006
Marie Creek Formation																														
P02-5	05-Oct-11	<0.002	<0.0002	0.0023	0.151	<0.0001	0.0006	0.084	0.00001	<0.0005	0.0007	<0.001	-	<0.0001	0.088	-	<0.0001	0.003	<0.0005	<0.0002	-	<0.00001	0.749	4.6	<0.0005	<0.001	0.0006	0.0060	0.0063	<0.001
	12-Jun-12	<0.002	<0.0002	0.0067	0.147	<0.0001	<0.0005	0.088	0.00002	0.0006	0.0004	0.003	0.29	<0.0001	0.096	0.098	<0.0001	0.002	0.0015	0.0004	9.05	0.00008	0.624	6.0	<0.00005	<0.001	<0.0005	0.0070	0.0047	0.005
	11-Oct-12	<0.002	<0.0002	0.0031	0.142	<0.0001	<0.0005	0.094	<0.00001	0.0019	0.0002	0.003	<0.01	<0.0001	0.078	0.077	<0.0001	0.002	<0.0005	0.0003	9.84	<0.00001	0.540	6.5	<0.00005	<0.001	<0.0005	0.0064	0.0050	0.003
Ethel Lake Formation																														
MW11-19-67	24-Jun-11	0.00	<0.001	0.0140	<0.05	<0.001	-	0.240	0.00005	<0.001	<0.001	0.006	<0.1	<0.001	0.054	0.219	-	0.009	0.0030	0.0010	8.97	<0.0001	0.626	-	<0.0001	0.001	<0.0001	0.0040	0.0010	0.032
	27-Jul-11	<0.002	0.001	0.0070	<0.05	<0.001	-	0.190	0.00006	<0.001	<0.001	0.003	<0.1	<0.001	0.058	0.252	-	0.022	0.0040	0.0040	6.16	<0.0001	0.560	-	<0.0001	0.001	<0.001	0.0080	<0.001	0.011
	25-Aug-11	0.06	0.001	0.0079	0.029	-	-	0.166	<0.00001	0.0012	-	0.001	-	<0.0001	-	-	<0.0001	-	0.0017	<0.0002	-	<0.00001	-	-	-	-	-	0.0062	-	0.007
	04-Oct-11	0.00	0.000	0.0059	0.019	<0.0001	<0.0005	0.182	<0.00001	0.0011	0.0006	<0.001	-	<0.0001	0.067	-	<0.0001	0.027	0.0006	<0.0002	4.87	<0.00001	0.420	83.6	<0.00005	<0.001	0.0045	0.0047	0.0033	0.008
	02-Nov-11	0.01	<0.0002	0.0076	0.024	<0.0001	<0.0005	0.186	0.00001	0.0016	0.0008	0.005	-	<0.0001	0.091	-	<0.0001	0.016	0.0025	0.0005	5.75	<0.00001	0.656	164.0	<0.00005	<0.001	0.0170	0.0039	0.0016	0.004
	12-Jun-12	0.01	<0.0002	0.0126	0.053	<0.0001	<0.0005	0.167	0.00002	0.0019	0.0005	0.002	3.77	<0.0001	0.075	0.632	<0.0001	0.008	0.0021	<0.0002	6.75	<0.00001	0.643	21.2	<0.00005	<0.001	0.0008	0.0048	0.0037	0.004
	02-Oct-12	<0.002	<0.0002	0.0052	0.063	<0.0001	<0.0005	0.160	<0.00001	0.0009	0.0004	<0.001	<0.01	<0.0001	0.076	0.567	<0.0001	0.007	<0.0005	<0.0002	6.61	<0.00001	0.668	18.4	<0.00005	<0.001	0.0005	0.0046	0.0027	0.001
MW11-20-53	24-Jun-11	0.01	<0.001	0.0010	0.050	<0.001	-	0.250	0.00008	0.0100	0.0020	0.006	<0.1	<0.001	0.057	1.250	-	0.007	0.0140	0.0010	8.00	<0.0001	0.452	-	<0.0001	0.001	<0.001	0.0100	<0.001	0.013
	26-Jul-11	0.01	0.001	0.0010	0.050	<0.001	-	0.220	<0.000017	<0.001	0.0020	<0.002	<0.1	<0.001	0.056	1.180	-	0.005	0.0050	<0.001	6.90	<0.0001	0.434	-	<0.0001	0.001	<0.001	0.0100	<0.001	0.006
	25-Aug-11	0.00	0.000	0.0012	0.057	-	-	0.245	<0.00001	0.0011	-	0.002	-	0.0004	-	-	<0.0001	-	0.0025	<0.0002	-	<0.00001	-	-	-	-	-	0.0101	-	0.008
	04-Oct-11	0.00	0.001	0.0011	0.053	<0.0001	<0.0005	0.249	0.00010	0.0016	0.0007	0.018	-	<0.0001	0.063	-	<0.0001	0.005	0.0019	<0.0002	7.45	<0.00001	0.445	67.7	<0.00005	<0.001	0.0032	0.0094	0.0055	0.035
	02-Nov-11	0.00	<0.0002	0.0011	0.058	<0.0001	<0.0005	0.258	0.00001	0.0024	0.0020	0.004	-	<0.0001	0.060	-	<0.0001	0.003	0.0046	0.0008	8.48	<0.00001	0.504	69.1	<0.00005	<0.001	0.0083	0.0110	0.0019	0.007
	12-Jun-12	<0.002	<0.0002	0.0008	0.051	<0.0001	<0.0005	0.295	0.00001	0.0013	0.0016	0.004	0.04	<0.0001	0.067	1.540	<0.0001	0.003	0.0036	<0.0002	8.16	<0.00001	0.514	67.5	<0.00005	<0.001	0.0016	0.0111	0.0040	0.007
	03-Oct-12	<0.0001	<0.002	0.0005	0.053	<0.0001	<0.0005	0.268	<0.00001	0.0006	0.0015	<0.001	<0.01	<0.0001	0.066	1.780	<0.0001	0.002	0.0012	<0.0002	9.54	<0.00001	0.543	77.7	<0.00005	<0.001	0.0018	0.0108	0.0016	0.001
MW11-21-54	24-Jun-11	0.00	<0.001	0.0010	<0.05	<0.001	-	0.250	0.00004	<0.001	0.0020	0.006	<0.1	<0.001	0.063	1.220	-	0.005	0.0060	0.0010	7.85	<0.0001	0.611	-	<0.0001	0.000	<0.001	0.0090	0.0010	0.028
	26-Jul-11	<0.002	0.001	<0.001	<0.05	<0.001	-	0.230	0.00005	<0.001	0.0020	0.002	<0.1	<0.001	0.061	1.560	-	0.003	0.0060	<0.001	8.40	<0.0001	0.609	-	<0.0001	0.001	<0.001	0.0070	<0.001	0.011
	25-Aug-11	0.00	0.000	0.0011	0.050	-	-	0.254	<0.00001	0.0014	-	0.002	-	0.0001	-	-	<0.0001	-	0.0021	<0.0002	-	<0.00001	-	-	-	-	-	0.0066	-	0.024
	04-Oct-11	<0.002	<0.0002	0.0008	0.044	<0.0001	<0.0005	0.294	0.00002	0.0028	0.0012	<0.001	-	<0.0001	0.076	-	<0.0001	0.003	<0.0005	<0.0002	8.96	<0.00001	0.632	68.9	<0.00005	<0.001	0.0035	0.0059	0.0085	0.002
	02-Nov-11	0.00	<0.0002	0.0010	0.044	<0.0001	<0.0005	0.253	0.00002	0.0008	0.0012	0.005	-	0.0001	0.068	-	<0.0001	0.002	0.0030	0.0002	8.40	<0.00001	0.655	66.3	<0.00005	<0.001	0.0079	0.0057	0.0010	0.007
	12-Jun-12	0.00	<0.0002	0.0005	0.039	<0.0001	<0.0005	0.247	0.00002	0.0012	0.0010	0.002	0.01	<0.0001	0.064	1.600	<0.0001	0.002	0.0034	<0.0002	8.81	<0.00001	0.652	67.6	<0.00005	<0.001	0.0016	0.0052	0.0038	0.005
	03-Oct-12	<0.002	<0.0002	0.0004	0.039	<0.0001	<0.0005	0.274	0.00001	0.0011	0.0010	<0.001	<0.01	<0.0001	0.071	1.800	<0.0001	0.002	0.0010	<0.0002	9.99	<0.00001	0.657	79.4	<0.00005	<0.001	0.0020	0.0058	0.0029	0.001
MW11-22-54	24-Jun-11	0.00	<0.001	0.0020	<0.05	<0.001	-	0.270	0.00004	<0.001	0.0010	0.007	<0.1	0.0040	0.049	1.040	-	0.003	0.0040	0.0010	8.95	0.00030	0.529	-	<0.0001	0.000	<0.001	0.0090	0.0010	0.010
	26-Jul-11	<0.002	<0.001	0.0020	<0.05	<0.001	-	0.240	0.00003	<0.001	0.0020	0.002	<0.1	<0.001	0.054	0.843	-	0.005	0.0040	<0.001	7.02	<0.0001	0.534	-	<0.0001	0.000	<0.001	0.0160	<0.001	0.004
	25-Aug-11	0.00	0.001	0.0031	0.045	-	-	0.252	<0.00001	0.0014	-	<0.001	-	<0.0001	-	-	<0.0001	-	0.0008	<0.0002	-	<0.00001	-	-	-	-	-	0.0124	-	0.019
	04-Oct-11	0.00	0.000	0.0026	0.035	<0.0001	<0.0005	0.294	<0.00001	0.0020	0.0009	0.002	-	<0.0001	0.067	-	<0.0001	0.005	<0.0005	<0.0002	7.65	<0.00001	0.551	71.0	<0.00005	<0.001	0.0037	0.0117	0.0061	0.007
	02-Nov-11	0.01	<0.0002	0.0036	0.036	<0.0001	<0.0005	0.263	0.00002	0.0016	0.0020	0.002	-	<0.0001	0.058	-	<0.0001	0.004	0.0027	0.0003	8.16	<0.00001	0.525	71.8	<0.00005	<0.001	0.0084	0.0112	0.0023	0.005
	12-Jun-12	0.00	<0.0002	0.0046	0.035	<0.0001	<0.0005	0.254	0.00001	0.0011	0.0016	0.002	0.67	<0.0001	0.056	0.831	<0.0001	0.004	0.0024	<0.0002	7.24	<0.00001	0.602	66.5	<0.00005	<0.001	0.0017	0.0109	0.0035	0.010
	03-Oct-12	<0.002	<0.0002	0.0022	0.034	<0.0001	<0.0005	0.274	<0.00001	0.0007	0.0010	<0.001	<0.01	<0.0001	0.065	1.020	<0.0001	0.003	<0.0005	<0.0002	8.44	<0.00001	0.542	71.8	<0.00005	<0.001	0.0019	0.0102	0.0021	0.002
MW13-23-50	10-Jun-13	<0.0050	<0.00040	<0.00040	0.054	-	-	0.313	<0.00010	<0.0050	-	0.002	0.03	<0.00010	-	0.879	<0.000020	-	0.0047	<0.00040	-	<0.00010	-	-	-	-	-	0.0092	-	0.003
	09-Oct-13	0.13	0.001	0.0019	1.300	<0.0001	<0.0005	0.050	0.00001	<0.0005	<0.0001	0.002	<0.01	<0.0001	0.014	-	<0.0001	0.041	0.0007	0.0005	5.04	<0.00001	1.580	7.6	<0.00005	<0.001	<0.0005	<0.0005	0.0019	0.001
MW13-27-55	16-Jun-13	<0.0050	<0.00040	0.0346	0.034	-	-	0.301	<0.00010	<0.0050	-	<0.0010	1.13	<0.00010	-	0.164	<0.00010	-	<0.0020	<0.00040	-	<0.00010	-	-	-	-	-	0.0035	-	<0.0030
	08-Oct-13	<0.002	<0.0002	0.0335	0.038	<0.0001	<0.0005	0.302	<0.00001	<0.0005	0.0003	<0.001	2.74	<0.0001	0.072	-	<0.0001	0.010	0.0008	<0.0002	10.10	<0.00001	0.691	48.8	<0.00005	<0.001	<0.0005	0.0028	<0.0001	0.002

Table 5: Groundwater Chemistry – Dissolved Metals Parameters

Well ID	Sampling Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Bismuth	Boron	Cadmium	Chromium	Cobalt	Copper	Iron	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Selenium	Silicon	Silver	Strontium	Sulphur	Thallium	Tin	Titanium	Uranium	Vanadium	Zinc
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Bonnyville Formation																														
MW11-20-74	24-Jun-11	0.00	<0.001	0.0130	0.070	<0.001	-	0.360	0.00007	0.0030	<0.001	0.006	<0.1	<0.001	0.068	0.154	-	0.013	0.0050	0.0010	9.95	<0.0001	0.670	-	<0.0001	0.002	<0.001	0.0020	0.0010	0.024
	26-Jul-11	<0.002	0.001	0.0110	0.110	<0.001	-	0.380	0.00003	<0.001	<0.001	0.002	0.40	<0.001	0.066	0.166	-	0.014	0.0030	<0.001	8.40	<0.0001	0.652	-	<0.0001	0.001	<0.001	0.0020	-	0.006
	25-Aug-11	<0.002	0.000	0.0193	0.068	-	-	0.334	<0.00001	0.0013	-	<0.001	-	<0.0001	-	-	<0.0001	-	<0.0005	<0.0002	-	<0.00001	-	-	-	-	-	0.0023	-	0.004
	04-Oct-11	<0.002	0.000	0.0122	0.061	<0.0001	<0.0005	0.378	0.00002	0.0021	0.0003	0.002	-	<0.0001	0.080	-	0.0001	0.014	<0.0005	<0.0002	9.41	<0.00001	0.680	0.3	<0.00005	<0.001	0.0034	0.0020	0.0053	0.011
	02-Nov-11	0.02	<0.0002	0.0190	0.067	<0.0001	<0.0005	0.345	0.00002	0.0038	0.0006	0.003	-	0.0002	0.072	-	<0.0001	0.013	0.0016	<0.0002	9.90	<0.00001	0.768	68.8	<0.00005	<0.001	0.0081	0.0018	0.0017	0.006
	12-Jun-12	0.02	0.001	0.0103	0.047	<0.0001	<0.0005	0.244	0.00004	0.0006	0.0005	0.005	0.25	0.0003	0.052	0.083	<0.0001	0.008	0.0032	<0.0002	4.91	0.00001	0.462	37.1	<0.00005	<0.001	0.0016	0.0008	0.0025	0.015
	03-Oct-12	<0.002	<0.0002	0.0182	0.029	<0.0001	<0.0005	0.330	<0.00001	0.0011	0.0004	<0.001	<0.01	<0.0001	0.082	0.158	<0.0001	0.012	<0.0005	<0.0002	11.10	<0.00001	0.732	75.6	<0.00005	<0.001	0.0018	0.0012	0.0033	0.001
MW13-19-82	10-Jun-13	0.04	<0.00040	0.0201	0.038	-	-	0.228	<0.00010	<0.0050	-	0.004	0.20	0.0002	-	0.096	<0.000020	-	<0.0020	<0.00040	-	<0.00010	-	-	-	-	-	0.0010	-	0.006
	08-Oct-13	<0.002	<0.0002	0.0216	0.031	<0.0001	<0.0005	0.246	<0.00001	<0.0005	0.0002	<0.001	1.86	<0.0001	0.059	-	<0.0001	0.008	0.0010	<0.0002	10.20	<0.00001	0.754	64.3	<0.00005	<0.001	<0.0005	0.0007	<0.0001	0.003
Muriel Lake Formation																														
MW13-27-90	16-Jun-13	0.08	<0.00050	0.0070	0.029	-	-	0.589	<0.00010	<0.0050	-	<0.0010	1.12	<0.00025	-	0.030	<0.00010	-	<0.0020	<0.00050	-	<0.00010	-	-	-	-	-	0.0002	-	0.007
	08-Oct-13	<0.002	<0.0002	0.0060	0.040	<0.0001	<0.0005	0.579	<0.00001	<0.0005	0.0006	<0.001	2.03	<0.0001	0.069	-	<0.0001	0.007	0.0012	<0.0002	7.84	<0.00001	0.781	198.0	<0.00005	<0.001	<0.0005	<0.0005	0.0002	0.003
Lea Park Formation																														
MW13-19-96	17-Oct-13	<0.004	<0.0004	0.0028	0.540	<0.0002	<0.001	0.592	<0.00002	<0.001	<0.0002	<0.002	<0.02	<0.0002	0.050	<0.01	<0.0001	0.020	0.0028	<0.0004	3.06	<0.00002	0.975	4.6	<0.0001	<0.002	<0.001	<0.001	0.0003	0.004
MW13-23-81	16-Oct-13	0.19	<0.001	0.0030	0.745	<0.0005	<0.002	0.260	<0.00005	<0.002	<0.0005	0.008	<0.05	<0.0005	0.050	<0.02	<0.0001	0.010	<0.002	<0.001	0.64	<0.00005	10.400	18.0	<0.0002	<0.005	<0.002	<0.002	<0.0005	0.010
MW13-24-94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MW13-25-29	10-Jun-13	23.20	0.002	0.0074	0.079	-	-	0.131	<0.00010	0.0080	-	0.011	7.77	0.0056	-	0.101	<0.000020	-	0.0096	0.0032	-	<0.00010	-	-	-	-	-	0.0221	-	0.203
	11-Oct-13	3.26	0.001	0.0078	0.189	0.0020	<0.0005	0.265	0.00031	0.0106	0.0123	0.013	12.20	0.0142	0.070	-	<0.0001	0.044	0.0289	0.0017	16.50	<0.00001	0.993	87.8	0.00014	<0.001	0.0233	0.0229	0.0160	0.067

Table 6: Groundwater Chemistry – Hydrocarbon Parameters

Well ID	Sampling Date	Benzene	Toluene	Ethylbenzene	Xylene	F1 (C6-C10) - BTEX	F2 (C10-C16 Hydrocarbons)	Naphthenic Acids	Phenols
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/mL	mg/L
Grand Centre Formation									
P10-12A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
Sand River Formation									
P02-1	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P02-4	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.003
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P02-6	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.003
	01-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P02-7	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
	01-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P02-8	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P05-9A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
P10-11A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-13A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	01-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-14A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-15A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-16A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-17A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
P10-18A	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-19-12	23-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	0.50	0.005
	27-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.005
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	4-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	2-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	2-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002

Table 6: Groundwater Chemistry – Hydrocarbon Parameters

Well ID	Sampling Date	Benzene	Toluene	Ethylbenzene	Xylene	F1 (C6-C10) - BTEX	F2 (C10-C16 Hydrocarbons)	Naphthenic Acid	Phenols
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/mL	mg/L
MW11-19-24	23-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.003
	27-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.003
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-20-7	23-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	0.60	0.003
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.003
	25-Aug-11	<0.001	0.0020	<0.001	<0.001	<0.2	<0.1	-	<0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-21-11	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.003
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.006
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-22-9	23-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	0.30	0.009
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW12-23-14	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.003
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW12-24-8	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW12-25-8	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.003
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW12-26-8	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.002
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW13-27-23	16-Jun-13	-	-	-	-	-	-	<1.0	<0.0010
	09-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	<1.0	<0.002
Marie Creek Formation									
P02-5	05-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	11-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
Ethel Lake Formation									
MW11-19-67	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.002
	27-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.003
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	02-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002

Table 6: Groundwater Chemistry – Hydrocarbon Parameters

Well ID	Sampling Date	Benzene	Toluene	Ethylbenzene	Xylene	F1 (C6-C10) - BTEX	F2 (C10-C16 Hydrocarbons)	Naphthenic Acid	Phenols
	Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µg/mL	mg/L
MW11-20-53	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	04-Oct-11	0.0220	0.0020	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.006
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-21-54	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.004
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	0.003
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW11-22-54	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.004
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW13-23-50	10-Jun-13	<0.00050	<0.00050	<0.00050	<0.00071	<0.10	<0.25	<1.0	<0.0010
	09-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	<1.0	<0.002
MW13-27-55	16-Jun-13	-	-	-	-	-	-	<1.0	<0.0010
	08-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	<1.0	<0.002
Bonnyville Formation									
MW11-20-74	24-Jun-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	26-Jul-11	<0.0005	<0.0005	<0.0005	<0.0005	<0.1	<0.1	<0.2	<0.002
	25-Aug-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.001
	04-Oct-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.001
	02-Nov-11	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.005
	12-Jun-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	0.006
	03-Oct-12	<0.001	<0.001	<0.001	<0.001	<0.2	<0.1	-	<0.002
MW13-19-82	10-Jun-13	<0.00050	0.0016	<0.00050	<0.00071	<0.10	<0.25	<1.0	0.003
	08-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	<1.0	<0.002
Muriel Lake Formation									
MW13-27-90	16-Jun-13	-	-	-	-	-	-	<1.0	0.001
	08-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	<1.0	<0.002
Lea Park Formation									
MW13-19-96	17-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	1.40	<0.002
MW13-23-81	16-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	4.20	0.006
MW13-24-94	-	-	-	-	-	-	-	-	-	-
MW13-25-29	10-Jun-13	<0.00050	<0.00050	<0.00050	<0.00071	<0.10	<0.25	3.40	0.014
	11-Oct-13	<0.001	<0.001	<0.001	<0.001	<0.2	<0.2	5.50	<0.002

Table 7: Arsenic Concentration in Soil

Formation	Well ID	Depth (m bgl)	Sampling Date	Arsenic Concentration (mg/kg)
Sand River equiv.	MW11-19-12	8.8-9.8	10-Jun-11	2.6
Sand River equiv.	MW11-21-54	4.5-5.0	11-Jun-11	1.1
Sand River equiv.	MW11-22-9	3.1-6.1	13-Jun-11	1.8
Sand River equiv.	MW13-27-23	20.4-23.5	01-Jun-13	1.9
Ethel Lake	MW11-19-67	68.6-70.1	09-Jun-11	5.3
Ethel Lake	MW11-20-74	53.0-53.3	04-Jun-11	6.6
Ethel Lake	MW11-21-54	53.6-53.9	11-Jun-11	24.4
Ethel Lake	MW11-22-54	51.0-54.0	13-Jun-11	3.8
Ethel Lake	MW13-23-50	44.8-46.0	01-Jun-13	2.24
Bonnyville	MW13-19-82	82.3	01-Jun-13	6.7
Muriel Lake	MW13-27-90	87.5-90.5	01-Jun-13	9.65
Lea Park	MW13-24-94	90.5-92.0	01-Jun-13	9.81

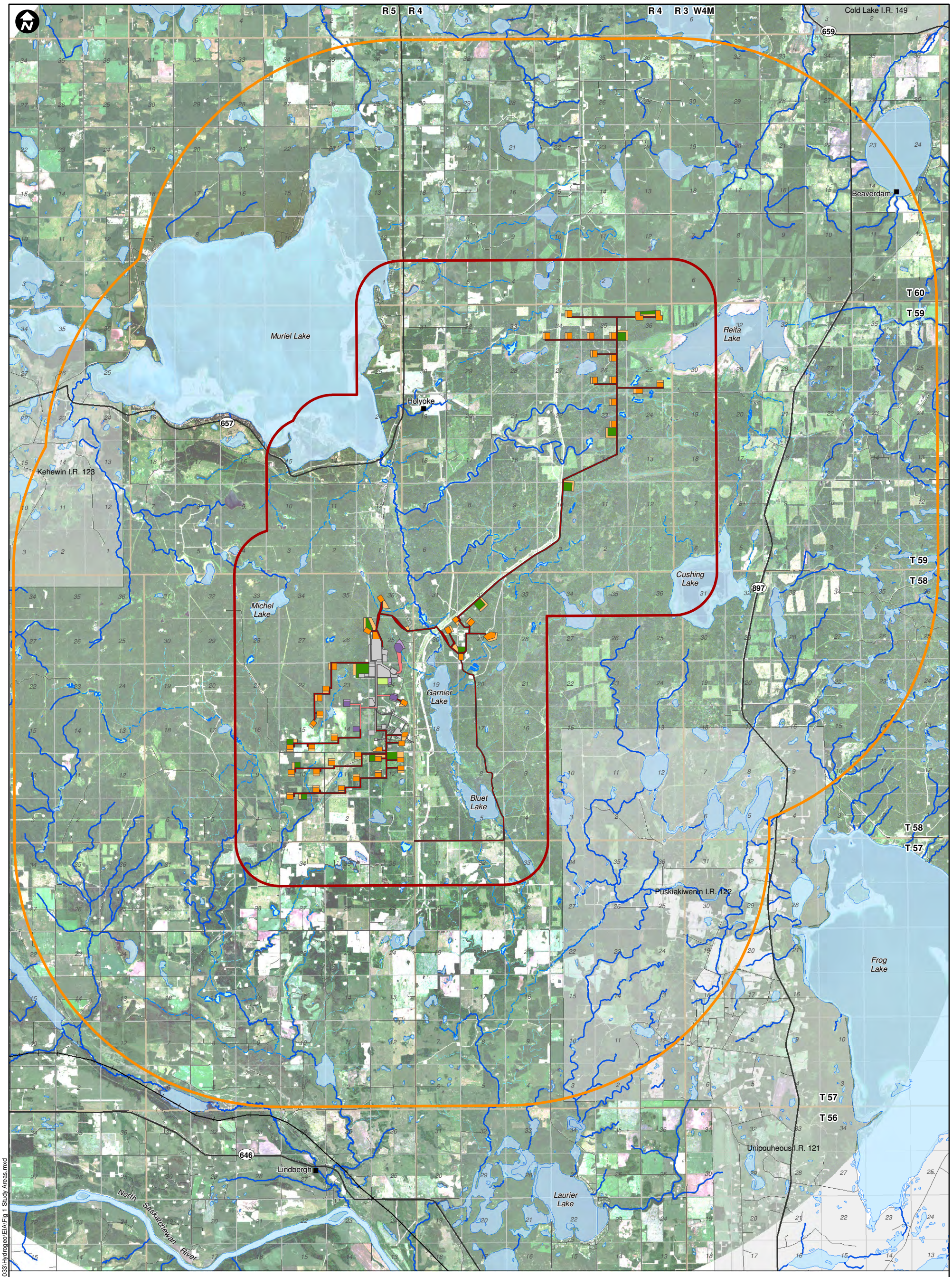
Table 8: Environmental Impact Assessment Summary

Valued Environmental Component	Nature of Potential Impact or Effect	Mitigation	Geographic Extent[1]	Duration[2]	Frequency[3]	Reversibility[4]	Magnitude[5]	Project Contribution[6]	Confidence Rating[7]	Probability of Occurrence[8]	Impact Rating[9]
Groundwater quality											
Aquifers in Quaternary Deposits	Surface Facilities	Groundwater Monitoring, Industry Standard Operating Practices, Preparedness for Upset Conditions, Spill and Groundwater Response Plans	Local	Long-term	Occasional	Reversible – long term	Moderate	Negative	Moderate	Medium	Low Impact
Surface Water Bodies and Wetlands[10]			N/A	N/A	N/A	N/A	N/A	N/A	Moderate	N/A	No Impact
Aquifers in Quaternary Deposits	Production and Steaming	Groundwater and Operational Monitoring, Well Design Measures	Local	Long-term	Isolated	Reversible – long term	Low	Negative	Moderate	Medium	Low Impact
Surface Water Bodies and Wetlands[10]			N/A	N/A	N/A	N/A	N/A	N/A	Moderate	N/A	No Impact

1. Local, Regional, Provincial, National, Global; **2.** Short, Long, Extended, Residual; **3.** Continuous, Isolated, Periodic, Occasional; **4.** Reversible in short term, Reversible in long term, Irreversible; **5.** Nil, Low, Moderate, High; **6.** Neutral, Positive, Negative; **7.** Low, Moderate, High; **8.** Low, Medium, High; **9.** No Impact, Low Impact, Moderate Impact, High Impact; **10.** Based on the current understanding of cause-effect relationships, groundwater will not provide a pathway for potential contaminants to reach surface water bodies or wetlands at detectable concentrations.

APPENDIX B: FIGURES

List of Figures



Legend

Development Footprint

Initial Development
- Access/Utility Corridor
- Well Pad
- Soil Storage
- Borrow Pit

Future Development
- Access/Utility Corridor
- Well Pad
- Soil Storage
- Borrow Pit

- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Existing and Approved Development
- First Nations
- Railway
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 1.25 2.5 5
Kilometres

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; RapidEye, June-July, 2013.

PROJECT: PENGROWTH **Lindbergh SAGD Expansion Project**

MILLENNIUM EMS Solutions Ltd.

TITLE: **Project Expansion Area and Study Areas**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **1**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 1 Study Areas.mxd

Legend

- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- First Nations
- Contour (20m interval, m asl)
- Railway
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds
- Drainage Basin

0 1.25 2.5 5
Kilometres

REF: NHC hydrology Oct 2013; RapidEye, June-July, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Topography**

DRAWN: JDC/SL	FIGURE: 2
CHECKED: JD	
DATE: Dec 4/13	
PROJECT: 11-033	

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 2 Topography.mxd

Stratigraphy							Hydrostatigraphy	
Eon	Era	Period	Group		Formation	Member/Unit	Unit	System
Phanerozoic	Cenozoic	Quaternary Tertiary			Grand Centre		Aquitard	
					Sand River Equivalent		Aquifer*	
					Marie Creek		Aquitard	
					Ethel Lake		Aquifer*	
					Bonnyville		Aquifer - Aquitard*	
					Muriel Lake		Aquifer*	
					Bronson Lake		Aquitard	
					Empress Unit 3		Aquifer*	
	Mesozoic	Cretaceous	Upper	Colorado	Upper	Lea Park	Aquitard	Colorado Aquitard System
							Aquitard	
						2nd White Specks Sandstone	Aquitard	
					Lower	LaBiche	Aquitard	
						Viking	Aquifer	
						Joli Fou	Aquifer - Aquitard	
			Lower	Mannville			Aquifer	
						McLaren Member	Aquifer	
					Grand Rapids	*Waseca Sand*	Aquifer	Grand Rapids Aquifer System
					Lower Grand Rapids	Sparky Sand	Aquifer - Aquitard	
						General Petroleum Sand	Aquifer - Aquitard	
						Rex Sand	Aquifer (Bitumen)	
						Lloydminster Sand	Aquifer (Bitumen)	
					Clearwater	Cummings Member	Aquitard	Clearwater Aquitard
					McMurray	Dina Member	Aquifer	McMurray Aquifer System
	Paleozoic	Devonian	Upper	Woodbend	Cooking Lake		Aquifer	
					Waterways		Aquifer - Aquitard	Beaverhill Lake - Cooking Lake Aquifer System
				Beaverhill Lake	Slave Point		Aquifer	
					Fort Vermillion		Aquiclude	Prairie - Watt Mountain Aquiclude System
			Middle	Elk Point	Upper	Watt Mountain	Aquitard	
						Prairie	Aquiclude	
						Winnipegosis	Aquifer	Contact Rapids - Winnipegosis Aquifer System
					Lower	Granite Wash	Contact Rapids	Aquifer - Aquitard	
			Lower				Cold Lake	Aquiclude	Lower Elk Point Aquitard - Aquiclude System
							Ernestina Lake	Aquifer - Aquitard	
							Upper Lotsberg	Aquiclude	
							Lower Lotsberg	Aquiclude	
						Basal Red Beds		Aquifer - Aquitard	Basal Aquifer
		Cambrian	Upper		Deadwood		Aquitard	
			Middle		Earlie		Aquitard	
					Basal Sandstone		Aquifer	
Pre-Cambrian							Aquiclude	

Pre-Quaternary Unconformity

Pre-Cretaceous Unconformity

Italics: Informal name

* Possible Domestic Use Aquifer

Adapted from: Bachu et.al. 1993, Regional-Scale Subsurface Hydrogeology in Northeast Alberta; EUB/AGS Special Report 74.

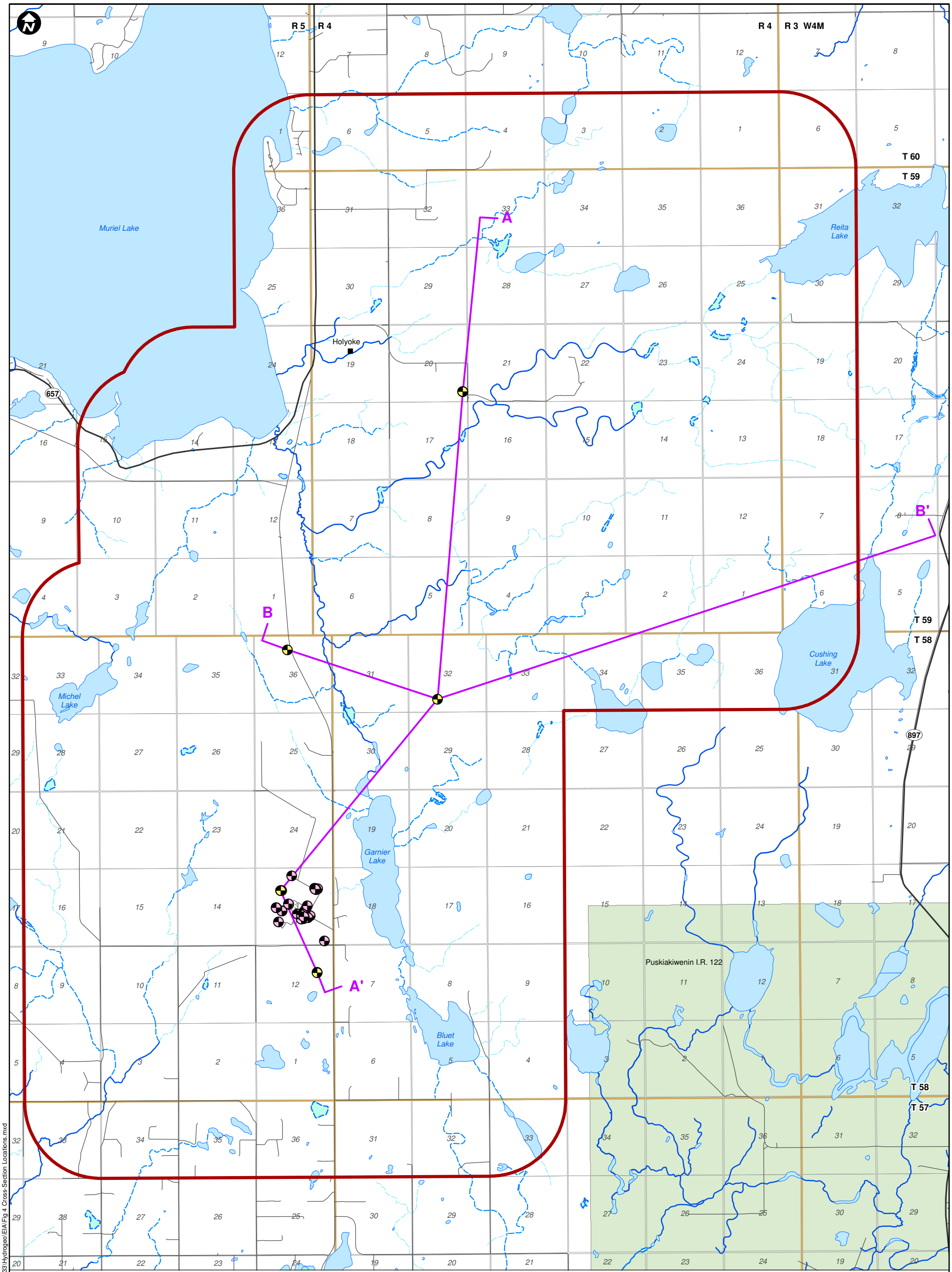
PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Stratigraphy and Hydrostratigraphy**

DRAWN: JDC
CHECKED: JD
DATE: Nov 13/13
PROJECT: 11-033

FIGURE: 3



Legend

- 2013 Monitoring Well
- Monitoring Well
- Hydrogeology Local Study Area
- First Nations
- A A' Cross-Section Line
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Cross-Section Locations**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 4

REF: NHC hydrology Oct 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 4 Cross-Section Locations.mxd

NORTH
A

SOUTH
A'

SW 33-059-04 W4M | 01-20-059-04 W4M | 03-32-058-04 W4 | 11-13-058-05 W4M | 09-12-058-05 W4M

Unnamed Creek | Unnamed Creek | Unnamed Creek | Unnamed Creek

Grand Centre Fm.

Marie Creek Fm.

Ethel Lake Fm.

Bonnyville Fm. Unit 2

Bonnyville Fm. Unit 1

Lea Park Fm.

Muriel Lake Fm.

Bronson Lake Fm.

Sand River Fm.

Sand River Fm. Equivalent

Sand River Fm. Equivalent

ELEVATION (m asl)

670 660 650 640 630 620 610 600 590 580 570 560 550 540 530 520 510

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000

DISTANCE (m)

Legend

Lithology

- Clay
- Clay with Gravel
- Sand with Clay
- Sand
- Silt and Sand
- Sand and Gravel
- Shale
- Estimated Stratigraphy (AGS Bulletin 57, Cross-Section E2-E2')

WATER LEVEL — MONITORING WELL COMPLETION INTERVAL

WATER LEVEL HAS NOT STABILIZED — MONITORING WELL COMPLETION INTERVAL

0 0.5 1 2km

Scale 1 : 50 000

50 x Vertical Exaggeration

REF: Geobase 2012.

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: North-South Cross-Section AA'

FILE: Final Docs\...EIA\Fig 5_6 Cross-Sections.dwg

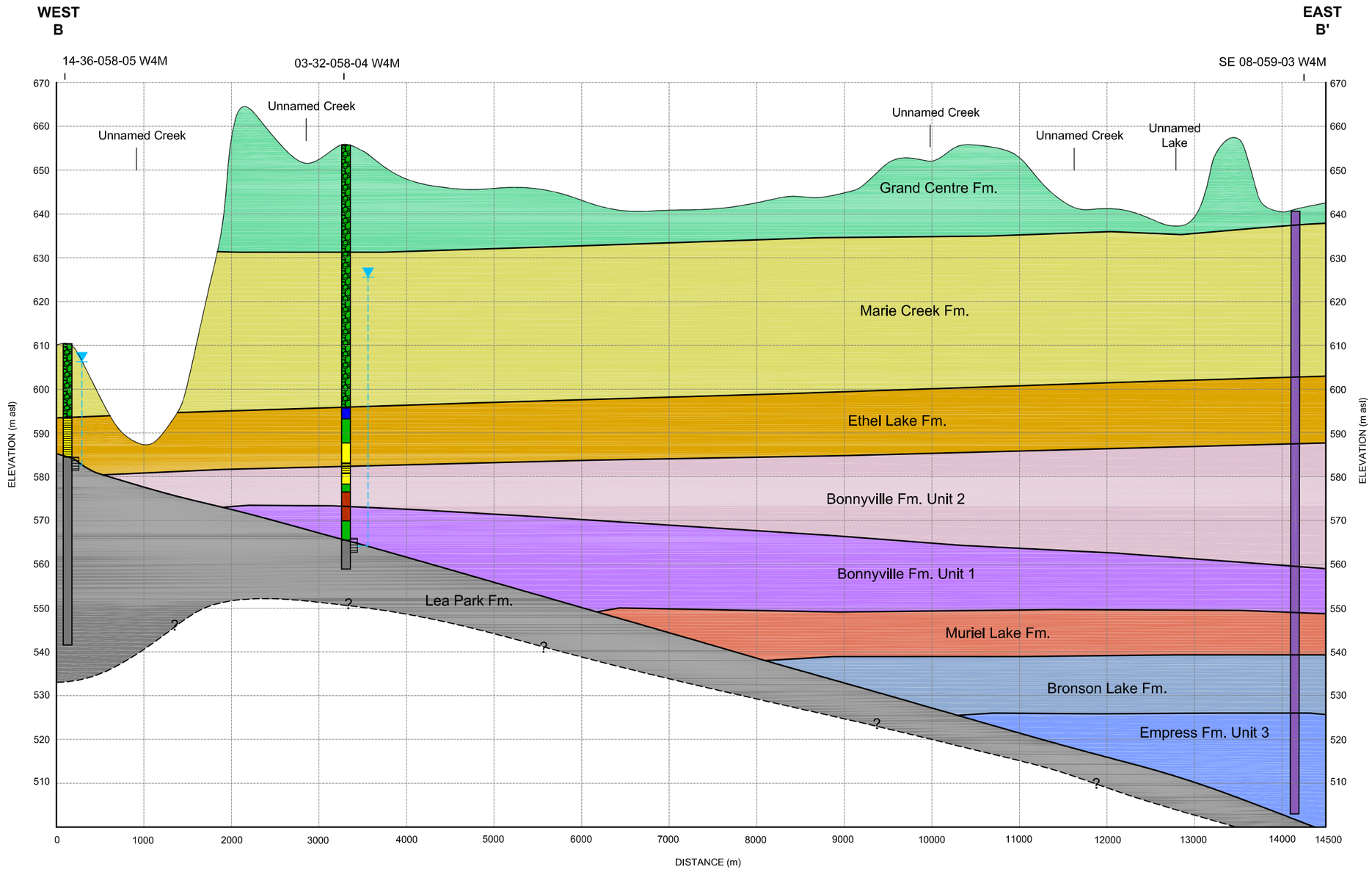
DRAWN: JDC/SL

CHECKED: JD

DATE: Dec 17/13

PROJECT: 11-033

FIGURE: 5



Legend

Lithology

- Clay
- Clay with Gravel
- Sand with Clay
- Sand
- Silt and Sand
- Sand and Gravel
- Shale
- Estimated Stratigraphy (AGS Bulletin 57, Cross-Section E2-E2')

WATER LEVEL — MONITORING WELL COMPLETION INTERVAL

WATER LEVEL HAS NOT STABILIZED — MONITORING WELL COMPLETION INTERVAL

0 0.5 1 2km

Scale 1 : 50 000

50 x Vertical Exaggeration

REF: Geobase 2012.

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: West-East Cross-Section BB'

FILE: Final Docs\...EIA\Fig 5_6 Cross-Sections.dwg

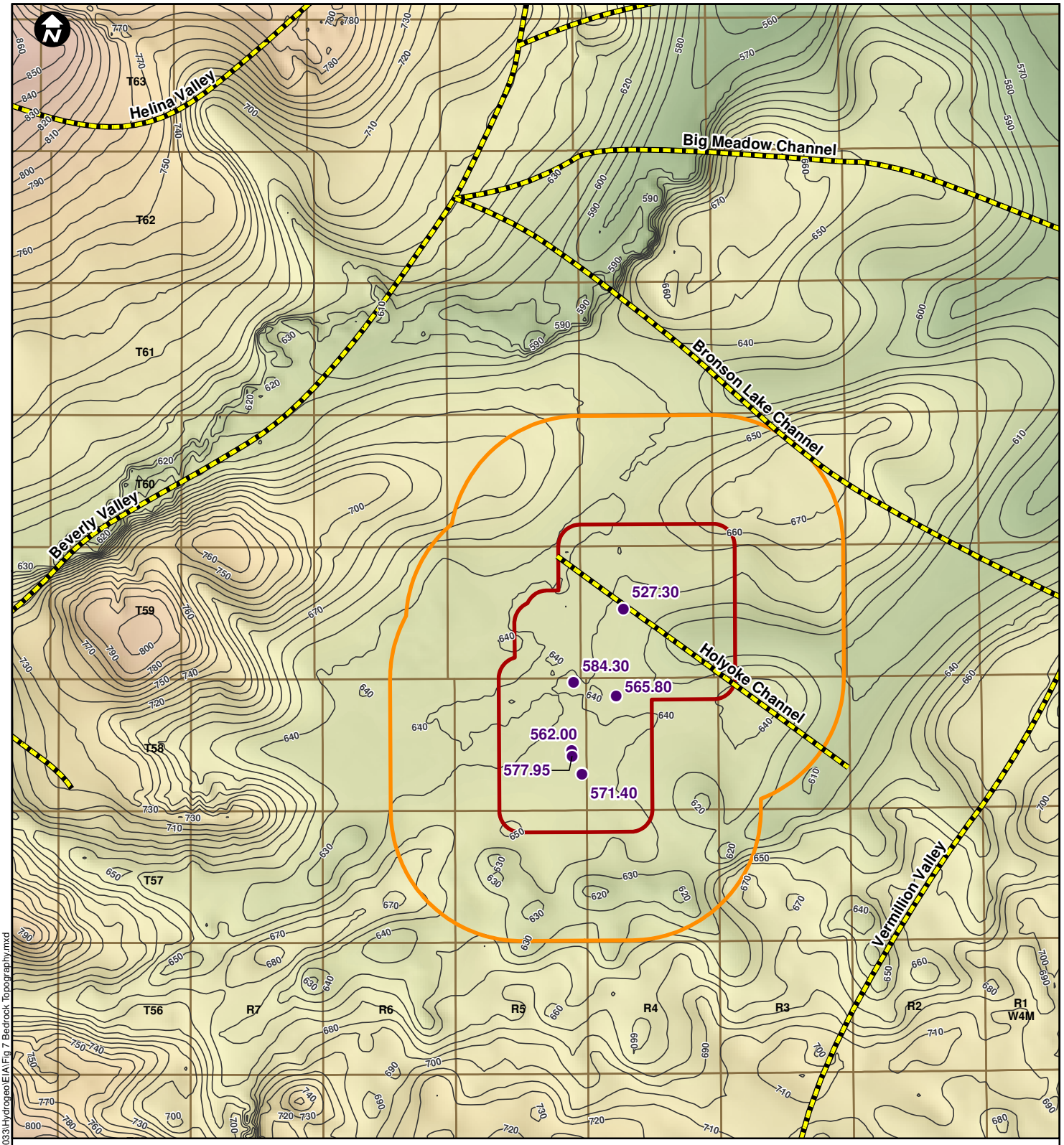
DRAWN: JDC/SL

CHECKED: JD

DATE: Dec 17/13

PROJECT: 11-033

FIGURE: 6



Legend

- Monitoring Well
- (577.95) Bedrock Elevation (m asl)
- Contour (10m interval, m asl)
- Channel
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area

Bedrock Topography (m asl)

- High : 880
- Low : 550

0 4 8 16
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

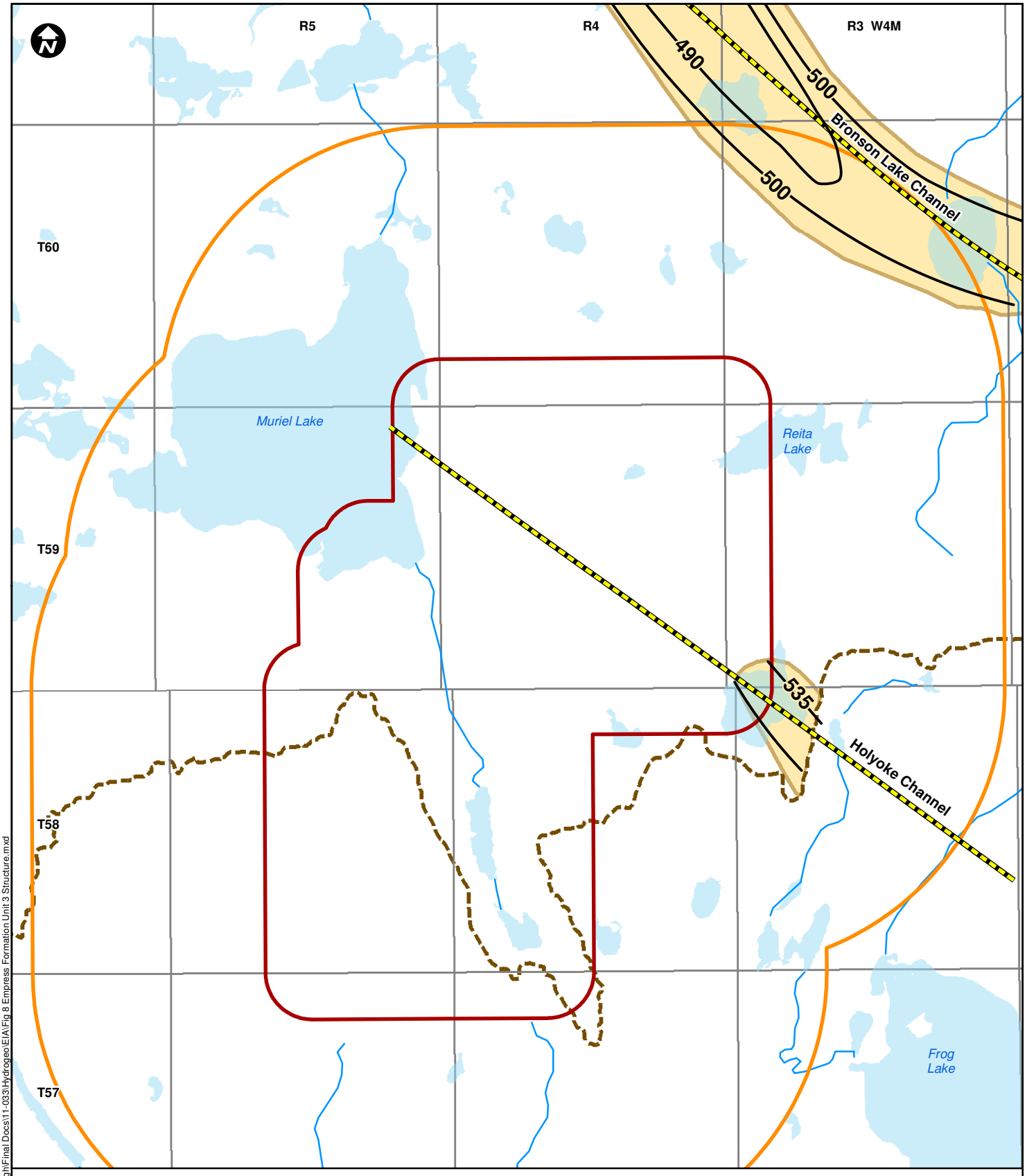
TITLE: **Bedrock Topography**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 7

REF: Atkinson and Lyster, 2010b; ARC, 1989.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 7 Bedrock Topography.mxd



Legend

- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Sand, gravel, silt
- Structure Contour (m asl)
- Limit of Structure Mapping
- Channel

0 2 4 8
Kilometres

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

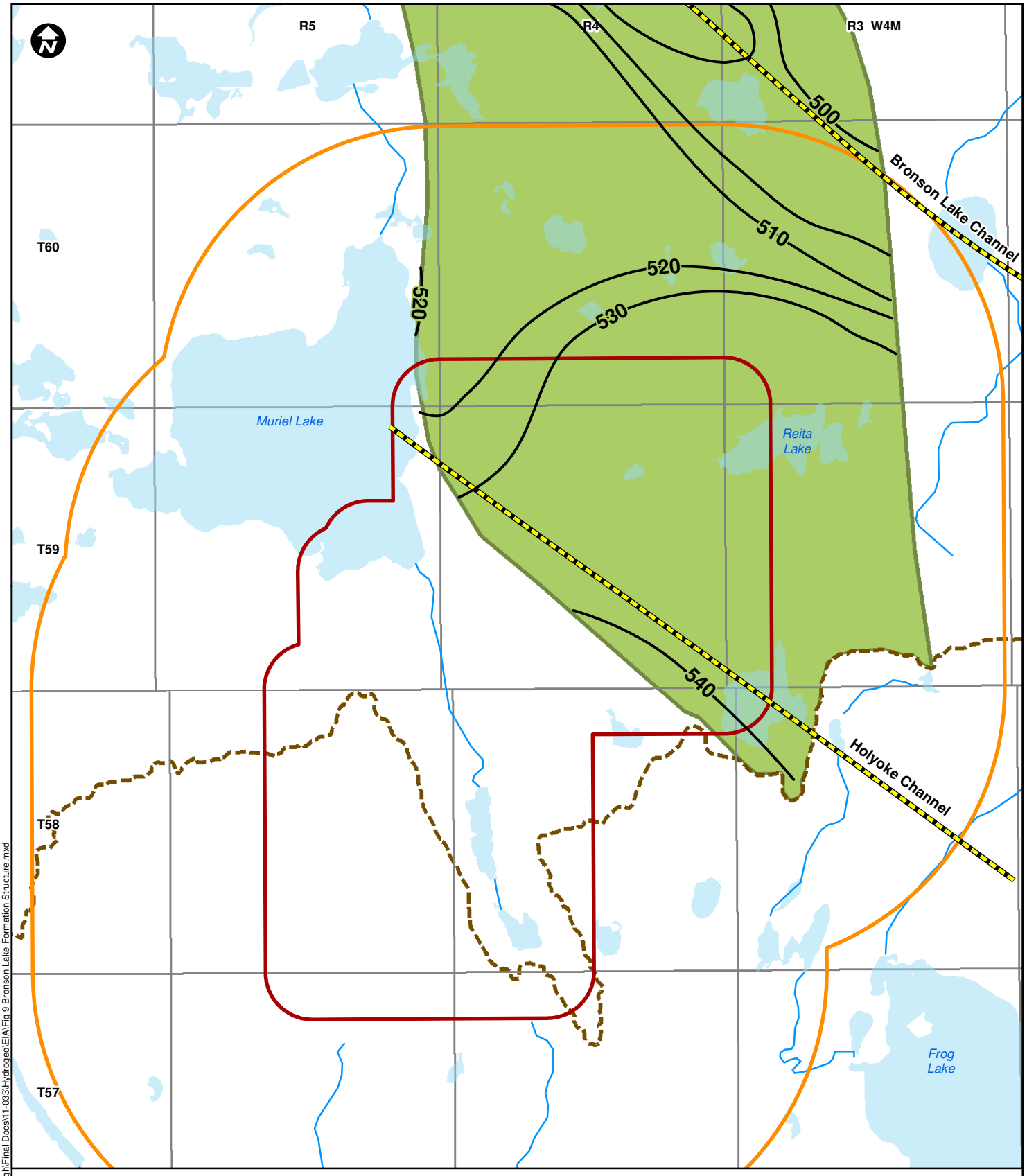
MILLENNIUM EMS Solutions Ltd.

TITLE: **Empress Formation Unit 3 Structure**

DRAWN:	JDC
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: 8

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 8 Empress Formation Unit 3 Structure.mxd



Legend

- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Diamict (till?)
- Structure Contour (m asl)
- Channel
- Limit of Structure Mapping

0 2 4 8
Kilometres

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

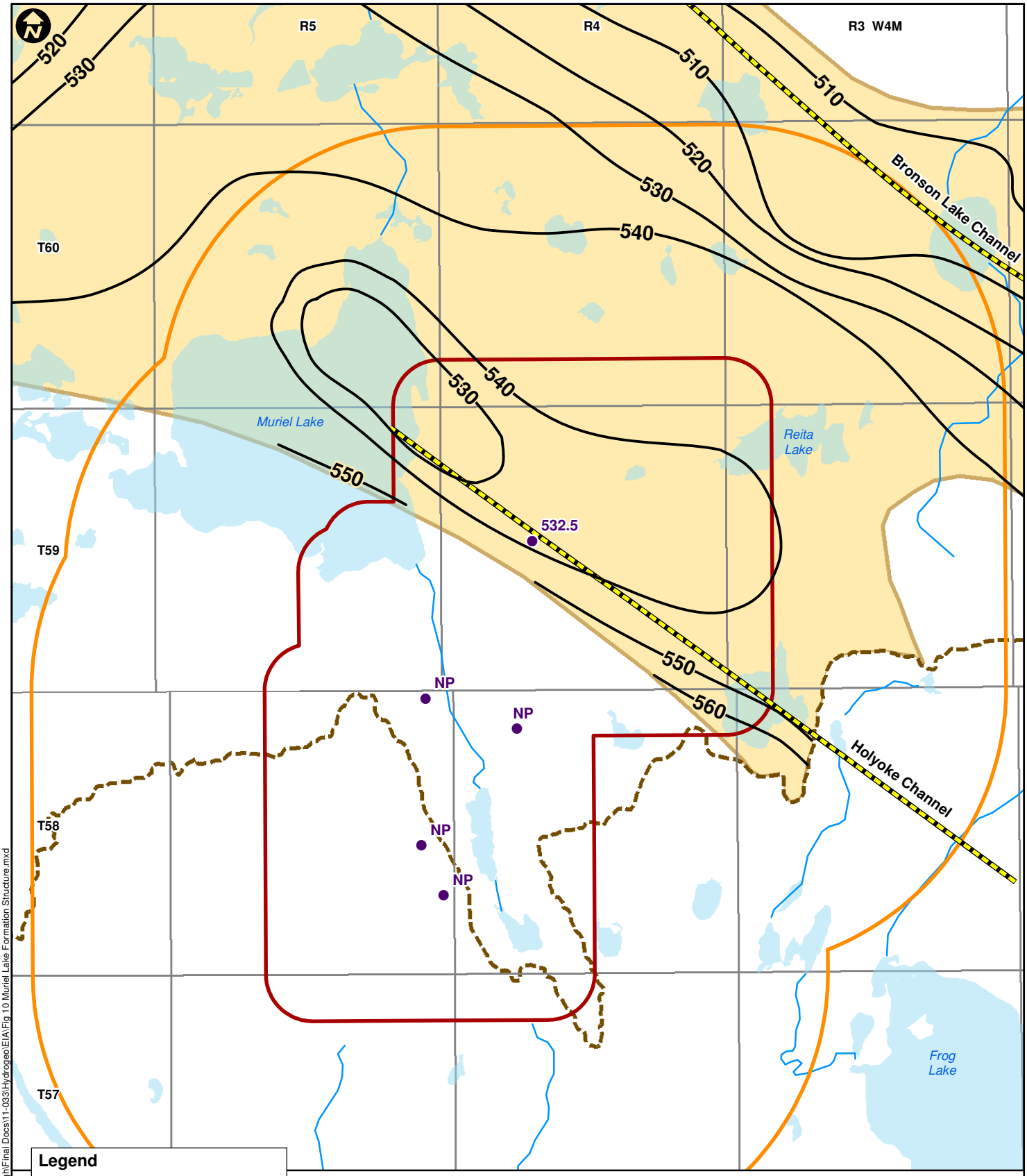
MILLENNIUM EMS Solutions Ltd.

TITLE: **Bronson Lake Formation Structure**

DRAWN:	JDC
CHECKED:	JD
DATE:	Nov 8/13
PROJECT:	11-033

FIGURE: 9

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 9 Bronson Lake Formation Structure.mxd



REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

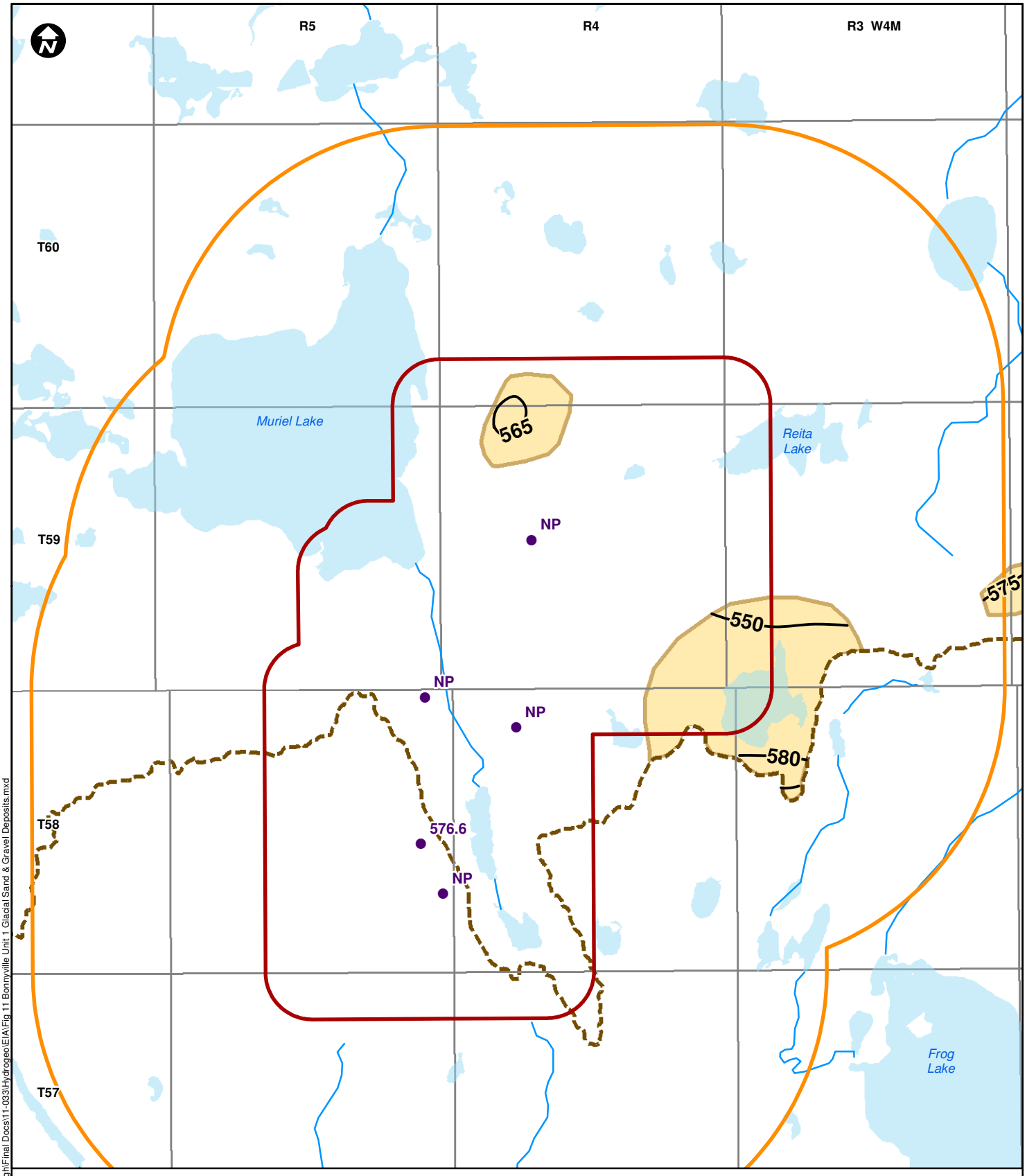
MILLENNIUM EMS Solutions Ltd.

TITLE: Muriel Lake Formation Structure

DRAWN: JDC
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 10

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 10 Muriel Lake Formation Structure.mxd



Legend

- Monitoring Well
- 576.6 Formation Elevation (m asl) NP = Not Present
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Sand, sand and gravel
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

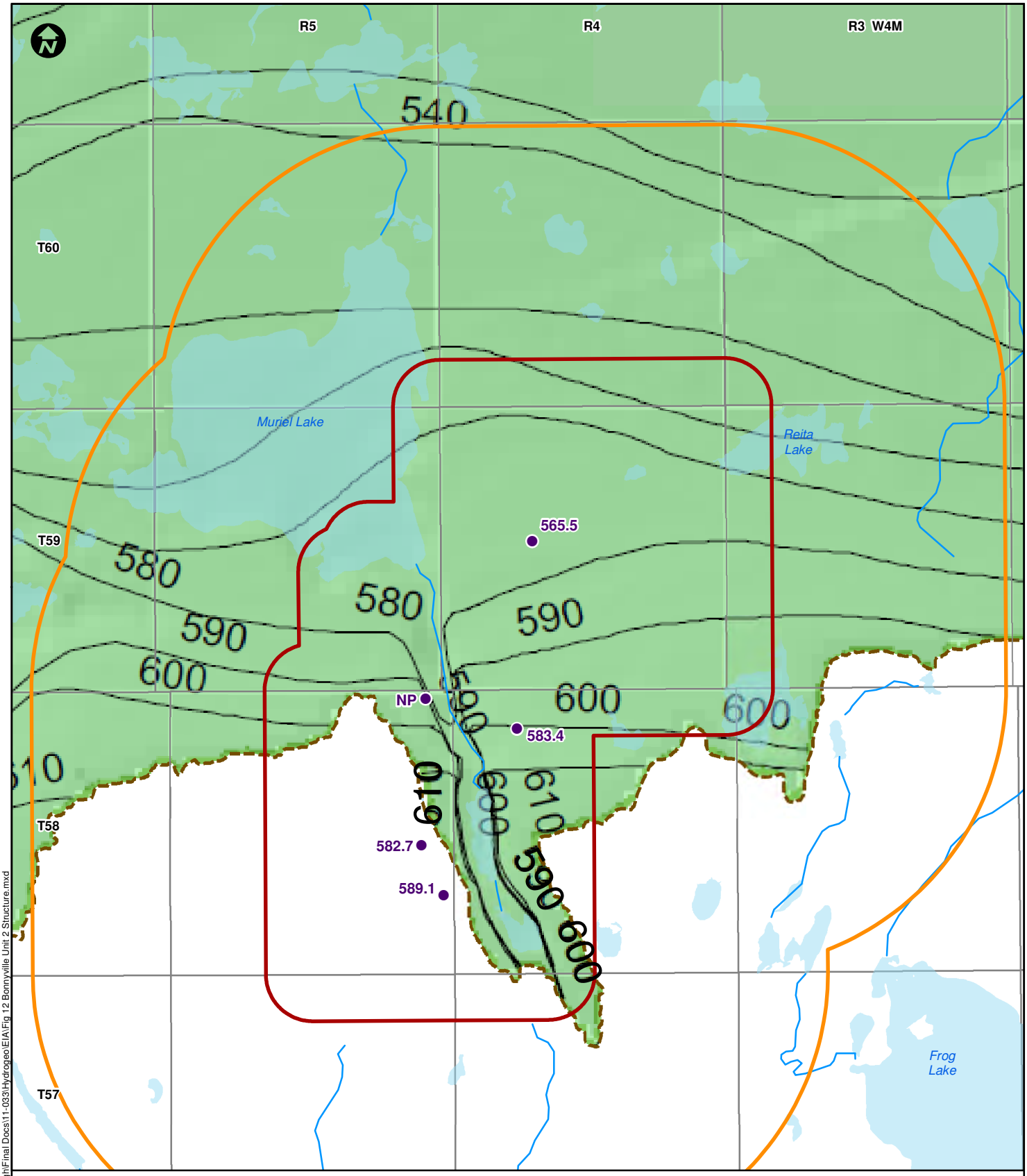
MILLENNIUM EMS Solutions Ltd.

TITLE: Bonnyville Formation Unit 1 Glacial Sand and Gravel Deposits

DRAWN: SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 11

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 11 Bonnyville Unit 1 Glacial Sand & Gravel Deposits.mxd



Legend

- Monitoring Well
- 565.5 Formation Elevation (m asl) NP = Not Present
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Till
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

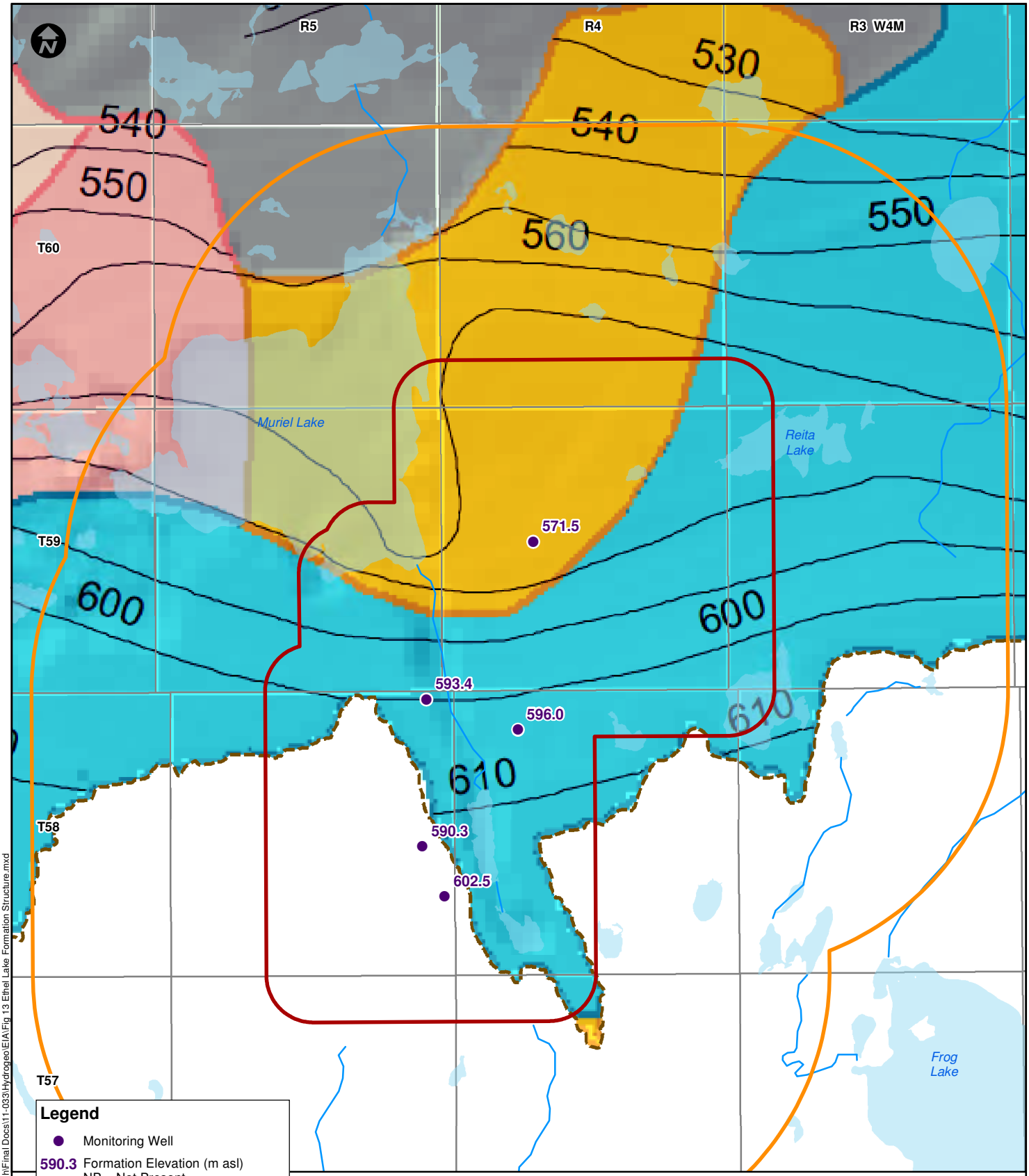
MILLENNIUM EMS Solutions Ltd.

TITLE: **Bonnyville Formation Unit 2 Structure**

DRAWN: SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 12

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 12 Bonnyville Unit 2 Structure.mxd



Legend

- Monitoring Well
- 590.3 Formation Elevation (m asl) NP = Not Present
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Clay, silt and clay
- Sand and silt
- Silt, clay, sand and gravel
- Sand, sand and gravel
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

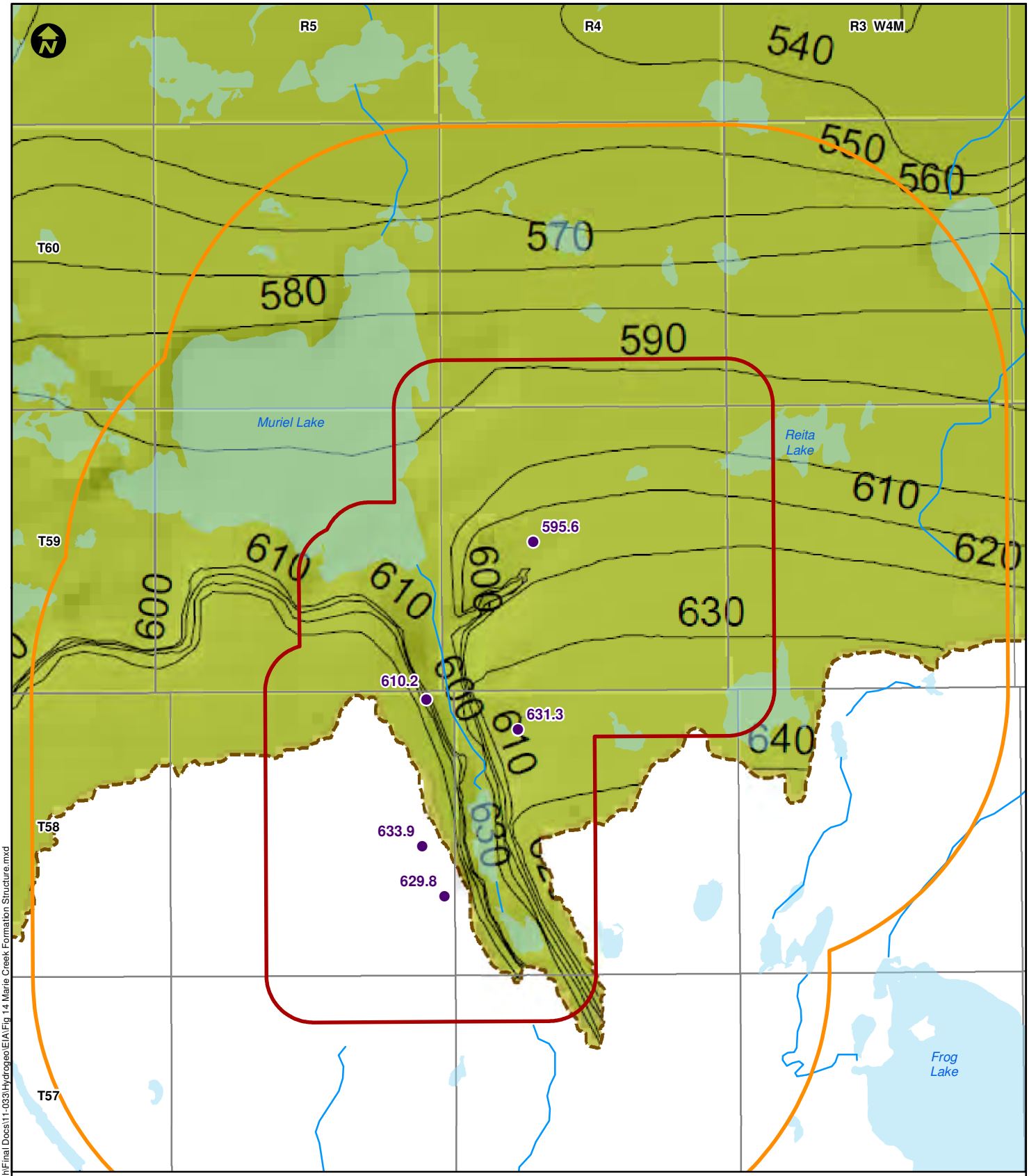
MILLENNIUM EMS Solutions Ltd.

TITLE: **Ethel Lake Formation Structure**

DRAWN:	SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **13**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 13 Ethel Lake Formation Structure.mxd



Legend

- Monitoring Well
- 595.6 Formation Elevation (m asl) NP = Not Present
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Till
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

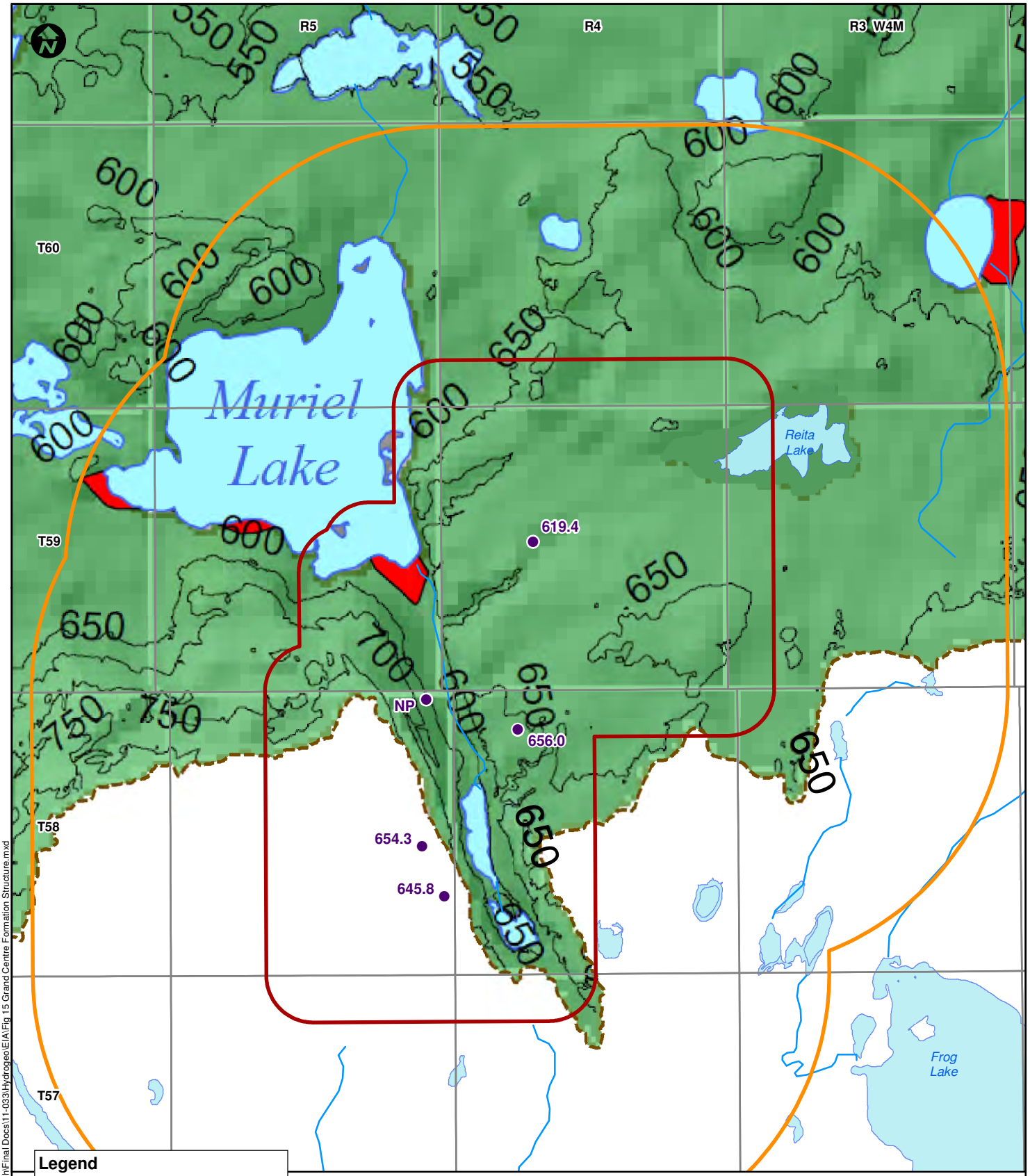
MILLENNIUM EMS Solutions Ltd.

TITLE: Marie Creek Formation Structure

DRAWN: SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 14

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 14 Marie Creek Formation Structure.mxd



Legend

- Monitoring Well
- 656.0 Formation Elevation (m asl) NP = Not Present
- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- Till
- Glaciofluvial deposits
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

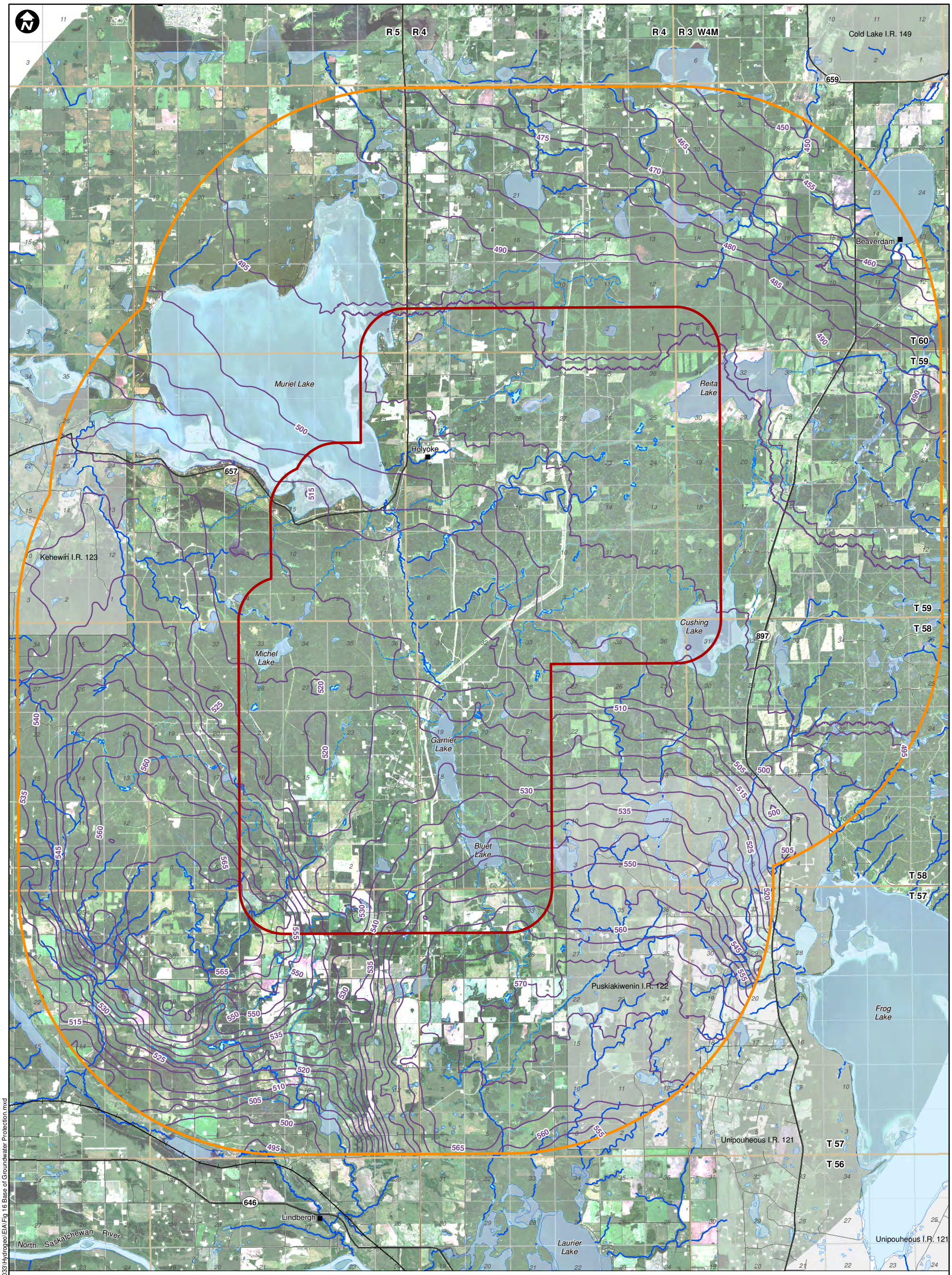
MILLENNIUM EMS Solutions Ltd.

TITLE: Grand Centre Formation Structure

DRAWN: SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 15

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 15 Grand Centre Formation Structure.mxd



Legend

- Hydrogeology Regional Study Area
- Hydrogeology Local Study Area
- First Nations
- Contour (5m interval, m asl)
- Railway
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 1.25 2.5 5
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

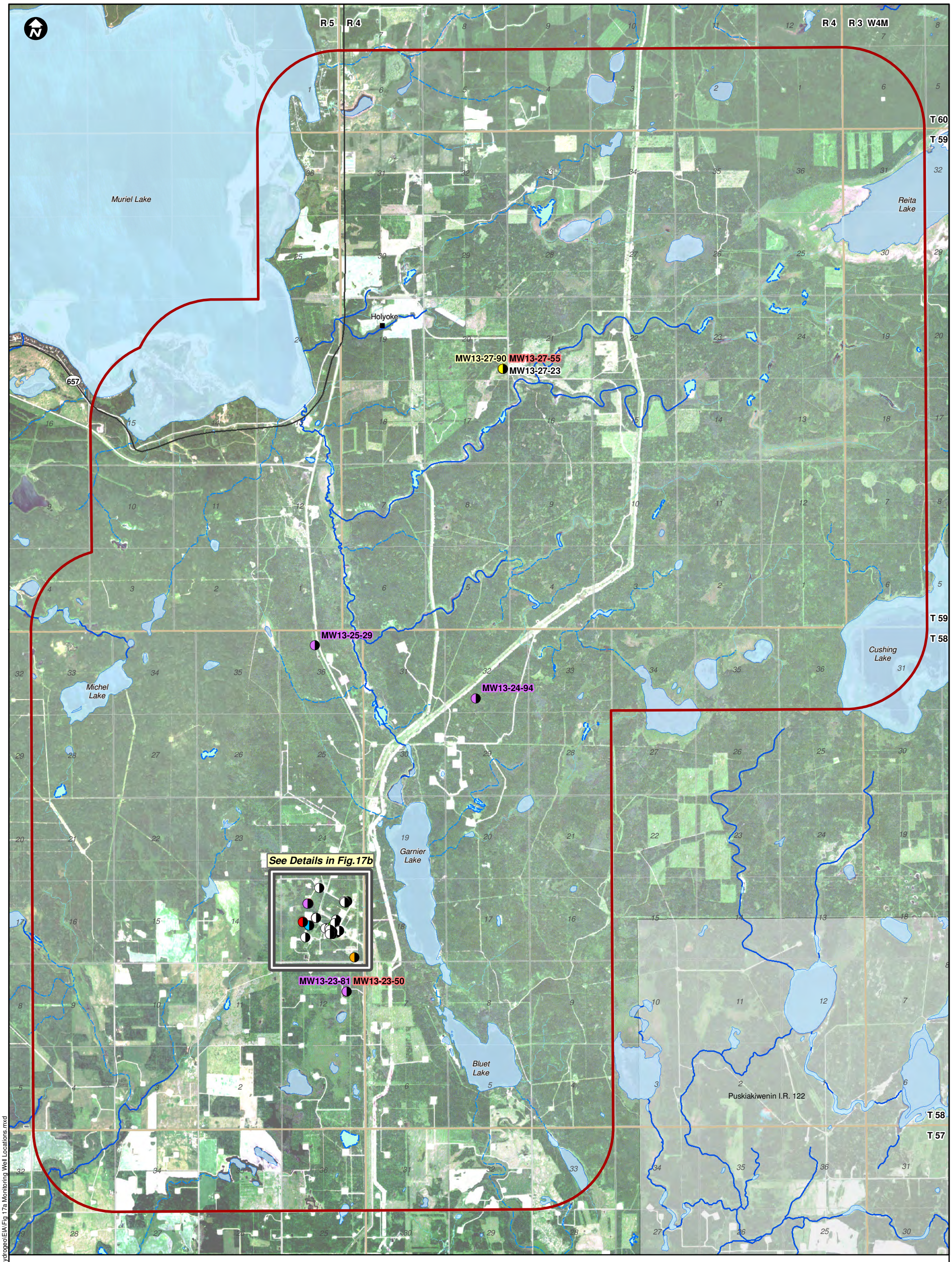
TITLE: **Base of Groundwater Protection**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 16

REF: AGS, October, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 16 Base of Groundwater Protection.mxd



Legend

Monitoring Well Completion Formation

- Bonnyville Unit 1 Fm.
- Ethel Lake Fm.
- Grand Centre Fm.
- Lea Park Fm.
- Marie Creek Fm.
- Muriel Lake Fm.
- Sand River equiv. Fm.

- Hydrogeology Local Study Area
- First Nations
- Secondary Highway
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 1.5 3
Kilometres

REF: MEMS, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

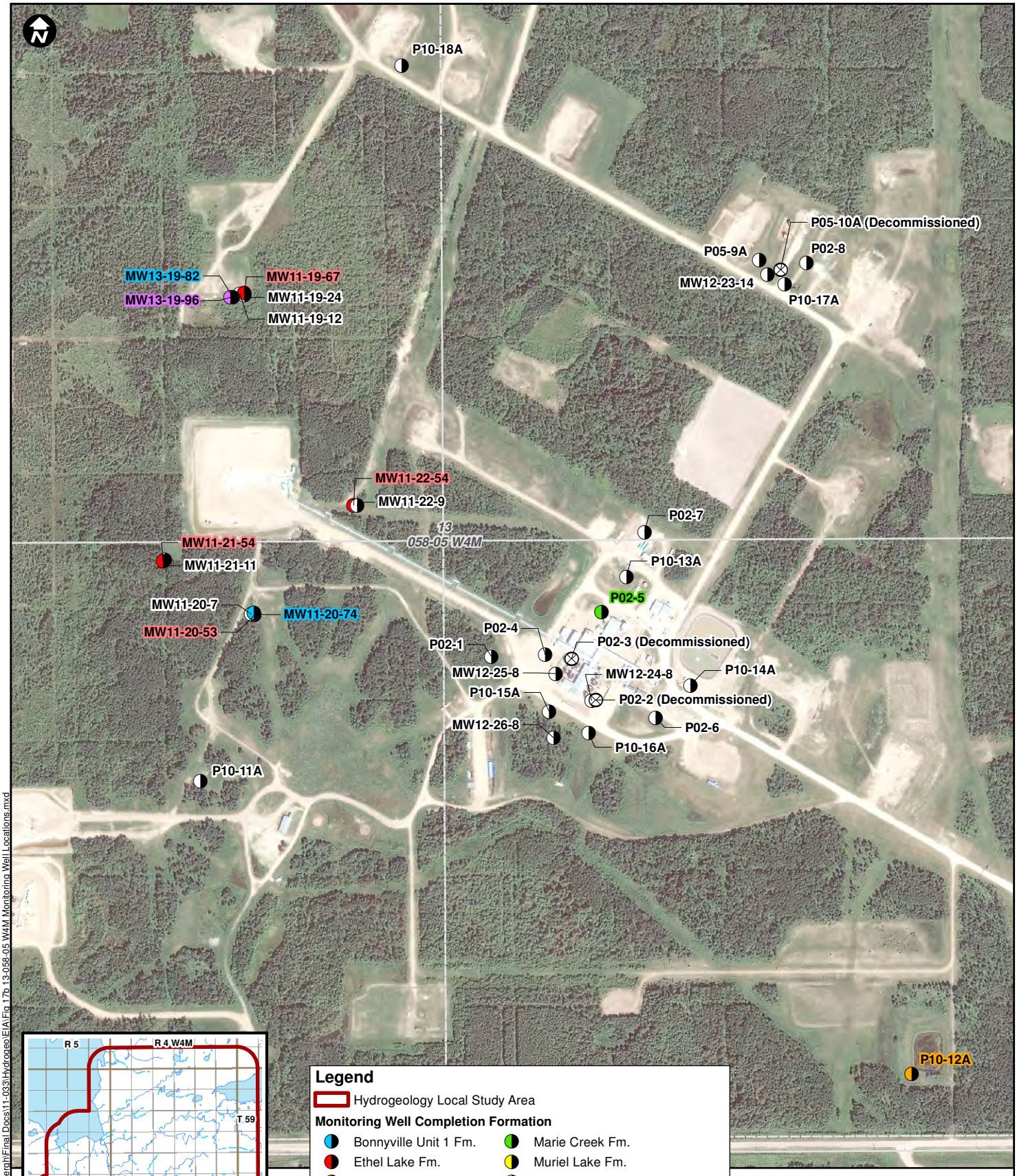
MILLENNIUM EMS Solutions Ltd.

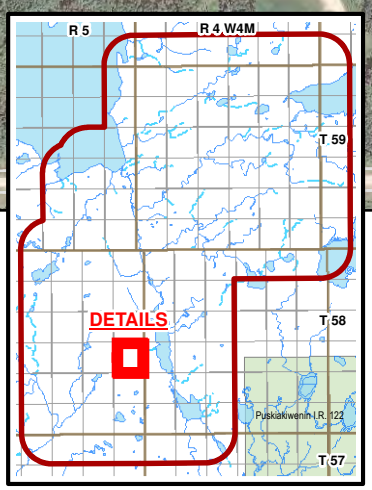
TITLE: **Monitoring Well Locations**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **17a**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 17a Monitoring Well Locations.mxd





Legend

- Hydrogeology Local Study Area

Monitoring Well Completion Formation

- Bonnyville Unit 1 Fm.
- Ethel Lake Fm.
- Grand Centre Fm.
- Lea Park Fm.
- Marie Creek Fm.
- Muriel Lake Fm.
- Sand River equiv. Fm.
- Decommissioned Monitoring Well

0 125 250
Metres

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

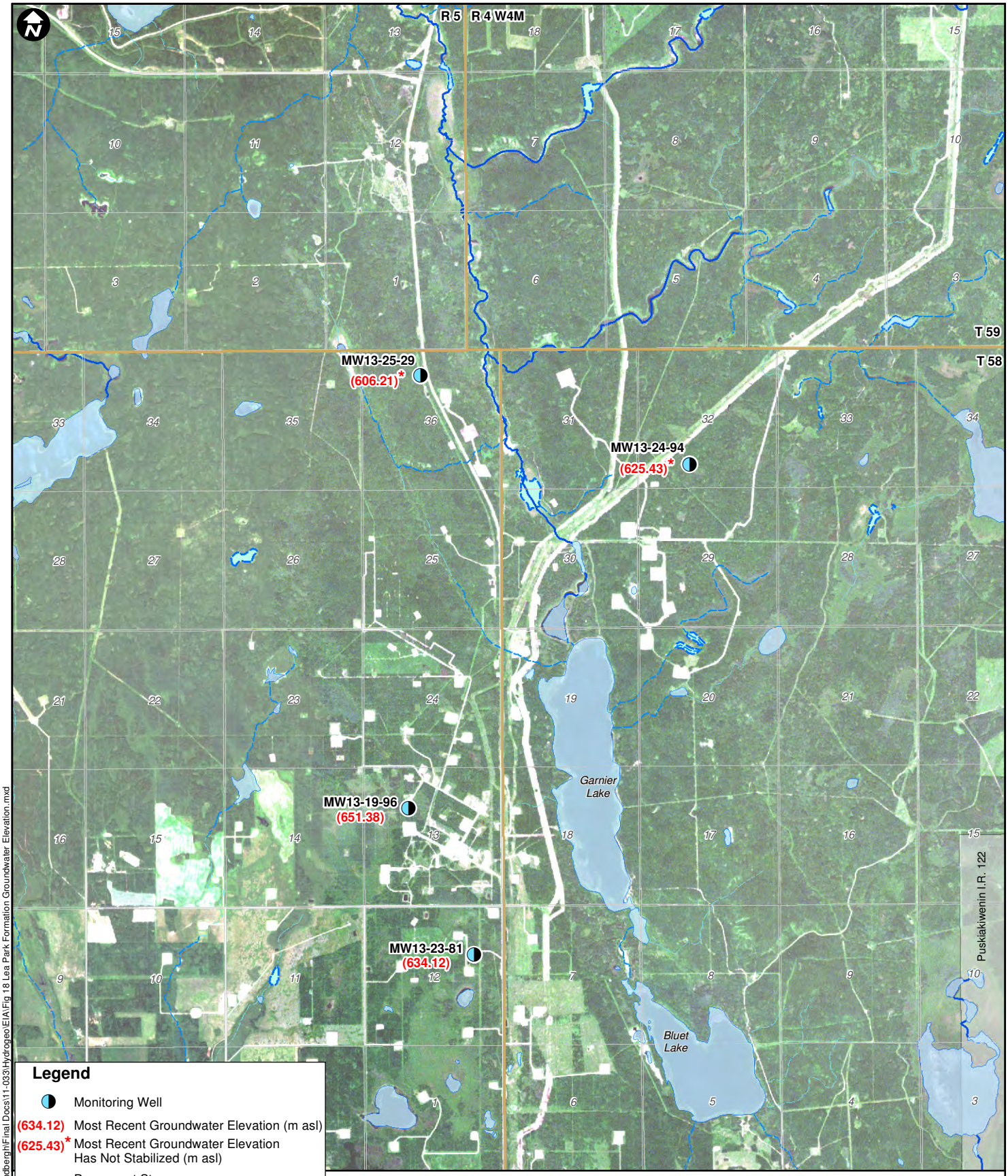
TITLE: 13-058-05 W4M Monitoring Well Locations

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 17b

REF: MEMS, 2013; Orthophoto from Pengrowth, June 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 17b 13-058-05 W4M Monitoring Well Locations.mxd



Legend

- Monitoring Well
- (634.12) Most Recent Groundwater Elevation (m asl)
- (625.43)* Most Recent Groundwater Elevation Has Not Stabilized (m asl)
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds
- First Nations

0 0.5 1 2
Kilometres

REF: MEMS, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 18 Lea Park Formation Groundwater Elevation.mxd

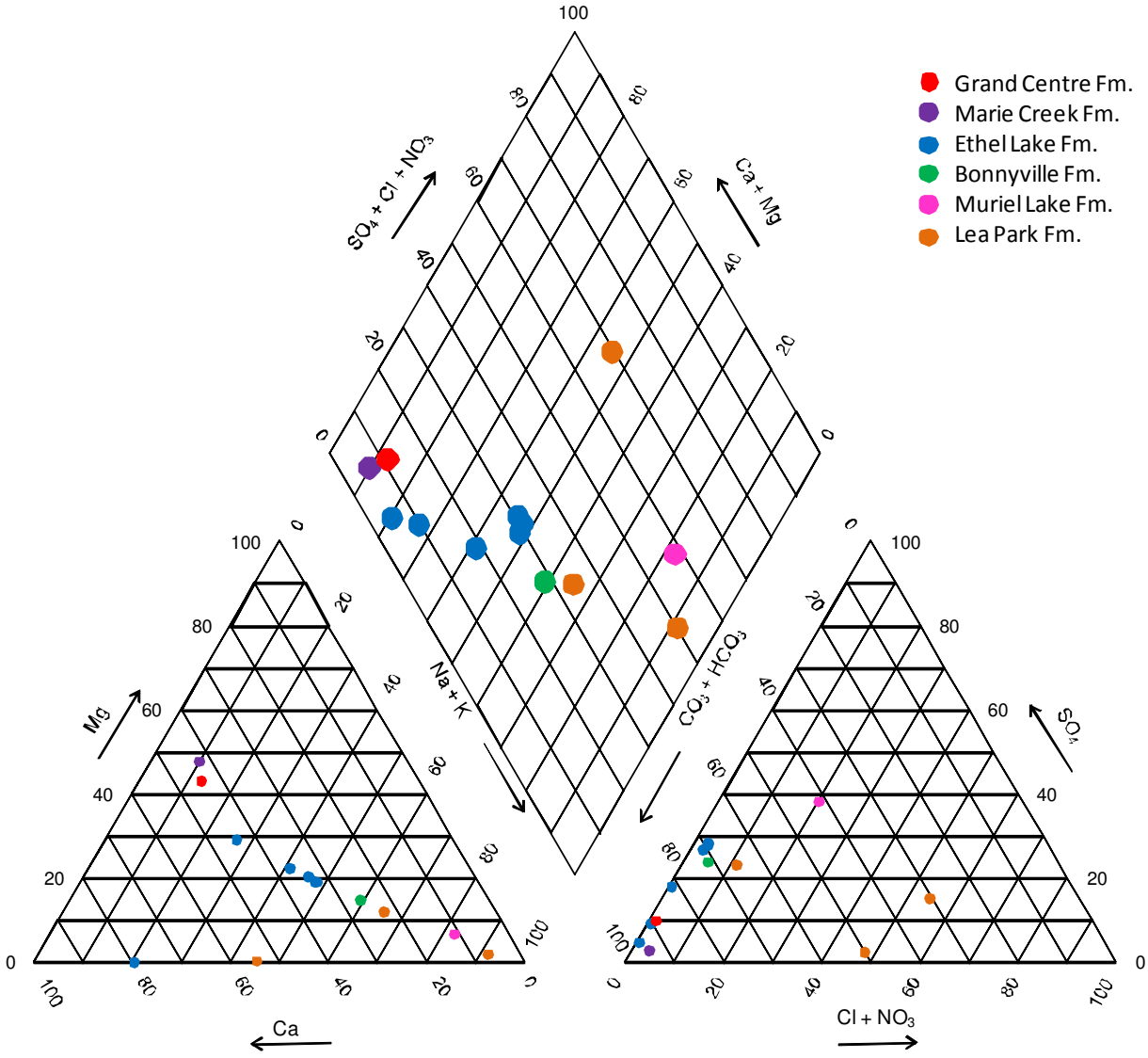
PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Lea Park Formation Groundwater Elevation**

DRAWN:	JDC/SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **18**



PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

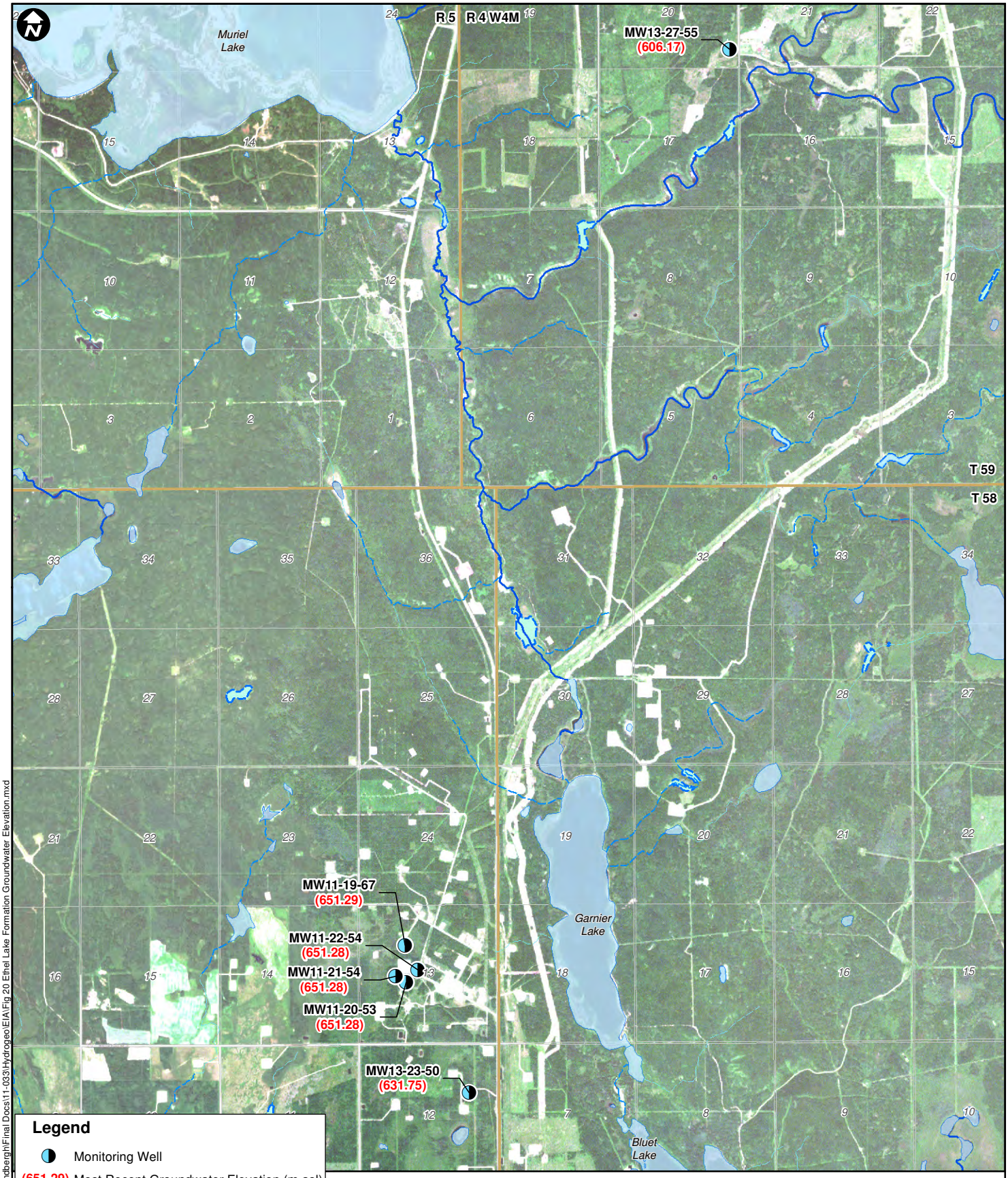
MILLENNIUM EMS Solutions Ltd.

TITLE: Piper Diagram

DRAWN: JDC
CHECKED: JD
DATE: Nov 13/13
PROJECT: 11-033

FIGURE: 19

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 19 Piper Diagram.mxd



REF: MEMS, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 20 Ethel Lake Formation Groundwater Elevation.mxd

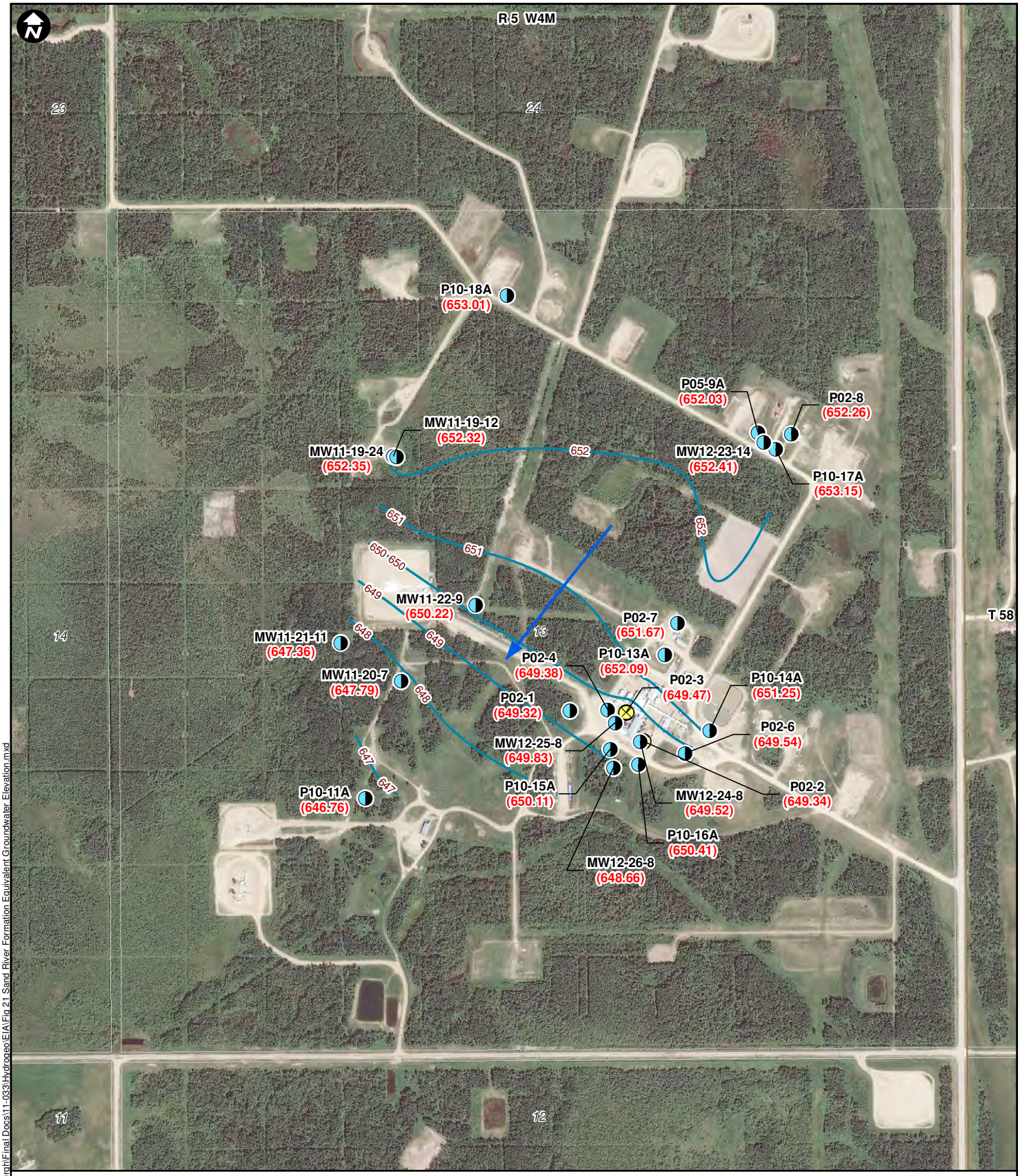
PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: Ethel Lake Formation Groundwater Elevation

DRAWN:	JDC/SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: 20



Legend

- Monitoring Well
- Decommissioned Monitoring Well
- Contour (1m interval, m asl)
- Groundwater Flow Direction
- (651.38) Most Recent Groundwater Elevation (m asl)

0 200 400
Metres

REF: MEMS, 2013; Orthophoto from Pengrowth, June 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

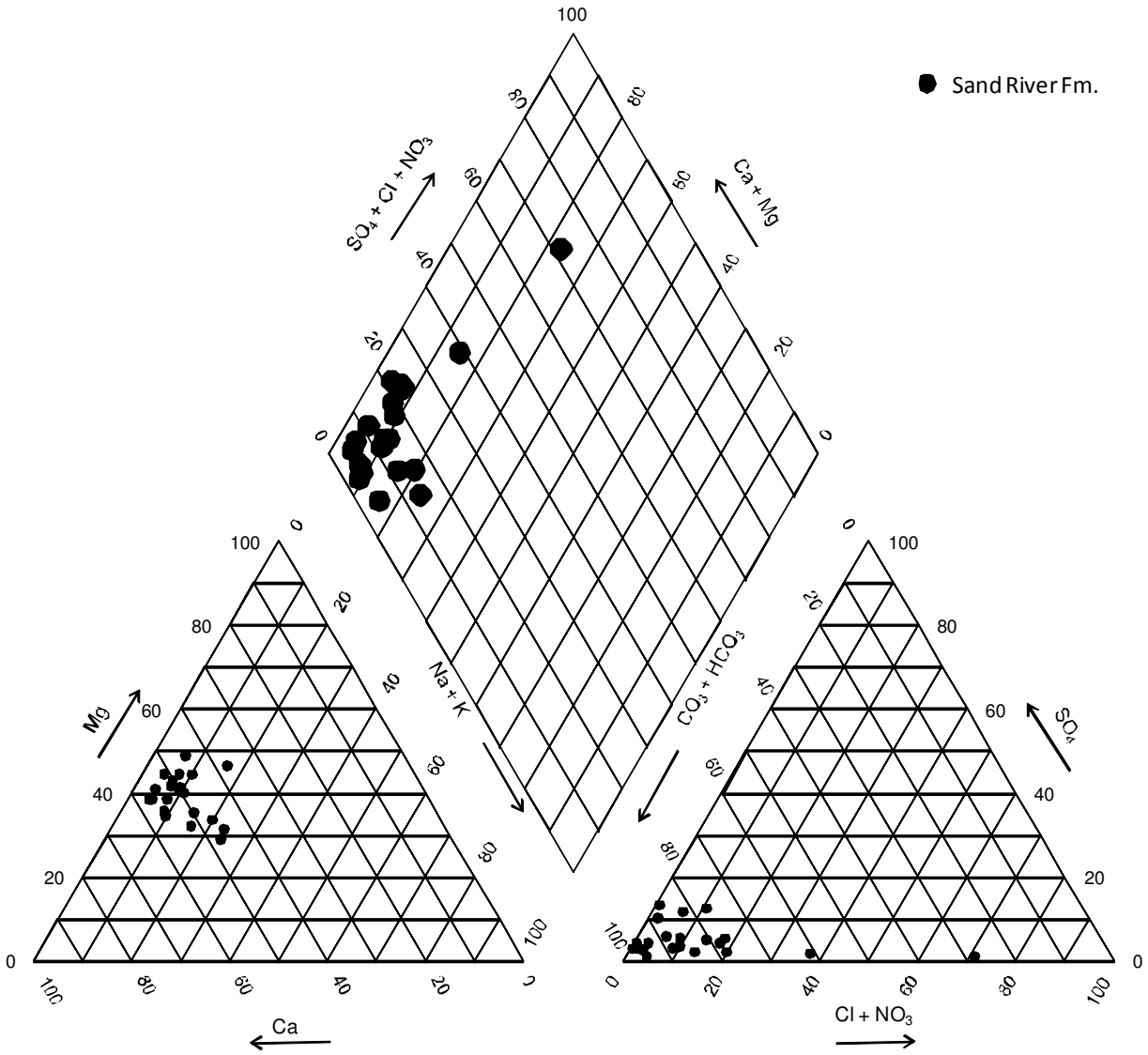
MILLENNIUM EMS Solutions Ltd.

TITLE: **Sand River Formation Equivalent Groundwater Elevation**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: 21

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 21 Sand River Formation Equivalent Groundwater Elevation.mxd



PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

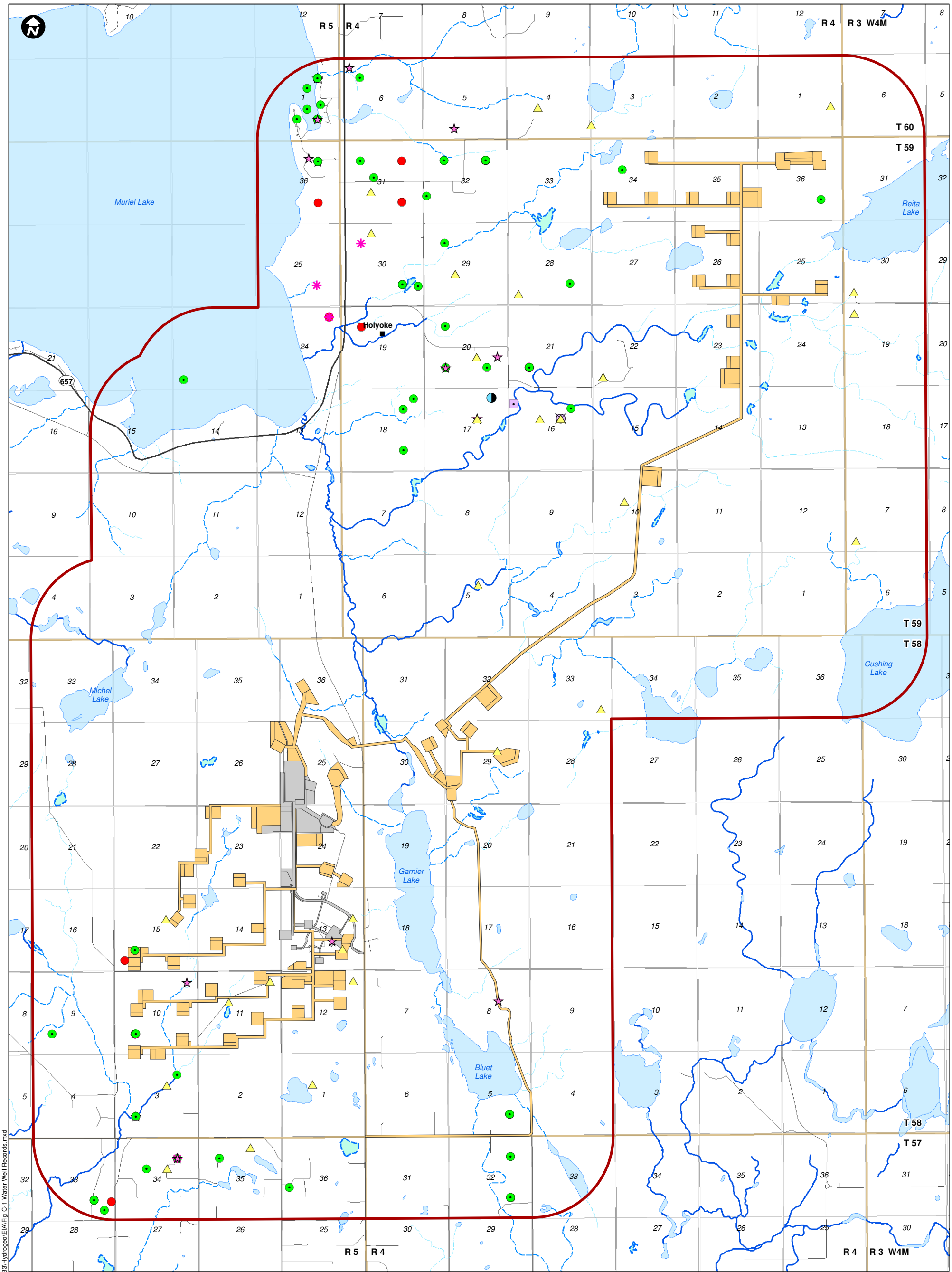
TITLE: **Piper Diagram – Sand River Formation Equivalent**

DRAWN: JDC
CHECKED: JD
DATE: Nov 8/13
PROJECT: 11-033

FIGURE: **22**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig 22 Piper Diagram – Sand River Formation Equivalent.mxd

APPENDIX C: WATER WELL RECORDS AND LICENSED USERS



Legend

Water Well

- Domestic
- Domestic/Stock
- Stock
- Monitoring
- Industrial
- Observation
- Old Well-Abandoned
- Unknown

- Local Study Area
- Development Footprint
- Existing and Approved Development
- Secondary Highway
- Improved Road

- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

PROJECT: PENGROWTH **Lindbergh SAGD Expansion Project**

MILLENNIUM EMS Solutions Ltd.

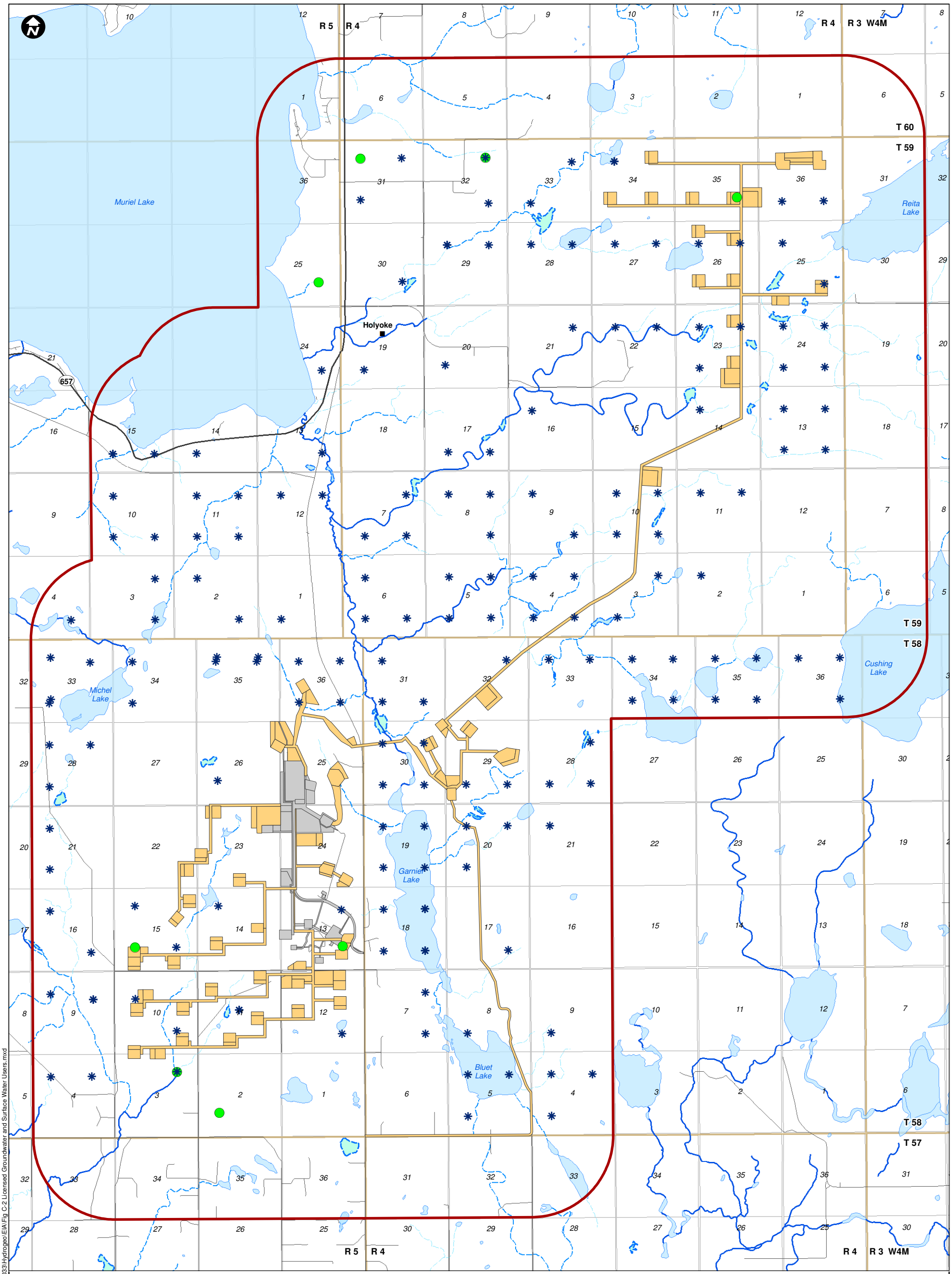
TITLE: **Water Well Records**

DRAWN: JDC/SL
CHECKED: JD
DATE: Nov 28/13
PROJECT: 11-033

FIGURE: **C-1**

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig C-1 Water Well Records.mxd



Legend

Water Users

- Groundwater
- Surface Water
- Local Study Area
- Development Footprint
- Existing and Approved Development
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Licensed Groundwater and Surface Water Users**

DRAWN: JDC/SL
CHECKED: JD
DATE: Nov 28/13
PROJECT: 11-033

FIGURE: **C-2**

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig C-2 Licensed Groundwater and Surface Water Users.mxd

Table C-1 Water Well Records within a 1.6 Kilometre Radius of the Project

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
153647	SW	21	59	4	4	TIZZARD DRILLING LTD.	10/23/1990	9.14	New Well	Stock	KELLERMAN, ERWIN	2.44	36.37
155035	SE	36	59	5	4	ROBERT, A. WATER WELL DRILLING LTD.	10/30/1979	67.06	New Well	Domestic & Stock	BROSSEAU, WILFRED	0	136.38
156194	1	33	57	5	4	MORTON'S WATER WELL DRILLING LTD.	5/10/1991	54.86	New Well	Domestic & Stock	ZAPESOCKI, HARRY	7.62	227.3
157070	NE	34	57	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	OPANAVICIUS, A.#WELL 2		
157213	1	1	60	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	WELSH, ROBERT		
158445	8	1	60	5	4	UNKNOWN DRILLER		25.91	Chemistry	Domestic	RONDEAU, CLAUDE		
158588	SE	33	57	5	4	R&D WW BORING	5/1/1972	26.52	New Well	Domestic	ZAPESOCKI, HARRY	4.88	6.82
161836	SW	10	58	5	4	UNKNOWN DRILLER		6.1	Chemistry	Domestic	OCKERMAN, ORIN		
164110	NE	34	57	5	4	LAKELAND DRILLING LTD.	3/26/1992	10.67	New Well	Stock	OPANAVICIUS, A.	6.1	54.55
165967	16	1	60	5	4	UNKNOWN DRILLER		33.53	Chemistry	Domestic	LAJEUNESSE, GERALD		
202834	1	33	57	5	4	BYRT, STAN & SONS LTD.	8/27/1975	36.58	New Well	Domestic	ZAPESOCKI, ED	4.24	54.55
202838	SE	33	57	5	4	UNKNOWN DRILLER		6.1	Chemistry	Domestic	ZAPESOCKI, NICK	3.05	
202839	SE	33	57	5	4	UNKNOWN DRILLER		24.38	Chemistry	Domestic	ZAPESOCKI, NICK	6.1	
202840	11	34	57	5	4	RONDEAU & DENOYER	9/29/1970	8.53	New Well	Domestic	HILLEBRAND, KENNETH	3.66	186.39
202845	NE	34	57	5	4	UNKNOWN DRILLER		7.62	Chemistry	Unknown	OPANAVICIUS, A.#WELL 1		
202846	NW	35	57	5	4	UNKNOWN DRILLER		7.32	Chemistry	Domestic	KUMMITZ, F.	6.71	
202848	15	35	57	5	4	UNKNOWN DRILLER	10/22/1946	599.24	Oil Exploratory	Industrial	ANGLO-CAN OIL CO #3 WELL		
206621	SE	32	57	4	4	LAKELAND DRILLING LTD.	4/1/1983	73.76	New Well	Domestic & Stock	MOLMAR, JOE	6.1	45.46
206629	SE	32	57	4	4	UNKNOWN DRILLER		45.72	Chemistry	Domestic	GALLAGHER, JUDY		
206630	NE	32	57	4	4	R&D WW BORING	4/1/1971	9.14	New Well	Domestic	GALLAGHER, ARTHUR		
206633	NE	32	57	4	4	UNKNOWN DRILLER		6.71	Chemistry	Domestic	GALLAGHER, ARTHUR	4.88	
206716	SE	5	58	4	4	MCALLISTER HOLDINGS LTD.	7/8/1988	6.71	New Well	Domestic	BLAIR, JOHN	1.83	6.82
206717	10	29	58	4	4	UNKNOWN DRILLER	10/23/1953	613.87	Structure Test Hole	Industrial	AMOCO		
206719	1	33	58	4	4	UNKNOWN DRILLER	6/28/1979	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
206733	11	1	58	5	4	UNKNOWN DRILLER		518.16	Structure Test Hole	Industrial	MURPHY OIL		
206739	SW	3	58	5	4	HORNESS D N	5/9/1965	8.23	New Well	Unknown	HILLEBRAND, E.		
206742	SW	3	58	5	4	MARTIN, J. WATER WELLS	8/29/1988	12.8	New Well	Domestic & Stock	HILLEBRAND, JOHN E.	7.32	90.92
206746	NE	3	58	5	4	UNKNOWN DRILLER		8.23	Chemistry	Domestic	GREKUL, WENDY		
206748	10	3	58	5	4	UNKNOWN DRILLER	12/13/1960	533.4	Structure Test Hole	Industrial	CAN SALT CO LTD		
206760	SW	10	58	5	4	UNKNOWN DRILLER		4.27	Chemistry	Domestic	YOUNG, BRUCE	3.35	
206769	SW	10	58	5	4	RONDEAU & DENOYER	4/1/1972	6.4	New Well	Domestic	JOHNSON, MAURICE	2.74	27.28
206773	SW	10	58	5	4	RONDEAU & DENOYER	4/1/1972	7.01	New Well	Stock	JOHNSON, MAURICE	2.74	40.91
206774	SW	10	58	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	FITZ, HEINZ		
206776	16	10	58	5	4	UNKNOWN DRILLER	9/1/1976	35.66	Test Hole	Unknown	ARC		
206780	11	11	58	5	4	UNKNOWN DRILLER	10/31/1961	548.64	Structure Test Hole	Industrial	CAN SALT CO LTD		
206784	16	11	58	5	4	UNKNOWN DRILLER	7/21/1964	502.92	Structure Test Hole	Industrial	CAN SALT CO LTD		
206785	16	12	58	5	4	UNKNOWN DRILLER	5/28/1967	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
206786	SE	13	58	5	4	UNKNOWN DRILLER		64.01	Chemistry	Industrial	MURPHY OIL CO LTD		
206799	9	13	58	5	4	UNKNOWN DRILLER	6/6/1967	518.16	Structure Test Hole	Industrial	CAN SALT CO LTD		
206802	SW	15	58	5	4	PARADIS BROS WW	9/29/1980	14.94	New Well	Domestic & Stock	BROWN, LLOYD	5.18	9.09
206805	4	15	58	5	4	PARADIS BROS WW	11/3/1980	6.4	New Well	Domestic & Stock	PARON, PAT	3.05	22.73
206808	10	15	58	5	4	UNKNOWN DRILLER	11/23/1965	606.55	Structure Test Hole	Industrial	TENNECO OIL CO		
206897	10	8	58	4	4	UNKNOWN DRILLER		23.47	Federal Well Survey	Unknown			
208711	4	7	59	3	4	UNKNOWN DRILLER	3/9/1966	264.87	Structure Test Hole	Industrial	UNION TEXAS OF CAN #M16		
208730	13	19	59	3	4	UNKNOWN DRILLER	3/7/1966	240.18	Structure Test Hole	Industrial	UNION TEXAS OF CAN #M5		
208750	4	30	59	3	4	UNKNOWN DRILLER	2/19/1971	525.78	Structure Test Hole	Industrial	GREAT NORTHERN OIL LTD		
208769	10	5	59	4	4	UNKNOWN DRILLER	2/12/1963	566.01	Structure Test Hole	Industrial	PAN AM PETRO CORP		

MILLENNIUM
EMS Solutions Ltd.

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
208771	11	10	59	4	4	UNKNOWN DRILLER	6/24/1969	457.2	Structure Test Hole	Industrial	CAN SALT CO LTD		
208772	11	16	59	4	4	UNKNOWN DRILLER	10/25/1953	452.32	Structure Test Hole	Industrial	MILL CITY PETRO LTD		
208774	NE	16	59	4	4	UNKNOWN DRILLER		13.72	Chemistry	Domestic	COULOUBE, PERCY	8.53	
208775	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	11/1/1982	130.45	New Well	Industrial	WORLD WIDE ENERGY CO #WELL 2	43.07	568.26
208779	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	11/19/1982	130.15	New Well	Industrial	WORLD WIDE ENERGY CO #WELL 5	42.67	
208783	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/20/1982	136.25	Test Hole	Unknown	WORLD WIDE ENERGY CO #WELL 1		
208785	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/27/1982	51.82	Test Hole	Unknown	WORLD WIDE ENERGY CO #4	18.35	9.09
208788	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/26/1982	51.82	Test Hole-Abandoned	Industrial	WORLD WIDE ENERGY CO #3		
208790	10	17	59	4	4	UNKNOWN DRILLER	8/9/1974	606.55	Structure Test Hole	Industrial	WORLD WIDE ENERGY CO		
208793	SE	18	59	4	4	UNKNOWN DRILLER		0	Chemistry	Domestic	ROBBIE, DENNY		
208794	NE	18	59	4	4	UNKNOWN DRILLER		9.14	Chemistry	Domestic	VACHON, MAURICE	3.05	
208796	16	18	59	4	4	RONDEAU PAUL	1/1/1967	27.13	New Well	Domestic	VACHON, JOSEPH	3.66	
208797	NW	19	59	4	4	SAWCHUK DRILLING	5/18/1989	73.15	New Well	Domestic & Stock	BROSSEAU, W.H.	18.9	45.46
208799	6	14	59	5	4	PARADIS BROS WW	7/9/1980	14.94	New Well	Domestic	BONNYVILLE, MD OF	10.97	9.09
208800	8	20	59	4	4	DESNOYER RENE	2/20/1969	32.61	Dry Hole	Unknown	SCHNIEDER, ROBERT		
208801	16	24	59	5	4	A&V ROBERT WW DRLG	10/9/1978	32	New Well	Domestic & Stock	BROSSEAU, GEORGE	9.14	22.73
208802	SE	20	59	4	4	UNKNOWN DRILLER		0	Chemistry	Domestic	KELLERMAN, BARB		
208803	7	20	59	4	4	UNKNOWN DRILLER	10/13/1962	428.24	Structure Test Hole	Industrial	BONNYVILLE OIL & REFINING CORP		
208804	16	24	59	5	4	A&V ROBERT WW DRLG	9/29/1980	64.01	New Well	Stock	BROSSEAU, GEORGE	30.48	45.46
208805	7	20	59	4	4	UNKNOWN DRILLER	8/6/1966	457.2	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208806	NW	20	59	4	4	R&D WW BORING	5/1/1974	10.67	New Well	Domestic	DAHL, LYLE	3.35	159.11
208809	SW	21	59	4	4	R&D WW BORING	4/29/1976	17.98	New Well	Domestic & Stock	BEAUCHEMIN, JACQUES P.	2.13	159.11
208811	NE	36	59	5	4	A&V ROBERT WW DRLG	7/16/1979	26.21	New Well	Domestic	SENECAL, DEAN	12.1	27.28
208813	SW	21	59	4	4	UNKNOWN DRILLER		3.96	Chemistry	Domestic	KELLERMAN, ERWIN		
208814	4	28	59	4	4	UNKNOWN DRILLER	9/27/1966	568.45	Structure Test Hole	Industrial	GREAT PLAIND DEV CO		
208816	NE	36	59	5	4	CHORNEY WATER WELL DRILLING LTD.	5/28/1982	28.96	Dry Hole	Unknown	SENECAL, DEAN		
208817	10	36	59	5	4	CHORNEY WATER WELL DRILLING LTD.		28.96	Dry Hole	Unknown	SENECAL, DEAN		
208820	6	29	59	4	4	UNKNOWN DRILLER	8/18/1966	457.2	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208822	6	29	59	4	4	UNKNOWN DRILLER	8/14/1963	396.24	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208827	SE	30	59	4	4	UNKNOWN DRILLER		14.63	Chemistry	Domestic	MARTY, FERNAND	7.32	
208828	SE	30	59	4	4	UNKNOWN DRILLER		17.68	Chemistry	Domestic	BUHL, JEAN	7.62	
208830	NW	29	59	4	4	UNKNOWN DRILLER		10.67	Chemistry	Domestic	CORBIERE, JOHN		
208831	SE	30	59	4	4	UNKNOWN DRILLER		4.27	Chemistry	Domestic	DUBEAU, JOSEPH		
208832	14	30	59	4	4	UNKNOWN DRILLER	7/9/1952	405.99	Structure Test Hole	Industrial	TOR AMERICAN OIL LTD		
208834	SE	31	59	4	4	DAN'S WATER WELL	6/20/1986	47.55	New Well	Domestic & Stock	MARTY, FERNEND	21.95	40.91
208837	6	31	59	4	4	UNKNOWN DRILLER	5/22/1964	377.95	Structure Test Hole	Industrial	CONSOLIDATED BONNYVILLE LTD		
208839	NW	31	59	4	4	UNKNOWN DRILLER	1/1/1970	9.75	Chemistry	Domestic	VACHON, PHILIPPE	4.88	
208840	NE	31	59	4	4	DAN'S WATER WELL	6/18/1986	47.24	New Well	Domestic & Stock	REGNIER, ED	22.25	45.46
208842	NW	32	59	4	4	UNKNOWN DRILLER		8.23	Chemistry	Domestic	BRUNET, GASTON	6.4	
208843	NW	32	59	4	4	UNKNOWN DRILLER		12.8	Chemistry	Domestic	JACKSON, WAYNE		
208845	NE	32	59	4	4	PARADIS BROS WW	5/31/1978	12.19	New Well	Domestic	WRIGHT, ED	2.13	9.09
208846	NE	32	59	4	4	ROBERT, A. WATER WELL DRILLING LTD.	10/10/1981	79.25	New Well	Domestic	BELANGER, RON	23.16	136.38
208848	NE	32	59	4	4	SAWCHUK DRILLING	12/5/1986	79.86	New Well	Domestic & Stock	BELANGER, RON	24.38	
208852	10	36	59	4	4	UNKNOWN DRILLER		25.91	Chemistry	Domestic	SENECAL, DEAN	24.08	
212124	8	1	60	4	4	UNKNOWN DRILLER	2/23/1966	231.34	Structure Test Hole	Industrial	UNION TEXAS CAN #UTEXCAN M7		
212126	4	3	60	4	4	UNKNOWN DRILLER	2/20/1966	197.21	Structure Test Hole	Industrial	UNION TEXAS CAN #UTEXCAN M8		
212130	6	4	60	4	4	UNKNOWN DRILLER	7/21/1972	551.69	Structure Test Hole	Industrial	GREAT NORTH OIL #GNOL MURIEL		

MILLENNIUM
EMS Solutions Ltd.

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
212133	3	5	60	4	4	UNKNOWN DRILLER	9/3/1976	33.53	Test Hole	Unknown	ARC		
212140	13	6	60	4	4	RONDEAU PAUL	7/17/1965	9.45	Well Inventory	Unknown	COTE, A.		
212160	SW	20	59	4	4	PETE'S WATERWELL CONTRACTING LTD.	5/9/1988	51.82	New Well	Domestic	VOTH, RICK	25.91	45.46
212161	SW	20	59	4	4	UNKNOWN DRILLER		50.29	Chemistry	Unknown	VACHON, MAURICE		
212163	1	1	60	5	4	UNKNOWN DRILLER		17.68	Chemistry	Domestic	LESSARD, ALPHONSE	6.1	
212165	1	1	60	5	4	UNKNOWN DRILLER		42.98	Chemistry	Unknown	MEAD, KENNETH E.		
212208	16	1	60	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	HIMSCHOOT, OCTANE	3.66	
212211	SH	1	60	5	4	UNKNOWN DRILLER		15.54	Chemistry	Domestic	MURIEL VIEWPOINT	2.44	
212213	16	1	60	5	4	CABAY DRLG SERVICE	10/24/1979	48.77	New Well	Domestic	ROWE, JAMES	2.44	22.73
212216	16	1	60	5	4	UNKNOWN DRILLER		27.43	Chemistry	Unknown	LAJUNESSE, GERALD/AUDRE		
212217	16	1	60	5	4	UNKNOWN DRILLER		41.15	Chemistry	Domestic	LAJEUNESSE, GERALD		
212218	16	1	60	5	4	DAN'S WATER WELL	4/5/1989	42.67	New Well	Domestic	LAJEUNESSE, GERALD/AUDREY	7.32	22.73
212227	16	1	60	5	4	DAN'S WATER WELL	8/2/1989	42.67	Test Hole-Abandoned	Unknown	HIMSCHOOT, OCTANE		
212230	16	1	60	5	4	DAN'S WATER WELL	8/3/1989	27.13	New Well	Domestic	HIMSCHOOT, OCTANE	3.35	31.82
214866	11	34	59	4	4	A&V ROBERT WW DRLG	12/2/1979	73.15	New Well	Domestic	BROUSSEAU, VINCENT	22.71	9.09
215001	NE	32	59	4	4	PARADIS BROS WW	10/19/1979	23.47	New Well	Domestic	OUELLETTE, LEO M	3.05	18.18
217752	SE	28	59	4	4	UNKNOWN DRILLER		74.37	Chemistry	Domestic	CARR, WM	51.82	
228496	10	34	57	5	4	UNKNOWN DRILLER	7/1/1959	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
235037	NW	6	60	4	4	CABAY DRLG SERVICE	5/9/1980	73.15	New Well	Domestic	VACHON, GIL	9.14	11.37
241162	SW	21	59	4	4	DAN'S WATER WELL	5/26/1994	40.84	New Well	Domestic	KELLERMAN, E.	17.22	36.37
254425	NE	36	59	5	4	A&C WATER WELL DRILLING	8/11/1994	51.82	Dry Hole-Abandoned	Domestic	DEARBORN, BOB		
285868	10	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/11/1996	109.73	Test Hole-Abandoned	Observation	ELAN ENERGY INC #2		
285869	10	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/9/1996	121.92	New Well	Industrial	ELAN ENERGY INC #1	17.31	45.46
285869	10	16	59	4	4	UNKNOWNDRILLINGCOMP11			Old Well - Abandoned	Old Well - Abandoned	ELAN ENERGY		
285869	10	16	59	4	4	UNKNOWNDRILLINGCOMP11			Old Well - Test	Industrial	ELAN ENERGY	18.06	74.97
285870	13	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/14/1996	140.21	Test Hole-Abandoned	Observation	ELAN ENERGY INC #3	23.47	
285871	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/10/1996	18.29	Test Hole-Abandoned	Industrial	ELAN ENERGY		
285872	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	84.73	Test Hole-Abandoned	Industrial	ELAN ENERGY	17.22	218.21
285873	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	82.91	Test Hole-Abandoned	Industrial	ELAN ENERGY		
285874	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	24.38	Test Hole-Abandoned	Industrial	ELAN ENERGY		
289206	SW	15	58	5	4	MORTON'S WATER WELL DRILLING LTD.	4/22/1998	30.48	New Well	Domestic	CAPJACK, BLAIR	8.2	31.82
291004	SW	9	58	5	4	MORTON'S WATER WELL DRILLING LTD.	4/21/1998	16.46	New Well	Domestic	GIBSON, OWEN/VAL	4.27	90.92
291020	NW	30	59	4	4	GRIZZLEY ENTERPRISES	11/20/1997	9.14	New Well	Stock	REGNIER, MORRIS	4.27	454.61
292277	16	1	60	5	4	PARKLAND DRILLING LTD.	4/19/1999	27.43	New Well	Domestic	VERRIER, SEAN	6.1	13.64
294188	SW	3	58	5	4	MARTIN WATER WELLS	5/16/2000	23.47	New Well	Domestic	HILLEBRAND, DAVID	0.61	181.84
294708	SE	5	58	4	4	HOLLAND WATER WELLS	5/18/2000	77.72	Dry Hole-Abandoned	Domestic	R.A.M. CONTRACTORS		
294709	SE	5	58	4	4	HOLLAND WATER WELLS	5/19/2000	33.53	Dry Hole-Abandoned	Domestic	R.A.M. CONTRACTORS		
1015149	7	13	58	5	4	A&C WATER WELL DRILLING		15.85	Old Well - Abandoned	Unknown	PENGROTH CORPORATION		
1420568	SE	25	59	5	4	LAKELAND DRILLING LTD.	9/24/2006	62.48	New Well	Stock	BROSSEAU, WILFRED	39.62	68.19
1490365	SW	10	58	5	4	MARTIN WATER WELLS	4/22/2009	18.29	New Well	Domestic	DESILETS, TRAVIS	3.07	54.55
1490406	5	36	57	5	4	MARTIN WATER WELLS	9/22/2009	24.38	New Well	Domestic	PRYMAK, CHRIS	12.23	86.38
1500075	SE	32	57	4	4	MCALLISTER DRILLING INC.	4/22/2003	77.11	New Well	Domestic	BRIFTOW, FRED	7.01	272.77
1580264	6	9	61	6	4	PARKLAND DRILLING LTD.	8/22/2008	48.77	New Well	Domestic	BLOCHA, RYAN	23.47	136.38
1580265	1	30	59	4	4	PARKLAND DRILLING LTD.	10/2/2008	77.72	New Well	Domestic	KOSHYKAR, TIM	21.64	227.3
1580311	11	31	59	4	4	PARKLAND DRILLING LTD.	10/16/2009	13.72	New Well	Domestic	VACHON, DIANE	5.79	31.82
1580388	4	32	59	4	4	PARKLAND DRILLING LTD.	6/1/2011	44.2	New Well	Domestic	VACHON, DIANE	23.77	54.55
2058762	16	17	59	4	4	UNKNOWN DRILLING COMP. 10		29.3	New Well	Monitoring	ALTA ENV 0W3		

Table C-2 Licensed/Registered Groundwater and Surface Water Users within a 1.6 Kilometre Radius of the Project

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
158791	54.14	-110.49	20020702002	BROSSEAU, WILFRID	BONNYVILLE/FARM UNIT/BROSSEAU WILFRED	00158791 00 00	104706	158791
251352	54.01	-110.61	20081027001	PENGROWTH ENERGY CORPORATION	ELK POINT/MUNICIPAL/PENGROWTH CORPORATION - F00251352	00251352 00 00	186690	251352
168568	54.15	-110.60	19690915003	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61132	F00168568
226730	53.98	-110.64	19751230265	OPANAVICIUS, ALFRED	ELK POINT/FARM UNIT/OPANAVICIUS ALFRED - F19138	00226730 00 00	168923	19138
148619	54.13	-110.61	19760601022	BROSSEAU, WILFRID	BONNYVILLE/FARM UNIT/BROSSEAU WILFRID - F00148619	00148619 00 00	94219	148619
164631	53.99	-110.65	19811231465	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108317	164631
163790	54.15	-110.56	19901231398	CLARK, MICHAEL	BONNYVILLE/FARM UNIT/CLARK MICHAEL -F00163790	00163790 00 00	63498	163790
160019	54.01	-110.67	19981229421	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91941	160019
259649	54.05	-110.46	19690901012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	156469	
259649	54.06	-110.46	19690901014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	156471	
259655	53.99	-110.56	19010101428	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146238	
259655	54.01	-110.58	19010101430	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146240	
259655	54.02	-110.58	19010101431	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146241	
259655	54.02	-110.58	19010101432	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146242	
259655	54.03	-110.58	19010101433	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146243	
259645	53.99	-110.57	19600101092	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153878	
259645	53.99	-110.53	19600101095	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153881	
259645	53.98	-110.57	19600101096	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153882	
259645	53.99	-110.58	19600101097	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153883	
259656	53.99	-110.57	19621101005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	154311	
259741	54.01	-110.58	19950120002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162442	
259741	54.01	-110.59	19950120003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162443	
259741	54.02	-110.59	19950120004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162444	
259741	54.02	-110.58	19950120005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162445	
259741	54.02	-110.59	19950120006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162446	
259741	54.03	-110.59	19950120007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162447	
259741	54.00	-110.58	19950120008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162448	
259674	54.05	-110.67	19651001008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	155440	
259674	54.06	-110.67	19651001009	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	155441	
259638	54.05	-110.68	19790601051	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159247	
259638	54.05	-110.69	19790601052	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159248	
160019	54.06	-110.69	19981229424	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91947	160019
160019	54.05	-110.69	19981229425	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91949	160019
259658	54.10	-110.67	19630401013	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	154438	
259660	54.11	-110.61	19630801052	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259660 00 00	154582	
259690	54.10	-110.66	19690701010	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	156401	
259698	54.13	-110.47	19710517003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157030	
259698	54.13	-110.49	19710517004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157031	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
158791	SE	35	59	4	4	Unnamed Aquifer - Potable	1602	9	1602	0	0	06AC	STCKWT	WALIC	16-Oct-02	15-Oct-27	62.8	65.8
251352	SE	13	58	5	4	Unnamed Aquifer - Potable	1825	5	1825	0	0	05ED	CAMPS	WALIC	21-Nov-08	20-Nov-33	68.3	70.3
168568	NW	31	59	4	4	Unnamed Aquifer - Unclassified	957	0	957	0	0	06AC	REGISTRY	WAREG	07-Mar-02			9.1
226730	SW	2	58	5	4	Unnamed Aquifer - Unclassified	2000	0	2000	0	0	05ED	REGISTRY	WAREG	05-Jan-06			10.7
148619	SE	25	59	5	4	Unnamed Aquifer - Unclassified	3125	0	3125	0	0	06AC	REGISTRY	WAREG	15-May-02			64
164631	NE	3	58	5	4	Unnamed Aquifer - Unclassified	1043	0	1043	0	0	05ED	REGISTRY	WAREG	11-Feb-03			8.4
163790	NE	32	59	4	4	Unnamed Aquifer - Unclassified	320	0	320	0	0	06AC	REGISTRY	WAREG	08-Mar-02			23.7
160019	SW	15	58	5	4	Unnamed Aquifer - Unclassified	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			30.5
259649	SE	36	58	4	4	Cushing Lake	372	0	372	0	0	06AD	REGISTRY	WAREG	29-May-09			
259649	NE	36	58	4	4	Cushing Lake	371	0	371	0	0	06AD	REGISTRY	WAREG	29-May-09			
259655	NE	5	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	18	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	18	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	19	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	19	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NW	5	58	4	4	Garnier Lakes	157	0	157	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NE	4	58	4	4	Garnier Lakes	156	0	156	0	0	05ED	REGISTRY	WAREG	29-May-09			
259645	SW	5	58	4	4	Garnier Lakes	156	0	156	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	SE	7	58	4	4	Garnier Lakes	156	0	156	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	SW	8	58	4	4	Garnier Lakes	1127	0	1127	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SE	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SW	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NW	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NE	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SW	19	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NW	19	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NE	7	58	4	4	Garnier Lakes	30	0	30	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	SW	34	58	5	4	Michel Lake	433	0	433	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	NW	34	58	5	4	Michel Lake	432	0	432	0	0	06AC	REGISTRY	WAREG	29-May-09			
259638	NE	28	58	5	4	Michel Lake	533	0	533	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SW	33	58	5	4	Michel Lake	533	0	533	0	0	06AC	REGISTRY	WAREG	29-May-09			
160019	NW	33	58	5	4	Michichi Lake	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	SW	33	58	5	4	Michichi Lake	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
259658	SW	15	59	5	4	Muriel Lake	398	0	398	0	0	06AC	REGISTRY	WAREG	29-May-09			
259660	SE	24	59	5	4	Muriel Lake	44	0	44	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SE	15	59	5	4	Muriel Lake	135	0	135	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	25	59	4	4	Reita Lake	228	0	228	0	0	06AD	REGISTRY	WAREG	29-May-09			
259698	NE	26	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259698	54.14	-110.46	19710517005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157032	
259698	54.14	-110.47	19710517006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157033	
259726	54.13	-110.46	19830801012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	160471	
259655	54.07	-110.50	19001225554	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189973	
259655	54.05	-110.59	19001225735	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188657	
259655	54.07	-110.51	19001225900	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189974	
259655	54.03	-110.56	19001225921	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190040	
259655	54.03	-110.54	19001225923	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190042	
259655	54.06	-110.48	19001227758	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150458	
259655	54.04	-110.58	19001227775	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150475	
259655	54.04	-110.59	19001227776	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150476	
259655	54.05	-110.59	19001227777	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150477	
259655	54.05	-110.51	19001227778	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150478	
259655	54.05	-110.52	19001227779	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150479	
259655	54.06	-110.52	19001227780	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150480	
259655	54.05	-110.49	19001227781	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150481	
259655	54.06	-110.49	19001227782	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150482	
259656	53.99	-110.61	19621101006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	154312	
259674	54.06	-110.63	19651001019	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	188379	
259674	54.06	-110.64	19651001020	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	190007	
259693	54.07	-110.66	19700101056	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156555	
259693	54.08	-110.64	19700101064	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156563	
259693	54.07	-110.62	19700101065	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156564	
259693	54.08	-110.65	19700101066	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156565	
259692	54.13	-110.50	19700901018	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156806	
259692	54.13	-110.51	19700901019	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156807	
259692	54.13	-110.52	19700901020	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156808	
259698	54.13	-110.54	19710517007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157034	
259698	54.14	-110.55	19710517008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157035	
259698	54.13	-110.55	19710517012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189932	
259593	54.10	-110.50	19780101015	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259593 00 00	158867	
259638	54.04	-110.69	19790601058	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159254	
259638	54.05	-110.69	19790601059	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159255	
226730	54.01	-110.65	19801230922	OPANAVICIUS, ALFRED	ELK POINT/FARM UNIT/OPANAVICIUS ALFRED - F19138	00226730 00 00	168925	19138
168568	54.14	-110.60	19841020001	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61137	F00168568
259698	54.15	-110.52	19890601093	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188892	
163790	54.15	-110.56	19901231399	CLARK, MICHAEL	BONNYVILLE/FARM UNIT/CLARK MICHAEL -F00163790	00163790 00 00	63501	163790
259698	54.13	-110.57	19910601063	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188381	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259698	SE	36	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			
259698	SW	36	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	SE	25	59	4	4	Reita Lake	504	0	504	0	0	06AD	REGISTRY	WAREG	29-May-09			
259655	NW	2	59	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	31	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	3	59	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	20	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	21	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	35	58	4	4	Surface Runoff	63	0	63	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	35	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	35	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	SE	12	58	5	4	Surface Runoff	376	0	376	0	0	05ED	REGISTRY	WAREG	29-May-09			
259674	NE	35	58	5	4	Surface Runoff	432	0	432	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	NW	35	58	5	4	Surface Runoff	443	0	443	0	0	05ED	REGISTRY	WAREG	29-May-09			
259693	SE	3	59	5	4	Surface Runoff	713	0	713	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SE	11	59	5	4	Surface Runoff	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	1	59	5	4	Surface Runoff	158	0	158	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	11	59	5	4	Surface Runoff	158	0	158	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	26	59	4	4	Surface Runoff	285	0	285	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	27	59	4	4	Surface Runoff	285	0	285	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	27	59	4	4	Surface Runoff	284	0	284	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	28	59	4	4	Surface Runoff	130	0	130	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	SW	33	59	4	4	Surface Runoff	130	0	130	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	28	59	4	4	Surface Runoff	390	0	390	0	0	06AC	REGISTRY	WAREG	29-May-09			
259593	NW	14	59	4	4	Surface Runoff	564	0	564	0	0	06AC	REGISTRY	WAREG	29-May-09			
259638	SW	28	58	5	4	Surface Runoff	89	0	89	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	NW	28	58	5	4	Surface Runoff	89	0	89	0	0	06AC	REGISTRY	WAREG	29-May-09			
226730	SE	15	58	5	4	Surface Runoff	688	0	688	0	0	05ED	REGISTRY	WAREG	05-Jan-06			
168568	SW	31	59	4	4	Surface Runoff	111	0	111	0	0	06AC	REGISTRY	WAREG	07-Mar-02			
259698	NW	34	59	4	4	Surface Runoff	344	0	344	0	0	06AC	REGISTRY	WAREG	29-May-09			
163790	NE	32	59	4	4	Surface Runoff	85	0	85	0	0	06AC	REGISTRY	WAREG	08-Mar-02			
259698	NW	29	59	4	4	Surface Runoff	344	0	344	0	0	06AC	REGISTRY	WAREG	29-May-09			

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
162976	54.11	-110.57	19951231180	VACHON, HELENE	BONNYVILLE/FARM UNIT/VACHON HELENE - F00162976	00162976 00 00	59974	162976
160019	54.00	-110.67	19981229422	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91942	160019
160019	54.02	-110.67	19981229423	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91944	160019
160019	54.06	-110.63	19981229427	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91952	160019
160019	54.04	-110.64	19981229428	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91953	160019
160019	54.06	-110.64	19981229429	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91954	160019
259655	54.05	-110.48	19001225555	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190062	
259655	54.08	-110.59	19001225566	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188363	
259655	54.02	-110.57	19001225567	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188366	
259655	54.04	-110.57	19001225568	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188367	
259655	54.09	-110.49	19001225572	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188376	
259655	54.04	-110.56	19001225573	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188377	
259655	54.07	-110.52	19001225722	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188626	
259655	54.07	-110.57	19001225723	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188630	
259655	54.07	-110.60	19001225724	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188631	
259655	54.09	-110.59	19001225725	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188632	
259655	54.09	-110.56	19001225726	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188633	
259655	54.09	-110.55	19001225727	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188634	
259655	54.04	-110.53	19001225731	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188652	
259655	54.04	-110.54	19001225733	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188654	
259655	54.05	-110.58	19001225734	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188655	
259655	54.06	-110.51	19001225736	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188658	
259655	54.09	-110.52	19001225895	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189916	
259655	54.08	-110.51	19001225896	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189917	
259655	54.08	-110.52	19001225897	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189918	
259655	54.09	-110.50	19001225898	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189919	
259655	54.09	-110.51	19001225899	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189939	
259655	54.07	-110.54	19001225901	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189975	
259655	54.07	-110.55	19001225902	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189976	
259655	54.07	-110.54	19001225903	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189981	
259655	54.07	-110.55	19001225904	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189982	
259655	54.07	-110.56	19001225905	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189983	
259655	54.07	-110.56	19001225906	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189984	
259655	54.07	-110.57	19001225907	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189985	
259655	54.07	-110.59	19001225908	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189986	
259655	54.07	-110.60	19001225909	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189987	
259655	54.08	-110.60	19001225910	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189988	
259655	54.09	-110.57	19001225911	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189989	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
162976	SW	20	59	4	4	Surface Runoff	200	0	200	0	0	06AC	REGISTRY	WAREG	06-Mar-02			
160019	NW	10	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NW	15	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NE	35	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	SW	26	58	5	4	Surface Runoff	237	0	237	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NW	35	58	5	4	Surface Runoff	237	0	237	0	0	05ED	REGISTRY	WAREG	06-May-02			
259655	SE	35	58	4	4	Unnamed Stream - Unclassified	30	0	30	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	20	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	29	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	11	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	29	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	3	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	9	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	30	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	30	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	34	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	11	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259655	54.08	-110.56	19001225912	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189990	
259655	54.08	-110.54	19001225913	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189991	
259655	53.99	-110.54	19001225914	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190032	
259655	54.01	-110.56	19001225920	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190039	
259655	54.03	-110.57	19001225922	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190041	
259655	54.05	-110.53	19001225930	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190052	
259655	54.06	-110.59	19001225933	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190057	
259655	54.05	-110.58	19001225934	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190058	
259655	54.06	-110.56	19001225935	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190059	
259655	54.06	-110.53	19001225936	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190060	
259655	54.06	-110.54	19001225937	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190061	
165271	54.02	-110.64	19281231204	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137800	165271
259627	53.99	-110.68	19560501014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	188620	
259627	54.00	-110.69	19560501025	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	190016	
259627	53.99	-110.69	19560501026	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	190064	
259645	53.98	-110.54	19600101124	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	188374	
259645	53.99	-110.54	19600101127	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	190031	
259656	54.02	-110.61	19621101024	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	190017	
164631	53.99	-110.65	19621231327	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108318	164631
164631	54.00	-110.65	19621231328	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108319	164631
259658	54.06	-110.68	19630401055	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	188636	
259658	54.07	-110.69	19630401070	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	189938	
259660	54.11	-110.60	19630801075	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259660 00 00	189924	
259676	54.09	-110.61	19651215002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155472	
259676	54.10	-110.61	19651215003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155473	
259676	54.05	-110.61	19651215005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155475	
259676	54.05	-110.62	19651215006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155476	
259676	54.06	-110.62	19651215007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155477	
259676	54.06	-110.61	19651215008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155478	
259676	54.09	-110.62	19651215009	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	189951	
259690	54.10	-110.65	19690701042	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	189952	
259690	54.10	-110.67	19690701043	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	189953	
259649	54.06	-110.47	19690901027	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	190063	
259693	54.08	-110.67	19700101130	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188380	
259693	54.07	-110.66	19700101131	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188686	
259693	54.08	-110.66	19700101132	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188692	
259693	54.09	-110.65	19700101133	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188694	
259693	54.07	-110.65	19700101137	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189936	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259655	SE	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	9	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	9	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	17	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	20	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	31	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	31	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	32	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	33	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	33	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271	NW	14	58	5	4	Unnamed Stream - Unclassified	1820	0	1820	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
259627	NE	4	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259627	NW	9	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259627	NW	4	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259645	SW	4	58	4	4	Unnamed Stream - Unclassified	312	0	312	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NW	4	58	4	4	Unnamed Stream - Unclassified	313	0	313	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	NE	13	58	5	4	Unnamed Stream - Unclassified	1503	0	1503	0	0	05ED	REGISTRY	WAREG	29-May-09			
164631	NE	3	58	5	4	Unnamed Stream - Unclassified	405	0	405	0	0	05ED	REGISTRY	WAREG	11-Feb-03			
164631	SE	10	58	5	4	Unnamed Stream - Unclassified	570	0	570	0	0	05ED	REGISTRY	WAREG	11-Feb-03			
259658	NE	33	58	5	4	Unnamed Stream - Unclassified	75	0	75	0	0	06AC	REGISTRY	WAREG	29-May-09			
259658	SE	4	59	5	4	Unnamed Stream - Unclassified	75	0	75	0	0	06AC	REGISTRY	WAREG	29-May-09			
259660	SW	19	59	4	4	Unnamed Stream - Unclassified	44	0	44	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NE	12	59	5	4	Unnamed Stream - Unclassified	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SE	13	59	5	4	Unnamed Stream - Unclassified	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SE	36	58	5	4	Unnamed Stream - Unclassified	54	0	54	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SW	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NW	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NE	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NW	12	59	5	4	Unnamed Stream - Unclassified	531	0	531	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SW	14	59	5	4	Unnamed Stream - Unclassified	67	0	67	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SW	15	59	5	4	Unnamed Stream - Unclassified	68	0	68	0	0	06AC	REGISTRY	WAREG	29-May-09			
259649	NW	36	58	4	4	Unnamed Stream - Unclassified	137	0	137	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	10	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NE	3	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SE	10	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	11	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	2	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			

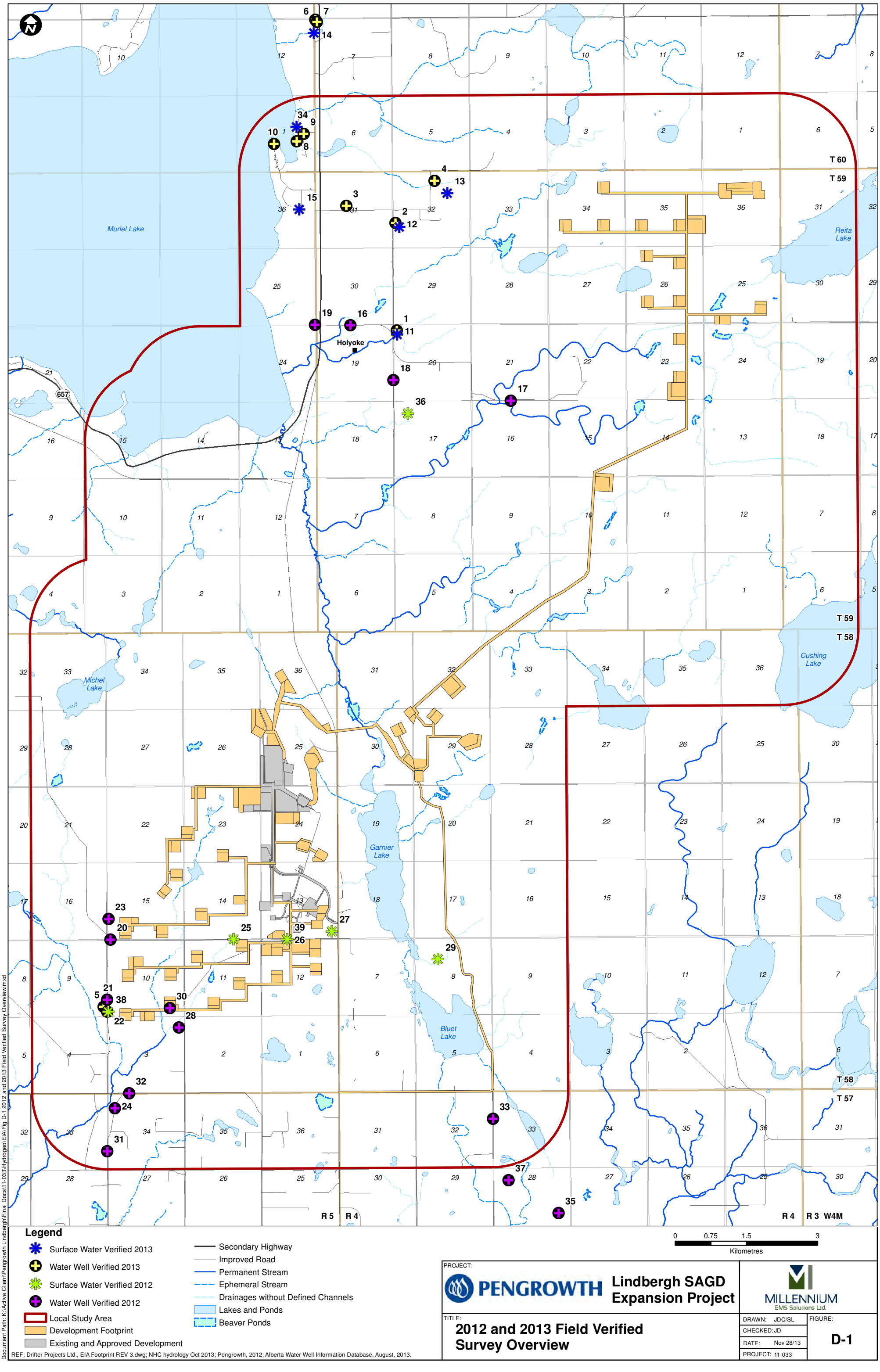
MILLENNIUM
EMS Solutions Ltd.

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259693	54.07	-110.64	19700101138	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189937	
259693	54.09	-110.67	19700101139	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189949	
259693	54.09	-110.64	19700101140	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189950	
260703	54.14	-110.56	19700701077	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00260703 00 00	189934	
259692	54.12	-110.54	19700901074	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	188360	
259692	54.11	-110.50	19700901075	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	188682	
259692	54.12	-110.51	19700901079	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189925	
259692	54.12	-110.52	19700901080	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189926	
259692	54.12	-110.49	19700901081	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189927	
259692	54.12	-110.50	19700901082	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189928	
165271	54.00	-110.64	19701230546	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137794	165271
259698	54.13	-110.57	19710517010	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188684	
259698	54.15	-110.52	19710517011	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188685	
259698	54.13	-110.56	19710517013	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189933	
259698	54.15	-110.54	19710517014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189935	
168568	54.15	-110.59	19721231188	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61149	F00168568
259638	54.02	-110.69	19790601097	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	189992	
259638	54.01	-110.68	19790601098	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	189993	
259638	54.03	-110.69	19790601105	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	190002	
259638	54.02	-110.69	19790601106	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	190003	
259726	54.11	-110.46	19830801021	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	188683	
259726	54.10	-110.46	19830801022	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189920	
259726	54.10	-110.47	19830801023	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189921	
259726	54.10	-110.46	19830801024	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189922	
259726	54.10	-110.47	19830801025	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189923	
259726	54.12	-110.46	19830801026	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189929	
259726	54.12	-110.47	19830801027	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189930	
259726	54.11	-110.47	19830801028	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189931	
165271	54.00	-110.64	19851230449	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137793	165271
156927	54.13	-110.59	19921009001	DONALD & CAROL-ANN CAMERON	BONNYVILLE/FARM UNIT/DONALD & CAROL-ANN CAMERON - F00156927	00156927 00 00	56864	156927
259744	54.10	-110.57	19970602002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162691	
259744	54.10	-110.55	19970602003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162692	
259744	54.10	-110.56	19970602004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162693	
180071	54.00	-110.68	19981229180	OCKERMAN, ERICA	DEWBERRY/FARM UNIT/OCKERMAN ERICA - F00180071	00180071 00 00	89289	180071
180071	54.00	-110.68	19981229181	OCKERMAN, ERICA	DEWBERRY/FARM UNIT/OCKERMAN ERICA - F00180071	00180071 00 00	89292	180071

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259693	SE	2	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	10	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NE	11	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
260703	SE	32	59	4	4	Unnamed Stream - Unclassified	136	0	136	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	21	59	4	4	Unnamed Stream - Unclassified	143	0	143	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	SW	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	22	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	22	59	4	4	Unnamed Stream - Unclassified	143	0	143	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271		11	58	5	4	Unnamed Stream - Unclassified	910	0	910	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
259698	NW	29	59	4	4	Unnamed Stream - Unclassified	228	0	228	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	34	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	29	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	33	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
168568	NE	31	59	4	4	Unnamed Stream - Unclassified	261	0	261	0	0	06AC	REGISTRY	WAREG	07-Mar-02			
259638	NW	16	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SE	16	58	5	4	Unnamed Stream - Unclassified	112	0	112	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	NW	21	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SW	21	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259726	SE	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	NE	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	NW	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SE	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SW	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	NE	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	NW	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SW	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271		11	58	5	4	Unnamed Stream - Unclassified	910	0	910	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
156927	SE	30	59	4	4	Unnamed Stream - Unclassified	185	0	185	0	0	06AC	REGISTRY	WAREG	05-Mar-02			
259744	SW	17	59	4	4	Unnamed Stream - Unclassified	74	0	74	0	0	06AC	REGISTRY	WAREG	29-May-09			
259744	NW	16	59	4	4	Unnamed Stream - Unclassified	73	0	73	0	0	06AC	REGISTRY	WAREG	29-May-09			
259744	SE	17	59	4	4	Unnamed Stream - Unclassified	73	0	73	0	0	06AC	REGISTRY	WAREG	29-May-09			
180071	NE	9	58	5	4	Unnamed Stream - Unclassified	471	0	471	0	0	05ED	REGISTRY	WAREG	29-Apr-02			
180071	NE	9	58	5	4	Unnamed Stream - Unclassified	471	0	471	0	0	05ED	REGISTRY	WAREG	29-Apr-02			

APPENDIX D: FIELD VERIFIED SURVEY INFORMATION



REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: 2012 and 2013 Field Verified Survey Overview

DRAWN: JDC/SL
CHECKED: JD
DATE: Nov 28/13
PROJECT: 11-033

FIGURE: D-1

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA\Fig D-1 2012 and 2013 Field Verified Survey Overview.mxd

Table D-1: Field Verified Survey Summary

Symbol No. on Figure D-1	FVS Date	Legal Location (W4M)	Latitude	Longitude	Ground Elevation	Water Source	Status	Well Depth (m)	GIC Well ID	Drill Date	Non-Pumping Water Level		Completion	Max Pumping Rate (L/min)	No. of Users	Purpose of Use	Run Dry? (Y/N)	Number of Previous Chemical Analyses
											Original (m)	Current (m)						
1	19-Jun-13	NW 20-059-04	54.12	-110.58	604.79	bored well	producing	10.7	-	1933	4.57	-	open Hole	-	2 people	Domestic/Livestock	Y	1
2	19-Jun-13	SW 32-059-04	54.14	-110.58	610.80	well	producing	39.6	-	2011	-	-	screened	32	1 person	Domestic	N	1
3	20-Jun-13	NE 31-059-04	54.15	-110.60	596.86	well	not in use	-	-	-	-	6.68	-	-	-	Not in use	-	-
4	20-Jun-13	NE 32-059-04	54.15	-110.57	605.99	bored well	producing	23.8	-	1970s	2.44	-	-	36	2 people, 30 cattle	Domestic/Livestock	N	2
5	20-Jun-13	SE 09-058-05	53.99	-110.67	649.25	well	producing	19.8	291004	1998	-	-	screened	295	4 people	Domestic	N	2
6	21-Jun-13	NW 07-060-04	54.18	-110.60	572.11	well	producing	44.5	-	2010	-	12.48	perforated or screened	-	3 people, 9 cattle, 3 donkey/llama	Domestic/Livestock	N	1
7	21-Jun-13	NW 07-060-04	54.18	-110.60	571.63	bored well	not in use	14.0	-	2005	-	1.74	open hole	-	-	Not in use	N	1
8	18-Jul-13	SE 01-060-05	54.16	-110.61	578.84	bored well	producing	25.9	-	1983 (Sep)	7.62	22.86	open hole	227-273	2 people	Domestic	Y	2
9	18-Jul-13	SE 01-060-05	54.16	-110.61	577.63	well	not in use	121.9	-	1995	-	6.68	screened	455	-	Not in use	Y	-
10	18-Jul-13, 18-Oct-13	SW 01-060-05	54.16	-110.62	575.71	artesian well	producing	43.0	-	16-Jun-83	-	-	-	-	3 people	Domestic	Y	2
11	19-Jun-13	NW 20-059-04	54.12	-110.58	600.71	dugout	active	-	-	-	-	-	-	-	-	Unknown	N	-
12	19-Jun-13	SW 32-059-04	54.14	-110.58	599.02	dugout	not in use	-	-	-	-	-	-	-	-	Not in use	-	-
13	20-Jun-13	NE 32-059-04	54.15	-110.56	601.67	dugout	active	-	-	-	-	-	-	-	-	Livestock	N	-
14	21-Jun-13	NW 07-060-04	54.18	-110.61	574.75	slough	active	-	-	-	-	-	-	-	9 cattle, 3 donkey/llama	Livestock	N	-
15	22-Jun-13	NE 36-059-05	54.14	-110.61	578.35	dugout	active	-	-	-	-	-	-	-	-	Landscape Maintenance	Y	-
34	18-Oct-13	NE 01-060-05	54.16	-110.61	580.04	spring	-	-	-	-	-	-	-	-	-	Unknown	-	-
16	16-Jun-12	NW 19-059-04	54.12	-110.59	591.81	well	active	86.9	208797	-	-	-	-	-	1 person	Domestic	N	1
17	14-Jun-12	NE 16-059-04	54.11	-110.54	613.92	well	active	59.1	-	1982 (spring)	-	-	-	-	1 person	Domestic	N	1
18	14-Jun-12	SW 20-059-04	54.11	-110.58	608.16	well	active	50.3	212161	1988	-	-	-	-	1 person	Domestic	N	1
19	14-Jun-12	NE 24-059-05	54.12	-110.61	598.06	well	active	-	208801	late 1970s	-	-	-	-	2 people	Domestic	N	1
20	18-Jan-12	SW 15-058-05	54.01	-110.67	659.59	well	active	6.1	206805	1989	-	2.74	-	-	2 people	Domestic	N	1
21	18-Jan-12	SW 10-058-05	53.99	-110.67	644.20	well	active	33.5	-	1970s	-	-	-	-	2 people	Domestic	N	1
22	18-Jan-12	SW 10-058-05	53.99	-110.67	648.05	well	active	-	-	-	-	-	-	-	4 people, 5 cattle	Domestic/Livestock	N	1
23	17-Jun-12	SW 15-058-05	54.01	-110.67	660.79	well	producing	30.5	289206	1998	-	-	screened	36	-	Domestic/Livestock	N	1
24	15-Jun-12	NW 34-057-05	53.97	-110.67	624.74	well	active	7.9	202840	1971	-	-	-	-	4 people	Domestic	N	1
25	15-Jun-12	SE 14-058-05	54.01	-110.63	644.20	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
26	15-Jun-12	SW 13-058-05	54.01	-110.62	649.01	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
27	15-Jun-12	SE 13-058-05	54.01	-110.60	650.93	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
28	15-Jul-12	NE 03-058-05	53.99	-110.65	646.85	well	active	8.5	-	1983	-	-	-	-	4 people, 400 cattle	Domestic/Livestock	N	1
29	15-Jun-12	NW 08-058-04	-	-	-	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
30	18-Jan-12	SE 10-058-05	53.99	-110.65	624.13	well	active	10.7	-	-	-	-	-	136	3 people	Domestic	N	1
31	18-Jan-12	SE 33-058-05	53.97	-110.67	626.90	well	active	61.0	-	-	-	-	-	-	2 people	Domestic/Livestock	-	-
32	15-Jun-12	SW 03-058-05	53.98	-110.67	644.20	well	active	12.2	206742	1980s or 90s	-	-	-	-	2 people, 5 cattle	Domestic/Livestock	N	1
33	30-Jan-12	NE 32-057-04	-	-	-	well	producing	73.2	-	2003 (summer)	6.40	6.40	screened	68	2 people, 20 livestock/ponies	Domestic/Livestock	N	2
37	30-Jan-12	NW 28-057-04	-	-	-	well	producing	47.9	-	1985 (fall)	4.57	47.85	screened	45	-	Livestock	N	1
35	30-Jan-12	SW 28-057-04	-	-	-	well	producing	62.5	-	2002 (fall)	-	-	screened	45	60 cattle	Livestock	N	1
36	14-Jul-12	NW 17-059-04	-	-	-	creek	active	-	-	-	-	-	-	-	30-35 cattle	Livestock	-	-
38	18-Jan-12	SW 10-058-05	53.99	-110.67	648.05	creek	active	-	-	-	-	-	-	-	5 cattle	Livestock	-	1
39	15-Jun-12	SW 13-058-05	54.01	-110.62	649.01	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-

APPENDIX E: GROUNDWATER MONITORING PROGRAM

MILLENNIUM
EMS Solutions Ltd.

6111 91 Street
Edmonton, AB T6E 6V6
tel: 780.496.9048
fax: 780.496.9049

Suite 325, 1925 18 Avenue NE
Calgary, AB T2E 7T8
tel: 403.592.6180
fax: 403.283.2647

#106, 10920 84 Avenue
Grande Prairie, AB T8X 6H2
tel: 780.357.5500
fax: 780.357.5501

toll free: 888.722.2563
www.mems.ca

Lindbergh SAGD Expansion Project
Groundwater Monitoring Program

Prepared for:
Pengrowth Energy Corporation

Prepared by:
Millennium EMS Solutions Ltd.
6111 – 91 Street
Edmonton, Alberta
T6E 6V6

December 2013
File #11-033

Table of Contents

Page

List of Appendices

1.0 INTRODUCTION

Pengrowth Energy Corporation (Pengrowth) received Approval No. 1581-02-00 under the *Environmental Protection and Enhancement Act* in 2011 to construct and operate the Lindbergh SAGD Pilot Project located approximately 30 km southeast of Bonnyville, Alberta. The Pilot Project central processing facility (CPF) is located in 07-13-058-05 W4M, with additional field production facilities associated with a former operation in close proximity. In accordance with the conditions of the approval, a groundwater monitoring program (GMP) was initiated. In 2013, the approval was amended (Approval No. 1581-02-01) to expand Pengrowth's operations for the Phase 1 development and the monitoring well network will be expanded to accommodate the additional Phase 1 project facilities.

Pengrowth is applying to further expand their operations in the Lindbergh area. If approved, this will also require expansion of the GMP. The present document has been prepared to outline the additional monitoring that is anticipated to identify any potential impacts to shallow aquifers due to the Lindbergh SAGD Expansion Project (the Project). The CPF for the Project will be in 25-058-05 W4M adjacent to proposed facilities for Phase 1.

The proposed GMP presented in this document was developed based on the current layout of project facilities presented in Pengrowth's Lindbergh SAGD Expansion Project Application (Pengrowth, 2013). Any changes made to the Project plans following the submission of the Application may impact the GMP. If changes are required, the GMP will be updated as appropriate.

For the purposes of this report, associated tables are included in Appendix E1 and figures are included in Appendix E2.

This report is intended to fulfill the typical requirements established by Alberta Environment and Sustainable Resource Development (ESRD) for a similar facility.

This GMP includes the following items:

- a description of the regional hydrogeology;
- a hydrogeological description and interpretation of the Project area;
- a map and description of surface water drainage patterns for the Project area;
- a lithological description and maps, including cross-sections, of the surficial and upper bedrock geological materials in the Project area;
- cross-section(s) showing depth to the water table, patterns of groundwater movement and hydraulic gradients in the Project area;
- the hydraulic conductivity of all surficial and bedrock materials in the Project area;

- a map showing the location of existing and additional proposed groundwater monitoring wells in the Project area;
- a lithological description of all boreholes drilled in the Project area;
- construction and completion details of existing groundwater monitoring wells;
- rationale for proposed groundwater monitoring well locations and proposed completion depths of those wells;
- a description of groundwater monitoring well development protocols;
- a list of parameters to be monitored and the monitoring frequency for each groundwater monitoring well or group of groundwater monitoring wells in the Project area;
- details of a plan to gather information on existing groundwater quality in the Project area prior to commencing the expansion operations;
- a description of the groundwater sampling and analytical quality assurance and quality control procedures;
- details of a groundwater response plan specifying actions to be taken should contaminants be identified through the GMP or in the event of a well casing failure; and
- a proposal to:
  - monitor and report anomalous trends in water levels at monitoring wells
  - address the potential that the approval holder's operations may have on liberating or introducing arsenic into groundwater; and
  - monitor groundwater levels and groundwater quality for the protection of Quaternary aquifers and surface water bodies.

Condition 7 of Schedule VI in a typical approval often requires that: *"The approval holder shall conduct at least five groundwater sampling events to establish baseline conditions for:*

a. *new facilities;*
b. *expansion areas which were not covered in prior sampling events; and*
c. *previously non-assessed relevant, non-saline hydrostratigraphic units at existing facilities; unless otherwise authorized in writing by the Director."*

Condition 8 of Schedule VI typically requires that: *"The approval holder shall conduct the sampling events referred in Condition 7 of Schedule VI at intervals of no less than one month and must demonstrate stable groundwater conditions."*

The Alberta Government has developed a Lower Athabasca Region Groundwater Management Framework and a Supporting Document for the Cold Lake – Beaver River (CLBR) Area, both of which cover groundwater management and monitoring in the Project area (Alberta Government, 2012 and 2013, respectively). In 2012, ESRD also circulated the draft Groundwater Monitoring Directive (ESRD, 2012) to environmental practitioners for comment. These documents will be considered in this proposal; however, the final GMP for the Project may change once the draft Groundwater Monitoring Directive is finalized or if other relevant regulatory direction is issued in the interim.

2.0 FACILITIES OVERVIEW

Detailed information related to the Project facilities can be found in the Application (Pengrowth, 2013). Facilities of importance to the GMP are addressed in the sections below.

Groundwater monitoring with respect to production facilities associated with a former operation, has been ongoing since 2002. Monitoring of the Pilot Project began in 2011 and has been ongoing on a biannual basis in 2012 and 2013. The monitoring well network for the Pilot Project included some of the pre-existing monitoring wells from the former operation at the site. Monitoring wells in areas that are being remediated were excluded from the Pilot Project monitoring program. No additional monitoring will be proposed as part of this GMP to address the historical operations, the Pilot Project or the Phase 1 Project.

2.1 Potential Sources of Contamination

New development related to the Project includes: access and utility corridors, well pads, soil storage, borrow pits and additions to the CPF as shown in Figure E2-1. Materials which will be produced and/or stored in the Project development areas in significant volumes include:

- bitumen;
- diluent;
- condensate;
- various water treatment chemicals;
- waste water;
- produced sand, water, emulsion and vapours;
- glycol;
- fuel gas (purchased natural gas); and
- septic fluid (domestic wastewater and sewage).

2.2 Areas of Environmental Concern

From a groundwater monitoring standpoint, the well pads and the CPF are the most significant new developments and will be the focus of this GMP. There are 55 planned well pads in total. The proposed facilities to be located at the well pad include wellheads, well steaming and gathering lines, a manifolds/header building, as well as an annulus gas collection system. Also required is an Electrical/Instrument Air/Controls Utility building. All pipelines used to connect the well pads to the CPF will be above ground.

Facilities associated with the Project CPF will be within the Phase 1 CPF footprint. Of interest for the GMP, the Project CPF will include additional fluid storage areas containing substances such as water, oil and glycol as well as a truck loading area.

3.0 LOCAL GROUNDWATER USERS

Water well records in the ESRD Water Well Information Database were reviewed within the Project area and a 1.6 km radius (ESRD, 2013). One hundred forty one records were identified within the search radius (65 domestic use, 12 domestic and stock use, six stock watering use, 38 industrial use, three monitoring or observation use, 16 unknown use, and one record for an "old well"). Sixteen records indicate that the feature is abandoned or was a dry hole. The nearest domestic water well record located downgradient of the Project CPF is approximately four kilometres southwest in 04-15-058-05 W4M (Well ID 289206). This water well is completed from 28.04 to 29.57 m below ground level (bgl) within Quaternary deposits.

A map showing the location of the water well records and a summary of the well details are included as Figure E3-1 and Table E3-1 in Appendix E3.

During field verified surveys conducted in 2012 and 2013, 162 residences were visited. Of the 162 residences, MEMS confirmed 39 water sources (12 for domestic, 11 for stock, nine for domestic and stock, one for landscape maintenance, two used for unknown purposes and four that are not in use). During the field survey, 26 groundwater samples and 13 surface water samples were collected. The water samples were submitted to ALS Environmental for total and dissolved metals analyses and routine potability analysis. A map summarizing the field survey and a summary table is included in Appendix E4.

4.0 LICENSED GROUNDWATER AND SURFACE WATER USE

There are two licensed and six registered groundwater users within the Project area and a 1.6 km radius. Based on the depths drilled and area water well lithologies, both of the licensed water wells are likely completed within Quaternary deposits; however, no information associated with the licenses or any corresponding water well records are available to confirm this interpretation. One

water well is licensed by Pengrowth in SE 13-058-05 W4M and is identified as being used for "camps" (*i.e.*, domestic purposes); the other is in SE 35-059-04 W4M and was licensed for stock watering purposes. The total annual quantity of licensed groundwater is 3,427 m^3 (9.4 m^3/day).

There are 179 registered surface water diversions within the Project area and a 1.6 km radius, and 159 of the applicants are listed as "Public Land Management".

Figure E3-2 and Table E3-2 in Appendix E3 summarize the licensed water well and surface water locations records.

5.0 PHYSICAL SETTING

The Project is located within the Eastern Alberta Plains physiographic region, and is situated over a surface water divide between the Beaver River basin and the North Saskatchewan River basin (Parks *et al.*, 2005). The area is characterized by relatively high relief, with ridged to hummocky rolling terrain. The Project is located on Crown and private land, with both anthropogenic and natural cover (Pengrowth, 2010). Surrounding land is primarily used for cattle grazing, although some hay cropping is also practiced; there are also several oilfield producers and industrial service providers in the immediate vicinity of the site (Pengrowth, 2010).

The ground surface in the vicinity of the Project varies between 570 and 720 m above sea level (asl) (Figure E2-2). Over the Project area, the topography generally slopes towards topographical lows such as lakes and creeks. Several unnamed surface water bodies lie within the Project area in addition to two main named lakes: Garnier and Bluet. Muriel Lake, Reita Lake and Cushing Lake are at the boundary of the Project area (Figure E2-1). Muriel Lake, Garnier Lake and Bluet Lake are within a valley and are at lower elevations than Reita and Cushing Lakes. Ground level in the valley is between 550 and 610 m above sea level (asl). The valley slopes to the northwest towards Muriel Lake.

6.0 GEOLOGY

A brief description of the Project area geology is provided in the subsections below. The detailed geology is presented in Section 4.2 of Consultants Report No. 5 (MEMS, 2013b) and the stratigraphy and hydrostratigraphy of the Project area is summarized in Figure E2-3. Cross-sections with the corresponding line of section map are included as Figures E2-4, 5 and 6.

Detailed borehole logs for monitoring wells drilled and completed as part of hydrogeological drilling programs are included in Appendix E5 and structure contour maps of the Quaternary formations described in the following sections are included as Figures E2-8 to E2-15.

6.1 Quaternary Deposits

The Grand Centre Formation is the uppermost Quaternary formation, present over the majority of the Project area and consists of clay till with minor silt and sand components. Where the Formation is absent, it has been eroded by more recent Quaternary channels (example shown in Figure E2-5). In the vicinity of the Pilot Project CPF, the Grand Centre Formation is expected to be approximately five metres thick and be underlain by the informally named Sand River Formation equivalent. The Sand River Formation equivalent is local in extent and is characterized as a poorly to moderately sorted sand layer with some traces of gravel.

Outside of the Pilot Project area, the Sand River Formation equivalent is largely absent and the Grand Centre Formation is underlain by the Marie Creek Formation. Based on hydrogeological drilling data from within the Project area, the Marie Creek Formation is approximately 30 m thick and composed of stiff, gravelly clay. The Ethel Lake Formation underlies the Marie Creek Formation and is described as being widespread but not continuous (Andriashek and Fenton, 1989). The Ethel Lake Formation is expected to be primarily composed of sand and gravel with some silt and clay components and is approximately 10 m thick. The Bonnyville Formation underlies the Ethel Lake Formation, consists primarily of clay till with a discontinuous sand and gravel unit and overlies the Lea Park Formation in the absence of buried bedrock channels.

6.1.1 Bedrock Channel Deposits

Within the Holyoke Channel in the Project area (Figure E2-7), the Muriel Lake, Bronson Lake and Empress Unit 3 formations are expected to be present. The Muriel Lake Formation was encountered during hydrogeological drilling in 01-20-059-04 W4M and consisted of approximately five metres of sand and gravel materials with some clay. The Bronson Lake Formation and Empress Formation Unit 3 are both expected to be present within the Holyoke Channel based on regional mapping. Hydrogeological drilling programs within the Project area to date have not been in areas where these Formations are expected based on mapping and have therefore not been encountered. The Bronson Lake Formation is expected to be less than 10 m thick and be composed of relatively clast free clay till and the Empress Formation Unit 3 can be up to 20 m thick and is described as a sand and gravel deposit with small occurrences of silt and clay (Andriashek and Fenton, 1989).

6.2 Bedrock Deposits

The upper bedrock in the Project area is the Cretaceous Colorado Group and the underlying Mannville Group. The uppermost formation is the Lea Park Formation of the Colorado Group. The Lea Park Formation is primarily composed of marine shale and is expected to be greater than 125 m thick in the Project area (Andriashek and Fenton, 1989).

Regional mapping of bedrock topography indicates that the Holyoke Channel is present within the Project area (Figure E2-7). The extent of this glacial channel has not been determined but it is predicted to run from beneath Muriel Lake towards the southeast (Township 059, Range 05, W4M towards Township 058, Range 03 W4M) and could merge with the preglacial Vermillion Valley beneath Frog Lake in Township 056, Range 02, W4M (Andriashek and Fenton, 1989). The Holyoke Channel is estimated to be between one and two kilometres wide and 115 to 120 m deep; the gradient of the Holyoke Channel is uncertain (Andriashek and Fenton, 1989).

Other significant bedrock channels outside of the Project area are shown on Figure E2-7 (Pawlowicz and Fenton, 1995).

7.0 HYDROGEOLOGY

The elevation of the base of groundwater protection in this area is shown in Figure E2-16, and the uppermost protected units are the Quaternary deposits (Alberta Energy Regulator, Ground Water Protection). Groundwater from bedrock aquifers is expected to be saline. For the purposes of the GMP, the hydrogeology of the Quaternary units and the Lea Park Formation are the focus of the following subsections. The hydrogeology is briefly described below and detailed descriptions can be found in Section 4.3 of the main document. Monitoring well installation programs within the Project area focused on the more permeable units encountered during drilling, therefore, often limited information is available regarding aquitards. The locations of the existing groundwater monitoring wells are shown on Figures E2-17 and E2-18 and completion details are in Table E1-1. The stratigraphy and hydrostratigraphy, adapted from Bachu *et al.*, (1993), is illustrated in Figure E2-3.

7.1 Quaternary Deposits

7.1.1 Grand Centre Formation

The Grand Centre Formation is the uppermost till unit in the Project area and is interpreted as an aquitard. One groundwater monitoring well is completed within the Grand Centre Formation and has a hydraulic conductivity of 8.5×10^{-7} m/s. The local hydrogeologic characteristics of the Grand Centre Formation are currently based on one monitoring well. During future hydrogeological drilling programs, where no shallow permeable units are present, additional monitoring wells may be installed within the Grand Centre Formation to improve the understanding of the hydrogeologic properties of the unit.

Groundwater from the Grand Centre Formation is determined to be bicarbonate type water with no dominant cation and have a total dissolved solids (TDS) concentration of between 580 and 710 mg/L (Figure E2-20).

7.1.2 Sand River Formation Equivalent

The Sand River Formation equivalent is present locally in the vicinity of the Pilot Project area and was also encountered in 01-20-059-04 W4M, underlying the Grand Centre Formation and overlying the Marie Creek Formation. The Sand River Formation equivalent is expected to be up to 15 m thick and is considered to be an aquifer as it primarily consists of sand and silt material. Hydraulic conductivity testing of the monitoring wells completed within the Sand River Formation equivalent resulted in hydraulic conductivities between 1.1×10^{-3} and 1.1×10^{-6} m/s and a geomean hydraulic conductivity of 3.5×10^{-5} m/s.

Water level measurements indicate that the groundwater flow within the Sand River Formation equivalent is to the southwest in the Pilot Project area (Figure E2-21). The groundwater elevations in the monitoring wells located near the Pilot Project CPF (in 13-058-05 W4M) are considered to be less representative of natural conditions due to development of the site including re-grading and changes to the surface materials. An approximate flow rate of 40 m per year within the Sand River Formation equivalent was calculated using the geometric mean hydraulic conductivity for this formation (3.5×10^{-5} m/s), the hydraulic gradient (approximately 0.01 m/m) and an assumed effective porosity of 30%.

Groundwater from the Sand River Formation equivalent is determined to be primarily calcium-bicarbonate type water or bicarbonate type water with no dominant cation (Figure E2-22).

7.1.3 Marie Creek Formation

The Marie Creek Formation is characterized as an aquitard. One monitoring well is completed within the Marie Creek Formation (P02-5) and it is completed within sandy clay and clay silt materials with a hydraulic conductivity of 3.0×10^{-7} m/s. The average water level measured in P02-5 is 650 m asl.

The most recent groundwater sampled from the Marie Creek Formation indicates that the water is bicarbonate type water with no dominant cation (Figure E2-20).

7.1.4 Ethel Lake Formation

The Ethel Lake Formation is primarily composed of sand and gravel and is interpreted as an aquifer. Six groundwater monitoring wells are completed within the Ethel Lake Formation that were drilled and completed in 2011 and 2013 (Table E1-1). Hydraulic conductivity testing resulted in hydraulic conductivities that range from 5.7×10^{-6} to 1.6×10^{-3} m/s with a geometric mean of 2.1×10^{-4} m/s.

Regional groundwater flow in the Ethel Lake Formation is to the north within the Beaver River basin (Parks *et al.*, 2005). Since there is only one monitoring well completed within the Ethel Lake Formation in the Beaver River basin, no further groundwater flow characteristics can be determined,

including the hydraulic gradient. Additional hydrogeological drilling will be completed in order to determine the groundwater flow within the Ethel Lake Formation in this basin.

The groundwater flow within the Ethel Lake Formation in the North Saskatchewan River basin appears be southward based on the difference in hydraulic head measurements (Figure E2-23). An approximate flow rate of 220 m per year within the Ethel Lake Formation in the North Saskatchewan River basin was calculated using the geometric mean hydraulic conductivity for the formation (2.1×10^{-4} m/s), the hydraulic gradient (approximately 0.01 m/m) and an assumed effective porosity of 30%. The hydraulic gradient within the Formation is based on very limited data and could be greater than expected for these high permeability deposits. Further investigation is planned and should help to determine an accurate hydraulic gradient and evaluation of the expected flow rate within the Ethel Lake Formation.

The groundwater from the Ethel Lake Formation is a bicarbonate type water with no dominant cation (Figure E2-20).

7.1.5 Bonnyville Formation

The majority of the Bonnyville Formation is characterized as an aquitard due to the clay till content of the Formation; however, the occurrence of a discontinuous sand and gravel aquifer between the Units may also be present. The Bonnyville Formation is therefore characterized as an aquifer-aquitard.

Hydraulic conductivity testing of MW13-19-82 completed within the Bonnyville Formation Unit 1 resulted in a value of 8.0×10^{-5} m/s. MW13-19-82 is completed within a discontinuous sand and gravel aquifer, therefore, the hydraulic conductivity is not considered representative of the entire unit. The local hydrogeologic characteristics of the Bonnyville Formation are currently based on only one monitoring well. Data collected from additional monitoring wells completed within the Bonnyville Formation in future will be used to verify and supplement the current evaluation.

Due to the low permeability of the Lea Park Formation a low degree of hydraulic connection is expected between the Bonnyville Formation and the upper bedrock. Since there is only one monitoring well completed within the Bonnyville Formation Unit 1 sands, the hydraulic gradient and groundwater flow direction and velocity are unable to be determined.

The groundwater from the Bonnyville Formation is sodium bicarbonate type water (Figure E2-20).

7.1.6 Bedrock Channel Deposits

The Muriel Lake, Bronson Lake and Empress Unit 3 formations are expected to only be present within the Project area in relation to the Holyoke Channel. The Muriel Lake Formation is typically composed of sand and gravel with minor amounts of clay materials and is characterized as an aquifer.

Hydraulic conductivity testing of MW13-27-90 which is completed within the Muriel Lake Formation indicates a hydraulic conductivity of 2.2 x 10^{-5} m/s.

The groundwater from the Muriel Lake Formation is a sodium type water with no dominant cation and has a TDS concentration of approximately 1,350 mg/L (Figure E2-20). The local hydrogeologic characteristics of the Muriel Lake Formation are currently based on only one monitoring well. Data collected from additional monitoring wells completed within the Muriel Lake Formation in future will be used to verify and supplement the current evaluation.

Regional mapping indicates that the Bronson Lake Formation and the Empress Formation Unit 3 should be present within the Project area in the Holyoke Channel; however, hydrogeological drilling programs to date have not encountered them. The Bronson Lake Formation is typically characterized as an aquitard and based on limited regional data, the geometric mean vertical hydraulic conductivity is reported as 2.2 x 10^{-8} m/s (Hitchon *et al.*, 1996). The Empress Formation Unit 3 is typically characterized as an aquifer as it is primarily composed of sand and gravel.

7.2 Bedrock

The Colorado aquitard system is expected to have a thickness of greater than 150 m and separate the overlying Quaternary sand aquifers from the underlying Cretaceous aquifers. The Joli Fou Formation is part of the Colorado aquitard system and is a relatively strong aquitard (Bachu *et al.*, 1993).

Regionally, the Lea Park Formation is interpreted as an aquitard based on the predominance of fine-grained materials that compose the unit. Localised permeable zones within the formation that consist of minor amounts of bentonitic sandstone material may also be present (HCL, 1998). Increased permeability at the top of the Lea Park Formation could also be an indication of a weathered contact surface.

There are four monitoring wells completed in the Lea Park Formation within the Project area. Of the four monitoring wells completed within the Lea Park Formation, only two appear to have reached static water levels following drilling in June 2013; therefore an interpretation of groundwater flow rate and direction within the Lea Park Formation is unable to be determined at this time. Hydraulic conductivity testing of the monitoring wells completed within the Lea Park Formation resulted in hydraulic conductivities of 3.3 x 10^{-9} and 2.0 x 10^{-9} m/s.

The groundwater from the Lea Park Formation is sodium bicarbonate type water or calcium type water with no dominant cation (Figure E2-20) and the TDS concentration primarily ranges between 900 and 1,900 mg/L. Although the chemical analyses indicate that the groundwater from the upper Lea Park Formation is non-saline, given the expected thickness of the Lea Park Formation, it is expected that the groundwater becomes saline within the Formation.

8.0 ENVIRONMENTAL MANAGEMENT CONTROLS AND PRACTICES

The GMP is intended to provide information on groundwater quality prior to the beginning of facility operations, and ongoing monitoring throughout facility operations. Baseline and ongoing monitoring in the Project area will be conducted. This will help detect any changes in groundwater conditions in response to the following potential impacts:

- accidental releases or spills; and
- thermal effects on groundwater chemistry.

Industry best practices employed by Pengrowth at the Project CPF will include double walled storage tanks, secondary protection, leak detection and good housekeeping practices; all of which will minimize the occurrence of product leaks from tanks and prevent any significant impacts to groundwater resources.

Control measures to mitigate risk associated with production wells, injection wells, and other facilities at the SAGD well pads will include:

- production and injection wells completed to industry standards using premium connections suitable for steam service, as well as thermal grade cement;
- production and injection volumes will be monitored;
- pressure, temperature, and steam flow rates will be collected and monitored to supervise casing integrity; and
- injection wells will be operated at pressures below the formation fracturing pressures.

Monitoring wells installed in the vicinity of the Project CPF will be designed and monitored to detect impacts related to spills or leaks at the site. The analysis of groundwater samples at the CPF during operational monitoring will reflect that there is virtually no operational activity on site that would have an impact on trace elements (trace metals) other than those trace elements possibly contained in produced water and that the most probable releases will include sodium, chloride and/or hydrocarbons. Monitoring wells installed to detect impacts due to steaming activities will focus on the possibility of the thermal mobilization of arsenic.

A summary of potential contaminant sources and indicator parameters is included in Tables E1-2.

9.0 GROUNDWATER MONITORING NETWORK

Groundwater monitoring wells have been completed within sand and gravel intervals encountered during drilling to target aquifer units that have the potential to transmit groundwater to receptors in usable quantities. Quaternary formations that were considered include the Sand River Formation

equivalent, Ethel Lake Formation, Bonnyville Formation Unit 1 and the Muriel Lake Formation. Not all of these aquifer units are expected to be present throughout the Project area. It is also possible that the Empress Formation Unit 3 aquifer underlies portions of the Project area based on regional mapping; this unit will be targeted for the installation of future monitoring wells. A table summarizing the aquifer units targeted based on potential sources is included as Table E1-3.

9.1 Current Groundwater Monitoring Network – Pilot Project

All of the monitoring wells currently operational as part of the Pilot Project GMP (the current monitoring network) will continue to be monitored as part of the Project GMP until the Pilot SAGD well pad is no longer active and provided that the groundwater response plan is inactive (Figure E2-17). The current monitoring network has been established to detect potential groundwater impacts related to the Pilot Project CPF and SAGD well pad. Table E1-1 summarizes the existing wells by area, and includes the completion details for the monitoring wells. Borehole logs are included in Appendix E5.

The current monitoring well network includes 29 monitoring wells located in 13-058-05 W4M (Figure E2-17). The first monitoring wells were completed in 2002 and the most recent monitoring wells were completed in 2012. At minimum, the monitoring wells have been sampled annually since 2002.

The groundwater monitoring wells that were installed in the vicinity of the Pilot Project SAGD well pad in 2011 were sampled five times prior to steaming as part of the Pilot Project (before February 2012). These chemical analysis results are considered to be representative of the background groundwater quality. Both *target* and *threshold* values were established for the hydrostratigraphic units of completion using approved methods outlined in the Annual Groundwater Monitoring Plan (MEMS, 2011) and the statistical methods presented in the 2011 Groundwater Monitoring report (MEMS, 2012).

Two groundwater sampling events occurred after steaming began; however, due to the number of samples available, no trend analysis has been completed (MEMS, 2013a). Of notable mention is all of the post steaming arsenic concentrations have been below the *targets* and *thresholds* established for each of the hydrostratigraphic units.

No monitoring wells representative of background conditions were completed in the Grand Centre or Marie Creek formations prior to steaming as part of the Pilot Project; therefore, background concentrations of chemical constituents were unable to be determined. Chemical analysis results from these Formations have been compared against the *targets* and *thresholds* established for the Sand River Formation equivalent for initial screening level purposes. The Pilot Project monitoring program

was designed to focus on aquifer units and only limited monitoring of aquitard units such as the Grand Centre and Marie Creek formations was undertaken.

MW11-20-74 is partially completed within the Bonnyville and Lea Park formations and has been used to characterize the Lea Park Formation in previous assessments because until 2013 there were no other monitoring wells completed in the Lea Park Formation. Moving forward, MW11-20-74 will be considered to be more representative of the hydrogeologic conditions of the Bonnyville Formation since the Bonnyville is the more permeable unit of the two that the monitoring well is completed within.

9.2 Proposed Groundwater Monitoring Network – Expansion Project

In addition to the monitoring wells already included in the monitoring network for the Pilot Project, nine new monitoring wells were drilled and completed in 2013. The locations and completion details for the new monitoring wells are included in Table E1-1 and the monitoring well locations are shown in Figure E2-18.

New groundwater monitoring wells will be installed in locations upgradient and downgradient of the Project CPF and well pads that are in close proximity to receptors based on the present knowledge of groundwater flow direction in the Project area. The current groundwater flow direction has been determined based on regional data and limited local water-level data; therefore, confirmation of the flow direction within the various aquifer units will be required prior to finalizing the Project monitoring well network. In the vicinity of the CPF, shallow sand units will be targeted. If the Sand River Formation equivalent is present it is expected that it will be the shallowest aquifer unit monitored. Where the Sand River Formation equivalent is absent, the Grand Centre Formation will be targeted.

The proximity of planned well pads to surface water bodies and domestic groundwater users also warrants groundwater monitoring between the possible sources and receptors. The locations, anticipated completions and rationale for the proposed groundwater monitoring network are included in Table E1-4 and the proposed locations are shown in Figures E2-18 and 19. It is noted that the proposed monitoring well locations may require modification based on project sequencing, access or changes in project design. Monitoring wells will be installed within each aquifer unit encountered during drilling at each of the planned locations outside the CPF. It is expected that the additional groundwater monitoring wells will ensure the timely detection of potential impacts on groundwater.

In addition to the monitoring wells, it is recommended that domestic water well owners within 1.6 km of planned well pads be offered voluntary monitoring of their water well(s). Monitoring of domestic water wells should be completed every two years and should include routine and metals chemical analyses.

New monitoring wells installed as part of the GMP will be included in the GMP summary report for the year in which the monitoring wells are drilled.

10.0 MONITORING PROGRAM

10.1 Groundwater Monitoring Schedule

Baseline data in the Project CPF area in 25-058-05 W4M and outside of the Pilot Project area will be collected from the monitoring wells that are existing and proposed. It is proposed that the groundwater from wells will be monitored and sampled a minimum of eight times at a frequency of three times per year to collect baseline data.

Following the completion of the baseline data collection, the chemistry and groundwater elevation data will be evaluated in order to provide a description of baseline conditions. The Pilot Project monitoring program established baseline conditions for each formation and ongoing groundwater monitoring of the current monitoring well network will continue to be compared against the *targets* and *thresholds* determined for the formation of completion. Baseline statistics for the proposed groundwater monitoring network will not follow the same formation-wide *target* and *threshold* determination. Instead, based on the current understanding of the Draft Groundwater Monitoring Guideline document (ESRD, 2012), control limits for each individual monitoring well will be determined. Procedures for establishing these limits are presented in Appendix E6.

Once baseline data is collected from the monitoring well network, four monitoring wells will no longer be sampled as part of the GMP. Water-level measurements from MW13-19-82 and 96, MW13-25-29 and MW13-24-94 will continue to be collected but based on the locations and completions of the monitoring wells, it is determined that regular groundwater quality monitoring is unnecessary in these areas. Future monitoring of these wells could be triggered by the groundwater response plan.

After operations commence, all of the remaining monitoring wells will be monitored semi-annually for a minimum of two full years. It is anticipated that the monitoring events will take place in May (spring) and October (fall) each year. Should concentrations of potential parameters of concern be detected in the groundwater, the established groundwater response plan will be initiated (Section 12.0). Following the two years of operational monitoring, the monitoring frequency will be re-evaluated to determine if annual monitoring frequency is appropriate.

An annual review of the monitoring network will be conducted when the annual GMP summary report is prepared. At that time, appropriate changes to improve the monitoring program will be considered.

10.2 Analytical Program

At minimum, during baseline data collection, laboratory analysis of chemical parameters shown in Table E1-5 will be completed for groundwater samples collected from each monitoring well. Additional parameters will be reported if analysed. Operational monitoring at the CPF will no longer include the dissolved metals analyses based on the rationale outlined in Section 8.0.

Detailed protocols for monitoring are presented in Appendix E7. Information collected during monitoring of the groundwater wells will include the measurement of static water levels and groundwater chemistry parameters (temperature, pH, electrical conductivity, oxidation reduction potential, and percent dissolved oxygen). Groundwater samples will be collected and submitted for laboratory analysis.

10.3 Sampling Methodology and Field Procedures

Groundwater monitoring well installation, purging, and sampling protocols will follow standard procedures. Appendix E7 provides the following protocols:

- Monitoring Well Installation Protocol;
- Monitoring Well Development Protocol;
- Hydraulic Conductivity Protocol; and
- Monitoring Protocol.

Groundwater samples will be collected into laboratory-supplied bottles with field filtering and/or preservation addition as appropriate. Standard chain of custody procedures will be followed.

11.0 QUALITY ASSURANCE AND QUALITY CONTROL

The quality assurance and quality control (QA/QC) program calls for the submission of duplicate samples at a rate of 10% from the entire set of monitoring wells sampled during each monitoring event. The purpose of a duplicate sample is to check the laboratory for reproducibility of results. The wells will be selected at random during sampling events to provide a blind duplicate sample for chemical analysis. Laboratory QA/QC procedure will be accepted pending the duplicate analysis.

The duplicate results will not become part of the database for the groundwater response plan; however, a file of original and duplicate analyses will be maintained and reported for comparison purposes.

The original and duplicate sample results will be compared and if it is determined that the analyses do not agree, the laboratory will be asked to check the results and report. Consistent variation

between the original and duplicate analyses could result in the preparation and submission of a spiked sample to test laboratory accuracy.

12.0 RESPONSE PLAN

12.1 Trigger Values

Baseline data will establish the natural magnitude and variation of groundwater quality and quantity in the Project area. This dataset will be used to establish well-specific trigger values for selected indicators that will be used to determine if the groundwater response plan becomes activated after start up.

Trigger values are intended to define a level beyond which environmental concerns could exist where receptors or groundwater may become impacted. Upper and lower control limits (UCLs and LCLs) are intended to define the natural range of variation in groundwater quality or quantity under baseline conditions. Trend analysis using control charts will also be applied when sufficient data are available.

Trigger values will be established and provided in the first annual report following baseline data collection. Monitoring results from the current monitoring well network and monitoring wells located downgradient from active operations will continue to be monitored and compared to previously determined *target* and *threshold* values established for the formations of completion. These ongoing monitoring results will also be included in the annual GMP summary reports.

Development of the trigger values will be based on the following principles:

- In general, only UCLs will be developed for chemical parameters as there are generally no environmental issues associated with lower than normal concentrations. LCLs will be established for those parameters where lower values are appropriate, such as pH and groundwater elevations.
- Control limits will be developed for all parameters included in the operational monitoring program (except electrical conductivity).
- Field measured parameters (*i.e.*, oxidation reduction potential, dissolved oxygen, electrical conductivity, pH, and temperature) will not be used to create control limits; they will be used to cross-reference with laboratory values as appropriate and to give preliminary field indications of changing conditions.
- The establishment of triggers for chemical parameters and changes in groundwater elevation will take into consideration the number of representative baseline data points available.

  - When greater than eight baseline data points exist, the Shewhart-CUSUM Control Chart Method will be used.
  - When four to seven baseline data points exist, the Mann-Kendall trend analysis will be used.
- In the case of quality indicators at concentrations not detected by the laboratory methods, the procedure outlined in Appendix E6.1 will be followed.
- When less than four baseline data points exist, chemical parameter will be compared against the Alberta Tier 1 Groundwater Remediation Guidelines (ESRD, 2010).
- Where baseline concentrations of indicator parameters exceed the Alberta Tier 1 Guideline, the UCL will be used.

12.2 Groundwater Response Plan

A schematic of the Groundwater Response Plan is presented in Figure E2-24. The Plan is described as follows:

- As each new analysis is added to the database after steaming has begun, the question asked is "Does the new value exceed a control limit?"
  - If the answer is no, then no response is necessary and regular monitoring continues.
  - If the answer is yes, then the response is to confirm the value with the laboratory.
  - In the case of a water level outside the control limit, the response is repeating the measurement during the next monitoring event.
- The laboratory check is made and there are two possible outcomes:
  - An error in reporting is confirmed and regular monitoring continues.
  - The laboratory confirms that there is no error:
    - The question is then posed "Is the value above the Alberta Tier 1 Guideline?"
      - If the answer is no then the parameter is flagged for attention and commented on in the annual report.
      - If the answer is yes then re-sampling is in order.
- Re-sampling and analysis of the parameter in question will be conducted as follows:
  - only the parameter outside of the limit will be the subject of analysis; and
  - the analysis will be completed as soon as is practical.
- Re-sampling and analysis will have two possible outcomes:
  - the new analysis is below the control limit, the new value is retained in the database and the previous value is flagged as anomalous, and regular monitoring resumes; or

- the concentration continues to be above the control limit and a review of the control chart for the parameter is triggered.

- The review of the control charts for the parameter results in two possible outcomes:
  - The value(s) outside of the control limits do not reflect any sort of trend and therefore are assumed, for the time being, to represent extremes that were not reflected in the baseline data set. A comparison to upgradient data will also be undertaken to determine whether the values identified are reflective of regional variations or reflective of project related impacts. If no deteriorating trend is identified or changes are regional and not project related, regular monitoring resumes with the understanding that a subsequent measurement outside the control limits will again trigger the groundwater response plan. If a pattern of stabilized values outside the limits becomes apparent, the control limits may be re-evaluated and adjusted as appropriate.
  - The values are noted to be part of a deteriorating trend. This triggers positive actions (described below) as it is now assumed that the groundwater has been impacted.
- Positive actions initiate source identification and groundwater assessment studies.
- ESRD will be notified by means of a release report if the presence of an impact to groundwater quality or quantity related to project activities is confirmed.
- If the source is unknown, a source identification study is initiated that is intended to evaluate and mitigate the source, where feasible.
  - If source mitigation is not implemented at this time, this will be taken into consideration during the groundwater assessment.
- If a spill incident (*i.e.,* surface release) or casing failure occurs, this event will trigger the groundwater response plan.
  - Spill incidents can occur both on the CPF and on a well pad.
  - Source removal will be undertaken as a component of the spill response plan and facility environmental procedures (*i.e.,* separate procedures from those outlined herein).
- The objective of the groundwater assessment is to determine the environmental significance of the groundwater plume. This will follow a sequence that could include:
  - determining the magnitude and extent of the groundwater plume;
  - evaluating the fate of the groundwater plume; and
  - undertaking risk screening.
- Once the significance of a groundwater plume is assessed, there are two possible outcomes:
  - If the groundwater assessment determines that this event is environmentally significant then mitigation options are to be evaluated and implemented. If source mitigation has not

already been undertaken, this will also be considered during the evaluation. Mitigation alternatives could include the following:

- risk assessment;
- risk management; and
- remediation.

- If the groundwater assessment determines that the plume does not present a significant or unacceptable risk to the environment, then this assessment is concluded and appropriate monitoring related to this event is evaluated and implemented.

- The process of groundwater assessment and the development of mitigation plans will be tailored to each event. In the case of simpler events it may be more practical to develop a mitigation plan without extensive assessment effort, whereas for events that are more significant or poorly understood, a detailed assessment may be required.
- Upon closure of the event, either through determining that the event does not represent an unacceptable environmental risk or through the application of mitigation measures expected to achieve closure, the need for ongoing monitoring will be evaluated.
  - Any additional monitoring requirements will be maintained until the parameter declines to within the control limits, then regular monitoring will resume.
  - New control limits may need to be established due to residuals of the incident or on the basis of risk assessments conducted as part of mitigation.

Timing to execute the groundwater response actions is summarized in Table E1-6. The timings provided are estimates and although it is expected that substantive progress will be achieved within the timeframes indicated, the estimates will vary depending on the event.

Annual GMP summary reports will include a discussion of any activation of the groundwater response plan, including a discussion of all actions undertaken and go-forward plans.

13.0 REPORTING

Annual GMP summary reports will be submitted to ESRD prior to March 31st of the following year or as required by the Director. The annual report will address the requirements outlined in any ensuing approval.

It is anticipated that the approval issued for the Project will contain a condition related to control charts as is typical in approvals for similar projects. The control charts will be defined as graphical representations of a chemical parameter versus time. However, since it is not practical to present control charts for all parameters for all wells, the following approach is proposed:

- if the concentration of a chemical parameter exceeds the control limit, charting will begin;

- charting will continue until the concentration of the parameter is below the control limit in two consecutive samples;
- charts produced under these conditions will be presented in the appropriate Annual Reports; and
- in addition to these charts, selected key indicator parameters (chloride, total dissolved solids and arsenic) will be charted and included in each Annual Report.

Each Annual Report will:

- discuss the installation of additional groundwater monitoring wells in the Project area;
- provide any additional hydraulic conductivity values; and
- present all available groundwater chemistry and water-level elevation data.

The control limits, along with relevant statistics relating to the background data set (groundwater quality and water-level elevation data), will be established and presented in the first annual GMP summary report for the Project.

14.0 REFERENCES

Alberta Energy Regulator. Ground Water Protection. Accessed at. https://www3.eub.gov.ab.ca/Eub/COM/BGP/UI/BGP-Main.aspx on September 20, 2013.

Alberta Environment and Sustainable Resource Development (ESRD). 2010. Alberta Tier 1 Soil and Groundwater Remediation Guidelines. Alberta Environment, Edmonton, Alberta. December 2010.

Alberta Environment and Sustainable Resource Development (ESRD), 2012. Groundwater Monitoring Directive, Groundwater Quality Monitoring and Management for Approved Facilities. Draft: September 2012.

Alberta Environment and Sustainable Resource Development (ESRD). 2013. Alberta Water Well Information Database. Accessed at http://groundwater.alberta.ca/WaterWells/ on July 24, 2013.

Alberta Government. 2012. Lower Athabasca Region Groundwater Management Framework. Alberta Environment and Sustainable Resource Development. August 2012.

Alberta Government. 2013. Lower Athabasca Region Groundwater Management Framework. Supporting Document for the Cold Lake – Beaver River (CLBR) Area. Alberta Environment and Sustainable Resource Development. June 2013.

Andriashek L.D. and M.M. Fenton. 1989. Quaternary Stratigraphy and Surficial Geology of the Sand River Area 73L. Alberta Research Council. Bulletin No. 57.

Bachu, S., J.R. Underschultz, Brian Hitchon and D. Cotterill. 1993. Regional-Scale Subsurface Hydrogeology in Northeast Alberta. Alberta Research Council. Bulletin No. 61.

Hydrogeological Consultants Limited. 1998. County of St. Paul No. 19, Part of the North Saskatchewan River Basin, Parts of Tp 055 to 062, R03 to 13, W4M, Regional Groundwater Assessment.

Millennium EMS Solutions Ltd. 2011. Lindbergh Enhanced Recovery Heavy Oil Processing Plant, 06-13-058-05 W4M, Annual Groundwater Monitoring Plan. File No. 10-131. November 2011.

Millennium EMS Solutions Ltd. 2012. Lindbergh Enhanced Recovery In-Situ Oil Sands Processing Plant, 06-13-058-05 W4M, 2011 Groundwater Monitoring Program Summary Report. File No. 10-131. March 2012.

Millennium EMS Solutions Ltd. 2013a. 2012 Groundwater Monitoring Program Summary Report. Lindbergh Enhanced Recovery In-Situ Oil Sands Processing Plant. 13-058-05 W4M. March 2013.

Millennium EMS Solutions Ltd. 2013b. Lindbergh SAGD Expansion Project. Hydrogeology. Consultant Report #5 in the Lindbergh SAGD Expansion Project Application for Approval to the Alberta Energy Resources Conservation Board and Alberta Environment and Sustainable Resource Development.

Parks, K., L.D. Andriashek, K. Michael, T. Lemay, S. Stewart, G. Jean and E. Kempin. 2005. Regional Groundwater Resource Appraisal, Cold Lake – Beaver River Drainage Basin, Alberta. Alberta Energy and Utilities Board and Alberta Geological Survey. Special Report 74. February 2005.

Pawlowicz, J.G. and M.M. Fenton. 1995. Bedrock Topography of Alberta. Map No. 226.

Pengrowth Corporation. 2010. Project Update and Supplemental Information Responses for Lindbergh SAGD Pilot Project. (Submitted to Alberta Environment). December 2010.

Pengrowth Energy Corporation. 2013. Lindbergh SAGD Expansion Project Application (Submitted to ERCB). December 2013.

APPENDIX E1: TABLES

List of Tables

Table E1-1: Monitoring Well Completion Details and Hydraulic Conductivities

Well ID	Location (W4M)	UTM Northing	UTM Easting	Ground Elevation (m asl)	Stickup (m)	Screen Interval (m bgl)	Hydraulic Conductivity (m/s)	Completion Lithology	Completion Formation	Most Recent Water Level (m asl)	Water-Level Measurement Date
P02-1	07-13-058-05	5984920	525525	655.82	0.70	5.0-8.0	4.0E-05	sand/silty clay	Sand River equiv. Fm.	649.32	18/10/2013
P02-4	07-13-058-05	5984922	525598	656.40	0.60	5.3-8.3	1.9E-05	sand	Sand River equiv. Fm.	649.38	18/10/2013
P02-5	07-13-058-05	5984980	525674	656.17	0.60	6.8-9.8	3.0E-07	sandy clay/clay silt	Marie Creek Fm.	650.14	18/10/2013
P02-6	07-13-058-05	5984838	525747	654.29	0.65	3.4-6.4	3.2E-05	silty clay/sand	Sand River equiv. Fm.	649.54	10/10/2013
P02-7	10-13-058-05	5985087	525732	659.82	0.55	7.0-10.0	>5.0E-05	sand	Sand River equiv. Fm.	651.67	10/10/2013
P02-8	09-13-058-05	5985449	525950	663.83	0.59	9.6-12.6	>5.0E-05	sand	Sand River equiv. Fm.	652.26	10/10/2013
P05-9A	09-13-058-05	5985453	525886	665.13	0.96	10.6-13.6	-	clay till/sand	Sand River equiv. Fm.	652.03	13/06/2012
P10-11A	06-13-058-05	5984752	525133	649.63	1.14	3.8-6.8	>1.0E-05	silty clay till/gravelly sand	Sand River equiv. Fm.	646.76	10/10/2013
P10-12A	01-13-058-05	5984358	526091	651.44	1.15	3.4-6.5	8.5E-07	silty clay till/clay	Grand Centre Fm.	648.23	10/10/2013
P10-13A	07-13-058-05	5985026	525707	660.11	1.13	6.4-9.4	6.1E-05	sand	Sand River equiv. Fm.	652.09	10/10/2013
P10-14A	07-13-058-05	5984881	525793	658.16	1.20	5.7-8.85	>1.0E-05	sand	Sand River equiv. Fm.	651.25	10/10/2013
P10-15A	07-13-058-05	5984846	525603	654.97	1.18	4.1-7.1	6.2E-06	silty clay till/sand	Sand River equiv. Fm.	650.11	18/10/2013
P10-16A	07-13-058-05	5984816	525657	654.65	1.20	3.3-6.3	>1.0E-05	silty clay till/gravelly sand	Sand River equiv. Fm.	650.41	18/10/2013
P10-17A	09-13-058-05	5985421	525920	666.01	1.01	13.7-16.7	4.3E-06	sand/clay	Sand River equiv. Fm.	653.15	10/10/2013
P10-18A	14-13-058-05	5985715	525405	661.76	1.18	7.15-10.1	1.1E-06	sand/gravelly sand	Sand River equiv. Fm.	653.01	18/10/2013
MW11-19-12	11-13-058-05	5985407	525187	654.31	0.68	10.1-11.6	7.5E-04	sand	Sand River equiv. Fm.	652.32	17/10/2013
MW11-19-24	11-13-058-05	5985405	525193	654.33	0.52	20.7-22.8	-	medium grained sand	Sand River equiv. Fm.	652.35	17/10/2013
MW11-19-67	11-13-058-05	5985409	525193	654.30	0.70	64.3-67.4	1.1E-04	sand	Ethel Lake Fm.	651.29	17/10/2013
MW11-20-53	06-13-058-05	5984975	525206	651.16	0.82	49.8-53.0	6.2E-04	coarse to very coarse sand	Ethel Lake Fm.	651.28	09/10/2013
MW11-20-7	06-13-058-05	5984976	525202	651.12	0.94	5.4-6.8	2.0E-05	coarse grained sand to gravel	Sand River equiv. Fm.	647.79	18/10/2013
MW11-20-74	06-13-058-05	5984979	525206	651.15	0.97	72.6-74.0	-	sand/shale	Bonnyville Unit 1 Fm.	651.27	09/10/2013
MW11-21-11	06-13-058-05	5985050	525085	651.49	0.72	7.6-10.8	-	medium grained sand	Sand River equiv. Fm.	647.36	18/10/2013
MW11-21-54	06-13-058-05	5985048	525083	651.45	0.77	52.5-54.0	1.6E-03	sand & gravel	Ethel Lake Fm.	651.28	09/10/2013
MW11-22-54	11-13-058-05	5985123	525340	654.46	0.80	51.0-54.2	3.0E-04	medium to coarse sand	Ethel Lake Fm.	651.28	10/10/2013
MW11-22-9	11-13-058-05	5985122	525345	654.88	0.65	6.2-9.2	-	fine to medium grained sand	Sand River equiv. Fm.	650.22	18/10/2013
MW12-23-14	09-13-058-05	5985433	525897	664.48	0.76	12.0-13.5	1.5E-04	medium sand	Sand River equiv. Fm.	652.41	17/10/2013
MW12-24-8	07-13-058-05	5984860	525660	655.71	0.85	6.3-7.8	2.7E-04	medium sand	Sand River equiv. Fm.	649.52	18/10/2013
MW12-25-8	07-13-058-05	5984896	525612	655.57	0.90	6.0-7.5	2.7E-04	clayey, sandy gravel	Sand River equiv. Fm.	649.83	18/10/2013
MW12-26-8	07-13-058-05	5984810	525609	652.43	0.90	6.0-7.5	2.0E-04	clayey sand	Sand River equiv. Fm.	648.66	18/10/2013
MW13-19-82	11-13-058-05	5985403	525177	654.32	0.90	78.6-81.6	8.0E-05	clay/silt/sand & gravel	Bonnyville Unit 1 Fm.	651.30	08/10/2013
MW13-19-96	11-13-058-05	5985403	525174	654.31	0.90	93.0-96.0	3.3E-09	shale	Lea Park Fm.	651.38*	15/10/2013
MW13-23-50	09-12-058-05	5983694	525940	645.76	0.95	47.0-50.0	4.7E-04	sand	Ethel Lake Fm.	631.75	09/10/2013
MW13-23-81	09-12-058-05	5983696	525940	645.88	0.97	77.8-80.8	2.0E-09	shale	Lea Park Fm.	634.12	16/10/2013
MW13-24-94	03-32-058-04	5989409	528453	656.04	0.97	90.5-93.5	-	shale	Lea Park Fm.	625.43	09/10/2013
MW13-25-29	14-36-058-05	5990442	525317	610.17	0.93	26.0-29.0	-	shale	Lea Park Fm.	606.21*	10/10/2013
MW13-27-23	01-20-059-04	5995839	528981	619.31	0.83	20.1-23.2	1.1E-03	sand & gravel/gravelly clay, sand	Sand River equiv. Fm.	613.77	08/10/2013
MW13-27-55	01-20-059-04	5995840	528977	619.38	0.96	51.5-54.5	5.7E-06	sand/silt	Ethel Lake Fm.	606.17	08/10/2013
MW13-27-90	01-20-059-04	5995840	528979	619.37	0.96	86.9-89.9	2.2E-05	clay, sand & gravel	Muriel Lake Fm.	596.17	08/10/2013

Notes: Coordinates are inferred, not surveyed

* water level has not stabilized

Table E1-2: Summary of Potential Contaminant Sources

Location	Source	Potential Contaminants	Indicators
Plant site	Accidental release	Bitumen	Routine, naphthenic acid, BTEX F1/F2, phenols
		Diluent	
		Condensate	
		Various water treatment chemicals	
		Waste water	
		Produced sand and water	
		Glycol	
		Fuel	
		Septic fluid	
SAGD activities	Thermal well bore effects	Heat	pH, temperature, metals

Table E1-3: Potential Contaminant Source – Receptor Matrix

Location	Potential Source	Site Groundwater Management Units				
		Sand River Formation equivalent	Ethel Lake Formation	Bonnyville Formation Unit 1	Muriel Lake Formation	Empress Formation Unit 3
CPF	Accidental release	✓				
SAGD wells	Thermal well bore effects	✓	✓	✓	✓	✓

Table E1-4: Proposed Monitoring Well Network

Operational Area	Existing Wells/ Proposed Location	Legal Location (W4M)	Formation of Completion	Depth of Completion (m)	Rationale
Pilot Project	MW13-19-82	11-13-058-05	Bonnyville	82	Upgradient of the Pilot Project SAGD well pad; to determine direction of groundwater flow in the Formations
	MW13-19-96	11-13-058-05	Lea Park	96	
Project Area	MW13-23-50	09-12-058-05	Ethel Lake	50	Downgradient of well pads
	MW13-23-81	09-12-058-05	Lea Park	81	
	MW13-25-29	14-36-058-05	Lea Park	29	Upgradient of well pads
	MW13-24-94	03-32-058-04	Lea Park	94	Downgradient of well pads
	MW13-27-23	01-20-059-04	Sand River equivalent	23	Upgradient of well pads and between well pads and Muriel Lake
	MW13-27-55	01-20-059-04	Ethel Lake	55	
	MW13-27-90	01-20-059-04	Muriel Lake	90	
Pad D46	MW1	01-25-59-04 W4	Ethel Lake* and Muriel Lake	*60 and 80*	Downgradient of well pad and upgradient of Reita Lake
Pad D39	MW2	04-29-58-04 W4	Ethel Lake*	*60*	Downgradient of well pad and upgradient of Garnier Lake on north side of valley
Pad D20	MW3	04-10-58-05 W4	Ethel Lake*	*50*	Downgradient of well pad and upgradient of field verified domestic and stock use water wells
Project CPF	MW4	05-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF fluid storage area
	MW5	05-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF fluid storage area
	MW6	04-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF fluid storage area
	MW7	04-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF fluid storage area
	MW8	04-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF fluid storage area
	MW9	04-25-58-05 W4	Sand River equivalent	*15*	Downgradient of CPF truck loading area

* Expected to be the shallowest sand unit. If the Sand River Formation equivalent is identified during drilling, a monitoring well will also be completed in those sands.

Estimated

Table E1-5: Chemical Parameters

Indicator	Analysis Type	Parameters			
		General Chemistry and Major Ions	Dissolved Metals		Petroleum Hydrocarbons
Groundwater Quality	Field Measured	Temperature			
		pH			
		Electrical Conductivity			
		Oxidation Reduction Potential			
		Dissolved Oxygen			
	Laboratory	pH	Aluminum	Molybdenum	Benzene
		Electrical Conductivity	Antimony	Nickel	Toluene
		Total Dissolved Solids	Arsenic	Phosphorus	Ethylbenzene
		Total Alkalinity	Barium	Selenium	Xylene
		Hardness	Beryllium	Silicon	F1 (C6-C10) - BTEX
		Bicarbonate	Bismuth	Silver	F2 (C10-C16 Hydrocarbons)
		Carbonate	Boron	Strontium	Naphthenic Acid
		Calcium	Cadmium	Sulphur	Phenols
		Magnesium	Chromium	Thallium	
		Sodium	Cobalt	Tin	
		Potassium	Copper	Titanium	
		Chloride	Iron	Uranium	
		Sulphate	Lead	Vanadium	
		Nitrate - N	Lithium	Zinc	
		Nitrite - N	Manganese		
		Ion Balance	Mercury		

Table E1-6: Groundwater Response Plan Timing

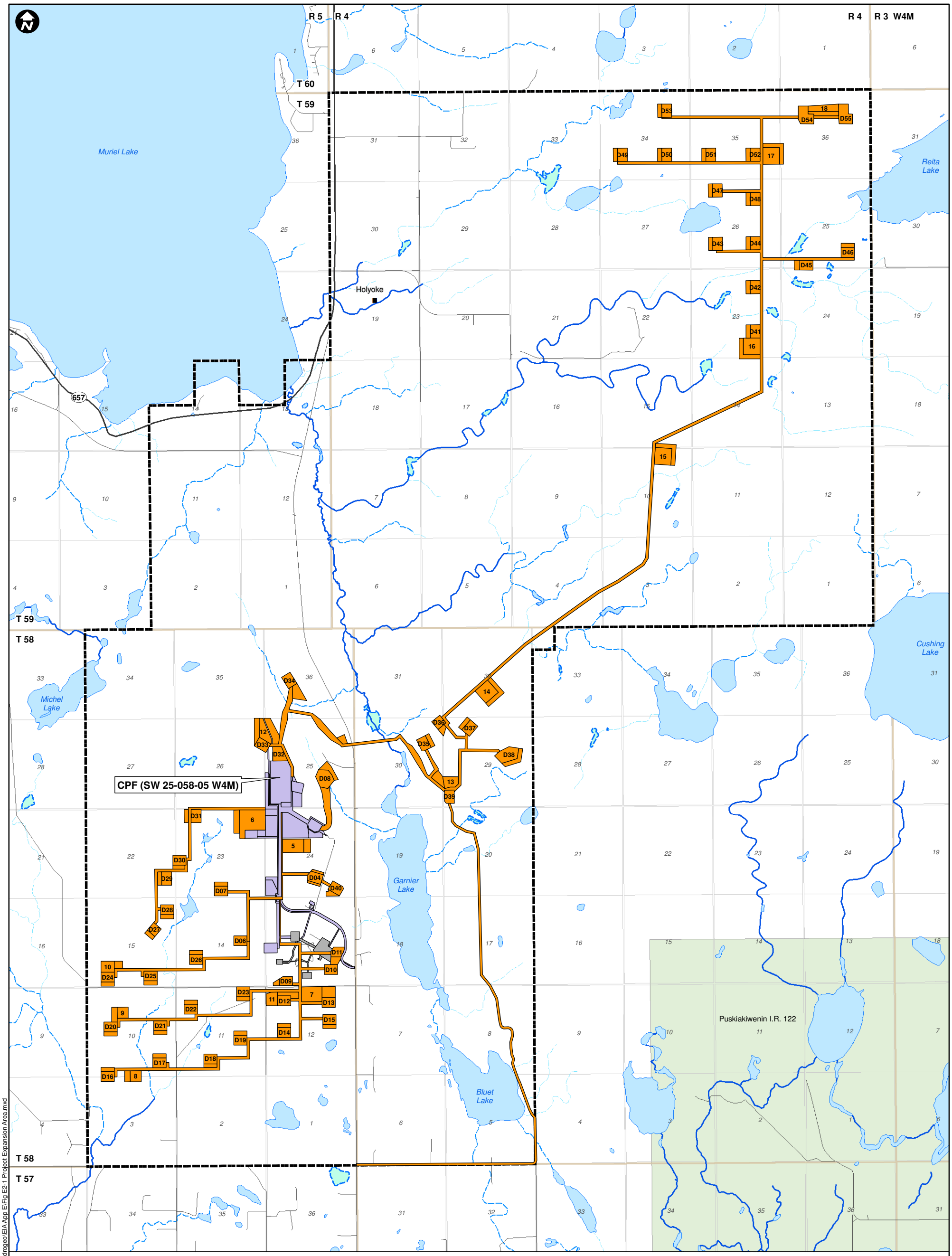
Action	Timing to Complete	Cumulative Time From Initiating Monitoring Event
Laboratory check	15 days	30 days
Re-sampling	Next Event (~ 6 months)	~ 7 months
Trend analysis	30 days	~ 8 months
Release report issued to ESRD	30 days	~ 9 months
Source investigation and mitigation	8 – 12 months	~ 1.5 years
Plume assessment (magnitude and extent)	8 – 20 months	~ 1.5 to 2.5 years
Plume evaluation (predictive modeling, risk-based screening)	12 months	2.5 to 3.5 years
Plume mitigation design and implementation	12 – 24 months	3.5 to 5 years

All time estimates assume the subject well is not frozen.

~ Approximate

APPENDIX E2: FIGURES

List of Figures



Legend

- EIA Project Area
- Expansion Development
- Pilot Development
- Phase 1 Develpment
- First Nations
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.7 1.4 2.8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

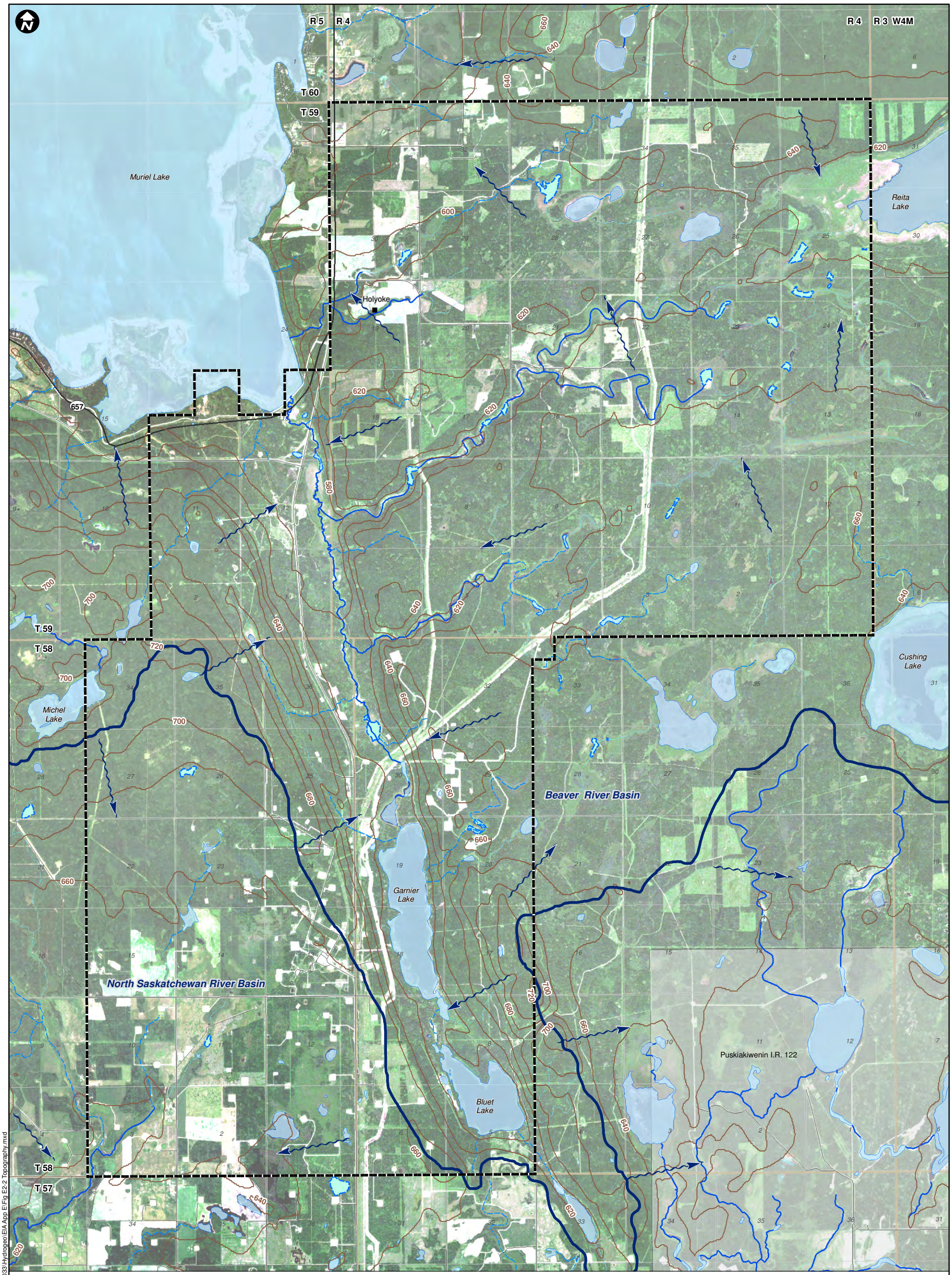
TITLE: **Project Expansion Area**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **E2-1**

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-1 Project Expansion Area.mxd



Legend

- EIA Project Area
- Drainage Basin
- Contour (20m interval, m asl)
- Surface Water Drainage Flow Direction
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds
- First Nations

0 0.75 1.5 3
Kilometres

REF: NHC hydrology Oct 2013; RapidEye, June-July, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Topography**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **E2-2**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-2 Topography.mxd

Stratigraphy						Hydrostatigraphy	
Eon	Era	Period	Group	Formation	Member/Unit	Unit	System
Phanerozoic	Cenozoic	Quaternary Tertiary		Grand Centre		Aquitard	
				Sand River Equivalent		Aquifer*	
				Marie Creek		Aquitard	
				Ethel Lake		Aquifer*	
				Bonnyville		Aquifer - Aquitard*	
				Muriel Lake		Aquifer*	
				Bronson Lake		Aquitard	
				Empress Unit 3		Aquifer*	
							Pre-Quaternary Unconformity
	Mesozoic	Cretaceous	Colorado Upper	Lea Park		Aquitard	Colorado Aquitard System
					2nd White Specks Sandstone	Aquitard	
				LaBiche		Aquitard	
			Colorado Lower	Viking		Aquifer	
				Joli Fou	Colony Sand	Aquifer - Aquitard	
			Mannville		McLaren Member	Aquifer	
				Grand Rapids	*Waseca Sand*	Aquifer	Grand Rapids Aquifer System
				Lower Grand Rapids	Sparky Sand	Aquifer - Aquitard	
					General Petroleum Sand	Aquifer - Aquitard	
					Rex Sand	Aquifer (Bitumen)	
					Lloydminster Sand	Aquifer (Bitumen)	
				Clearwater	Cummings Member	Aquitard	Clearwater Aquitard
				McMurray	Dina Member	Aquifer	McMurray Aquifer System
							Pre-Cretaceous Unconformity

Italics: Informal name
*Possible Domestic Use Aquifer

Adapted from: Bachu et.al. 1993, Regional-Scale Subsurface Hydrogeology in Northeast Alberta; EUB/AGS Special Report 74.

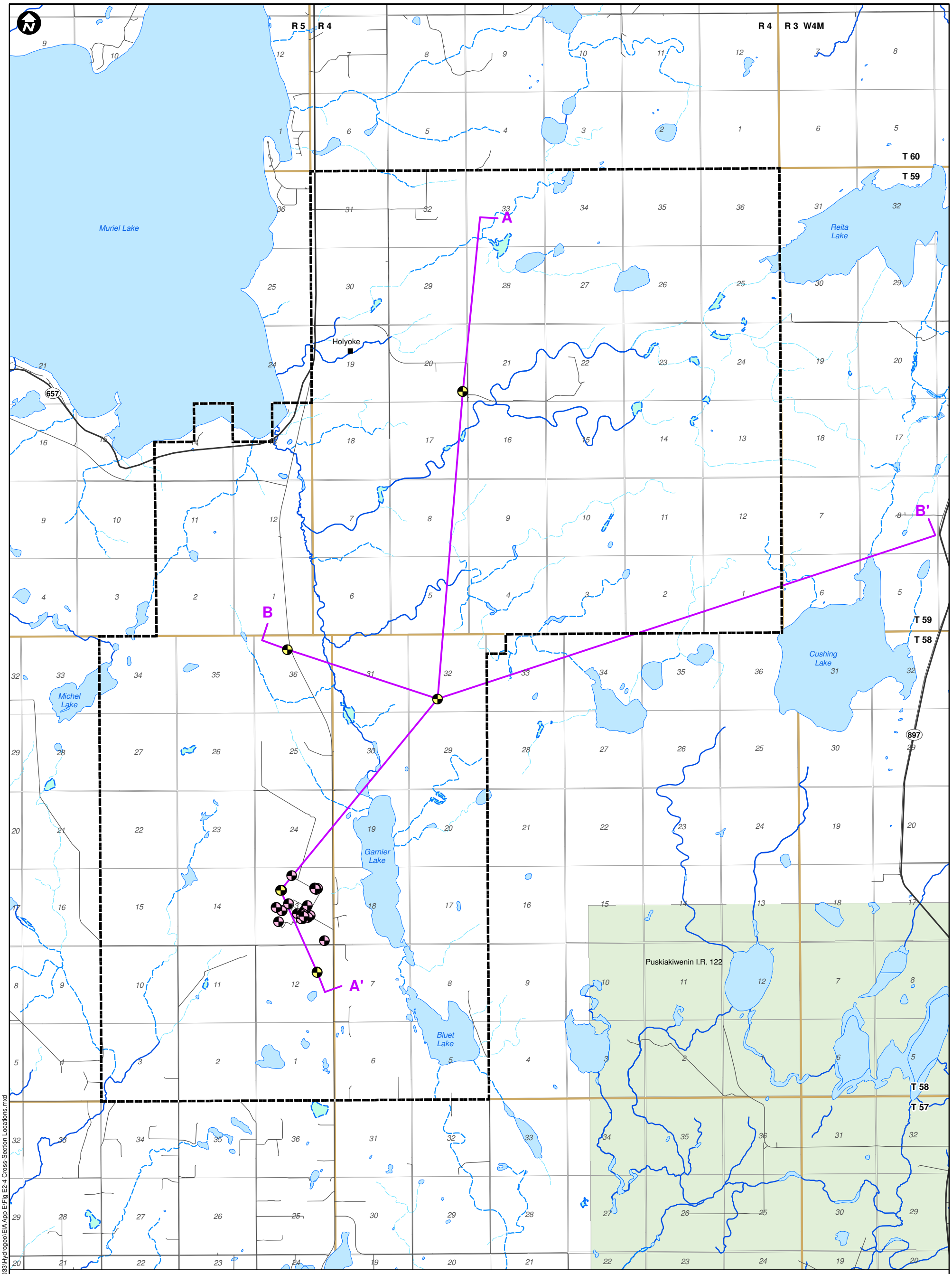
PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Stratigraphy and Hydrostratigraphy**

DRAWN: JDC
CHECKED: JD
DATE: Dec 5/13
PROJECT: 11-033

FIGURE: **E2-3**



Legend

- 2013 Monitoring Well
- Monitoring Well
- EIA Project Area
- A A' Cross-Section Line
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds
- First Nations

0 0.75 1.5 3
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: Cross-Section Locations

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: E2-4

REF: NHC hydrology Oct 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydroge\EIA App E\Fig E2-4 Cross-Section Locations.mxd

NORTH
A

SOUTH
A'

SW 33-059-04 W4M | 01-20-059-04 W4M | 03-32-058-04 W4 | 11-13-058-05 W4M | 09-12-058-05 W4M

Unnamed Creek | Unnamed Creek | Unnamed Creek | Unnamed Creek

Grand Centre Fm.

Marie Creek Fm.

Ethel Lake Fm.

Bonnyville Fm. Unit 2

Bonnyville Fm. Unit 1

Lea Park Fm.

Muriel Lake Fm.

Bronson Lake Fm.

Sand River Fm.

Sand River Fm. Equivalent

Sand River Fm. Equivalent

ELEVATION (m asl)

670 660 650 640 630 620 610 600 590 580 570 560 550 540 530 520 510

0 1000 2000 3000 4000 5000 6000 7000 8000 9000 10000 11000 12000 13000 14000 15000 16000 17000 18000

DISTANCE (m)

Legend

Lithology

- Clay
- Clay with Gravel
- Sand with Clay
- Sand
- Silt and Sand
- Sand and Gravel
- Shale
- Estimated Stratigraphy (AGS Bulletin 57, Cross-Section E2-E2')

WATER LEVEL — MONITORING WELL COMPLETION INTERVAL

WATER LEVEL HAS NOT STABILIZED — MONITORING WELL COMPLETION INTERVAL

0 0.5 1 2km

Scale 1 : 50 000

50 x Vertical Exaggeration

REF: Geobase 2012.

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: North-South Cross-Section AA'

FILE: Final Docs\...EIA App E\Fig E2-5_6 Cross-Sections.dwg

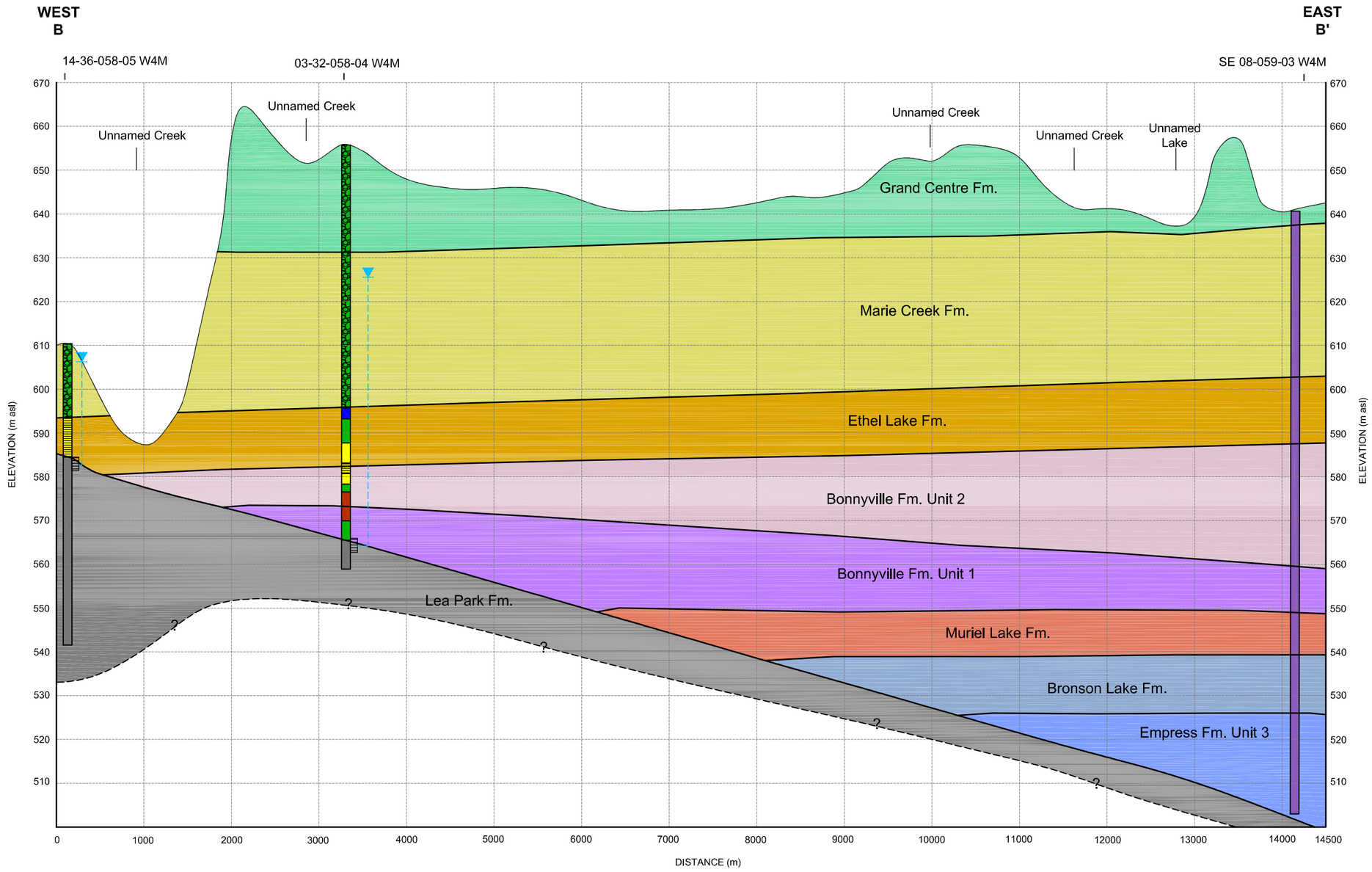
DRAWN: JDC/SL

CHECKED: JD

DATE: Dec 17/13

PROJECT: 11-033

FIGURE: E2-5



Legend

Lithology

- Clay
- Clay with Gravel
- Sand with Clay
- Sand
- Silt and Sand
- Sand and Gravel
- Shale
- Estimated Stratigraphy (AGS Bulletin 57, Cross-Section E2-E2')

WATER LEVEL — MONITORING WELL COMPLETION INTERVAL

WATER LEVEL HAS NOT STABILIZED — MONITORING WELL COMPLETION INTERVAL

0 0.5 1 2km

Scale 1 : 50 000

50 x Vertical Exaggeration

REF: Geobase 2012.

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

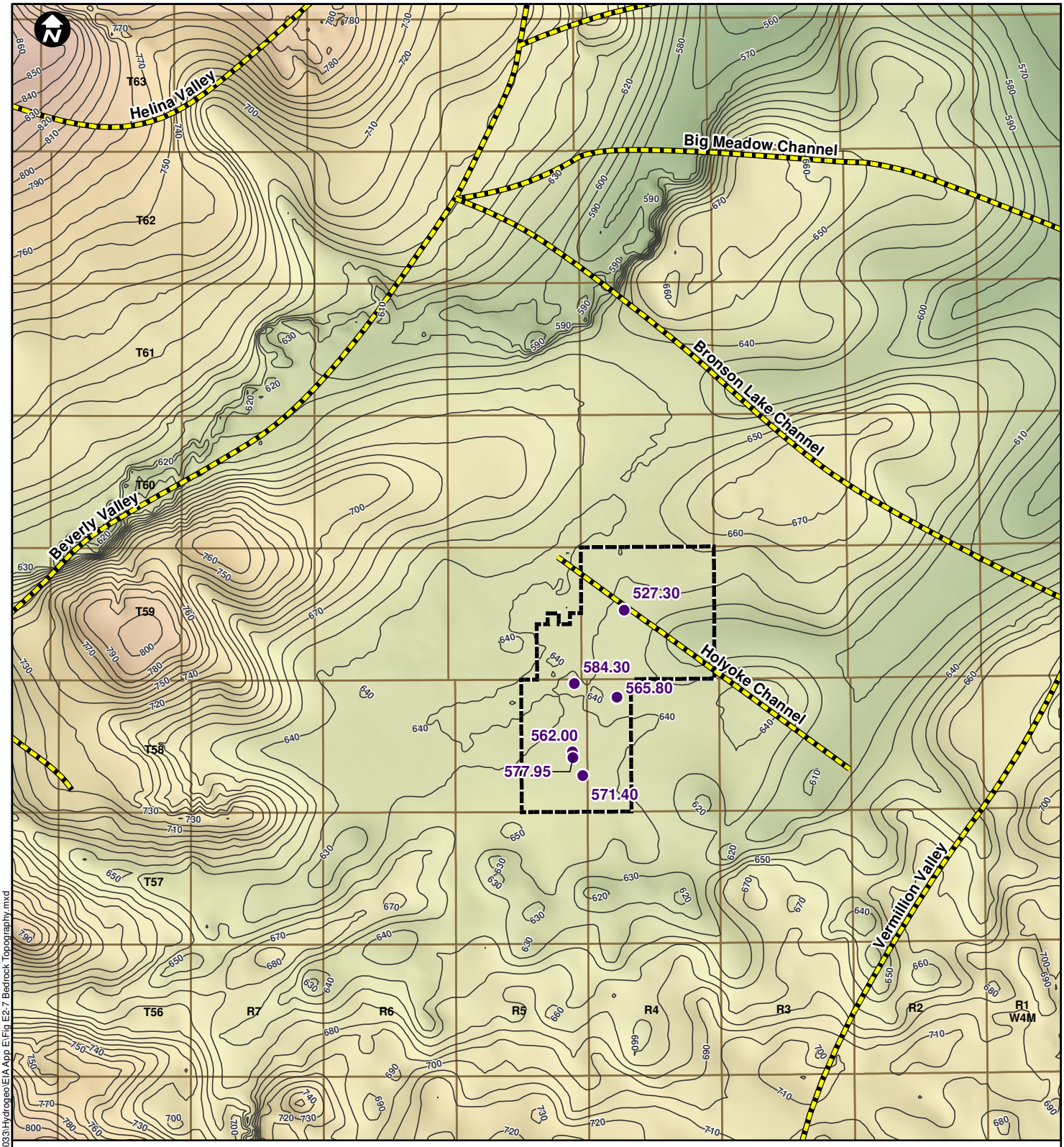
MILLENNIUM EMS Solutions Ltd.

TITLE: West-East Cross-Section BB'

FILE: Final Docs\...EIA App E\Fig E2-5_6 Cross-Sections.dwg

DRAWN:	JDC/SL
CHECKED:	JD
DATE:	Dec 17/13
PROJECT:	11-033

FIGURE: E2-6



Legend

- EIA Project Area
- Monitoring Well
- (577.95) Bedrock Elevation (m asl)
- Contour (10m interval, m asl)
- Channel

Bedrock Topography (m asl)

- High : 880
- Low : 550

0 4 8 16
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

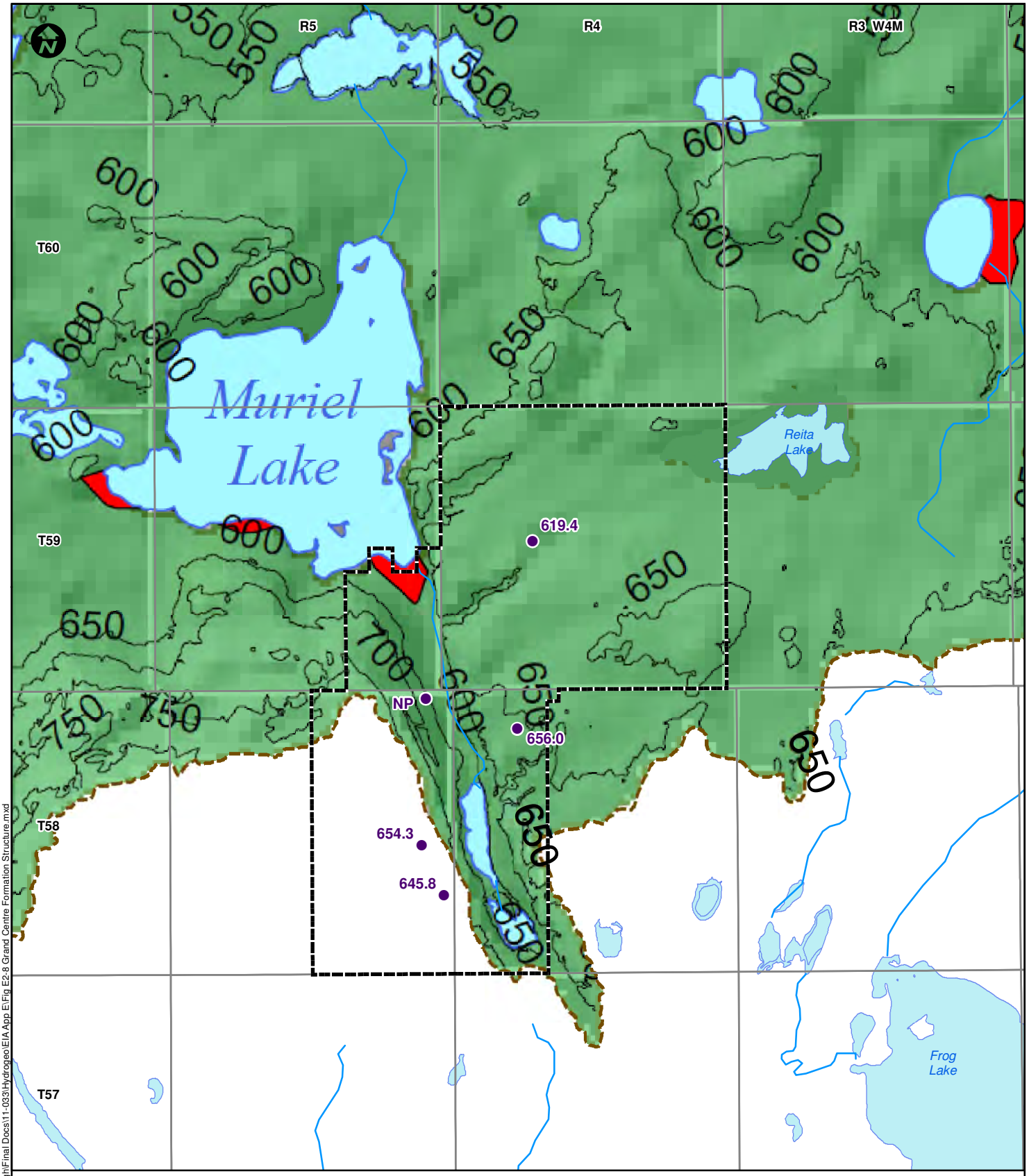
TITLE: **Bedrock Topography**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **E2-7**

REF: Atkinson and Lyster, 2010b; ARC, 1989.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-7 Bedrock Topography.mxd



Legend

- Monitoring Well
- 656.0 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Till
- Glaciofluvial deposits
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

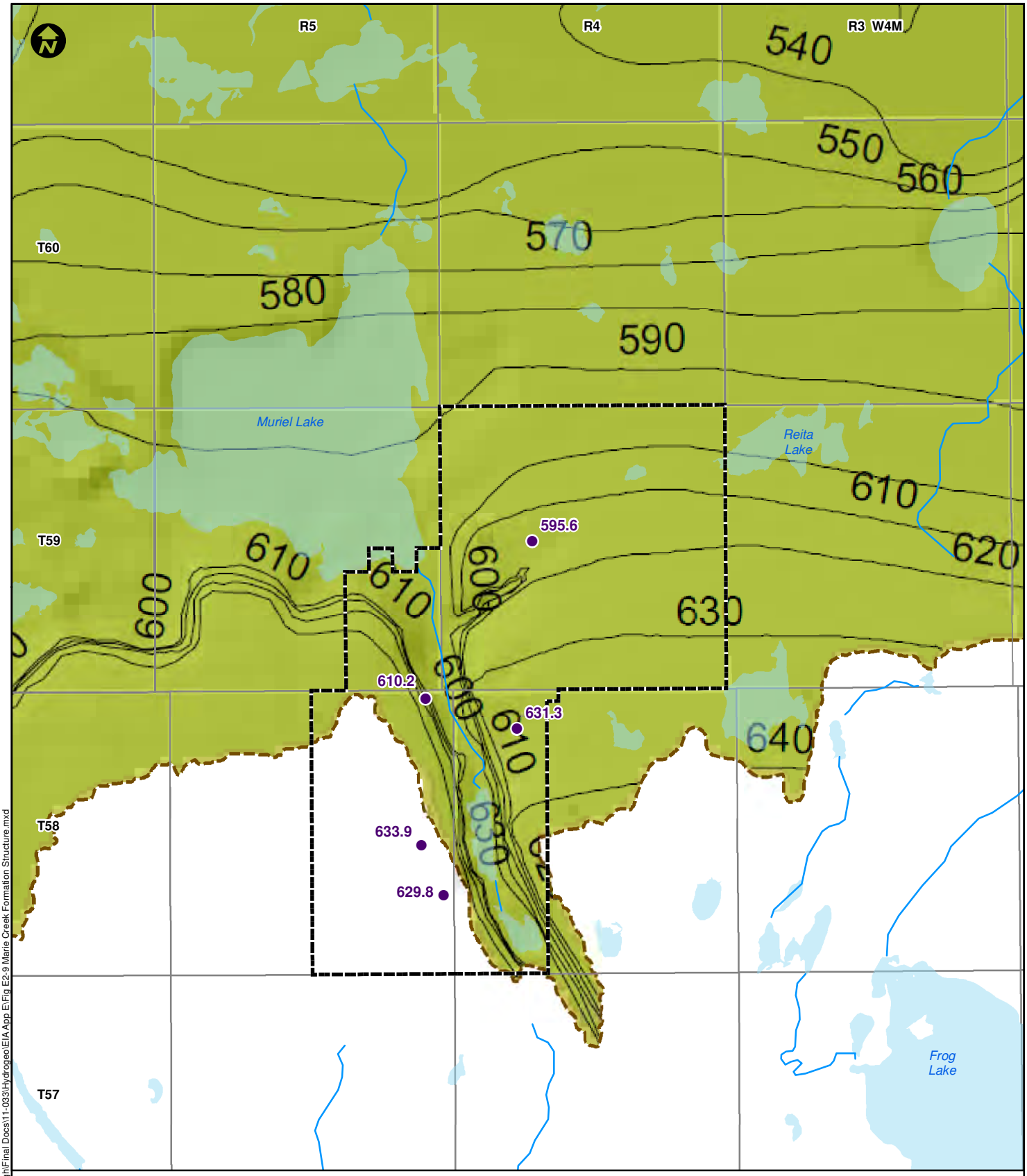
MILLENNIUM EMS Solutions Ltd.

TITLE: **Grand Centre Formation Structure**

DRAWN:	SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **E2-8**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-8 Grand Centre Formation Structure.mxd



Legend

- Monitoring Well
- 595.6 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Till
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

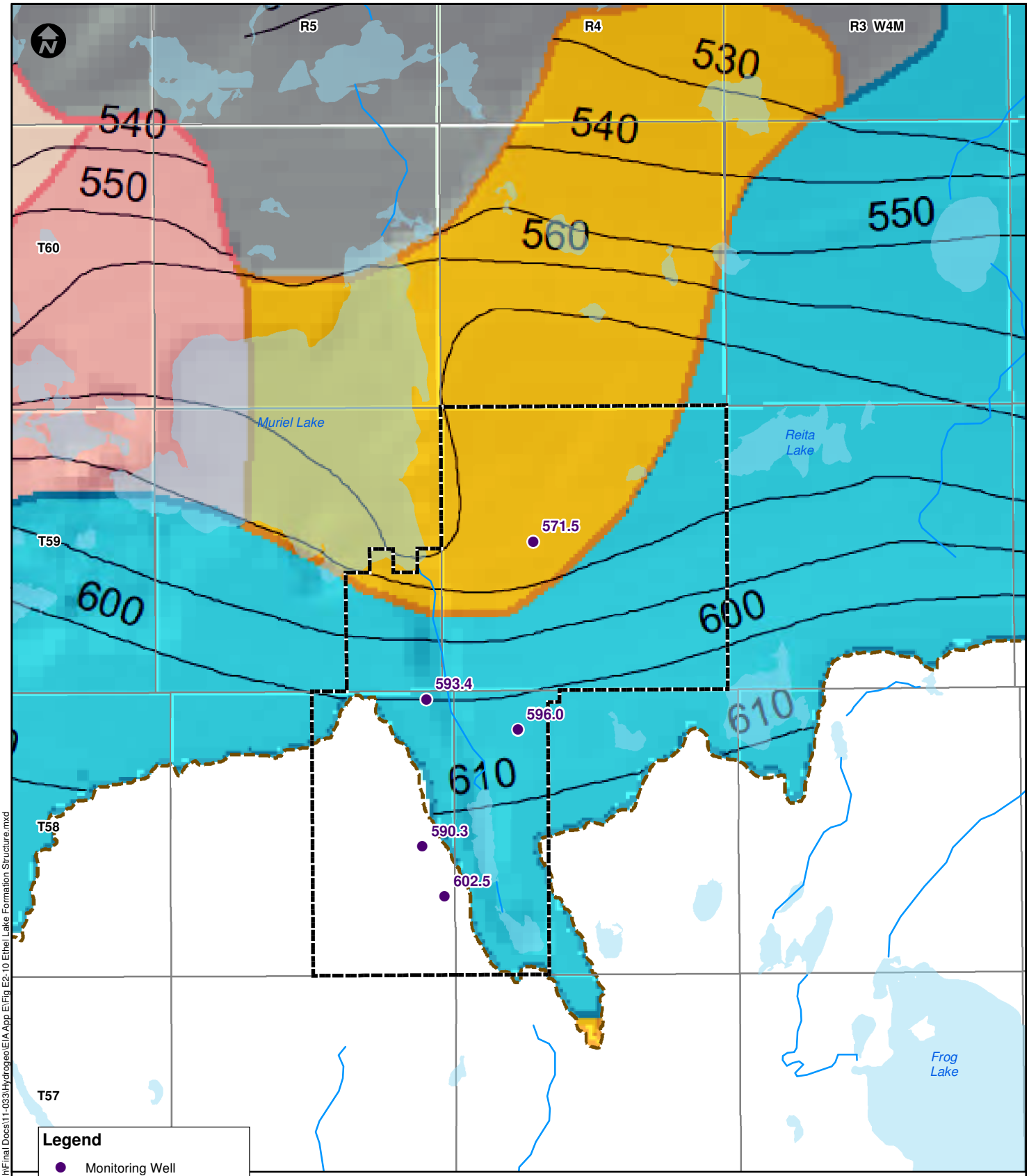
MILLENNIUM EMS Solutions Ltd.

TITLE: Marie Creek Formation Structure

DRAWN:	SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: E2-9

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-9 Marie Creek Formation Structure.mxd



Legend

- Monitoring Well
- 590.3 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Clay, silt and clay
- Sand and silt
- Silt, clay, sand and gravel
- Sand, sand and gravel
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

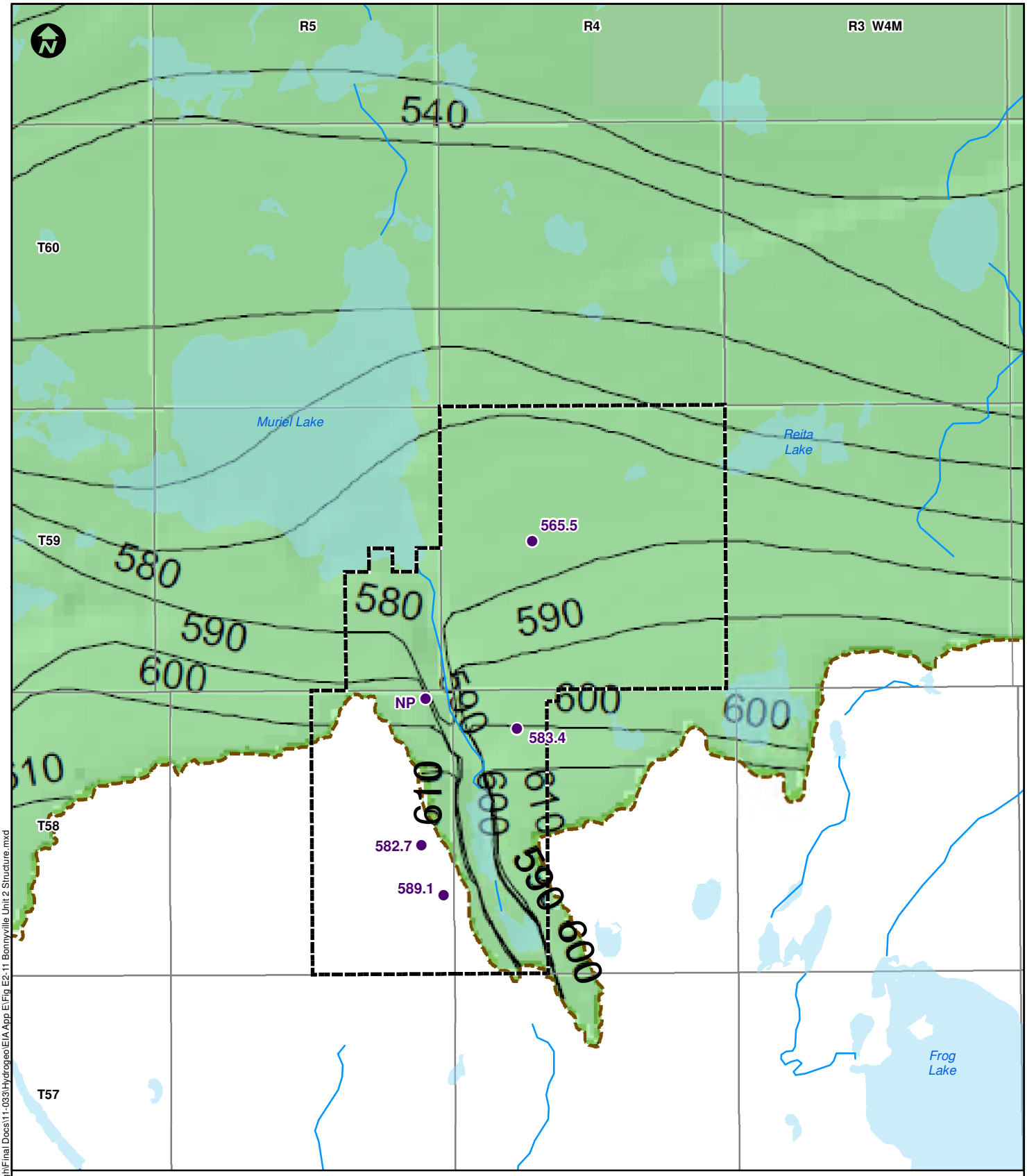
MILLENNIUM EMS Solutions Ltd.

TITLE: **Ethel Lake Formation Structure**

DRAWN:	SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **E2-10**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-10 Ethel Lake Formation Structure.mxd



Legend

- Monitoring Well
- 565.5 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Till
- Structure Contour (m asl)
- Limit of Structure Mapping

0 2 4 8
Kilometres

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

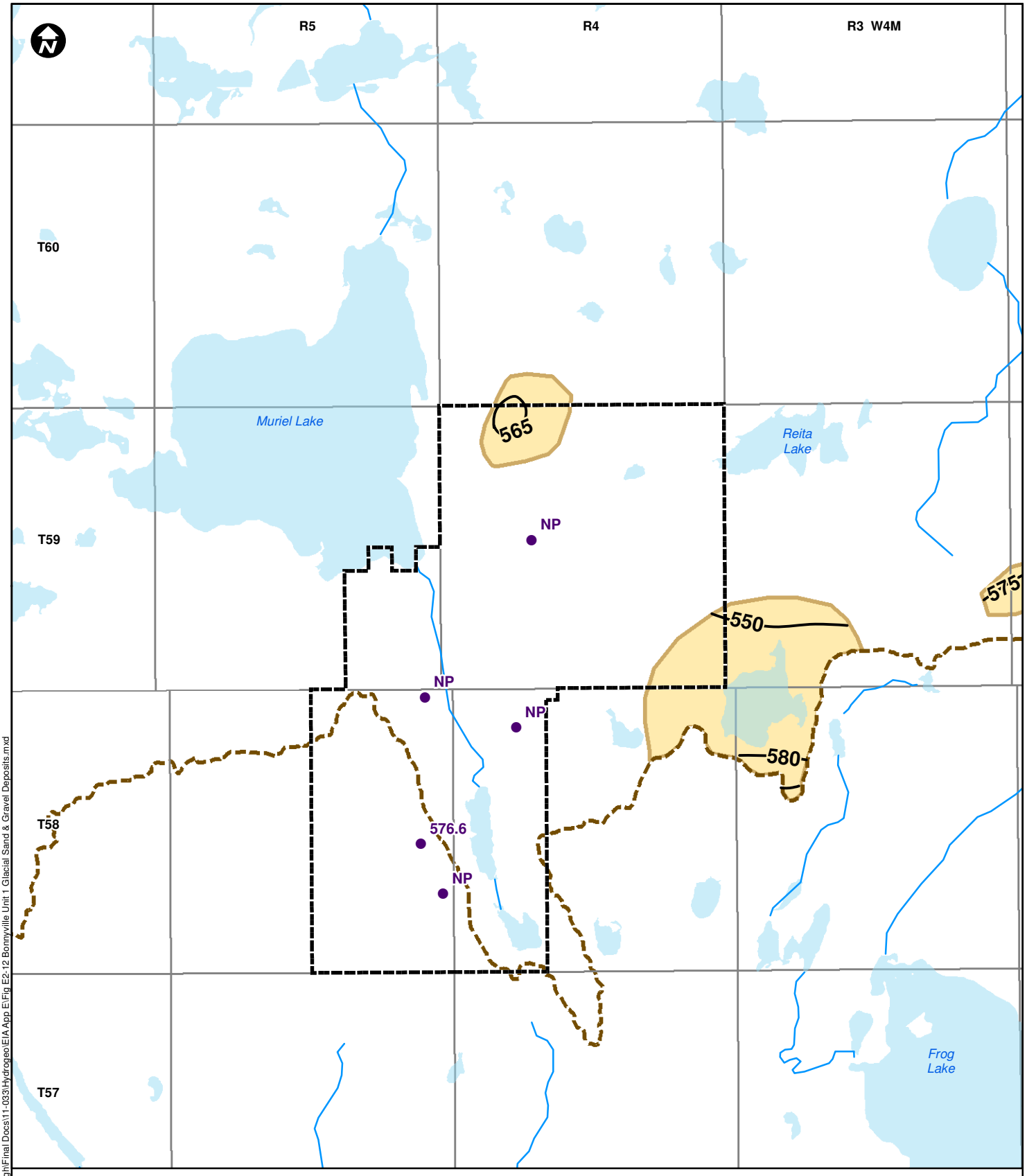
MILLENNIUM EMS Solutions Ltd.

TITLE: Bonnyville Formation Unit 2 Structure

DRAWN: SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: E2-11

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-11 Bonnyville Unit 2 Structure.mxd



Legend

- Monitoring Well
- 576.6 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Sand, sand and gravel
- Structure Contour (m asl)
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

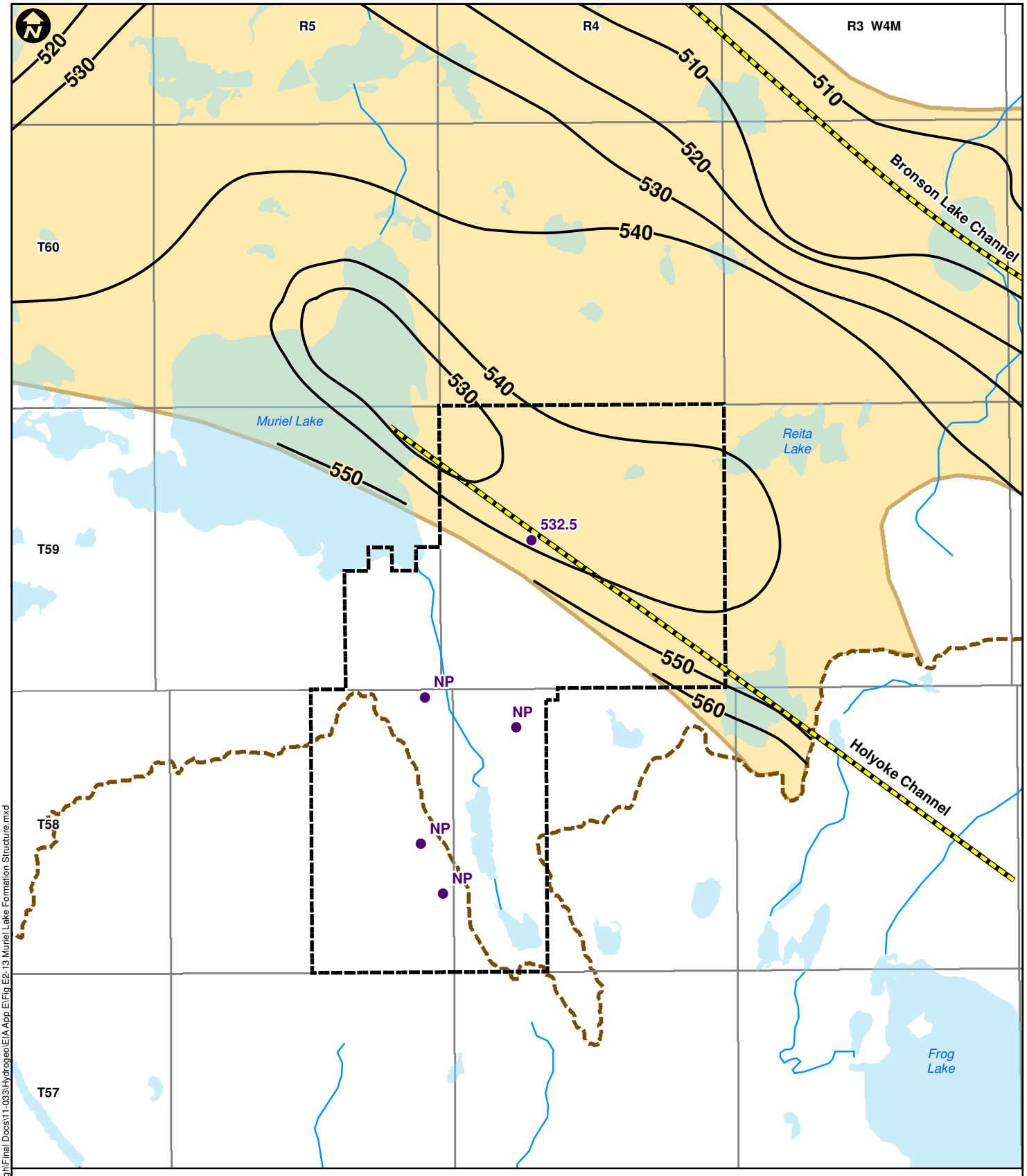
MILLENNIUM EMS Solutions Ltd.

TITLE: **Bonnyville Formation Unit 1 Glacial Sand and Gravel Deposits**

DRAWN:	SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **E2-12**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-12 Bonnyville Unit 1 Glacial Sand & Gravel Deposits.mxd



Legend

- Monitoring Well
- 532.5 Formation Elevation (m asl) NP = Not Present
- EIA Project Area
- Sand, sand and gravel
- Structure Contour (m asl)
- Channel
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

0 2 4 8
Kilometres

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

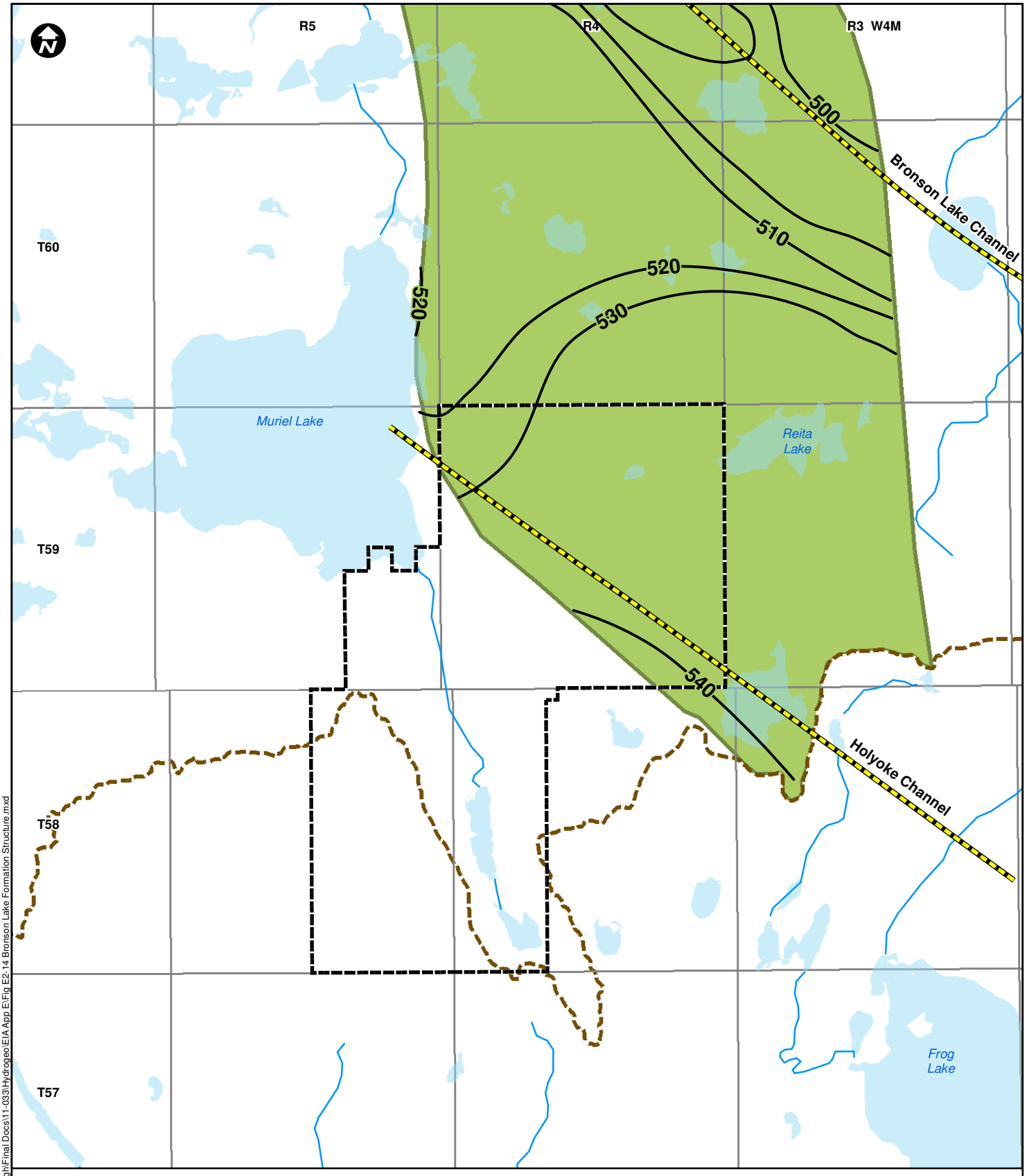
MILLENNIUM EMS Solutions Ltd.

TITLE: **Muriel Lake Formation Structure**

DRAWN: JDC
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **E2-13**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-13 Muriel Lake Formation Structure.mxd



Legend

- EIA Project Area
- Diamict (till?)
- Structure Contour (m asl)
- Channel
- Limit of Structure Mapping

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

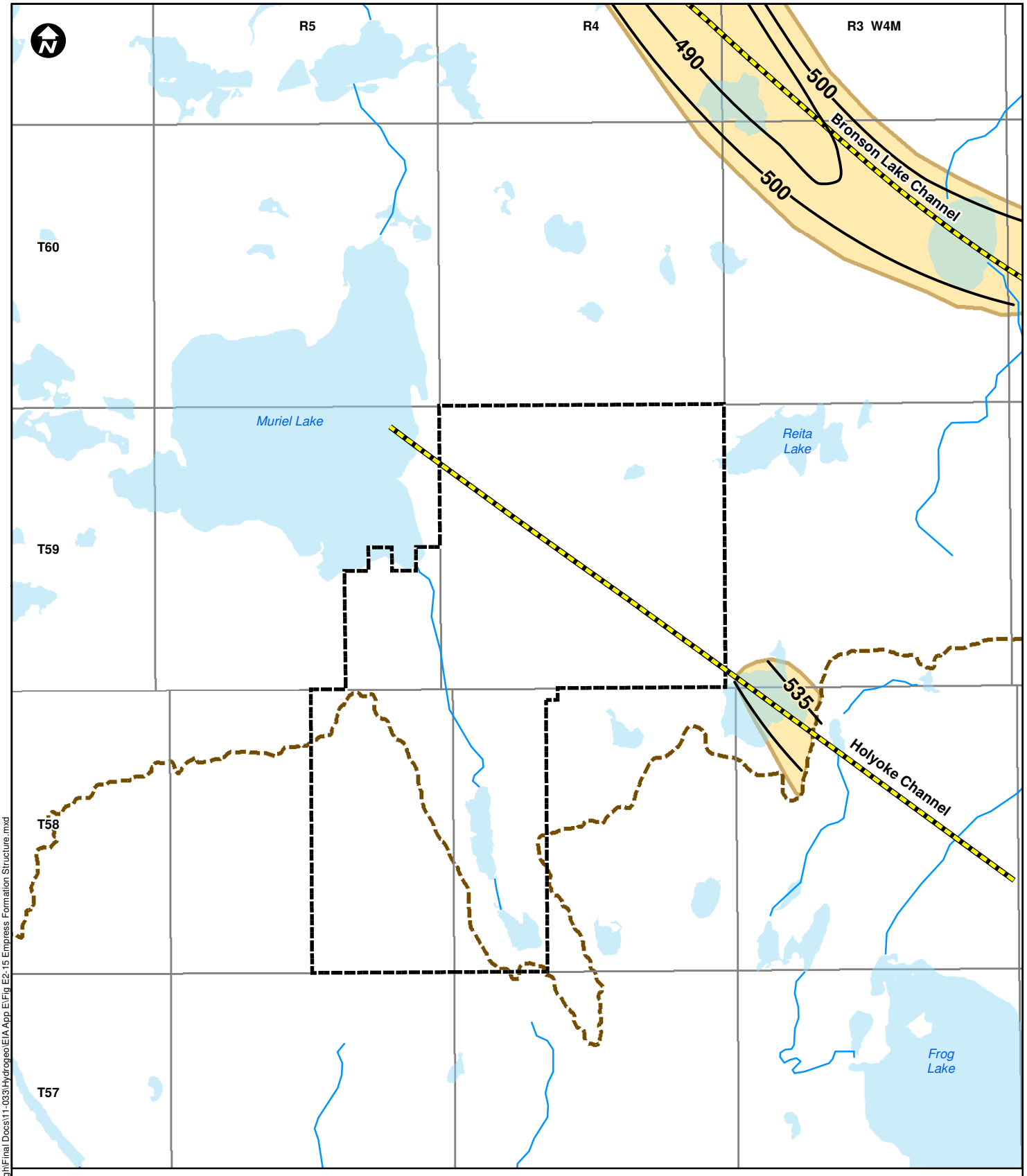
MILLENNIUM EMS Solutions Ltd.

TITLE: Bronson Lake Formation Structure

DRAWN: JDC
CHECKED: JD
DATE: Nov 8/13
PROJECT: 11-033

FIGURE: E2-14

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-14 Bronson Lake Formation Structure.mxd



Legend

- EIA Project Area
- Sand, gravel, silt
- Structure Contour (m asl)
- Limit of Structure Mapping
- Channel

REF: AGS, Special Report 74, Feb. 2005.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

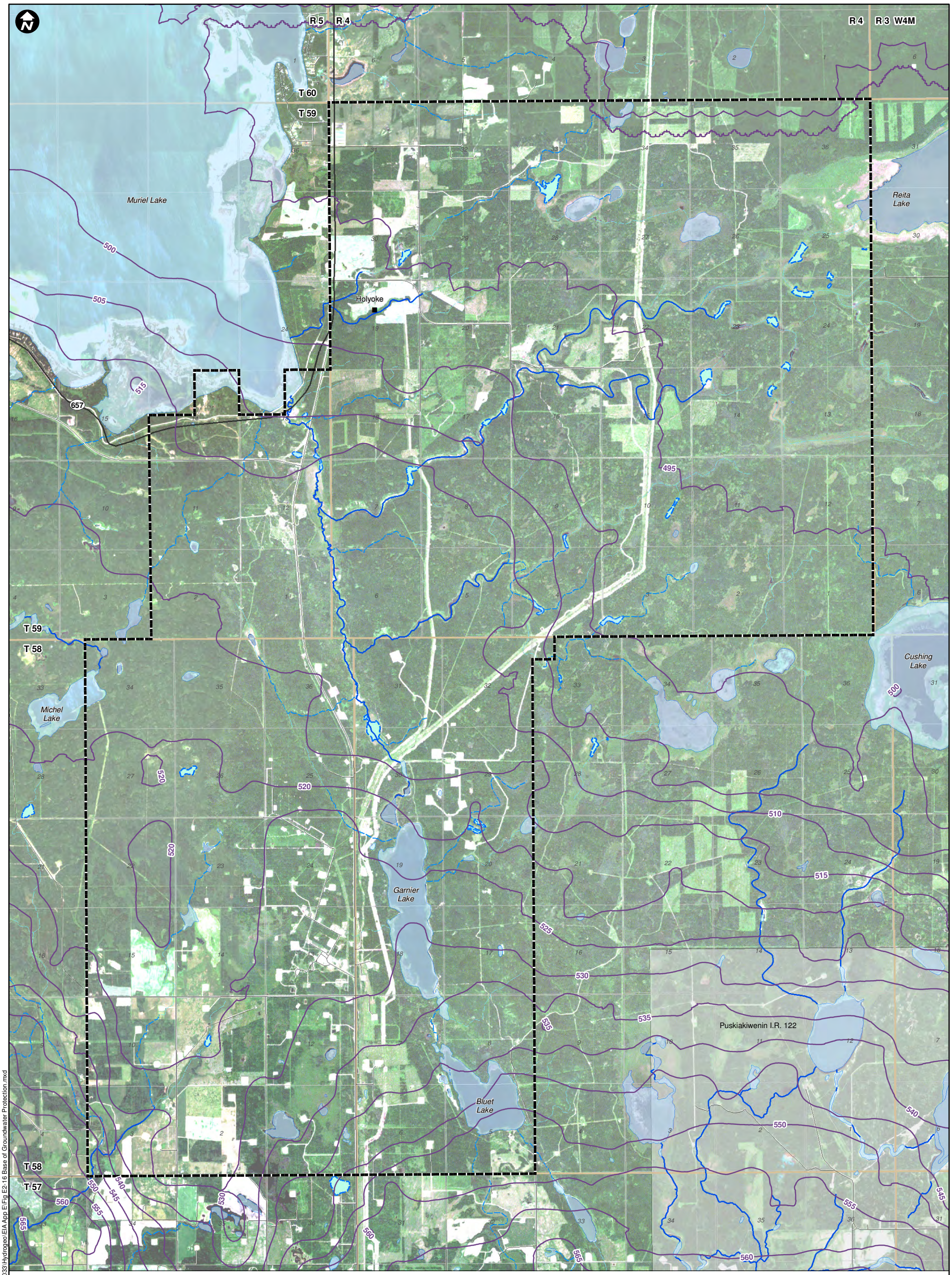
MILLENNIUM EMS Solutions Ltd.

TITLE: **Empress Formation Unit 3 Structure**

DRAWN:	JDC
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **E2-15**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-15 Empress Formation Structure.mxd



Legend

- EIA Project Area
- First Nations
- Contour (5m interval, m asl)
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

REF: AGS, October, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

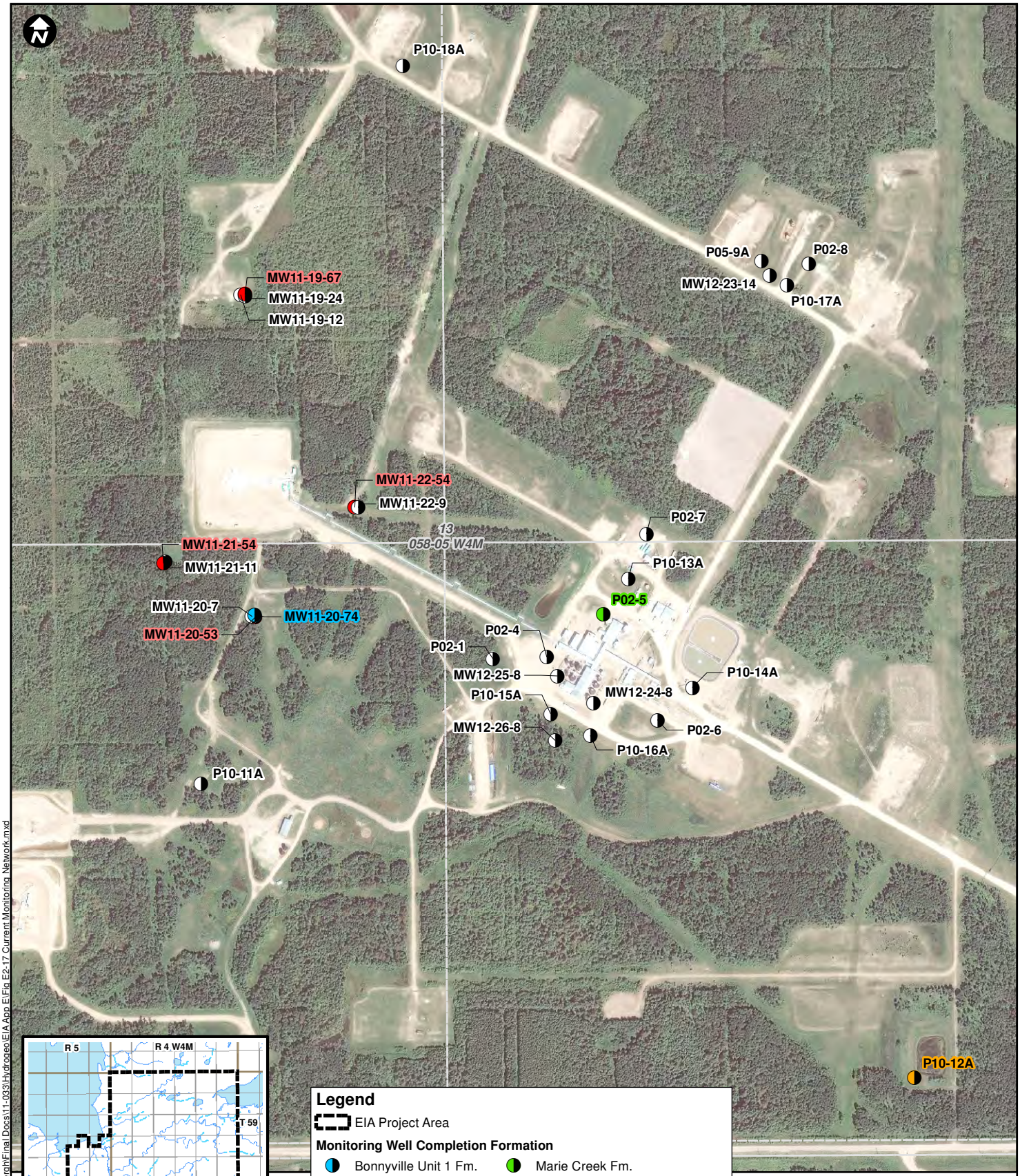
MILLENNIUM EMS Solutions Ltd.

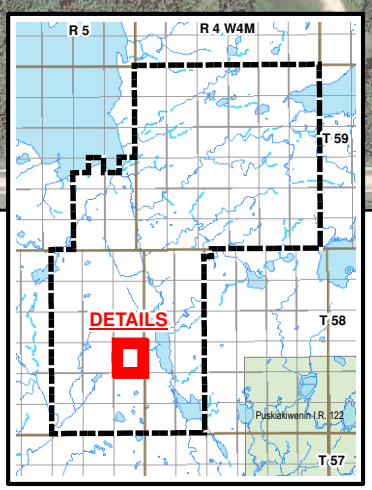
TITLE: Base of Groundwater Protection

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: E2-16

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-16 Base of Groundwater Protection.mxd





Legend

EIA Project Area

Monitoring Well Completion Formation

- Bonnyville Unit 1 Fm.
- Ethel Lake Fm.
- Grand Centre Fm.
- Marie Creek Fm.
- Muriel Lake Fm.
- Sand River equiv. Fm.

0 125 250
Metres

PROJECT: PENGROWTH — Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

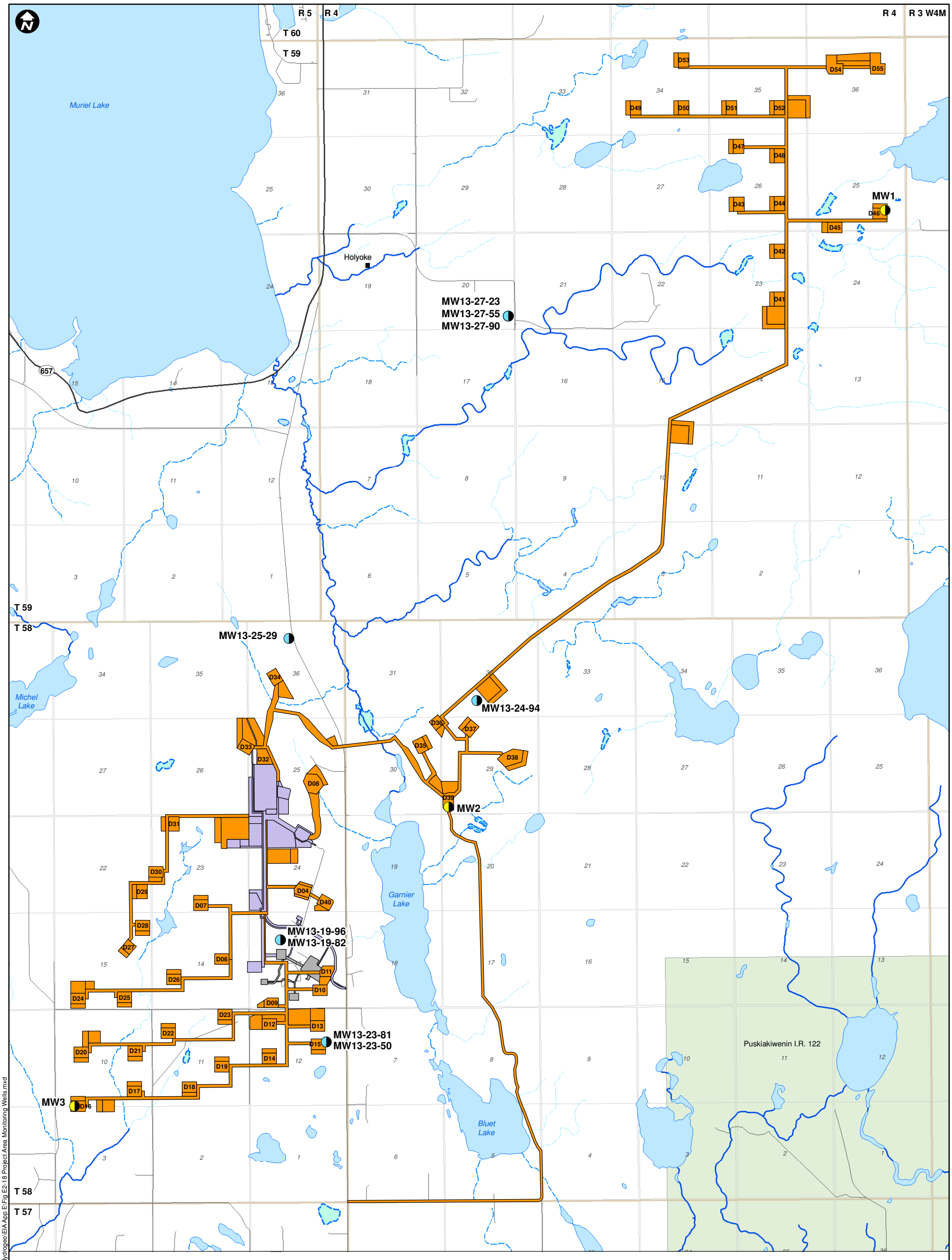
TITLE: **Current Monitoring Network Pilot Project Area**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 9/13
PROJECT: 11-033

FIGURE: **E2-17**

REF: MEMS, 2013; Orthophoto from Pengrowth, June 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-17 Current Monitoring Network.mxd



Legend

- Existing Monitoring Well
- Proposed Monitoring Well
- Expansion Development
- Pilot Development
- Phase 1 Develpment
- First Nations
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

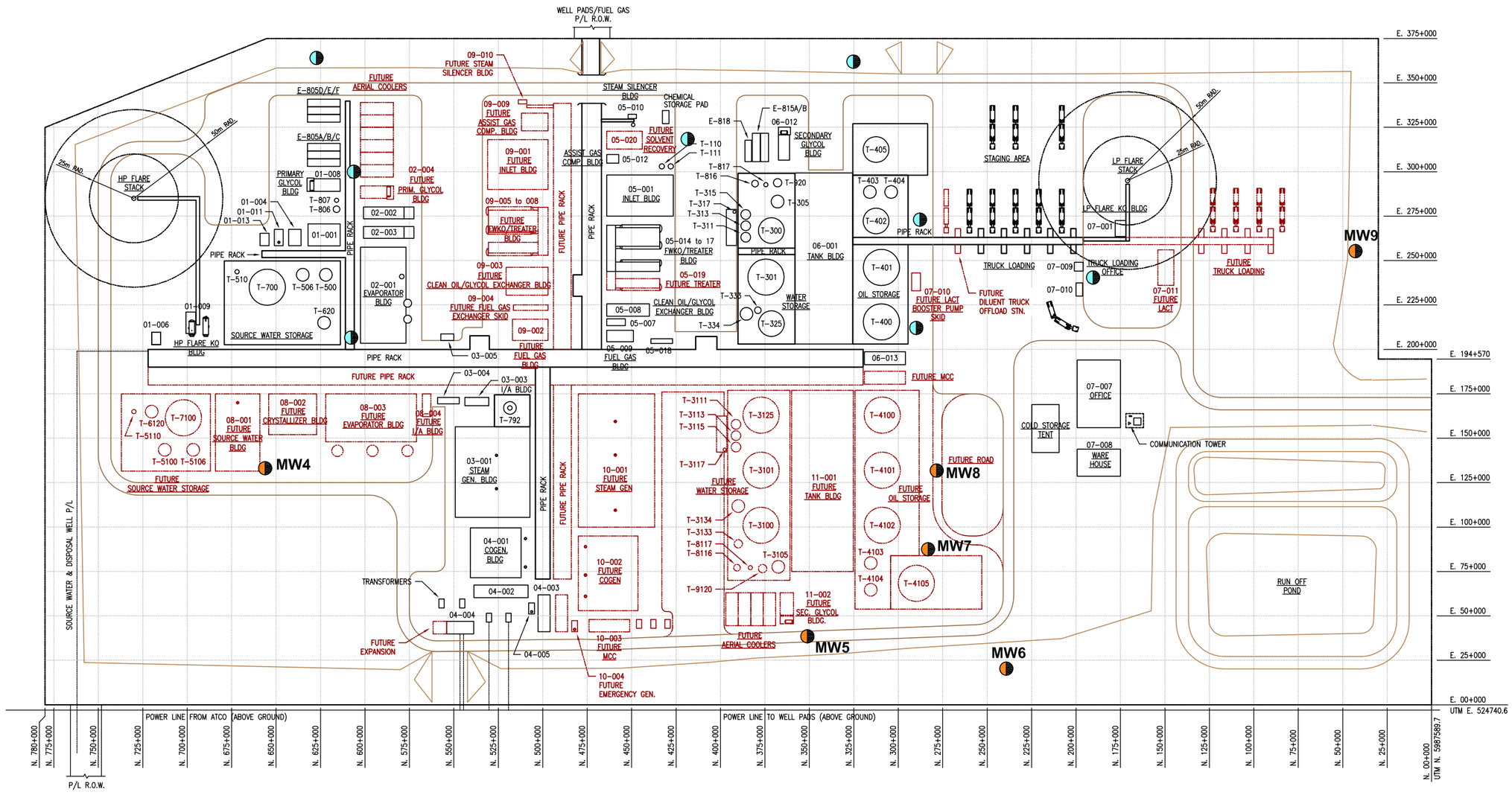
TITLE: Project Area Monitoring Wells

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: E2-18

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-18 Project Area Monitoring Wells.mxd

TAG	BUILDING/EQUIPMENT DESCRIPTION	WIDTH	LENGTH	HEIGHT
01-001	SOURCE WATER BUILDING	12300	18025	5550
01-004	BFW BOOSTER PUMP SKID	7000	8400	3048
01-006	PW/SAC REGEN WASTE INJ. PUMP SKID	5000	7000	3048
01-008	PRIMARY GLYCOL BUILDING	7000	18620	5280
01-009	HP FLARE KO BUILDING	5500	12000	3200
01-011	UTILITY STEAM BOILER SKID	5000	7000	3048
01-013	NITROGEN SKID	5334	8712	N/A



TAG	BUILDING/EQUIPMENT DESCRIPTION	WIDTH	LENGTH	HEIGHT
02-001	EVAPORATOR BUILDING	25908	51816	11430
02-002	MCC-02-002	7315	23000	3048
02-003	MCC-02-003	7315	23000	3048
03-001	STEAM GENERATOR BUILDING	43000	51000	11239
03-003	INSTRUMENT AIR BUIDLING	3700	7400	3048
03-004	UTILITY LAB	3000	9000	3048
03-005	UTILITY BUILDING A	N/A	N/A	N/A
04-001	COGEN. BUILDING	28000	33500	11430
04-002	MCC-04-002	7315	23000	3048
04-003	MCC-04-003	7315	23000	3048
04-004	25kV BUILDING	N/A	N/A	N/A
04-005	EMERGENCY GENERATOR	N/A	N/A	N/A
05-001	INLET BUILDING	23200	37450	12000
05-007	FUEL GAS HEATER SKID	2800	14000	N/A
05-008	CLEAN OIL/GLYCOL EXCH. BLDG	7000	24000	5100
05-009	FUEL GAS BUILDING	6400	14800	5300
05-010	STEAM SILENCER BUILDING	2400	4700	3048
05-012	ASSIST GAS COMPRESSOR BUILDING	10000	15000	3048
05-013	PROCESS LAB	3000	9000	6400
05-014	FWKO/TREATER CONTROL BUILDING	23850	31000	6400
05-015	FWKO 102 BUILDING	6800	26000	6400
05-016	FWKO 103 BUILDING	6800	26000	6400
05-017	TREATER 104 BUILDING	5000	26000	6400
05-018	UTILITY BUILDING B	N/A	N/A	N/A
06-001	TANK BUILDING	32500	96300	11000
06-012	SECONDARY GLYCOL BUILDING	7500	17400	3048
06-013	MCC-06-013	7315	23000	3048
07-001	LP FLARE KO BUILDING	6000	9000	3200
07-007	OFFICE BUILDING	24300	38100	3048
07-008	WAREHOUSE	12000	24300	3048
07-009	TRUCK LOADING OFFICE BUILDING	5000	5000	3048
07-010	UTILITY BUILDING C	N/A	N/A	N/A
E-805A/B/C/D/E/F	PRIMARY GLYCOL AERIAL COOLER	4270	18290	–
E-815A/B	PW GLYCOL AERIAL COOLER	4480	15850	–
E-818	VRU GLYCOL AERIAL COOLER	3710	11890	–
T-110	EMULSION BREAKER TANK	3000ø	–	3050
T-111	REVERSE EMULSION BREAKER TANK	3000ø	–	3050
T-300	PRODUCED WATER SURGE TANK	14500ø	–	9760
T-301	ORF FEED TANK	20380ø	–	9760
T-305	DESAND TANK	7163ø	–	9760
T-311	1st STAGE DE-OILING TANK	5486ø	–	9760
T-313	2nd STAGE DE-OILING TANK	5486ø	–	9760
T-315	3rd STAGE DE-OILING TANK	5486ø	–	9760
T-317	FROTH OIL TANK	1830ø	–	2440
T-325	DE-OILED WATER TANK	14500ø	–	9760
T-333	BRINE TANK	3759ø	–	6096
T-334	SAC REGEN WASTE TANK	7163ø	–	9760
T-400	PRODUCTION TANK	20380ø	–	9760
T-401	SALES OIL TANK	20380ø	–	9760
T-402	OFF-SPEC OIL TANK	14500ø	–	9760
T-403	SLOP OIL TANK	7163ø	–	9760
T-404	SLOP OIL TANK	7163ø	–	9760
T-405	DILUENT TANK	14500ø	–	9760
T-500	RAW WATER TANK	7163ø	–	9760
T-506	SOFT WATER TANK	7163ø	–	9760
T-510	SOURCE WATER BRINE TANK	2235ø	–	2286
T-620	EVAPORATOR WASTE TANK	7163ø	–	9760
T-700	BOILER FEEDWATER TANK	20380ø	–	9760
T-792	BLOWDOWN TANK	7163ø	–	9760
T-806	PRIMARY GLYCOL STORAGE TANK	3658ø	–	3048
T-807	PRIMARY GLYCOL POP TANK	2388ø	–	1529
T-816	SECONDARY GLYCOL STORAGE TANK	3658ø	–	3048
T-817	SECONDARY GLYCOL POP TANK	2388ø	–	1829
T-920	FLOOR DRAIN TANK	4724ø	–	4877

GENERAL NOTES:
1. NAD 83 UTM COORDINATES FOR REFERENCE.

Legend

- Phase 1 Monitoring Well
- Project Monitoring Well
- Process Components Associated with Phase 1
- Process Components Associated with the Project

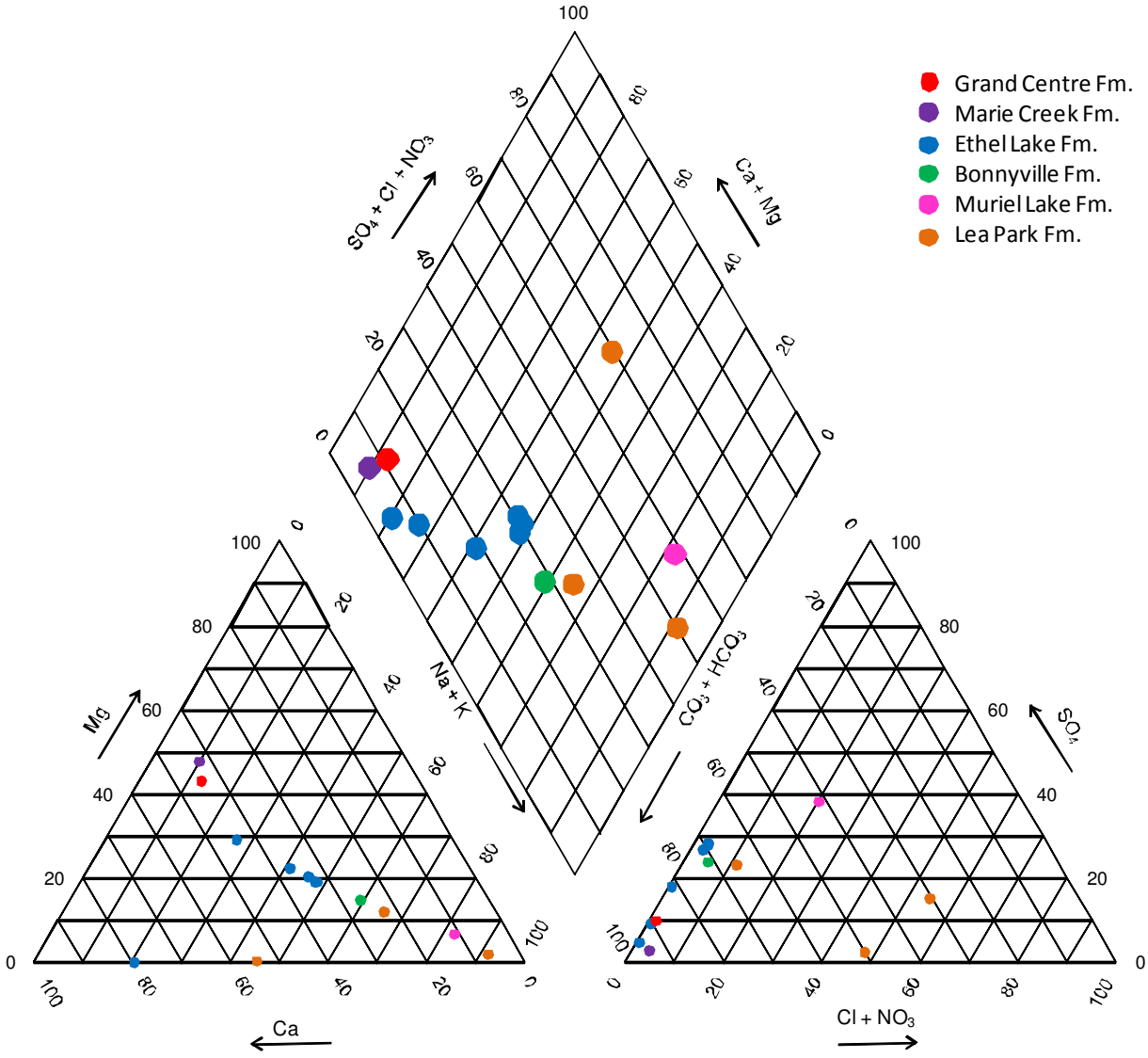
REF: SCOVAN Engineering Inc., 2013.

0 25 50 100m
Scale 1 : 2 500

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

TITLE: Project CPF Monitoring Wells

FILE: ...Final Docs\11-033\Hydrogeo\E2-19.dwg
DRAWN: SL
CHECKED: JD
DATE: Dec 9/13
PROJECT: 11-033
FIGURE: E2-19



PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

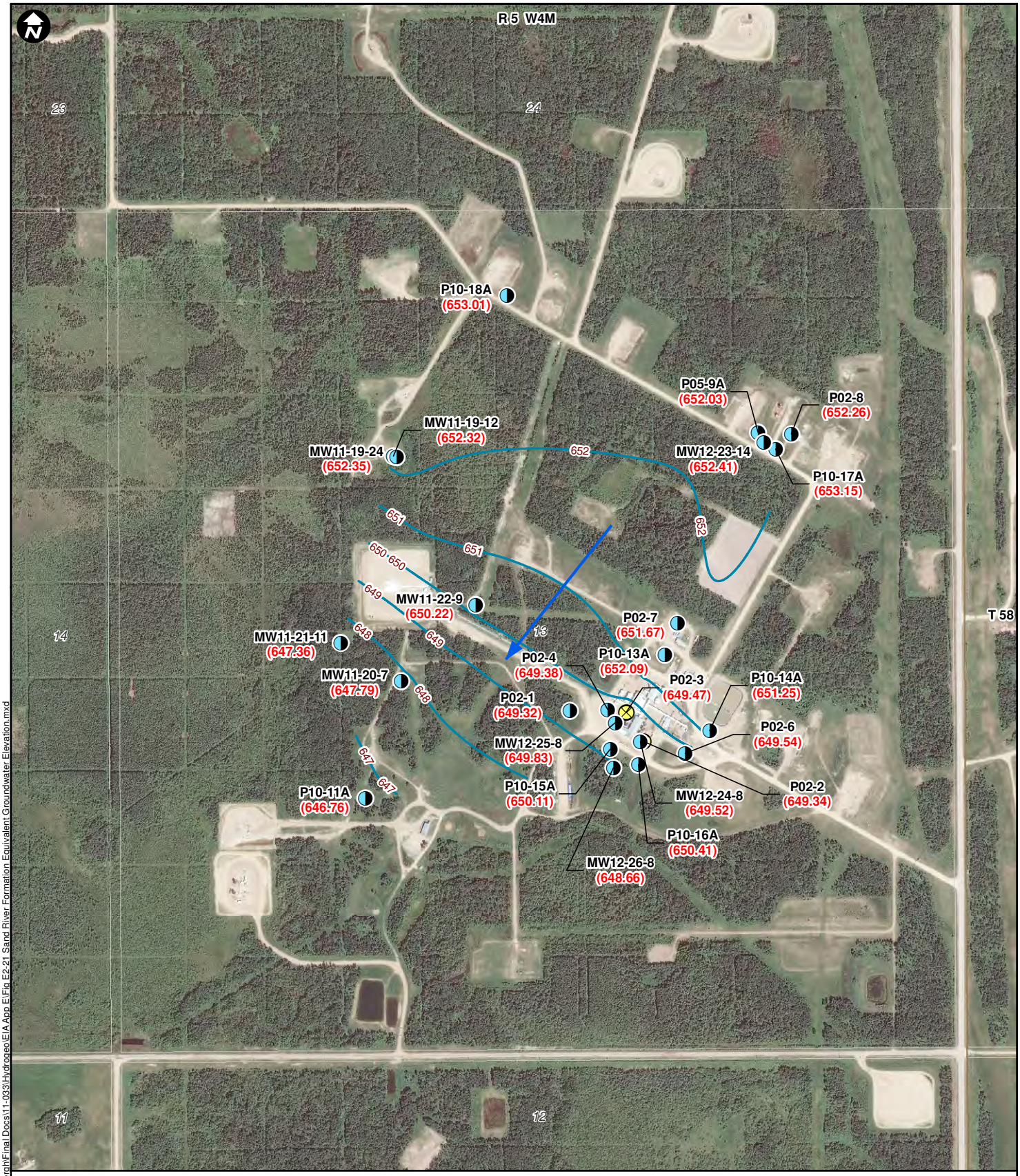
MILLENNIUM EMS Solutions Ltd.

TITLE: Piper Diagram

DRAWN: JDC
CHECKED: JD
DATE: Dec 5/13
PROJECT: 11-033

FIGURE: E2-20

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-20 Piper Diagram.mxd



Legend

- Monitoring Well
- Decommissioned Monitoring Well
- Contour (1m interval, m asl)
- Groundwater Flow Direction
- (651.38) Most Recent Groundwater Elevation (m asl)

0 200 400
Metres

REF: MEMS, 2013; Orthophoto from Pengrowth, June 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

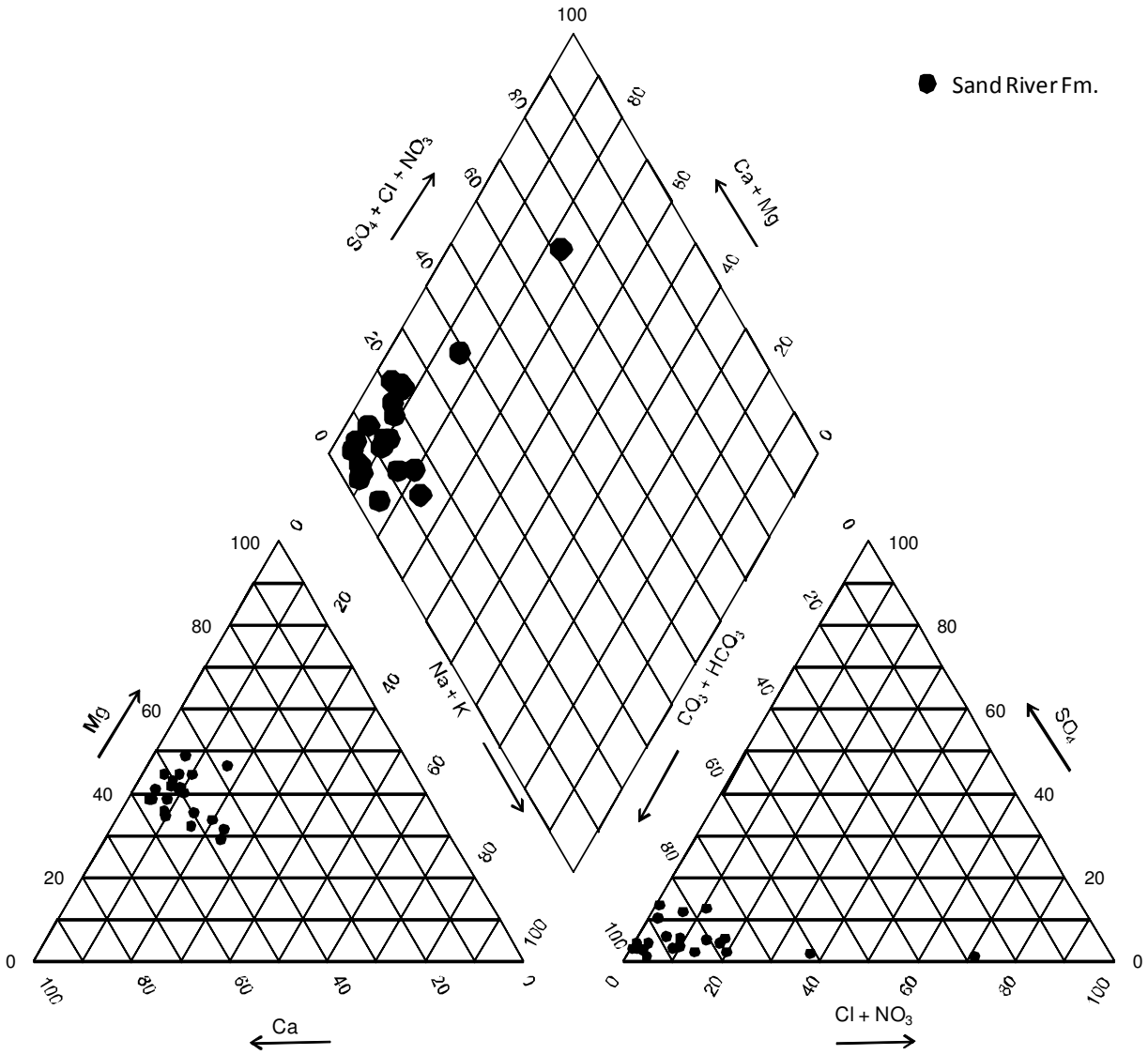
MILLENNIUM EMS Solutions Ltd.

TITLE: **Sand River Formation Equivalent Groundwater Elevation**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: **E2-21**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-21 Sand River Formation Equivalent Groundwater Elevation.mxd



PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

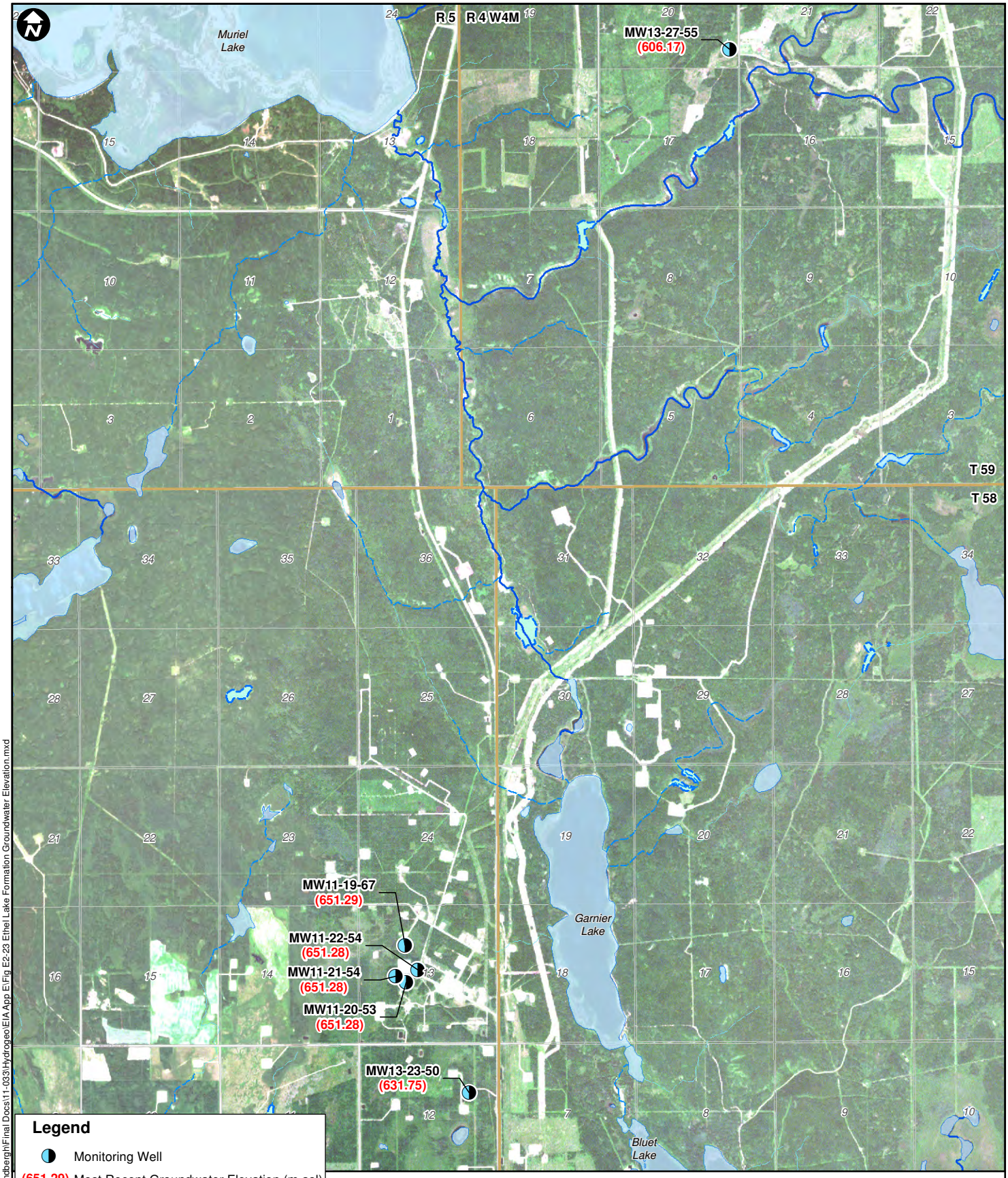
MILLENNIUM EMS Solutions Ltd.

TITLE: **Piper Diagram – Sand River Formation Equivalent**

DRAWN: JDC
CHECKED: JD
DATE: Nov 8/13
PROJECT: 11-033

FIGURE: **E2-22**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-22 Piper Diagram – Sand River Formation Equivalent.mxd



Legend

- Monitoring Well
- (651.29) Most Recent Groundwater Elevation (m asl)
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.6 1.2 2.4
Kilometres

REF: MEMS, 2013; NHC hydrology Oct 2013; RapidEye, June-July, 2013.

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-23 Ethel Lake Formation Groundwater Elevation.mxd

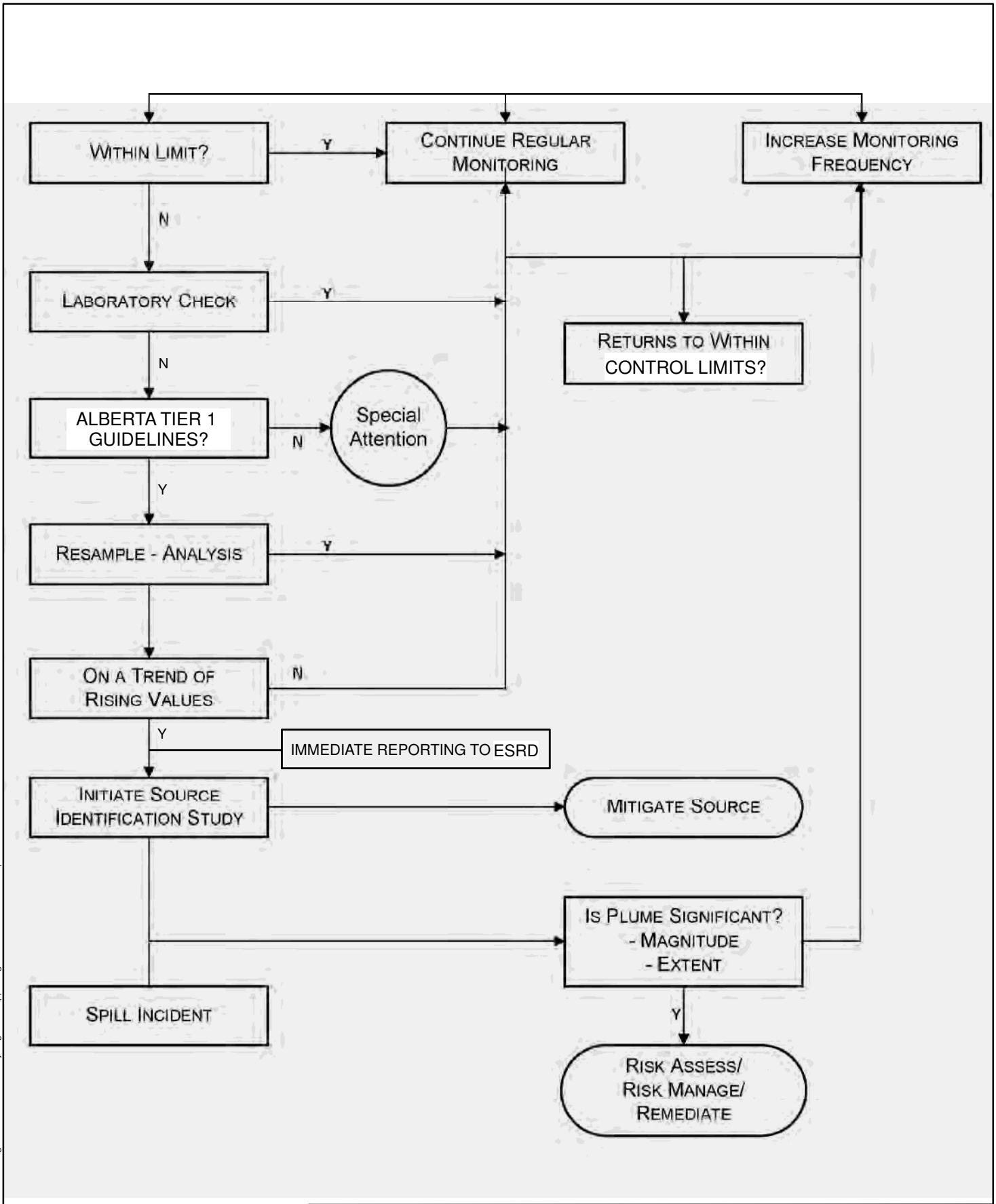
PROJECT: PENGROWTH **Lindbergh SAGD Expansion Project**

MILLENNIUM EMS Solutions Ltd.

TITLE: **Ethel Lake Formation Groundwater Elevation**

DRAWN:	JDC/SL
CHECKED:	JD
DATE:	Dec 4/13
PROJECT:	11-033

FIGURE: **E2-23**



PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

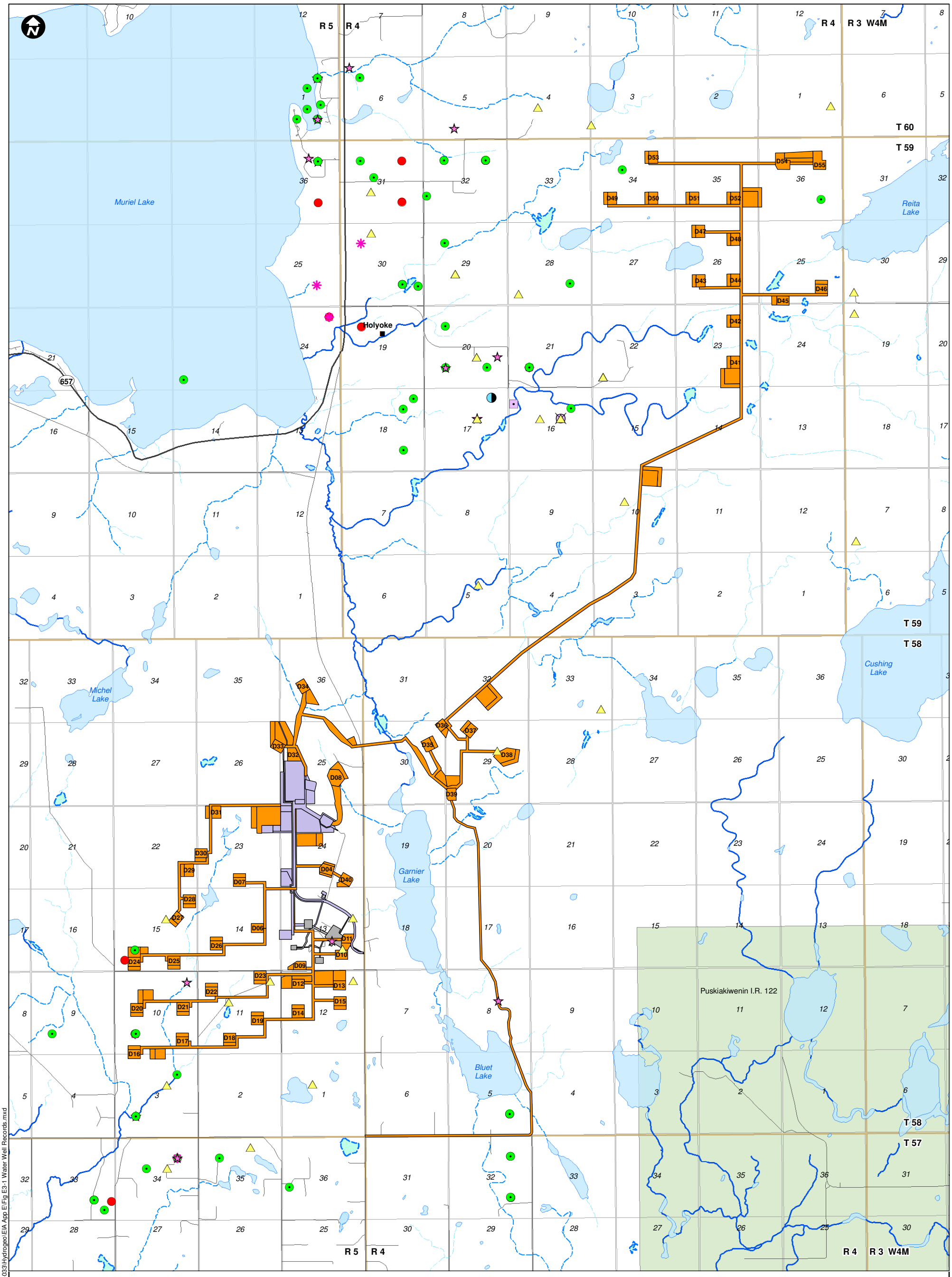
TITLE: Groundwater Response Plan

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 4/13
PROJECT: 11-033

FIGURE: E2-24

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E2-24 Groundwater Response Plan.mxd

APPENDIX E3: WATER WELL RECORDS AND LICENSED USERS



Legend

Water Well

- Domestic
- Domestic/Stock
- Stock
- Monitoring
- Industrial
- Observation
- Old Well-Abandoned
- Unknown

- Expansion Development
- Pilot Development
- Phase 1 Develpment
- First Nations
- Secondary Highway
- Improved Road

- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

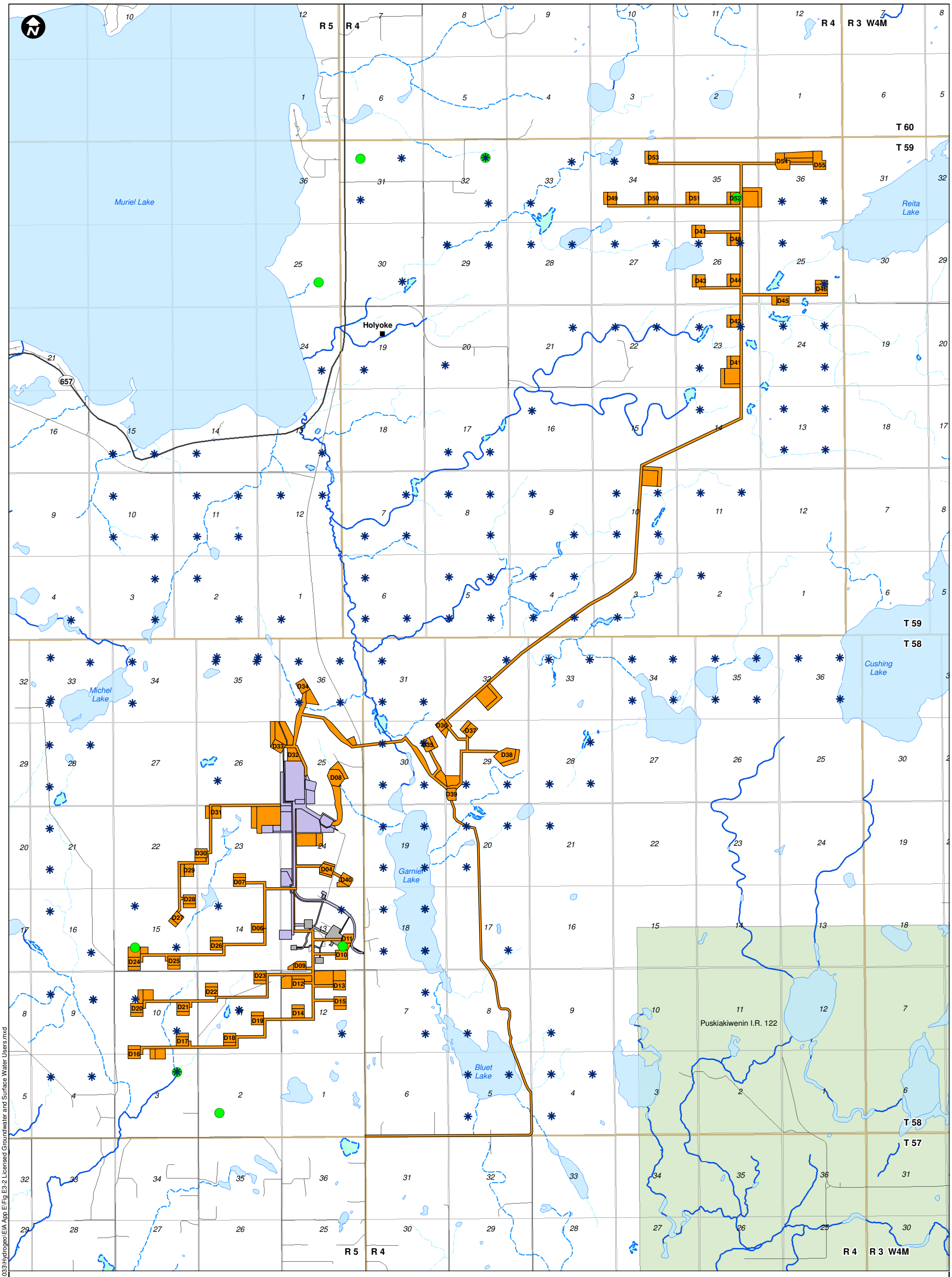
MILLENNIUM EMS Solutions Ltd.

TITLE: **Water Well Records**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 9/13
PROJECT: 11-033

FIGURE: **E3-1**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E3-1 Water Well Records.mxd



Legend

Water Users

- Groundwater
- Surface Water
- Expansion Development
- Pilot Development
- Phase 1 Develpment
- First Nations

- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: **Licensed Groundwater and Surface Water Users**

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 9/13
PROJECT: 11-033

FIGURE: **E3-2**

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E3-2 Licensed Groundwater and Surface Water Users.mxd

Table E3-1 Water Well Records within a 1.6 Kilometre Radius of the Project

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
153647	SW	21	59	4	4	TIZZARD DRILLING LTD.	10/23/1990	9.14	New Well	Stock	KELLERMAN, ERWIN	2.44	36.37
155035	SE	36	59	5	4	ROBERT, A. WATER WELL DRILLING LTD.	10/30/1979	67.06	New Well	Domestic & Stock	BROSSEAU, WILFRED	0	136.38
156194	1	33	57	5	4	MORTON'S WATER WELL DRILLING LTD.	5/10/1991	54.86	New Well	Domestic & Stock	ZAPESOCKI, HARRY	7.62	227.3
157070	NE	34	57	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	OPANAVICIUS, A.#WELL 2		
157213	1	1	60	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	WELSH, ROBERT		
158445	8	1	60	5	4	UNKNOWN DRILLER		25.91	Chemistry	Domestic	RONDEAU, CLAUDE		
158588	SE	33	57	5	4	R&D WW BORING	5/1/1972	26.52	New Well	Domestic	ZAPESOCKI, HARRY	4.88	6.82
161836	SW	10	58	5	4	UNKNOWN DRILLER		6.1	Chemistry	Domestic	OCKERMAN, ORIN		
164110	NE	34	57	5	4	LAKELAND DRILLING LTD.	3/26/1992	10.67	New Well	Stock	OPANAVICIUS, A.	6.1	54.55
165967	16	1	60	5	4	UNKNOWN DRILLER		33.53	Chemistry	Domestic	LAJEUNESSE, GERALD		
202834	1	33	57	5	4	BYRT, STAN & SONS LTD.	8/27/1975	36.58	New Well	Domestic	ZAPESOCKI, ED	4.24	54.55
202838	SE	33	57	5	4	UNKNOWN DRILLER		6.1	Chemistry	Domestic	ZAPESOCKI, NICK	3.05	
202839	SE	33	57	5	4	UNKNOWN DRILLER		24.38	Chemistry	Domestic	ZAPESOCKI, NICK	6.1	
202840	11	34	57	5	4	RONDEAU & DENOYER	9/29/1970	8.53	New Well	Domestic	HILLEBRAND, KENNETH	3.66	186.39
202845	NE	34	57	5	4	UNKNOWN DRILLER		7.62	Chemistry	Unknown	OPANAVICIUS, A.#WELL 1		
202846	NW	35	57	5	4	UNKNOWN DRILLER		7.32	Chemistry	Domestic	KUMMITZ, F.	6.71	
202848	15	35	57	5	4	UNKNOWN DRILLER	10/22/1946	599.24	Oil Exploratory	Industrial	ANGLO-CAN OIL CO #3 WELL		
206621	SE	32	57	4	4	LAKELAND DRILLING LTD.	4/1/1983	73.76	New Well	Domestic & Stock	MOLMAR, JOE	6.1	45.46
206629	SE	32	57	4	4	UNKNOWN DRILLER		45.72	Chemistry	Domestic	GALLAGHER, JUDY		
206630	NE	32	57	4	4	R&D WW BORING	4/1/1971	9.14	New Well	Domestic	GALLAGHER, ARTHUR		
206633	NE	32	57	4	4	UNKNOWN DRILLER		6.71	Chemistry	Domestic	GALLAGHER, ARTHUR	4.88	
206716	SE	5	58	4	4	MCALLISTER HOLDINGS LTD.	7/8/1988	6.71	New Well	Domestic	BLAIR, JOHN	1.83	6.82
206717	10	29	58	4	4	UNKNOWN DRILLER	10/23/1953	613.87	Structure Test Hole	Industrial	AMOCO		
206719	1	33	58	4	4	UNKNOWN DRILLER	6/28/1979	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
206733	11	1	58	5	4	UNKNOWN DRILLER		518.16	Structure Test Hole	Industrial	MURPHY OIL		
206739	SW	3	58	5	4	HORNESS D N	5/9/1965	8.23	New Well	Unknown	HILLEBRAND, E.		
206742	SW	3	58	5	4	MARTIN, J. WATER WELLS	8/29/1988	12.8	New Well	Domestic & Stock	HILLEBRAND, JOHN E.	7.32	90.92
206746	NE	3	58	5	4	UNKNOWN DRILLER		8.23	Chemistry	Domestic	GREKUL, WENDY		
206748	10	3	58	5	4	UNKNOWN DRILLER	12/13/1960	533.4	Structure Test Hole	Industrial	CAN SALT CO LTD		
206760	SW	10	58	5	4	UNKNOWN DRILLER		4.27	Chemistry	Domestic	YOUNG, BRUCE	3.35	
206769	SW	10	58	5	4	RONDEAU & DENOYER	4/1/1972	6.4	New Well	Domestic	JOHNSON, MAURICE	2.74	27.28
206773	SW	10	58	5	4	RONDEAU & DENOYER	4/1/1972	7.01	New Well	Stock	JOHNSON, MAURICE	2.74	40.91
206774	SW	10	58	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	FITZ, HEINZ		
206776	16	10	58	5	4	UNKNOWN DRILLER	9/1/1976	35.66	Test Hole	Unknown	ARC		
206780	11	11	58	5	4	UNKNOWN DRILLER	10/31/1961	548.64	Structure Test Hole	Industrial	CAN SALT CO LTD		
206784	16	11	58	5	4	UNKNOWN DRILLER	7/21/1964	502.92	Structure Test Hole	Industrial	CAN SALT CO LTD		
206785	16	12	58	5	4	UNKNOWN DRILLER	5/28/1967	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
206786	SE	13	58	5	4	UNKNOWN DRILLER		64.01	Chemistry	Industrial	MURPHY OIL CO LTD		
206799	9	13	58	5	4	UNKNOWN DRILLER	6/6/1967	518.16	Structure Test Hole	Industrial	CAN SALT CO LTD		
206802	SW	15	58	5	4	PARADIS BROS WW	9/29/1980	14.94	New Well	Domestic & Stock	BROWN, LLOYD	5.18	9.09
206805	4	15	58	5	4	PARADIS BROS WW	11/3/1980	6.4	New Well	Domestic & Stock	PARON, PAT	3.05	22.73
206808	10	15	58	5	4	UNKNOWN DRILLER	11/23/1965	606.55	Structure Test Hole	Industrial	TENNECO OIL CO		
206897	10	8	58	4	4	UNKNOWN DRILLER		23.47	Federal Well Survey	Unknown			
208711	4	7	59	3	4	UNKNOWN DRILLER	3/9/1966	264.87	Structure Test Hole	Industrial	UNION TEXAS OF CAN #M16		
208730	13	19	59	3	4	UNKNOWN DRILLER	3/7/1966	240.18	Structure Test Hole	Industrial	UNION TEXAS OF CAN #M5		
208750	4	30	59	3	4	UNKNOWN DRILLER	2/19/1971	525.78	Structure Test Hole	Industrial	GREAT NORTHERN OIL LTD		
208769	10	5	59	4	4	UNKNOWN DRILLER	2/12/1963	566.01	Structure Test Hole	Industrial	PAN AM PETRO CORP		

MILLENNIUM
EMS Solutions Ltd.

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
208771	11	10	59	4	4	UNKNOWN DRILLER	6/24/1969	457.2	Structure Test Hole	Industrial	CAN SALT CO LTD		
208772	11	16	59	4	4	UNKNOWN DRILLER	10/25/1953	452.32	Structure Test Hole	Industrial	MILL CITY PETRO LTD		
208774	NE	16	59	4	4	UNKNOWN DRILLER		13.72	Chemistry	Domestic	COULOUBE, PERCY	8.53	
208775	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	11/1/1982	130.45	New Well	Industrial	WORLD WIDE ENERGY CO #WELL 2	43.07	568.26
208779	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	11/19/1982	130.15	New Well	Industrial	WORLD WIDE ENERGY CO #WELL 5	42.67	
208783	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/20/1982	136.25	Test Hole	Unknown	WORLD WIDE ENERGY CO #WELL 1		
208785	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/27/1982	51.82	Test Hole	Unknown	WORLD WIDE ENERGY CO #4	18.35	9.09
208788	10	17	59	4	4	MCALLISTER HOLDINGS LTD.	10/26/1982	51.82	Test Hole-Abandoned	Industrial	WORLD WIDE ENERGY CO #3		
208790	10	17	59	4	4	UNKNOWN DRILLER	8/9/1974	606.55	Structure Test Hole	Industrial	WORLD WIDE ENERGY CO		
208793	SE	18	59	4	4	UNKNOWN DRILLER		0	Chemistry	Domestic	ROBBIE, DENNY		
208794	NE	18	59	4	4	UNKNOWN DRILLER		9.14	Chemistry	Domestic	VACHON, MAURICE	3.05	
208796	16	18	59	4	4	RONDEAU PAUL	1/1/1967	27.13	New Well	Domestic	VACHON, JOSEPH	3.66	
208797	NW	19	59	4	4	SAWCHUK DRILLING	5/18/1989	73.15	New Well	Domestic & Stock	BROSSEAU, W.H.	18.9	45.46
208799	6	14	59	5	4	PARADIS BROS WW	7/9/1980	14.94	New Well	Domestic	BONNYVILLE, MD OF	10.97	9.09
208800	8	20	59	4	4	DESNOYER RENE	2/20/1969	32.61	Dry Hole	Unknown	SCHNIEDER, ROBERT		
208801	16	24	59	5	4	A&V ROBERT WW DRLG	10/9/1978	32	New Well	Domestic & Stock	BROSSEAU, GEORGE	9.14	22.73
208802	SE	20	59	4	4	UNKNOWN DRILLER		0	Chemistry	Domestic	KELLERMAN, BARB		
208803	7	20	59	4	4	UNKNOWN DRILLER	10/13/1962	428.24	Structure Test Hole	Industrial	BONNYVILLE OIL & REFINING CORP		
208804	16	24	59	5	4	A&V ROBERT WW DRLG	9/29/1980	64.01	New Well	Stock	BROSSEAU, GEORGE	30.48	45.46
208805	7	20	59	4	4	UNKNOWN DRILLER	8/6/1966	457.2	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208806	NW	20	59	4	4	R&D WW BORING	5/1/1974	10.67	New Well	Domestic	DAHL, LYLE	3.35	159.11
208809	SW	21	59	4	4	R&D WW BORING	4/29/1976	17.98	New Well	Domestic & Stock	BEAUCHEMIN, JACQUES P.	2.13	159.11
208811	NE	36	59	5	4	A&V ROBERT WW DRLG	7/16/1979	26.21	New Well	Domestic	SENECAL, DEAN	12.1	27.28
208813	SW	21	59	4	4	UNKNOWN DRILLER		3.96	Chemistry	Domestic	KELLERMAN, ERWIN		
208814	4	28	59	4	4	UNKNOWN DRILLER	9/27/1966	568.45	Structure Test Hole	Industrial	GREAT PLAIND DEV CO		
208816	NE	36	59	5	4	CHORNEY WATER WELL DRILLING LTD.	5/28/1982	28.96	Dry Hole	Unknown	SENECAL, DEAN		
208817	10	36	59	5	4	CHORNEY WATER WELL DRILLING LTD.		28.96	Dry Hole	Unknown	SENECAL, DEAN		
208820	6	29	59	4	4	UNKNOWN DRILLER	8/18/1966	457.2	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208822	6	29	59	4	4	UNKNOWN DRILLER	8/14/1963	396.24	Structure Test Hole	Industrial	COLD LAKE PIPELINE CO LTD		
208827	SE	30	59	4	4	UNKNOWN DRILLER		14.63	Chemistry	Domestic	MARTY, FERNAND	7.32	
208828	SE	30	59	4	4	UNKNOWN DRILLER		17.68	Chemistry	Domestic	BUHL, JEAN	7.62	
208830	NW	29	59	4	4	UNKNOWN DRILLER		10.67	Chemistry	Domestic	CORBIERE, JOHN		
208831	SE	30	59	4	4	UNKNOWN DRILLER		4.27	Chemistry	Domestic	DUBEAU, JOSEPH		
208832	14	30	59	4	4	UNKNOWN DRILLER	7/9/1952	405.99	Structure Test Hole	Industrial	TOR AMERICAN OIL LTD		
208834	SE	31	59	4	4	DAN'S WATER WELL	6/20/1986	47.55	New Well	Domestic & Stock	MARTY, FERNEND	21.95	40.91
208837	6	31	59	4	4	UNKNOWN DRILLER	5/22/1964	377.95	Structure Test Hole	Industrial	CONSOLIDATED BONNYVILLE LTD		
208839	NW	31	59	4	4	UNKNOWN DRILLER	1/1/1970	9.75	Chemistry	Domestic	VACHON, PHILIPPE	4.88	
208840	NE	31	59	4	4	DAN'S WATER WELL	6/18/1986	47.24	New Well	Domestic & Stock	REGNIER, ED	22.25	45.46
208842	NW	32	59	4	4	UNKNOWN DRILLER		8.23	Chemistry	Domestic	BRUNET, GASTON	6.4	
208843	NW	32	59	4	4	UNKNOWN DRILLER		12.8	Chemistry	Domestic	JACKSON, WAYNE		
208845	NE	32	59	4	4	PARADIS BROS WW	5/31/1978	12.19	New Well	Domestic	WRIGHT, ED	2.13	9.09
208846	NE	32	59	4	4	ROBERT, A. WATER WELL DRILLING LTD.	10/10/1981	79.25	New Well	Domestic	BELANGER, RON	23.16	136.38
208848	NE	32	59	4	4	SAWCHUK DRILLING	12/5/1986	79.86	New Well	Domestic & Stock	BELANGER, RON	24.38	
208852	10	36	59	4	4	UNKNOWN DRILLER		25.91	Chemistry	Domestic	SENECAL, DEAN	24.08	
212124	8	1	60	4	4	UNKNOWN DRILLER	2/23/1966	231.34	Structure Test Hole	Industrial	UNION TEXAS CAN #UTEXCAN M7		
212126	4	3	60	4	4	UNKNOWN DRILLER	2/20/1966	197.21	Structure Test Hole	Industrial	UNION TEXAS CAN #UTEXCAN M8		
212130	6	4	60	4	4	UNKNOWN DRILLER	7/21/1972	551.69	Structure Test Hole	Industrial	GREAT NORTH OIL #GNOL MURIEL		

MILLENNIUM
EMS Solutions Ltd.

Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (m)	TYPE OF WORK	USE	WELL OWNER	STATIC LEVEL (m)	TEST RATE (L/min)
212133	3	5	60	4	4	UNKNOWN DRILLER	9/3/1976	33.53	Test Hole	Unknown	ARC		
212140	13	6	60	4	4	RONDEAU PAUL	7/17/1965	9.45	Well Inventory	Unknown	COTE, A.		
212160	SW	20	59	4	4	PETE'S WATERWELL CONTRACTING LTD.	5/9/1988	51.82	New Well	Domestic	VOTH, RICK	25.91	45.46
212161	SW	20	59	4	4	UNKNOWN DRILLER		50.29	Chemistry	Unknown	VACHON, MAURICE		
212163	1	1	60	5	4	UNKNOWN DRILLER		17.68	Chemistry	Domestic	LESSARD, ALPHONSE	6.1	
212165	1	1	60	5	4	UNKNOWN DRILLER		42.98	Chemistry	Unknown	MEAD, KENNETH E.		
212208	16	1	60	5	4	UNKNOWN DRILLER		7.62	Chemistry	Domestic	HIMSCHOOT, OCTANE	3.66	
212211	SH	1	60	5	4	UNKNOWN DRILLER		15.54	Chemistry	Domestic	MURIEL VIEWPOINT	2.44	
212213	16	1	60	5	4	CABAY DRLG SERVICE	10/24/1979	48.77	New Well	Domestic	ROWE, JAMES	2.44	22.73
212216	16	1	60	5	4	UNKNOWN DRILLER		27.43	Chemistry	Unknown	LAJUNESSE, GERALD/AUDRE		
212217	16	1	60	5	4	UNKNOWN DRILLER		41.15	Chemistry	Domestic	LAJEUNESSE, GERALD		
212218	16	1	60	5	4	DAN'S WATER WELL	4/5/1989	42.67	New Well	Domestic	LAJEUNESSE, GERALD/AUDREY	7.32	22.73
212227	16	1	60	5	4	DAN'S WATER WELL	8/2/1989	42.67	Test Hole-Abandoned	Unknown	HIMSCHOOT, OCTANE		
212230	16	1	60	5	4	DAN'S WATER WELL	8/3/1989	27.13	New Well	Domestic	HIMSCHOOT, OCTANE	3.35	31.82
214866	11	34	59	4	4	A&V ROBERT WW DRLG	12/2/1979	73.15	New Well	Domestic	BROUSSEAU, VINCENT	22.71	9.09
215001	NE	32	59	4	4	PARADIS BROS WW	10/19/1979	23.47	New Well	Domestic	OUELLETTE, LEO M	3.05	18.18
217752	SE	28	59	4	4	UNKNOWN DRILLER		74.37	Chemistry	Domestic	CARR, WM	51.82	
228496	10	34	57	5	4	UNKNOWN DRILLER	7/1/1959	487.68	Structure Test Hole	Industrial	CAN SALT CO LTD		
235037	NW	6	60	4	4	CABAY DRLG SERVICE	5/9/1980	73.15	New Well	Domestic	VACHON, GIL	9.14	11.37
241162	SW	21	59	4	4	DAN'S WATER WELL	5/26/1994	40.84	New Well	Domestic	KELLERMAN, E.	17.22	36.37
254425	NE	36	59	5	4	A&C WATER WELL DRILLING	8/11/1994	51.82	Dry Hole-Abandoned	Domestic	DEARBORN, BOB		
285868	10	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/11/1996	109.73	Test Hole-Abandoned	Observation	ELAN ENERGY INC #2		
285869	10	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/9/1996	121.92	New Well	Industrial	ELAN ENERGY INC #1	17.31	45.46
285869	10	16	59	4	4	UNKNOWNDRILLINGCOMP11			Old Well - Abandoned	Old Well - Abandoned	ELAN ENERGY		
285869	10	16	59	4	4	UNKNOWNDRILLINGCOMP11			Old Well - Test	Industrial	ELAN ENERGY	18.06	74.97
285870	13	16	59	4	4	MCALLISTER WATERWELLS LTD.	6/14/1996	140.21	Test Hole-Abandoned	Observation	ELAN ENERGY INC #3	23.47	
285871	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/10/1996	18.29	Test Hole-Abandoned	Industrial	ELAN ENERGY		
285872	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	84.73	Test Hole-Abandoned	Industrial	ELAN ENERGY	17.22	218.21
285873	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	82.91	Test Hole-Abandoned	Industrial	ELAN ENERGY		
285874	4	22	59	4	4	MCALLISTER HOLDINGS LTD.	1/9/1996	24.38	Test Hole-Abandoned	Industrial	ELAN ENERGY		
289206	SW	15	58	5	4	MORTON'S WATER WELL DRILLING LTD.	4/22/1998	30.48	New Well	Domestic	CAPJACK, BLAIR	8.2	31.82
291004	SW	9	58	5	4	MORTON'S WATER WELL DRILLING LTD.	4/21/1998	16.46	New Well	Domestic	GIBSON, OWEN/VAL	4.27	90.92
291020	NW	30	59	4	4	GRIZZLEY ENTERPRISES	11/20/1997	9.14	New Well	Stock	REGNIER, MORRIS	4.27	454.61
292277	16	1	60	5	4	PARKLAND DRILLING LTD.	4/19/1999	27.43	New Well	Domestic	VERRIER, SEAN	6.1	13.64
294188	SW	3	58	5	4	MARTIN WATER WELLS	5/16/2000	23.47	New Well	Domestic	HILLEBRAND, DAVID	0.61	181.84
294708	SE	5	58	4	4	HOLLAND WATER WELLS	5/18/2000	77.72	Dry Hole-Abandoned	Domestic	R.A.M. CONTRACTORS		
294709	SE	5	58	4	4	HOLLAND WATER WELLS	5/19/2000	33.53	Dry Hole-Abandoned	Domestic	R.A.M. CONTRACTORS		
1015149	7	13	58	5	4	A&C WATER WELL DRILLING		15.85	Old Well - Abandoned	Unknown	PENGROTH CORPORATION		
1420568	SE	25	59	5	4	LAKELAND DRILLING LTD.	9/24/2006	62.48	New Well	Stock	BROSSEAU, WILFRED	39.62	68.19
1490365	SW	10	58	5	4	MARTIN WATER WELLS	4/22/2009	18.29	New Well	Domestic	DESILETS, TRAVIS	3.07	54.55
1490406	5	36	57	5	4	MARTIN WATER WELLS	9/22/2009	24.38	New Well	Domestic	PRYMAK, CHRIS	12.23	86.38
1500075	SE	32	57	4	4	MCALLISTER DRILLING INC.	4/22/2003	77.11	New Well	Domestic	BRIFTOW, FRED	7.01	272.77
1580264	6	9	61	6	4	PARKLAND DRILLING LTD.	8/22/2008	48.77	New Well	Domestic	BLOCHA, RYAN	23.47	136.38
1580265	1	30	59	4	4	PARKLAND DRILLING LTD.	10/2/2008	77.72	New Well	Domestic	KOSHYKAR, TIM	21.64	227.3
1580311	11	31	59	4	4	PARKLAND DRILLING LTD.	10/16/2009	13.72	New Well	Domestic	VACHON, DIANE	5.79	31.82
1580388	4	32	59	4	4	PARKLAND DRILLING LTD.	6/1/2011	44.2	New Well	Domestic	VACHON, DIANE	23.77	54.55
2058762	16	17	59	4	4	UNKNOWN DRILLING COMP. 10		29.3	New Well	Monitoring	ALTA ENV 0W3		

Table E3-2 Licensed/Registered Groundwater and Surface Water Users within a 1.6 Kilometre Radius of the Project

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
158791	54.14	-110.49	20020702002	BROSSEAU, WILFRID	BONNYVILLE/FARM UNIT/BROSSEAU WILFRED	00158791 00 00	104706	158791
251352	54.01	-110.61	20081027001	PENGROWTH ENERGY CORPORATION	ELK POINT/MUNICIPAL/PENGROWTH CORPORATION - F00251352	00251352 00 00	186690	251352
168568	54.15	-110.60	19690915003	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61132	F00168568
226730	53.98	-110.64	19751230265	OPANAVICIUS, ALFRED	ELK POINT/FARM UNIT/OPANAVICIUS ALFRED - F19138	00226730 00 00	168923	19138
148619	54.13	-110.61	19760601022	BROSSEAU, WILFRID	BONNYVILLE/FARM UNIT/BROSSEAU WILFRID - F00148619	00148619 00 00	94219	148619
164631	53.99	-110.65	19811231465	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108317	164631
163790	54.15	-110.56	19901231398	CLARK, MICHAEL	BONNYVILLE/FARM UNIT/CLARK MICHAEL -F00163790	00163790 00 00	63498	163790
160019	54.01	-110.67	19981229421	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91941	160019
259649	54.05	-110.46	19690901012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	156469	
259649	54.06	-110.46	19690901014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	156471	
259655	53.99	-110.56	19010101428	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146238	
259655	54.01	-110.58	19010101430	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146240	
259655	54.02	-110.58	19010101431	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146241	
259655	54.02	-110.58	19010101432	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146242	
259655	54.03	-110.58	19010101433	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	146243	
259645	53.99	-110.57	19600101092	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153878	
259645	53.99	-110.53	19600101095	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153881	
259645	53.98	-110.57	19600101096	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153882	
259645	53.99	-110.58	19600101097	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	153883	
259656	53.99	-110.57	19621101005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	154311	
259741	54.01	-110.58	19950120002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162442	
259741	54.01	-110.59	19950120003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162443	
259741	54.02	-110.59	19950120004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162444	
259741	54.02	-110.58	19950120005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162445	
259741	54.02	-110.59	19950120006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162446	
259741	54.03	-110.59	19950120007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162447	
259741	54.00	-110.58	19950120008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259741 00 00	162448	
259674	54.05	-110.67	19651001008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	155440	
259674	54.06	-110.67	19651001009	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	155441	
259638	54.05	-110.68	19790601051	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159247	
259638	54.05	-110.69	19790601052	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159248	
160019	54.06	-110.69	19981229424	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91947	160019
160019	54.05	-110.69	19981229425	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91949	160019
259658	54.10	-110.67	19630401013	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	154438	
259660	54.11	-110.61	19630801052	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259660 00 00	154582	
259690	54.10	-110.66	19690701010	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	156401	
259698	54.13	-110.47	19710517003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157030	
259698	54.13	-110.49	19710517004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157031	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
158791	SE	35	59	4	4	Unnamed Aquifer - Potable	1602	9	1602	0	0	06AC	STCKWT	WALIC	16-Oct-02	15-Oct-27	62.8	65.8
251352	SE	13	58	5	4	Unnamed Aquifer - Potable	1825	5	1825	0	0	05ED	CAMPS	WALIC	21-Nov-08	20-Nov-33	68.3	70.3
168568	NW	31	59	4	4	Unnamed Aquifer - Unclassified	957	0	957	0	0	06AC	REGISTRY	WAREG	07-Mar-02			9.1
226730	SW	2	58	5	4	Unnamed Aquifer - Unclassified	2000	0	2000	0	0	05ED	REGISTRY	WAREG	05-Jan-06			10.7
148619	SE	25	59	5	4	Unnamed Aquifer - Unclassified	3125	0	3125	0	0	06AC	REGISTRY	WAREG	15-May-02			64
164631	NE	3	58	5	4	Unnamed Aquifer - Unclassified	1043	0	1043	0	0	05ED	REGISTRY	WAREG	11-Feb-03			8.4
163790	NE	32	59	4	4	Unnamed Aquifer - Unclassified	320	0	320	0	0	06AC	REGISTRY	WAREG	08-Mar-02			23.7
160019	SW	15	58	5	4	Unnamed Aquifer - Unclassified	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			30.5
259649	SE	36	58	4	4	Cushing Lake	372	0	372	0	0	06AD	REGISTRY	WAREG	29-May-09			
259649	NE	36	58	4	4	Cushing Lake	371	0	371	0	0	06AD	REGISTRY	WAREG	29-May-09			
259655	NE	5	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	18	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	18	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	19	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	19	58	4	4	Garnier Lakes	396	0	396	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NW	5	58	4	4	Garnier Lakes	157	0	157	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NE	4	58	4	4	Garnier Lakes	156	0	156	0	0	05ED	REGISTRY	WAREG	29-May-09			
259645	SW	5	58	4	4	Garnier Lakes	156	0	156	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	SE	7	58	4	4	Garnier Lakes	156	0	156	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	SW	8	58	4	4	Garnier Lakes	1127	0	1127	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SE	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SW	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NW	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NE	18	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	SW	19	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NW	19	58	4	4	Garnier Lakes	31	0	31	0	0	06AC	REGISTRY	WAREG	29-May-09			
259741	NE	7	58	4	4	Garnier Lakes	30	0	30	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	SW	34	58	5	4	Michel Lake	433	0	433	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	NW	34	58	5	4	Michel Lake	432	0	432	0	0	06AC	REGISTRY	WAREG	29-May-09			
259638	NE	28	58	5	4	Michel Lake	533	0	533	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SW	33	58	5	4	Michel Lake	533	0	533	0	0	06AC	REGISTRY	WAREG	29-May-09			
160019	NW	33	58	5	4	Michichi Lake	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	SW	33	58	5	4	Michichi Lake	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
259658	SW	15	59	5	4	Muriel Lake	398	0	398	0	0	06AC	REGISTRY	WAREG	29-May-09			
259660	SE	24	59	5	4	Muriel Lake	44	0	44	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SE	15	59	5	4	Muriel Lake	135	0	135	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	25	59	4	4	Reita Lake	228	0	228	0	0	06AD	REGISTRY	WAREG	29-May-09			
259698	NE	26	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259698	54.14	-110.46	19710517005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157032	
259698	54.14	-110.47	19710517006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157033	
259726	54.13	-110.46	19830801012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	160471	
259655	54.07	-110.50	19001225554	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189973	
259655	54.05	-110.59	19001225735	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188657	
259655	54.07	-110.51	19001225900	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189974	
259655	54.03	-110.56	19001225921	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190040	
259655	54.03	-110.54	19001225923	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190042	
259655	54.06	-110.48	19001227758	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150458	
259655	54.04	-110.58	19001227775	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150475	
259655	54.04	-110.59	19001227776	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150476	
259655	54.05	-110.59	19001227777	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150477	
259655	54.05	-110.51	19001227778	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150478	
259655	54.05	-110.52	19001227779	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150479	
259655	54.06	-110.52	19001227780	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150480	
259655	54.05	-110.49	19001227781	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150481	
259655	54.06	-110.49	19001227782	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	150482	
259656	53.99	-110.61	19621101006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	154312	
259674	54.06	-110.63	19651001019	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	188379	
259674	54.06	-110.64	19651001020	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259674 00 00	190007	
259693	54.07	-110.66	19700101056	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156555	
259693	54.08	-110.64	19700101064	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156563	
259693	54.07	-110.62	19700101065	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156564	
259693	54.08	-110.65	19700101066	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	156565	
259692	54.13	-110.50	19700901018	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156806	
259692	54.13	-110.51	19700901019	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156807	
259692	54.13	-110.52	19700901020	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	156808	
259698	54.13	-110.54	19710517007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157034	
259698	54.14	-110.55	19710517008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	157035	
259698	54.13	-110.55	19710517012	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189932	
259593	54.10	-110.50	19780101015	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259593 00 00	158867	
259638	54.04	-110.69	19790601058	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159254	
259638	54.05	-110.69	19790601059	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	159255	
226730	54.01	-110.65	19801230922	OPANAVICIUS, ALFRED	ELK POINT/FARM UNIT/OPANAVICIUS ALFRED - F19138	00226730 00 00	168925	19138
168568	54.14	-110.60	19841020001	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61137	F00168568
259698	54.15	-110.52	19890601093	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188892	
163790	54.15	-110.56	19901231399	CLARK, MICHAEL	BONNYVILLE/FARM UNIT/CLARK MICHAEL -F00163790	00163790 00 00	63501	163790
259698	54.13	-110.57	19910601063	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188381	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259698	SE	36	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			
259698	SW	36	59	4	4	Reita Lake	227	0	227	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	SE	25	59	4	4	Reita Lake	504	0	504	0	0	06AD	REGISTRY	WAREG	29-May-09			
259655	NW	2	59	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	31	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	3	59	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	20	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	21	58	4	4	Surface Runoff	375	0	375	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	35	58	4	4	Surface Runoff	63	0	63	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	30	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	34	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	35	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	35	58	4	4	Surface Runoff	62	0	62	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	SE	12	58	5	4	Surface Runoff	376	0	376	0	0	05ED	REGISTRY	WAREG	29-May-09			
259674	NE	35	58	5	4	Surface Runoff	432	0	432	0	0	06AC	REGISTRY	WAREG	29-May-09			
259674	NW	35	58	5	4	Surface Runoff	443	0	443	0	0	05ED	REGISTRY	WAREG	29-May-09			
259693	SE	3	59	5	4	Surface Runoff	713	0	713	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SE	11	59	5	4	Surface Runoff	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	1	59	5	4	Surface Runoff	158	0	158	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	11	59	5	4	Surface Runoff	158	0	158	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	26	59	4	4	Surface Runoff	285	0	285	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	27	59	4	4	Surface Runoff	285	0	285	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	27	59	4	4	Surface Runoff	284	0	284	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	28	59	4	4	Surface Runoff	130	0	130	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	SW	33	59	4	4	Surface Runoff	130	0	130	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	28	59	4	4	Surface Runoff	390	0	390	0	0	06AC	REGISTRY	WAREG	29-May-09			
259593	NW	14	59	4	4	Surface Runoff	564	0	564	0	0	06AC	REGISTRY	WAREG	29-May-09			
259638	SW	28	58	5	4	Surface Runoff	89	0	89	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	NW	28	58	5	4	Surface Runoff	89	0	89	0	0	06AC	REGISTRY	WAREG	29-May-09			
226730	SE	15	58	5	4	Surface Runoff	688	0	688	0	0	05ED	REGISTRY	WAREG	05-Jan-06			
168568	SW	31	59	4	4	Surface Runoff	111	0	111	0	0	06AC	REGISTRY	WAREG	07-Mar-02			
259698	NW	34	59	4	4	Surface Runoff	344	0	344	0	0	06AC	REGISTRY	WAREG	29-May-09			
163790	NE	32	59	4	4	Surface Runoff	85	0	85	0	0	06AC	REGISTRY	WAREG	08-Mar-02			
259698	NW	29	59	4	4	Surface Runoff	344	0	344	0	0	06AC	REGISTRY	WAREG	29-May-09			

MILLENNIUM EMS Solutions Ltd.

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
162976	54.11	-110.57	19951231180	VACHON, HELENE	BONNYVILLE/FARM UNIT/VACHON HELENE - F00162976	00162976 00 00	59974	162976
160019	54.00	-110.67	19981229422	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91942	160019
160019	54.02	-110.67	19981229423	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91944	160019
160019	54.06	-110.63	19981229427	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91952	160019
160019	54.04	-110.64	19981229428	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91953	160019
160019	54.06	-110.64	19981229429	CAPJACK, BLAIR	ELK POINT/FARM UNIT/CAPJACK BLAIR - F00160019	00160019 00 00	91954	160019
259655	54.05	-110.48	19001225555	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190062	
259655	54.08	-110.59	19001225566	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188363	
259655	54.02	-110.57	19001225567	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188366	
259655	54.04	-110.57	19001225568	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188367	
259655	54.09	-110.49	19001225572	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188376	
259655	54.04	-110.56	19001225573	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188377	
259655	54.07	-110.52	19001225722	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188626	
259655	54.07	-110.57	19001225723	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188630	
259655	54.07	-110.60	19001225724	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188631	
259655	54.09	-110.59	19001225725	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188632	
259655	54.09	-110.56	19001225726	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188633	
259655	54.09	-110.55	19001225727	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188634	
259655	54.04	-110.53	19001225731	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188652	
259655	54.04	-110.54	19001225733	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188654	
259655	54.05	-110.58	19001225734	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188655	
259655	54.06	-110.51	19001225736	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	188658	
259655	54.09	-110.52	19001225895	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189916	
259655	54.08	-110.51	19001225896	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189917	
259655	54.08	-110.52	19001225897	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189918	
259655	54.09	-110.50	19001225898	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189919	
259655	54.09	-110.51	19001225899	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189939	
259655	54.07	-110.54	19001225901	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189975	
259655	54.07	-110.55	19001225902	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189976	
259655	54.07	-110.54	19001225903	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189981	
259655	54.07	-110.55	19001225904	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189982	
259655	54.07	-110.56	19001225905	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189983	
259655	54.07	-110.56	19001225906	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189984	
259655	54.07	-110.57	19001225907	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189985	
259655	54.07	-110.59	19001225908	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189986	
259655	54.07	-110.60	19001225909	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189987	
259655	54.08	-110.60	19001225910	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189988	
259655	54.09	-110.57	19001225911	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189989	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
162976	SW	20	59	4	4	Surface Runoff	200	0	200	0	0	06AC	REGISTRY	WAREG	06-Mar-02			
160019	NW	10	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NW	15	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NE	35	58	5	4	Surface Runoff	238	0	238	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	SW	26	58	5	4	Surface Runoff	237	0	237	0	0	05ED	REGISTRY	WAREG	06-May-02			
160019	NW	35	58	5	4	Surface Runoff	237	0	237	0	0	05ED	REGISTRY	WAREG	06-May-02			
259655	SE	35	58	4	4	Unnamed Stream - Unclassified	30	0	30	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	20	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	29	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	11	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	29	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	3	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	9	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	30	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	34	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	11	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	10	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	4	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	5	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	6	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	7	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259655	54.08	-110.56	19001225912	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189990	
259655	54.08	-110.54	19001225913	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	189991	
259655	53.99	-110.54	19001225914	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190032	
259655	54.01	-110.56	19001225920	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190039	
259655	54.03	-110.57	19001225922	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190041	
259655	54.05	-110.53	19001225930	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190052	
259655	54.06	-110.59	19001225933	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190057	
259655	54.05	-110.58	19001225934	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190058	
259655	54.06	-110.56	19001225935	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190059	
259655	54.06	-110.53	19001225936	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190060	
259655	54.06	-110.54	19001225937	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259655 00 00	190061	
165271	54.02	-110.64	19281231204	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137800	165271
259627	53.99	-110.68	19560501014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	188620	
259627	54.00	-110.69	19560501025	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	190016	
259627	53.99	-110.69	19560501026	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259627 00 00	190064	
259645	53.98	-110.54	19600101124	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	188374	
259645	53.99	-110.54	19600101127	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259645 00 00	190031	
259656	54.02	-110.61	19621101024	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259656 00 00	190017	
164631	53.99	-110.65	19621231327	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108318	164631
164631	54.00	-110.65	19621231328	HILLE BRAND FARMS	ELK POINT/FARM UNIT/HILLE BRAND FARMS - F00164631	00164631 00 00	108319	164631
259658	54.06	-110.68	19630401055	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	188636	
259658	54.07	-110.69	19630401070	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259658 00 00	189938	
259660	54.11	-110.60	19630801075	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259660 00 00	189924	
259676	54.09	-110.61	19651215002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155472	
259676	54.10	-110.61	19651215003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155473	
259676	54.05	-110.61	19651215005	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155475	
259676	54.05	-110.62	19651215006	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155476	
259676	54.06	-110.62	19651215007	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155477	
259676	54.06	-110.61	19651215008	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	155478	
259676	54.09	-110.62	19651215009	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259676 00 00	189951	
259690	54.10	-110.65	19690701042	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	189952	
259690	54.10	-110.67	19690701043	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259690 00 00	189953	
259649	54.06	-110.47	19690901027	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259649 00 00	190063	
259693	54.08	-110.67	19700101130	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188380	
259693	54.07	-110.66	19700101131	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188686	
259693	54.08	-110.66	19700101132	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188692	
259693	54.09	-110.65	19700101133	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	188694	
259693	54.07	-110.65	19700101137	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189936	

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259655	SE	8	59	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	9	59	4	4	Unnamed Stream - Unclassified	21	0	21	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SW	9	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	17	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	20	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	28	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	31	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	SE	31	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	32	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NE	33	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
259655	NW	33	58	4	4	Unnamed Stream - Unclassified	22	0	22	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271	NW	14	58	5	4	Unnamed Stream - Unclassified	1820	0	1820	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
259627	NE	4	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259627	NW	9	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259627	NW	4	58	5	4	Unnamed Stream - Unclassified	62	0	62	0	0	05ED	REGISTRY	WAREG	29-May-09			
259645	SW	4	58	4	4	Unnamed Stream - Unclassified	312	0	312	0	0	06AC	REGISTRY	WAREG	29-May-09			
259645	NW	4	58	4	4	Unnamed Stream - Unclassified	313	0	313	0	0	06AC	REGISTRY	WAREG	29-May-09			
259656	NE	13	58	5	4	Unnamed Stream - Unclassified	1503	0	1503	0	0	05ED	REGISTRY	WAREG	29-May-09			
164631	NE	3	58	5	4	Unnamed Stream - Unclassified	405	0	405	0	0	05ED	REGISTRY	WAREG	11-Feb-03			
164631	SE	10	58	5	4	Unnamed Stream - Unclassified	570	0	570	0	0	05ED	REGISTRY	WAREG	11-Feb-03			
259658	NE	33	58	5	4	Unnamed Stream - Unclassified	75	0	75	0	0	06AC	REGISTRY	WAREG	29-May-09			
259658	SE	4	59	5	4	Unnamed Stream - Unclassified	75	0	75	0	0	06AC	REGISTRY	WAREG	29-May-09			
259660	SW	19	59	4	4	Unnamed Stream - Unclassified	44	0	44	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NE	12	59	5	4	Unnamed Stream - Unclassified	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SE	13	59	5	4	Unnamed Stream - Unclassified	159	0	159	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SE	36	58	5	4	Unnamed Stream - Unclassified	54	0	54	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	SW	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NW	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NE	36	58	5	4	Unnamed Stream - Unclassified	53	0	53	0	0	06AC	REGISTRY	WAREG	29-May-09			
259676	NW	12	59	5	4	Unnamed Stream - Unclassified	531	0	531	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SW	14	59	5	4	Unnamed Stream - Unclassified	67	0	67	0	0	06AC	REGISTRY	WAREG	29-May-09			
259690	SW	15	59	5	4	Unnamed Stream - Unclassified	68	0	68	0	0	06AC	REGISTRY	WAREG	29-May-09			
259649	NW	36	58	4	4	Unnamed Stream - Unclassified	137	0	137	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SW	10	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NE	3	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	SE	10	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	11	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	2	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			

Approval ID	Latitude	Longitude	Priority	Applicant	Project	Interim Licence Number	Water Allocation ID	File Number
259693	54.07	-110.64	19700101138	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189937	
259693	54.09	-110.67	19700101139	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189949	
259693	54.09	-110.64	19700101140	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259693 00 00	189950	
260703	54.14	-110.56	19700701077	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00260703 00 00	189934	
259692	54.12	-110.54	19700901074	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	188360	
259692	54.11	-110.50	19700901075	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	188682	
259692	54.12	-110.51	19700901079	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189925	
259692	54.12	-110.52	19700901080	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189926	
259692	54.12	-110.49	19700901081	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189927	
259692	54.12	-110.50	19700901082	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259692 00 00	189928	
165271	54.00	-110.64	19701230546	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137794	165271
259698	54.13	-110.57	19710517010	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188684	
259698	54.15	-110.52	19710517011	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	188685	
259698	54.13	-110.56	19710517013	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189933	
259698	54.15	-110.54	19710517014	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259698 00 00	189935	
168568	54.15	-110.59	19721231188	PHILIPPE & DIANE VACHON	BONNYVILLE/FARM UNIT/PHILIPPE & DIANE VACHON - F00168568	00168568 00 00	61149	F00168568
259638	54.02	-110.69	19790601097	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	189992	
259638	54.01	-110.68	19790601098	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	189993	
259638	54.03	-110.69	19790601105	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	190002	
259638	54.02	-110.69	19790601106	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259638 00 00	190003	
259726	54.11	-110.46	19830801021	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	188683	
259726	54.10	-110.46	19830801022	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189920	
259726	54.10	-110.47	19830801023	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189921	
259726	54.10	-110.46	19830801024	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189922	
259726	54.10	-110.47	19830801025	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189923	
259726	54.12	-110.46	19830801026	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189929	
259726	54.12	-110.47	19830801027	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189930	
259726	54.11	-110.47	19830801028	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259726 00 00	189931	
165271	54.00	-110.64	19851230449	OPANAVICIUS, MARC	ELK POINT/FARM UNIT/OPANAVICIUS MARC	00165271 00 00	137793	165271
156927	54.13	-110.59	19921009001	DONALD & CAROL-ANN CAMERON	BONNYVILLE/FARM UNIT/DONALD & CAROL-ANN CAMERON - F00156927	00156927 00 00	56864	156927
259744	54.10	-110.57	19970602002	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162691	
259744	54.10	-110.55	19970602003	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162692	
259744	54.10	-110.56	19970602004	PUBLIC LAND MANAGEMENT	CROWN LAND/FARM UNIT/ASRD/ST PAUL	00259744 00 00	162693	
180071	54.00	-110.68	19981229180	OCKERMAN, ERICA	DEWBERRY/FARM UNIT/OCKERMAN ERICA - F00180071	00180071 00 00	89289	180071
180071	54.00	-110.68	19981229181	OCKERMAN, ERICA	DEWBERRY/FARM UNIT/OCKERMAN ERICA - F00180071	00180071 00 00	89292	180071

MILLENNIUM
EMS Solutions Ltd.

Approval ID	Qua	Sec	Twp	Rng	Mer	Source	Quantity (m^3)	PUMP RATE (Surface Water - ft^3/sec Ground Water - m^3/day)	Consumptive Use (m^3)	Losses (m^3)	Return Flow (m^3)	River Sub-basin	Specific Purpose	Type	Licenced Date	Expiry Date	Upper Prod'n Interval (m)	Lower Prod'n Interval (m)
259693	SE	2	59	5	4	Unnamed Stream - Unclassified	149	0	149	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NW	10	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
259693	NE	11	59	5	4	Unnamed Stream - Unclassified	148	0	148	0	0	06AC	REGISTRY	WAREG	29-May-09			
260703	SE	32	59	4	4	Unnamed Stream - Unclassified	136	0	136	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	21	59	4	4	Unnamed Stream - Unclassified	143	0	143	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	SW	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	22	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	22	59	4	4	Unnamed Stream - Unclassified	143	0	143	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NE	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
259692	NW	23	59	4	4	Unnamed Stream - Unclassified	142	0	142	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271		11	58	5	4	Unnamed Stream - Unclassified	910	0	910	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
259698	NW	29	59	4	4	Unnamed Stream - Unclassified	228	0	228	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NW	34	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	29	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
259698	NE	33	59	4	4	Unnamed Stream - Unclassified	227	0	227	0	0	06AC	REGISTRY	WAREG	29-May-09			
168568	NE	31	59	4	4	Unnamed Stream - Unclassified	261	0	261	0	0	06AC	REGISTRY	WAREG	07-Mar-02			
259638	NW	16	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SE	16	58	5	4	Unnamed Stream - Unclassified	112	0	112	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	NW	21	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259638	SW	21	58	5	4	Unnamed Stream - Unclassified	111	0	111	0	0	05ED	REGISTRY	WAREG	29-May-09			
259726	SE	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	NE	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AD	REGISTRY	WAREG	29-May-09			
259726	NW	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SE	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SW	13	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	NE	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	NW	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
259726	SW	24	59	4	4	Unnamed Stream - Unclassified	56	0	56	0	0	06AC	REGISTRY	WAREG	29-May-09			
165271		11	58	5	4	Unnamed Stream - Unclassified	910	0	910	0	0	05ED	REGISTRY	WAREG	20-Jul-04			
156927	SE	30	59	4	4	Unnamed Stream - Unclassified	185	0	185	0	0	06AC	REGISTRY	WAREG	05-Mar-02			
259744	SW	17	59	4	4	Unnamed Stream - Unclassified	74	0	74	0	0	06AC	REGISTRY	WAREG	29-May-09			
259744	NW	16	59	4	4	Unnamed Stream - Unclassified	73	0	73	0	0	06AC	REGISTRY	WAREG	29-May-09			
259744	SE	17	59	4	4	Unnamed Stream - Unclassified	73	0	73	0	0	06AC	REGISTRY	WAREG	29-May-09			
180071	NE	9	58	5	4	Unnamed Stream - Unclassified	471	0	471	0	0	05ED	REGISTRY	WAREG	29-Apr-02			
180071	NE	9	58	5	4	Unnamed Stream - Unclassified	471	0	471	0	0	05ED	REGISTRY	WAREG	29-Apr-02			

APPENDIX E4: FIELD VERIFIED SURVEY INFORMATION

Muriel Lake
Reita Lake
Michel Lake
Cushing Lake
Garnier Lake
Bluet Lake
Holyoke
Puskiakiwenin I.R. 122
657
T 60
T 59
T 58
T 57
R 5
R 4
R 3 W4M

Legend

- Surface Water Verified 2013
- Water Well Verified 2013
- Surface Water Verified 2012
- Water Well Verified 2012
- Expansion Development
- Pilot Development
- Phase 1 Develpment
- First Nations
- Secondary Highway
- Improved Road
- Permanent Stream
- Ephemeral Stream
- Drainages without Defined Channels
- Lakes and Ponds
- Beaver Ponds

0 0.75 1.5 3
Kilometres

REF: Drifter Projects Ltd., EIA Footprint REV 3.dwg; NHC hydrology Oct 2013; Pengrowth, 2012; Alberta Water Well Information Database, August, 2013.

PROJECT: PENGROWTH Lindbergh SAGD Expansion Project

MILLENNIUM EMS Solutions Ltd.

TITLE: 2012 and 2013 Field Verified Survey Overview

DRAWN: JDC/SL
CHECKED: JD
DATE: Dec 9/13
PROJECT: 11-033

FIGURE: E4-1

Document Path: K:\Active Client\Pengrowth Lindbergh\Final Docs\11-033\Hydrogeo\EIA App E\Fig E4-1 2012 and 2013 Field Verified Survey Overview.mxd

Symbol No. on Figure E4-1	FVS Date	Legal Location (W4M)	Latitude	Longitude	Ground Elevation	Water Source	Status	Well Depth (m)	GIC Well ID	Drill Date	Non-Pumping Water Level		Completion	Max Pumping Rate (L/min)	No. of Users	Purpose of Use	Run Dry? (Y/N)	Number of Previous Chemical Analyses
											Original (m)	Current (m)						
1	19-Jun-13	NW 20-059-04	54.12	-110.58	604.79	bored well	producing	10.7	-	1933	4.57	-	open Hole	-	2 people	Domestic/Livestock	Y	1
2	19-Jun-13	SW 32-059-04	54.14	-110.58	610.80	well	producing	39.6	-	2011	-	-	screened	32	1 person	Domestic	N	1
3	20-Jun-13	NE 31-059-04	54.15	-110.60	596.86	well	not in use	-	-	-	-	6.68	-	-	-	Not in use	-	-
4	20-Jun-13	NE 32-059-04	54.15	-110.57	605.99	bored well	producing	23.8	-	1970s	2.44	-	-	36	2 people, 30 cattle	Domestic/Livestock	N	2
5	20-Jun-13	SE 09-058-05	53.99	-110.67	649.25	well	producing	19.8	291004	1998	-	-	screened	295	4 people	Domestic	N	2
6	21-Jun-13	NW 07-060-04	54.18	-110.60	572.11	well	producing	44.5	-	2010	-	12.48	perforated or screened	-	3 people, 9 cattle, 3 donkey/llama	Domestic/Livestock	N	1
7	21-Jun-13	NW 07-060-04	54.18	-110.60	571.63	bored well	not in use	14.0	-	2005	-	1.74	open hole	-	-	Not in use	N	1
8	18-Jul-13	SE 01-060-05	54.16	-110.61	578.84	bored well	producing	25.9	-	1983 (Sep)	7.62	22.86	open hole	227-273	2 people	Domestic	Y	2
9	18-Jul-13	SE 01-060-05	54.16	-110.61	577.63	well	not in use	121.9	-	1995	-	6.68	screened	455	-	Not in use	Y	-
10	18-Jul-13, 18-Oct-13	SW 01-060-05	54.16	-110.62	575.71	artesian well	producing	43.0	-	16-Jun-83	-	-	-	-	3 people	Domestic	Y	2
11	19-Jun-13	NW 20-059-04	54.12	-110.58	600.71	dugout	active	-	-	-	-	-	-	-	-	Unknown	N	-
12	19-Jun-13	SW 32-059-04	54.14	-110.58	599.02	dugout	not in use	-	-	-	-	-	-	-	-	Not in use	-	-
13	20-Jun-13	NE 32-059-04	54.15	-110.56	601.67	dugout	active	-	-	-	-	-	-	-	-	Livestock	N	-
14	21-Jun-13	NW 07-060-04	54.18	-110.61	574.75	slough	active	-	-	-	-	-	-	-	9 cattle, 3 donkey/llama	Livestock	N	-
15	22-Jun-13	NE 36-059-05	54.14	-110.61	578.35	dugout	active	-	-	-	-	-	-	-	-	Landscape Maintenance	Y	-
34	18-Oct-13	NE 01-060-05	54.16	-110.61	580.04	spring	-	-	-	-	-	-	-	-	-	Unknown	-	-
16	16-Jun-12	NW 19-059-04	54.12	-110.59	591.81	well	active	86.9	208797	-	-	-	-	-	1 person	Domestic	N	1
17	14-Jun-12	NE 16-059-04	54.11	-110.54	613.92	well	active	59.1	-	1982 (spring)	-	-	-	-	1 person	Domestic	N	1
18	14-Jun-12	SW 20-059-04	54.11	-110.58	608.16	well	active	50.3	212161	1988	-	-	-	-	1 person	Domestic	N	1
19	14-Jun-12	NE 24-059-05	54.12	-110.61	598.06	well	active	-	208801	late 1970s	-	-	-	-	2 people	Domestic	N	1
20	18-Jan-12	SW 15-058-05	54.01	-110.67	659.59	well	active	6.1	206805	1989	-	2.74	-	-	2 people	Domestic	N	1
21	18-Jan-12	SW 10-058-05	53.99	-110.67	644.20	well	active	33.5	-	1970s	-	-	-	-	2 people	Domestic	N	1
22	18-Jan-12	SW 10-058-05	53.99	-110.67	648.05	well	active	-	-	-	-	-	-	-	4 people, 5 cattle	Domestic/Livestock	N	1
23	17-Jun-12	SW 15-058-05	54.01	-110.67	660.79	well	producing	30.5	289206	1998	-	-	screened	36	-	Domestic/Livestock	N	1
24	15-Jun-12	NW 34-057-05	53.97	-110.67	624.74	well	active	7.9	202840	1971	-	-	-	-	4 people	Domestic	N	1
25	15-Jun-12	SE 14-058-05	54.01	-110.63	644.20	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
26	15-Jun-12	SW 13-058-05	54.01	-110.62	649.01	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
27	15-Jun-12	SE 13-058-05	54.01	-110.60	650.93	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
28	15-Jul-12	NE 03-058-05	53.99	-110.65	646.85	well	active	8.5	-	1983	-	-	-	-	4 people, 400 cattle	Domestic/Livestock	N	1
29	15-Jun-12	NW 08-058-04	-	-	-	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-
30	18-Jan-12	SE 10-058-05	53.99	-110.65	624.13	well	active	10.7	-	-	-	-	-	136	3 people	Domestic	N	1
31	18-Jan-12	SE 33-058-05	53.97	-110.67	626.90	well	active	61.0	-	-	-	-	-	-	2 people	Domestic/Livestock	-	-
32	15-Jun-12	SW 03-058-05	53.98	-110.67	644.20	well	active	12.2	206742	1980s or 90s	-	-	-	-	2 people, 5 cattle	Domestic/Livestock	N	1
33	30-Jan-12	NE 32-057-04	-	-	-	well	producing	73.2	-	2003 (summer)	6.40	6.40	screened	68	2 people, 20 livestock/ponies	Domestic/Livestock	N	2
37	30-Jan-12	NW 28-057-04	-	-	-	well	producing	47.9	-	1985 (fall)	4.57	47.85	screened	45	-	Livestock	N	1
35	30-Jan-12	SW 28-057-04	-	-	-	well	producing	62.5	-	2002 (fall)	-	-	screened	45	60 cattle	Livestock	N	1
36	14-Jul-12	NW 17-059-04	-	-	-	creek	active	-	-	-	-	-	-	-	30-35 cattle	Livestock	-	-
38	18-Jan-12	SW 10-058-05	53.99	-110.67	648.05	creek	active	-	-	-	-	-	-	-	5 cattle	Livestock	-	1
39	15-Jun-12	SW 13-058-05	54.01	-110.62	649.01	dugout	active	-	-	-	-	-	-	-	-	Livestock	-	-

APPENDIX E5: BOREHOLE LOGS

HGS-01

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant **Northing:** 643.3m
Drilled By: Mobile Augers **Easting:** 734.6m
Drill Date: Oct. 28, 2002 **Elevation:** 656.52m (PVC)
Compiled By: MPD

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-01/P02-1 (Background)

Project #: C55790200

Depth (m)	Description	Sample Depth (m)	Sample Type	LEL % / OVA mS/m	Well Data	Comments
0	Ground Surface					Stick Up = 0.70m
	SILTY CLAY (0.0-0.2m) Light grey, dry, loose, uniform, no odour/staining.	0.00-0.15		40		Borehole dia. 15cm
		0.15-0.30		50		
	CLAY SILT (0.2-1.9m) Trace sand, medium grey brown, moist, firm, no odour/staining.	0.3-0.6		40		Piezo dia. 5cm
1		0.6-1.0		40		
		1.0-1.5		100		
		1.5-2.0		60		
2	***SILT CLAY (1.9-3.2m)*** Medium brown grey, moist, very firm, no odour/staining. Lower contact gradual over approx. 20cm, rare pebbles.	2.0-2.5		140		
		2.5-3.0		100		
3	Rusty patches at 3.0m and below.	3.0-3.5		125		
	SILTY CLAY (3.2-4.5m) Medium orange brown, moist, very firm, no odour/staining. Rusty patches common to 3.7m, grading to medium grey brown.	3.5-4.0		125		Bentonite Chips 0.0-4.2m
4		4.0-4.5		200		
	SAND (4.5-5.1m) Light brown, slightly moist, loose on auger, coarse grained, some fine-grained gravel, no odour/staining.	4.5-5.0		160		Peltonite 4.2-4.8m
5	***SILTY CLAY (5.1-5.3m)*** Medium grey, moist, firm, no odour/staining.					Top of Sand 4.8m 10/20 Frac Sand Top of Screen 5.0m
	SAND (5.3-8.3m) Light orange brown, poorly sorted, moist, loose, rare pebbles, rare clay lenses, no odour/staining.	5.0-6.5		90		
6						0.02 Slot Screen
	Wet at 6.7m.					
7	Saturated at 7.3m.	6.5-8.0		160		Water Level 7.02m bgs (Oct. 29, 2002)
8	Water in hole at end of run.					Bottom of Screen 8.0m Bottom of Sand 8.1m Slough 8.1-8.3m
	8.3m End of Borehole					
9	LOCATION: 60m SW of Process Area. NOTE: Drilled with solid stem auger					
10						

File Path: J:\55790000\55790100\sp02-01 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant
Drilled By: Mobile Augers
Drill Date: Oct. 29, 2002
Compiled By: MPD

Northing: 581.6m
Easting: 592.7m
Elevation: 656.05m (PVC)

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-04/P02-2

Project #: C55790200

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	LEL % (25, 50, 75) / OVA mS/m (100, 200, 300, 400)	Well Data	Comments
							Stick Up = 0.60m
0		Ground Surface					Borehole dia. 15cm
		CLAY SILT FILL (0.0-1.2m) Mixture of medium brown clay silt, some firm clayey patches, dry, silty intervals, loose, no odour/staining. Moist below 0.4m.	0.00-0.15		75		
			0.15-0.30		100		
			0.3-0.6		100		Piezo dia. 5cm
			0.6-1.0		150		
1		***SILTY CLAY (1.2-2.4m)*** Dark grey and brown grey, moist, very firm, slight natural organic smell (swamp), no odour/staining. Medium grey interval from 2.0-2.2m, rare pebbles, some rusty staining at 2.5m.	1.0-1.5		150		
			1.5-2.0		250		
2			2.0-2.5		225		
		SILTY CLAY (2.4-6.0m) Medium yellow brown, moist, very firm to hard, rare mottles and white precipitates, rare pebbles and coal fragments, no odour/staining. Rare clasts (silt) below 3.0m.	2.5-3.0		175		
3			3.0-3.5		175		Bentonite Chips 0.0-3.5m
			3.5-4.0		250		Peltonite 3.5-4.0m
4		Rusty patches below 4.0m.	4.0-4.5		200		Top of Sand 4.0m 10/20 Frac Sand
			4.5-5.0		225		Top of Screen 4.6m
5		Soft below 5.0m.					
		SAND AND GRAVEL (6.0-7.5m) Medium orange brown, moist to wet, loose on auger, coarse-grained sand, poorly sorted, no odour/staining.	5.0-6.5		125		
6		Saturated from 6.5-7.5m.					0.02 Slot Screen
7			6.5-8.0		250		Water Level 6.93m bgs (Oct. 29, 2002)
		ORGANIC LAYER/SILT (7.5-8.2m) Black organic layer, peat, dry at 7.5-7.6m and 8.1-8.2m, with dark grey silt, moist, no odour/staining.					Bottom of Sand and Screen 7.6m Slough 7.6-8.2m
8		8.2m End of Borehole					
		LOCATION: Surface RO Collection Area.					
9		NOTE: Drilled with solid stem auger.					
10							

File Path: J:\55790000\55790100\s02-04p2 | Generated By: WH | Date Generated: Nov. 6, 2002 | Page: 1 of 1

HGS-01

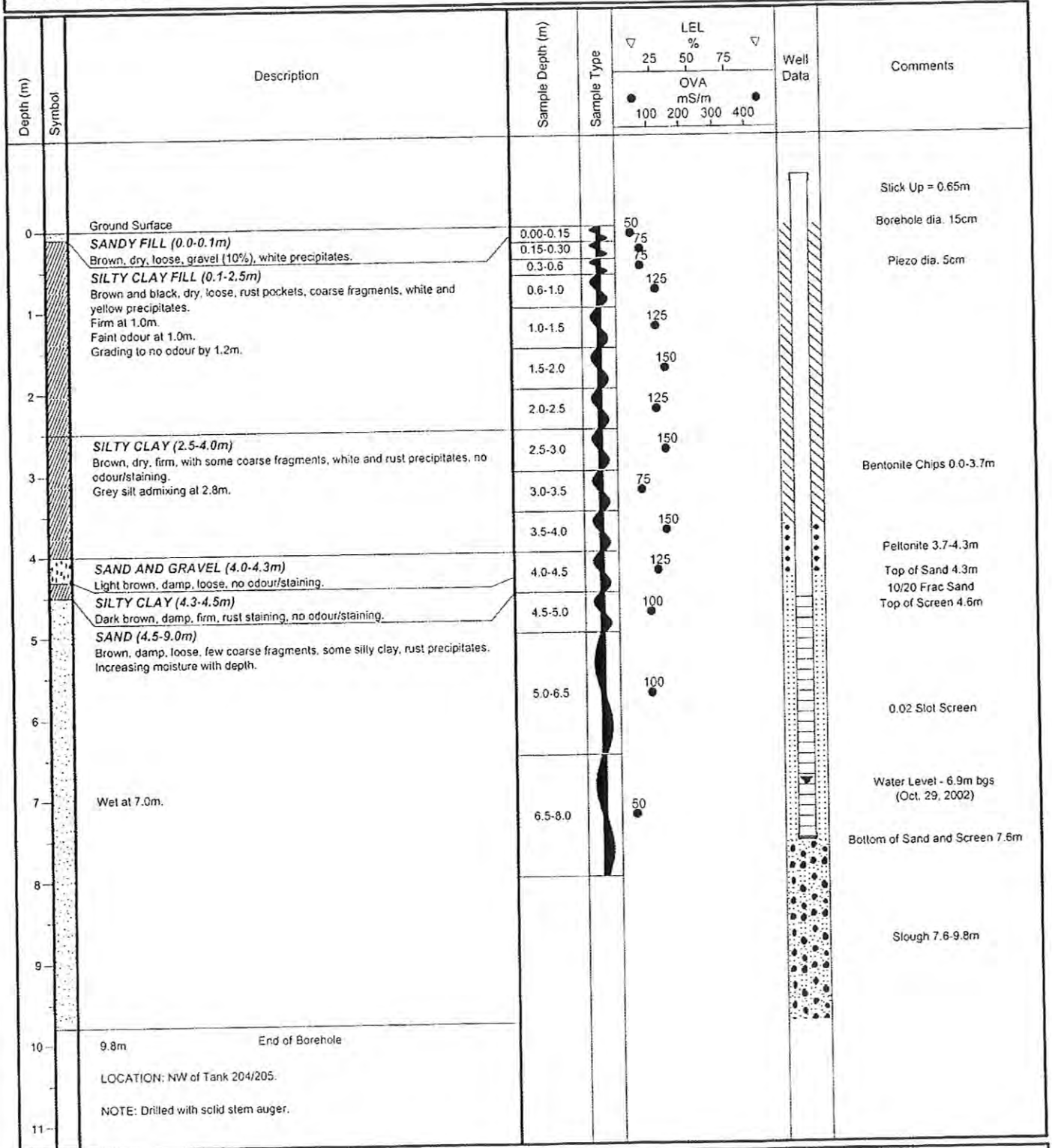
Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant
Drilled By: Mobile Augers
Drill Date: Oct. 29, 2002
Compiled By: JLJ/MPD

Northing: 640.3m
Easting: 629.1m
Elevation: 656.38m (PVC)

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-06/P02-3

Project #: C55790200



File Path: J:\55790000\55790100\S02-06p3 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

HGS-01

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant **Northing:** 645.9m
Drilled By: Mobile Augers **Easting:** 662.7m
Drill Date: Oct. 29, 2002 **Elevation:** 657.00m (PVC)
Compiled By: JLJ/MPD

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-09/P02-4

Project #: C55790200

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	LEL % / OVA mS/m	Well Data	Comments
0		Ground Surface					Stick Up = 0.60m
		SANDY CLAY (0.0-1.0m) Brown, dry, loose, coarse fragments, white precipitates, no odour/staining. Increasing stiffness at 0.45m.	0.00-0.15		50		Borehole dia. 15cm
			0.15-0.30		50		
			0.3-0.6		75		Piezo dia. 5cm
1			0.6-1.0		225		
		SILTY CLAY (1.0-5.0m) Brown, damp, stiff, coarse fragments, white and yellow precipitates, rust precipitates, grey silt pockets, rare rusty sand patches, rare dark grey silt clasts, no odour/staining.	1.0-1.5		125		
			1.5-2.0		125		
2			2.0-2.5		125		
			2.5-3.0		150		
3			3.0-3.5		125		
			3.5-4.0		200		
4			4.0-4.5		150		Bentonite Chips 0.0-4.6m
			4.5-5.0		200		Peltonite 4.6-5.0m
5		***SAND (5.0-9.3m)*** Medium orange brown, moist, loose on auger, coarse grained, poorly sorted, some gravel, no hydrocarbon odour/staining. Grades downwards to medium-grained sand.					Top of Sand 5.0m 10/20 Frac Sand Top of Screen 5.3m
			5.0-6.5		100		
6		Very rusty at 6.5m.					
7		Wet at 7.2m.	6.5-8.0		75		0.02 Slot Screen
							Water Level 7.57m bgs (Oct. 29, 2002)
8							Bottom of Screen 8.3m
9		***SILT (9.3-9.6m)*** Medium grey, moist, compact, uniform, no hydrocarbon odour/staining.					Bottom of Sand 9.6m
10		9.6m End of Borehole					
		LOCATION: S of Primary Pump Building.					
		NOTE: Drilled with solid stem auger.					
11							

File Path: J:\55790000\55790100\S02-09p4 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant
Drilled By: Mobile Augers
Drill Date: Oct. 29, 2002
Compiled By: JLJ/MPD

Northing: 706.9m
Easting: 734.6m
Elevation: 656.77m (PVC)

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-12/P02-5

Project #: C55790200

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	LEL % (25, 50, 75) / OVA mS/m (100, 200, 300, 400)	Well Data	Comments
0		Ground Surface					Stick Up = 0.60m
		CLAYEY SAND FILL (0.0-0.15m) Brown, damp, loose, with gravel (15%), no odour/staining.	0.00-0.15		25		Borehole dia. 15cm
			0.15-0.30		100		
			0.3-0.6		50		Piezo dia. 5cm
		SILTY CLAY (0.15-2.1m) Brown, damp, stiff, coarse fragments, white precipitates, light brown clay pockets, no odour/staining.	0.6-1.0		50		
1			1.0-1.5		100		
			1.5-2.0		100		
2		***SAND (2.1-2.8m)*** Light orange brown, dry, loose on auger, fine grained, rare pebbles and slightly coarser intervals, uniform, dry at base, no odour/staining.	2.0-2.5		50		
			2.5-3.0		75		
3		***SILTY CLAY (2.8-3.75m)*** Brown, damp, firm, coarse fragments, grey clay pockets, rust precipitates, slight to no odour.	3.0-3.5		25		
			3.5-4.0		50		
4			4.0-4.5		50		
			4.5-5.0		75		Bentonite Chips 0.0-6.2m
5			5.0-6.5		100		
6							Peltonite 6.2-6.5m Top of Sand 6.5m
			6.50-7.25		75		10/20 Frac Sand Top of Screen 6.8m
7							Water Level - Dry (Oct. 29, 2002)
			7.25-8.50				0.02 Slot Screen
8		***CLAY SILT (8.0-9.9m)*** Very dark grey, moist to wet, soft, no odour/staining.					
9			8.5-9.9		75		
10		9.9m End of Borehole					Bottom of Sand and Screen 9.8m Slough 9.8-9.9m
		LOCATION: Water Treatment Area.					
		NOTE: Drilled with solid stem auger.					
11							

HGS-01

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant **Northing:** 560.5m
Drilled By: Mobile Augers **Easting:** 520.0m
Drill Date: Oct. 29-30, 2002 **Elevation:** 654.94m (Grd)
Compiled By: MPD

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-16/P02-6

Project #: C55790200

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	LEL % (25 50 75) / OVA mS/m (100 200 300 400)	Well Data	Comments
							Slick Up = 0.65m
0		Ground Surface					
		SANDY SILT (0.0-0.5m) Trace clay, medium brown, moist, no odour/staining.	0.00-0.15		50		Borehole dia. 15cm
			0.15-0.30		50		
			0.3-0.6		50		Piezo dia. 5cm
		SILTY CLAY (0.5-3.9m) Dark brown, moist, very firm, rare pebbles and dark grey siltstone clasts, no odour/staining, rare light grey and rust patches.	0.6-1.0		225		
1			1.0-1.5		100		
			1.5-2.0		400		
2			2.0-2.5		5		Bentonite Chips 0.0-2.5m
		No light grey patches below 2.3m. Relatively uniform below 2.3m.	2.5-3.0		175		Peltonite 2.5-3.0m
3			3.0-3.5				Top of Sand 3.0m
							Top of Screen 3.4m
			3.5-4.0		125		
4		***SAND (3.9-7.6m)*** Light brown grey, moist, loose on auger, medium and fine-grained sand, rare coarse-grained sand patches and gravel, no odour/staining.	4.0-4.5		100		10/20 Frac Sand
			4.5-5.0		75		
5		Wet to saturated below 5.2m.					
			5.0-6.5		125		0.02 Slot Screen Water Level 5.72m bgs (Oct. 29, 2002)
6							Bottom of Sand and Screen 6.4m
7							Slough 6.4-7.6m
		7.6m End of Borehole					
8		LOCATION: Flare Stack.					
		NOTE: Drilled with solid stem auger.					
9							
10							

File Path: J:\55790000\55790100\s2-016p6 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

HGS-01

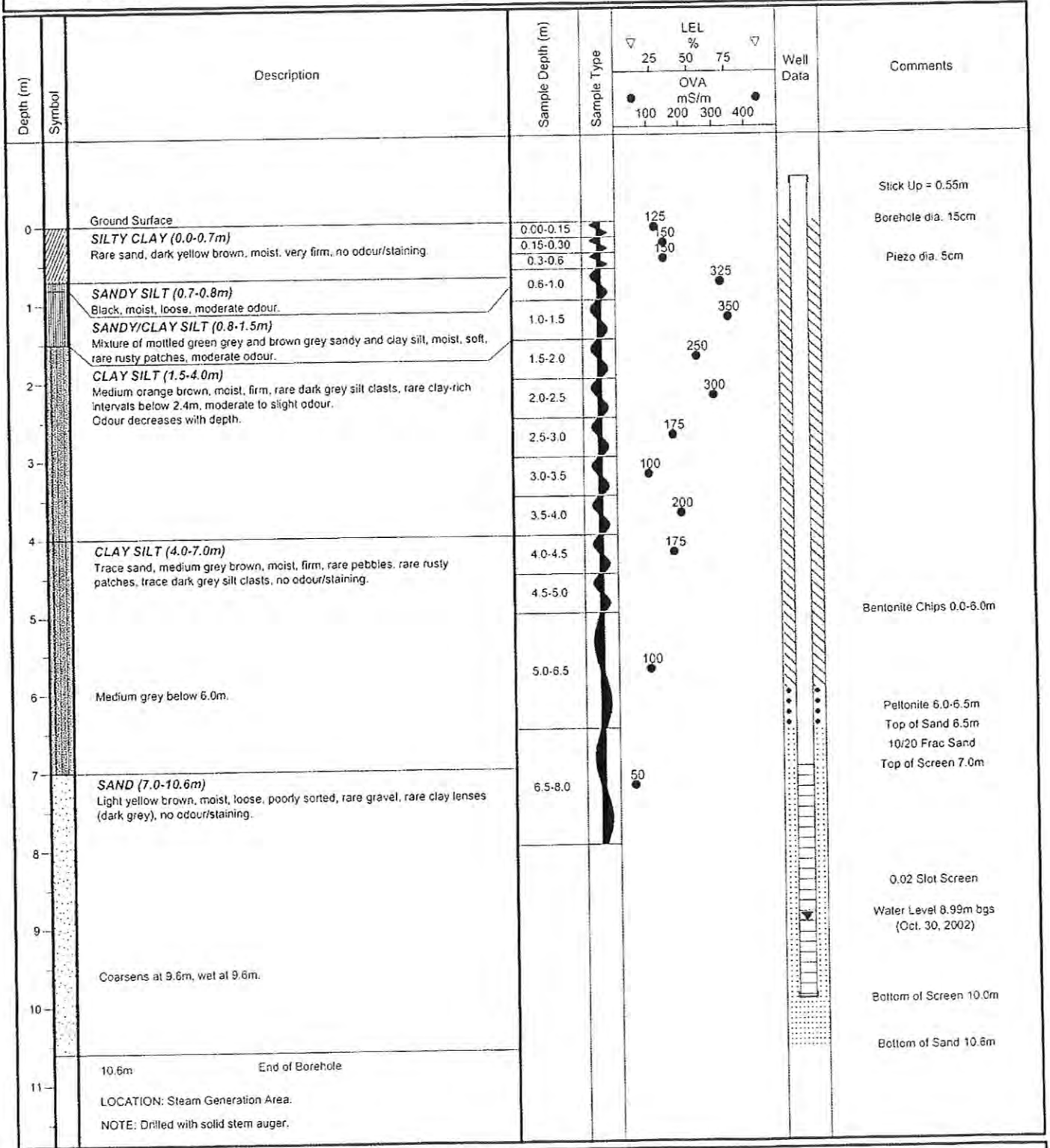
Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant
Drilled By: Mobile Augers
Drill Date: Oct. 30, 2002
Compiled By: MPD

Northing: 805.0m
Easting: 527.6m
Elevation: 660.37m (PVC)

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: S02-19/P02-7

Project #: C55790200



File Path: J:\55790000\55790100\s02-19p7 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

HGS-01

Project Name: Soil and GW Monitoring Program
Client: Murphy Oil Company
Location: Lindbergh Processing Plant **Northing:** 1157.8m
Drilled By: Mobile Augers **Easting:** 306.4m
Drill Date: Oct. 31, 2002 **Elevation:** 664.42m (PVC)
Compiled By: MPD

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

Borehole #: P02-08

Project #: C55790200

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	LEL % 25 50 75 / OVA mS/m 100 200 300 400	Well Data	Comments
0		Ground Surface					Stick Up = 0.60m
		SILTY SAND (0.0-0.8m) Trace clay, medium brown, moist, loose on auger, no odour/staining. White precipitates at 0.5m.	0.00-0.75		40		Borehole dia. 15cm Piezo dia. 5cm
1		*CLAY SILT (0.8-5.0m)* Medium grey brown, moist, firm to very firm, rare pebbles and sand, white precipitates to approx. 1.25m, no odour/staining. Rusty patches below 2.0 to approx. 5.0m.	0.75-2.25		110		
2							
3		Rare soft clay-rich intervals below 3.0m.	2.25-3.75		125		
4			3.75-5.25		150		
5		*SANDY SILT (5.0-7.2m)* Trace clay, medium brown, moist, firm, rare pebbles, no odour/staining.					
6			5.25-6.75		120		
7							
		SAND AND GRAVEL (7.2-8.4m) Medium to light brown, moist, loose on auger, rare silt lenses, no odour/staining.	6.75-8.25		140		
8							Bentonite Chips 0.0-8.7m
		SAND (8.4-12.8m) Light yellow brown, poorly sorted, moist, loose on auger, rare granules and dark grey clay lenses, no odour/staining.	8.25-9.75		50		Peltonite 8.7-9.3m Top of Sand 9.3m 10/20 Frac Sand Top of Screen 9.6m
9							
10			9.75-11.25		20		
11							0.02 Slot Screen
		Wet at 11.5m.					
12			11.25-12.75		20		Water Level 12.18m bgs (Oct. 31, 2002)
		Dark grey, saturated silt layer from 12.6-12.8m.					Bottom of Sand and Screen 12.6m Slough 12.6-12.8m
13		12.8m End of Borehole					
		LOCATION: Ecology Pit					
14		NOTE: Drilled with solid stem auger.					

File Path: J:\55790000\55790100\p02-08 Generated By: WH Date Generated: Nov. 6, 2002 Page: 1 of 1

Kom-HG&S-01

Project Name: Lindbergh Processing Plant
Client: Pengrowth Corporation
Location: 06-13-58-05 W4M
Drilled by: Mobile Augers and Research Ltd.
Drill Date: Nov. 7/05
Compiled by: R. Dieterman

Northing: 1121.30
Easting: 301.20
Elevation: 666.09

KOMEX INTERNATIONAL LTD.
ENVIRONMENT AND WATER RESOURCES

Borehole # P05-9A

PROJECT # E18710105

SUBSURFACE PROFILE

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC % LEL (25, 50, 75) / ppm (100, 300)	Well Data	Lab Analysis or Well Details
-1							Stick-Up 0.94 m
0		Ground Surface					
		ORGANICS (0.0-0.2 m) Topsoil.					Surface Cuttings (0.0-0.1 m)
		SANDY CLAY FILL (0.2-1.1 m) Brown; firm; some gravels greater than 3 cm. At 0.8-1.1 m: Some cobbles.	0.5-0.6		100		
1		***CLAY TILL (1.1-9.0 m)*** Brown; firm; damp to moist; medium plasticity; some coarse fragments; coal; no HC noted.	1.0-1.25		110		
2		At 2.25-3.75 m: Carbonates present; moist.	2.0-2.25		100		51 mm ID Sch 40 PVC pipe
			2.5-2.7		100		
3			3.5-3.75		85		
4		At 3.75-5.25 m: Firm, low to medium plasticity; some iron staining; occasional sand blebs.	4.0-4.25		120		
5		At 5.25-6.75 m: Olive brown; firm; low plasticity; coarse fragments; some iron staining; coal.	5.0-5.25		100		
			5.5-5.75		80		
6			6.5-6.75		110		
7		At 6.75-8.25 m: Brown; firm; moist; medium plasticity; coarse fragment; coal; some sand.	7.0-7.25		95		
8		At 8.25-9.0 m: Brown to olive brown.	8.0-8.25		100		Bentonite Chips (0.1-8.99 m)
			8.5-8.75		110		
9							

Kom-HG&S-01

Project Name: Lindbergh Processing Plant
Client: Pengrowth Corporation
Location: 06-13-58-05 W4M
Drilled by: Mobile Augers and Research Ltd.
Drill Date: Nov. 7/05
Compiled by: R. Dieterman

Northing: 1121.30
Easting: 301.20
Elevation: 666.09

KOMEX INTERNATIONAL LTD.
ENVIRONMENT AND WATER RESOURCES

Borehole # P05-9A

PROJECT # E18710105

SUBSURFACE PROFILE

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC % LEL (25, 50, 75) / ppm (100, 300)	Well Data	Lab Analysis or Well Details
		SILT (9.0-9.15 m) Light brown; damp.					Hydrated Bentonite Pellets (8.99-9.60 m)
		SAND (9.15-13.50 m) Light brown; very fine-grained; dry to damp.	9.5-9.75		110		
10		At 9.75-11.25 m: Brown; fine-grained; damp; poorly sorted.	10.0-10.25		90		Top of Sand at 9.60 m 10/20 Frac Sand Natural Sand Pack (12.80-13.56 m)
11			11.0-11.25		100		Top of Screen at 10.56 m
			11.50-11.75		80		3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
12							Solid Stem Borehole (152 mm diameter)
			12.5-12.75		110		
13		At 12.75-13.50 m: Wet.			80		
		CLAY (13.50-14.75 m) Brown; soft; wet; some sand; medium plasticity; some iron staining.	13.0-13.25				Slough (13.56-14.75 m)
14							
			14.5-14.75		90		
		End of Borehole					TD of Borehole at 14.75 m
15							
16							
17							
18							
19							

Kom-HG&S-01

Project Name: Lindbergh Processing Plant
Client: Pengrowth Corporation
Location: 06-13-58-05 W4M
Drilled by: Mobile Augers and Research Ltd.
Drill Date: Nov. 7/05
Compiled by: R. Dieterman

Northing: 1104.05
Easting: 275.54
Elevation: 665.52

KOMEX INTERNATIONAL LTD.
ENVIRONMENT AND WATER RESOURCES

Borehole # P05-10A

PROJECT # E18710105

SUBSURFACE PROFILE

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC % LEL (25, 50, 75) / ppm (100, 300)	Well Data	Lab Analysis or Well Details
0		Ground Surface					Stick-Up 0.84 m
0		***ORGANICS (0.0-0.2 m)*** Topsoil.					(0.0-0.1 m)
0.2		***CLAY TILL (0.2-9.25 m)*** Olive brown; firm; carbonates; damp; no HC noted.	0.5-0.6		30		
1		At 0.8-2.25 m: Sand blebs; coarse fragments; coal; iron staining; no HC noted.	1.0-1.25		35		
2		At 2.25-3.85 m: As above; no HC noted.	2.0-2.25		30		51 mm ID Sch 40 PVC pipe
			2.5-2.75		40		
3		At 3.75-5.25 m: As above; medium plasticity.	3.5-3.75		30		
4			4.0-4.25		65		Bentonite Chips (0.0-8.10 m)
5		At 5.25-6.75 m: As above; increased coarse fragments.	5.0-5.25		110		
			5.5-5.75		40		
6			6.25-6.50		100		
7		At 7.25 m: grey mottling.	7.0-7.25		35		Hydrated Bentonite Pellets (7.10-7.20 m) Top of Sand at 7.20 m Top of Screen at 7.50 m
8			8.0-8.25		15		10/20 Frac Sand
			8.5-8.75		50		Solid Stem Borehole (152 mm diameter)
9							

Kom-HG&S-01

Project Name: Lindbergh Processing Plant
Client: Pengrowth Corporation
Location: 06-13-58-05 W4M
Drilled by: Mobile Augers and Research Ltd.
Drill Date: Nov. 7/05
Compiled by: R. Dieterman

Northing: 1104.05
Easting: 275.54
Elevation: 665.52

KOMEX INTERNATIONAL LTD.
ENVIRONMENT AND WATER RESOURCES

Borehole # P05-10A

PROJECT # E18710105

SUBSURFACE PROFILE

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC % LEL (25, 50, 75) / ppm (100, 300)	Well Data	Lab Analysis or Well Details
10		***SILT (9.25-9.50 m)*** Light brown; damp.	9.5-9.75		50		3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
		SAND (9.5-11.25 m) Brown; wet; poorly sorted.	10.0-10.25		100		Slough (10.50-11.25 m)
11			11.0-11.25		100		TD of Borehole at 11.25 m
		End of Borehole					

12 13 14 15 16 17 18 19

WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-09/P10-11A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem/Hollow Stem
Drill Date: 22-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984751.783
Easting: 525133.239
Elevation: 648.490 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ 0 25 50 75 100 / • ppm • 0 500 1000	Electrical Conductivity (mS/cm) 0 10 20	Well Data
		Ground Surface			0		Stick-Up 1.14 m
0		***TOPSOIL (0-0.3 m)*** Black; damp; loose; roots; no HC noted.	0-0.15		25		
			0.15-0.3				
		SILTY CLAY TILL (0.3-5.0 m) Olive; damp; firm; coarse fragments; iron flecks; no HC noted.			30	1.01	
			0.4-0.6				51 mm ID Sch 40 PVC Pipe
1					35	0.89	
			1.0-1.2				
		At 1.3 m: Moist; moderately firm; gravels <2 cm.					Hydrated Bentonite Chips (0-3.20 m)
					25	0.81	
2			1.8-2.0				
					70	0.89	
		At 2.6 m: Iron staining.	2.5-2.7				
					35	1.10	
3			3.1-3.3				Hydrated Bentonite Pellets (3.20-3.50 m)
		At 3.5 m: Wet.					Top of Sand at 3.50 m
							10/20 Frac Sand
					25	0.98	Top of Screen at 3.75 m
4			3.8-4.0				3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
							Hollow Stem Borehole (203 mm nominal diameter)
					25	0.96	
			4.8-5.0				
5		At 5.0-5.25 m: No recovery.					Natural Sand Pack (4.00-6.80 m)
		GRAVELLY SAND (5.25-6.75 m) Brownish orange; saturated; loose; coarse-grained; no HC noted.					
					45		
			5.8-6.0				

WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-09/P10-11A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem/Hollow Stem
Drill Date: 22-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984751.783
Easting: 525133.239
Elevation: 648.490 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ 0 25 50 75 100 / • ppm • C 45 500 1000	Electrical Conductivity (mS/cm) 0 10 20	Well Data
6			5.8-6.0				
		End of Borehole					Bottom of Screen at 6.80 m T.D. of Borehole at 6.80 m
7							
8							
9							
10							
11							
12							

WP-Piezo-OVA1000-EC20-type3

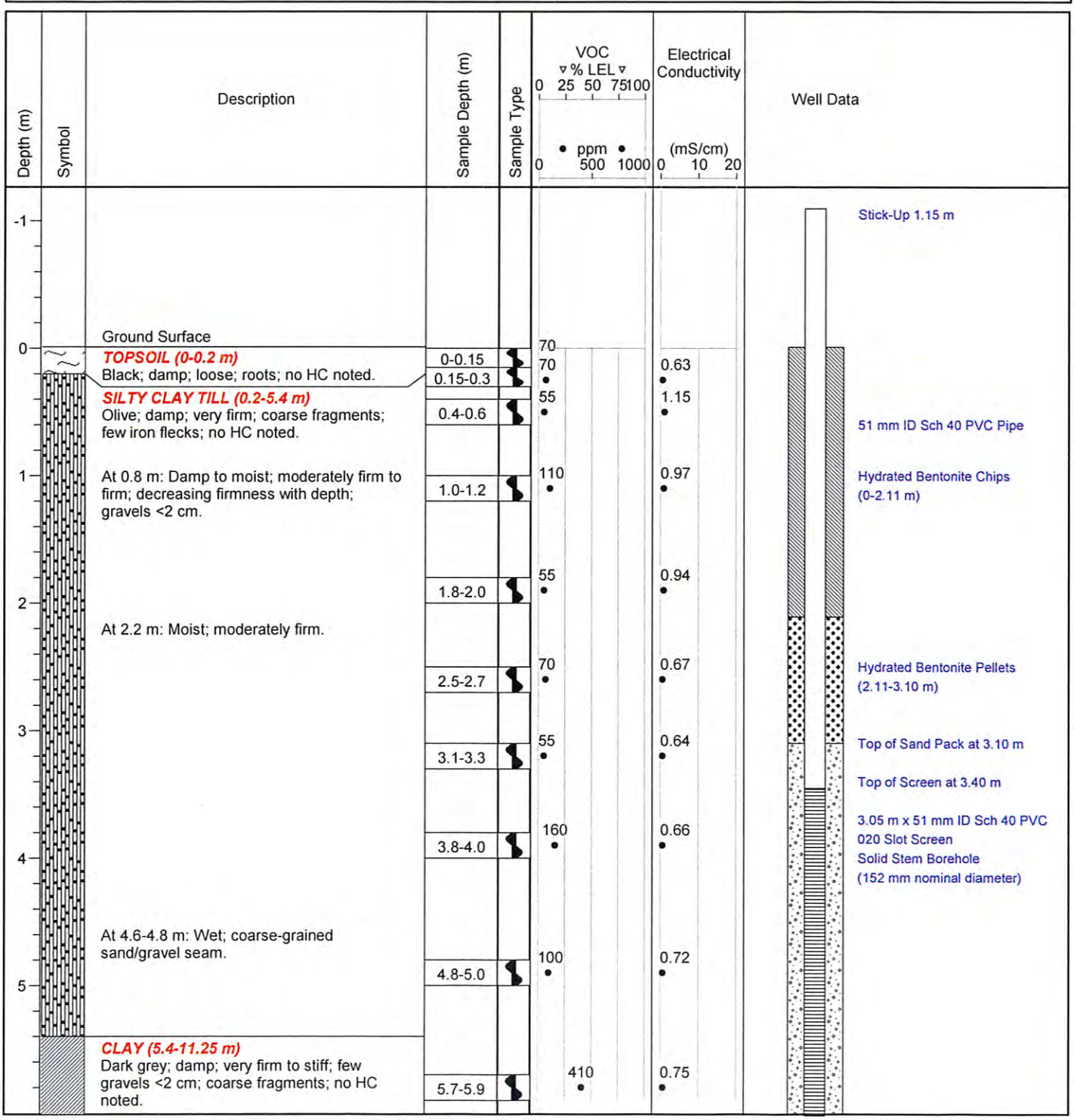
WorleyParsons
resources & energy

Borehole # S10-14/P10-12A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 23-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984358.248
Easting: 526091.441
Elevation: 650.297 m asl (ground)



File Path/Location: N\E187\E18710112 Created by: LA Date Created: 01-Jul-10 Approved by:

WP-Piezo-OVA1000-EC20-type3

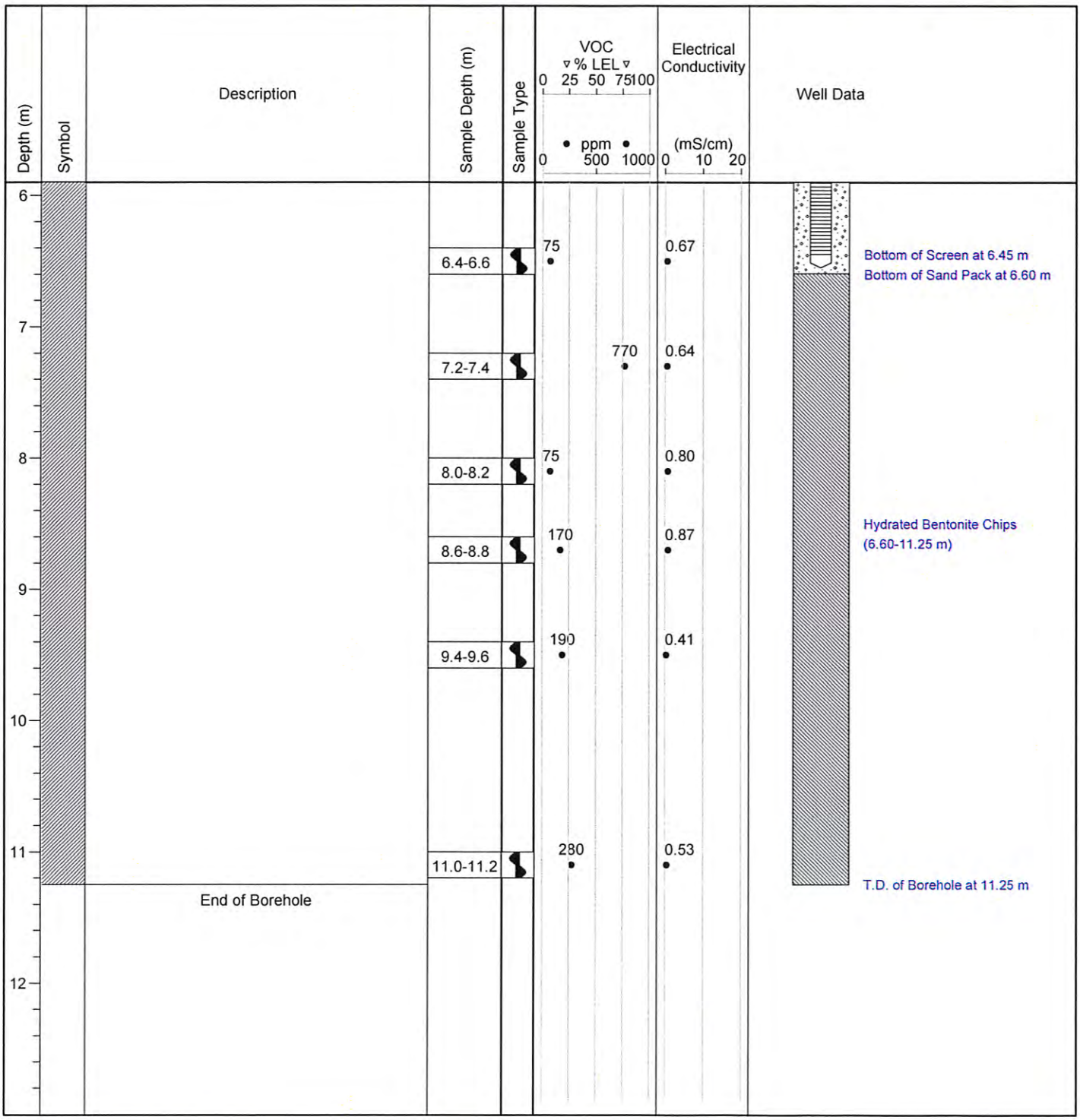
WorleyParsons
resources & energy

Borehole # S10-14/P10-12A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 23-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984358.248
Easting: 526091.441
Elevation: 650.297 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

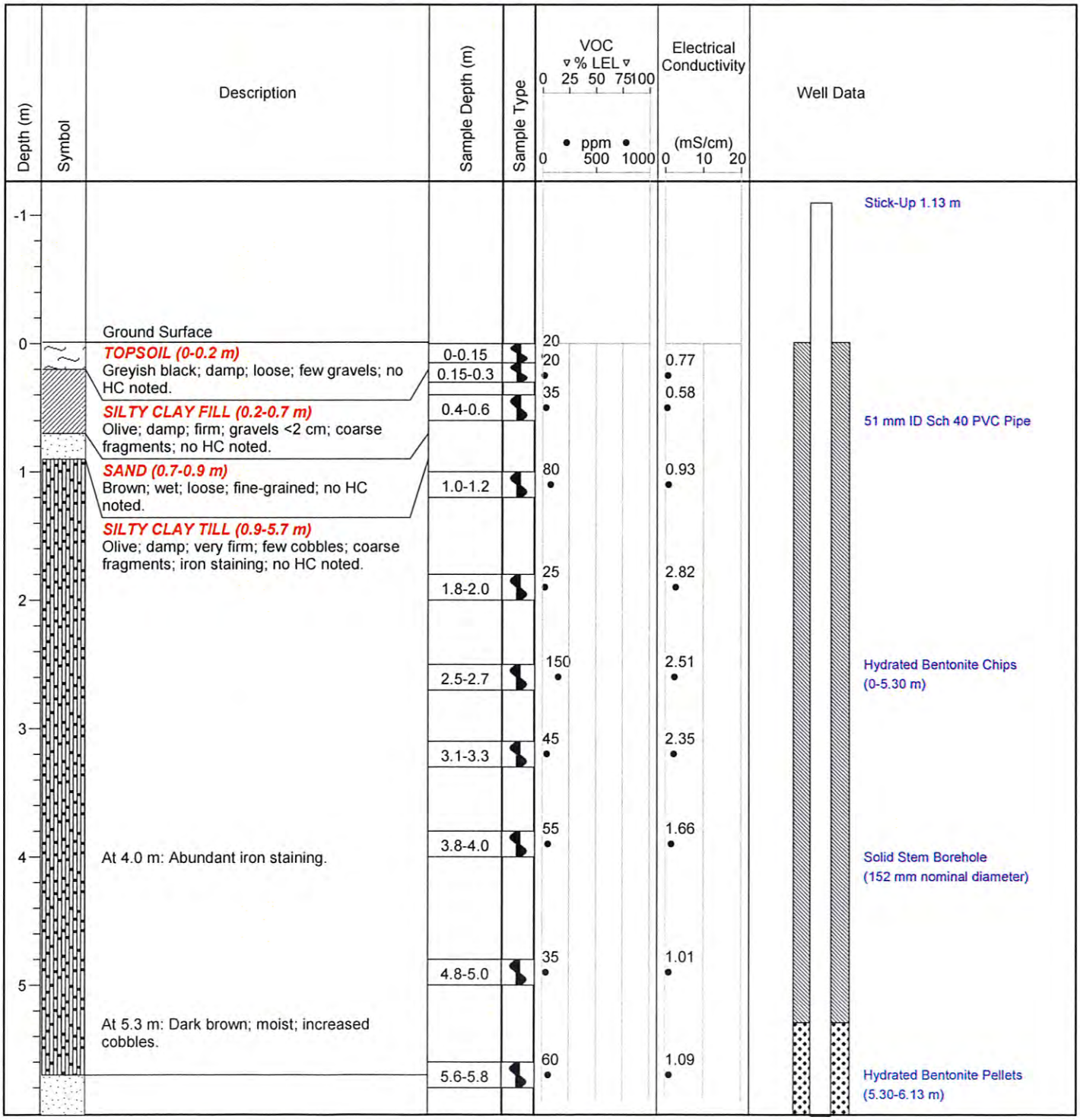
WorleyParsons
resources & energy

Borehole # S10-22/P10-13A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985026.482
Easting: 525707.392
Elevation: 658.983 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-22/P10-13A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985026.482
Easting: 525707.392
Elevation: 658.983 m asl (ground)

Depth (m)	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ (0 25 50 75 100) • ppm • (0 500 1000)	Electrical Conductivity (mS/cm) (0 10 20)	Well Data
6	***SAND (5.7-9.5 m)*** Brown; damp; loose; coarse-grained; abundant cobbles; abundant gravels; no HC noted.					Top of Sand at 6.13 m
						Top of Screen at 6.35 m
		6.5-6.7		15	0.55	
	At 6.7 m: Moist to wet.					3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
7						
		7.2-7.4		20	0.10	10/20 Frac Sand
8						
		8.0-8.2		45	0.07	
	At 8.3 m: Saturated.					Natural Sand Pack (7.61-9.40 m)
		8.6-8.8		45	1.45	
9						
	CLAYEY SAND (9.50-9.75 m) Brown; wet; loose; gravels; coarse fragments; no HC noted.	9.5-9.7		25	1.19	Bottom of Screen at 9.40 m
10	End of Borehole					T.D. of Borehole at 9.40 m
11						
12						

File Path/Location: N\E187\E18710112 Created by: LA Date Created: 01-Jul-10 Approved by:

WP-Piezo-OVA1000-EC20-type3

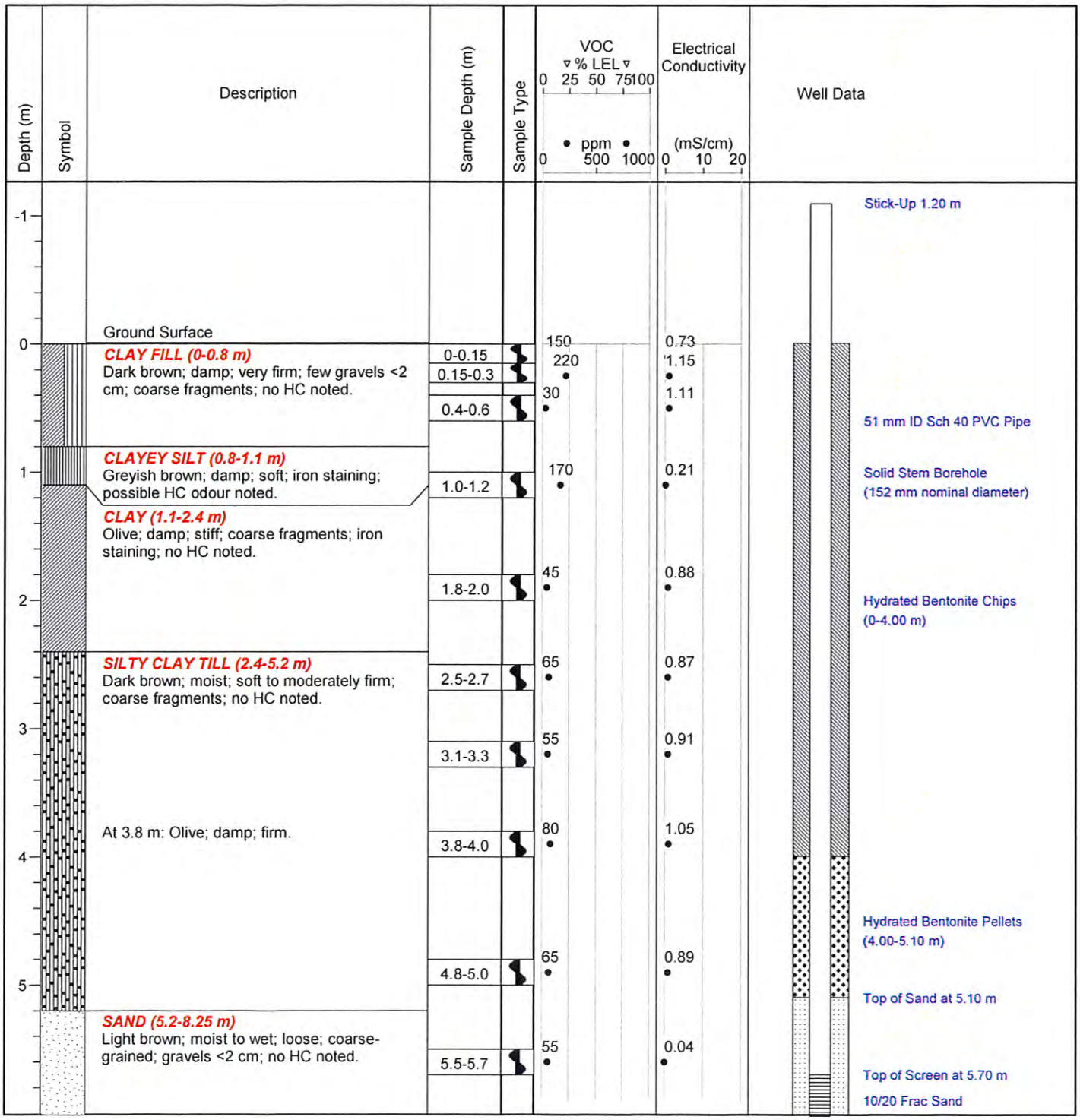
WorleyParsons
resources & energy

Borehole # S10-26/P10-14A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 525793.394
Easting: 5984881.167
Elevation: 656.960 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

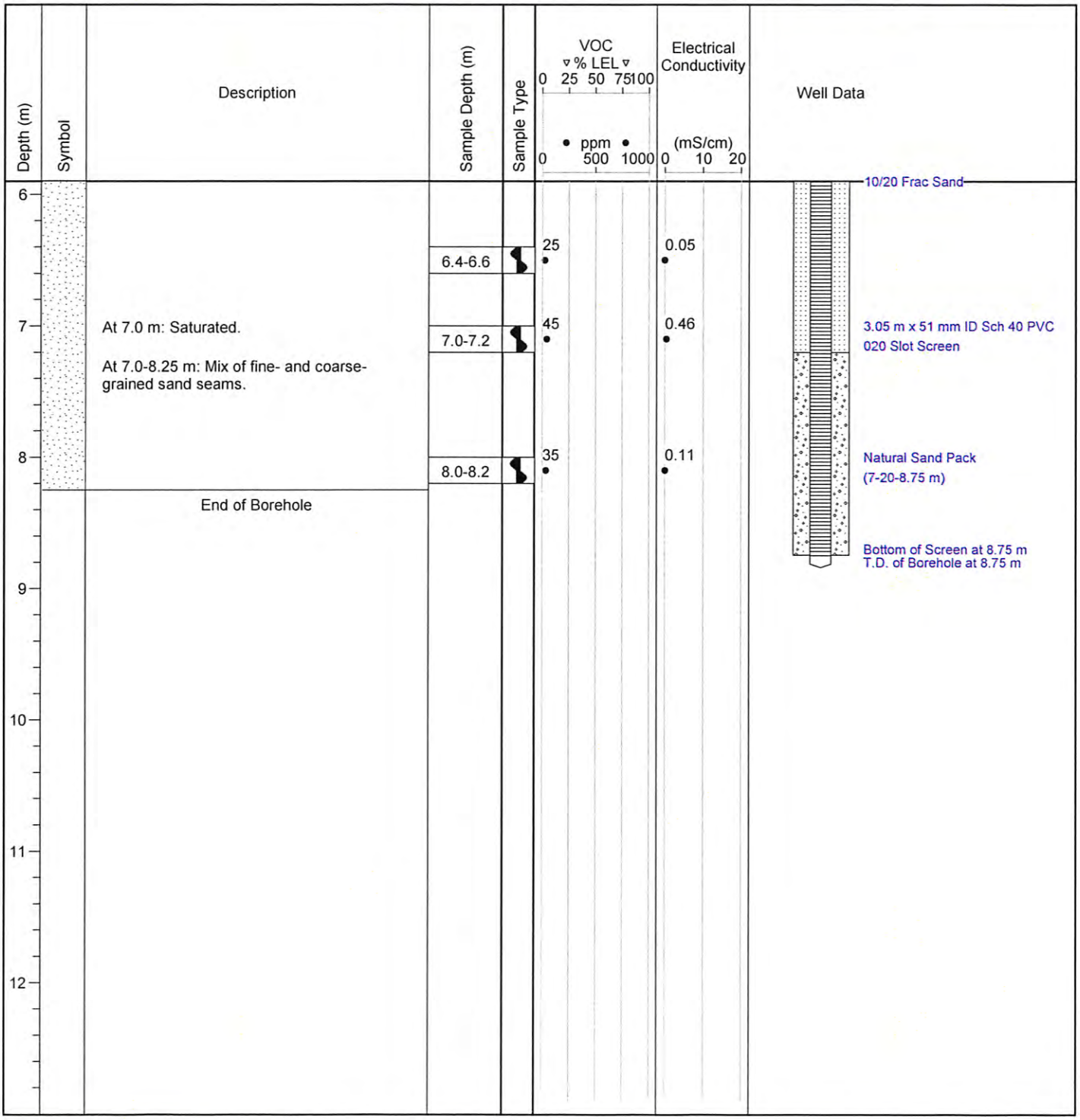
WorleyParsons
resources & energy

Borehole # S10-26/P10-14A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 525793.394
Easting: 5984881.167
Elevation: 656.960 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

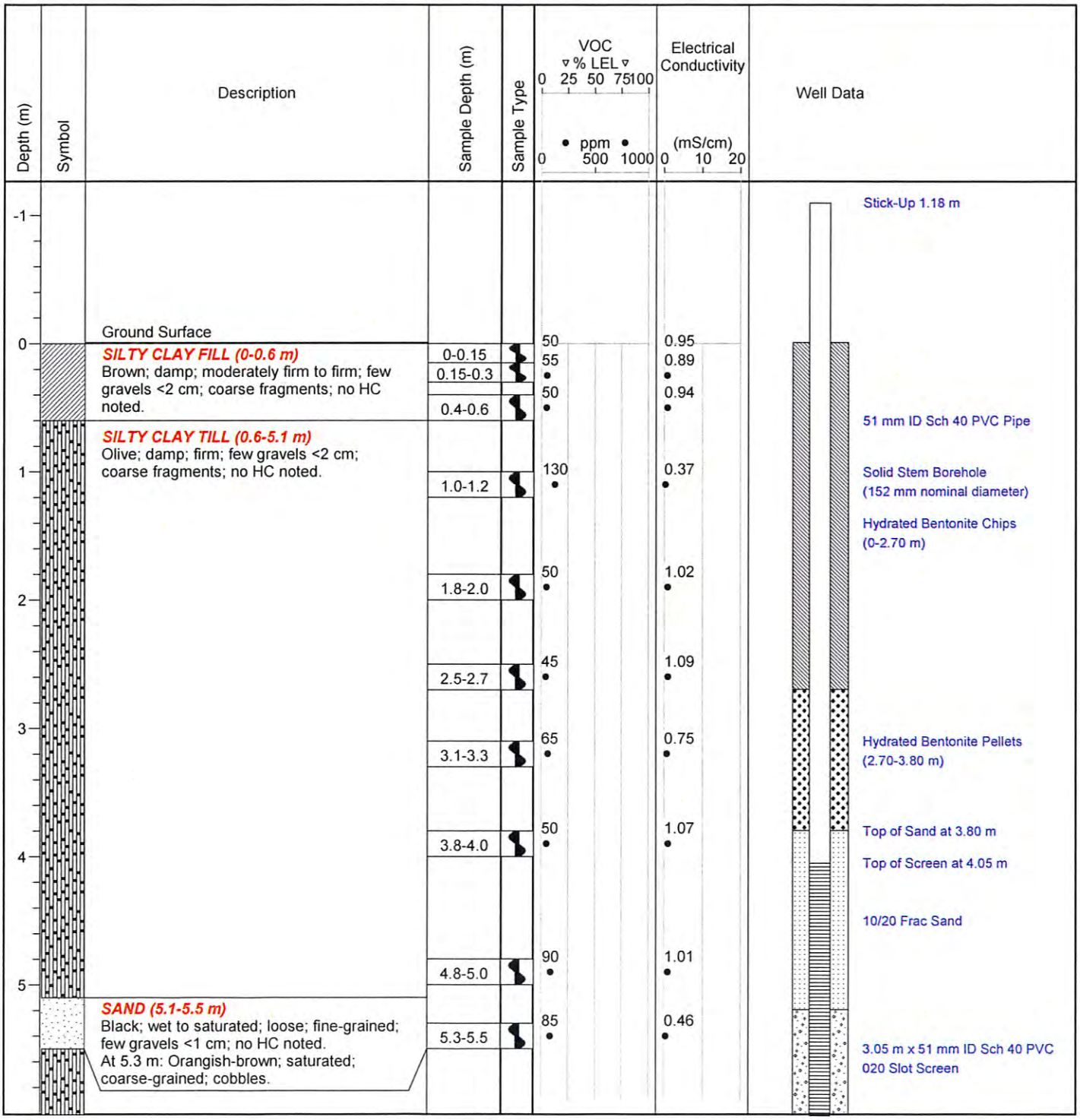
WorleyParsons
resources & energy

Borehole # S10-27/P10-15A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984845.921
Easting: 525602.973
Elevation: 653.790 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-27/P10-15A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984845.921
Easting: 525602.973
Elevation: 653.790 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ 0 25 50 75 100 / • ppm • 0 500 1000	Electrical Conductivity (mS/cm) 0 10 20	Well Data
6		***SILTY CLAY TILL (5.5-7.1 m)*** Olive; damp; firm; coarse fragments; iron staining; no HC noted.					
			6.5-6.7		50	0.88	Natural Sand Pack (5.20-7.10 m)
7		End of Borehole					Bottom of Screen at 7.10 m T.D. of Borehole at 7.10 m
8							
9							
10							
11							
12							

File Path/Location: N\E187\E18710112 Created by: LA Date Created: 01-Jul-10 Approved by:

WP-Piezo-OVA1000-EC20-type3

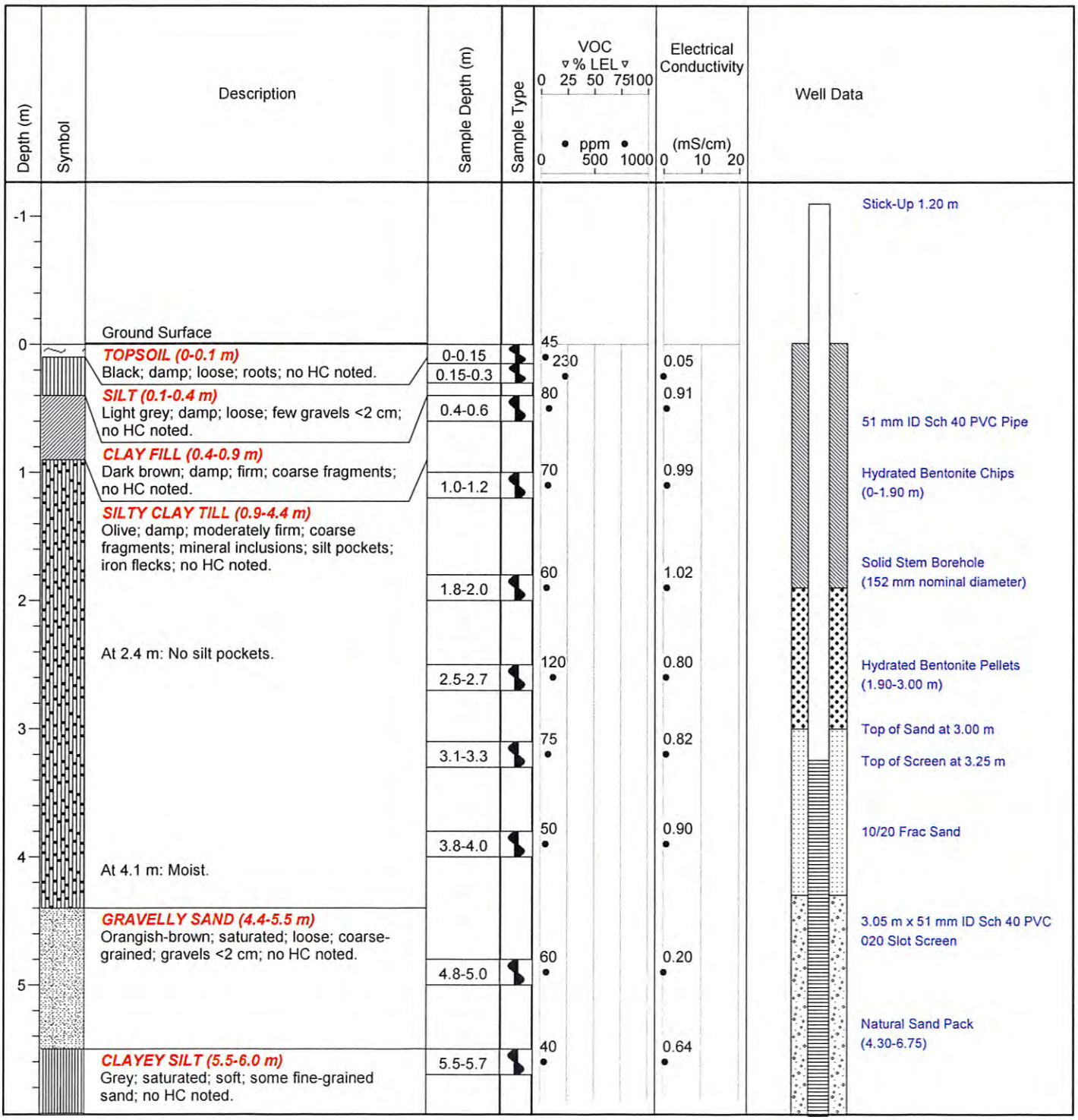
WorleyParsons
resources & energy

Borehole # S10-28/P10-16A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984816.466
Easting: 525656.628
Elevation: 653.451 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-28/P10-16A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5984816.466
Easting: 525656.628
Elevation: 653.451 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ (0 25 50 75 100) • ppm • (0 500 1000)	Electrical Conductivity (mS/cm) (0 10 20)	Well Data
6		***SAND (6.0-6.75 m)*** Greenish brown; saturated; loose; fine-grained; some silt; no HC noted.	6.4-6.6		80	0.46	Bottom of Screen at 6.30 m
		End of Borehole					T.D. of Borehole at 6.75 m
7							
8							
9							
10							
11							
12							

WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-29/P10-17A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985420.980
Easting: 525920.187
Elevation: 665.004 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ (0 25 50 75 100) • ppm • (0 500 1000)	Electrical Conductivity (mS/cm) (0 10 20)	Well Data
-1							Stick-Up 1.01 m
0		Ground Surface					
		SANDY CLAY FILL (0-0.9 m) Dark brown; damp; firm; abundant cobbles; coarse-grained sand; coarse fragments; no HC noted.	0-0.15		100	0.87	
			0.15-0.3		70	0.93	
			0.4-0.6		45	1.03	51 mm ID Sch 40 PVC Pipe
1		***SILTY CLAY TILL (0.9-8.7 m)*** Olive; damp; firm; few gravels <2 cm; coarse fragments; iron staining; no HC noted.	1.0-1.2		100	0.90	
			1.8-2.0		35	0.87	Solid Stem Borehole (152 mm nominal diameter)
2			2.5-2.7		100	0.85	
			3.1-3.3		55	1.00	
3			3.8-4.0		70	0.95	
4			4.8-5.0		60	0.43	
			5.5-5.7		95	0.80	
5							

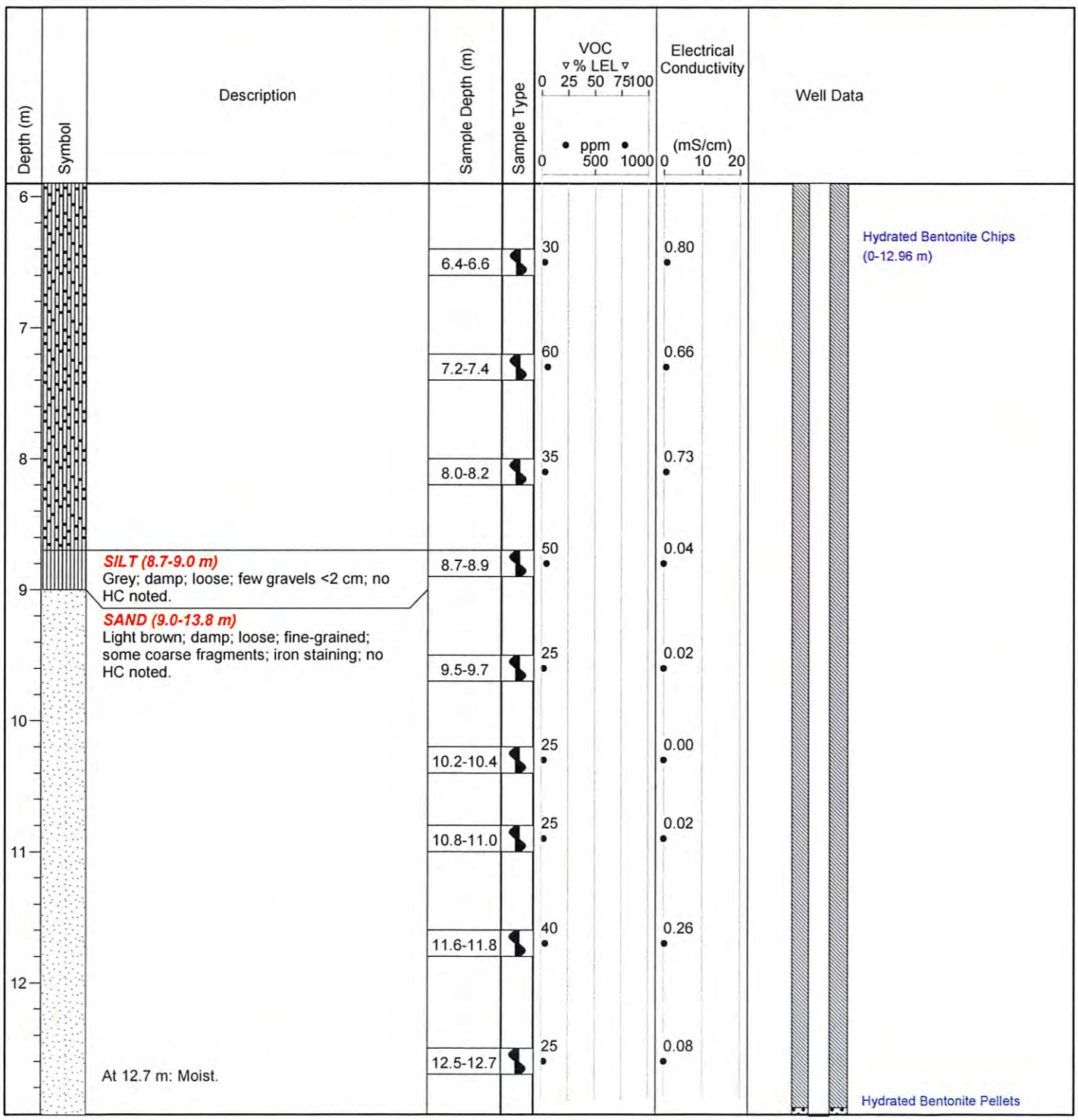
WP-Piezo-OVA1000-EC20-type3

Borehole # S10-29/P10-17A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985420.980
Easting: 525920.187
Elevation: 665.004 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-29/P10-17A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 24-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985420.980
Easting: 525920.187
Elevation: 665.004 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ (0 25 50 75 100) • ppm • (0 500 1000)	Electrical Conductivity (mS/cm) (0 10 20)	Well Data
13		At 13.1 m: Wet. At 13.3 m: Saturated.	13.2-13.4		25	0.24	Hydrated Bentonite Pellets (12.96-13.26 m) Top of Sand Pack at 13.26 m Top of Screen at 13.65 m
14		***CLAY (13.8-15.75 m)*** Grey; moist; stiff; no HC noted.	14.0-14.2		65	1.41	3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
15			14.8-15.0		40	0.75	Natural Sand Pack (13.26-16.70 m)
16		End of Borehole					Bottom of Screen at 16.70 m T.D. of Borehole at 16.70 m
17							
18							
19							

WP-Piezo-OVA1000-EC20-type3

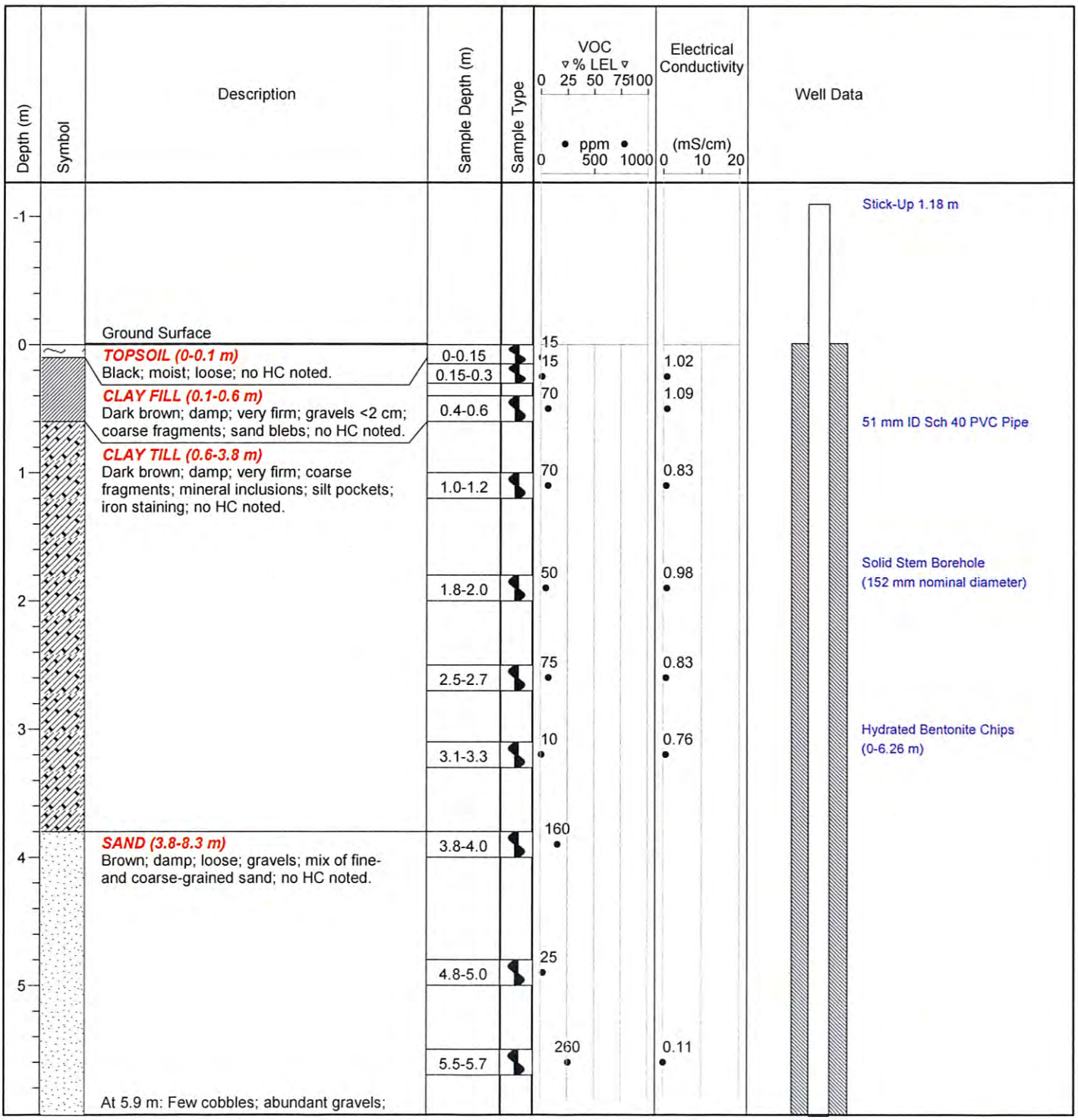
WorleyParsons
resources & energy

Borehole # S10-34/P10-18A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 25-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985714.898
Easting: 525404.740
Elevation: 660.583 m asl (ground)



WP-Piezo-OVA1000-EC20-type3

WorleyParsons
resources & energy

Borehole # S10-34/P10-18A

PROJECT # E18710112

Project Name: 2010 Soil Management Activities
Client: Pengrowth Energy Corporation
Drilled by: Mobile Augers and Research Ltd.
Drilling Method: Solid Stem
Drill Date: 25-Jun-10
Logged by: L. Atkinson

Location: 13-58-05 W4M
Northing: 5985714.898
Easting: 525404.740
Elevation: 660.583 m asl (ground)

Depth (m)	Symbol	Description	Sample Depth (m)	Sample Type	VOC ▿ % LEL ▿ (0 25 50 75 100) • ppm • (0 500 1000)	Electrical Conductivity (mS/cm) (0 10 20)	Well Data
6							Hydrated Bentonite Pellets (6.26-6.79 m)
			6.4-6.6		25	0.05	Top of Sand at 6.79 m
7							Top of Screen at 7.05 m
			7.5-7.7		70	0.42	
8			8.0-8.2		90	0.12	
		GRAVELLY SAND (8.3-10.4 m) Orange; saturated; loose; coarse-grained; cobbles; no HC noted.					Natural Sand Pack (7.00-12.75 m)
			8.7-8.9		35		3.05 m x 51 mm ID Sch 40 PVC 020 Slot Screen
9							
			9.5-9.7		15		
10							Bottom of Screen at 10.10 m
			10.2-10.4		60	0.43	
		SILTY CLAY (10.4-12.75 m) Grey; wet; soft to moderately firm; coarse fragments; no HC noted.					
11			11.0-11.2		35	0.80	
			11.6-11.8		40		
12							T.D. of Borehole at 12.75 m
		End of Borehole					

Project No: 10-131GW

Borehole No: MW11-19-12

Drill Method: Mud Rotary (6 1/4")

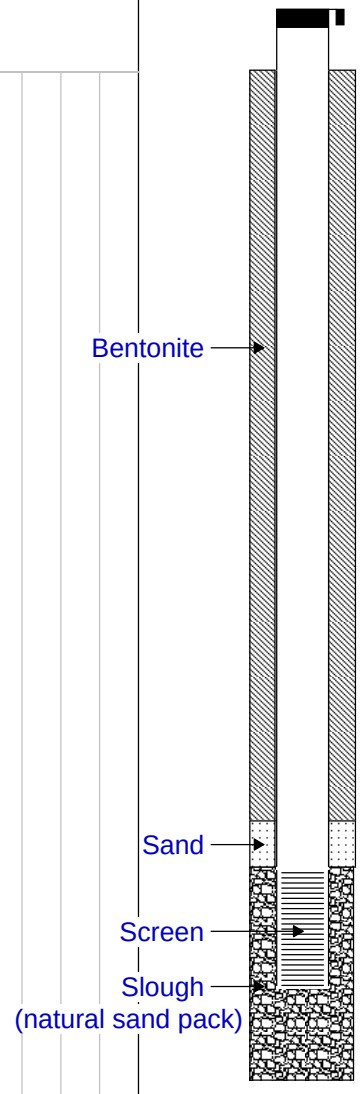
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
	Sandy Clay Light brown, firm			
2.0				
	Sandy Clay Gray			
8.0				
	Sand Coarse, some gravel, poorly sorted, subangular			
9.5	***Sand*** Fine, well sorted, subangular			
13.0	End of Borehole			



Logged By: AL/AK

Entered By: SC

Drill Date: June 10, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-19-24

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
1.0	***Fill-Clay*** Brown, firm			
3.0	***Sandy Clay*** Gray, soft			Bentonite
8.0	***Sand*** Medium, well sorted, subangular			
12.0	@ 12.2m, sand is getting more coarse			Slough (natural sand pack)
19.0				

Logged By: AK

Entered By: SC

Drill Date: June 7, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-19-24

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	
20.0				
21.0	@ 20.7m, medium grained sand, well sorted, some gray clay			
22.0				
23.0	@ 22.8m, coarse to very coarse sand at bottom			Screen
24.0				
25.0	Transition from sand to clay			
26.0				
27.0				Slough (natural sand pack)
28.0	***Clay*** Gray, soft and plastic			
29.0				
30.0				
31.0				
32.0				
33.0	***Sandy Clay*** Light gray, soft, no return (or little)			
34.0				
35.0				
36.0				
37.0	End of Borehole			
38.0				
39.0				

Logged By: AK

Entered By: SC

Drill Date: June 7, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-19-67

Drill Method: Mud Rotary (9 5/8" from 0-24m; 6 1/4" from 24-70m)

Client: Pengrowth Corporation

GPS Location:

Note: Well was e-logged

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	

Ground Surface

0.0 – 1.0 – 2.0 – 3.0 – 4.0 – 5.0 – 6.0 – 7.0 – 8.0 – 9.0 – 10.0 – 11.0 – 12.0 – 13.0 – 14.0 – 15.0 – 16.0 – 17.0 – 18.0 – 19.0 – 20.0 – 21.0 – 22.0 – 23.0 – 24.0 – 25.0 – 26.0 – 27.0 – 28.0 – 29.0 – 30.0 – 31.0 – 32.0 – 33.0 – 34.0 – 35.0

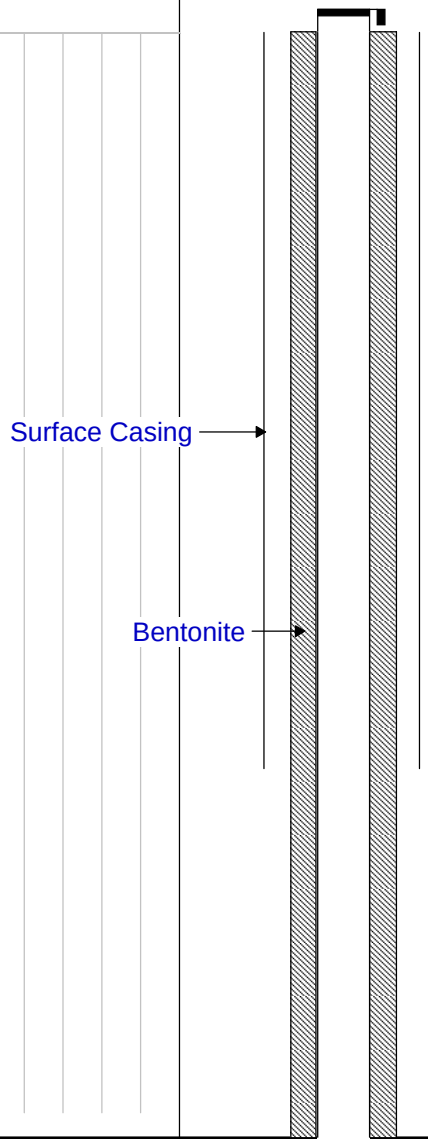
Fill-Clay
Brown, firm

Sandy Clay
Gray, soft

Sand
Medium, well sorted, subangular

Clay
Dark gray, soft plastic

Sand
Lense?



Logged By: AK

Entered By: SC

Drill Date: June 9, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-19-67

Drill Method: Mud Rotary (9 5/8" from 0-24m; 6 1/4" from 24-70m)

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100 200 300 400; % LEL: 10 30 50 70 90	
36.0	***Clay*** Dark gray, firm, slightly sandy, very sticky, becomes sandier with depth			
44.0	***Sand*** Fine, well sorted (almost no return)			
47.0	Alternating clay and sand stringers			Bentonite
56.0	***Sand*** Coarse, gravel, poorly sorted, (some rocks)			
59.0	***Sandy Clay*** Dark gray, firm, sticky			
64.0	***Sand*** Fine, well sorted, getting more coarse with depth @ bottom of layer, very coarse, poorly sorted, subangular sand/gravel			Sand Screen Slough
71.0	End of Borehole			

Logged By: AK

Entered By: SC

Drill Date: June 9, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-53

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm: 100, 200, 300, 400 / % LEL: 10, 30, 50, 70, 90	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
0.0	***Sandy Clay*** Brown, firm			
6.0	@ 5.5m, becomes gray			
10.0	@ 9.1m, some sparse sand and gravel			
15.0				Bentonite

Logged By: AL/AK

Entered By: SC

Drill Date: June 6, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-53

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

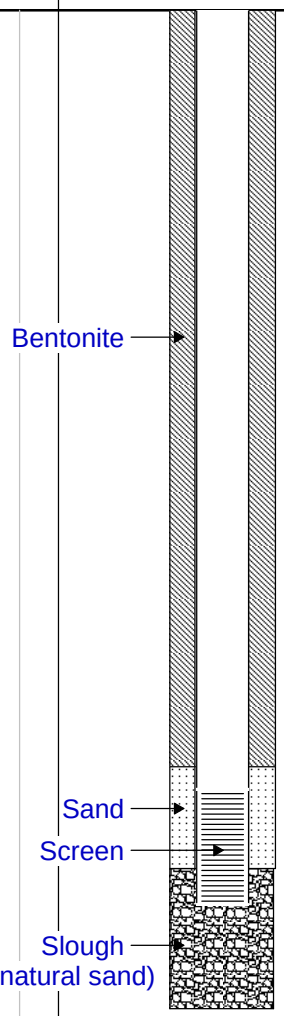
GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	

30.0
31.0 — ***Clay*** Sand stringers
32.0
33.0
34.0
35.0
36.0
37.0
38.0
39.0
40.0
41.0
42.0
43.0
44.0
45.0
46.0
47.0
48.0
49.0
50.0 — ***Sand*** Coarse
51.0
52.0 — ***Sand*** Very coarse, well sorted, subangular
53.0
54.0
55.0 — ***Sandy Clay*** Gray
56.0
57.0 — End of Borehole
58.0
59.0



Logged By: AL/AK

Entered By: SC

Drill Date: June 6, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-7

Drill Method: Mud Rotary (6 1/4")

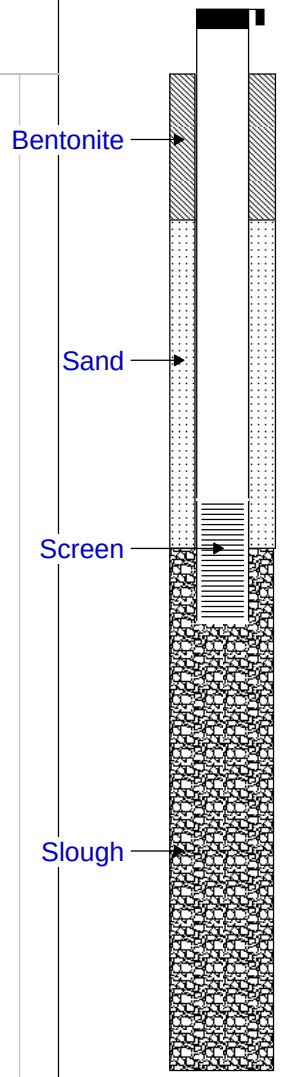
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	
Depth (m)	Description	Sample Point (m)	ppm: 100 200 300 400; % LEL: 10 30 50 70 90	Well Completion Details
0.0	Ground Surface			
	Sandy Clay Brown			
6.0	***Sand*** Coarse, some gravel, moderately sorted			
12.0	End of Borehole			



Logged By: AL/AK

Entered By: SC

Drill Date: June 7, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-74

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	
Depth (m)	Description	Sample Point (m)	ppm: 100 200 300 400; % LEL: 10 30 50 70 90	Well Completion Details

Ground Surface

0.0 – 1.0: ***Sandy Clay*** Brown

1.0 – 3.0: ***Clay*** Brown, firm, slightly sandy

3.0 – 8.0: @ 6.1m, becomes gray; Gray, soft, interbedded sand and clay layers

8.0 – 9.0: ***Sand*** Moist, coarse grained, poorly sorted, subangular

9.0 – 11.0: ***Clay*** Gray, firm, slightly sandy

11.0 – 15.0: ***Sand*** Wet, coarse grained, well sorted, subangualr, produced water

15.0 – 22.0: ***Clay*** Gray, firm, slightly sandy; @ 16.9m, becomes very soft

22.0 – 23.0: ***Sandy Clay Till*** Gray, soft

Bentonite

Logged By: AL/AK

Entered By: SC

Drill Date: June 4, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-74

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	

30.0
31.0
32.0
33.0
34.0
35.0
36.0
37.0
38.0
39.0
40.0
41.0
42.0
43.0
44.0
45.0
46.0
47.0
48.0
49.0
50.0
51.0
52.0
53.0
54.0
55.0
56.0
57.0
58.0
59.0

Bentonite

53.0 ***Gravel***
Poor to moderate sorted, subangular

55.0 ***Sandy Clay Till***
Gray, soft

Logged By: AL/AK

Entered By: SC

Drill Date: June 4, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-74

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

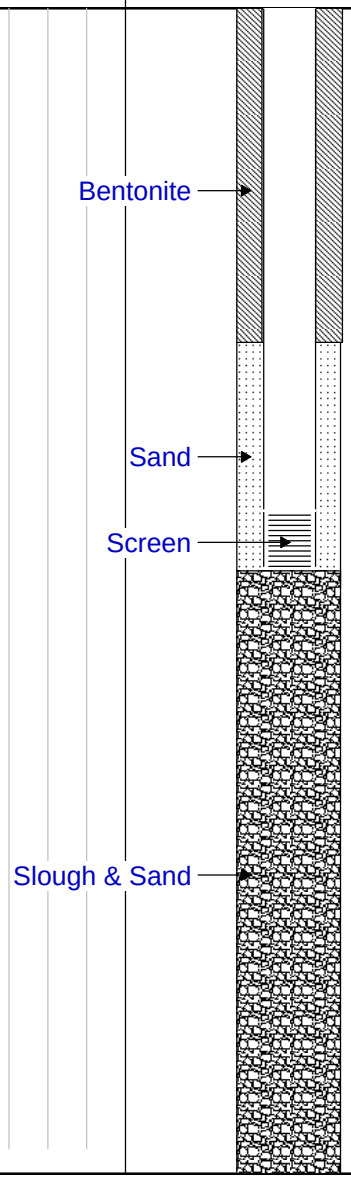
Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	

60.0
61.0
62.0
63.0
64.0
65.0
66.0
67.0
68.0
69.0
70.0
71.0
72.0
73.0
74.0
75.0
76.0
77.0
78.0
79.0
80.0
81.0
82.0
83.0
84.0
85.0
86.0
87.0
88.0
89.0

Sand
Coarse grained, dirty (some clay), poorly sorted, subangular

Sandy Clay Till
Gray

Shale
Dark gray, very plastic, (bedrock), clean, very weathered



Logged By: AL/AK

Entered By: SC

Drill Date: June 4, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-20-74

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400 % LEL: 10, 30, 50, 70, 90	

90.0
91.0
92.0
93.0 — ***Sandstone*** Very soft
94.0
95.0 — ***Shale*** Dark gray, very plastic
96.0
97.0 — End of Borehole
98.0
99.0
100.0
101.0
102.0
103.0
104.0
105.0
106.0
107.0
108.0
109.0
110.0
111.0
112.0
113.0
114.0
115.0
116.0
117.0
118.0
119.0

Slough & Sand

Logged By: AL/AK

Entered By: SC

Drill Date: June 4, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-21-11

Drill Method: Mud Rotary (6 1/4")

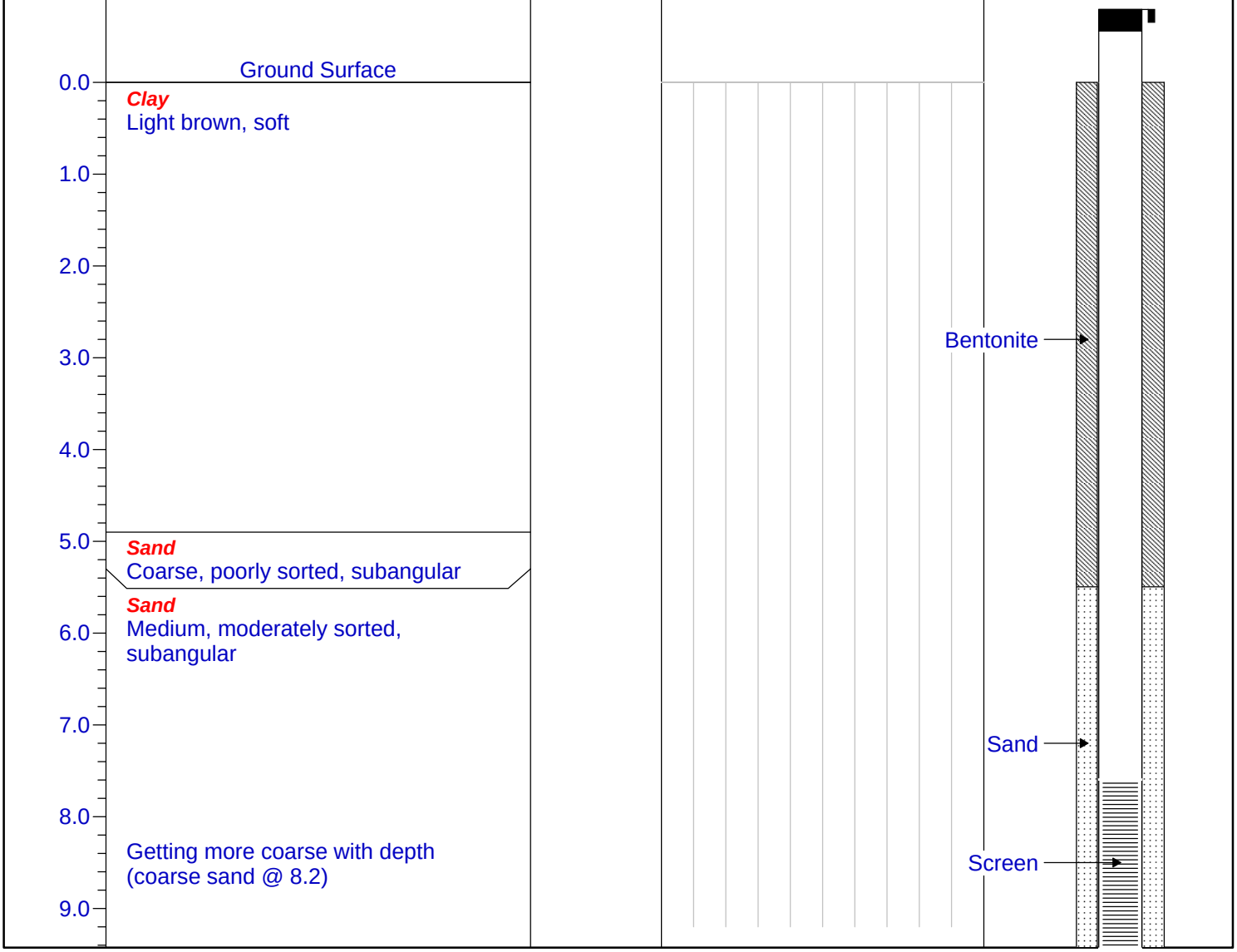
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
	Clay Light brown, soft			
1.0				
2.0				
3.0				Bentonite
4.0				
5.0	***Sand*** Coarse, poorly sorted, subangular			
	Sand Medium, moderately sorted, subangular			
6.0				
7.0				Sand
8.0	Getting more coarse with depth (coarse sand @ 8.2)			Screen
9.0				



Logged By: AL/AK

Entered By: SC

Drill Date: June 12, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-21-11

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	
10.0				Sand
11.0	Interbedded clay with medium to coarse sand stringers			
12.0	***Sandy Clay*** Dark gray, soft, some rocks Getting cleaner with depth (no rocks)			
13.0				
14.0				
15.0				Slough & Sand
16.0				
17.0				
18.0				
19.0	End of Borehole			

Logged By: AL/AK

Entered By: SC

Drill Date: June 12, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-21-54

Drill Method: Mud Rotary (6 1/4")

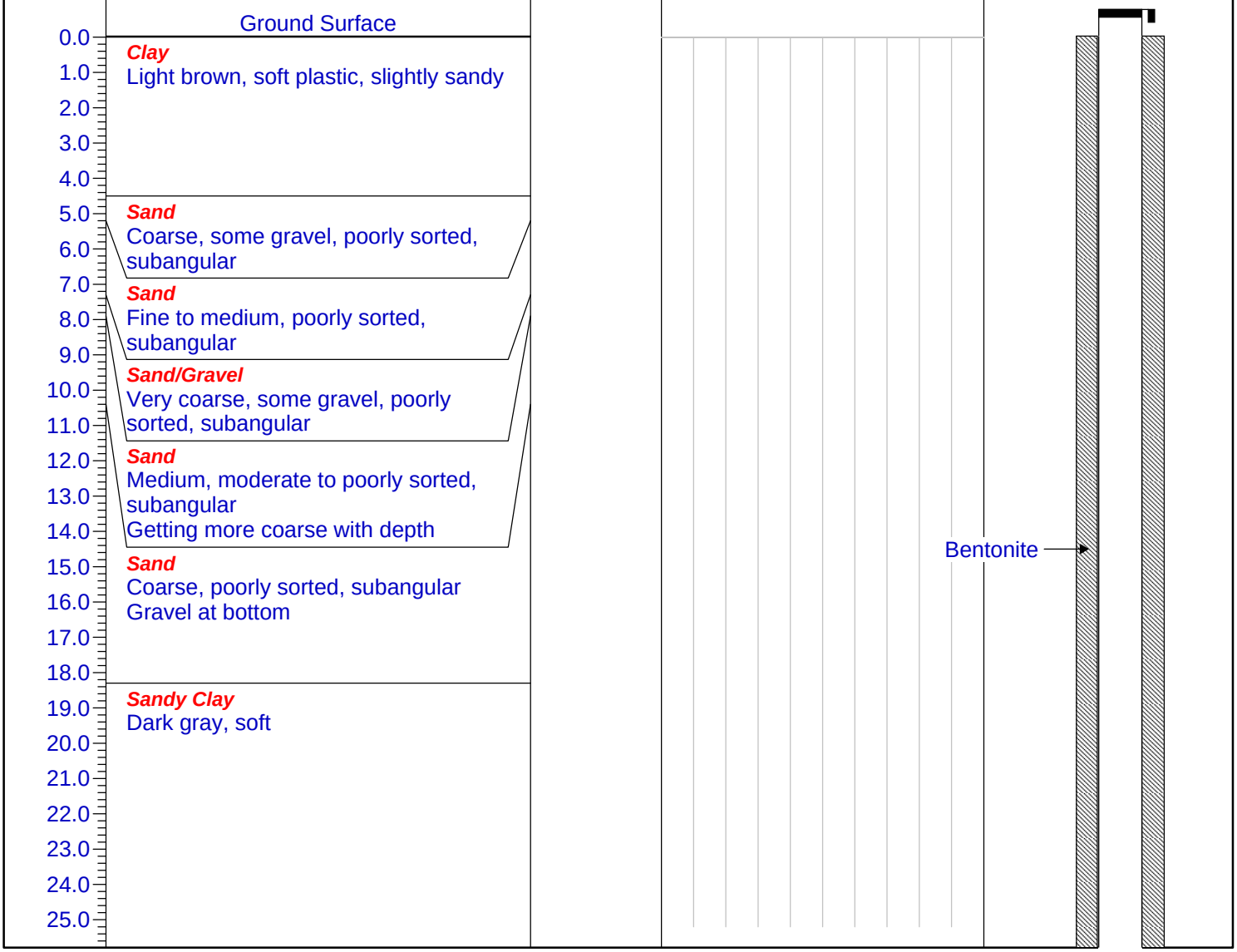
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
1.0	***Clay*** Light brown, soft plastic, slightly sandy			
5.0	***Sand*** Coarse, some gravel, poorly sorted, subangular			
7.0	***Sand*** Fine to medium, poorly sorted, subangular			
10.0	***Sand/Gravel*** Very coarse, some gravel, poorly sorted, subangular			
12.0	***Sand*** Medium, moderate to poorly sorted, subangular Getting more coarse with depth			
15.0	***Sand*** Coarse, poorly sorted, subangular Gravel at bottom			Bentonite
18.0	***Sandy Clay*** Dark gray, soft			
25.0				



Logged By: AL/AK

Entered By: SC

Drill Date: June 11, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-21-54

Drill Method: Mud Rotary (6 1/4")

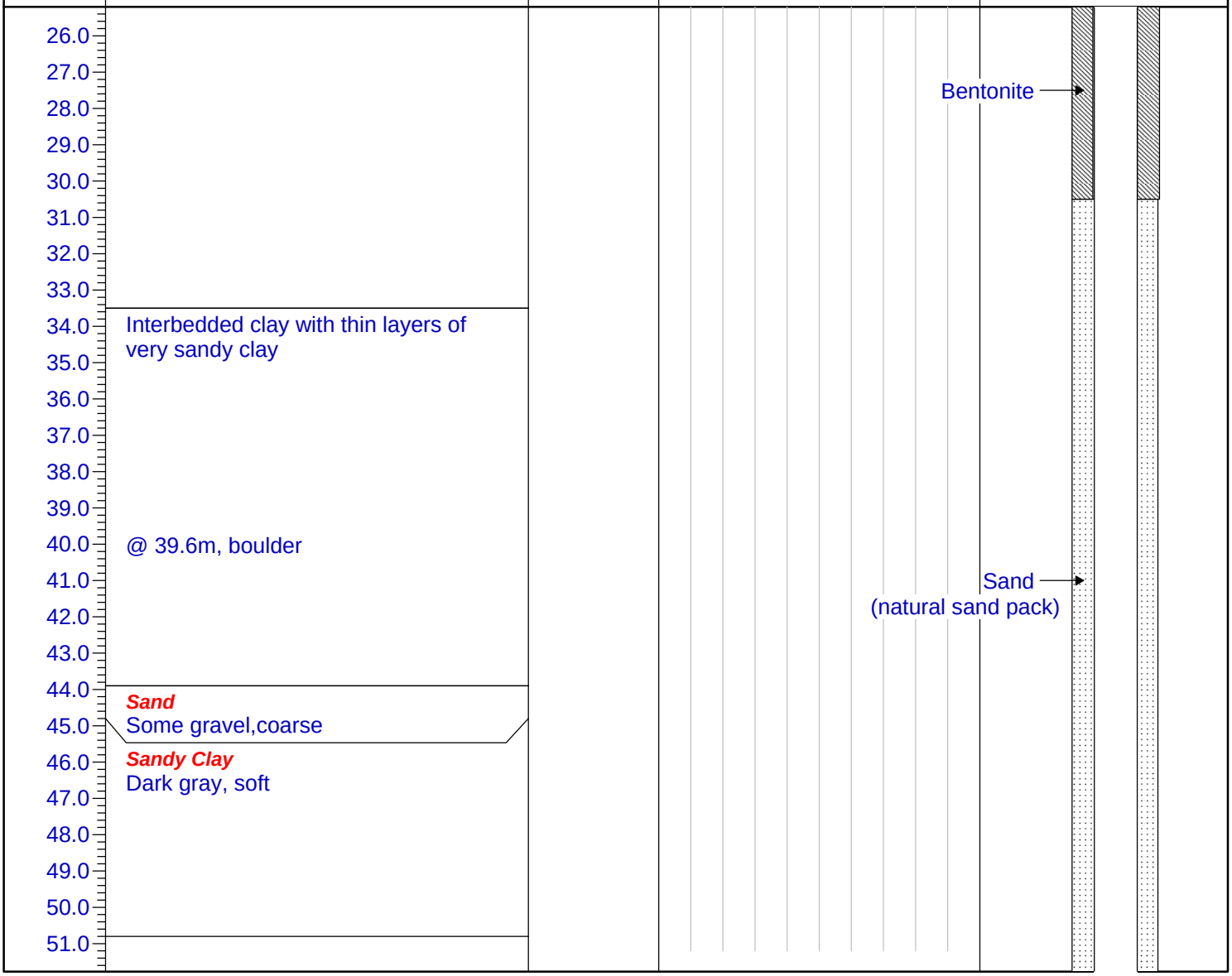
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400 % LEL: 10, 30, 50, 70, 90	



Logged By: AL/AK

Entered By: SC

Drill Date: June 11, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-21-54

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100 200 300 400; % LEL: 10 30 50 70 90	
52.0	***Sand*** Coarse, subangular, poorly sorted			Sand, Screen
53.0				
54.0	***Gravel*** Some rocks, well sorted			
55.0				
56.0	***Sandy Clay*** No return			
57.0	End of Borehole			
58.0				
59.0				
60.0				
61.0				
62.0				
63.0				
64.0				
65.0				
66.0				
67.0				
68.0				
69.0				
70.0				
71.0				
72.0				
73.0				
74.0				
75.0				
76.0				
77.0				

Logged By: AL/AK

Entered By: SC

Drill Date: June 11, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-22-54

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
0.0 – 3.0	***Clay*** Light brown, soft			
3.0 – 5.0	***Sand*** Medium, some gravel, moderately sorted, subangular			
5.0 – 10.0	***Sand*** Coarse, moderately sorted, subangular Getting more coarse with depth (gravel at bottom)			
10.0 – 14.0	Interbedded thin layers of clay and sand (gravel at bottom)			
14.0 – 21.0	***Clay*** Dark gray, soft, slightly sandy			Bentonite
21.0 – 29.0	***Clay*** Dark gray, soft, silty sandy			

Logged By: AL/AK

Entered By: SC

Drill Date: June 12, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-22-54

Drill Method: Mud Rotary (6 1/4")

Client: Pengrowth Corporation

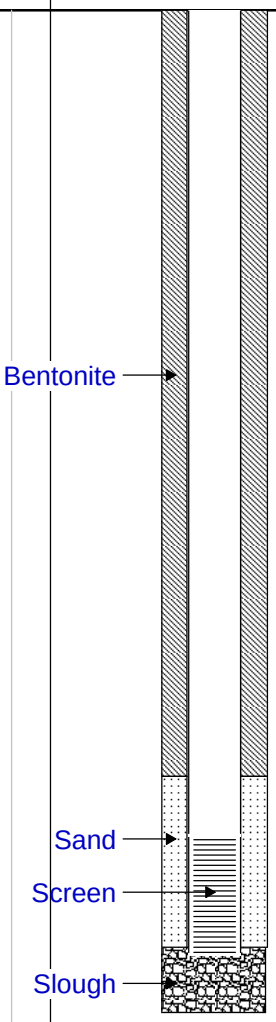
GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	

30.0
31.0
32.0
33.0
34.0 — @ 33.5m, becomes sandier
35.0
36.0
37.0
38.0
39.0 — @ 38.1m, very sandy clay
40.0
41.0
42.0
43.0
44.0
45.0
46.0
47.0 — Interbedded very thin layers of clay and sand
48.0
49.0
50.0
51.0 — ***Sand*** Medium, moderately sorted, subangular
52.0
53.0
54.0 — ***Sand*** Coarse, moderately sorted, subangular
55.0
56.0 — Interbedded thin layers of clay and sand
57.0
58.0
59.0 — End of Borehole



Logged By: AL/AK

Entered By: SC

Drill Date: June 12, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131GW

Borehole No: MW11-22-9

Drill Method: Mud Rotary (6 1/4")

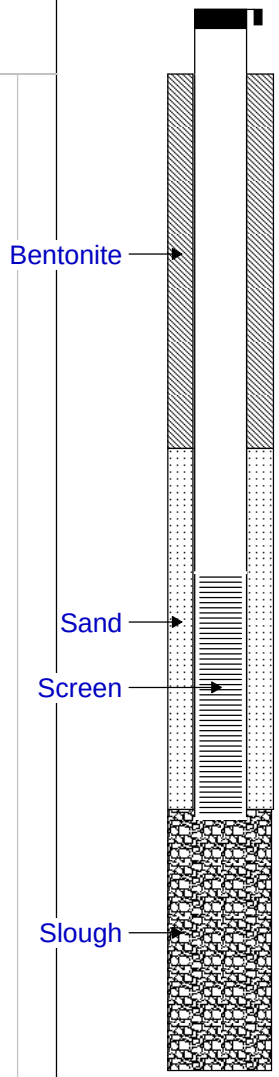
Client: Pengrowth Corporation

GPS Location:

APEC:

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
	Clay Light brown, soft			
3.0	***Sand*** Medium, well sorted, subangular			
6.0	***Clay*** Dark gray, soft			
7.0	***Sand*** Coarse, some cobbles/rocks			
9.0	***Sandy Clay*** Dark gray, soft			
12.0	End of Borehole			



Logged By: AL/AK

Entered By: SC

Drill Date: June 12, 2011

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-01

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Truck Load-out

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400 / % LEL: 10, 30, 50, 70, 90	Well Completion Details
0.0	Ground Surface			
	Medium Sand/Gravel 15% coarse fragments, brown, moist, loose, pad material	0.3	0	
	Disturbed Clay 5% coarse fragments, brown/gray, moist, very firm, disturbed pad material, few inclusions, some gleying	0.7	20	
1.0		1.6	220	
	Silty Clay Till 5-10% coarse fragments, brown/gray, dry-moist, firm, laminated till, carbonates, common, some rust, pebble clasts	2.2	0	
2.0				
	Clay 15% coarse fragments, light brown, moist, soft, blocky clay, uniform, some gleying, carbonates, rust common	3.1	0	Bentonite
3.0		3.8	0	
4.0		4.4	0	
5.0		5.2	0	
		5.9		

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-01

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Truck Load-out

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	
6.0	Wet @ 6.0m	5.9	0	
	Clayey, Sandy Gravel 30% coarse fragments, brown/white/gray, wet, loose/firm, poorly sorted, sandy gravel, ~15% clay, rounded clasts	7.0	5	Slough, Screen
7.0		7.6	15	
	Organic Soil Layer Black, wet, moderately firm, buried organics			
8.0	***Clayey Sand*** 5-10% coarse fragments, light brown/gray, wet, soft/loose, medium clayey sand, gleyed, rusted			
9.0	End of Borehole			
10.0				
11.0				
12.0				

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-02

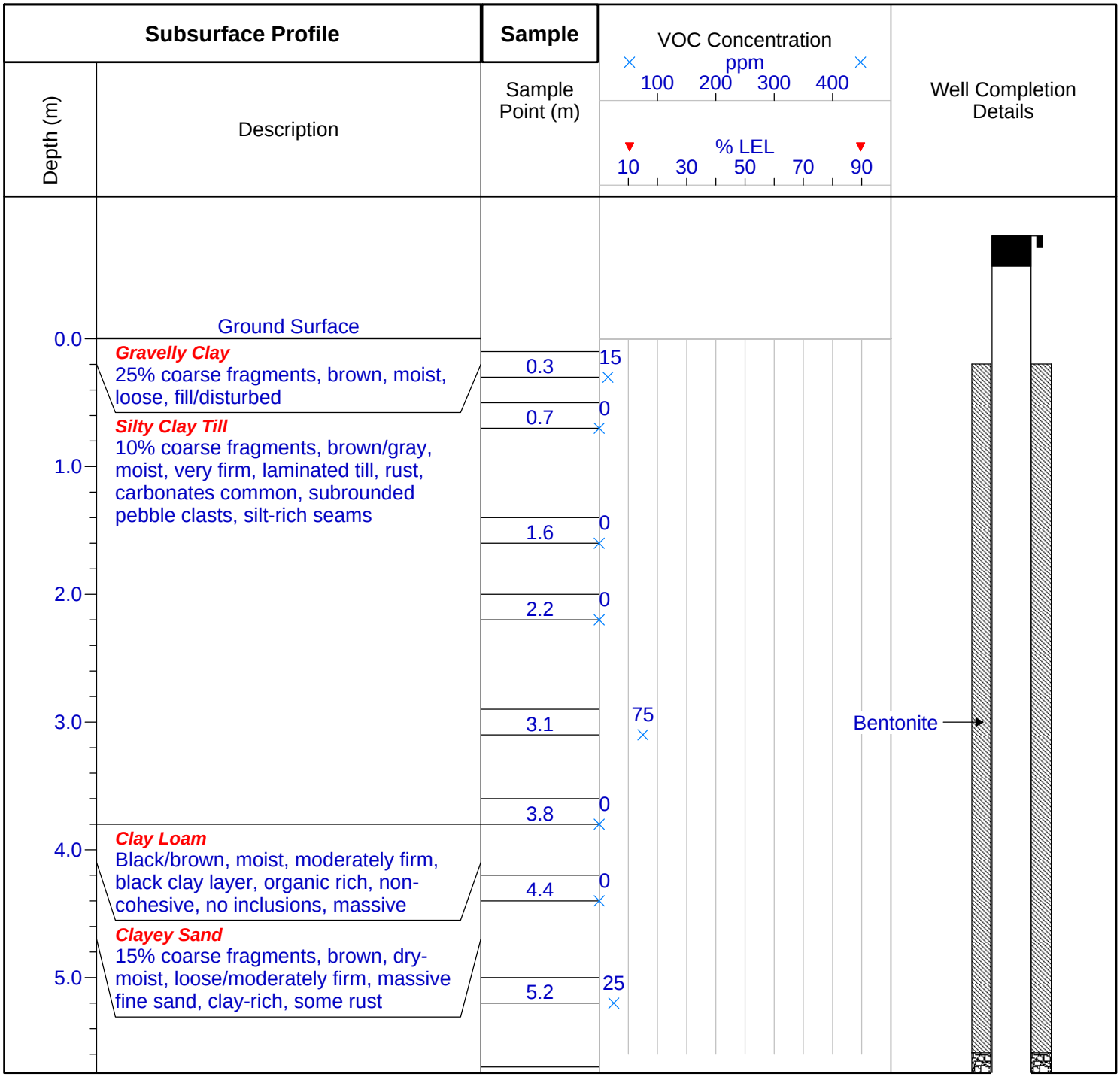
Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Tank Farm

Millennium EMS Solutions Ltd.



Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-02

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Tank Farm

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration	Well Completion Details
Depth (m)	Description	Sample Point (m)	ppm: 100, 200, 300, 400; % LEL: 10, 30, 50, 70, 90	
6.0	***Medium Sand*** <5% coarse fragments, gray/brown, moist-wet, loose/soft, non-cohesive medium sand, subangular grains	5.9	60	
7.0		7.0	0	Slough, Screen
	End of Borehole			
8.0				
9.0				
10.0				
11.0				
12.0				

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-03

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Down Gradient Trees

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
	Clay Till 10% coarse fragments, brown, dry-moist, stiff/firm, laminated till, carbonates common, rust streaks common with depth, softer/wetter with depth	0.3	20	
		0.7	0	
1.0		1.6	90	
2.0		2.2	0	
3.0		3.1	0	Bentonite
		3.8	60	
4.0		4.4	0	
5.0		5.2	45	

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-03

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: Down Gradient Trees

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
6.0	***Clayey Sand*** 15% coarse fragments, brown, wet, loose/soft, medium grained sand, pebble clasts, ~25% clay, non-cohesive, lower clay content with depth	5.9	0	
7.0	***Clayey Sand*** <5% coarse fragments, light gray, wet, soft, fine grained sand, gleyed, rust staining common, saturated	7.0	510	Slough; Screen
	End of Borehole			
8.0				
9.0				
10.0				
11.0				
12.0				

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-04

Drill Method: Solid Stem Auger

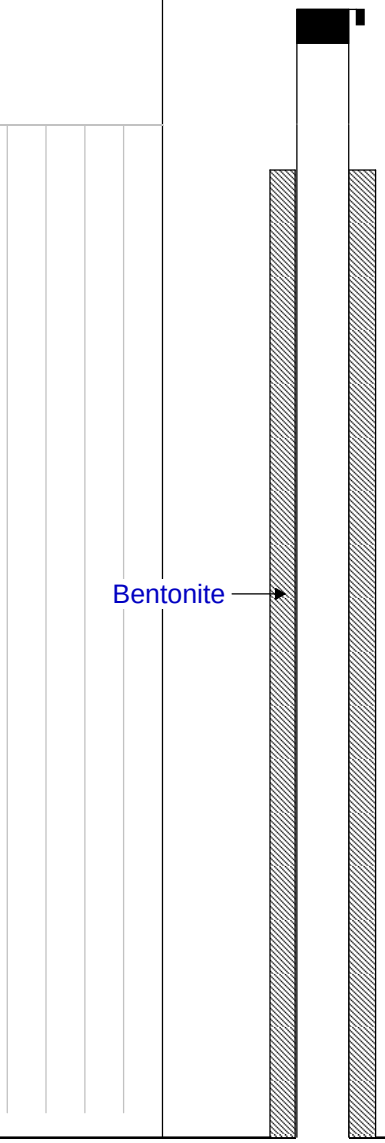
Client: Pengrowth

GPS Location:

APEC: ECO Pit

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
0.0	Ground Surface			
	Silty Clay Till 10-15% coarse fragments, brown, moist, firm/stiff, laminated till, subrounded pebble clasts, discontinuous sand pocket, minor rust staining, increasing clasts with depths	0.3	0	
		0.15	5	
		0.7	5	
1.0		1.6	35	
2.0		2.2	60	
3.0		3.1	20	Bentonite
		3.8	30	
4.0		4.4	0	
5.0		5.2	0	
	Silty Clay Till (Con't)	5.9	0	
6.0				



Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project No: 10-131A

Borehole No: MW12-04

Drill Method: Solid Stem Auger

Client: Pengrowth

GPS Location:

APEC: ECO Pit

Millennium EMS Solutions Ltd.

Subsurface Profile		Sample	VOC Concentration ppm (100, 200, 300, 400) / % LEL (10, 30, 50, 70, 90)	Well Completion Details
Depth (m)	Description	Sample Point (m)		
7.0		6.75	10	
		7.5	0	
8.0	Gleyed @ 8.0m	8.0	40	
				Bentonite
9.0		9.0	25	
10.0	***Clay*** <5% coarse fragments, light brown, moist-wet, firm, rust staining, blocky clay, mottling	10.0		
11.0	***Clayey Sand*** 15% coarse fragments, light brown, wet, soft/loose, gravel common, unconsolidated, poorly sorted, fine sand	11.0	100	
12.0	***Medium Sand*** 5% coarse fragments, light gray/pink/brown, moist, loose/soft, unconsolidated, well sorted, uniform, some rust staining	12.0	10	Sand
				Screen
13.0		13.0	260	Slough
	End of Borehole			

Logged By: CM

Entered By: SC

Drill Date: June 12, 2012

Millennium EMS Solutions Ltd.
#208, 4207- 98 Street
Edmonton, AB T6E 5R7

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

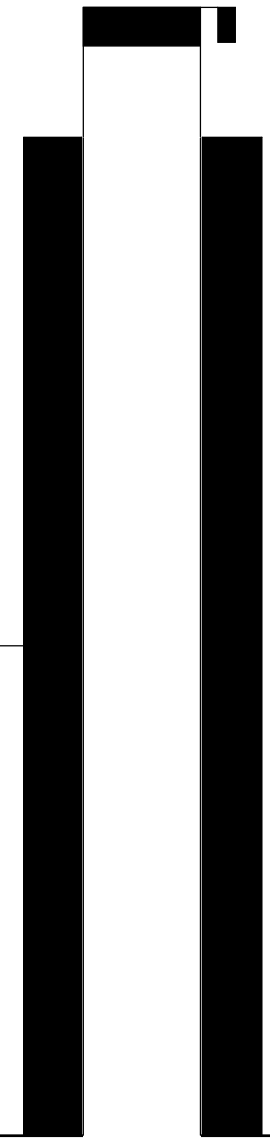
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	CLAY/SILT Light brown, medium, slightly humid, trace to some sand and gravel, some roots trace oxides, fg to mg gravel (Q) c++ light grey pockets	
1.0		
	PEAT	
2.0		
	CLAY Olive grey to grey, soft, plastic, humid to moist, clean, increasing gravel content with depth	
3.0	At 3m, light brown streaks	
	At 3.3m, dark grey, medium, humid, fg to mg gravel <sA>, some very small ironstone chunks c++, light grey streaks	Grout
4.0	At 3.7m, brown, moist, mg sand pockets, few orange oxides	
5.0		
6.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
7.0	***CLAY (Con't)***	
8.0	***SAND*** All colors, moist, some silt and clay, mg to cg sand At 8.5m, clay seam (2cm) At 8.8m, gravelly and clayey, all colors, humid to moist, mg to cg sand <sA>	
9.0		
10.0	***CLAY*** Dark brown turning grey, medium to stiff, trace to some gravel, clay becoming cleaner with depth	
	gravelly and silty SAND Brown, wet, fg poorly sorted sand	
11.0	***CLAY*** Brown, medium, humid, sandy coming silty with depth At 10.7m, grey, medium, some fg to mg gravel <sA>	Grout
12.0		
13.0		
14.0	***sandy and gravelly CLAY/SILT*** Soft, fg gravel<A to R>(S), fg sand	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
15.0	***very silty/clayey SAND*** Grey, loose, mg cobbles, moderately sorted fg sand At 14.5m, increasing with depth, some fg to cg gravel <sR to sA>	
	very sandy SILT Grey, soft, wet, some fg to cg gravel <sA-sR>, fg sand, no c+	
16.0	***SAND*** Grey, loose, wet, poorly sorted mg sand	
	SILT Grey, soft, wet, some fg to mg gravel, no c+ At 16.6m, gravelly and very sandy, all colors, fg to cg gravel (S+Q)<sR-sA>, mg sand Between 17.1m and 18.3m, decreasing gravel and sand content	
17.0		
18.0		Grout
19.0		
20.0		
	CLAY Grey, medium, moist, fg to cg gravel <sA-sR>	
21.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
22.0	***CLAY (Con't)***	
23.0	***SAND*** All colors, wet, well sorted cg sand, cg gravel layer at bottom	
	sandy CLAY Grey, stiff, moist, some fg to mg gravel <sA-sR>(S), c+ white specks	
24.0		
25.0		
26.0		Grout
27.0		
28.0	At 28m, fg sand seam, few orange oxides	
29.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

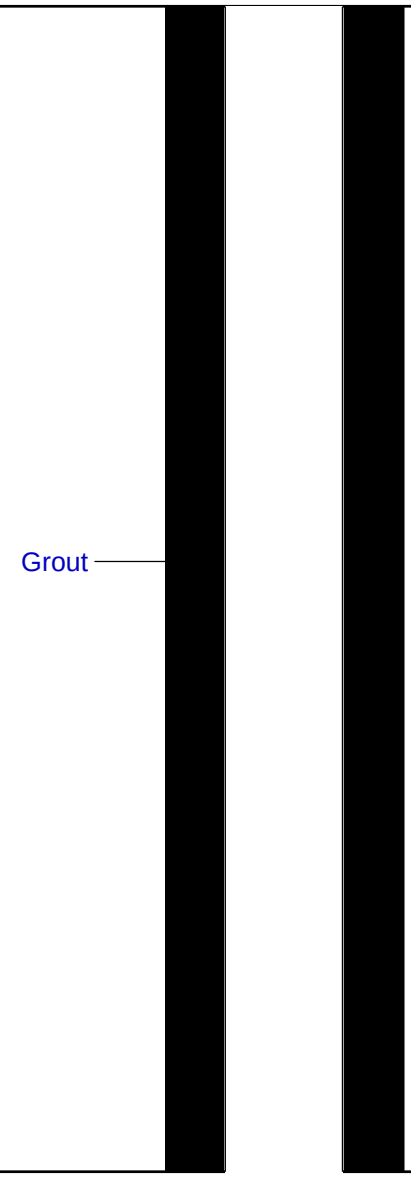
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
30.0	***sandy CLAY (Con't)***	
31.0	***CLAY/SAND*** Grey, soft, wet, cg sand	
32.0		
33.0	***sandy CLAY*** Grey, stiff, humid, c+/- matrix, c++ white specks	Grout
34.0		
35.0		
36.0		
37.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	Between 37.2m and 45.1m, multiple wet mg sand pockets throughout	
38.0		
39.0		
40.0		
	gravelly CLAY Gravel <sR-sA>, fg to cg sand c++ white soft oxides	
41.0		Grout
42.0		
43.0		
44.0		
	Between 44.2m and 53.3m, NO RETURN (most likely gravelly clay)	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
45.0	***gravelly CLAY (Con't)***	
46.0		
47.0		
48.0		Grout
49.0		
50.0		
51.0		
52.0	***gravelly CLAY (Con't)***	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
53.0		
	gravelly CLAY Dark grey, stiff, humid, fg to cg gravel (S)<sA-sR>, no c+	
54.0		
55.0		
56.0		Grout
57.0		
	Between 57.3m and 62.5m, few sand pockets, seams throughout, c+ carbonate chunks	
58.0		
59.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
60.0	***gravelly CLAY (Con't)***	
61.0		
62.0		
	At 62.5m, cobbles (S)	Grout
63.0		
64.0	***SAND and GRAVEL*** All colors, mg to cg gravel (S)<sR>	
65.0	***GRAVEL*** All colors, wet, fg to cg gravel, some cg sand gravel coarsening downwards	
66.0	***SAND and GRAVEL*** All colors, wet, cg sand to mg gravel	
	GRAVEL All colors, wet, gravel <sA-sR>, fg to cg cobble at bottom coarsening with depth	
67.0	***SAND and GRAVEL*** Wet, gravel (S+Q)<sA-sR>, cg sand to cg gravel getting siltier with depth	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

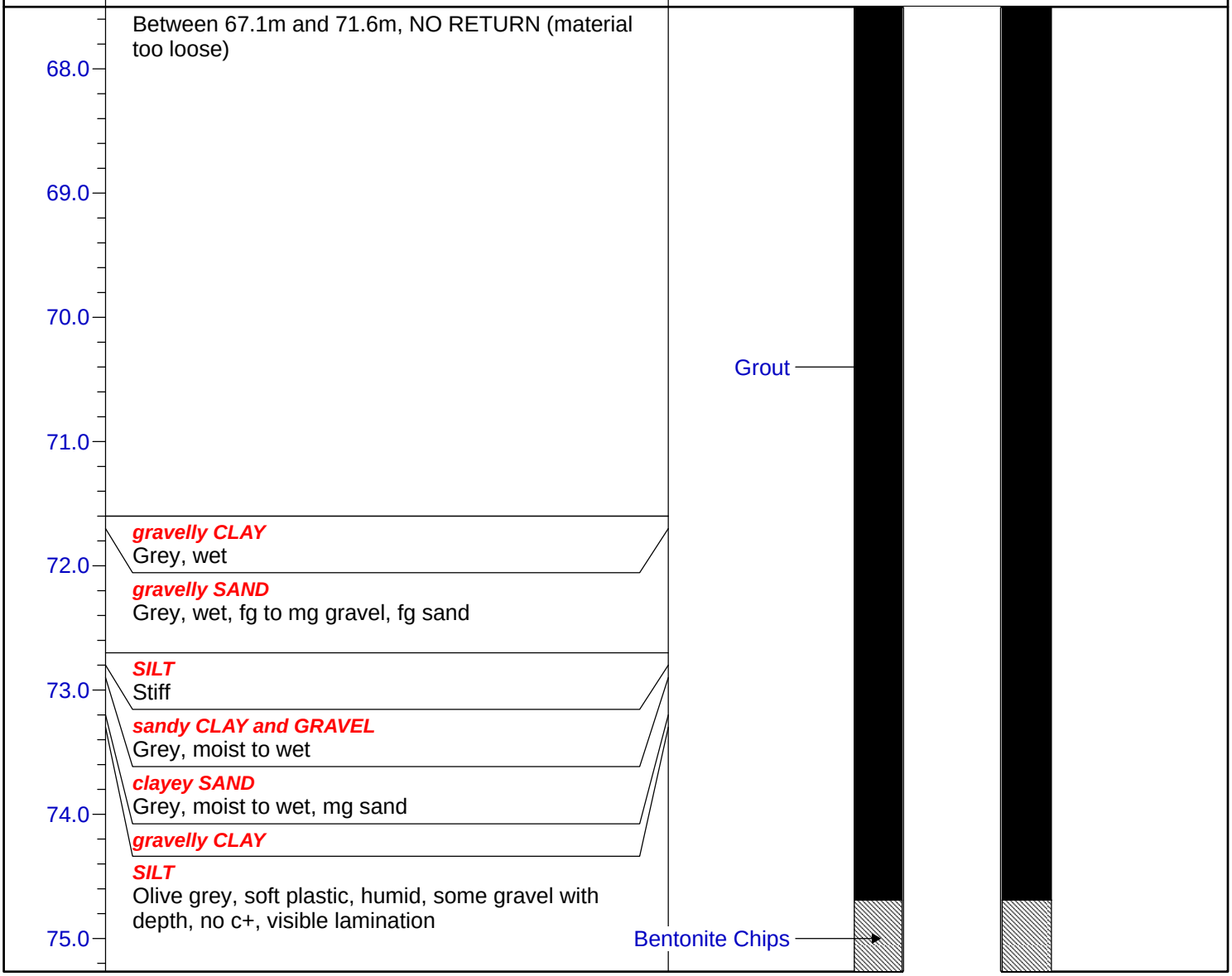
Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

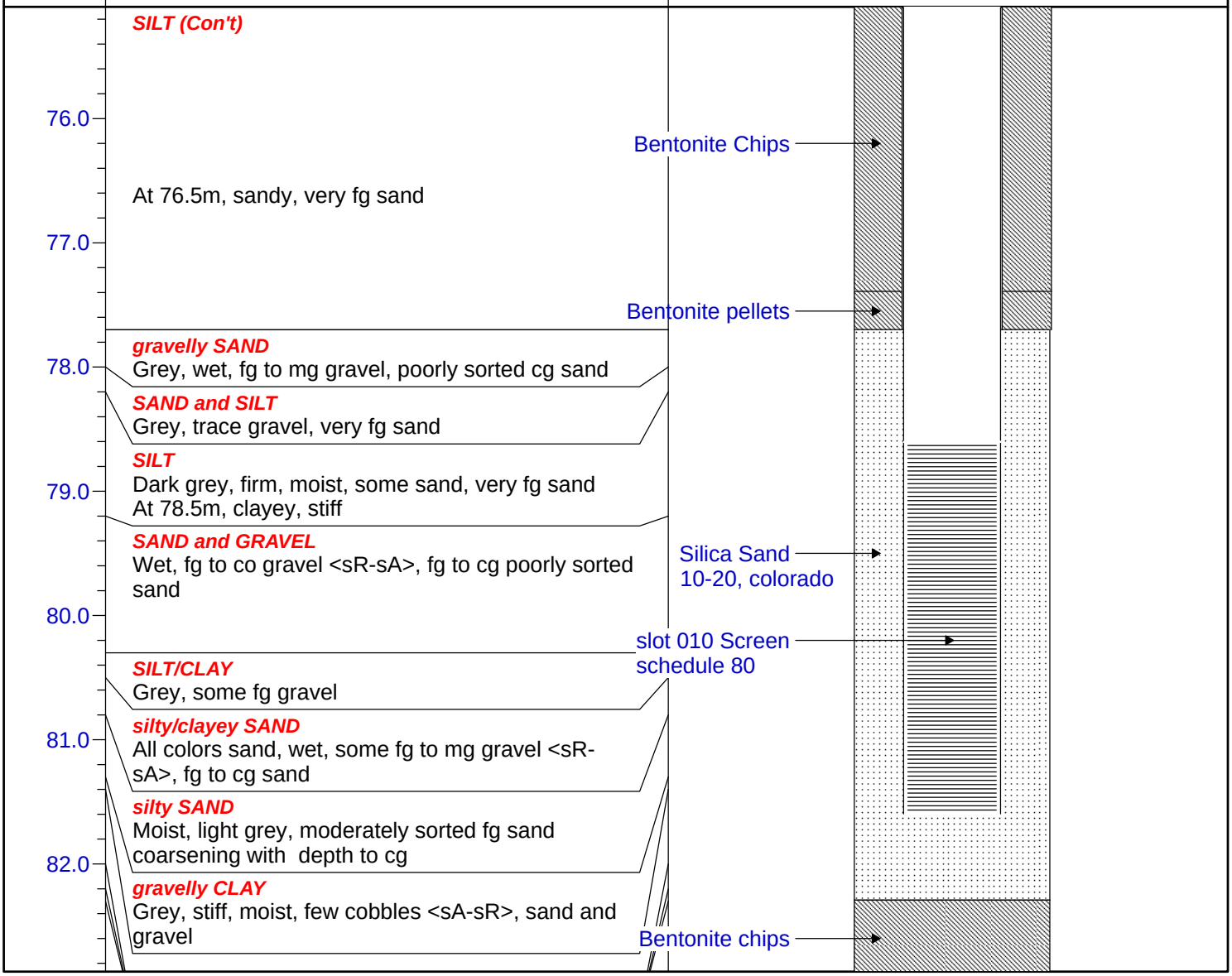
Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
83.0	***gravelly SILT and SAND*** Loose plastic, wet, fg to mg gravel, fg to cg sand	
	gravelly CLAY Dark grey, stiff, moist, fg to mg gravel	
	gravelly SAND fg to mg gravel (S)<sA-sR>, poorly sorted mg sand	
84.0	***gravelly SILT and SAND*** Moist to wet, fg to mg gravel (S), very fg sand	
	gravelly SAND Grey, loose, wet, fg to mg gravel (S)<sR-sA>, mg sand	
85.0	***gravelly/sandy SILT*** Grey, soft to medium, mg to cg gravel <sR-sA>, very fg sand	
	gravelly SAND All colors, loose, wet, fg to mg gravel (S)<sA>	Bentonite chips →
86.0	***SILT*** Grey, soft to firm, moist	
	gravelly and clayey SAND Grey, loose, wet, fg to mg gravel <sA>, cg sand	
87.0	***gravelly SILT/CLAY*** Dark grey, very stiff, humid, fg to cg gravel <sA-sR>, few cobbles (S) iron concretions	
	At 84.3m, sand seam	
88.0	At 85m, light grey, silt pocket	
89.0		
90.0	***gravelly SILT/CLAY (Con't)***	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
91.0		
92.0		
93.0	***silty CLAY*** Dark grey, stiff	
94.0	At 94.2m, trace gravel At 94.5m, gravelly, dark brown/grey, very stiff, gravel <sA-sR>, orange oxides, white specks At 94.8m, dark grey, very stiff, trace fg gravel, c+ white specks	Bentonite chips →
95.0		
96.0	***SHALE*** Dark grey, very stiff, c++ white shell pieces few iron concretions	
97.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-82

Client: Pengrowth Corporation

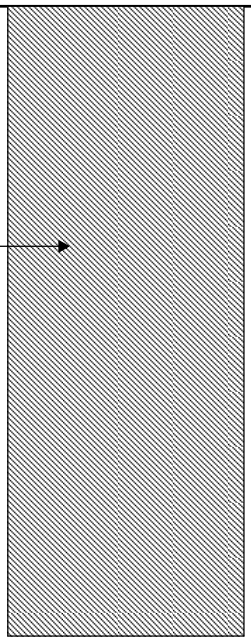
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
98.0	***SHALE (Con't)***	
99.0	At 99m, hard, fractured	Bentonite chips →
100.0		
101.0		
102.0	End of Borehole	
103.0		
104.0		
105.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

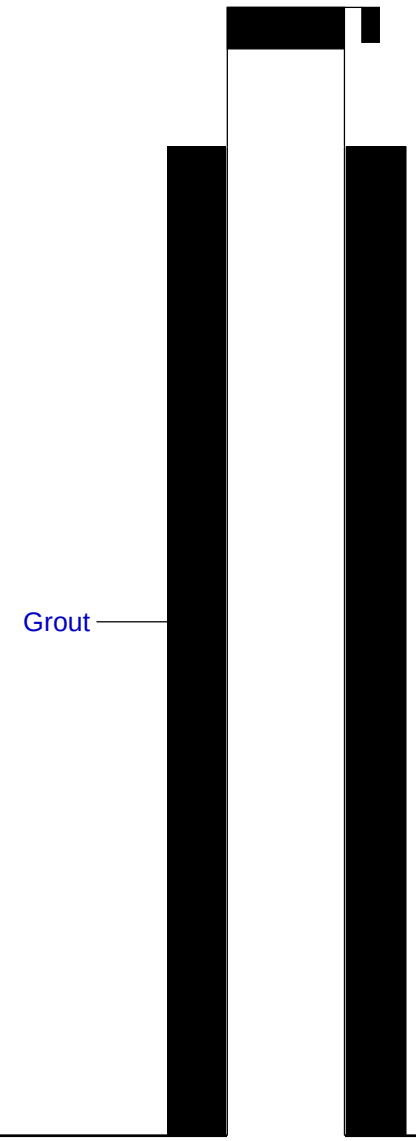
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	Ground Surface	
0.0	***CLAY/SILT*** Light brown, medium, slightly humid, trace to some sand and gravel, some roots trace oxides, fg to mg gravel (Q), c++ light grey pockets	
1.0		
	PEAT Brown/black, very organic	
2.0	***CLAY*** Olive grey to grey, soft plastic, humid to moist, clean increasing gravel content with depth	
3.0	At 3m, light brown streaks	Grout
	At 3.3m, dark grey, medium, humid, fg to mg gravel <sA>, some very small ironstone chunks c++ light grey streaks	
4.0		
5.0		
6.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
7.0	***CLAY (Con't)***	
8.0	***SAND*** All colors, moist, some silt & clay, mg to cg sand At 8.5m, 5cm clay layer At 8.8m, gravelly & clayey, all colors, humid to moist, mg to cg sand <sA> Between 8.8m to 9.5m, interbedded gravelly sand with sand/clay layer, some cobbles	
9.0	***CLAY*** Dark brown turning grey, medium to stiff, trace to some gravel, clay becoming cleaner with depth	
10.0		Grout
11.0	***SAND*** Light grey, moist, some silt, moderately sorted mg sand	
12.0	***sandy CLAY*** Dark brown, medium to stiff, humid, trace gravel rare cobble Between 12.2m to 64m, some gravel and cobbles (S) throughout, sand pockets/lenses throughout, c+/- in matrix to c++ in grey streaks when present	
13.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
14.0		
15.0		
16.0		
17.0		Grout
18.0		
19.0		
20.0		

Logged By: AcK/Jchan
Entered By: SC
Drill Date: June 2013

Driller: Major Drilling
Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
21.0		
22.0		
23.0		Grout
24.0		
25.0		
26.0		
27.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
28.0		
29.0		
30.0		Grout
31.0		
32.0		
33.0		
34.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
35.0		
36.0		
37.0		Grout
38.0		
39.0		
40.0		
41.0		

Logged By: AcK/Jchan
Entered By: SC
Drill Date: June 2013

Driller: Major Drilling
Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
42.0	***sandy CLAY (Con't)***	
43.0		
44.0		Grout
45.0		
46.0		
47.0		
48.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
49.0	***sandy CLAY (Con't)***	
50.0		
51.0		Grout
52.0		
53.0		
54.0		
55.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
56.0	***sandy CLAY (Con't)***	
57.0		
58.0		Grout
59.0		
60.0		
61.0		
62.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
63.0		
64.0	***SAND and GRAVEL*** Brown with all color sand & gravel, wet, some mg gravel <sR-sA>, cg sand	
65.0	***GRAVEL*** All colors, wet, fg to cg gravel, some cg sand, gravel coarsening downwards At 65.2m, all colors, mg to cg gravel (S)<sR> At 65.5m, all colors, wet, gravel (S+Q)<sA-sR>, fg to mg sand, fg gravel <A>	Grout
66.0	***SAND*** Brown & all colors, wet, trace gravel, well sorted mg sand no c+	
67.0	At 67.4m, trace iron stones (<1mm), iron staining	
68.0	At 68m, light brown silt, some fg gravel <sA-sR>, trace silt and clay	
69.0	***sandy CLAY*** Dark grey, very stiff, humid, trace fg gravel<R-sR> (white), no c+	

Logged By: AcK/Jchan
Driller: Major Drilling

Entered By: SC
Drill Method: Sonic

Drill Date: June 2013

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sand CLAY (Con't)	
70.0		
	At 70.7m, all colors, trace to some fg to cg gravel (S)	
71.0		
	clayey/silty SAND Dark grey, moist, fg sand at top increasing coarseness with depth	
72.0	***sandy SILT*** Dark grey, soft plastic, moist, fg sand, trace cg sand	Grout
	clayey/silty SAND Moist, fg to cg sand mixed with gravel	
73.0	***sandy SILT*** Dark grey, medium soft plastic, moist, some cg gravel, fg sand, yellow & orange oxides	
74.0	At 73.2m, gravelly SILT, dark grey, medium plastic, fg to mg sand pockets trace ironstones	
	At 73.3m, fg sand seam (15 cm) with mg to cg gravel; wet	
75.0		
76.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	At 75.9m, becomes cleaner, trace fg gravel & sand, humid, c+/- matrix	
77.0	***SILT and SAND*** Dark grey, soft to medium plastic, humid, trace gravel, fg sand	
78.0	***silty SAND*** Light grey, wet, very fg sand, fg sand at bottom	
	sandy SILT Light grey, moist, very fg sand	
79.0	***CLAY*** Grey, humid, trace to some silt	
	SILT and SAND Wet, very fg sand, alternating more sandy & more silty layers	Grout
80.0	***SAND*** Grey/brown all color sand, wet, trace silt, sand coarsening with depth, mg sand with fg to mg gravel	
81.0	***sandy GRAVEL*** Grey, wet, fg to mg gravel (S+Q)<sA-sR>, mg to cg sand	
	silty SAND Grey, moist, fg to mg sand	
82.0	***sandy and silty GRAVEL*** Grey, moist, mg gravel (S)<sR-sA>, cg sand	
	SILT/CLAY Grey, humid	
	sandy and silty GRAVEL Grey, humid, mg to cg gravel (S)<A>	
83.0	At 81.1m, very clayey, stiff	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

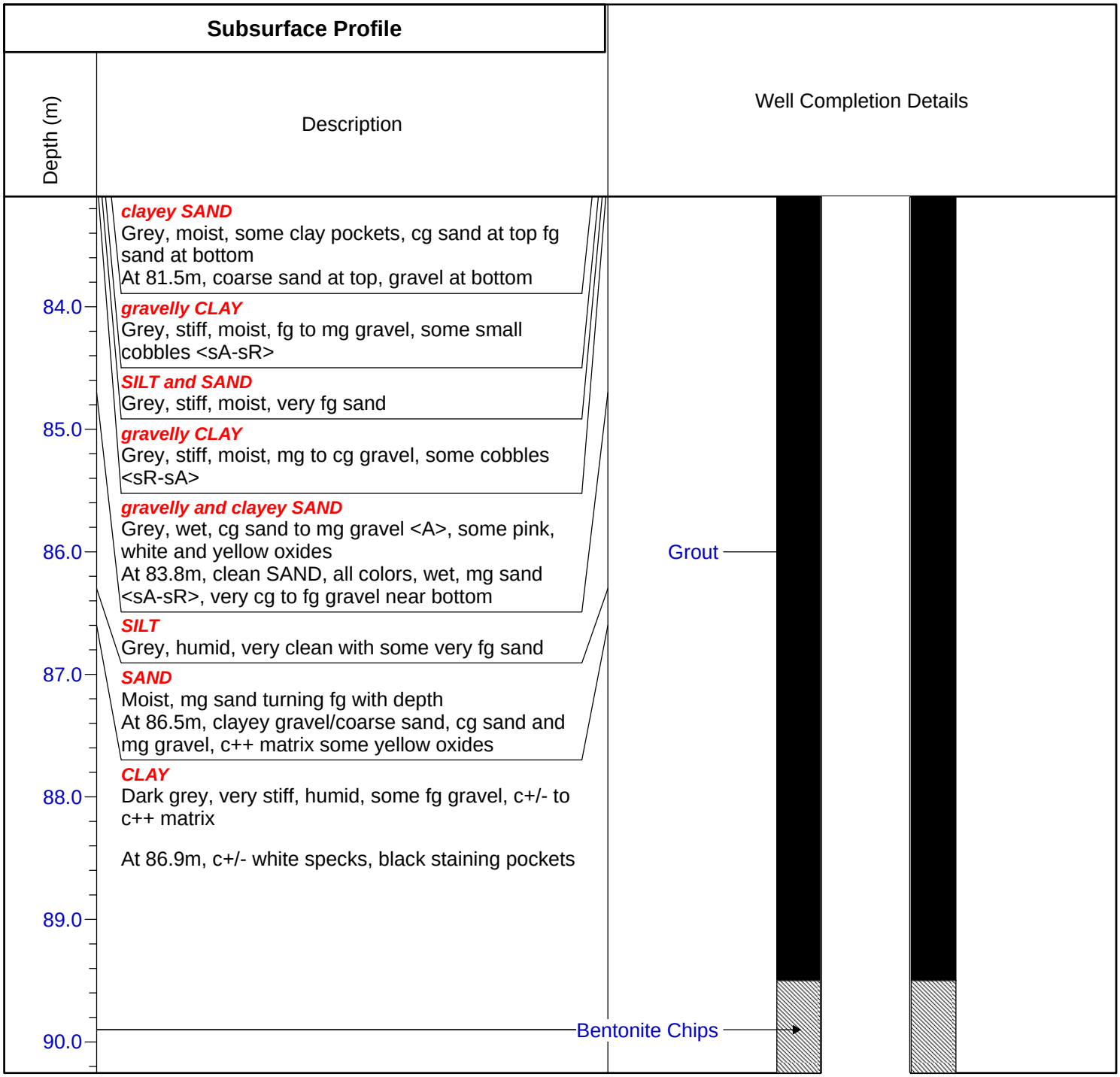
Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-19-96

Client: Pengrowth Corporation

GPS Location:

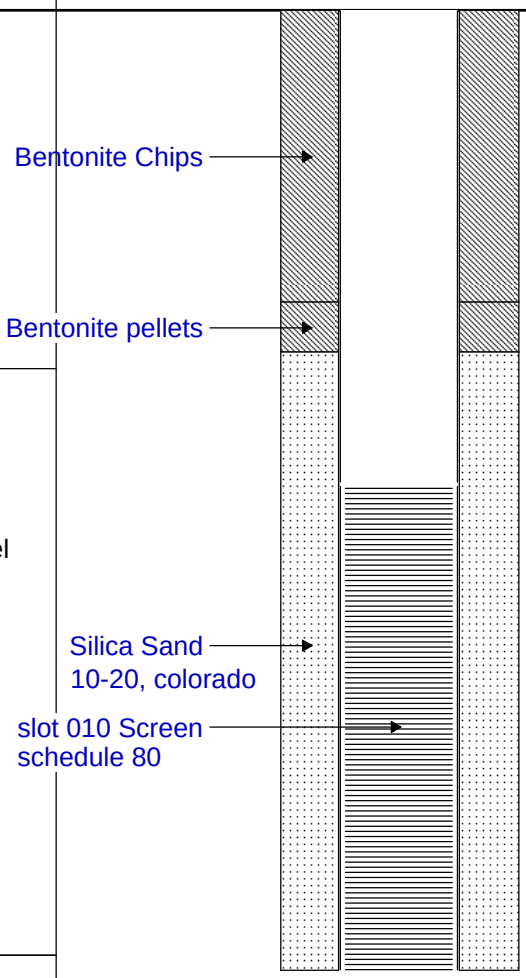
Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description
91.0	***SILT/CLAY*** Dark grey, very stiff, humid, some very fg gravel
92.0	***SHALE*** dark grey, very stiff, humid, no c+
93.0	At 93m, dark grey, stiff, very fg grey stringers
	At 93.3m, rafted till, dark brown, very stiff, fg gravel <sR-sA>, some cobbles iron (orange) concretions and white specks
94.0	At 93.6m, dark grey, very stiff, c+ shells, pieces of shell
	At 94.5m, dark grey, stiff plastic
95.0	At 95.1m, dark grey, very stiff, fractured, few orange concretions
96.0	End of Borehole
97.0	

Well Completion Details



Logged By: AcK/Jchan
Driller: Major Drilling

Entered By: SC
Drill Method: Sonic

Drill Date: June 2013

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

GPS Location:

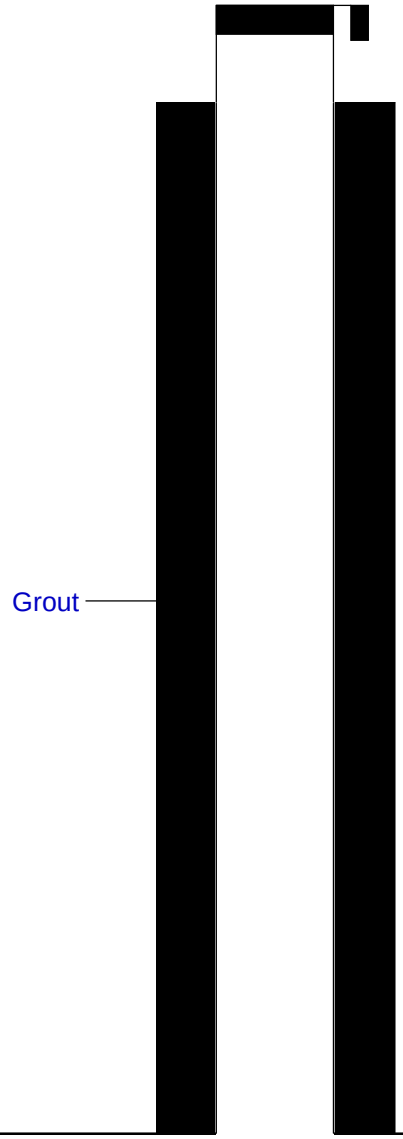
Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description
0.0	Ground Surface
	sandy CLAY Medium brown, firm/friable, dry to humid, trace gravel <sR-sA>, poorly sorted mg to cg sand, no c+ trace roots
1.0	Between 0.75m-1.3m, light grey, moist to humid, some gravel (S)<sR-sA>, trace roots & oxides, mg sand lenses @ 1.3m & 1.45m, c++
2.0	At 1.45m, brown with grey strikes
	clayey SAND Light brown, moist to humid, mg to cg sand
3.0	***SAND*** Light grey, dry, large cobble (S), some silt
	sandy CLAY Light to medium grey, firm plastuc, humid to moist, trace to some gravel (S)<sA>
4.0	At 3m, becomes dark brown
5.0	
6.0	
7.0	
8.0	At 7.6m, very stiff, grey, humid to moist, gravel & cobble <sR-sA>, no c+, trace to some silt
9.0	

Well Completion Details



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

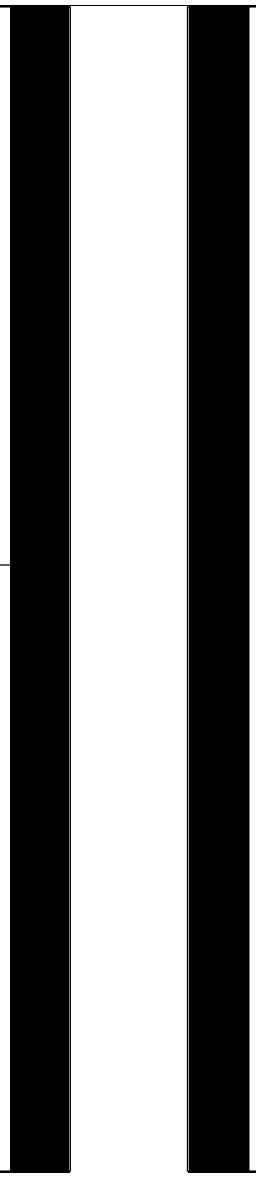
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
10.0	At 9m, some gravel medium grey, very stiff, moist, c+, trace silt	
11.0		
12.0		
13.0		
14.0		Grout
15.0		
15.0	Between 15.2m - 16.8m, c+/- throughout matrix	
16.0		
17.0	At 16.8m, fg to mg gravel <sR-A>	
18.0		
19.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
20.0	***sandy CLAY (Con't)***	
21.0		
22.0	At 21.6m, very fg, sand seam	
23.0	At 22.9m, becomes gravelly, fg to mg gravel <sA-sR>, trace cobbles (S), trace small sand pockets	
24.0		Grout
25.0	***gravelly CLAY*** Grey, all colored gravel, stiff to very stiff, humid, fg to mg gravel (S+Q) <sA-sR>, no c+ to c+/-	
26.0		
27.0		
28.0	Between 28m-28.3m, mg sand seam	
29.0	Between 29m-32m, becomes sandier with depth	

Logged By: AcK/Jchan
Driller: Major Drilling

Entered By: SC
Drill Method: Sonic

Drill Date: June 2013

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
30.0	***gravelly CLAY (Con't)***	
31.0		
32.0		
33.0		
34.0		Grout
35.0		
36.0	***SAND*** Light brown, all colors, coarser grained sand with depth (fg at top, cg at bottom) At 36.3m, light brown, all colors, medium dense, moist, trace silt, getting siltier with depth, fg to mg sand, coarser grain sand with depth (fg at top cg at bottom)	
37.0		
38.0	***gravelly CLAY*** Grey matrix, stiff to very stiff, humid, fg to mg gravel (S+Q), some cobbles (S)<sA-sR> At 38.3m, cobble (S)	
39.0	At 38.7m, sandy and gravelly, dark brown/grey, fg to mg gravel, mg sand	

Logged By: AcK/Jchan

Driller: Major Drilling

Entered By: SC

Drill Method: Sonic

Drill Date: June 2013

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
40.0	***gravelly CLAY (Con't)***	
	At 39.6m, brown, cobble (S), fg sand seam	
41.0		Grout
42.0		
43.0	***SAND and GRAVEL*** Dark brown, moist, cg sand & fg gravel <A>, interbedded with clay with cobbles(S)<A>	
	SAND Light brown, moist, trace silt & clay, mg sand coarsening downwards	
44.0	At 43.2m, alternating mg and cg sand layers with more silt at bottom, some gf gravel <sR>	
45.0	At 44.4m, silt pocket, olive brown with ion staining	Bentonite Chips
	At 45.1m, alternating mg to cg sand layers	
46.0	At 45.7m, fg sand	Bentonite pellets
47.0	Between 47.2m - 50.2m NO RETURN (very wet sand)	Silica Sand 10-20, colorado
48.0		slot 010 Screen schedule 80
49.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-50

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
50.0	***SAND (Con't)***	Silica Sand →
51.0	End of Borehole	
52.0		
53.0		
54.0		
55.0		
56.0		
57.0		
58.0		
59.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

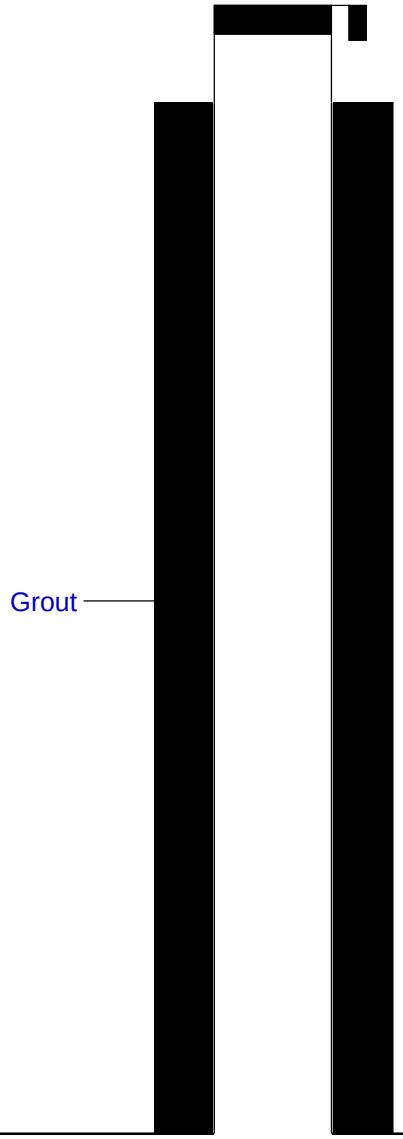
Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description
0.0	Ground Surface
	sandy CLAY Medium brown, firm/friable, dry to humid, trace gravel <sR-sA>, poorly sorted mg to cg sand, no c+ trace roots
1.0	Between 0.75m to 1.3m, light grey, moist to humid, some gravel (S)<sR-sA>, trace roots & oxides, mg sand lenses @ 1.3m & 1.45m; c++
2.0	At 1.45m, brown with grey strikes
	clayey SAND Light brown, moist to humid, mg to cg sand
3.0	***sandy CLAY*** Light to medium brown, firm plastic, humid to moist, trace to some fg gravel (S) <sA>, cg sand (increasing sand content with depth), c+/- grey streaks; iron streaks
4.0	
5.0	At 5m, grey
6.0	***NO RETURN***
7.0	
8.0	***sandy CLAY*** Grey, very stiff, humid to moist, gravel & cobble <sR-sA>, no c+, trace to some silt
9.0	

Well Completion Details



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

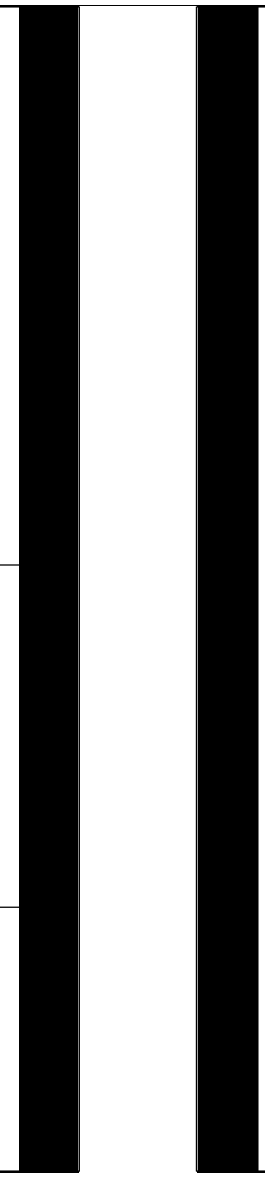
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
10.0	***sandy CLAY (Con't)***	
11.0		
12.0		
13.0		
14.0	At 13.7m, less sandy, more silty clay	Grout
15.0		
16.0		
17.0	Between 16.8m & 37.5m, few sand seams, few silt seams, some fg to cg gravel with some cobbles, few carbonates c+/-	Grout
18.0		
19.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
20.0	***sandy CLAY (Con't)***	
21.0		
22.0		
23.0		
24.0		Grout
25.0		
26.0		
27.0		
28.0		
29.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
30.0	***sandy CLAY (Con't)***	
31.0		
32.0		
33.0		
34.0		Grout
35.0		
36.0		
37.0		Grout
38.0		
39.0	At 38.4m, c++ grey streaks	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
40.0	***sandy CLAY (Con't)***	
41.0		
42.0		
43.0		
44.0	***SAND*** Light brown, loose, wet, trace cg gravel <sA>, no c+, poorly sorted fg to cg stratified sand	Grout
45.0	At 44.5m, some silt, grey - silt, wet, rare cg gravel <sR>, poorly sorted mg sand	
46.0	At 45.4m, light brown, wet, poorly sorted cg sand At 45.7m, very silty, grey - silt, wet, poorly sorted mg sand	
47.0		
48.0	***SAND and GRAVEL*** Light brown, wet, fg to cg gravel <sA-sR>, poorly sorted fg to mg sand ***SAND*** Light brown, wet, some mg gravel <sA-sR>, moderately sorted mg to cg sand	
49.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
50.0	Between 48.8m - 49.1m, silt layer, light grey, moist, no c+	
	Between 50.3m - 53.3m, NO RETURN	
51.0		
52.0		
53.0	At 53.3m, all colors, dense, moist, some silt with cg gravel layer, cg sand to gravel At 53.6m, light brown, medium dense, light brown, some fg to mg gravel <sA>	
54.0	***SAND and GRAVEL*** Light brown, loose, moist, trace boulder <sA-sR>, cg sand to mg gravel	Grout
55.0	***SAND*** Light brown, dense, fg sand At 55.2m, all colors, dense, moist, cg sand to mg gravel <sA-sR>	
56.0	At 55.5m, light brown, some cg gravel <sA-sR>, mg to cg sand	
57.0	***sandy CLAY/SILT*** Light grey with brown streaks, humid, no c+ to c+/-	
58.0		
	At 58.8m, cg sand seam	
59.0	At 59.1m, very stiff, humid, some gravel <A-sA>	

Logged By: AcK/Jchan
Driller: Major Drilling

Entered By: SC
Drill Method: Sonic

Drill Date: June 2013

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
60.0	***COBBLES*** Dark grey sand pink/grey/black cobbles, 1-10cm cobbles (S) <A-sA>, mg to cg sand	
61.0	***CLAY*** Grey, firm, plastic, humid, trace fg sand, no c+	
62.0	***SAND and CLAY*** Grey, firm, trace silt, mg sand At 61.9m, humid, some gravel <sA> At 62m, getting cleaner with depth, light grey with yellow and brown streaks	
63.0	***CLAY*** Brown, very stiff, humid, fg gravel, trace cg sand and silt c+/-	
64.0	At 64m, grey, chunks of iron stones, increasing iron staining with depth	Grout
65.0		
66.0		
67.0		
68.0	***SILT*** Light grey, humid, trace iron oxides	
69.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

GPS Location:

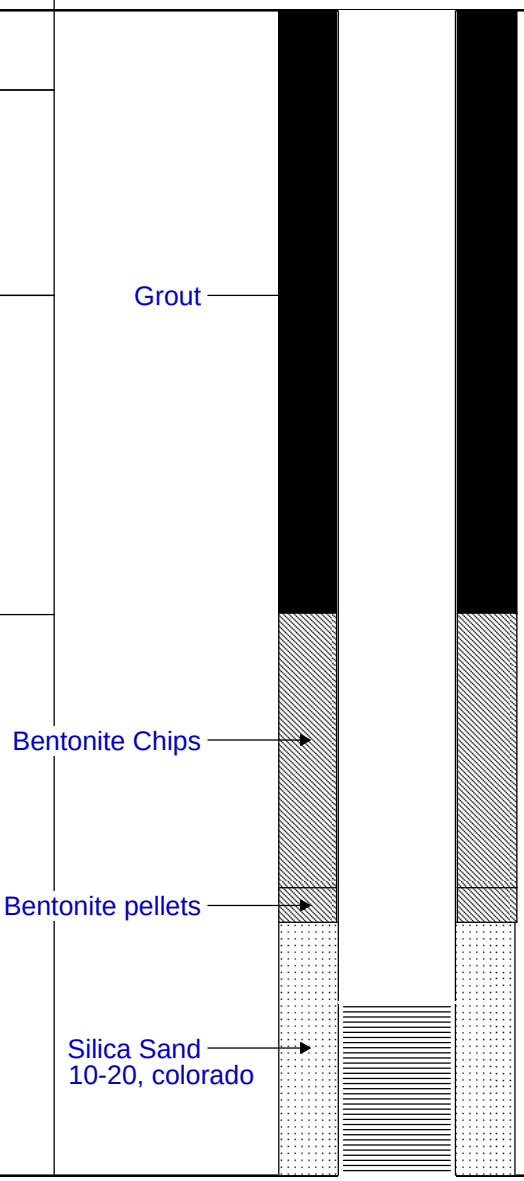
Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description
	At 69.2m, wet
70.0	***CLAY/SILT*** Dark grey, stiff to very stiff, humid, trace iridescent pink shells, alternating layers of more clayey or more silty alyers, c+/- silty layers
71.0	At 71m, clean massive clay
72.0	***CLAY*** Grey, very stiff, humid, alternating very fg sandier layers c++ carbonate veins At 71.6m, silty seam
73.0	
74.0	
75.0	***SHALE*** Dark grey, very stiff, humid, no c+
76.0	
77.0	
78.0	
79.0	Between 78.3m - 79.9m, dark grey, very soft, fractured, thinly to thickly laminated

Well Completion Details



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-23-81

Client: Pengrowth Corporation

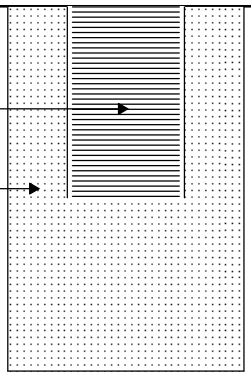
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
80.0	***SHALE (Con't)***	slot 010 Screen schedule 80
81.0		Silica Sand 10-20, colorado
82.0	End of Borehole	
83.0		
84.0		
85.0		
86.0		
87.0		
88.0		
89.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

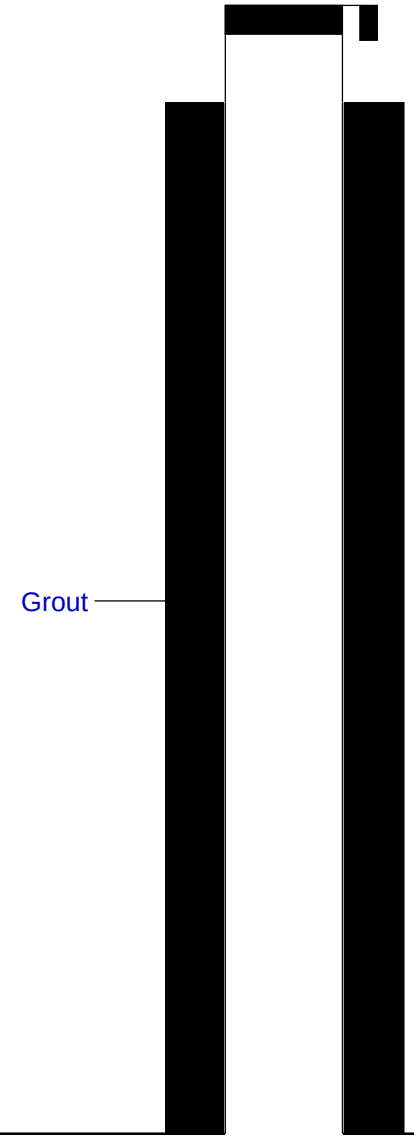
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	sandy CLAY Brown, soft, moist, trace fine gravel, few iron oxides, few sand pockets, c+ grey streaks	
1.0		
2.0		
3.0		
4.0		Grout
5.0		
6.0	Getting stiffer with depth	
7.0		
8.0		
9.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
10.0	***sandy CLAY (Con't)***	
11.0	***sandy GRAVEL*** Gravel <sR-sA>, brown, moist to wet, some cobbles <a>, (S)	
12.0	***gravelly CLAY*** Dark grey, very stiff, humid, fg to cg gravel <sR-sA>, c++ few iron oxides	
13.0		
14.0	AT 14m, large cobble <sA>; granite, no more c+	Grout
15.0		
16.0		
17.0		
18.0		
19.0	At 18.6m, small sand pocket	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	gravelly CLAY (Con't)	
20.0		
21.0		
22.0	Between 21.9m and 23.5m, cg sand pocket, trace gravels, humid	
23.0		
24.0		Grout
	CLAY/SILT Olive grey, firm, humid, travel gravel, c++ few iron oxides	
25.0	***gravelly CLAY*** Dark grey, stiff, humid, fg to cg gravel (S+Q), no c+	
26.0	At 25.6m, cobble (8cm) (S)	
27.0		
28.0		
29.0	At 29m, mg to cg sand seam	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	gravelly CLAY (Con't)	
30.0		
31.0	At 31.1m, boulder	
32.0		
33.0		
34.0		Grout
35.0	At 35.1m, fg sand pocket	
36.0		
37.0		
38.0		
39.0	At 38.7m, c+/-	

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

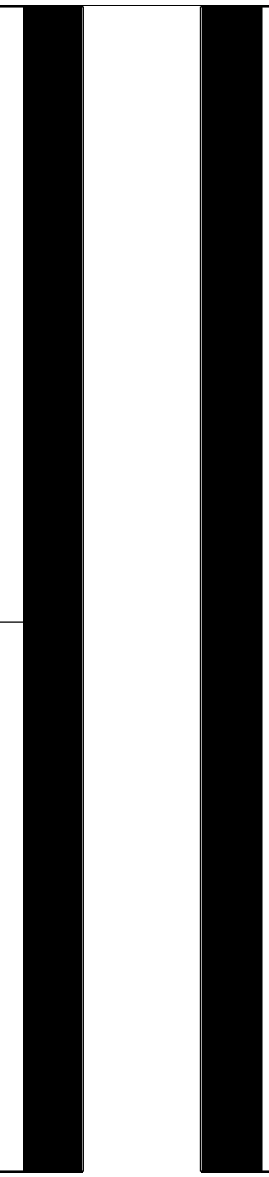
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
40.0	***gravelly CLAY (Con't)***	
41.0		
42.0		
43.0	At 43.2m, large boulder, (S)	
44.0		Grout
45.0		
46.0	Between 45.7m and 49.7m, boulder every 50cm (S)	
47.0		
48.0		
49.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

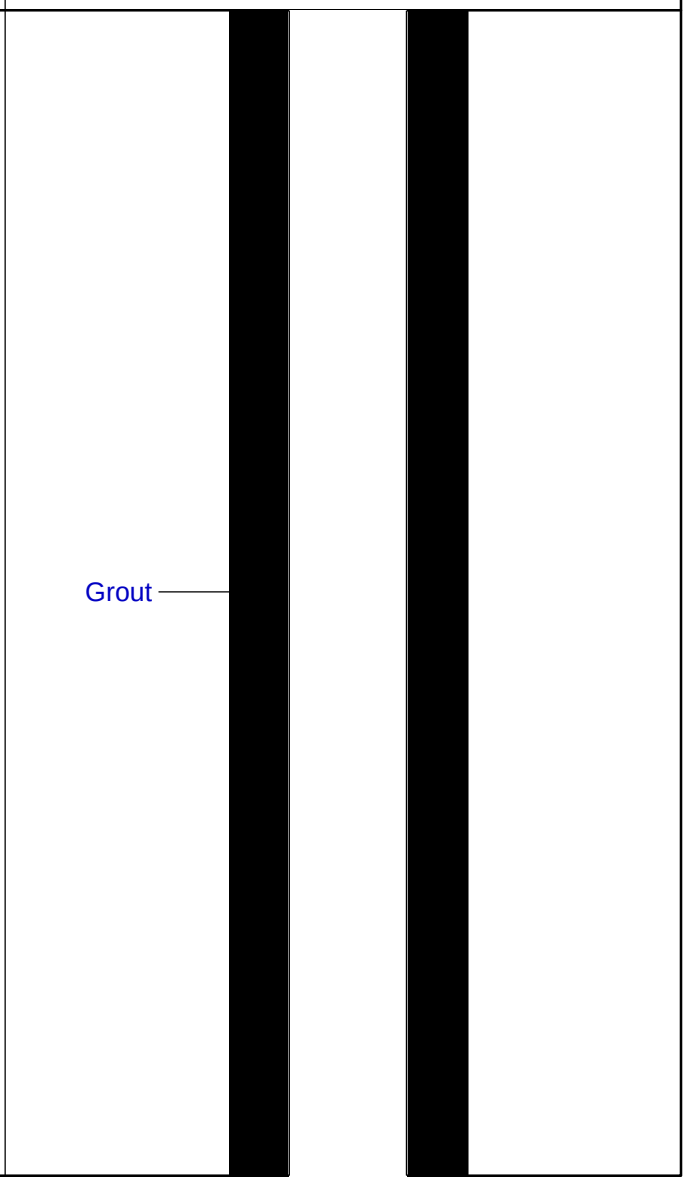
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
50.0	***gravelly CLAY (Con't)***	
51.0		
52.0	At 51.8m, c+/-	
53.0		
54.0	Starting at 53.9m c+ increasing in strength with depth	Grout
55.0		
56.0		
57.0		
58.0		
59.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
60.0	***SAND and GRAVEL*** Brown & all colors, wet, trace clay, fg gravel, cg sand	
61.0	***SAND*** Brown & all colors, wet, some fg gravel, cg sand At 61m, gravels At 61.3m, gravel layer 10cm thick, cg <sA>	
62.0	***SILT and SAND*** Llight brown, medium, moist, no gravel, fg sand	
	SAND Light brown & all colors, wet, mg	
63.0	***gravelly SAND*** Light brown & all color, wet, cg sand fg to mg gravel At 62.4m, boulder, very sharp contact	
64.0	***sandy CLAY*** Dark brown, very soft, humid to moist, fg to mg sand, some fg gravel , c+/- on small chunks	Grout
65.0	At 63.1m, becomes gravelly	
	At 64m, sand seam 10cm thick, fg, wet	
66.0	Between 64m and 66m, tracel small light blue-green shale	
	At 65.5m, trace small iron oxides	
67.0		
68.0	***SAND*** Light brown, moist to wet,fg to mg well sorted, no c+	
69.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	gravelly CLAY Dark brown, fg to mg gravel (S)<sR-sA>	
70.0	***SAND*** Light brown, moist to wet, fg to mg well sorted At 69.2m, vfg sand, wet At 69.5m, fg sand, wet At 69.8m, mg to cg sand, wet	
71.0	At 70.1m, becomes silty	
	SILT and SAND Humid to moist, very clean, fg sand, alternating more silty and sandy	
72.0		
	SAND Light brown and red, very dense, moist, mg sand	
73.0		
	sandy gravelly CLAY Dark brown, very stiff, humid	Grout
74.0	***SAND*** Light brown, very dense, moist, mg sand	
	sandy gravelly CLAY Dark brown, very stiff, humid, c+, some tiny iron oxides At 74m, 74.4m and 74.7m, sand layers 10-20cm thick, mg, wet	
75.0		
76.0	At 75m, boulder (S)<sR>	
	SAND Light brown, moist to wet, mg to cg, very clean	
77.0	***SILT and SAND*** Brown, soft to medium, moist	
	SAND Moist to wet, mg At 77.1m, fg sand, trace silt At 77.3m, mg sand	
78.0		
	sandy gravelly CLAY Dark brown grey, very stiff, humid At 78.2m, sand seam (mg)	
79.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
80.0	***clayey silty SAND*** Dark grey, humid to moist, fg to mg	
81.0	***sandy SILT*** Dark grey, humid, fg	
82.0		Grout
83.0	***clayey silty SAND*** Dark grey, moist, fg to mg At 82.8m, sand pocket, mg, wet	
84.0	***sandy SILT*** Dark grey, stiff, humid, some gravels (S+Q)<sR-sA>	
85.0	***SAND and SILT*** Dark grey, moist, trace gravel	
86.0	***SHALE*** Rusty, dry to humid	
87.0	***silty gravelly CLAY*** Dark grey, very stiff, iron oxides (S) ***SILT*** Dark grey, very stiff, trace gravels At 87.2m, sand seam, fg	Bentonite Chips
88.0	***CLAY, SILT and SAND*** Dark grey, moist, some gravels	
89.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-24-94

Client: Pengrowth Corporation

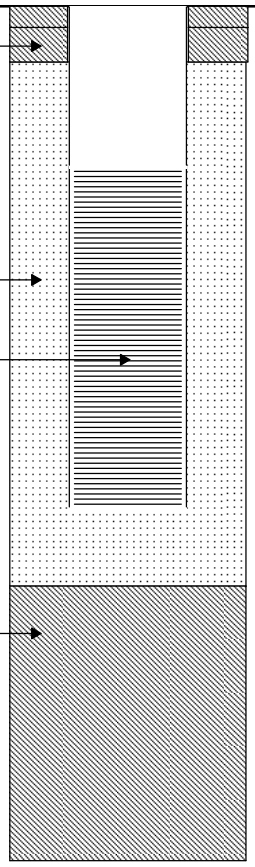
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
90.0	***CLAY, SILT and SAND (Con't)***	Bentonite pellets
	SHALE Dark grey, humid, trace iron oxides and shells	Silica Sand 10-20, colorado slot 010 Screen schedule 80
97.0	End of Borehole	Bentonite Chips
99.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

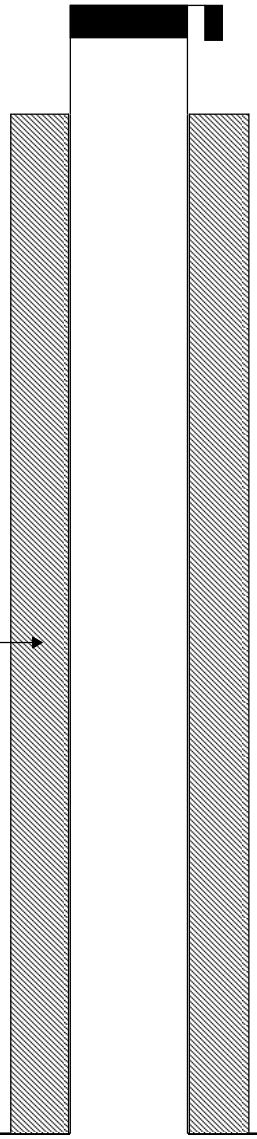
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	ORGANIC Black, very soft, loose	
1.0	***silty SAND*** Light brown, soft, loose	
	CLAY Brown, very plastic, moist, some fg sand, roots, trace iron oxides	
2.0	At 1.1m, cg sand seam with some mg gravel, moist to wet, pink/brown	
	SILT/CLAY Light brown, very plastic, moist to wet, some sand (pink), trace fg gravel	
3.0	At 1.5m, some light brown and grey mottling, very plastic, soft, humid to moist, trace fg to mg gravel <sA> c+/- light brown, abundant iron staining and small ironstones	
4.0		Bentonite Chips →
5.0	Less gravel and more clayey with depth, little to no iron staining	
6.0		
7.0	***CLAY*** Dark grey, medium pastic, humid to moist	
8.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
9.0	***CLAY (Con't)***	
10.0		
11.0		
12.0		
	sandy CLAY Grey, very plastic, some fg gravel (S)<sR>, fg sand	
13.0		Bentonite Chips →
14.0		
15.0		
16.0		
17.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

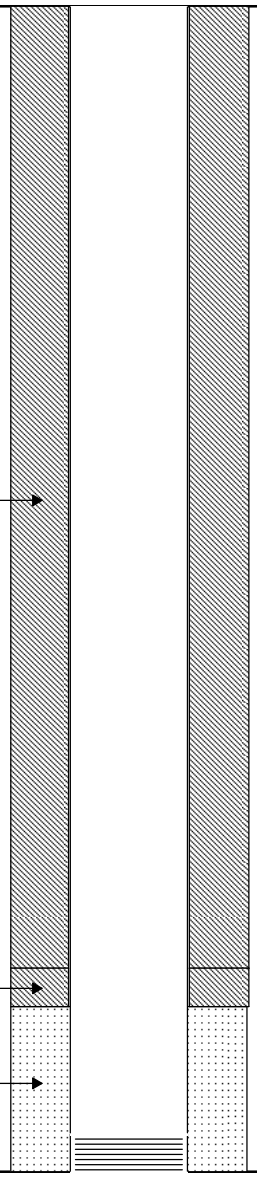
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
18.0	***clayey/silty SAND*** Dark grey with light brown sand, wet, trace fg gravel	
19.0		
20.0		
21.0	At 20.4m, decreasing sand content with depth, few cg gravel (S)<A-sR>	Bentonite Chips
22.0		
23.0		
24.0		
25.0	Between 24.4m and 25.9m C++ grey streaks and white carbonates	Bentonite pellets
	Between 25.9m and 35.1m NO RETURN (transition to SHALE)	Silica Sand 10-20, colorado
26.0	***SHALE***	



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

GPS Location:

Purpose:

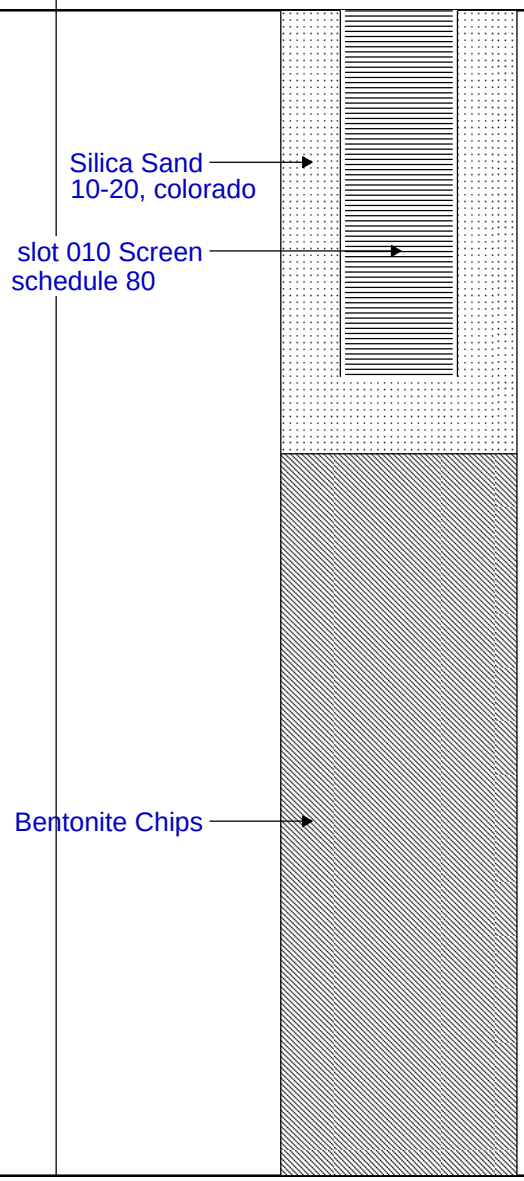
MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m) | Description | Well Completion Details

SHALE (Con't)

27.0
28.0
29.0
30.0
31.0
32.0
33.0
34.0
35.0



Logged By: AcK/Jchan
Entered By: SC
Drill Date: June 2013

Driller: Major Drilling
Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
36.0	At 35.1m, light humid, light grey silt pockets, very fg white specks, no c+	
37.0		
38.0	At 38.1m, dark grey, stiff, humid, few silt stringers	
39.0		Bentonite Chips →
40.0	At 39.6m, c++ few shells and white specks	
41.0		
42.0	At 41.5m, hard black shale chunks	
43.0		
44.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	SHALE (Con't)	
45.0		
46.0		
47.0		
48.0		
		Bentonite Chips →
49.0		
50.0		
51.0		
52.0		
53.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
54.0	***SHALE (Con't)***	
55.0		
56.0		
57.0		
58.0		Bentonite Chips →
	At 58.2m, fractures	
59.0		
60.0		
61.0		
62.0		

Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-032

Borehole: MW13-25-29

Client: Pengrowth Corporation

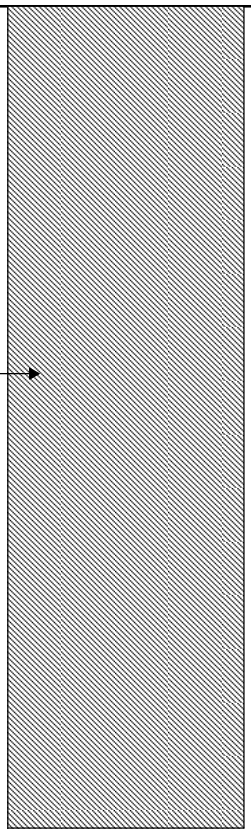
GPS Location:

Purpose:

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	SHALE (Con't)	
63.0		
64.0		
65.0		Bentonite Chips →
66.0		
67.0		
68.0		
	End of Borehole	
69.0		
70.0		
71.0		



Logged By: AcK/Jchan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-23

Client: Pengrowth

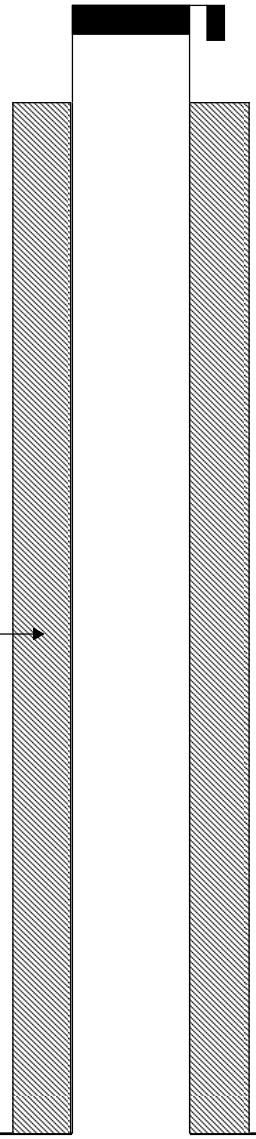
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	clayey SAND Brown, soft, moist, rootlets	
1.0	***sandy CLAY*** Brown, firm, moist, some fg gravels (S)<sA-sR>, c++ white silty pocket, rootlets, small sand pocket At 0.6m few iron oxides	
2.0	***CLAY*** Brown grey, firm plastic, moist, some gravel sand, silt, fg to cg gravel (S) - pockets of black sand	
3.0		
4.0		
5.0	At 5.2m no more silt	Bentonite chips
6.0	At 5.9m trace fg gravel (S)<sR>, dark grey, stiff, humid, no c+	
7.0	At 6.7m mottled grey/brown, trace iron oxides	
8.0		
9.0		



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-23

Client: Pengrowth

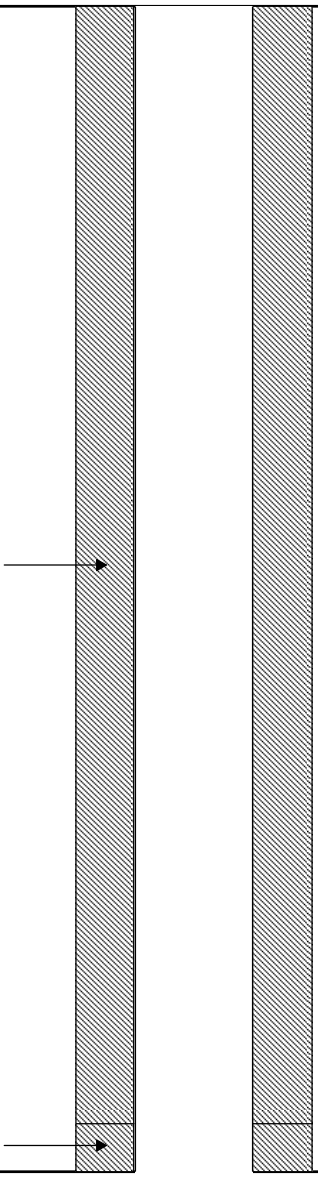
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
10.0	***CLAY (Con't)***	
11.0		
12.0		
13.0		
14.0		Bentonite chips
	At 14.3m becomes silty and gravelly	
15.0		
16.0		
17.0	***CLAY/SILT*** Grey, moist, some fg to cg gravels <A-sR>	
	gravelly CLAY Dark grey, stiff, humid, fg to cg gravel (S)<A-sR>, c++	
18.0		
19.0		Bentonite pellets



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-23

Client: Pengrowth

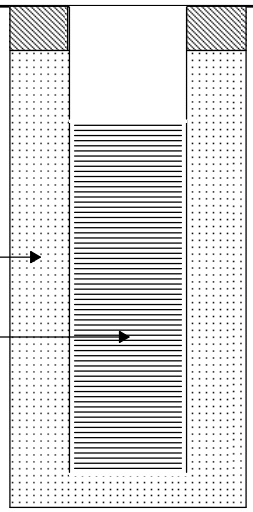
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
20.0		
	gravelly SAND All color, wet, fg to cg gravel (S), cg sand	Silica Sand 10-20, colorado
21.0		
22.0		slot 010 Screen schedule 80
23.0	***SAND and GRAVEL*** All colors, wet, fg to cg gravel <A-R> , cg sand	
	CLAY/SILT Dark grey, humid, some gravel, c++	
24.0	End of Borehole	
25.0		
26.0		
27.0		
28.0		
29.0		



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

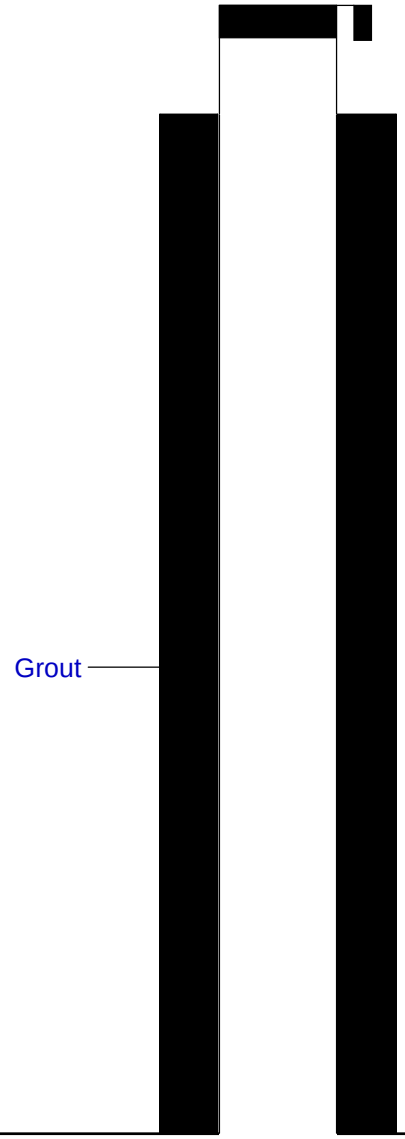
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	very clayey SAND Brown, soft, moist, rootlets	
1.0	***very sandy CLAY*** Brown, firm, moist, some fg to cg gravel (S), mg sand, c+ white silty pockets, rootlets, few sand pockets. At 0.6m few iron oxides, less sandy	
2.0	***CLAY*** Brown, grey, firm, plastic, moist, some gravel, sand, silt, fg to cg gravel (S), pockets of black sand	
3.0		
4.0		Grout
5.0	At 5.1m no more silt	
6.0	At 5.7m trace fg gravel (S) <sR>, dark grey, stiff, humid, no c+	
7.0		
8.0	At 8.1m cobble <sA>(G)	



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
9.0	***CLAY*** Brown, firm, humid, some sand and gravel, no c+, fg to cg gravel <A-sR>, some iron oxides	
	sandy gravelly CLAY Brown, firm, gravels fg to cg, <A-sR>	
10.0		
11.0		
12.0		Grout
13.0		
14.0		
	At 14.3m silty gravelly	
15.0		
16.0		
17.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy gravelly CLAY (Con't)	
18.0		
	gravelly SAND Grey, wet, poorly sorted sand gravels <sA-sR>	
19.0	***gravelly CLAY*** Grey, humid, fg to cg gravels At 18.9 cobble (S)<sA>	
20.0	***SILT*** Grey, very stiff, moist, trace gravel	
	gravelly SAND Grey, wet, fg to cg gravels (S)	
21.0	***clayey SILT*** Grey, very stiff	
	CLAY Firm, plastic, moist, trace fg to mg gravel	
22.0		Grout
	At 22.3m becomes silty, gravelly, dark grey, stiff, humid, some sand pockets, no c+	
23.0		
24.0		
25.0		
	At 25.3m becomes gravelly, some carbonate pockets c++, c+/- in matrix	
26.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
27.0	***CLAY (Con't)***	
28.0		
29.0		
30.0		
31.0		Grout
32.0		
33.0		
34.0	At 34m carbonates in matrix c++	
35.0		

Logged By: AcK/JChan
Entered By: SC
Drill Date: June 2013

Driller: Major Drilling
Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

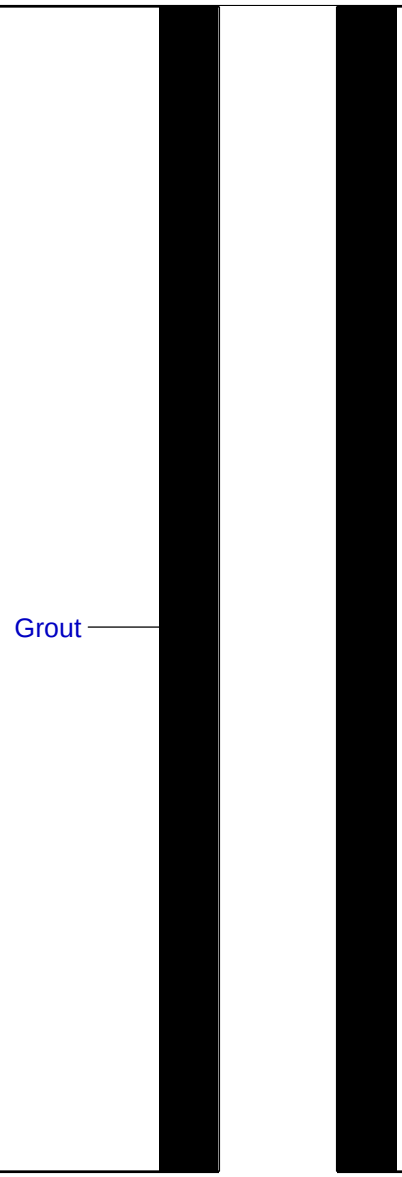
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	CLAY (Con't)	
36.0		
37.0		
38.0		
39.0		
40.0		Grout
41.0		
42.0		
43.0		
44.0		



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

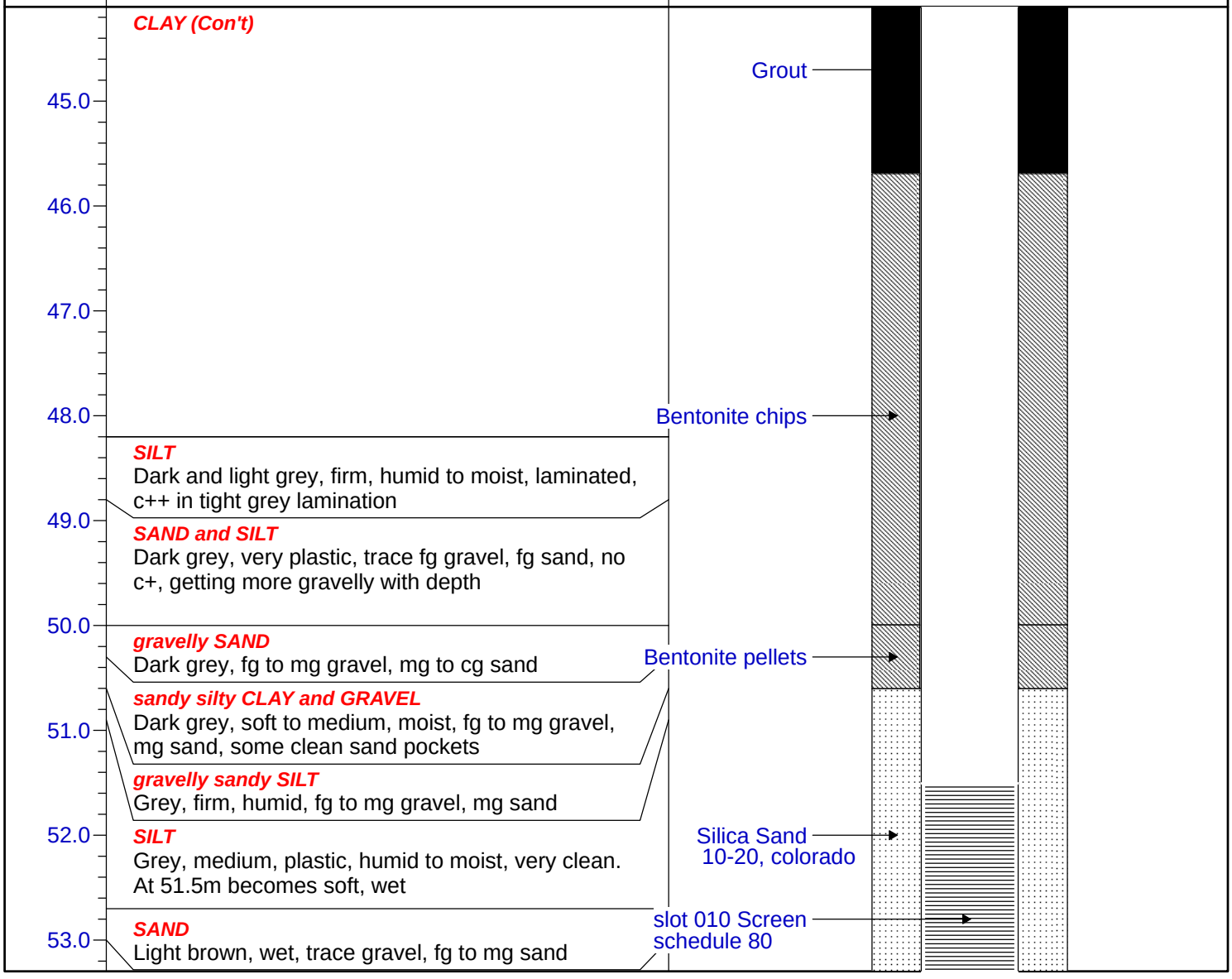
Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

GPS Location:

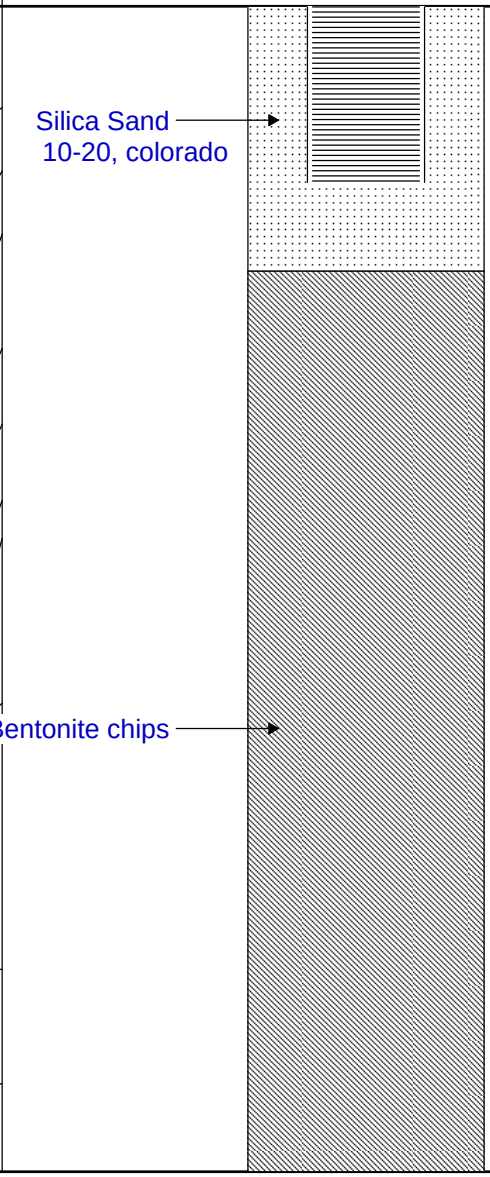
Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description
54.0	***SILT and SAND*** Moist, vfg sand At 53.6m clean cg sand pocket, wet. At 53.7m becomes gravelly, humid
	SAND Light brown, wet, trace silt and clay pockets, mg sand
55.0	***SILT and SAND*** Grey, humid, fg sand At 54.6m cg sand seam 10cm thick
56.0	***gravelly CLAY*** Dark grey, stiff, humid, fg to mg gravel (S), c+ in light grey carbonate streaks
	CLAY,SILT and SAND Dark grey, stiff, humid, trace fg gravel, c+/-
57.0	***gravelly CLAY*** Dark grey, stiff, humid, mg gravels At 56.7m fg sand seam, wet
58.0	***SAND*** Grey, wet, trace gravel and clay, fg to mg sand
	gravelly CLAY Dark grey, very stiff, humid, no c+, fg gravel
59.0	***clayey gravelly SAND*** Dark grey, wet, fg to mg gravel, mg to cg sand
	gravelly CLAY Dark grey, very stiff, humid, trace sand and gravel, c+/- At 59.4m silt seam about 15cm thick
60.0	
61.0	***SAND*** Grey, wet, trace gravel and silt, fg to mg sand, c+/- on silt At 61m becomes moist and dryer with depth
62.0	

Well Completion Details



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-55

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
63.0	***gravelly CLAY*** Dark grey, very stiff, humid At 61.9m becomes sandy, fg, trace fg gravel. At 62.2m no more gravels	Bentonite chips →
64.0		
65.0		
66.0	End of Borehole	
67.0		
68.0		
69.0		
70.0		
71.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
0.0	Ground Surface	
	very clayey SAND Brown, soft, moist, rootlets	
1.0	***very sandy CLAY*** Brown, firm, moist, some fg to cg gravel (S), mg sand, c+ white silty pockets, rootlets, few sand pockets.	
2.0	At 0.6m few iron oxides, less sandy	
	CLAY Brown, grey, firm, plastic, moist, some gravel, sand, silt, fg to cg gravel (S) pockets of black sand	
3.0		
4.0		Grout
5.0	At 5.1m no more silt	
6.0	At 5.7m trace fg gravel (S) <sR>, dark grey, stiff, humid, no c+	
7.0		
8.0	At 8.1m cobble <sA>(G)	
	CLAY Brown, firm, humid, some sand and gravel, no c+, fg to mg gravel <A-sR>, some iron oxides	
9.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

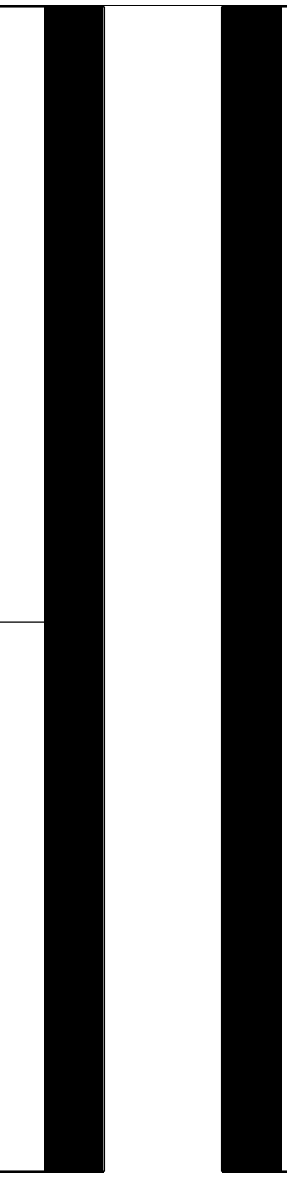
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
10.0	***Clay (Con't)***	
11.0	At 11.1m no more sand, dark grey, stiff, some gravel, fg to cg gravel <A-R>	
12.0		
13.0		
14.0		Grout
15.0		
16.0		
17.0	At 16.8m c++ cluster of carbonates	
18.0		
19.0	At 18.9m fg, poorly sorted sand seam	



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
20.0	***gravelly SILT*** Grey, humid, some fg to cg gravel <sA-sR>, no c++	
	SAND Brown, moist to wet, a lot of cg gravel <A-R>	
21.0	At 21.3m some gravel (S), wet	
	At 21.6m decreasing gravel content, wet	
22.0		
	SAND and GRAVEL all colors, moist to wet, fg to cg gravel (S)<A-sR>	
23.0	***very sandy SILT*** Grey, soft, moist, trace fg gravel <A>, decreasing silt content with depth	
24.0	***gravelly CLAY*** Dark grey, stiff, humid, fg to cg gravel <sA-sR>, c+/-, iron oxides	Grout
25.0		
26.0		
27.0		
28.0	At 28.2m tabular cobble (S)<sA>, 10cm in length	
29.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

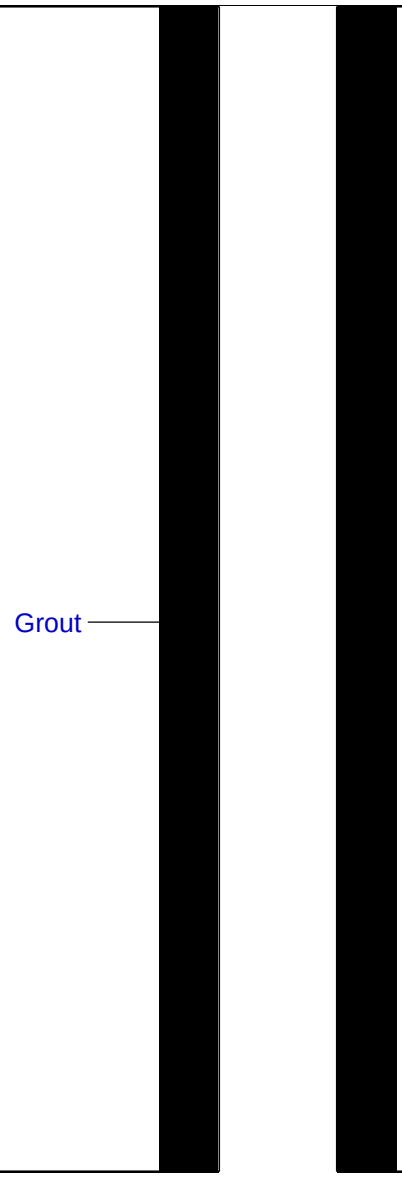
GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
30.0	***gravelly CLAY (Con't)***	
31.0		
32.0	At 32.1m dark grey, stiff, some silt and gravel, fg to cg gravel (S)<A-R> trace light grey silt pockets	
33.0		
34.0		Grout
35.0	At 35.1m no more silt, fg to cg gravel (S+Q)	
36.0		
37.0		
38.0		
39.0		



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033
Borehole: MW13-27-90
Client: Pengrowth
GPS Location:
Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
40.0	***gravelly CLAY (Con't)***	
41.0	At 40.8m soft high plasticity	
42.0	At 42.3m fg grey sand pockets, cobbles <sA>(S) c++	
43.0		
44.0		Grout
45.0		
46.0	At 45.6m some gravel and silt, some fg sand seams c++	
47.0		
48.0	***SILT*** Firm, trace gravel	
49.0		

Logged By: AcK/JChan
Entered By: SC
Drill Date: June 2013

Driller: Major Drilling
Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
50.0	At 48.2m dark grey, firm, moist, some fg to cg gravel <sR-sA>, getting sandy with depth some iron oxides ***SILT (Con't)***	
51.0	At 50.9m grey, soft plastic,trace to no gravel At 51.2m thickly laminated, alternating light brown and dark grey	
52.0	***SAND and CLAY*** Grey, moist, fg sand	
53.0	***SAND*** Light brown, moist to wet, fg to mg clean sand	
54.0	***SILT*** Grey, medium, humid to moist, some sand and gravel, fg gravel, fg sand ***gravelly CLAY*** Dark grey, firm, crumbly, humid, fg gravel <sA-sR>, c+/-	Grout
55.0	***SAND and SILT*** Moist, fg sand	
56.0	***sandy CLAY and GRAVEL*** Dark grey, stiff, humid, mg gravel <sR-sA>, c+/- carbonate flakes At 54.8m sand pocket At 55.1m sand pocket	
57.0	***clayey SAND*** Dark grey, moist, trace tabular gravel <sR>, fg to mg sand At 56.5m some fg to mg gravel	
58.0	***sandy CLAY and GRAVEL*** Dark grey, very stiff, humid, fg to mg gravel, c+/- carbonate flakes	
59.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
60.0	***SAND*** Dark grey, humid to moist, some clay and gravel, gravel <A>	
	sandy CLAY and GRAVEL Dark grey, very stiff	
61.0	***clayey SAND*** Grey, wet, fg red gravel, fg to mg sand	
	At 61.9m no more gravel, dark grey, soft, moist, very stinky	
62.0	***sandy CLAY*** Dark grey, very soft, humid, trace fg gravel, c+/- to c++ in matrix	
63.0	***CLAY and GRAVEL*** Dark grey, stiff, humid, mg gravel <sR> At 63.7m mg sand seam, moist	
64.0	***sandy CLAY*** Some to trace gravel	Grout
65.0		
	At 65.5m boulder-weathered sandstone, c++	
66.0	At 65.8m c+/- m matrix	
67.0		
68.0		
69.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
	sandy CLAY (Con't)	
70.0	***CLAY*** Stiff plastic, interlaminated light and dark grey with some black	
71.0		
72.0		
73.0	At 73.2m dark grey, very stiff, some sand and gravel, fg sand and gravel no c+ to c+/-	
74.0		Grout
75.0	At 75.3m stiff plastic, interlaminated light and dark grey with some black, possibly some coal present, c++ light grey layers	
76.0		
77.0		
78.0	At 78.3m dark grey, very stiff, humid, some fg sand and gravel, some iron concretions and stains	
79.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

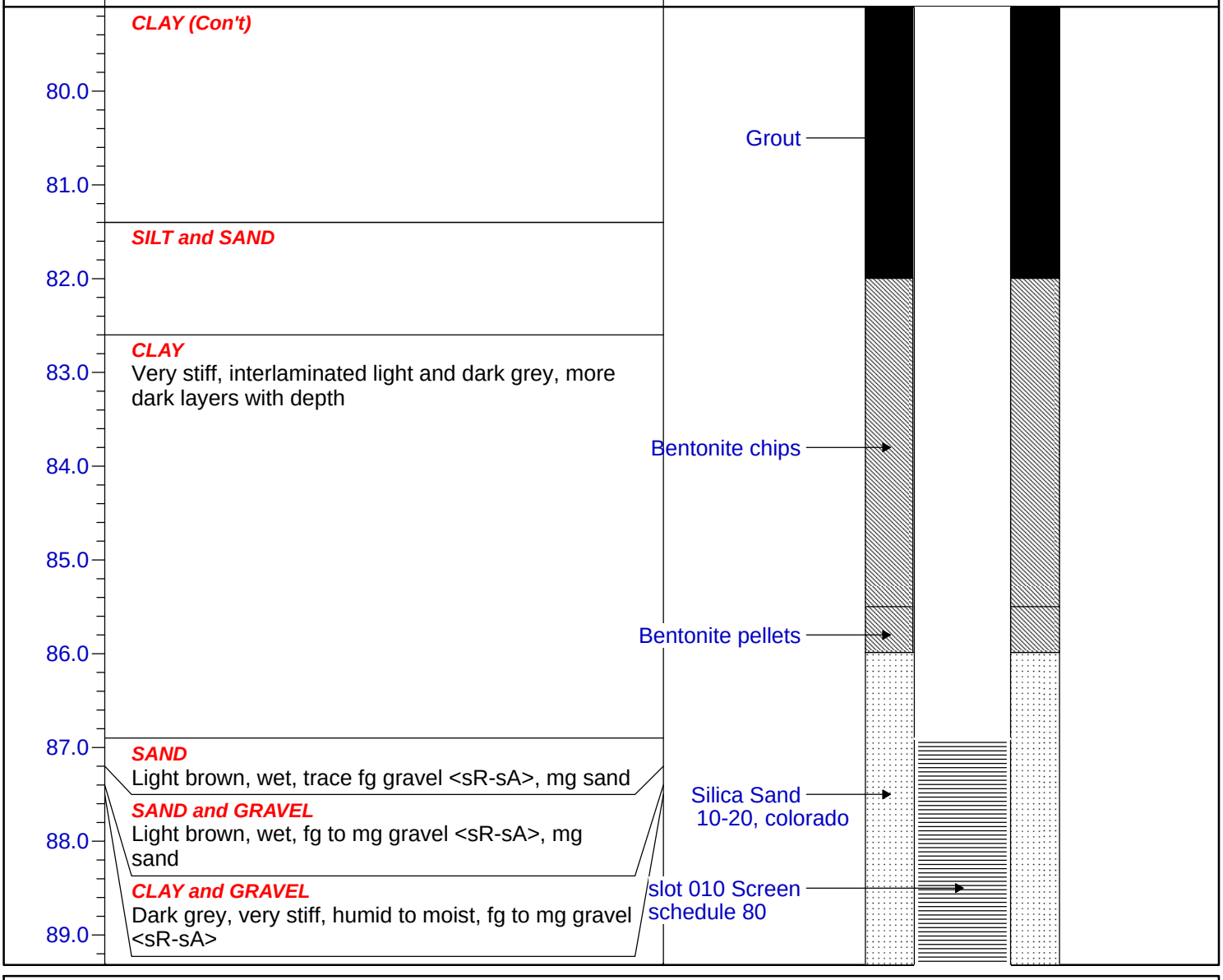
Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile



Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

Project Number: 11-033

Borehole: MW13-27-90

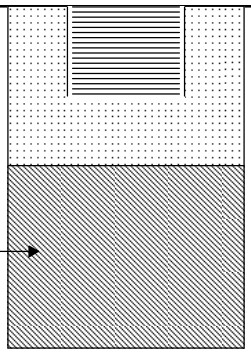
Client: Pengrowth

GPS Location:

Purpose: Monitoring Wells

MILLENNIUM
EMS Solutions Ltd.

Subsurface Profile

Depth (m)	Description	Well Completion Details
90.0	***CLAY, SAND and GRAVEL*** Dark grey, wet, mg gravel trace cg gravel, cg sand	
	clayey SAND and GRAVEL Dark grey, wet	
91.0	***CLAY, SAND and GRAVEL*** At 90.2m c++, carbonate silt layer, stiff	Bentonite chips
	CLAY Very stiff, humid, dark grey with some thin light grey, black medium grains laminated, no c+	
92.0	End of Borehole	
93.0		
94.0		
95.0		
96.0		
97.0		
98.0		
99.0		

Logged By: AcK/JChan

Entered By: SC

Drill Date: June 2013

Driller: Major Drilling

Drill Method: Sonic

Millennium EMS Solutions Ltd.
6111 - 91 Street
Edmonton, AB T6E 6V6

APPENDIX E6: STATISTICAL ANALYSIS

Appendix E6: Statistical Analysis Plan for a New Facility According to the Draft Groundwater Monitoring Directive

INTRODUCTION

In 2012, Alberta Environment and Sustainable Resources (ESRD) circulated the draft Groundwater Monitoring Directive (ESRD, 2012, henceforth referred to as the Directive) to environmental practitioners for comment. The Directive describes statistical procedures to analyze groundwater data in order to establish baseline groundwater quality and the natural range of variability, and to identify groundwater quality trigger levels for the initiation of groundwater response plans. This appendix describes the statistical procedures used to satisfy the requirements described in the Directive for the submission of a Groundwater Management Plan (GMP) as part of an approval application for a new facility under the Environmental Protection and Enhancement Act.

STATISTICAL ANALYSIS PLAN

The proposed statistical analysis plan is made up of the following steps:

1. Identifying compliance monitoring wells and selecting indicator parameters.
2. Evaluating data for non-detects and outliers.
3. Establishing baseline conditions and natural variations using trend analysis.
4. Developing trigger levels and determine compliance status level.
5. Updating baseline values and the control chart.

Details of each step are described in the following sections.

Step 1: Identifying Compliance Monitoring Wells and Selecting Indicator Parameters

The Directive defines a compliance monitoring well (CMW) as "*a well for which groundwater quality is measured and used for regulatory purposes to assess the facility's performance with respect to groundwater*". At each CMW, a list of parameters including naturally occurring chemicals, facility-specific substances and prescribed field measurements are monitored. From this list, specific groundwater quality indicator parameters are selected for statistical analyses in order to establish the baseline groundwater quality and calculate the natural range of groundwater quality variability. The USEPA Unified Guide suggests that "*10-15 parameters per compliance well is a reasonable target depending on site-specific needs*" (USEPA, 2009). The parameters monitored and the indicator parameters for statistical analyses are listed for each CMW in the GMP.

At a new facility, a baseline groundwater quality database at each CMW for each indicator parameter will be developed using eight sets of groundwater quality samples. The initial sampling frequency will be three times per year until the baseline conditions are established.

Step 2: Evaluating Data for Non-Detects and Outliers

For each CMW, the Directive requires "*the first eight (8) sampling events to be used to define baseline groundwater quality and calculate the natural range of groundwater quality variability*". In the subsequent discussion, "data" refers to the values of an indicator parameter obtained from available sampling events.

Step 2 will be carried out according to the number of available sampling events: less than four events, four to seven events, and greater than seven events.

If there are less than four sampling events, statistical analyses will not be carried out and one can jump to Step 4: Developing Trigger Levels.

When there are four or more sampling events, summary statistics (mean, maximum, minimum and interquartile range) will be calculated and the data plotted in a box plot and a quantile-quantile (q-q) plot. A box plot is a graphical tool to identify suspected outliers while a q-q plot is used to demonstrate whether the data distribution can be approximated by a normal distribution (USEPA, 2009).

Non-detect (ND) or left-censored data are parameter values below the laboratory reporting limit and they should be incorporated when computing descriptive statistics, testing hypotheses and performing correlation (Helsel, 2012). When ND data are present, the statistical procedure recommended by Helsel (2012) is followed and is described in Appendix E6.1. In a laboratory report, each non-detect (ND) value is usually reported as <RL, where RL is the laboratory reporting limit. A reporting limit is also termed a "practical quantification limit" (PQL); they both represent the threshold above which reliable single numbers can be reported by an analytical laboratory (Helsel, 2012). For each RL, the Directive (Clause 5.6.2) implies that the method detection limit (MDL) should also be given by the laboratory such that persistent presence of a parameter not present naturally in groundwater at concentrations below the RL but above MDL can be identified.

An outlier is a data point that does not conform to the pattern established by other observations in the data set (Gilbert, 1987). One of the easiest ways to detect possible outliers is using the box-plot, also known as a box and whisker plot (Helsel and Hirsch, 2002). When one or more suspected outliers are detected, each outlier will be examined for cause and then verified that it is truly an outlier using statistical procedures described in Appendix E6.2. As described in Step 3, verified outliers will be omitted from the control limit calculations but retained in the trend analysis.

Step 3: Establishing Baseline Conditions and Natural Variations Using Trend Analysis

Before discussing the statistical procedure to establish baseline conditions and natural variations of groundwater quality for a new facility, the requirements described in the Directive (ESRD, 2012) are summarized below.

1. By definition, the baseline groundwater quality is the groundwater quality prior to the facility commencing operations and it includes both natural geochemistry and potential anthropogenic impacts on local groundwater quality.
2. Groundwater quality parameters are classified into "parameters not present naturally in groundwater" (NPN) and "parameters present naturally in groundwater" (PN). Procedures to establish control limits and trigger values are different between the two classes.
3. NPN parameters include (Cl. 5.4.1.4):
   a. parameter that do not occur naturally in groundwater at the site; and
   b. natural parameters that are present at the site in concentrations less than the laboratory's reporting limit (*e.g.*, some metals).
4. For an NPN parameter, its upper control limit (UCL) is the laboratory reporting limit presented in Table 3 of the Directive (Cl. 5.4.2.1). Guidance is also provided when an NPN parameter is not listed in Table 3 of the Directive.
5. For each PN parameter at a new facility, control limits can be calculated after the eighth water quality sampling event. Upper control limit (UCL) and lower control limit (LCL) will be determined for each indicator parameter at each CMW using statistical procedures prescribed in the Directive (Cl. 5.4.1.1) and discussed further in the following points.
6. UCL and LCL are used to define the natural range of groundwater quality variability for a PN parameter (Cl. 4.2.1). If a statistically-based UCL exceeds the applicable Tier 1 Guideline, the UCL value will be justified in writing to the Director to apply for a written authorization.
7. The baseline condition for a PN parameter is defined by the UCL and LCL, and the baseline condition for an NPN parameter is defined by the UCL.

At a new facility, the statistical procedure to obtain the control limits for a PN indicator parameter will depend on the number of sampling events as shown in Table E6-1.

Table E6-1 Statistical Procedure Selection Based on Number of Sampling Events	
No. of Sampling Events	**Statistical Procedure**
< 4	Not Available
4 to 7	Mann-Kendall
≥ 8	Shewhart-CUSUM Control Chart

When there are less than four sampling events, control limits cannot be established. With four to seven sampling events, the trend condition (increasing, decreasing or no-trend) can be estimated using the Mann-Kendall trend analysis. When there are eight or more sampling events, control limits (UCL and LCL) can be calculated using the Shewhart-CUSUM procedure. The trend condition or the control limits are then used in Step 4.

Additional details for Mann-Kendall trend analysis and the Shewhart-CUSUM control chart procedure are presented in Appendices E6.3 and E6.4, respectively.

A flow-chart summarizing the statistical analysis procedure to obtain the UCL and LCL for a PN indicator parameter is shown on Figure E6-1.

Step 4: Developing Trigger Levels and Determining Compliance Status Level

When there are less than four sampling events, control limits or trends, hence trigger levels, cannot be established using statistical methods described in the Directive. However, parameter values can be compared to the available Tier 1 Guideline (Alberta Environment, 2010). This comparison may indicate unusual naturally occurring concentrations.

When there are at least four sampling events, the procedure for developing trigger levels for groundwater quality indicator parameters is summarized in Table E6-2.

For each indicator parameter present naturally in groundwater, both the trend analysis and control chart are used to create the triggers that will activate the Groundwater Response Plan. From a trend analysis, a confirmed increasing or decreasing trend will create a trigger. From a control chart, the UCL and LCL bound the limits of data variability and a trigger is reached when the concentration of the indictor parameter is at or above the UCL; or when the concentration is at or below the UCL (Cl. 5.6.1.1).

For each indicator parameter not present naturally (NPN) in groundwater, the UCL is the laboratory reporting limit presented in Table 3 of the Directive (Cl. 5.4.2.1). If the indicator parameter is not

listed in Table 3, a reporting limit for that parameter will be derived and presented as a recommended change to the GMP that will be submitted to ESRD in the next scheduled Groundwater Monitoring Report (Cl. 5.4.2.2). When the NPN parameter is consistently detected below the UCL but above the laboratory method detection limit for three or more sampling events, this situation will be identified and explained in the annual monitoring report (Appendix B.3, the Directive).

Table E6-2 Developing Triggers for an Indicator Parameter

Indicator Parameter	Trigger	
Present Naturally in Groundwater	Trend Analysis:	increasing or decreasing trend
	Control Chart:	at or exceeds UCL; at or below LCL
Not Present Naturally in Groundwater	UCL determined using laboratory reporting limit presented in Table 3 (Directive) or Cl. 5.4.2.2	

When a trigger has been reached, the Groundwater Management Plan's level of compliance status will be moved from Level 1 to Level 2 (Table 2, the Directive) and the Groundwater Response Plan will be activated to investigate the cause of the trigger.

Step 5: Updating Baseline Values and the Control Chart

This step is only applicable after a baseline dataset has been established.

When more than four additional data points are available, the baseline dataset will be updated as described in Appendix C of the Directive according to the following steps:

1. Conduct a Student's t-test or Wilcoxon rank sum test between the baseline dataset and the potential set of new data. The new data will only be incorporated if there is no difference between the two groups at 0.01 level of significance. Student's t-test and Wilcoxon rank sum test are implemented in ProUCL (USEPA, 2010).
2. Carry out a Mann-Kendall trend analysis on the new data. If a trend is identified at 0.01 level of significance, all data that are part of trend will be rejected.
3. Compute sample-based mean and standard deviation.
4. Recompute the UCL and LCL for the new baseline dataset.
5. Reset the CUSUM portion of the Shewhart-CUSUM control chart to zero prior to the new comparison against the new limit.
6. Document the above process in the Groundwater Monitoring Report.

REFERENCES

Alberta Environment, 2010. Alberta Tier 1 Soil and Groundwater Remediation Guidelines, December 2010. Available from: http://environment.gov.ab.ca/info/library/7751.pdf [accessed on April 24, 2013]

Alberta Environment and Sustainable Resource Development (ESRD), 2012. Groundwater Monitoring Directive, Groundwater Quality Monitoring and Management for Approved Facilities. Draft, September 2012.

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company Inc., New York, NY.

Helsel, D.R., 2012. Statistics for Censored Environmental Data Using Minitab and R, 2nd Edition. John Wiley & Sons, Inc., Hoboken, NJ.

Helsel, D.R. and Hirsch, R.M., 2002. Statistical Methods in Water Resources in Techniques of Water Resources Investigations, Book 4, Chapter A3, US Geological Survey. Available from: http://pubs.usgs.gov/twri/twri4a3/ [accessed on April 18, 2013]

Nelson, A.C. Jr., Armentrout, D.W., and Johnson, T.R., 1980. Validation of Air Monitoring Data, EPA-600/4-80-030. US Environmental Protection Agency, National Technical Information Service, Springfield, VA.

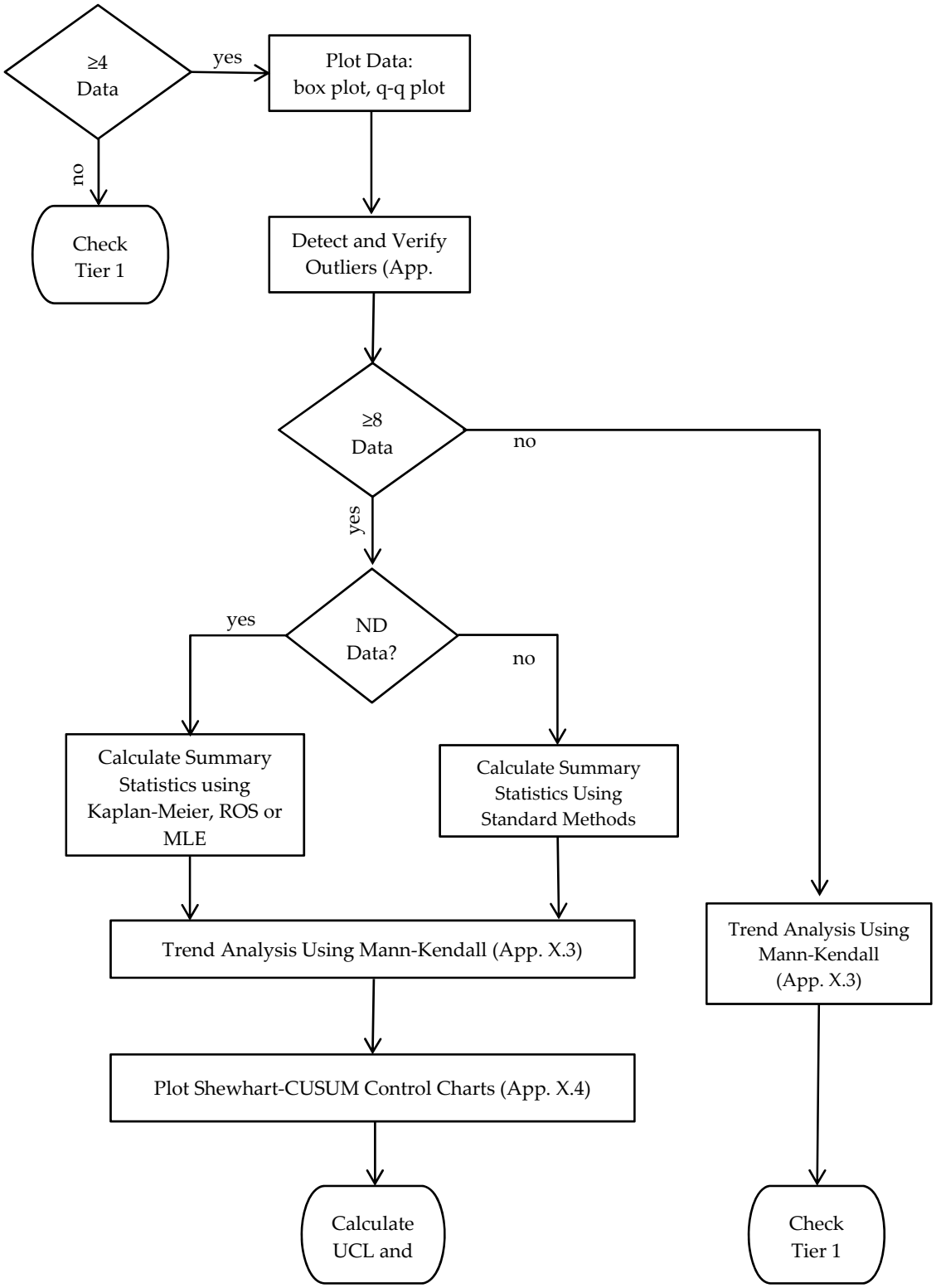
Sanitas Technologies, 2012. Sanitas Statistical Software, Version 9.3. Information available from: http://www.sanitastech.com/ [accessed on April 17, 2013]

US Army Corps of Engineers (USACE), 2008. Environmental Quality, Environmental Statistics, Manual 1110-1-4014. Available from: http://publications.usace.army.mil/publications/eng-manuals/EM_1110-1-4014_sec/ [accessed on April 22, 2013]

US Environmental Protection Agency (USEPA), 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Unified Guide. Office of Resource Conservation and Recovery, March 2009. Available from: http://www.epa.gov/osw/hazard/correctiveaction/resources/guidance/sitechar/gwstats/ [accessed on April 17, 2013]

US Environmental Protection Agency (USEPA), 2010. ProUCL Version 4.1.00 Technical Guide (Draft), May 2012. Available from: http://www.epa.gov/osp/hstl/tsc/software.htm [accessed on April 17, 2013]

Figure E6.1 Flow Chart for Statistical Analysis to Calculate UCL and LCL for a Parameter Present Naturally in Groundwater



Appendix E6.1: Summary Statistics for Non-Detect Data

INTRODUCTION

This appendix describes the statistical procedures used to compute summary statistics for a dataset when non-detect data are encountered. By definition, non-detect (ND) data are those values below the corresponding laboratory reporting limits and are usually reported as less than reporting limit (<RL) values in a laboratory report. ND data are also called left-censored data.

CALCULATING SUMMARY STATISTICS FOR DATA SETS CONTAINING NON-DETECTS

Before one can plot a data series containing ND data in a box plot, one needs to estimate the summary statistics, such as mean, median, upper and lower quartiles. Taking into account the percentage ND observations and total number of observations (n), Table E6.1.1 presents the proposed statistical methods based on recommendations suggested in Helsel (2012, Table 6.11).

Table E6-1.1 Methods for Estimating Summary Statistics for Datasets Containing NDs

Percent ND	$n < 50$	$n \geq 50$
< 50%	Kaplan-Meier	Kaplan-Meier
50-80%	Robust ROS	MLE
>80%	Report only % above a meaningful threshold	Report high sample percentiles (90^{th}, 95^{th})

ROS: Regression on order statistics
MLE: Maximum likelihood estimation

As shown in Table E6-1.1, summary statistics cannot be obtained when the percent ND is greater than 80%.

The USEPA Unified Guide (USEPA, 2009) suggests that, when the percent ND is between 10% and 15%, the ND data can be substituted by one-half of the RL. This substitution is controversial; Helsel (2012) presents a list of papers in the literature pointing out such substitution will mask "*the signals that are present in the data*". If one is to develop a baseline line case using eight sampling events and using the EPA suggested 10% ND limit, the substitution method can only be used when there is only one ND result. Consequently, the substitution method, though simple to apply, is not considered for the present application.

The Kaplan-Meier (KM) method is a non-parametric method that can be used to estimate the mean and standard deviation of the underlying population. The basic assumption is that the dataset consists of a mixture of detects and non-detects, both coming from the same distribution (Helsel, 2012; USEPA, 2009). The procedure for KM is described in the Unified Guide (USEPA, 2009). This method is implemented in the public domain software ProUCL (USEPA, 2010) and in commercial software such as Sanitas Version 9.5 (Sanitas Technologies, 2012).

As described in the Unified Guide (USEPA, 2009), the robust regression on order statistics (ROS) method is a quasi-non-parametric method that assumes the combined group of detects and non-detects come from a common distribution. ROS imputes a distinct estimated value for each ND value and estimates the mean and standard deviation of the underlying distribution. This method is implemented in ProUCL (USEPA, 2010).

The Maximum Likelihood Estimate (MLE) is a parametric method that requires the assumption that a distribution (normal, lognormal or others) will closely fit the shape of the observed data (Helsel, 2012). Helsel (2012) also states that "*MLE estimates can be thought of as the statistics of the distribution most likely to have produced the observed data, both censored and uncensored…Checking this distribution assumption before computing estimates is a first step*". The MLE method is available in ProUCL (USEPA, 2010).

It should be pointed out when using ProUCL (USEPA, 2010), the "Summary Statistics/with NDs" option only provides simple statistics based on detected values". Estimates of mean, variance and percentiles for data with ND observations are given in other menu options such as background statistics and upper confidence limit calculations.

Appendix E6.2: Statistical Procedure for Outliers

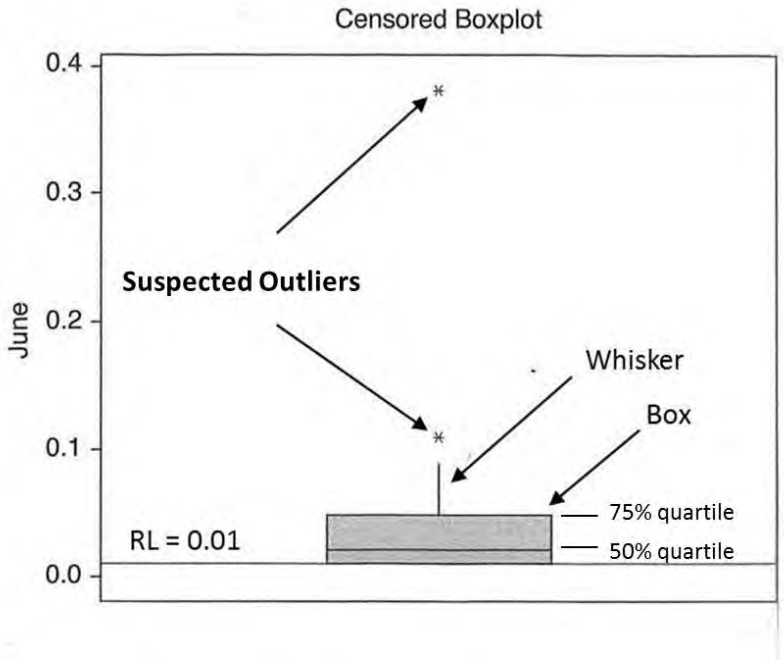
INTRODUCTION

An outlier is a data point that does not conform to the pattern established by other observations in the data set (Gilbert, 1987). Potential outliers can be detected graphically using box plots or q-q plots taking into account of any non-detect data (Helsel, 2012; USEPA, 2010). The appendix describes the procedure for data screening and validation for each potential outlier and the statistical procedure to test for outliers.

DATA SCREENING AND VERIFICATION FOR A SUSPECTED OUTLIER

The statistical procedure to estimate summary statistics for a dataset with non-detects (NDs) is described in Appendix E6.1. From the estimated quartiles (25%, 50% or median and 75%), a box plot can be drawn as shown in Figure E6-2.1. In a box plot, the box is typically bounded by the 25% and 75% quartiles. The length of the whisker is usually 1.5 times the inter-quartile range (Helsel and Hirsch, 2002). When ND data are present, the box is truncated by the reporting limit (RL). Data points outside the whisker are suspected outliers (USEPA, 2010).

Figure E6-2.1 A typical box plot for a dataset with ND data and suspected outliers (modified from Helsel, 2012)



The following steps can be taken to screen and verify suspect outliers:

1. Making routine checks during data entry and processing, *e.g.,* looking for errors in identification codes, sampling locations and sampling time, *etc.*
2. Comparing current data with historical data to check for consistency over time.
3. Ensuring that data have been correctly transmitted from the laboratory.

Steps 1 and 2 are suggested by Nelson *et al.,* (1980, quoted in Gilbert, 1987).

STATISTICAL TESTS FOR OUTLIERS

Statistical tests will be applied to a dataset with suspected outliers to confirm that they are outliers. Common statistical tests and their limitations are summarized in Table E6-2.1 based on USACE (2008, Appendix I).

Table E6-2.1 Statistical Tests for Outliers

Sample Size	Test	Assumes Normality	No. of Outliers
$n \leq 25$	Dixon's Extreme Value	Yes	1
$n \geq 25$	Rosner's Test	Yes	<10
$n \geq 60$ for $\alpha = 0.10$	Walsh's Test	No	>10

α = *significance level*

Although Dixon's test can only pick out 1 outlier at each application, it can be used repeatedly to identify multiple outliers. Table E6-2.1 also shows that Dixon's test and Rosner's test are only valid when the dataset is normally distributed. The non-parametric Walsh's test is only available for a large dataset. Normality test can be carried out using graphical plots such as a q-q plot or statistical tests such as Shapiro-Wilk (Gilbert, 1987). If a dataset is not normally distributed, Helsel and Hirsch (2002, Section 1.6) describe some methods that may transform the data closer to normally distributed and then apply Dixon's or Rosner's method to detect outliers.

Procedures for Dixon's test and Rosner's test are described in the Unified Guide (USEPA, 2009) and implemented in ProUCL (USEPA, 2010). The procedure for Walsh's test is outlined in USACE (2008).

A confirmed outlier will be removed from the control limit calculations but will be retained on the trend analysis and control chart plots.

Appendix E6.3: Mann-Kendall Trend Test

INTRODUCTION

The Mann-Kendall trend test is a non-parametric test for detecting monotonic trends at single or multiple monitoring locations (Gilbert, 1987). This procedure is useful since missing values and non-detect (ND) data are allowed.

MANN-KENDALL TEST

The Mann-Kendall test uses only the rank or relative magnitude of the data rather than their actual values. It is customary to assign the ND data a common value that is smaller than the higher reporting limit. Gilbert (1987) suggests that the test can be viewed as a non-parametric test for zero slope of the linear regression of time-ordered data versus time. The Directive prescribes using the Mann-Kendall test at 95% confidence level for trend analysis when there are four to seven data points. The result of a trend analysis is used to identify triggers (Step 5 of the Statistical Analysis Plan).

It is common for some groundwater parameters to show a seasonal trend, *e.g.*, water levels tend to fluctuate with the seasons. If seasonal cycles are present, seasonal Mann-Kendall tests that remove these cycles or are not affected by them should be used (Gilbert, 1987).

Detailed procedures for both Mann-Kendall and seasonal Mann-Kendall are described in the Unified Guide (USEPA, 2009) and Gilbert (1987).

The Mann-Kendall trend analysis is included in the free EPA software ProUCL (USEPA, 2010) but the seasonal Mann-Kendall trend test can only be found in commercial statistical software (*e.g.*, Sanitas).

Appendix E6.4: Shewhart-CUSUM Control Charts

INTRODUCTION

Shewhart-CUSUM Control Chart is a graphical tool used to quantitatively and visually track concentrations at a groundwater monitoring well over time to determine whether they exceed critical thresholds (called control limits), thus implying a significant change from baseline conditions (modified from the Unified Guide, USEPA, 2009).

The Directive prescribes using the Shewhart-CUSUM control chart method to calculate the upper control limit (UCL) and lower control limit (LCL) for an indicator parameter present naturally in groundwater at a compliance monitoring well after at least eight sampling events. The use of the Shewhart-CUSUM control chart assumes that the observations are statistically independent and either normally distributed or can be normalized by simple mathematical transformation. At present, non-parametric Shewhart-CUSUM procedures are not available in the literature.

PROCEDURE FOR USING THE SHEWHART-CUSUM CONTROL CHART METHODOLOGY TO CALCULATE CONTROL LIMITS

The procedure of plotting a Shewhart-CUSUM is detailed in the Unified Guide (USEPA, 2009). This section provides a summary of the key steps in using the Shewhart-CUSUM control chart for an indicator parameter as suggested by the Directive.

1. Check the dataset for normality using graphical plots or statistical tests. Graphical plots such as box plots (discussed in Appendix E6.2) or quantile-quantile plots provide a direct visual presentation of the data. For datasets without non-detect (ND) values, the common standard normality tests are the Shapiro and Wilk W-test, the Shapiro and Francia test and the D'Agostino test (Gilbert, 1987). For datasets with small to moderate fraction of ND data, the Kaplan-Meier test can be used (see Appendix E6.1). These statistical tests are implemented in the ProUCL software (USEPA, 2010).
2. If the normality test fails, normalize the dataset using simple mathematical transformation. The common transformation is the (natural) logarithm; other transformation methods are described in Helsel and Hirsch (2002). The transformation that provides the closest match to the normal distribution will be adopted.
3. Check the dataset for outliers (see Appendix E6.2) and trends (see Appendix E6.3). The Directive requires the data to be statistically independent, showing no trend and not containing verified outliers.
4. Compute the sample mean, $\bar{x}$, and sample standard deviation, s, taking into account any ND data (see Appendix E6.1).

5. Calculate the upper control limit, UCL, and lower control limit, LCL, using (ESRD, 2012): Plot the Shewhart-CUSUM control chart showing the time-series of the indicator parameter values, the cumulative sums (CUSUM), the UCL and LCL. A typical control chart is shown on Figure C-1 of the Directive.

$$UCL = \bar{x} + h.s$$

$$LCL = \bar{x} + h.s$$

Where: $\bar{x}$ = sample mean (arithmetic)
s = sample standard deviation
h = the control chart factor = 4.5 for this application

APPENDIX E7: PROTOCOLS

Monitoring Well Installation Protocol

General

1. All dimensions, depths, purge volumes to be recorded and dated.
2. All wells to be constructed of 51 mm ID PVC pipe.
3. Screen to have 10-slot openings.
4. Sand pack to be 10-20 sand or equivalent.
5. Silt socks may be placed over the screen.
6. All wells to have steel surface protector cemented into place with lockable lid and padlock.
7. Development is to be by bailer, air lift, pump and/or Waterra until water is acceptably free of sediment.
8. Hydraulic conductivity tests are to be done with bailer or solid slug – no introduction of water.
9. All wells to have elevation of top of casing established to a common datum.
10. Write name and depth of well inside the surface protector.

Water Table or Drift Monitor

Procedure for installation and completion of a water table monitoring well:

1. Drill to intended depth with solid stem augers recording the lithologies present.
2. Estimate the position of the water table and auger two metres beyond that depth.
3. Make up the well to have 2 m of screen below the estimated water table and 2 m of screen above the water table. Screen above water table can be reduced if it brings the screen within 0.5 m of surface.
4. Place well in borehole recording depth of bottom below ground surface.
5. Place sand pack to approximately 0.3 to 0.5 m above the top of the screen. Measure and record depth to top of final sand pack.
6. Backfill to surface with bentonite chips.
7. Install the steel protector in the ground with cement inside and out.
8. Follow well purging and hydraulic conductivity protocol.

Bedrock Monitor

Procedure for installation and completion of a bedrock monitoring well:

1. Drill to intended depth.
2. Completion:
   - As a conventional water supply well, or
   - Cased, cemented, and perforated.

Monitoring Well Development Protocol

1. Purge monitoring well until water is depleted or flows clean.
2. Purging methods can vary with the depth of the well and the depth to water. Acceptable techniques include:
   - Waterra;
   - Air lift with compressor;
   - Dedicated bailer; and
   - Submersible pump.
3. Record volume of water produced. Repeat as necessary to obtain clean water.

Hydraulic Conductivity Protocol

Hydraulic conductivity is to be determined using one of the following methods:

1. Introduction of a solid slug of known volume followed by measurements of water level recovery.
2. Withdrawal of a slug of water of known volume followed by measurements of water level recovery.

Hydraulic conductivity testing will be conducted only after the water level in the monitoring well has stabilized.

Analysis will be by accepted techniques.

Monitoring Protocol

1. Order appropriate bottles, preservatives, *etc.,* from the laboratory allowing for duplicate samples and possible breakage.
2. Check previous measurements and then measure and record current depth to water in the well.
3. Select the well(s) to provide the duplicate sample(s).
4. Purge monitoring well of two or more well volumes. Purging methods can vary with the depth of the well and the depth to water. Acceptable techniques include:
   - Waterra;
   - Air lift with compressor;
   - Dedicated bailer; and
   - Submersible pump.

   Measure (or estimate) amount purged and record. If the well is slow to respond this procedure could take several days.
5. Measure and record field parameters of electrical conductivity (EC), temperature and pH. Compare to previous measurements and determine if there is need for further purging.
6. Fill sample containers using a dedicated bailer, filtering and adding preservative as appropriate.
7. Duplicate samples are to be collected concurrent with the non-duplicate for that well for each individual bottle to be sent to the laboratory. This means for instance: collect the trace elements sample for regular analysis for that well followed immediately by the duplicate sample. This allows the water going into each bottle to be as similar as possible for the regular and the duplicate. Do **not** collect the full suite of bottles for the regular sample and then the duplicate.
8. Pack samples in cooler with ice; keep from freezing and ship/deliver to receiving laboratory.
9. Enter field parameters into the database as soon as possible.

APPENDIX F: AUTHENTICATION

AUTHENTICATION

The Engineering, Geological and Geophysical Professions Act (the Act) of Alberta requires that engineering, geological or geophysical work be authenticated by the application of:

- The professional seal or stamp of the individual member responsible for preparing the work **and**
- The corporate permit number or stamp of the company employing the responsible individual member.

This section identifies those portions of this report that fall under the Act and will be authenticated in compliance with the Act.

The report entitled:

Lindbergh SAGD Expansion Project
Hydrogeology

meets the definition of engineering or geology within the Act and is authenticated with APEGA Permit to Practice Number P07002 and the professional stamp applied below:

Millennium EMS Solutions Ltd. provides the same level of quality assurance to our clients throughout this report.