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HYDROGEOLOGY BASELINE STUDY
OIL SANDS LEASE 13

PREPARED FOR:

SHELL CANADA LIMITED

KI97-4577A **NOVEMBER 1997**

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1. INTRODUCTION

1.1 GENERAL

Shell Canada Limited is proposing to develop an open pit oil sands mine and bitumen extraction plant within the western part of the Bituminous Sands Lease 13. Related transportation and utility facilities would be established as well. The Lease is located 64 km north of Fort McMurray on the east side of the Athabasca River. The community of Fort MacKay is approximately 12 km southwest of the center of the Lease. The project lands occupy all or parts of Township 95 Ranges 9, 10 and 11, West of the 4th Meridian.

1.2 DEFINITION OF THE REGIONAL AND LOCAL STUDY AREAS

The EIA Study Areas, as defined by Final Terms of Reference, Environmental Impact Assessment (EIA) Report for the proposed Shell Canada Limited, Lease 13 Project, Fort McMurray, Alberta, include the Project Area, as well as, the spatial and temporal areas of individual environmental components outside the Lease 13 boundaries where an effect can be reasonably expected. With respect to this definition, the study area can be divided into:

1. Regional Study Area (RSA) is defined by the Athabasca River to the West, a line following McMurray Formation subcrop toward the east to the Firebag River (approximate location Range 6 Township 97 W4M). From this point, it extends southeast to a boundary between Ranges 5 and 6 W4M. The eastern limit is defined by a line separating Ranges 5 and 6 W4M to Township 90. The southern limit is this Township southern boundary which extends west to the Athabasca River (Figure 1). The RSA includes the following other oil sands projects: Lease 13 (Shell), Aurora North (Syncrude), Aurora South (Syncrude), Lease 13 (Mobil), Lease 30 (Gulf), Steepbank Mine (Suncor) and Project Millenium (Suncor).

2. Local Study Area (LSA) encompasses Lease 13 extending between Muskeg River and Athabasca River. The north boundary extends 2 km into Syncrude Aurora North Mine (Figure 2) and the South boundary follows a line separating Townships 94 and 95. This area includes open pit mine, tailings disposal areas, overburden and muskeg waste dump/storage areas, overburden drainage, bitumen extraction plant and associated utilities.

The RSA boundaries (Figure 1) were selected based on the following hydrogeological considerations:

1. Athabasca River to the west is a regional drainage feature controlling groundwater circulation in the Quaternary, Cretaceous and possibly upper sections of the upper part of

the Devonian Waterways Formation. Project impacts on groundwater regime will not extend to the west bank of the Athabasca River.

2. Northern boundary follows the northern subcrop of the Cretaceous age McMurray Formation to the Firebag River as shown by Green *et al.* (1962). Drawdown cone around mining operations in the Basal Aquifer will likely extend to its northern limit, which lies just south of McClelland Lake. Devonian age Waterways Formation sediments encountered within Lease 13 are usually of low hydraulic conductivity. Thus the cone of depression is not expected to extend for a large distance in these deposits.

3. Theoretical extent of the drawdown cone in the Basal Aquifer may reach tens of kilometres. Considering the Basal Aquifer's variable thickness, and possible lack of hydraulic connections between Devonian surface lows, it is not expected that a drawdown exceeding one to two metres will be observed at a distance exceeding 30 km. Thus, eastern and southern RSA boundaries were established within this approximate distance.

The LSA boundaries (Figure 2) were chosen based on the following hydrogeological considerations:

1. Overburden (Quaternary sediments and McMurray Formation rejects) drainage, tailings (TFT, MFT, CT) seepage, and potential contamination originating from the extraction plant and mining activities will not extend across Athabasca and Muskeg Rivers.

2. Drawdown promoted by overburden drainage will be limited to < 2 km from the mine pit and/or drainage network.

The proposed RSA and LSA were chosen based on interpretation of regional hydrogeological conditions. In our opinion, the coverage selected is conservative and extends beyond expected significant physical and environmental impact zones.

1.3 TERMS OF REFERENCE

Under the Alberta Environmental Protection and Enhancement Act, an Environmental Impact Assessment (EIA) is required for consideration of the Lease 13 Project. The EIA will also serve to provide information for Shell's application to the Alberta Energy and Utilities Board for project approval.

Terms of reference for the EIA issued by Alberta Environmental Protection (November 1997) in respect to groundwater include the following activities:

- discuss the groundwater regime of the Local Study Area by summarizing the existing regional databases including flow patterns, groundwater quality and interaction with regional groundwater flows;
- describe the effects of the Project on the existing groundwater resources of the Local Study Area, including water quality, quantity and thermal regime;
- discuss the effects of the Project on the Basal Aquifer;
- discuss the relationship between groundwater and surface water in the Local Study Area;
- describe groundwater monitoring programs and mitigative measures to address impacts on groundwater; and
- describe both the surficial and upper bedrock groundwater regimes in the Local Study Area.

Komex International Ltd. was contracted to provide a hydrogeological assessment as set out in the Terms of Reference. It consists of two major components:

1. evaluation of background conditions and preparation of a baseline report; and

2. assessment of the potential impacts and interactions associated with the proposed project developments and preparation of an EIA report.

1.4 PROJECT OBJECTIVES

The objectives of the hydrogeological evaluation (baseline and EIA) are to:

- establish background hydrogeological conditions (groundwater circulation and quality) in the study area;
- define present groundwater use in the Local Study Area;
- identify data gaps and recommend measures to eliminate these deficiencies;
- identify potential impacts of project development on groundwater resources;
- define groundwater/surface water interactions;
- evaluate potential impacts of groundwater on project development;
- develop a plan to mitigate any identified impacts of mine projects on the groundwater regime; and
- identify any adverse hydrogeological impacts that cannot be mitigated.

2. REGIONAL BACKGROUND INFORMATION

2.1 TOPOGRAPHY, DRAINAGE AND CLIMATE

2.1.1 TOPOGRAPHY AND DRAINAGE

The regional study area falls within the Saskatchewan Plain division of the Interior Plains physiographic region (Bostock, 1967). Adjacent to the northeast edge of the area is the Athabasca Plain, a subdivision of the Canadian Shield major physiographic region.

To the east of the regional study area is Muskeg Mountain, which rises to approximately 610 metres above seal level (masl). The regional study area itself is an area of subdued topography which slopes gently from Muskeg Mountain towards the Athabasca and Clearwater Rivers (Figures 1 and 2).

Lease 13 is relatively flat, although the ground surface generally slopes to the west toward Athabasca River valley. Ground surface elevations range from approximately 280 to 295 masl. Extensive muskeg deposits occur throughout the Lease. These are locally separated by granular material ridges of glaciofluvial origin.

The Athabasca River flows from south-southeast to north-northwest in a deeply incised valley. Water level in the river fluctuates seasonally. Approximate water elevation may be assumed to be on the order of 232 masl. An approximately 45 m high escarpment is present at the east bank of the river. This topographic feature corresponds to the western boundary of Lease 13. The Muskeg River flows from the northeast to southwest. This low gradient surface drainage feature forms the majority of the eastern boundary of Lease 13. Approximately 8 km south of the Lease 13 southern boundary, the Muskeg River joins the Athabasca River, the major drainage system in the region.

The Athabasca River is adjacent to the western boundary of Lease 13. Mean monthly flows between 1958 and 1994 for "Athabasca River below McMurray" (Environment Canada station #07DA001) are maximum in July (1,420 m^3/s) and minimum in February (164 m^3/s), data for 1974 - 1994 period, (Environment Canada, 1996). Mean monthly flows for "Muskeg River near Fort MacKay" (Environment Canada station #07DA008) are maximum in May (11.7 m^3/s), data for 1974 - 1994 period, and minimum in February (0.3 m^3/s, data for 1974 - 1987 period, (Environment Canada, 1996). A detailed description of the hydrological conditions in the study area is provided in Alsands Energy Ltd. (1981a) and Golder Associates Ltd. (1997b).

2.1.2 CLIMATE

The climate of the Fort McMurray area is characterized by long cold winters and short, cool summers. Available meteorological data for the area include:

1. long term records available for the Atmospheric Environment Service station at Fort McMurray (Environment Canada, 1994);

2. records kept at forestry lookout stations; and

3. results of a study of nine stations in the Athabasca oil sands undertaken by the Alberta Oil Sands Environmental Research Program (AOSERP) between 1976 and 1982 (Rudolph *et al.*, 1984).

Rudolph *et al.* (1984) show that, while precipitation is generally higher and temperature lower in the upland areas, the climate in the vicinity of Lease 13 is likely very similar to that in Fort McMurray. The following data are taken from the 30 year climate normals for Fort McMurray for the period 1961 - 1990 (Environment Canada, 1994), and are expected to closely approximate average conditions at Lease 13.

Mean monthly temperature varies between -19.8°C in January and 16.6°C in July. Temperatures recorded over the same period fall between extreme values of -50.6°C and 37.0°C. On average, the temperature stays below freezing for 121 days each year.

Precipitation is moderate, with an annual mean value of 465 mm of which 335 mm falls as rain and the remainder as snow. Precipitation is typically greater in summer than in winter, with mean monthly values of 79.1 mm in July, and 16.0 mm in February. There is typically snow on the ground between October and April. The average depth of snow on the ground at the end of February is 32 cm. The variation of temperature and precipitation with season is shown in Table 1.

Winds are typically moderate, with an annual mean speed of 10 km/h.

Potential evapotranspiration is estimated by Hackbarth and Nastasa (1979) to be 493 mm, slightly greater than the mean annual precipitation. Rudolph et al. (1984) measured pan evaporation daily at their Mildred Lake station in the Athabasca oil sands area. Their results are summarized in Table 2.

The mean daily rates listed in Table 2 may be summed to give a mean pan evaporation value of 824 mm for the period April to October. Negligible pan evaporation is expected to occur between November and March.

2.2 GEOLOGY

Several regional scale studies on the geology of the McMurray area have been carried out (Greiner, 1956; Carrigy, 1959, 1966, 1973a, 1973b; Norris, 1973; and McPherson and Kathol, 1977; Mossop and Shetsen, 1994). These references give detailed descriptions of the regional geology.

The first comprehensive survey of the geology of the Athabasca oil sands area was conducted by Carrigy (1959). The following summary of the geology of this area is based on that work, except where indicated. The table below summarizes the main stratigraphic units which occur within the regional study area. Formations noted in brackets are not present in the local study area. Figure 3a (from Green and Mellon, 1962) illustrates the bedrock geology of the regional study area. The legend is provided in Figure 3b.

A summary of main stratigraphic units, compiled from the above cited literature, is given in Table 3.

2.2.1 PRECAMBRIAN

Precambrian outcrops occur approximately 70 km northeast of Lease 13. Meta-sediments and granite are dominant rock types in this part of the Canadian Shield. The Precambrian rocks are usually considered to be of low hydraulic conductivity and it is expected that they form an impermeable base in the study area.

There is thought to be considerable topography on the Precambrian surface. In the study area two boreholes encountered rocks of Precambrian age at depths ranging between approximately 315 and 325 m below ground surface (W805027 and W751717).

2.2.2 DEVONIAN

Middle Devonian. Formations of the Elk Point Group are the oldest of the Devonian sediments in the regional study area. The deepest Formation in the Group is the La Loche, which consists of coarse grained arkosic sandstones which unconformably overlie the Precambrian basement. The Precambrian surface topography to a large extent controls the thickness of the La Loche Formation which may range between 0 and 40 m (Sproule and Associates, 1974). The shale, siltstone, and dolostone beds of the McLean River Formation (20 - 50 m thick) conformably overlie the La Loche Formation.

The Methy Formation conformably overlies the McLean River Formation, and is predominantly a reefal dolostone in the regional study area. The Methy Formation thins abruptly east of the Athabasca River, suggesting the presence of a reef front along the edge of the Canadian Shield (Hamilton, 1969). Sproule (1974) indicates formation thickness ranges between 0 and 80 m.

The Prairie Evaporite Formation forms the upper beds of the Elk Point Group and consists of halite and anhydrite. The greatest thickness (up to 240 m) of Prairie Evaporite in the regional study area occurs close to the Athabasca River. East of the River, the Formation thins rapidly before pinching out. This thinning is attributed to depositional shallowing, and post depositional solution weathering. The Prairie Evaporite is potentially of hydrogeological importance in the area due to the possibility of collapse structures in overlying beds and increasing groundwater salinity being generated by solution weathering of evaporites (McPherson and Kathol, 1977).

The Watt Mountain Formation conformably overlies older sediments. It is represented by an approximately 15 m thick shale bed (Sproule, 1974).

Upper Devonian. The Slave Point Formation in the Athabasca oil sands region is a thin rock unit (less than 15 m thick) consisting of limestone, silty limestone and siltstone. Mossop and Shetsen (1994) indicate that the Slave Point formation is Middle Devonian in age. The Slave Point Formation is bounded top and bottom by paraconformities.

The Waterways Formation comprises the main Upper Devonian rock unit which occurs within the regional study area. Crickmay (1957) subdivided the Waterways Formation into five members. In ascending order, there are: Firebag, Calumet, Christina, Moberly and Mildred. The different members of the Waterways Formation form a series of limestone beds with varying proportions of shale.

2.2.3 LOWER CRETACEOUS

McMurray Formation. The deepest Cretaceous strata in the regional study area are rocks of the McMurray Formation. These strata are separated from the underlying Devonian succession by a major erosional unconformity. The present stream profiles of the lower Athabasca and Clearwater Rivers are now controlled by the pre-Cretaceous erosion surface. Carrigy (1959) suggests that the McMurray Formation may have been deposited in a basin created by solution and removal of evaporite beds within the Devonian sequence. The McMurray Formation has been divided into four stratigraphic units by Carrigy (1959), as described below.

The Pre-McMurray Beds are a coarse grained, cemented quartzose sandstone thought to unconformably underlie the McMurray Formation (Carrigy, 1966), but are not commonly found in the regional study area.

The Lower Member of the McMurray Formation overlies the erosional surface on the Devonian strata, and its lowest beds consist of residual clays formed from weathering of Devonian limestones. These are overlain by coarse sands (the "Basal Aquifer") whose thickness is largely controlled by the topography of the erosional surface on the Devonian sequence. These sands are reported to contain large fragments of uncarbonized wood, well rounded quartz grains, numerous feldspar cleavage fragments, and small amounts of mica. At the top of this stratigraphic unit is found a black or dark grey carbonaceous shale (the "basal clays"), which contains wood fragments.

The Middle and Upper Members of the McMurray Formation consist mainly of an oil-cemented quartz sand, interbedded with lenticular beds of micaceous silts, shales, and in places, clay. The Middle Member, which generally occurs between elevations of 230 and 280 masl is characterized by frequent primary sedimentary structures, particularly current bedding, while the Upper Member is more commonly horizontally bedded. The Middle and Upper Members constitute the ore body being mined in the Athabasca oil sands area.

The Clearwater Formation conformably overlies the McMurray Formation. The deepest beds are composed of glauconitic sandstone and have been termed the Wabiskaw Member. Their distinctive olive green colour makes them useful as an easily identifiable marker bed throughout the area. The Wabiskaw Member grades up into a grey marine shale which makes up the remainder of this Formation. According to Green and Mellon (1962) (Figure 3a), the Clearwater Formation does not occur on Lease 13 but is present in adjacent leases.

Grand Rapids Formation. The Grand Rapids Formation is not found in the area of Lease 13. Where it does occur (further from the Athabasca River), it is described as a "salt and pepper" sand, generally uncemented, and consisting of fragments of quartz, feldspar, glauconite, chert, muscovite and biotite.

2.2.4 QUATERNARY

The surficial geology of the regional study area consists of deposits of Pleistocene and Recent age. These "drift" deposits range from lacustrine clays through a range of glacial and fluvial deposits to aeolian sand. Bayrock (1970) shows the distribution of types of surficial deposits over the regional study area (Figures 4a/b).

McPherson and Kathol (1977) indicate that the thickness of drift varies throughout the regional study area from less than 7.5 m up to 135 m. The thickest drift (typically 70 to 135 m) is identified in upland areas such as the north and west slopes of Muskeg Mountain, and in kame deposits (typically glacio-fluvial sand) in the Fort Hills area. Lease 13 is located in an area, bounded by the Athabasca River, the Fort Hills and Muskeg Mountain, where the drift is generally less than 25 m thick.

2.2.5 STRUCTURE

Two faults affecting the Precambrian surface are discussed by Hackbarth and Nastasa (1979). Of particular significance to the hydrogeology of the region is the Sewetakun Fault, trending from

Tp 81, R 3 to Tp 97, R 11, or approximately south south-west from Bitumount. This fault is discussed further in Section 2.3.

Another structural feature of importance is a post-Cretaceous collapse feature of approximately 60 m depth around Bitumount, known as the Bitumount Basin. This is thought to have been formed due to the solution of water soluble evaporite strata.

2.3 HYDROGEOLOGY

Composition and migration of formation fluids in Western Canada was studied by Hichon (1963, 1964, 1969a, 1969b) and Bachu and Underschultz (1993). The first general description of the regional hydrogeology of the Athabasca oil sands area is given in a report by Sproule and Associates (1974). Between 1975 and 1979 the Alberta Research Council (ARC) conducted a large scale hydrogeological study in the Athabasca oil sands region. A number of observation wells were installed, and existing oil industry exploration wells were utilized for groundwater monitoring by the ARC between 1975 - 1979 (Hackbarth, 1977a).

A detailed evaluation of Athabasca oil sands groundwater monitoring network is given in Piteau Associates Ltd. (1983). Papers of a regional nature include Hackbarth (1971, 1974a, 1974b, 1977a, 1977b, 1978a, 1978b, 1980a and 1980b), Hackbarth and Nastasa (1979), Ozoray (1977 and 1979), Ozoray *et al.* (1979), Schwartz (1979), and Slayback (1979).

A summary of geological, hydrological and hydrogeological studies conducted within Lease 13 area is given in the following Alsands Energy Ltd. documents (1978a, 1978b, 1979a, 1979b, and 1981b). Isotope hydrochemistry in the proposed Alsands project area is discussed in Wallick and Dabrowski (1982).

Operations at the Suncor and Syncrude mines have contributed greatly to the knowledge of hydrogeological conditions in the region. This has been further augmented by many papers published on various aspects of dewatering the Basal Aquifer and overburden (*i.e.*, lean oil sand and Quaternary sediments) (Coward et al., 1977; Coward et al., 1978; Kahil, 1968, 1969; Khan et al., 1982 and Martschuk et al., 1985).

It is generally considered that the following five groundwater-bearing intervals (listed in ascending order) are of regional significance in the Athabasca oil sands area:

- La Loche Formation;
- Methy Formation;
- water sand at the base of the McMurray Formation (Basal Aquifer);
- water-bearing lenses within the oil sands (Intra-orebody aquifers); and
- Quaternary deposits (Surficial aquifers).

These water-bearing zones are discussed in the following sub-sections. Hackbarth and Nastasa (1979) undertook one of the more complete regional hydrogeological studies, and the following is a summary of their work, except where indicated.

2.3.1 DEVONIAN

Devonian strata in the area are divided by Hackbarth and Nastasa (1979) into hydrostratigraphic units D1 and D2. The two units are, however, distinct only west of the Sewetakun Fault. The D1 unit comprises the Middle Devonian Methy and La Loche Formations. The D2 unit includes the Upper Devonian Waterways Formation. The two units are separated west of the Sewetakun Fault by Middle Devonian evaporite beds. East of the Fault, solution of the evaporite has resulted in the hydraulic connection of the two units.

Though control is sparse, the La Loche Formation in the McMurray area is known to vary in thickness from 0 to 40 m and to be permeable at some locations (Sproule and Associates, 1974). The McLean River Formation overlies the La Loche Formation, and is generally impermeable. In that case, it is expected to act as an aquiclude and to isolate La Loche water-bearing strata from shallower aquifers. Information on the Methy Formation is also sparse, but it is known to be porous and permeable at some locations.

The D2 unit in the regional study area (Waterways Formation) is relatively impermeable: it is reported to have a median hydraulic conductivity (K) of around 3×10^{-9} m/s. This unit is expected to act as an effective barrier to upward flow, except in areas where significant fracturing is present (such as the Sewetakun Fault). Hydraulic heads in both D1 and D2 units increase to the east and west away from the Sewetakun Fault (Hackbarth and Nastasa, 1979). This indicates that regional flow in both units is towards the fault. In addition, the hydraulic head in both units in the vicinity of the Sewetakun Fault is similar to the elevation of the Athabasca River (approximately 230 masl), which indicates that these units may discharge into the Athabasca River. The flow rates are not expected to be very high (Hackbarth and Nastasa, 1979).

Available hydrochemical data (Sproule and Associates, 1974) indicate that groundwater in the D1 and D2 units is predominantly of a sodium chloride type. Degree of mineralization varies considerably. Total dissolved solids (TDS) concentrations in the D1 and D2 units east of the Sewetakun Fault decrease rapidly from around 100,000 mg/L close to the Fault to less than 1,000 mg/L within approximately 10 km of the Fault. Higher salinities are found west of the Sewetakun Fault.

Recharge to the Devonian aquifers in the regional study area has been interpreted to occur by infiltration in upland areas east of the Athabasca River basin. Groundwater in the Devonian aquifers in the regional study area is interpreted to flow generally westward, dissolving remaining salts within the Prairie Evaporite. This would have caused, through geologic time, the westerly migration of the eastern edge of the Devonian salt. The possibility of salt solution causing fracture permeability in the Upper Devonian, and hence possible mixing of Devonian and McMurray waters has also been raised (Sproule and Associates, 1974).

2.3.2 LOWER CRETACEOUS

Cretaceous aquifers in the regional study area include the McMurray Basal Aquifer, minor Intra-orebody aquifers within the McMurray Formation, Wabiskaw Member of the Clearwater Formation, and the Grand Rapids Formation.

Throughout much of the regional study area the Basal Aquifer is present between the top of Devonian formations and the base of the McMurray oil-bearing sands. However, its thickness and other hydrogeological properties are controlled by the topography on the Devonian erosional surface, and thus show wide variation throughout the area. The distribution of hydraulic heads in the Basal Aquifer indicates that it may discharge to the Athabasca River. The discharge rate, however, is expected to be relatively insignificant when compared to the flow rate in the River.

Hackbarth and Nastasa (1979), report hydraulic conductivities for the McMurray Formation to range between approximately 10^{-4} to 10^{-9} m/s. Towards the high end, values are assumed to relate to the Basal Aquifer, while towards the low end, values would relate to actual oil sands. The hydraulic properties of the Basal Aquifer are of importance to any mining operation in the area.

The median hydraulic conductivity of the oil sand-bearing formations, calculated from laboratory measurements on re-packed oil sand samples has been reported to be 5×10^{-7} m/s, (Clark, 1960). Water-bearing lenses within the oil sands are generally of limited extent; the majority of the groundwater in the McMurray Formation occurs within the Basal Aquifer.

The Wabiskaw Member is expected to be of only minor significance as an aquifer, and, where present, will be treated together with the Quaternary overburden aquifers. The Grand Rapids Formation is porous, permeable and water-bearing, but as previously noted does not occur within the boundaries of Lease 13. Therefore, it is not discussed further.

Groundwater chemistry is quite variable throughout the McMurray Formation. Both sodium chloride and sodium bicarbonate types are present. Sproule and Associates (1974) report chloride concentrations ranging from less than 100 to approximately 15,000 mg/L, an increase in mineralization west of the Athabasca River, and a change from sodium bicarbonate to sodium chloride waters on moving from east to west of the River. They also note an increase of salinity with depth in many cases, and suggest that this is evidence of possible upwards migration of waters from Devonian strata into the McMurray Formation.

Hackbarth and Nastasa (1979) provide maps of TDS and chloride distribution in the McMurray Formation. These maps indicate chloride concentrations of the order of 1,000 mg/L east of the Athabasca River and an increase to values of approximately 5,000 mg/L on the west side. Sproule and Associates (1974), however, note that there can be sharp local variations in chloride concentrations superimposed on these larger scale trends.

2.3.3 QUATERNARY

Little detailed information is available concerning the stratigraphy and properties of the Quaternary aquifers. This is due to the fact that few of the boreholes in the area have adequate logs of the near surface deposits. It is expected that at least part of the Quaternary strata will be composed of coarser grained material and form locally important unconfined or confined aquifers. Significant Pleistocene buried channels may exist within the surficial deposits. Hackbarth and Nastasa (1979) give a frequency distribution for hydraulic conductivity in the glacial drift with a median value of approximately 10^{-5} m/s.

Hydrochemistry in the Quaternary deposits was reviewed by Sproule and Associates (1974). They concluded that the waters were generally of a calcium magnesium bicarbonate type with a mineralization of less than 1,000 mg/L TDS, but that the chemistry changed quite rapidly with depth to a sodium bicarbonate type with mineralization between 1,000 and 3,000 mg/L TDS. They reported chloride concentrations up to 750 mg/L for this unit.

2.4 HYDROGEOLOGICAL INFORMATION FROM SURROUNDING LEASES

Lease 13 is surrounded by other oil sands leases (Figure 2). To the north are Leases 10, 12 and 34, which are owned by Syncrude and are collectively known as the Aurora Mine North. To the east and northeast are Shell Leases 13 East, 88 and 89. Further east, southeast and northeast are Syncrude Lease 31 (Aurora South) and Mobil Lease 13. To the south is Gulf Lease 30 and approximately 25 km south of Lease 13 are Suncor Steepbank Mine and proposed Millenium Mine.

Available information from recent studies at the Aurora Mine (North and South) includes a hydrogeology baseline study (Golder Associates Ltd., 1996), an environmental impact study (Bovar Environmental, 1996) and supplemental information given in Syncrude Canada Ltd. (1997a and 1997b). Earlier work in this area includes Piteau Engineering Ltd. (1985). Description of hydrogeological conditions in the Steepbank Mine is provided in Klohn-Crippen (1996a and 1996b).

Alsands Energy Ltd. (1981b and 1982) and Golder Associates Ltd. (1996 and 1997a) reports provide summaries of chemical analyses from different aquifers in the Lease 13 and Aurora

Mines. Their findings regarding hydrochemical types and groundwater mineralization are summarized in Table 4.

The Devonian aquifers typically yield highly saline water, with sodium and chloride being the predominant ions. Overall, there is a trend from highly saline sodium chloride type waters in the Devonian formations at depth to fresh calcium bicarbonate type waters near surface. Groundwater in the Basal and Intra-orebody aquifers of the McMurray Formation shows a greater degree of mineralization than that in the Surficial aquifers, with sodium, bicarbonate and chloride ions present in more significant quantities. Groundwater samples collected during Syncrude's (Lease 34) April 1996 aquifer test indicate the presence of sixteen polycyclic aromatic hydrocarbons (PAHs) and alkylated PAHs as well as naphthenic acids (Golder Associates Ltd., 1996).

Groundwater in the Surficial aquifers is typically fresh, with a mineralization of less than 1,000 mg/L TDS. Bicarbonate and calcium are the predominant dissolved ions, with minor amounts of chloride and magnesium. Waters of this type would be considered typical of "young" (*i.e.,* recently recharged) groundwater.

The hydrogeological regime in Aurora Mines (North and South), Steepbank Mine and Lease 13 is broadly consistent with the regional situation described in this section. Overall, the hydrogeological findings at these projects are consistent with (while adding further detail to) the regional picture described by Hackbarth and Nastasa (1979).

2.5 PRESENT GROUNDWATER USE

A search was conducted to find the locations of water wells on record with Alberta Environmental Protection (AEP), in an area defined by Township 94-96 and Range 9-11 W4M. Table 5 summarizes the number of wells on file with AEP within the areas of each of the current leases, the recorded well owner, and the proposed use. Further details of these wells are included in Appendix I.

The water well records obtained show an absence of domestic water wells (*i.e.*, no potential groundwater receptors via water wells). Most wells appear to be of a test or exploration variety. A field-verified survey of water wells in this relatively remote study area was not conducted.

3. SUMMARY OF HYDROGEOLOGICAL EXPLORATION PROGRAMS - LEASE 13

3.1 INITIAL PHASES, 1971 - 1973

During a 1971 exploration program two groundwater samples were collected from Intra-orebody water-bearing zones, and one groundwater sample was collected from the Basal Aquifer. These samples were analyzed for major and minor ions as well as selected general parameters (electric conductivity and pH). No records are available on monitoring well installation and sampling procedures. It is possible that these samples were collected using drill-stem testing equipment.

The first documented hydrogeological exploration at Lease 13 was initiated in May 1972. One water well and five observation wells were drilled as part of this program (Leggette, *et al.*, 1972). During July and August 1972, Leggette, *et al.* (1972) conducted an aquifer test. This test provided the first reliable data on Basal Aquifer hydraulic characteristics and water quality. This information was required for preliminary design of the test pit depressurization system.

The second Basal Aquifer test was initiated in 1973. The main objectives of the program were to obtain more information on hydraulic properties of the Basal Aquifer, observe the effects of long term pumping on the groundwater (potentiometric) surface and to verify the validity of the Leggette *et al.* (1972) proposals regarding the design of a proposed dewatering scheme. The groundwater observation system included the 1972 system (water well and five observation wells) and two additional observation wells drilled in 1973 (de Korompay, 1973).

In 1972 one deep hole penetrating the Methy Aquifer was drilled (W72-1240). Losses of circulation during drilling, relatively high groundwater yield, high piezometric pressure and water salinity caused concern regarding the potential impact of this aquifer on mine design and operations. To map the Methy Aquifer and to determine its hydrogeological regime, three additional deep holes (W73-1404, W73-1481, W73-1489) were drilled and tested in 1973 (de Korompay, 1973).

3.2 TEST PIT DEPRESSURIZATION, 1974 - 1975

In preparation for the Test Pit excavation in early 1974, Shell Canada Limited installed three additional water wells and several observation wells. Depressurization of the Basal Aquifer was initiated in March 1974. Groundwater surface measurements were recorded and a number of water samples for chemical analysis were collected. In the fall of 1974 Hydrology Consultants Ltd. were contracted by Shell to assist in the evaluation, design and supervision of Basal Aquifer depressurization. Following the consultants recommendations, Shell installed five additional wells outside the Test Pit. Data on well construction, performance and effects of depressurization on groundwater surface are summarized in the "Summary Report on Control of Groundwater for Shell Canada, Lease C-13, Alberta" (Hydrology Consultants Ltd., 1976).

3.3 ALSANDS ENERGY LTD., 1978 - 1982

3.3.1 DEVELOPMENT OF HYDROGEOLOGICAL PROGRAM, 1979

In the summer of 1979, Alsands Energy Ltd. began preparation for a detailed hydrogeological exploration program required for mine plan development.

The first phase, conducted in the fall of 1979, included:

- a review of the existing data;
- identification of potential hydrogeological concerns related to mine development;
- recommendations for the Winter 1980 hydrogeological exploration program; and
- recommendations for on-going studies.

Based on the above information, Alsands Energy Ltd. developed a long range hydrogeological exploration program, which was initiated during the winter of 1980 (Leggette, *et al.*, 1979; EBA Engineering Consultants Ltd., 1979).

3.3.2 GEOTECHNICAL EXPLORATION PROGRAMS, 1978 - 1981

The objective of geotechnical exploration programs conducted in various areas (e.g., Fresh Water Intake, Alternate Water Intake, Temporary Water Intake, Plant Site, Tailings Pond and Mine Site) was to assess foundation conditions, potential seepage and drainage/dewatering requirements. These studies further contributed to the understanding of geological conditions in the Quaternary sediments and Cretaceous formations (*i.e.*, Clearwater, McMurray). During the course of these exploration programs, information on groundwater occurrences, depth to groundwater surface, and hydraulic properties of different sediments were collected. A brief summary of activities is given below.

Fresh Water Intake Areas

The objective of the 1980 Winter geotechnical exploration program conducted by Hardy Associates (1978) Ltd. was to provide baseline information required for a design of the Freshwater Intake in the Isadore's Lake area. Depth of exploration ranged from 4.5 m (80-WI-12) to 87.8 m (80-WI-14). Sixteen holes were drilled around the southern part of the lake. Ten "stand-pipe" and eight pneumatic piezometers were installed in these holes. Groundwater monitoring devices were installed in Quaternary and Cretaceous sediments (upper zone and in the White Sand - Basal Aquifer). Detailed description of this exploration program, including piezometer installation details, is given in Hardy Associates (1978) Ltd. (1980b).

An Alternate Water Intake area located east of the northern part of Ings Island was investigated by EBA Engineering Consultants Ltd. Twenty boreholes were drilled on the river bank and through ice. Depth of exploration ranged from 3.5 to 15.4 m. Fifteen standpipes were installed in the Cretaceous sediments. Detailed description of this exploration program, including standpipe installation details, is given in EBA Engineering (1981b).

Temporary Water Intake area, water supply line and drainage facilities located at approximate northing 6351800N investigated by EBA Engineering (1981c) are located outside of the present project area in the Aurora North Leases.

Plant Site

The objective of the Winter 1980 geotechnical field exploration program conducted by Hardy Associates (1978) Ltd. was to collect sufficient subsurface information for a site preparation and general foundation conditions assessments. Forty-six boreholes were drilled to determine stratigraphy and lithology of geological units intersected. Depth of exploration ranged from 5.1 m (80-P-32, 80-P-39) to 25.05 m (80-P-10). Standpipes were installed in a total of 17 boreholes intersecting various Quaternary and Cretaceous (upper zone) sediments. Detailed description of this exploration program is given in Hardy Associates (1980a).

The second phase of detailed geotechnical investigations was undertaken by EBA Engineering in February 1981. The objective was delineation of subsurface conditions and assessment of their significance to the location of the proposed plant facilities. A total of 104 boreholes were drilled in the plant site area. Depth of exploration ranged from 1.0 m (815166G) to 30.2 m (815122G). Standpipe piezometers were installed in 48 boreholes intersecting Quaternary and Cretaceous sediments (Clearwater Formation locally and McMurray Formation throughout the area). Detailed description of this exploration program is given in EBA Engineering (1981d).

It should be noted that only a few holes were drilled by Hardy Associates and EBA Engineering south of latitude 6351000N (present northern boundary of Lease 13). All other holes are located outside of the present local study area. Information gathered from these investigation advances general knowledge of hydrogeological conditions in the regional study area.

Tailings Pond

In the summer of 1978 and winter of 1980, R.M. Hardy Associates (1978) Ltd. conducted geotechnical investigations in the proposed tailings pond area. In 1978, only 12 holes were drilled due to difficult access conditions. Depth of holes ranged from 9.4 m (78-TP-11) to 25.5 m (78-TP-9). Standpipes were installed in nine holes and groundwater levels recorded. Preliminary site assessment results are described in R.M. Hardy & Associates (1978a and 1978b).

The Winter 1980 program was designed to provide detailed subsoil information to enable preliminary design for the starter and final dykes. A total of 79 boreholes were drilled in the tailings pond area, concentrating along the proposed dyke outline. Depth of exploration ranged from 2 m (80-TP-16, 80-TP-83) to 16.5 m (80-TP-109) intersecting Quaternary and Cretaceous sediments (upper part). Twenty-two standpipes were installed to facilitate groundwater surface elevation measurements. Depth to groundwater surface was also recorded in the majority of holes following completion of drilling. Detailed description of this exploration program is given in Hardy Associates (1980c).

Mine Site

The objective of the 1979 and 1980 exploration programs was an overall geotechnical and geological evaluation of overburden in the 25-year mine area. Approximately 230 boreholes were drilled in the mine area. Depth of investigation ranged from 1.5 m (80-MS-162) to 19.8 m (80-MS-208). Upon completion of each boring, standpipes were inserted into the open holes. The standpipes were left protruding up to 1 m above ground level. These installations were installed to permit monitoring of groundwater levels during drainage of the proposed mine area. Detailed description of these exploration programs is given in Dames & Moore (1979, 1980) and Reimchen Surficial Geology Ltd. (1980).

3.3.3 GROUNDWATER EXPLORATION PROGRAMS

These programs were designed to provide hydrogeological information on bedrock aquifers, namely the Lower Cretaceous - Basal Aquifer and Middle Devonian - Methy Formation. These groundwater-bearing zones are considered to be of regional significance and are important to the project from both environmental and technical perspectives. In the course of these activities some shallow piezometers (Quaternary and Cretaceous - upper part) were also upgraded to ensure that groundwater samples and water level measurements related to a discrete interval. The following is a brief description of three exploration programs.

Piezometer Installation, Winter 1980

During the Winter 1980 program, the following instruments were installed within Lease 13 area:

- nine piezometers in the Basal Aquifer; and
- two observation wells in the Methy Aquifer.

Recognizing the importance of hydrochemistry in the evaluation of hydrogeological conditions, an extensive program of groundwater sampling and laboratory testing was conducted.

Details on piezometer construction, development, recovery tests and groundwater sampling procedures are described in a report by EBA Engineering Consultants (1980a).

Groundwater Monitoring, Summer 1980

This program included upgrading of 33 piezometers installed in the overburden and the re-development and upgrading of 33 Basal Aquifer piezometers.

Selected shallow (overburden) piezometers were bailed and water samples were collected for chemical analysis. All piezometers in the Basal and Methy Aquifers were evacuated using compressed air. Groundwater surface recovery was recorded to enable calculation of hydraulic conductivity and groundwater samples were collected for chemical analyses.

Groundwater monitoring was conducted from June to September, 1980 (EBA Engineering Consultants Ltd., 1980b). A summary of hydrogeological exploration programs covering the period ending in 1980 is given in Alsands Energy Ltd. (1981b).

Expansion of Groundwater Monitoring Network, Winter 1981

The program included installation of 10 piezometers in the Basal Aquifer and upgrading of seven piezometers in the Methy Formation. All new piezometers were developed, hydraulic conductivity tests conducted and groundwater samples collected for chemical analyses. Depth to groundwater surface in a number of shallow piezometers was also measured. The objective of this program was to provide additional information required for evaluation of the potential impact of groundwater on mining and the potential affect of mining on groundwater resources in the project area. This includes evaluation of:

- technical aspects of depressurization and dewatering of the Basal Aquifer;
- potential hydraulic connection between Methy Formation and Basal Aquifer; and
- groundwater quality.

Detailed program description and analytical results are given in EBA Engineering Consultants Ltd. (1981a) report. A summary of hydrogeological activities conducted in 1981 is provided in the draft report "Groundwater Hydrology, 1981 Exploration, Alsands Project" (Alsands Energy Ltd., 1982).

3.4 HYDROGEOLOGICAL ASSESSMENT

As part of the mine feasibility assessment, Komex was retained by Fording Coal Ltd. in 1996 to provide a hydrogeological evaluation of potential effects of mine development on the groundwater flow system. The specific objectives of this project were to:

- calculate potential groundwater inflows to the proposed mine blocks;
- perform a preliminary depressurization/dewatering analysis; and
- assess potential impacts from dewatering on streamflow in the Muskeg and Athabasca Rivers.

Program description and assessment results are provided in Komex (1996).

3.5 1997 EXPLORATION PROGRAM

3.5.1 MARCH/APRIL

During this program, Golder Associates Ltd. installed five shallow piezometers (Quaternary interval) along Muskeg River, north of Isadore's Lake and a double (Intra-orebody and Basal Aquifer) piezometer east of Isadore's Lake.

The objective of this program was to enhance the groundwater database for the EIA by collecting the following information:

- geological profile, hydraulic properties, depth to groundwater surface and groundwater quality in the Quaternary deposits present along the Muskeg River; and
- depth, thickness, hydraulic properties, vertical hydraulic gradients and groundwater quality in the Basal Aquifer near Isadore's Lake.

A groundwater sample collected from piezometer MW97-3 completed within Quaternary silty medium grained sand overlying oil sands (3.0 - 5.2 m below ground surface) was submitted for an inorganic and organic laboratory analyses. The results confirmed that this groundwater is typical for this aquifer's ionic composition (HCO_3-Ca-Mg hydrochemical type with a mineralization of TDS = 307 - 416 mg/L).

Organic analysis detected measurable phenol concentration (0.4 µg/L) and presence of nine PAHs and alkylated PAHs (Golder Associates Ltd., 1997a) in concentrations not exceeding 0.16 µg/L (per compound).

Program description and interpretation of the hydrogeological data are provided in Golder Associates Ltd. (1997a).

3.5.2 OCTOBER

An inventory of twenty-seven piezometers selected for Winter 1997/98 sampling program was planned. The program objectives are as follows:

1. to find and mark piezometers to allow easier location during the winter program;
2. to assess each piezometer technical status and suitability for sampling; and
3. to check for the presence of H_2S using olfactory method.

Seven Methy Aquifer, fifteen Basal Aquifer and five Quaternary aquifers piezometers were originally selected. The field verified survey confirmed the existence of all Methy installations in acceptable technical state. Fifteen Basal Aquifer piezometers were located. More than half (eight) were found in good technical state, while seven were damaged to various degrees. It is expected that the majority of the damaged piezometers can be repaired. Only one Quaternary installation was found in good technical state. Two other piezometers were not located in the field. Time restriction did not allow a search for the remaining two piezometers.

Hydrocarbon odour was detected in four of the Basal Aquifer installations. None of the groundwater samples collected from this aquifer had H_2S odour.

4. HYDROGEOLOGY OF THE LOCAL STUDY AREA

Hydrogeological investigations within Lease 13 span a period between 1971 and 1997. Work was done by Shell and a number of consulting companies. Description of program objectives and methodology is usually given in the summary reports (see References in Section 8). Most of these programs were discussed and referenced in the previous section of this report.

With the advent of increasing environmental awareness, groundwater has become recognized as a valued environmental component. Over the past two decades considerable progress has been made in monitoring well design, construction materials, development, sampling techniques, sample preservation and laboratory techniques. These technological and scientific advances have contributed to the higher quality of hydrogeological data collected during more recent programs.

This does not necessarily indicate, however, that data collected in the more distant past are of limited value. On the contrary, exploration programs which followed historically established and proven methodology remain valid and useful in evaluation of local and regional hydrogeological conditions. To support this view, it is noteworthy that the 1980 - 1981 programs confirmed 1971 - 1975 exploration findings, and recent (1995 - 1997) studies in Aurora Mine, Steepbank Mine and Lease 13 are confirming groundwater circulation and quality data collected during the 1971 - 1981 investigations.

A detailed description of hydrogeological programs within Lease 13 including methodology of piezometers installation, development, testing, sampling, and chemical analyses are given in EBA Engineering (1980a, 1980b and 1981b) and Alsands Energy Ltd. (1981b and 1982).

A summary of the early hydrogeological exploration programs and interpretations is given in Alsands Energy Ltd. (1981b). Detailed description of Lease 13 geological conditions is given in Shell Canada Limited (1997). The following description is based on Alsands Energy Ltd. (1981b) updated with 1981 and 1997 exploration results.

According to archival records there are:

- 7 monitoring wells which intercept the Middle Devonian Methy Formation, with 7 chemical analyses of groundwater;
- 35 monitoring wells installed in the Lower Cretaceous Basal Aquifer, with 60 chemical analyses of groundwater;
- 31 monitoring wells installed in the Lower Cretaceous Intra-orebody and near the contact with Quaternary deposits, with 14 chemical analyses of groundwater; and
- 39 monitoring wells installed in Quaternary deposits, with 18 chemical analyses of groundwater.

It should be noted that these wells and analytical data do not include standpipes installed in the course of geotechnical exploration work and chemical analyses which show anomalous groundwater quality results due to drilling fluids and/or cement filtrate influences.

Analytical schedules commonly include main ions (calcium, magnesium, sodium, potassium, bicarbonate, sulphate and chloride), minor ions (iron, manganese and fluoride), general parameters (EC, pH and TDS) and, in selected cases, total metals. The 1997 program included analyses for a number of organic compounds.

The purpose of the groundwater monitoring system was to establish groundwater baseline conditions, collect data required to evaluate potential changes in the groundwater regime as a result of proposed mine development and plant operations, as well as to assess groundwater impact on Project development.

The following is a summary of hydrogeological conditions in the main groundwater-bearing units given in ascending order from the oldest (La Loche Formation) to the youngest (Quaternary sediments). Locations of piezometers (observation wells) in the major groundwater-bearing units are shown on Figures 5 (Methy Formation), 6 (Basal Aquifer), 7 (Intra-orebody) and 8 (Quaternary). The relation between different units along selected lines (Figure 9) is shown on schematic hydrogeological cross-sections in Figures 10, 11 and 12.

4.1 LA LOCHE FORMATION

This formation is located beyond the zone potentially affected by the proposed mining operation, thus no piezometers were installed in this unit.

Drill stem tests (DST) conducted in hole W805021 (now outside of the project area, within Aurora North Leases) and W805027 indicate the presence of groundwater-bearing zones with highly variable thickness and hydraulic properties. The potentiometric surface (converted to equivalent freshwater) stabilizes approximately 25 m below ground surface (W805021) and approximately 12 m above the Methy Aquifer (Alsands Energy Ltd., 1981b). The drill stem tests conducted within high porosity intervals indicate hydraulic conductivity ranging from practically zero to $2x10^{-5}$ m/s. Due to insufficient number of observation wells, groundwater flow direction and velocities cannot be readily defined within this stratigraphic unit.

Only one groundwater sample was collected from this formation (W805021). Groundwater pH was 8.0, mineralization approximately 172,000 mg/L TDS and chloride concentration 102,206 mg/L. This brine represents a sodium-chloride hydrochemical type (Alsands Energy Ltd., 1981b).

4.2 METHY FORMATION

This unit is underlain by a 18 to 48 m thick layer of low hydraulic conductivity McLean River Formation. Observed differences in piezometric elevations between La Loche and Methy Formations indicate that these units are hydraulically separated by intervening McLean River sediments. Location of piezometers completed within the Methy Formation is given on Figure 5. Piezometer completion details, groundwater surface elevations and hydraulic conductivity values are shown in Table 6A.

Groundwater surface elevations in this confined groundwater-bearing zone, as measured in March, 1981 range between 256 masl (W8015039) and 267.8 masl (W731489) (Figure 13). Some of these elevations may represent resultant groundwater surface elevations originating from relatively long sand pack and/or screen interval completions. The hydrographs presented in Alsands Energy Ltd. (1981b) indicate that very small temporal changes (<0.5 m) occur in groundwater surface elevations. This indicates hydraulic isolation of this groundwater-bearing zone.

The Methy Formation includes zones of highly variable hydraulic conductivity. Based on two DST tests, Alsands Energy Ltd. (1981b) reports hydraulic conductivities ranging from unmeasurably small to $3x10^{-6}$ m/s, and from $7x10^{-10}$ to $3x10^{-9}$ m/s based on analysis from two cores. Piezometers completed in this formation indicate hydraulic conductivities ranging from $2x10^{-9}$ m/s to $>1x10^{-4}$ m/s. Zones of high hydraulic conductivity, and associated high yields encountered during piezometer development are most likely limited to reefal build-ups.

Distribution of hydrochemical types and groundwater mineralization, and chloride concentrations within this stratigraphic unit are shown on Figures 14 and 15, respectively. Hydrochemical data are summarized in Tables 8A and 9A.

Groundwater in this unit represents a sodium-chloride hydrochemical type, with mineralization ranging from 9,824 to 78,666 mg/L TDS. This variability is most likely related to either inadequate piezometer development and/or piezometer designs. Sampling during the winter 1997/98 program, more than 15 years following piezometer reconstruction, should clarify the issue of groundwater mineralization.

During the 1980/81 groundwater quality monitoring programs, samples were taken for total metal analyses. The results indicate the presence of high and very high concentrations of some metals (Tables 8A and 9A). These anomalous results are most likely related to high levels of suspended solids and thus are not likely representative of actual concentrations of metals dissolved in groundwater.

For example, during observation well (piezometer) drilling and installation activities, residual drill cutting and materials introduced for construction (sand, bentonite) are usually present. Despite initial development, associated particles may continue to enter the well. When high concentrations of the suspended solids are present and an unfiltered sample is then acidified, the particles become dissolved. Analysis of such a solute loading will represent combined chemistry of water and solids.

In our opinion, analyzing for total metals does not provide replicable results and does not describe natural groundwater chemistry. In the future, analysis for dissolved metals should be conducted.

Hydrogeological cross-sections A-A' and B-B' (Figures 10 and 11) show schematically the relation between Methy Formation and other hydrogeological units in the Lease 13 area. An issue of potential hydraulic connection between Methy and Basal Aquifer, and its impact on proposed mine development, has been raised in the past.

Hydrogeological information available to date indicate that such a hydraulic connection does not exist. The factors leading to this conclusion are as follows:

- piezometric pressures in the Basal Aquifer and Methy Formation are different (Tables 6A and 6B; Figures 10 and 11);
- during long term Basal Aquifer dewatering, associated with the test pit excavation, no drawdown was observed in the Methy Formation (Alsands Energy Ltd., 1981b);
- low seasonal groundwater surface fluctuations in the Methy Formation indicate hydraulic isolation from shallower units (including the Basal Aquifer);
- groundwater chemistry and mineralization is significantly different in both zones (Tables 8A and 8B) and Alsands Energy Ltd. (1981b). Environmental isotopes further confirm isolation of these two groundwater-bearing zones (Wallick and Dabrowski, 1982); and
- the Prairie Evaporite Formation, Watt Mountain Formation and Beaverhill Lake Group, representing in excess of 100 m of low hydraulic conductivity sediments, are acting as an aquiclude, effectively separating the Methy Formation and Basal Aquifer.

In an unlikely event that a hydrogeological "window" between the Methy Formation and Basal Aquifer is opened, in our opinion, saline groundwater inflows can be controlled using a conventional engineering approach. Grouting of groundwater circulation routes may be the best approach in achieving separation between those two aquifers. This should be feasible due to the following factors:

- relatively small differences (10 to 20 m) in piezometric levels exist between the two zones of concern;

- presence of thick sequence (>100 m) of low permeability sediments separating both geological units;
- relatively small storage of saline water within reefal build-ups in Methy Formation; and
- possible lack of hydraulic connection between reefal build-ups.

4.3 BASAL AQUIFER

This confined aquifer is underlain by low hydraulic conductivity basal clay (if present) and Beaverhill Lake Group sediments (Alsands Energy Ltd., 1981b). Locally, groundwater may occur within the upper Devonian fractured zones and/or the weathered uppermost part of this stratigraphic unit. In this instance, it is expected that the upper zone would remains in hydraulic communication with the overlying Basal Aquifer.

The Basal Aquifer is represented by fine to coarse grained sand (0 to 40 m thick) deposited on the erosional surface of Upper Devonian sediments. A number of monitoring wells were installed in this major aquifer (Figure 6). Piezometer completion details, groundwater surface elevations and hydraulic conductivity test results are summarized in Table 6B.

Groundwater surface elevations range from 230.9 to 289.9 masl. Depth to groundwater surface varies from less than 2 m to more than 60 m below ground surface. The vertical hydraulic gradient between the Basal Aquifer and Methy Formation is downward in the mine area and upward in the area adjacent to the Athabasca River. Hydrographs obtained from Basal Aquifer piezometer measurements indicate that very small seasonal changes occur in groundwater surface elevations. In most cases, these fluctuations do not exceed 1 m (Alsands Energy Ltd., 1981b). Small amplitude and lack of a distinct seasonal trend in the groundwater surface elevation fluctuations indicate that direct recharge to the Basal Aquifer occurs far beyond the local study area.

Significant recharge will occur in the areas where McMurray Formation basal sands are subcropping below permeable Quaternary sediments or are outcropping at the ground surface. The presence of tritium in pore water, obtained from oil sands indicates that groundwater in the Basal Aquifer is also recharged through the oil sands. In some areas, (lean oil sands and higher permeability sediments), such recharge may occur within a timeframe of 5 - 10 years (Wallick and Dabrowski, 1982). Where thick layers of high grade oil sands are present, recharge rates will be much slower.

A potentiometric surface contour map for the Basal Aquifer is shown as Figure 16. It shows that in the proposed mine area, groundwater surface elevations range from approximately 275 masl to 289.9 masl.

Although not confirmed, the change in hydraulic gradient west of the proposed mine may reflect a constriction of groundwater flow in the Basal Aquifer. This may be due to relief variations on the Devonian surface which in turn would directly impinge on Basal Aquifer thickness. This may also reflect an overall increase in the hydraulic conductivity of the Basal Aquifer adjacent to Athabasca River. For example, hydraulic connection between the Basal Aquifer and the Athabasca River is inferred to occur in the vicinity of piezometers W805053, W805054, and MW97-42, where groundwater surface elevations (230 - 235 masl) are comparable with elevations in the Athabasca River (230 - 235 masl).

Groundwater flow is generally toward the west with hydraulic gradients ranging between approximately 0.002 (in the proposed mine area) to 0.025 (in the zone of steep hydraulic gradients west of the proposed mine area).

Aquifer tests on Lease 13 performed between 1972 and 1974 were interpreted to give a range of hydraulic conductivity of $2x10^{-5}$ to $3x10^{-4}$ m/s with a geometric mean of $5x10^{-5}$ m/s (Alsands Energy Ltd., 1981b). In addition, 26 single well tests were performed during development of wells in 1981. Sixteen of the wells gave a range of hydraulic conductivity from $1x10^{-5}$ to $>1x10^{-4}$ m/s (Table 6B), which is similar to the range found from the aquifer test referred to above. Ten of the wells gave lower values, in a range of $5x10^{-8}$ to $7x10^{-6}$ m/s (Alsands Energy Ltd., 1981b and 1982). These lower values may be related to some degree of plugging of the piezometer screen with heavy oil, or placement of the screen within oil sands where Basal Aquifer is absent.

Other measurements of hydraulic conductivity based on pumping tests in the Basal Aquifer are also available. Golder Associates Ltd. (1996) refers to the analysis of pumping test on Lease 34 (Aurora Mine North) which was analyzed to give a transmissivity ranging from 21 to 61 m^2/d. If a Basal Aquifer thickness of 25 m is assumed (based on isopach maps in Golder Associates Ltd. (1996), then a range in hydraulic conductivity values of $1x10^{-5}$ to $3x10^{-5}$ m/s may be calculated.

Based on the results of these aquifer tests, it appears that the Basal Aquifer (clean sand) in the Lease 13 area has a hydraulic conductivity in the range of $1x10^{-5}$ to $>1x10^{-4}$ m/s. Lower values are associated with oil saturated sands.

Storativity for the Basal Aquifer was calculated from each of four aquifer tests (1972 - 1974) referred to in Alsands Energy Ltd. (1981b). A total of fourteen values were requested. Eleven were within a 0.00001 - 0.0001 range. The two tests conducted in 1974 yielded higher values up to 0.02 which would be considered unusual for a confined aquifer and one was 0.001. Analysis of aquifer tests at OSLO Lease 31 yielded storativity values between $2.2x10^{-5}$ and $1.3x10^{-4}$. Analysis of the 1996 aquifer test at Lease 34 (Aurora Mine North) gave values ranging from $4x10^{-5}$ to $3x10^{-4}$ (Golder Associates Ltd., 1996).

Based on these aquifer tests, it would appear that the Basal Aquifer in the Aurora Leases and Lease 13 has a storativity in the range $1x10^{-5}$ to $4x10^{-4}$ m/s, typical of a confined aquifer.

In the past programs (1971 - 1981), field measurements of pH, electrical conductivity were not taken. The 1997 results for these parameters are presented in Table 7A. All groundwater analyses representing natural water quality are summarized in Tables 8B and 9B. Samples showing signs of anomalous values due to either drilling fluids and/or cement filtrate influences were excluded from this evaluation.

Distribution of hydrochemical types is shown on Figure 17. Groundwater represents mostly Na-Cl-HCO_3 and Na-HCO_3-Cl hydrochemical types, with mineralization ranging between 1,430 and 7,407 mg/L TDS. An anomalous hydrochemical type was encountered in piezometer W810061, where Na-HCO_3 type water with a relatively low mineralization of 1,430 mg/L TDS was found.

Chloride distribution is shown on Figure 18. Concentrations range from 81 mg/L (W810061) to 2,793 mg/L (W810068). The anomalous hydrochemical type combined with low TDS and chloride concentrations in W810061 suggest the presence of a hydrogeological "window" in the area adjacent to this monitoring well.

Total metal concentrations are generally low. Exceptions are elevated to high iron, manganese, boron and barium concentrations. High concentration of metals recorded in W810069 are most probably associated with high total suspended solids content in the groundwater sample (Table 9C).

4.4 CRETACEOUS - INTRA-OREBODY AND NEAR CONTACT WITH QUATERNARY

Intra-orebody groundwater-bearing zones are represented by generally thin and locally discontinuous layers of silty sands and/or sands with low bitumen content. Such aquifers may be present within the McMurray Formation profile extending from the contact with Quaternary deposits and top of the Basal Aquifer. Groundwater may be under confined conditions, especially in the lower parts of the McMurray Formation. Due to restricted recharge and low storage capacity, the groundwater reserves in the Intra-orebody aquifers are expected to be relatively small.

A relatively small number of observation wells have been installed in this zone (Figure 7). Screened sections (Table 6C) were placed at different elevations, thus development of a representative groundwater surface elevation map was not readily possible. Groundwater surface elevations range from approximately 230 to 300 masl. Seasonal changes in groundwater surface elevations are within 1.5 m range. It is expected that a downward hydraulic gradient dominates within the McMurray Formation.

The bitumen content of the oil sands results in a low hydraulic conductivity, which is often difficult to measure in well tests. Analysis of a Syncrude 1996 pumping test using the Neuman and Witherspoon (1972) method gave an estimate of $2x10^{-10}$ m/s for the vertical hydraulic conductivity of the oil sands (Golder Associates Ltd., 1996). Clark (1960) estimated a range of $3.2x10^{-8}$ to $1x10^{-5}$ m/s based on laboratory studies. Wallick and Dabrowski (1982) estimate a vertical hydraulic conductivity of $4x10^{-8}$ m/s based on a study of tritium concentrations in porewater.

Golder Associates Ltd. (1997a) measured hydraulic conductivity in piezometer MW97-42A within an interval 20.7 - 24.5 m below ground surface. The result, $7x10^{-8}$ m/s, is consistent with results obtained from the literature.

Groundwater quality data are summarized in Table 7B, 8C, and 9C. Six different hydrochemical types of groundwater were encountered within the McMurray Formation (Figure 19). Associated with this variability is a wide range of mineralization 277 - 2,148 mg/L TDS. Chloride concentrations are relatively low and do not exceed 122 mg/L (Table 8C and Figure 20). Total metal concentrations are also relatively low, with the exception of iron and manganese (Tables 8C and 8D).

4.5 QUATERNARY

The Surficial aquifers are represented by relatively thin (less than 20 m) glaciofluvial and alluvial sands and gravels of Quaternary age. These aquifers are usually unconfined. Within the Project area, depth to the phreatic surface varies from 0 to 7 m below ground surface.

A tributary buried valley was identified in the western part of Lease 13, extending north from Isadore's Lake. Groundwater reserves associated with such channels are highly variable depending on the extent and thickness of water-bearing granular deposits.

Depth to the groundwater surface within the Project area was measured periodically to define seasonal groundwater surface fluctuations and direction of groundwater flow. The direction of groundwater flow in surficial sediments is not well defined. However, the aquifers drain toward local topographical depressions and surface drainage systems. A downward vertical hydraulic gradient exists between the Surficial aquifers and the Basal Aquifer.

Hydrographs obtained from Surficial aquifer piezometers indicate a relatively slow response of the groundwater surface to extended periods of rain. In general, seasonal fluctuations in the groundwater surface do not exceed 1.5 m (Table 6D). This is mostly due to the significant storage capacity of the Quaternary sediments. Most surficial piezometers are frozen from December until the end of May. Hydrographs of selected Surficial aquifer piezometers are given in Alsands Energy Ltd., (1981b).

Hydraulic conductivities of Surficial aquifers are highly variable and range from approximately $1x10^{-8}$ to $1x10^{-3}$ m/s.

Golder Associates Ltd. (1996) note a range of 10^{-9} to 10^{-3} m/s for the hydraulic conductivity of surficial deposits in the Aurora Mine areas, while Alsands Energy Ltd. (1981b) indicate a range of 10^{-6} to 10^{-3} m/s for Lease 13. The large range is due to the variation in surficial materials from highly permeable sands and gravels to low permeability lacustrine clays. Golder Associates Ltd. (1996) also give a vertical hydraulic conductivity of $5x10^{-10}$ m/s for lacustrine clay, a vertical hydraulic conductivity range of $6x10^{-11}$ to $4x10^{-8}$ m/s for till, and a horizontal hydraulic conductivity range of $6x10^{-8}$ to $2x10^{-7}$ m/s for till.

A pumping test performed in the main Pleistocene channel in the Aurora Mine South area gave a transmissivity of $3.6x10^{-3}$ m^2/s, which was reported to correspond to a hydraulic conductivity of $1.9x10^{-3}$ m/s (Golder Associates Ltd., 1996).

Groundwater in Quaternary aquifers represents mostly Ca-Mg-HCO_3 and Ca-Mg-Na-HCO_3 hydrochemical types. Distribution of groundwater hydrochemical types is shown on Figure 21.

The majority of the samples collected from the zone encompassing the Quaternary sediments indicate the presence of fresh water in these aquifers. The data on the chemical composition of the groundwater are summarized in Tables 7C, 8D and 9D. In general, mineralization varies from 239 to 1,729 mg/L TDS, while chloride concentrations are below 135 mg/L (Table 8D).

Local hydrochemical anomalies were found in the Isadore's Lake area, where relatively high mineralization was encountered in holes 80-W1-2 and 80-W1-5. In these holes, mineral content exceed 1,300 mg/L TDS (Table 8D). These holes may be in hydraulic contact with Cretaceous deposits.

Elevated to very high iron, manganese and fluoride concentrations were locally detected (Table 8D). Anomalously high total metal concentrations were found locally (Table 9D). These anomalies are most likely related to high concentrations of total suspended solids.

5. GROUNDWATER AND SURFACE WATER INTERACTIONS

Both the Athabasca and Muskeg Rivers, as well as McClelland and Kearl Lake lie within the theoretical drawdown cone of the proposed mine. The river surface elevations are above the level of the base of the pits, and hence the possibility exists for leakage to occur from the rivers into the Basal Aquifer during dewatering operations. This is of potential concern both from the viewpoint of reduced baseflow to the rivers or lakes, and from the potential cost of pumping extra water from the open pit mines.

Mine pit dewatering will require: 1) draining of Surficial and Intra-orebody aquifers in the area of the active pit; and 2) depressurization of the Basal Aquifer from a piezometric level of approximately 280 masl to an elevation close to the base of the oil sands. The exact depth to which depressurization is required would be determined by operational and mine safety considerations. The possible effects of dewatering on the various surface water bodies are discussed below.

5.1 ATHABASCA RIVER

The Athabasca River is located a minimum of 3 km to the west of the western edge of the proposed mine area. Typical surface elevation of the river is 230 masl. Average low and high water flows are 166 and 990 m^3/s, respectively (Water Surveys of Canada, 1991). The potentiometric surface of the Basal Aquifer appears to coincide with the water level in the river (Alsands Energy Ltd., 1981a), possibly indicating hydraulic connection between the two. Drilling in the Isadore's Lake area, at least locally confirmed connection between the Quaternary alluvium and Cretaceous Basal Aquifer. Overall, the river acts as a regional drainage feature for both the Quaternary and the Cretaceous groundwater-bearing zones.

Information on hydraulic heads in the Devonian aquifers is sparse, but regional data presented in Hackbarth and Nastasa (1979) indicate potentiometric surfaces for the Upper and Middle Devonian aquifers slope towards the Athabasca River and reach values similar to River elevation. The above data suggest that the Athabasca River may also act as the discharge zone for Devonian aquifers in the regional study area.

Assuming that the alluvial sediments in the Athabasca River valley and Basal Aquifer are hydraulically connected and that both units are continuous, flow may be induced from the River and alluvial deposits into the Basal Aquifer under proposed mine dewatering conditions. The theoretical rate of seepage, which would occur under this scenario may be determined using the Darcy equation (Darcy, 1856).

where: $Q = kiA$
Q = leakage flux $[L^3/T]$

k = hydraulic conductivity [L/T]
A = area of aquifer [L^2]
i = hydraulic gradient [L/L]

The following parameters may be selected:

- average distance between the Athabasca River and the pit, L = 3,000 m;
- maximum drawdown created near open pit closest to the river as a result of dewatering/ depressurization, s = 50 m (static = 260 masl, dynamic = 210 masl);
- river stage elevation = 235 masl;
- hydraulic gradient (i) between the river and pit, = $\frac{235 - 210}{3000} \cong 0.01$;
- vertical hydraulic conductivity (k) of 10^{-5} m/s for alluvial sediments is assumed; and
- affected river channel area (A) has width of 500 m and length of 10,000 m.

Based on these assumptions, leakage flux (Q) is estimated to be in the order of 0.5 m^3/s. This represents less than 1% of the low flow in the Athabasca River assumed to be approximately 166 m^3/s.

It should be noted that a different larger leakage flux will occur if plant water supply originates from the Athabasca River. Under this scenario, induced infiltration wells would be placed along the river bank and would draw water from both the river and the alluvial sediments.

5.2 MUSKEG RIVER

The Muskeg River flows through the low lying terrains along the southeastern edge of the proposed mine area. Both swampy and higher topographic areas drain toward the river.

The proposed mine area comes within a minimum of 100 m of the Muskeg River along much of its southeast boundary. Because of this close proximity, dewatering of the Surficial aquifers could have an effect on baseflow to the river. Hydraulic conductivities of surficial deposits along the river vary substantially from 2×10^{-7} to $>10^{-4}$ m/s (Golder Associates Ltd., 1997a).

Using the formula described in Section 5.1, seepage from the Muskeg River may also be estimated. The following parameters may be selected:

- average distance between the Muskeg River and the pit bottom, L = 300 m;
- maximum drawdown created near open pit closest to the river, s = 100 m;
- hydraulic gradient, i = $\frac{100}{300} = 0.333$;

- average vertical hydraulic conductivity, $k = 5x10^{-6}$ m/s; and
- affected river channel area has with 10 m, and length 5,000 m.

Based on these assumptions, leakage flux (Q) is estimated to be in the order of 0.08 m^3/s. This represents nearly 25% of the low flow in the Muskeg River, assumed to be 0.3 m^3/s.

Thus, reduction in groundwater discharge will vary considerably along the river bank. It is expected that discharge of water originating from overburden drainage in the project area will more than compensate seepage losses. An overall increase in the river flow is therefore anticipated.

Seepage from the Muskeg River and/or alluvial sediment toward the mine pit, through very low transmissivity oil sands and estuarine deposits is expected to be insignificant.

5.3 KEARL LAKE

Kearl Lake is a shallow water body located more than 12 km from the proposed mine area. It is anticipated that the relatively low to very low transmissivities of the intervening Quaternary and Cretaceous sediments will limit the extent of the drawdown cone development. This, combined with the distance between the lake and the mine, suggests that development of Lease 13 should not have any impact on Kearl Lake.

Presence of a Pleistocene buried channel system was identified by drilling exploration programs in Lease 13 East and Lease 31. It is possible that this system extends toward Kearl Lake. If the Pleistocene channel intersects the full thickness of oil sands and it is hydraulically connected to Kearl Lake, then dewatering of the Basal Aquifer may induce seepage from the lake. Available information is not sufficient to allow a quantitative estimate of the potential losses.

5.4 MCCLELLAND LAKE

McClelland Lake is located approximately 18 km northeast of the proposed mine development. The southern shore of the lake is beyond the subcrop of the Basal Aquifer (Figures 3a and 3b). Thus, it is not expected that Lease 13 development will have any impact on water levels in the lake.

5.5 MUSKEG

Development of a surface drainage system, combined with overburden dewatering operations, will lower the water surface in adjacent muskeg areas. The width of the zone affected will depend on the hydraulic properties of muskeg and underlying strata as well as drawdown development. It is assumed that the impact of drainage is not going to extend more than 1 km from the drainage features. In Section 1.2, the north Local Study Area boundary was conservatively assumed to be at a distance of 2 km from the Lease 13 drainage.

6. SUMMARY AND CONCLUSIONS

The exploration programs conducted at Lease 13 between 1981 - 1997, provided sufficient information to characterize the hydrogeological regime within the Local Study Area. Published and unpublished literature also provides a very detailed description of groundwater conditions within the Regional Study Area.

The Devonian to Quaternary hydrostratigraphy at the Lease 13 broadly conforms to the pattern found regionally. In ascending order, major groundwater-bearing units are as follows:

- Middle Devonian La Loche Formation;
- Middle Devonian Methy Formation;
- Lower Cretaceous - Basal Aquifer;
- Lower Cretaceous - Intra-orebody; and
- Quaternary (Surficial) sediments.

There are significant differences in the hydrogeological regimes of the La Loche Formation, Methy Formation and Basal Aquifer. Specifically, each aquifer is characterized by a different circulation and hydrochemical regime. Groundwater in Quaternary sediments is usually fresh and represents a HCO_3-Ca-Mg hydrochemical type. Migrating downward, this water is subject to chemical diagenesis resulting in changes in ionic composition and mineralization. Groundwater in the Intra-orebody aquifers forms a transitional zone between Quaternary water-bearing units and Basal Aquifer. The hydraulic and groundwater chemistry properties measured in major groundwater-bearing units are consistent with Regional Study Area data.

La Loche and Methy Aquifers are believed to be isolated from the active groundwater circulation zone within the Local Study Area. Conceptually, recharge to the Basal Aquifer is interpreted to occur by vertical migration of infiltrating precipitation through overlying sediments and via direct recharge in the subcrop/outcrop area northeast of Lease 13. Groundwater flow is generally westerly towards the Athabasca River, which forms a regional groundwater discharge zone. Intra-orebody and Surficial aquifers drain toward local topographical depressions and/or surface drainage systems.

A number of groundwater exploration/monitoring wells have been installed in the Regional Study Area for industrial purposes. There are no records on file with AEP, of domestic groundwater users in either the Regional or Local Study Areas.

Groundwater control in the Basal and Surficial aquifers is required to assure safe and efficient mining. The Methy Aquifer will be closely monitored during exploration and proposed mining operations. Observations collected to date indicate hydraulic isolation exists between the Basal

Aquifer and the Methy Formation. From these observations it is inferred that the Methy Formation will not be affected by the proposed mining operation.

Mine pit dewatering will require: 1) draining of the Quaternary and Intra-orebody aquifers in the areas adjacent to the open pit; and 2) depressurization of the Basal Aquifer. The potential impacts of these proposed operations on the Athabasca River, Muskeg River, Kearl Lake, McClelland Lake and Muskeg/Wetland have been considered and are estimated to be insignificant outside of the Local Study Area.

Groundwater from the Basal Aquifer in the Regional Study Area was found to contain significant quantities of phenols, naphthenic acids and some polycyclic aromatic hydrocarbons. As discharge of groundwater from the depressurization/dewatering system to the watershed is not anticipated, the presence of these naturally occurring compound are of little significance.

One groundwater sample collected from Quaternary sediments contained measurable concentrations of phenol (0.4 µg/L) and low concentrations of PAHs and alkylated PAHs (concentrations ranged between 0.02 - 0.16 µg/L). This single analysis does not allow characterization of organic compounds dissolved in groundwater in Surficial aquifers throughout Lease 13.

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7. GLOSSARY OF TERMS

Alluvial Deposits Alluvium — Particles of minerals or rocks which are transported by a river and deposited along its valley.

Aquiclude — A material of such low permeability that it effectively prevents any movement of water through it or reduces water movement to such a low value relative to the surrounding materials that it can be considered an impervious barrier.

Aquifer — Any water-saturated body of geological material from which enough water can be drawn at a reasonable cost for the purpose required. An aquifer is only a relative term determined largely by economics and is best illustrated by extreme examples. An aquifer in an arid prairie area required to supply water to a single farm may be adequate if it can supply 1 m^3/day. This would not be considered an aquifer by any industry looking for cooling water in volumes of 10,000 m^3/day. A common usage of the term aquifer is to indicate the water-bearing material in any area from which water is most easily extracted.

Aquifer Test — A method of obtaining quantitative information on the hydraulic characteristics of an aquifer by removing water from the aquifer in a controlled manner and measuring the groundwater surface or piezometric response. Often referred to as a "pump test" or "drawdown test".

Aquitard — A material of intermediate permeability between an aquifer and an aquiclude. An aquitard allows some measure of leakage between the aquifers it separates.

Bitumen — Naturally occurring solid or semi-solid hydrocarbons.

Brackish Water — Water with total dissolved solids concentration ranging from 1,000 to 10,000 g/m^3.

Brine — Water with total dissolved solids concentration exceeding 100,000 g/m^3.

Cone of Depression — An inverted cone depression in groundwater surface surrounding a pumped well or dewatered/depressurized excavation.

Confined Aquifer — A completely saturated aquifer whose upper and lower boundaries are impervious layers. In confined aquifers the pressure of the water is usually higher than that of the atmosphere and the water in wells stands above the top of the aquifer. The water in a confined aquifer is called confined or artesian water.

Connate Water	Water entrapped in the interstices of a sedimentary rock at the time the rock was deposited.
Depressurization	The lowering of the groundwater piezometric surface over the desired area of a mine or construction site, using a well system.
Dewatering	Removal of groundwater from geological formation using well for drainage ditch system.
Diagenesis	Process involving physical and chemical changes in groundwater, this includes solution of soluble minerals, cation exchange between groundwater and rock, ions diffusion, etc.
Drawdown	Lowering of water level caused by pumping. It is measured for a given quantity of water pumped during a specified period, or after the pumping level has become constant.
Drawdown Cone	A conical groundwater surface created in an unconfined aquifer due to pumping, or an imaginary conical surface indicating pressure relief in a confined aquifer due to pumping.
Drift Deposits	Any sediment laid down by, or in association with, the activity of glaciers and ice sheets.
Drill Stem Tester (DST)	A device used in a borehole to measure hydraulic properties of a tested interval and/or to collect fluid sample.
Evapotranspiration	Combined term for water lost as vapour from soil/water surface (evaporation) and water lost through plants (transpiration).
Fresh Water	Water with total dissolved solids concentration below 1,000 g/m^3.
Geomorphology	The study of the land-forms on Earth's surface and of the processes that formed them.
Glaciofluvial	Sediments or land-forms produced by meltwaters originating from glacier/ice sheet.
Groundwater	All the water contained in the pores/voids within rocks (unconsolidated and consolidated).
Hydraulic Conductivity	A coefficient "k" depends on the physical properties of formation and fluid. It describes the "ease" with which a fluid will flow through a porous material. "k" is the rate of flow per unit cross-sectional area under the influence of a unit gradient, and has the dimension of: $\text{Length}^3/\text{Length}^2 \times \text{Time}$ or Length/Time (e.g., m/s) but should not be confused with velocity.

Hydraulic Gradient Is the change in groundwater elevation per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head. This coefficient is dimensionless.

Hydrochemical Type The definition of a chemical composition of groundwater based on cation and anion concentrations.

Hydrogeological Window The erosional, sedimentional or structural break in geological strata, which allows hydraulic connection between different aquifers.

Hydrogeology The science that relates to groundwater. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals.

Hydrograph A graph showing water surface elevations or flow versus time.

Infiltration The flow or movement of precipitation or surface water through the ground surface into the ground. Infiltration is the main factor in recharge of groundwater reserves.

Leakage The flow of water from one hydrogeological unit to another. It may be natural or anthropogenic.

Lithology A term usually applied to describe composition and texture of sediments and rocks.

Meteoric Water That which occur in or is derived from the atmosphere.

Mineralization of Groundwater Synonym of total dissolved solid concentration.

Observation Well A constructed controlled point of access to an aquifer which allows groundwater observations. Small diameter observation wells are often called piezometers.

Olfactory Concerned with smelling.

Overburden

1. Any loose material which overlies bedrock (often used as a synonym for Quaternary sediments and/or surficial deposits).
2. Any barren material, consolidated or loose, that overlies an ore body.

Paraconformity An uncertain or obscure unconformity in which no erosion surface is discernible or in which the contact is a simple bedding plane and in which the beds above and below the break are parallel.

Permeability	A physical property of the porous medium. Has dimensions Length^2. When measured in cm^2, the value of permeability is very small, therefore more practical units are commonly used - darcy (D) or millidarcy (mD).
Physiography	Synonym of geomorphology.
Phreatic Surface	Synonym of unconfined groundwater surface.
Piezometer	See Observation Well.
Piezometric Surface	An imaginary surface that everywhere coincides with the static level of the water in the aquifer. The surface to which the water from a given aquifer will rise under its full head.
Pneumatic Piezometer	A device used to measure hydrostatic and/or pore pressure in a borehole or engineered structure.
Potentiometric	Synonym to piezometric.
Radius of Well	Is the distance from the centre of the well (test pit) to the limit of the
(Test Pit) Influence	drawdown cone.
Recharge	Water added to the saturated zone from any source. This term is commonly combined with other terms to indicate some specific mode of recharge such as recharge well, recharge area, or artificial recharge.
Recovery Test	A method of obtaining quantitative information on the hydraulic characteristics of an aquifer, routinely utilized following a pump test. After pumping has been terminated, the water level will stop dropping and will begin to rise towards its original position. The rise of the water level can be measured as residual drawdowns, i.e., as the difference between the original water level prior to pumping and the actual water level measured at a given time after pumping stopped.
Saline Water	Water with total dissolved solids concentration ranging from 10,000 to 100,000 g/m^3.
Seepage	1. Slow water movement in subsurface. 2. Flow of water from man made retaining structures. 3. A spot or zone, where water oozes from the ground, often forming the source of a small spring.
Spring	A place where water flows from rock or soil upon the land or into body of surface water.

Standpipe — A device consisting of a perforated/slotted pipe often used in the past to measure depth to groundwater surface at shallow depths.

Storage Coefficient — The storage coefficient and the specific yield are both defined as the volume of water released or stored per unit surface area of the aquifer per unit change in the component of head normal to that surface. Both are designated by the symbol S and are dimensionless.

The storage coefficient refers only to the confined parts of an aquifer and depends on the elasticity of the aquifer material and the fluid. It typically has an order of magnitude of 10^{-4} to 10^{-6}.

The specific yield refers to the unconfined parts of an aquifer. In practice, it may be considered to equal the effective porosity or drainable pore space because in unconfined aquifers the effects of the elasticity of aquifer material and fluid are generally negligible.

It should be kept in mind that small pores do not contribute to the effective pore space because in small pores the retention forces are greater than the weight of the water. For sands the specific yield may be in the order of 0.1 to 0.2.

In American Literature the terms storage coefficient and specific yield are often used synonymously.

Stratigraphy — The geological science concerned with the study of sedimentary rocks in terms of time and space.

Subcrop — Bedrock unit occurring at the bedrock surface but covered by Quaternary deposits.

Surficial Deposits — See Overburden (1).

Transmissivity — The product of the average coefficient of hydraulic conductivity (or permeability) and the thickness of the aquifer. Consequently, transmissivity is the rate of flow under a hydraulic gradient equal to unity through a cross-section of unit width over the whole thickness of the aquifer. It is designated by the symbol T. It has the dimension of:

$$Length^3/Time \times Length \text{ or } Length^2/Time \quad (e.g., m^2/day)$$

Unconfined Aquifer — A permeable bed only partly filled with water and overlying a relatively impervious layer. Its upper boundary is formed by a free water table under atmospheric pressure. Water in a well penetrating an unconfined aquifer does not, in general, rise above the water surface, except when there is vertical flow.

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Table 1
Variation of Precipitation and Temperature With Season

Month	Precipitation			Temperature		
	Rainfall (mm)	Snowfall (cm)	Total [1] Precipitation (mm)	Mean Daily Maximum (°C)	Mean Daily Minimum (°C)	Mean Daily Temperature (°C)
January	0.6	27.2	20.4	-14.5	-25.3	-19.8
February	0.8	21.3	16.0	-8.6	-21.3	-14.9
March	0.9	23.2	17.3	-1.1	-14.8	-7.9
April	8.0	15.8	22.6	9.3	-3.8	2.8
May	37.2	3.6	40.7	17.1	3.0	10.1
June	63.9	0.0	63.9	21.5	7.7	14.6
July	79.1	0.0	79.1	23.2	10.0	16.6
August	71.7	+ 0.0	71.8	21.8	8.5	15.2
September	48.1	3.3	51.4	15.1	3.2	9.1
October	20.0	14.1	32.2	8.4	-1.9	3.3
November	2.9	33.1	26.4	-4.5	-13.5	-9.0
December	1.1	30.5	23.0	-12.6	-22.1	-17.3
Annual	**335**	**172**	**465**	**6.3**	**-5.9**	**0.2**

__Note:__ [1] *Total precipitation is calculated by summing the rainfall, and the amount of water released by melting the snowfall. Note that the amount of water released by melting 1 cm of snowfall varies with the density of the snow from approximately 1.0 mm (wet, warm snow) to approximately 0.7 mm (cold, dry snow).*

Table 2
Mean Daily Pan Evaporation for the Mildred Lake Station

Month	Mean Daily Pan Evaporation *(mm)*	Month	Mean Daily Pan Evaporation *(mm)*
April	4.1	August	3.7
May	4.3	September	4.4
June	4.7	October	0.8
July	5.0		

Table 3
Summary of the Main Geological Formations East of the Athabasca River
(Regional Study Area)

Period	Group	Formation	Composition	Thickness *(m)*
Quaternary	- - -	- - -	Till, clay, sand, silt, and gravel	≤ 135
Lower Cretaceous	Mannville	(Grand Rapids)	Lithic sand and sandstone	≤ 90
		Clearwater	Shale and siltstone	≤ 130
		McMurray	Quartzose sand with heavy oil	≤ 105
Upper Devonian	Beaverhill Lake	Waterways	Limestone, argillaceous limestone, and calcareous shale	≤ 220
		Slave Point	Limestone, silty limestone, and siltstone	≤ 15
Middle Devonian	Elk Point	Watt Mountain	Shale	≤ 15
		Prairie Evaporite	Halite and anhydrite	≤ 240
		Methy	Reefal dolostone	≤ 85
		McLean River	Shale, siltstone, and dolostone	18 to 48
		La Loche	Arkosic sandstone	≤ 40
Precambrian	- - -	- - -	Granite and metasedimentary rocks	

Table 4
Hydrochemical Types in Major Stratigraphic Units

	Golder Associates Ltd. (1997a)		Alsands Energy Ltd. (1981b, 1982)	
Stratigraphic Interval	Mineralization *(mg/L TDS)*	Predominant Hydrochemical Types	Mineralization *(mg/L TDS)*	Predominant Hydrochemical Types
Surficial Aquifers [(1)]	290 - 827	$Ca-Na-HCO_3$ $Na-Ca-HCO_3$	239 - 1729	$Ca-Mg-HCO_3$ $Ca-Mg-Na-HCO_3$ $Na-Ca-Mg-HCO_3$ $Ca-HCO_3-SO_4$ $Na-HCO_3$ $Na-Ca-HCO_3-Cl$
Clearwater	348 - 3058	$Na-HCO_3$	- - -	- - -
Intra-Orebody Aquifers [(1)]	968 - 1,556	$Na-HCO_3-Cl$	277 - 2,148	$Ca-Mg-HCO_3$ $Ca-Mg-Na-HCO_3$ $Ca-Na-Mg-HCO_3$ $Na-Ca-Mg-HCO_3$ $Na-Ca-HCO_3$ $Na-HCO_3$
Basal Aquifer	330 - 1970	$Na-HCO_3-Cl$	1,430 - 7,407	$Na-HCO_3$ $Na-HCO_3-Cl$ $Na-Cl-HCO_3$
Upper Devonian [(1)]	2,034 - 6,014	$Na-HCO_3-Cl$	- - -	- - -
Methy	13,050	$Na-Cl-SO_4$	9,824 - 78,666	Na-Cl
La Loche	16,100	$Na-Ca-Cl-SO_4$	172,000	Na-Cl

Note: [(1)] *Upper Devonian is not a formation.*

Table 5
Summary of AEP Well Records for Township 94-96, Range 9-10, W4M

Township	Range W4M	Current Lease Holder	Number of Wells	Proposed Use
94	9	Gulf, Mobil, Home Oil	19	Observation/Industrial
	10	Gulf, Mobil, Home Oil	6	Observation/Industrial
		Fort McKay IR 174	35	Observation/Industrial
	11	Fort McKay IR 174	16	Observation/Industrial
		Talisman	1	Observation/Industrial
95	9	Shell Canada	10	Observation/Industrial
	10	Shell Canada	15	Observation/Industrial
	11	Shell Canada	1	Observation/Industrial
96	9	None	- - -	- - -
	10	Syncrude	4	Observation/Industrial
		Crown Land	1	Observation/Industrial
		Solvex	2	Observation/Industrial
	11	Syncrude	12	Observation/Industrial

Table 6A

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Devonian-Methy Formation

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W72-1240	288.19	1.00	289.19	0.051	216.0	190.0 - 216.0	81-Mar-17	26.49	262.70	> 1E-04	*Methy Formation*
W73-1404	285.45	1.00	286.45	0.051	252.3	219.0 - 252.3	81-Mar-14	20.53 *	265.92	3E-08	*Methy Formation*
W73-1481	293.38	0.10	293.48	0.120	230.0	108.9 - 227.0	81-Mar-17	32.86	260.62	9E-05	*See note 5*
W73-1489	293.99	1.60	295.59	0.051	213.5	190.0 - 211.0	81-Mar-17	27.74	267.85	> 1E-04	*Methy Formation*
W75-1717	289.41	1.30	290.71	0.051	297.0	239.0 - 284.0	81-Mar-17	24.11	266.60	2E-08	*Methy Formation*
W80-5027	298.89	0.77	299.66	0.051	282.0	215.0 - 282.0	81-Mar-17	36.05 *	263.61	2E-09	*Methy Formation*
W80-5039	287.25	1.15	288.40	0.051	285.0	125.0 - 285.0	81-Mar-09	32.40	256.00	2E-06	*See note 5*

NOTES:

1. *All Devonian piezometers were reconstructed during February and March 1981 program. (EBA Engineering Consultants, 1981a).*
2. *For pre-1981 completion details and chemical analyses see Alsands Energy Ltd., May 1981, Hydrology, Part 2 - Groundwater Hydrology, Alsands Project, Calgary, Alberta.*
3. *NA denotes not available.*
4. ** denotes groundwater surface elevation possibly not stabilized.*
5. *Hole was in bad condition due to washouts, age, and loss of circulation during drilling. Piezometer pipe broke during installation, effectively leaving an open interval extending throughout Beaverhill Lake Group, Prairie Evaporite Formation, and Methy Formation.*
6. *Masl denotes metres above sea level.*

Table 6B

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W72-1233	289.25	0.60	289.85	0.114	87.5	76.1 - 82.4	80-Jul-05	17.90	271.95	8E-05 (1); 2E-05 (2)	*Sand*
							80-Jul-29	18.55	271.30		
							80-Sep-07	18.01	271.84		
							81-Mar-16	16.55	273.30		
W72-1234	Construction details not available										
W72-1235	288.25	0.20	288.45	0.203	94.8	78.4 - 87.5	80-Jul-04	17.16	271.29	4E-05 (1); 8E-05 (3)	*Sand*
							80-Jul-27	16.35	272.10		
							80-Sep-07	15.76	272.69		
							81-Mar-16	14.42	274.03		
W72-1238	287.25	1.50	288.75	0.168	94.6	76.2 - 85.4	80-Jul-04	17.20	271.55	6E-04 (1); 2E-05 (2)	*Sand*
							80-Jul-29	17.00	271.75		
							80-Sep-07	16.49	272.26		
							81-Mar-16	14.97	273.78		
W72-1239	289.75	0.97	290.72	0.159	96.4	78.1 - 87.4	80-Jul-05	18.65	272.07	8E-05 (1); 2E-05 (2)	*Sand*
							80-Jul-29	18.46	272.26		
							80-Sep-07	17.32	273.40		
							81-Mar-16	16.46	274.26		
W73-1364	284.00	0.69	284.69	0.060	90.0	85.7 - 86.6	80-Jul-06	7.10	277.59	NA	*Sand*
							80-Jul-29	6.85	277.84		
							80-Sep-07	6.57	278.12		
							81-Mar-16	5.80	278.89		
W73-1365	Construction details not available										
W73-1432	286.50	1.19	287.69	0.060	68.3	64.7 - 66.4	80-Jul-03	16.62	271.07	NA	*Sand*
							80-Jul-29	16.39	271.30		
							80-Sep-07	15.88	271.81		

Table 6B

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W73-1434	292.00	0.50	292.50	0.114	85.4	83.9 - 85.4	80-Jul-07	19.00	273.50	7E-05 (2)	*Sand*
							80-Jul-27	18.75	273.75		
							80-Sep-07	18.21	274.29		
							81-Mar-16	16.87	275.63		
W73-1439	292.50	0.70	293.20	0.060	91.5	90.0 - 91.5	80-Jul-26	16.80	276.40	NA	*Sand*
							80-Sep-07	16.40	276.80		
							81-Feb-18	15.36	277.84		
W73-1441	295.75	0.81	296.56	0.060	89.1	81.6 - 82.6	80-Jul-07	21.43	275.13	NA	*Sand*
							80-Jul-26	20.10	276.46		
							80-Sep-03	20.70	275.86		
							81-Feb-18	19.61	276.95		
W73-1478	296.25	0.70	296.95	0.060	84.2	83.2 - 84.2	80-Jul-07	15.45	281.50	NA	*Sand*
							80-Jul-27	15.39	281.56		
							80-Aug-08	15.20	281.75		
							80-Aug-17	15.07	281.88		
							80-Sep-03	15.00	281.95		
							80-Nov-27	14.78	282.17		
							81-Feb-13	14.53	282.42		
W74-1510	291.00	0.90	291.90	0.060	90.3	82.7 - 83.6	80-Jul-06	21.10	270.80	NA	*Sand*
							80-Jul-29	20.10	271.80		
							80-Sep-07	20.17	271.73		
							81-Feb-18	18.94	272.96		
W74-1511	289.25	0.05	289.30	0.340	84.8	75.2 - 83.9	80-Jul-06	19.20	270.10	2E-04 (3)	*Sand*
							80-Jul-29	18.62	270.68		
							80-Sep-07	18.05	271.25		
							81-Mar-16	16.35	272.95		

Table 6B
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation	Stick-Up or Steel PVC Pipe (above ground)	Datum Elevation (top of PVC casing)	Pipe (Steel or PVC) Diameter	Total Depth Of Piezo. (below ground)	Open Interval (below ground)	Date	Depth To Water Below Datum	Groundwater Surface Elevation	Hydraulic Conductivity	Lithology
	(masl)	*(m)*	*(masl)*	*(m)*	*(m)*	*(m)*	*(y-m-d)*	*(m)*	*(masl)*	*(m/s)*	
W74-1512	Construction details not available										
W75-1751	288.75	1.25	290.00	0.219	91.8	75.9 - 88.4	80-Jan-18	20.94	269.06	NA	*Sand*
							80-Feb-14	20.52	269.48		
							80-Mar-13	20.00	270.00		
							80-Apr-10	19.38	270.62		
							80-May-08	19.14	270.86		
							80-Jun-08	18.62	271.38		
							80-Jul-07	19.14	270.86		
							80-Jul-30	18.44	271.56		
							80-Aug-27	18.05	271.95		
							80-Sep-24	17.89	272.11		
							80-Oct-22	17.66	272.34		
							80-Nov-20	17.27	272.73		
W75-1752	Construction details not available										
W75-1753	289.40	0.30	289.70	0.219	88.8	79.2 - 85.6	80-Jul-05	19.20	270.50	2E-05 [(3)]	*Sand*
							80-Jul-29	17.32	272.38		
							80-Sep-07	18.00	271.70		
							81-Mar-16	15.90	273.80		
W75-1754	289.40	0.34	289.74	0.168	95.2	81.4 - 91.0	80-Jul-05	17.99	271.75	5E-05 [(3)]	*Sand*
							80-Jul-29	17.64	272.10		
							80-Sep-07	17.11	272.63		
							81-Mar-16	15.56	274.18		
W80-5025	288.40	0.60	289.00	0.051	122.0	NA	80-Mar-11	6.77	282.23	5E-08 [(3)]	*Sand*
							80-Aug-09	5.10	283.90		
							80-Aug-18	5.03	283.97		
							80-Sep-05	5.30	283.70		
							80-Sep-08	6.05	282.95		
							80-Nov-12	5.94	283.06		

Table 6B
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W80-5026	291.60	0.20	291.80	0.051	98.0	80.1 - 86.4	80-Mar-05	16.88	274.92	4E-05 [3]	*Sand*
							80-Jul-08	16.16	275.64		
							80-Jul-26	16.01	275.79		
							80-Aug-04	15.94	275.86		
							80-Aug-17	15.85	275.95		
							80-Sep-03	15.67	276.13		
							80-Nov-11	15.68	276.12		
							81-Feb-15	14.83	276.97		
W80-5043	287.94	0.80	288.74	0.051	100.0	85.0 - 93.5	80-Jul-15	51.62	237.12	1E-05 [3]	*Sand*
							80-Jul-25	51.65	237.09		
							80-Sep-02	51.60	237.14		
							81-Feb-15	51.90	236.84		
W80-5053	293.46	0.90	294.36	0.051	98.0	75.8 - 91.5	80-Mar-20	61.14	233.22	Results not interpretable	*Sand*
							80-Jul-16	61.80	232.56		
							80-Jul-24	61.25	233.11		
							80-Aug-17	60.92	233.44		
							80-Sep-06	61.11	233.25		
							80-Sep-09	61.65	232.71		
							80-Nov-25	61.50	232.86		
W80-5054	290.74	0.60	291.34	0.051	80.0	70.8 - 75.0	80-Mar-11	55.98	235.36	7E-06 [3]	*Sand*
							80-Jul-24	56.58	234.76		
							80-Aug-18	56.61	234.73		
							80-Sep-06	56.42	234.92		
							80-Sep-09	56.52	234.82		
							80-Nov-26	56.54	234.80		
							81-Feb-15	56.39	234.95		

Table 6B
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W80-5069	291.75	1.00	292.75	0.051	89.0	75.0 - 83.0	80-Mar-20	20.03	272.72	5E-05 (3)	*Sand*
							80-Jul-14	20.05	272.70		
							80-Jul-25	20.01	272.74		
							80-Aug-05	19.91	272.84		
							80-Aug-17	19.86	272.89		
							80-Sep-04	19.86	272.89		
							80-Nov-26	19.81	272.94		
							81-Feb-15	19.82	272.93		
W80-5072	291.16	0.70	291.86	0.051	77.0	61.8 - 64.5	80-Jul-12	5.05	286.81	NA	*Sand*
							80-Jul-25	4.04	287.82		
							80-Sep-07	1.95	289.91		
							81-Mar-17	1.91	289.95		
W80-5076	299.54	0.60	300.14	0.051	86.0	74.3 - 76.2	80-Mar-07	21.59	278.55	5E-05 (3)	*Sand*
							80-Jul-14	21.36	278.78		
							80-Aug-15	22.30	277.84		
							80-Sep-04	21.24	278.90		
							80-Sep-09	22.26	277.88		
							80-Nov-28	22.09	278.05		
							81-Mar-17	21.07	279.07		
W80-5077	298.62	1.00	299.62	0.051	88.0	74.9 - 81.0	80-Mar-22	21.96	277.66	1E-04 (3)	*Sand*
							80-Jul-14	21.80	277.82		
							80-Jul-25	21.86	277.76		
							80-Aug-14	21.74	277.88		
							80-Sep-03	21.68	277.94		
							80-Sep-08	21.73	277.89		
							80-Nov-27	21.56	278.06		
							81-Mar-17	21.50	278.12		

Table 6B

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous-Basal Aquifer

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
W81-0029	297.10	1.00	298.10	0.051	81.7	70.0 - 81.7	81-Mar-07	22.24	275.86	< 1E-07	*Sand*
W81-0041	299.50	1.25	300.75	0.051	81.7	70.0 - 81.7	81-Mar-09	46.23 *	254.52	< 1E-07	*Sand*
W81-0043	291.50	1.50	293.00	0.051	75.0	63.5 - 75.0	81-Mar-04	14.08	278.92	1E-06	*Sand*
W81-0046	293.20	1.25	294.45	0.051	89.6	77.8 - 89.6	81-Mar-07	17.55	276.90	< 1E-07	*Sand*
W81-0051	286.70	1.31	288.01	0.051	71.5	53.9 - 71.5	81-Mar-08	12.99	275.02	4E-07	*Sand*
W81-0053	288.00	1.20	289.20	0.051	90.7	78.0 - 90.7	81-Mar-07	53.00	236.20	3E-07	*Sand*
W81-0061	299.60	1.30	300.90	0.051	89.0	67.5 - 89.0	81-Mar-05	21.43	279.47	6E-05	*Sand*
W81-0068	289.80	1.40	291.20	0.051	83.0	70.5 - 83.0	81-Mar-09	13.54	277.66	< 1E-07	*Sand*
W81-0069	287.90	1.50	289.40	0.051	102.0	81.6 - 102.0	81-Mar-10	11.90	277.50	1E-05	*Sand*
W81-0072	300.10	1.30	301.40	0.051	82.9	72.0 - 82.9	81-Mar-08	22.74	278.66	2E-07	*Sand*
MW97-42	280.75	0.61	281.36	0.051	89.0	77.0 - 89.0	97-Apr-03	50.50	230.86	> 1E-04	*Sand*

NOTES:

1. *Hydraulic conductivity measurements were conducted by Leggette, Brashears, and Graham Consulting Groundwater Geologists on August 23-27, 1972.*
2. *Hydraulic conductivity measurements were conducted by Shell Canada Ltd. on September 21 - October 11, 1973.*
3. *Hydraulic conductivity measurements were conducted by EBA Engineering Consultants Ltd. following instrument development using compressed air. Therefore, the results should be considered as approximate.*
4. *NA denotes not available.*
5. ** denotes groundwater surface elevation possibly not stabilized.*
6. *Hydrographs for piezometers 1478 and 1751 for periods 1974-1976 and 1975-1979 (respectively) are shown in Alsands, 1981 - Hydrology, Part 2 - Groundwater Hydrology, Alsands Project, Calgary, Alberta, May 1981.*
7. *Piezometer installation details for MW97- series were taken from Golder Associates 1997 report.*
8. *Where the basal sand is absent, piezometers may be completed in the oil sand (>7% bitumen).*
9. *Masl denotes metres above sea level.*

Table 6C

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous - Intra Orebody and Near Contact with Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
<u>Alsands Water Intake Area</u>											
80-WI-1A	284.64	1.0	249.64	0.025	6.7	NA	80-Mar-24	4.40	245.24	NA	Silty Clay/Oil Sand
							80-Mar-25	4.38	245.26		
							80-Aug-10	4.54	245.10		
							80-Sep-08	4.52	245.12		
<u>Alsands North of Isadore's Lake</u>											
815002G	244.4	NA	NA	NA	11.7	11.1 - 11.7	81-Mar-11	1.5	232.9	NA	Oil Sand
815003G	240.9	NA	NA	NA	9.0	8.4 - 9.0	81-Feb-10	6.3	234.6	NA	Clay Shale, Oil Sand
							81-Mar-11	1.5	239.4		
815004G	236.3	NA	NA	NA	8.5	7.9 - 8.5	81-Feb-10	2.4	233.9	NA	Clay Shale, Oil Sand
							81-Mar-11	2.7	233.6		
815005G	237.3	NA	NA	NA	13.1	12.5 - 13.1	81-Mar-11	1.2	236.1	NA	Oil Sand
815006G	238.2	NA	NA	NA	9.5	8.8 - 9.5	81-Mar-11	7.4	230.8	NA	Clay Shale, Oil Sand
815007G	249.1	NA	NA	NA	12.6	12.0 - 12.6	81-Mar-11	1.6	247.5	NA	Clay Shale, Oil Sand
815008G	248.9	NA	NA	NA	6.1	5.5 - 6.1	81-Mar-12	5.8	243.1	NA	Oil Sand
815009G	250.0	NA	NA	NA	5.9	5.3 - 5.9	81-Feb-12	7.6	242.4	NA	Oil Sand
							81-Mar-12	0.4	249.6		
815010G	260.0	NA	NA	NA	14.2	13.6 - 14.2	81-Mar-11	10.4	249.6	NA	Clay Shale, Oil Sand
815011G	245.4	NA	NA	NA	5.5	4.9 - 5.5	81-Mar-11	0.8	244.6	NA	Oil Sand, Clay Shale
815012G	246.3	NA	NA	NA	7.2	6.6 - 7.2	81-Feb-09	7.1	239.2	NA	Oil Sand
							81-Mar-11	0.3	246.0		
815013G	239.8	NA	NA	NA	14.5	13.9 - 14.5	81-Mar-11	2.2	237.6	NA	Clay Shale, Oil Sand

Table 6C

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous - Intra Orebody and Near Contact with Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
815014G	238.9	NA	NA	NA	12.6	12.0 - 12.6	81-Mar-11	11.8	227.1	NA	Clay Shale
815017G	242.3	NA	NA	NA	4.6	4.0 - 4.6	81-Mar-11	1.6	240.7	NA	Clay Shale, Oil Sand
815018G	246.2	NA	NA	NA	5.9	5.3 - 5.9	81-Mar-11	2.1	244.1	NA	Oil Sand
Alsands Plant Site											
80-P-01	299.4	1.72	301.12	0.075	12.14	NA	80-Feb-17	3.02	298.10	NA	Oil Sand
							80-Mar-08	3.47	297.65		
							80-Mar-23	3.72	297.40		
							80-Sep-04	3.42	297.70		
							80-Sep-08	3.42	297.70		
							81-Feb-19	3.81	297.31		
80-P-18	299.43	0.43	299.86	0.075	10.57	NA	80-Sep-04	1.12	298.74	NA	Clay Shale/Oil Sand
							80-Sep-08	1.20	298.66		
							81-Feb-20	0.30	299.56		
80-P-19	297.74	0.84	298.58	0.075	14.34	NA	80-Mar-08	2.13	296.45	NA	Oil Sand
							80-Mar-23	2.58	296.00		
							80-Sep-04	0.93	297.65		
							80-Sep-08	0.90	297.68		
							81-Feb-19	0.95	297.63		
80-P-20	296.57	1.11	297.68	0.075	12.02	NA	80-Mar-08	1.64	296.04	NA	Oil Sand
							80-Sep-04	2.46	295.22		
							80-Sep-08	2.86	294.82		
							81-Feb-19	2.59	295.09		
Alsands Tailings Pond Area											
80-TP-5	300.76	0.14	300.90	0.075	8.11	NA	80-Mar-23	1.54	299.36	NA	Clay Shale/Oil Sand
							80-Jul-13	1.12	299.78		
							80-Jul-29	0.60	300.30		
							80-Sep-06	1.30	299.60		
							80-Sep-08	1.31	299.59		
							80-Nov-27	1.12	299.78		

Table 6C

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Cretaceous - Intra Orebody and Near Contact with Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
80-TP-13	294.17	1.20	295.37	0.075	8.12	NA	80-Mar-23	1.37	294.00	NA	Clay Shale/Oil Sand
							80-Jul-28	2.00	293.37		
							80-Sep-06	1.93	293.44		
80-TP-42	284.02	0.70	284.72	0.075	11.54	NA	80-Mar-23	1.30	283.42	NA	Clay Shale/Oil Sand
							80-Jul-29	1.00	283.72		
							80-Sep-06	0.88	283.84		
							81-Feb-20	0.78	283.94		
80-TP-48	283.55	0.80	284.35	0.075	9.33	NA	80-Mar-09	1.30	283.05	NA	Oil Sand
							80-Jul-12	0.91	283.44		
							80-Jul-29	1.00	283.35		
							80-Aug-11	1.00	283.35		
							80-Aug-16	0.96	283.39		
							80-Sep-06	0.98	283.37		
							80-Nov-26	0.88	283.47		
80-TP-58	296.49	0.80	297.29	0.075	7.86	NA	80-Mar-09	2.20	295.09	NA	Clay Shale/Oil Sand
							80-Jul-29	1.20	296.09		
							80-Sep-06	0.98	296.31		
							81-Feb-20	1.04	296.25		
80-TP-66	288.05	0.40	288.45	0.075	9.08	NA	80-Mar-24	4.50	283.95	NA	Clay Shale
							80-Jul-29	2.23	286.22		
							80-Sep-06	2.11	286.34		
							81-Feb-20	2.04	286.41		
MW97-42A	NA	0.61	NA	0.051	24.5	20.7 - 24.5	81-Apr-03	14.14	267.3	7×10^{-8}	Sand

Table 6C
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Cretaceous - Intra Orebody and Near Contact with Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pipe (Steel or PVC) Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Open Interval (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
Mine Site Area											
W71-1119	Construction details not available										
W71-1182	Construction details not available										
W72-1213	Construction details not available										
815185G	299.9	NA	NA	NA	4.6	NA	81-Mar-06	2.0	NA	NA	Oil Sand
815186G	299.2	NA	NA	NA	4.7	3.7 - 4.7	81-Mar-07	1.8	NA	NA	Oil Sand
815188G	297.9	NA	NA	NA	5.0	NA	81-Mar-07	2.3	NA	NA	Oil Sand
815189G	296.9	NA	NA	NA	5.0	4.2 - 5.0	81-Mar-07	3.1	NA	NA	Clay Shale, Oil Sand

NOTES:

1. *80- and 81- series piezometer installation details for Water Intake, North of Isadore's Lake, Plant Site, Tailings Pond and Mine Site areas were taken from Hardy Associates (1978) Ltd. and EBA Engineering Consultants Ltd. reports prepared for Alsads in 1980 and 1981.*
2. *NA denotes not available.*
3. *Selected hydrographs are shown in Alsads, 1981 - Hydrology, Part 2 - Groundwater Hydrology, Alsads Project, Calgary, Alberta, May, 1981.*
4. *Piezometer installation details for MW-series were taken from Golder Associates, 1997 report.*
5. *"Standpipes" installed during the geotechnical exploration programs, unless upgraded, are not included in this table.*
6. *Masl denotes metres above sea level.*

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
Alsands Water Intake Area											
80-WI-2	239.22	0.50	239.72	0.025	9.0	NA	80-Mar-24	0.57	239.15	NA	Silty Clay
							80-Aug-10	1.13	238.59		
							80-Sep-08	1.50	238.22		
80-WI-4B	233.06	0.50	233.56	0.025	5.5	NA	80-Aug-10	0.52	233.04	NA	Silty Clay
							80-Sep-08	0.45	233.11		
80-WI-5	237.32	1.10	238.42	0.025	10.55	NA	80-Mar-24	3.30	235.12	NA	Silty Clay
							80-Mar-25	3.82	234.60		
							80-Aug-10	4.72	233.70		
							80-Sep-08	3.68	234.74		
80-WI-6A	250.37	NA	NA	NA	NA	NA	80-Mar-25	1.12	249.25	NA	NA
80-WI-7	234.92	NA	NA	NA	5.2	NA	80-Mar-25	0	234.92	NA	Sand/clay
80-WI-9	234.69	NA	NA	NA	6.5	NA	80-Mar-24	3.60	231.09	NA	Sand
							80-Mar-25	3.69	231.00		
80-WI-13	233.09	NA	NA	NA	6.0	NA	80-Mar-24	1.30	231.79	NA	Sand
							80-Mar-25	1.32	231.77		
80-WI-14B	233.20	NA	NA	NA	5.2	NA	80-Mar-24	0.3	232.90	NA	Sand
80-WI-15B	232.90	NA	NA	NA	2.6	NA	80-Mar-25	0.1	232.80	NA	Peat

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
Alsands Plant Site Area											
80-P-04	299.24	1.05	300.29	0.075	2.85	NA	80-Mar-08	2.70	297.59	NA	Sand
							80-Sep-04	2.23	298.06		
							80-Sep-08	2.26	298.03		
							81-Feb-19	2.85	297.44		
Alsands Tailings Pond Area											
80-TP-80	283.87	1.09	284.96	0.075	2.17	NA	80-Mar-10	1.45	283.51	NA	Peat
							80-Jul-15	1.24	283.72		
							80-Jul-29	1.00	283.96		
							80-Aug-11	0.93	284.03		
							80-Aug-16	0.93	284.03		
							80-Sep-06	0.94	284.02		
							80-Nov-29	0.87	284.09		
80-TP-84	288.01	1.00	289.01	0.075	2.80	NA	80-Mar-13	1.50	287.51	NA	Sand
							80-Jul-10	1.90	287.11		
							80-Jul-29	1.20	287.81		
							80-Aug-17	1.39	287.62		
							80-Sep-06	1.37	287.64		
							80-Sep-09	1.41	287.60		
							80-Nov-25	1.40	287.61		
80-TP-120	284.38	0.74	285.12	0.075	4.29	NA	80-Jul-29	2.55	282.57	NA	Gravel
							80-Sep-06	2.10	283.02		
							80-Sep-08	2.09	283.03		
MW97-6	283.32	0.76	284.08	0.051	2.20	0.60 - 1.70	97-Mar-29	Dry	<282.48	NA	Sandy Silt

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
Mine Site Area											
80-MS-33	282.17	0.60	282.77	0.025	2.75	NA	80-Jul-27	0.78	281.99	NA	Sand, Clay, Peat
							80-Aug-01	0.70	282.07		
							80-Aug-03	0.59	282.18		
							80-Aug-19	0.55	282.22		
							80-Sep-05	0.53	282.24		
							80-Nov-11	0.38	282.39		
							81-Mar-03	0.48	282.29		
80-MS-35	286.71	0.29	287.00	0.025	3.05	NA	80-Aug-01	0.90	286.10	NA	Silty Sand
							80-Sep-05	0.60	286.40		
							81-Feb-13	1.55	285.45		
80-MS-37	293.81	1.00	294.81	0.025	11.87	NA	80-Aug-01	1.86	292.95	NA	Sand, Clay
							80-Sep-05	1.32	293.49		
							80-Sep-07	1.34	293.47		
							81-Mar-03	3.10	291.71		
80-MS-101	283.65	0.50	284.15	0.025	2.80	NA	80-Aug-08	1.45	282.70	NA	Sand
							80-Sep-03	1.45	282.70		
							80-Sep-07	1.51	282.64		
80-MS-103	280.12	1.33	281.45	0.025	2.10	NA	80-Jul-27	1.65	279.80	NA	Sand, Peat
							80-Aug-08	1.60	279.85		
							80-Aug-14	1.57	279.88		
							80-Sep-03	1.53	279.92		
							80-Sep-07	1.52	279.93		
							80-Nov-27	1.45	280.00		

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
80-MS-104	289.52	0.50	290.02	0.025	2.65	NA	80-Aug-01	0.68	289.34	NA	Sand
							80-Sep-03	0.64	289.38		
							80-Sep-07	0.73	289.29		
80-MS-106	287.45	0.91	288.36	0.025	3.45	NA	80-Aug-01	2.02	286.34	NA	Sand
							80-Sep-03	1.51	286.85		
							80-Sep-07	1.53	286.83		
80-MS-108	289.95	0.50	290.45	0.025	1.05	NA	80-Aug-08	0.59	289.86	NA	Sand, Peat
							80-Sep-03	0.60	289.85		
							80-Sep-07	0.61	289.84		
80-MS-112	291.89	1.60	293.49	0.025	4.13	NA	80-Aug-08	1.63	291.86	NA	Sand, Peat
							80-Sep-03	1.67	291.82		
							80-Sep-07	1.69	291.80		
80-MS-116	293.71	1.15	294.86	0.025	2.93	NA	80-Aug-06	1.20	293.66	NA	Sand, Clay
							80-Sep-05	1.21	293.65		
							81-Mar-03	0.85	294.01		
80-MS-223	282.77	0.60	283.37	0.025	4.74	NA	80-Aug-01	1.20	282.17	NA	Sand, Clay
							80-Sep-05	0.53	282.84		
							80-Sep-07	0.53	282.84		
							81-Mar-03	4.55	278.82		
80-MS-224	288.44	1.95	290.39	0.025	3.10	NA	80-Aug-07	1.95	288.44	NA	Sand
							80-Sep-05	1.90	288.49		
							80-Sep-07	1.85	288.54		
							81-Mar-03	1.80	288.59		

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
80-MS-227	299.62	0.80	300.42	0.025	1.89	NA	80-Jul-30	0.86	299.56	NA	Sand
							80-Sep-05	0.79	299.63		
							80-Sep-08	0.80	299.62		
80-MS-249	293.16	0.56	293.72	0.025	2.70	NA	80-Jul-31	1.20	292.52	NA	NA
							80-Sep-05	1.17	292.55		
							81-Feb-13	0.67	293.05		
80-MS-253	284.12	0.80	284.92	0.025	3.75	NA	80-Aug-07	3.54	281.38	NA	NA
							80-Sep-05	3.40	281.52		
							80-Sep-07	3.42	281.50		
							81-Mar-04	2.46	282.46		
80-MS-260	298.45	0.95	299.40	0.025	2.82	NA	80-Apr-16	2.62	296.78	NA	NA
							80-Apr-23	2.61	296.79		
							80-Apr-27	2.14	297.26		
							80-May-05	1.91	297.49		
							80-May-22	1.91	297.49		
							80-May-27	1.49	297.91		
							80-Jun-06	1.58	297.82		
							80-Jun-17	1.81	297.59		
							80-Jun-25	1.74	297.66		
							80-Jul-02	2.09	297.31		
							80-Jul-06	1.83	297.57		
							80-Jul-26	1.67	297.73		
							80-Jul-30	1.40	298.00		
							80-Aug-08	2.09	297.31		
							80-Aug-15	1.98	297.42		
							80-Sep-05	1.93	297.47		
							80-Nov-27	1.78	297.62		

Table 6D
Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities
Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
80-MS-264	291.16	0.90	292.06	0.025	4.20	NA	80-Aug-08	0.92	291.14	NA	NA
							80-Sep-05	0.97	291.09		
							80-Sep-07	0.95	291.11		
							81-Mar-17	0.90	291.16		
80-MS-273	292.31	1.56	293.87	0.075	4.62	NA	80-Apr-12	2.96	290.91	NA	Clayey Silt
							80-Apr-17	3.01	290.86		
							80-Apr-22	2.87	291.00		
							80-Apr-27	2.53	291.34		
							80-May-05	2.17	291.70		
							80-May-21	2.18	291.69		
							80-May-28	2.37	291.50		
							80-Jun-05	2.45	291.42		
							80-Jun-16	2.10	291.77		
							80-Jun-23	2.15	291.72		
							80-Jul-02	2.37	291.50		
							80-Jul-07	2.03	291.84		
							80-Jul-15	2.26	291.61		
							80-Jul-21	1.98	291.89		
							80-Jul-25	1.84	292.03		
							80-Jul-31	1.80	292.07		
							80-Aug-05	1.65	292.22		
							80-Aug-15	1.53	292.34		
							80-Aug-16	1.61	292.26		
							80-Aug-27	1.65	292.22		
							80-Sep-04	1.64	292.23		
							80-Sep-05	1.62	292.25		
							80-Sep-22	1.51	292.36		
							80-Oct-03	2.21	291.66		
							80-Nov-26	Frozen @ 292.14			

Table 6D

Piezometer Installation Details, Datum / Groundwater Surface Elevations And Hydraulic Conductivities

Quaternary Deposits

Piezometer No.	Ground Elevation (masl)	Stick-Up or Steel PVC Pipe (above ground) (m)	Datum Elevation (top of PVC casing) (masl)	Pvc Pipe Diameter (m)	Total Depth Of Piezo. (below ground) (m)	Depth Interval Of Sand (below ground) (m)	Date (y-m-d)	Depth To Water Below Datum (m)	Groundwater Surface Elevation (masl)	Hydraulic Conductivity (m/s)	Lithology
80-MS-280	292.21	0.44	292.65	0.025	4.19	NA	80-Jul-31	1.65	291.00	NA	Silty Sand
							80-Sep-05	1.58	291.07		
80-MS-286	295.50	0.90	296.40	0.025	2.90	NA	80-Jul-31	0.90	295.50	NA	Sand
							80-Sep-05	0.86	295.54		
							80-Sep-08	0.88	295.52		
MW97-1	284.77	0.73	285.50	0.051	4.60	2.00 - 3.80	97-Apr-03	3.18	282.32	4×10^{-7}	Silty Gravel
MW97-2	283.14	0.73	283.87	0.051	3.80	1.10 - 2.90	97-Apr-03	1.17	282.70	$>10^{-4}$	Fine to Medium Grained Sand
MW97-3	287.30	0.70	288.00	0.051	5.20	3.10 - 5.20	97-Apr-03	3.48	284.52	9×10^{-7}	Silty, Medium Grained Sand
MW97-4	282.25	0.61	282.86	0.051	3.40	2.30 - 3.40	97-Apr-03	1.14	281.72	2×10^{-7}	Medium Grained, Silty Sand
MW97-5	284.95	0.85	285.80	0.051	3.70	1.50 - 3.70	97-Apr-03	3.51	282.29	2×10^{-6}	Silty Gravel

NOTES:

1. *80- series piezometer installation details for Water Intake, Plant Site, and Tailings Pond Areas were taken from Hardy Associates (1978) Ltd. and EBA Engineering Consultants Ltd. reports prepared for Alsands in 1980 and 1981.*
2. *Piezometer installation details for Mine Site Area were taken from Robinson Dames & Moore reports prepared for Alsands in 1980.*
3. *NA denotes not available.*
4. *Selected hydrographs are shown in Alsands, 1981 - Hydrology, Part 2 - Groundwater Hydrology, Alsands Project, Calgary, Alberta, May 1981.*
5. *Piezometer installation details for MW97-series were taken from Golder Associates, 1997 report.*
6. *"Standpipes" installed during the geotechnical exploration programs, unless upgraded, are not included in this table.*
7. *Masl denotes metres above sea level.*

Table 7A

Groundwater Quality: Field Measured Parameters

Cretaceous - Basal Aquifer

Monitoring Station	Date of Sampling *(y-m-d)*	Temperature *(^0C)*	EC *(µS/cm)*	pH *(units)*	Remarks
MW97-42	97-Apr-04	6.9	3740	7.12	---

Table 7B

Groundwater Quality: Field Measured Parameters

Cretaceous - Intra Orebody and Near Contact with Quarternary Deposits

Monitoring Station	Date of Sampling *(y-m-d)*	Temperature *(^0C)*	EC *(µS/cm)*	pH *(units)*	Remarks
MW97-42A	97-Apr-04	4.5	1326	6.92	---

Table 7C

Groundwater Quality: Field Measured Parameters

Quaternary Deposits

Monitoring Station	Date of Sampling *(y-m-d)*	Temperature *(^0C)*	EC *(µS/cm)*	pH *(units)*	Remarks
Alsands Tailings Pond Area					
MW97-6	97-Apr-04	NA	NA	NA	Dry
Mine Site Area					
MW97-1	97-Apr-04	2.1	741	7.14	---
MW97-2	97-Apr-04	1.1	377	7.14	---
MW97-3	97-Apr-04	0.9	518	6.80	---
MW97-4	97-Apr-04	1.3	867	6.96	---
MW97-5	97-Apr-04	2.3	1285	7.70	---

NOTES: *1. NA denotes not available or not analysed.*

Table 8A

Water Quality: Indicator Concentrations

Devonian - Methy Formation

Monitoring Station	Date of Sampling *(y-m-d)*	pH *(units)*	Sulphate *(mg/L)*	Chloride *(mg/L)*	Total Dissolved Solids *(mg/L)*	Iron *(mg/L)*	Manganese *(mg/L)*	Fluoride *(mg/L)*	Hydrochemical Type
W72-1240	81-Mar-14	7.3	3,734	22,340	42,468	0.45	0.11	NA	*Cl-Na*
W73-1404	81-Mar-13	*See note 3*							
W73-1481	81-Mar-13	7.4	3,640	21,223	40,724	59.5	1.64	NA	*Cl-Na*
W73-1489	81-Mar-08	7.6	2,726	5,920	13,948	10.9	0.43	NA	*Cl-Na*
	81-Mar-15	7.4	2,551	5,735	13,462	0.12	0.06	NA	*Cl-Na*
W75-1717	81-Mar-16	7.6	3,177	9,606	20,638	200	2.15	NA	*Cl-Na*
W80-5027	81-Mar-01	7.6	1,160	4,915	9,824	0.10	< 0.01	NA	*Cl-Na*
W80-5039	81-Mar-06	7.3	4,737	43,563	78,666	3.30	0.38	NA	*Cl-Na*

NOTES:

1. ***All piezometers completed in the Methy Formation Carbonates were reconstructed in February and March 1981. (EBA Consultants Ltd. 1981a).***
2. ***The hydrochemical data for these piezometers, prior to reconstruction, are given in Alsands Energy Ltd. - Hydrogeology, Part 2 - Groundwater hydrogeology, Alsands Project, May 1981, Calgary, Alberta.***
3. ***Groundwater sample collected from piezometer 1404 on March 13, 1981 had pH = 11.1, indicating contamination with cement filtrate.***
4. ***Iron and manganese represent total concentrations. High concentration of suspended solids is expected to contribute to elevated and high levels of these metals.***
5. ***NA denotes not available or not analysed.***

Table 8B
Groundwater Quality: Indicator Concentrations
Cretaceous - Basal Aquifer

Monitoring Station	Date of Sampling (y-m-d)	pH (units)	Sulphate (mg/L)	Chloride (mg/L)	Total Dissolved Solids (mg/L)	Iron (mg/L)	Manganese (mg/L)	Fluoride (mg/L)	Hydrochemical Type
W71-1119	1971	8.1	34	949	4,046	NA	NA	NA	HCO_3-Cl-Na
	1971	7.9	60	1,170	3,992	NA	NA	NA	Cl-HCO_3-Na
W72-1233	80-Aug-06	8.6	39	1,050	3,280	0.1	0.4	NA	Cl-HCO_3-Na
W72-1235	72-Aug-26	7.5	46	1,056	3,764	Trace	NA	NA	Cl-HCO_3-Na
	73-Sep-30	7.5	55	1,173	3,929	NA	NA	NA	Cl-HCO_3-Na
	73-Oct-05	7.4	35	1,173	3,881	NA	NA	NA	Cl-HCO_3-Na
	73-Oct-11	7.4	16	1,173	3,938	NA	NA	NA	Cl-HCO_3-Na
	80-Jul-04	8.3	24	1,139	3,699	0.6	0.1	1.6	Cl-HCO_3-Na
	80-Jul-27	8.1	22	1,095	3,745	2.5	0.2	1.6	Cl-HCO_3-Na
W72-1238	80-Jul-04	8.2	64	1,061	3,894	0.1	0.1	1.8	Cl-HCO_3-Na
W73-1365	74-Oct-23	7.6	27	1,050	3,734	NA	NA	NA	Cl-HCO_3-Na
	75-Jan-28	7.9	60	1,028	3,695	0.2	NA	NA	Cl-HCO_3-Na
	75-Jan-29	7.9	60	1,028	3,682	0.2	NA	NA	Cl-HCO_3-Na
	75-Jan-30	7.9	63	1,028	3,686	< 0.1	NA	NA	Cl-HCO_3-Na
W73-1432	80-Jul-03	8.4	21	1,435	4,586	1.4	0.9	1.0	Cl-HCO_3-Na
	80-Jul-25	8.4	6	1,363	4,459	NA	NA	NA	Cl-HCO_3-Na
W73-1434	80-Jul-07	8.2	29	1,033	3,613	0.9	0.1	1.7	Cl-HCO_3-Na
	80-Jul-24	8.1	16	1,072	3,693	NA	NA	NA	Cl-HCO_3-Na
W73-1439	74-Oct-27	8.0	12	1,011	3,711	NA	NA	NA	Cl-HCO_3-Na
	74-Oct-07	8.0	16	1,044	3,770	NA	NA	NA	Cl-HCO_3-Na
	80-Jul-27	8.1	10	1,050	3,653	< 0.1	< 0.1	1.8	Cl-HCO_3-Na
W74-1510	80-Jul-07	8.2	33	1,083	3,706	0.7	0.6	1.9	Cl-HCO_3-Na
W74-1511	74-Oct-24	7.7	32	1,106	3,877	NA	NA	NA	Cl-HCO_3-Na
	80-Jul-06	8.2	27	1,056	3,684	0.2	0.1	1.6	Cl-HCO_3-Na
W74-1512	74-Oct-27	8.0	21	1,296	3,639	NA	NA	NA	Cl-HCO_3-Na
	74-Oct-27	8.0	13	1,167	3,672	NA	NA	NA	Cl-HCO_3-Na
W75-1750	75-Jan-26	8.2	16	1,061	3,511	NA	NA	NA	Cl-HCO_3-Na
W75-1751	75-Feb-01	8.1	39	1,050	3,590	NA	NA	NA	Cl-HCO_3-Na
	76-Jul-16	7.5	36.7	1,010	3,658	NA	NA	1.5	Cl-HCO_3-Na
W75-1752	75-Jan-29	8.3	58	1,050	3,492	NA	NA	NA	Cl-HCO_3-Na
W75-1753	75-Feb-02	8.1	52	1,072	3,693	NA	NA	NA	Cl-HCO_3-Na
	80-Jul-06	8.2	30	1,117	3,617	0.1	0.1	1.8	Cl-HCO_3-Na
W75-1754	80-Jul-05	8.1	45	1,061	3,715	0.1	0.1	1.8	Cl-HCO_3-Na

Table 8B

Groundwater Quality: Indicator Concentrations

Cretaceous - Basal Aquifer

Monitoring Station	Date of Sampling *(y-m-d)*	pH *(units)*	Sulphate *(mg/L)*	Chloride *(mg/L)*	Total Dissolved Solids *(mg/L)*	Iron *(mg/L)*	Manganese *(mg/L)*	Fluoride *(mg/L)*	Hydrochemical Type
W80-5025	80-Mar-10	8.0	28	729	2,943	1.3	0.1	2.0	*HCO_3-Cl-Na*
W80-5026	80-Mar-05	8.5	90	1,089	4,069	9.0	0.5	2.3	*Cl-HCO_3-Na*
	80-Jul-08	8.3	29	1,111	3907	0.2	0.1	1.6	*Cl-HCO_3-Na*
W80-5043	80-Mar-20	8.0	8	639	3650	0.6	0.1	1.3	*HCO_3-Cl-Na*
	80-Jul-15	8.4	16	693	4003	0.1	0.1	1.0	*HCO_3-Cl-Na*
	80-Jul-25	8.3	3	693	3973	0.1	0.1	1.2	*HCO_3-Cl-Na*
W80-5053	80-Mar-20	8.0	11	517	2294	3.5	0.4	1.4	*HCO_3-Cl-Na*
	80-Jul-16	8.3	12	335	2503	1.6	0.3	1.4	*HCO_3-Cl-Na*
	80-Jul-24	8.1	52	346	2599	0.8	0.3	1.5	*HCO_3-Cl-Na*
W80-5054	80-Mar-11	7.9	22	385	2378	0.8	0.1	1.5	*HCO_3-Cl-Na*
	80-Jul-24	8.2	5	424	2507	0.1	0.1	1.5	*HCO_3-Cl-Na*
W80-5069	80-Mar-20	8.0	7	729	3393	0.7	0.1	1.3	*HCO_3-Cl-Na*
	80-Jul-14	8.3	12	726	3425	0.3	0.1	NA	*HCO_3-Cl-Na*
W80-5076	80-Mar-06	8.3	17	246	2080	5.5	0.3	1.2	*HCO_3-Cl-Na*
	80-Jul-14	8.4	12	257	2021	0.8	0.2	NA	*HCO_3-Cl-Na*
W80-5077	80-Mar-22	8.5	74	614	3255	3.0	0.2	1.3	*HCO_3-Cl-Na*
	80-Jul-14	8.5	13	681	3164	0.3	0.1	1.2	*HCO_3-Cl-Na*
W81-0043	81-Mar-04	8.2	7	1385	4516	0.07	0.08	NA	*Cl-HCO_3-Na*
W81-0051	81-Mar-08	8.2	14	1229	4360	0.13	0.03	NA	*Cl-HCO_3-Na*
W81-0053	81-Mar-07	8.1	6	648	3857	0.68	0.05	NA	*HCO_3-Cl-Na*
W81-0061	81-Mar-03	7.9	4	113	1407	0.16	0.14	NA	*HCO_3-Na*
	81-Jul-23	7.9	3	81	1430	NA	NA	NA	*HCO_3-Na*
W81-0068	81-Mar-18	7.9	12	2793	7407	30.3	1.06	NA	*Cl-HCO_3-Na*
W81-0069	81-Mar-10	8.2	22	1206	3966	0.05	0.02	NA	*Cl-HCO_3-Na*
W81-0072	81-Mar-08	8.2	8	2039	5942	2.77	0.18	NA	*Cl-HCO_3-Na*
MW97-42	97-Apr-06	7.4	85.7	122	815	2.85	0.42	NA	*Cl-HCO_3-Na-Ca*
	97-Apr-10	7.3	24.0	548	2380	NA	NA	NA	*HCO_3-Cl-Na*

NOTES:

1. ***Iron and manganese represent total concentrations. High concentration of suspended solids is expected to contribute to elevated and high levels of these metals.***
2. ***NA denotes not available or not analysed.***

Table 8C

Groundwater Quality: Indicator Concentrations

Cretaceous - Intra Orebody and Near Contact with Quarternary Deposits

Monitoring Station	Date of Sampling (y-m-d)	pH (units)	Sulphate (mg/L)	Chloride (mg/L)	Total Dissolved Solids (TDS) (mg/L)	Iron (mg/L)	Manganese (mg/L)	Fluoride (mg/L)	Hydrochemical Type
Alsands Plant Site Area									
80-P-1	80-Jul-20	7.1	10	14	542	NA	NA	NA	HCO3-Ca-Mg-Na
Alsands Tailings Pond Area									
80-TP-5	80-Jul-16	7.0	7	6	429	NA	NA	NA	HCO3-Ca-Mg
80-TP-13	80-Jul-16	7.1	4	7	739	Trace	NA	NA	HCO3-Ca-Mg
	80-Aug-05	7.1	3	7	734	20.0	3.4	0.2	HCO3-Ca-Mg
80-TP-42	80-Aug-12	7.6	18	6	562	NA	NA	NA	HCO3-Ca-Mg
80-TP-48	80-Aug-12	7.1	24	8	277	NA	NA	NA	HCO3-Ca-Na-Mg
80-TP-58	80-Aug-07	6.6	7	7	385	NA	NA	NA	HCO3-Ca-Mg-Na
80-TP-66	80-Jul-16	7.7	5	6	1,451	NA	NA	NA	HCO3-Ca-Mg-Na
	80-Aug-07	7.3	6	9	1,279	9.4	1.7	0.4	HCO3-Na-Ca-Mg
MW97-42	1997	7.4	81.3	122	799	3.32	0.5	NA	HCO3-Na-Ca
Mine Site Area									
W71-1119	1971	8.0	12	42	1,002	NA	NA	NA	HCO3-Na
	1971	8.3	63	67	2,148	NA	NA	NA	HCO3-Na
W71-1182	1971	7.6	8	7	846	Trace	NA	NA	HCO3-Na-Ca-Mg
W72-1213	1971	8.0	2	7	971	Trace	NA	NA	HCO3-Na-Ca

NOTES:

1. *Iron and manganese represent total concentrations. High concentration of suspended solids is expected to contribute to elevated and high levels of these metals.*
2. *NA denotes not available or not analysed.*

Table 8D

Groundwater Quality: Indicator Concentrations

Quaternary Deposits

Monitoring Station	Date of Sampling	pH	Sulphate	Chloride	Total Dissolved Solids (TDS)	Iron	Manganese	Fluoride	Hydrochemical Type
	(y-m-d)	*(units)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	
Alsands Water Intake Area									
80-WI-2	80-Sep-15	7.5	42	134	1,328	3.9	4.0	NA	*HCO_3-Cl-Na-Ca*
80-WI-4B	80-Sep-15	7.2	34	34	677	14.4	0.5	NA	*HCO_3-Ca-Na-Mg*
80-WI-5	80-Sep-15	7.7	119	34	1,729	0.2	0.6	NA	*HCO_3-Na*
Alsands Plant Site Area									
No hydrochemical data are available for this area.									
Alsands Tailings Pond Area									
80-TP-80	80-Aug-16	7.0	2	8	302	Trace	NA	NA	*HCO_3-Ca-Mg*
80-TP-84	80-Jul-21	6.9	24	6	321	Trace	NA	NA	*HCO_3-Ca-Mg*
80-TP-120	80-Jul-16	7.3	10	5	478	NA	NA	NA	*HCO_3-Ca-Mg*
Mine Site Area									
80-MS-35	80-Aug-04	6.7	6	13	593	2.2	0.9	0.2	*HCO_3-Ca-Mg-Na*
80-MS-37	80-Aug-01	7.6	20	20	749	NA	NA	NA	*HCO_3-Na-Ca-Mg*
80-MS-104	80-Aug-01	6.9	44	23	367	NA	NA	NA	*HCO_3-Cl-SO_4-Ca-Na*
80-MS-227	80-Jul-28	7.2	72	6	500	Trace	NA	NA	*HCO_3-SO_4-Ca*
80-MS-273	80-Jul-22	7.0	5	11	291	4.2	0.2	< 0.1	*HCO_3-Na-Ca-Mg*
80-MS-286	80-Jul-31	6.8	26	8	414	NA	NA	NA	*HCO_3-Ca-Mg*
MW97-1	97-Apr-04	7.3	48.8	2.4	464	23.2	2.08	NA	*HCO_3-Ca-Mg*
MW97-2	97-Apr-04	7.4	28.5	2.4	239	6.3	0.215	NA	*HCO_3-Ca-Mg*
MW97-3	97-Apr-04	6.8	13.3	1.6	307	8.98	1.14	NA	*HCO_3-Ca-Mg*
	97-Apr-10	6.9	7.1	0.9	416	NA	NA	NA	*HCO_3-Ca-Mg*
MW97-4	97-Apr-04	7.2	13.3	24.5	539	8.23	0.516	NA	*HCO_3-Ca-Mg*
MW97-5	97-Apr-04	7.9	300	5	846	0.634	0.507	NA	*HCO_3-SO_4-Na-Ca-Mg*

<u>NOTES:</u>

1. ***Iron and manganese represent total concentrations. High concentration of suspended solids is expected to contribute to elevated and high levels of these metals.***
2. ***Deeper piezometers, eg. 80-WI-5, 80-MS-37 may be completed partially in Quaternary and partially in Cretaceous sediments. This may result in higher TDS of groundwater.***
3. ***NA denotes not available or not analysed.***

Table 9A

Groundwater Quality: Selected Metals Concentrations (Total)

Devonian - Methy Formation

Monitoring Station	Date of Sampling (y-m-d)	Aluminum mg/L	Boron mg/L	Barium mg/L	Cadmium mg/L	Chromium mg/L	Copper mg/L	Lead mg/L	Tin mg/L	Zinc mg/L	Silver mg/L	Mercury µg/L	Selenium mg/L	Arsenic mg/L	Uranium mg/L
W72-1240	81-Mar-14	1.35	2.80	0.05	<0.1	0.11	<0.05	<0.2	NA	0.22	<0.2	<0.01	<0.001	<0.001	0.05
W73-1404	81-Mar-13	See Note 3													
W73-1481	81-Mar-13	31.3	2.50	0.22	<0.1	0.12	0.01	0.08	NA	0.76	<0.2	<0.01	<0.001	0.022	0.10
W73-1489	81-Mar-08	0.95	0.82	0.018	<0.02	0.02	0.016	0.02	NA	0.42	0.04	<0.01	<0.001	<0.001	NA
	81-Mar-15	0.40	0.44	0.01	<0.01	0.01	0.01	<0.03	NA	0.11	<0.03	<0.01	<0.001	<0.001	NA
W75-1717	81-Mar-16	95.5	1.58	0.36	0.04	0.29	0.36	0.16	NA	2.81	0.06	<0.01	<0.001	0.080	NA
W80-5027	81-Mar-01	0.34	0.02	0.13	<0.02	<0.02	0.15	<0.04	NA	0.22	<0.04	<0.01	<0.001	<0.001	NA
W80-5039	81-Mar-06	18.7	36.8	3.4	<0.2	<0.2	<0.1	<0.4	NA	<0.4	<0.4	<0.01	<0.001	<0.001	0.05

NOTES:

1. *All piezometers completed in the Methy Formation Carbonates were reconstructed in February and March 1981. (EBA Consultants Ltd. 1981a).*
2. *The hydrochemical data for these piezometers, prior to reconstruction, are given in Alsands Energy Ltd. - Hydrogeology, Part 2 - Groundwater hydrogeology, Alsands Project, May 1981, Calgary, Alberta.*
3. *Groundwater sample collected from piezometer 1404 on March 13, 1981 had pH = 11.1, indicating contamination with cement filtrate.*
4. *NA denotes not available or not analysed.*

Table 9B

Groundwater Quality: Selected Metals Concentrations (Total)

Cretaceous - Basal Aquifer

Monitoring Station	Date of Sampling (y-m-d)	Aluminum mg/L	Boron mg/L	Barium mg/L	Cadmium mg/L	Chromium mg/L	Copper mg/L	Lead mg/L	Tin mg/L	Zinc mg/L	Silver mg/L	Mercury µg/L	Selenium mg/L	Arsenic mg/L	Uranium mg/L
W72-1238	80-Jul-04	<0.05	1.44	0.165	<0.01	<0.01	<0.005	<0.02	0.5	<0.02	<0.02	NA	NA	NA	NA
W73-1434	80-Jul-07	<0.05	1.45	0.145	<0.01	<0.01	<0.005	<0.02	<0.1	<0.02	<0.02	0.05	<0.001	0.008	NA
W75-1753	80-Jul-06	<0.05	1.51	0.186	<0.01	<0.01	<0.005	<0.02	<0.1	<0.02	<0.02	NA	NA	NA	NA
W75-1754	80-Jul-05	<0.05	1.46	0.044	<0.01	<0.01	<0.005	<0.02	<0.1	<0.02	<0.02	NA	NA	NA	NA
W80-5026	80-Jul-18	0.06	1.48	0.236	<0.01	0.02	0.019	<0.02	<0.1	<0.02	<0.02	NA	NA	NA	NA
W80-5043	80-Jul-15	<0.05	3.34	0.305	<0.01	<0.01	0.009	0.07	0.2	<0.02	<0.02	<0.05	<0.001	<0.001	NA
W80-5053	80-Jul-16	<0.05	3.48	0.164	<0.01	<0.01	<0.005	0.02	0.2	0.5	<0.02	<0.05	<0.001	<0.001	NA
W80-5077	80-Jul-14	0.16	2.27	0.249	<0.01	<0.01	0.005	0.02	NA	0.3	<0.02	<0.05	<0.001	<0.001	NA
W81-0043	81-Feb-04	0.17	1.33	0.25	<0.01	<0.01	0.006	<0.02	NA	0.09	<0.02	<0.01	<0.001	<0.001	<0.02
W81-0051	81-Mar-08	0.15	2.24	0.33	<0.01	<0.01	<0.005	<0.02	NA	0.08	<0.02	<0.01	<0.001	<0.001	<0.02
W81-0053	81-Mar-07	0.38	3.00	0.40	<0.01	<0.01	<0.005	<0.02	NA	0.20	<0.02	<0.01	<0.001	<0.001	0.38
W81-0061	81-Mar-05	0.25	1.81	0.54	<0.01	<0.01	<0.005	<0.02	NA	0.07	<0.02	<0.01	<0.001	<0.001	<0.02
W81-0068	81-Mar-09	13.9	2.23	37.9	<0.01	<0.01	0.06	0.16	NA	0.68	<0.02	<0.01	<0.001	0.009	<0.02
W81-0069	81-Mar-10	0.10	1.40	0.31	<0.01	<0.01	<0.005	<0.02	NA	0.33	<0.02	<0.01	<0.001	<0.001	0.10
W81-0072	81-Mar-08	1.22	2.02	1.49	<0.01	<0.01	0.005	<0.02	NA	0.24	<0.02	<0.01	<0.001	<0.001	<0.02

NOTES: *1. NA denotes not available or not analysed.*

Table 9C

Groundwater Quality: Selected Metals Concentrations (Total)

Cretaceous - Intra Orebody and Near Contact with Quaternary Deposits

Monitoring Station	Date of Sampling *(y-m-d)*	Aluminum *mg/L*	Boron *mg/L*	Barium *mg/L*	Cadmium *mg/L*	Chromium *mg/L*	Copper *mg/L*	Lead *mg/L*	Tin *mg/L*	Zinc *mg/L*	Silver *mg/L*	Mercury *µg/L*	Selenium *mg/L*	Arsenic *mg/L*
<u>Alsands Plant Site Area</u>														
80-P-1	80-Aug-20	0.05	0.06	0.088	<0.01	<0.01	0.131	<0.02	<0.1	0.23	<0.02	NA	NA	NA
80-P-9	80-Aug-20	0.13	0.05	0.087	<0.01	<0.01	0.051	0.02	<0.1	0.16	<0.02	NA	NA	NA
<u>Alsands Tailings Pond Area</u>														
80-TP-5	80-Aug-18	0.26	0.02	0.249	<0.01	<0.01	0.106	<0.02	<0.1	0.12	<0.02	<0.05	0.001	0.003
80-TP-13	80-Aug-18	0.10	0.12	0.394	<0.01	<0.01	0.2	<0.02	0.1	0.19	<0.02	NA	NA	NA
80-TP-42	80-Aug-12	0.46	0.05	0.166	<0.01	<0.01	0.3	0.25	NA	0.12	<0.02	<0.05	0.006	<0.001
80-TP-48	80-Aug-12	0.64	0.05	0.136	<0.01	<0.01	0.281	0.14	NA	0.21	<0.02	<0.05	0.006	<0.001
80-TP-66	80-Aug-07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	<0.05	<0.001	0.002

<u>NOTES:</u> *1. NA denotes not available or not analysed.*

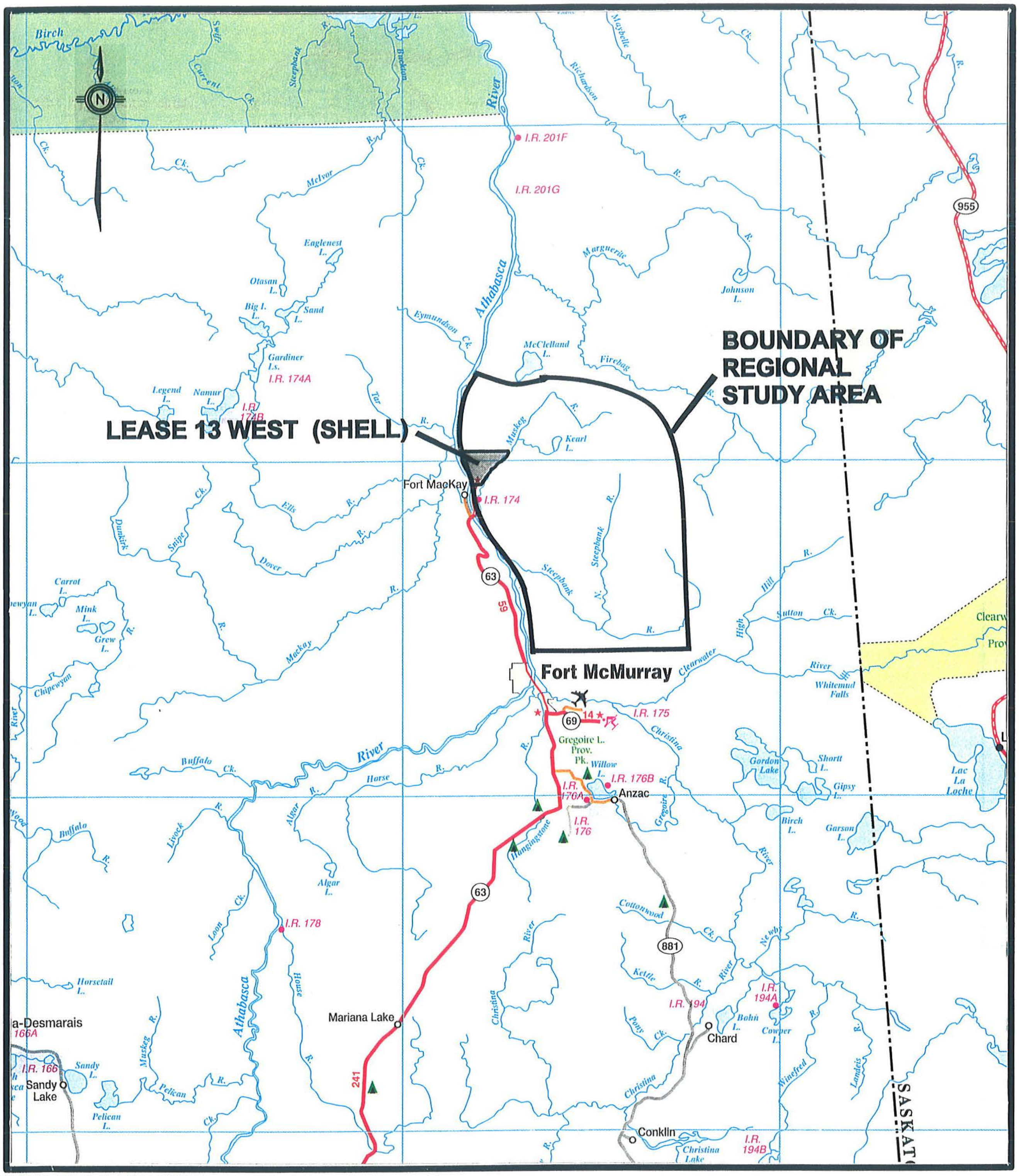
Table 9D

Groundwater Quality: Selected Metals Concentrations (Total)

Quaternary Deposits

Monitoring Station	Date of Sampling (y-m-d)	Aluminum mg/L	Boron mg/L	Barium mg/L	Cadmium mg/L	Chromium mg/L	Copper mg/L	Lead mg/L	Tin mg/L	Zinc mg/L	Silver mg/L	Mercury µg/L	Selenium mg/L	Arsenic mg/L
<u>Alsands Tailings Pond Area</u>														
80-TP-80	80-Aug-06	0.17	0.02	0.071	<0.01	<0.01	0.156	<0.02	<0.1	0.18	<0.02	<0.05	<0.001	0.002
80-TP-84	80-Aug-21	6.3	0.04	0.276	<0.01	<0.01	0.678	0.04	<0.1	0.60	<0.02	<0.05	<0.001	<0.001
80-TP-120	80-Aug-16	0.42	0.02	0.161	<0.01	<0.01	0.139	<0.02	<0.1	0.18	<0.02	<0.05	<0.001	0.002
<u>Mine Site Area</u>														
80-MS-37	80-Sep-23	0.27	0.51	0.229	<0.01	<0.01	0.194	<0.02	NA	0.14	<0.02	<0.05	0.003	<0.001
80-MS-104	80-Aug-01	132	0.77	4.08	0.19	0.34	0.770	0.81	NA	1.13	<0.02	<0.05	0.023	0.001
80-MS-227	80-Jul-28	1.0	0.04	0.412	<0.01	<0.01	0.172	<0.02	<0.1	0.30	<0.02	NA	NA	NA
80-MS-286	80-Jul-31	0.27	0.51	0.276	<0.01	<0.01	0.194	<0.02	NA	0.14	<0.02	NA	NA	NA

<u>**NOTES:**</u> *1. NA denotes not available or not analysed.*



SCALE 1:1,500,000

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KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

REGIONAL STUDY AREA AND LOCATION OF LEASE 13

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	OCT.10/97

APPROVED:	FIGURE:
	1

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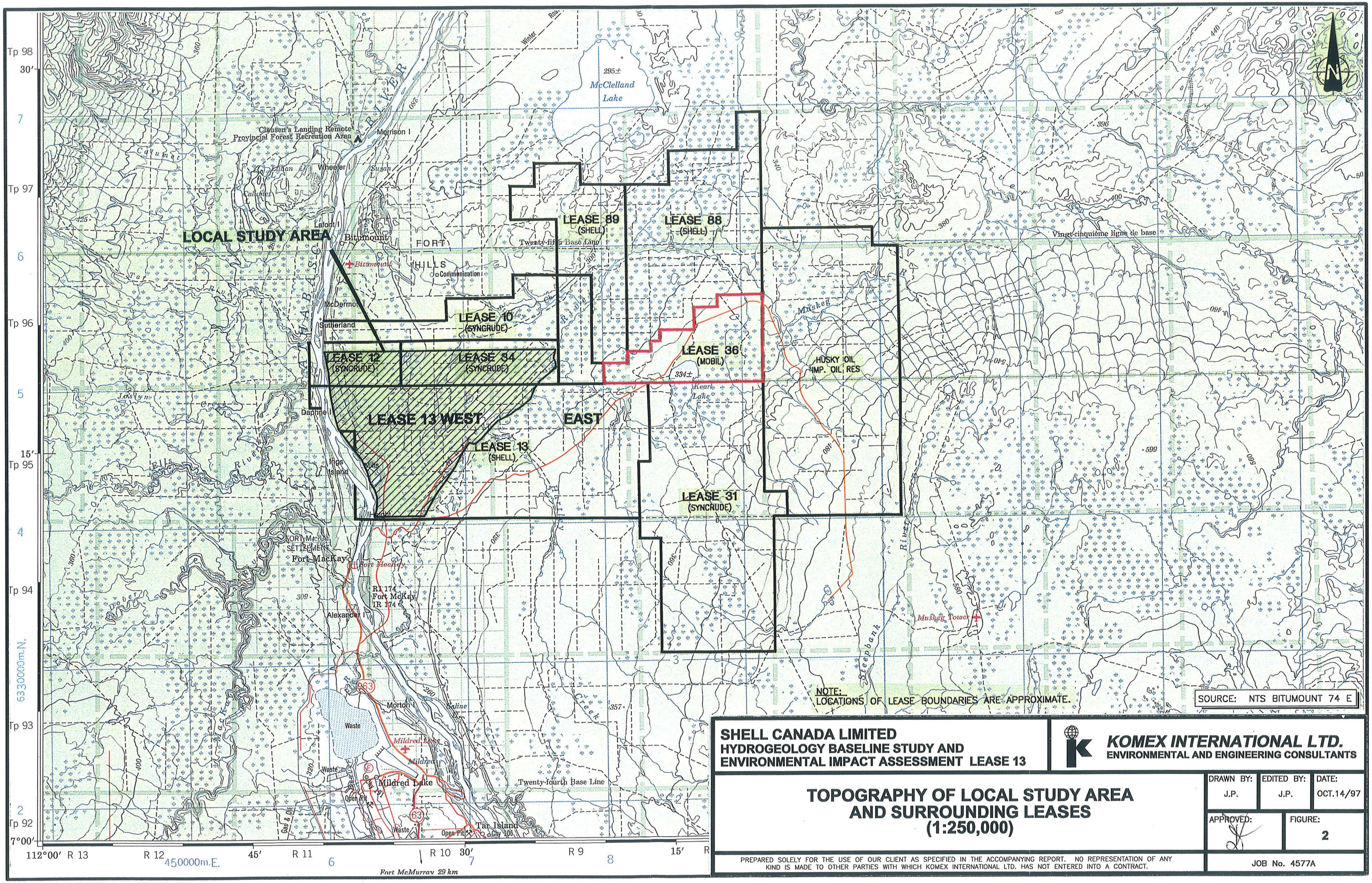
JOB No. 4577A



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HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

TOPOGRAPHY OF LOCAL STUDY AREA AND SURROUNDING LEASES (1:250,000)

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	OCT.14/97

APPROVED: FIGURE: 2

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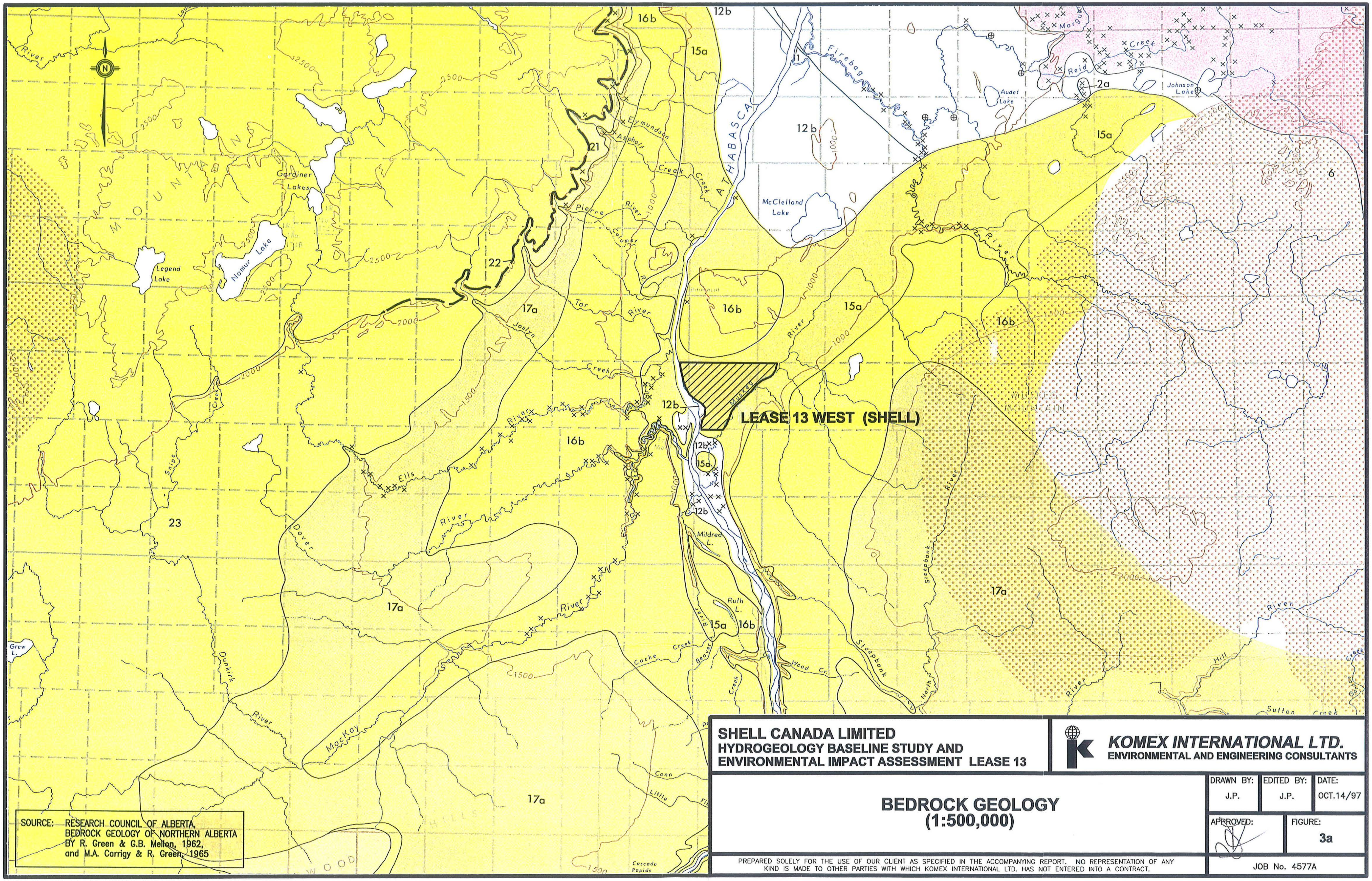

SOURCE: RESEARCH COUNCIL OF ALBERTA, BEDROCK GEOLOGY OF NORTHERN ALBERTA BY R. Green & G.B. Mellon, 1962, and M.A. Carrigy & R. Green, 1965

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BEDROCK GEOLOGY (1:500,000)

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	OCT.14/97
APPROVED:	FIGURE:	
	3a	

JOB No. 4577A

LEGEND

CRETACEOUS

23	*LABICHE FORMATION:* dark grey shale and silty shale, ironstone partings and concretions; thin fish scale-bearing silty beds in lower part; marine
20	*PELICAN FORMATION:* fine-grained quartzose sandstone, silty and glauconitic in lower part; marine
19	*JOLI FOU FORMATION:* dark grey fossiliferous shale, silty interbeds in upper part; marine
17a	*GRAND RAPIDS FORMATION:* fine-grained quartzose and feldspathic sandstone, laminated siltstone and silty shale; thin coaly beds; deltaic to marine
16b	*CLEARWATER FORMATION:* dark grey fossiliferous silty shale, laminated siltstone, fine-grained cherty sandstone; glauconitic sandstone *(WABISKAW MEMBER)* near base; marine
15a	*McMURRAY FORMATION:* crossbedded quartzose sandstone and siltstone; oil-impregnated with grey silty shale interbeds in upper part; deltaic

DEVONIAN

12b	*WATERWAYS FORMATION:* grey and greenish-grey shale and argillaceous limestone units alternating with grey and greyish-brown fine-grained and clastic limestone units; marine
11	*CARIBOU MEMBER, SLAVE POINT FORMATION:* grey and brown fine- to medium-grained limestone and dolomitic limestone; minor shale, gypsum; marine
6	*MIDDLE DEVONIAN* (undivided) includes *METHY FORMATION:* brown and buff massive porous dolomite, brown to grey thin-bedded dolomite, dolomitic limestone, minor anhydrite and gypsum; *McLEAN RIVER FORMATION* and leached *PRAIRIE EVAPORITE FORMATION:* gypsum, anhydrite, grey-green silty and dolomitic shale, minor dolomite; marine to evaporitic

PRECAMBRIAN

2a	*UNDIVIDED GRANITIC PLUTONIC ROCKS:* including biotite granite, porphyroblastic and porphyritic granites; some granite gneiss and metasedimentary rocks

Geological boundary	———
Outcrop location	×
Loose slab, probably from nearby unexposed bedrock	⊕
Spring	
Thick drift	
Sinkhole area	
Surface contour (contour interval 500 feet)	1000
Highway	(35)
Road	
Township boundary	
Indian reservation	
Railway	
Park boundary	

SOURCE: RESEARCH COUNCIL OF ALBERTA, BEDROCK GEOLOGY OF NORTHERN ALBERTA, BY R. Green & G.B. Mellon, 1962, and M.A. Carrigy & R. Green, 1965

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LEGEND FOR BEDROCK GEOLOGY

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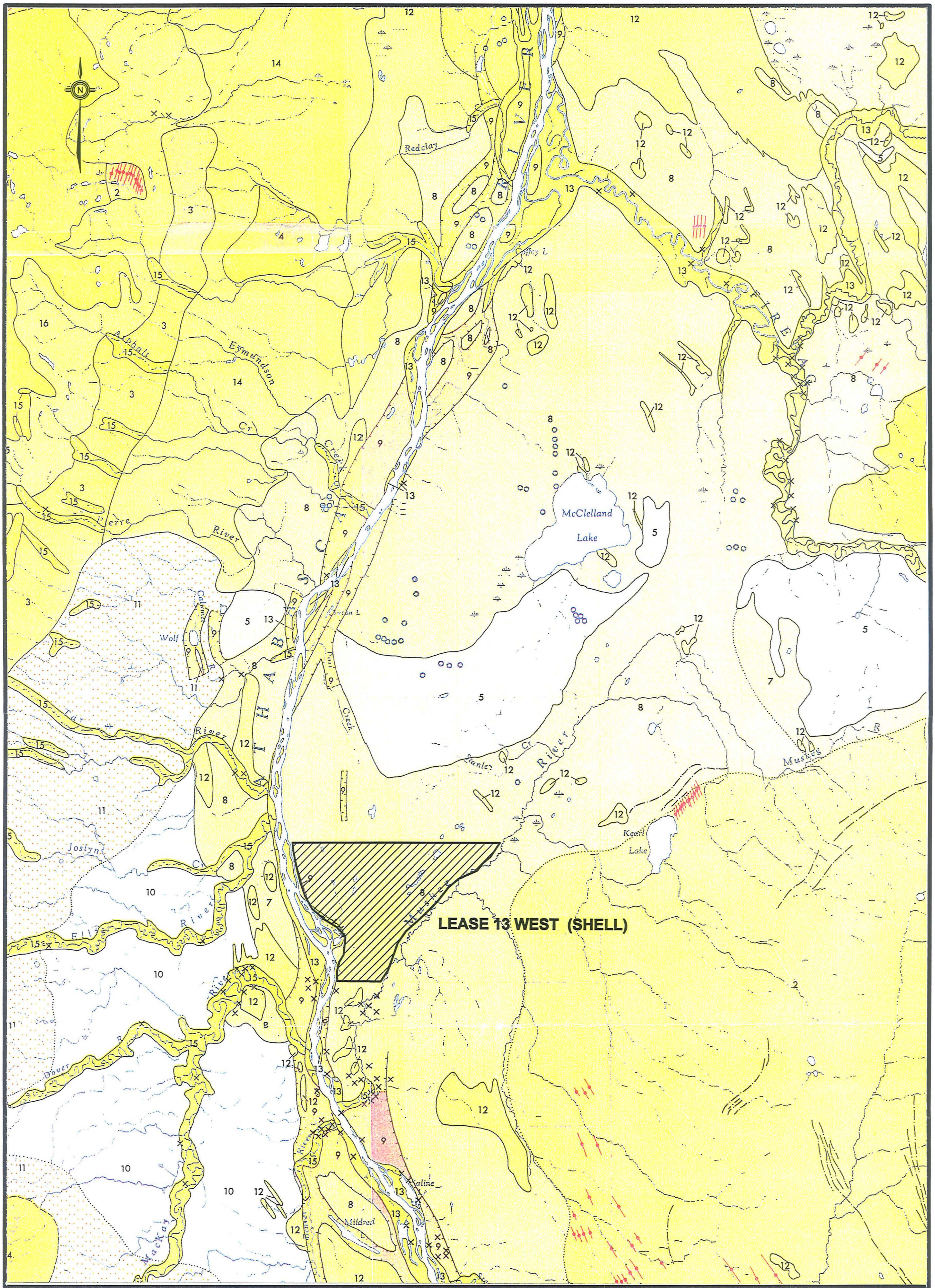
J.P.	J.P.	OCT.14/97

APPROVED: | FIGURE: 3b

JOB No. 4577A



NOTE:
FOR LEGEND OF SURFICIAL GEOLOGY, REFER TO FIGURE 4B

SOURCE:
RESEARCH COUNCIL OF ALBERTA, SURFICIAL GEOLOGY BITUMOUNT, NTS 74E BY L.A. Boyrock, 1969 & 1970

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SURFICIAL GEOLOGY (1:250,000)

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	OCT.15/97

APPROVED:	FIGURE:
	4a

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JOB No. 4577A

RECENT

EROSIONAL FEATURES

16	Slump: *mixed glacial and bedrock materials; unstable slope*
15	Gully, creek valley: *thin colluvial cover on valley slopes; thin alluvial materials along streams*

ALLUVIAL DEPOSITS

14	Alluvial fan: *bedded silt, sand and clay; variable thickness, overlying glacial deposits*
13	Stream alluvium: *mainly sand along Athabasca River; silt, clay and sand along other streams*

AEOLIAN DEPOSITS

12	Aeolian sand, dunes: *medium-grained quartzitic sand in sheet and dune form; thick in dunes, 2 to 10 feet in sheet sand*

PLEISTOCENE

GLACIOLACUSTRINE DEPOSITS

11	Mixed: *bedded silt, clay and sand with pebbles and till-like layers; overlying till*
10	Silt and clay: *bedded silt and clay with minor sand; overlying till*

GLACIOFLUVIAL DEPOSITS

9	Meltwater channel sediment: *medium- to coarse-grained sand, overlying thin gravel and lag gravel containing many large boulders; in part, early Athabasca River sediments*
8	Outwash sand: *medium- to coarse-grained sand with pebbles and small gravel lenses; generally thin; surface level to gently undulating*
7	Outwash sand and gravel: *sand and gravel to gravel forming outwash plains; generally thick; surface level to gently undulating; some discontinuous terraces*
6	Outwash sand and gravel overridden by glacier: *fluted and drumlinized outwash of sand and gravel to gravel, with many large boulders; generally thick to very thick; topography undulating to rolling*
5	Ice-contact deposits: *sand and gravel to gravel, numerous very large boulders; rolling topography, individual hills reach heights of several hundred feet; includes kame moraine, eskers, moulin kames, crevasse fillings, and other related ice-contact glaciofluvial deposits; form end moraines of glacier advances*

GLACIAL DEPOSITS

4	Hummocky moraine: *till composed of mixed sand, silt and clay with gravel; generally thick; topography undulating to gently rolling*
3	Colluviated ground moraine: *till composed of sand, silt and clay, mantling colluviated steep slopes; partly bedded near surface; stable slope; generally thin*
2	Ground moraine: *till composed of sand, silt and clay with gravel, variable in thickness; topography level to undulating*

PRECAMBRIAN

1	Granite, gneiss and metasedimentary rocks: *outcrops form hills and knolls; generally bare with glacial deposits on the lee side of outcrops*†

Geological boundary; defined, approximate, assumed
Abandoned beach
Channel scarp (ticks indicate downslope side)
Bedrock outcrop (not Precambrian) ×
Crag and tail (head of symbol indicates stoss side)
Crevasse filling
Drumlin (outline to scale)
Glacial fluting
Karst area
Sink hole

SOURCE:
RESEARCH COUNCIL OF ALBERTA,
SURFICIAL GEOLOGY BITUMOUNT, NTS 74E
BY L.A. Bayrock, 1969 & 1970

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LEGEND FOR SURFICIAL GEOLOGY (1:250,000)

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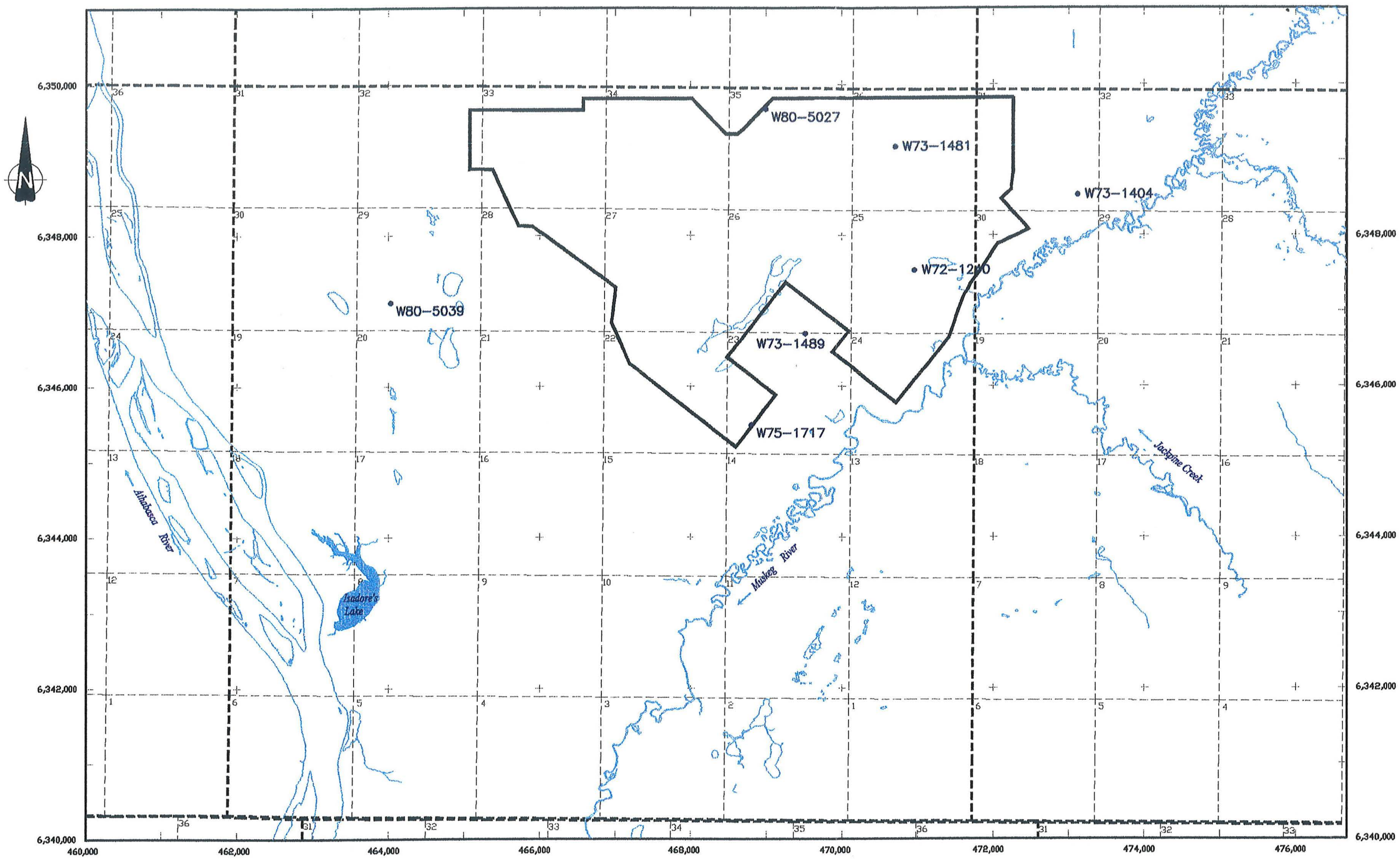
J.P.	J.P.	OCT.15/97
APPROVED:	FIGURE: 4b	

JOB No. 4577A



LEGEND

• W80-5039 PIEZOMETER LOCATION – METHY FORMATION

0 1.5 3.0 km
SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

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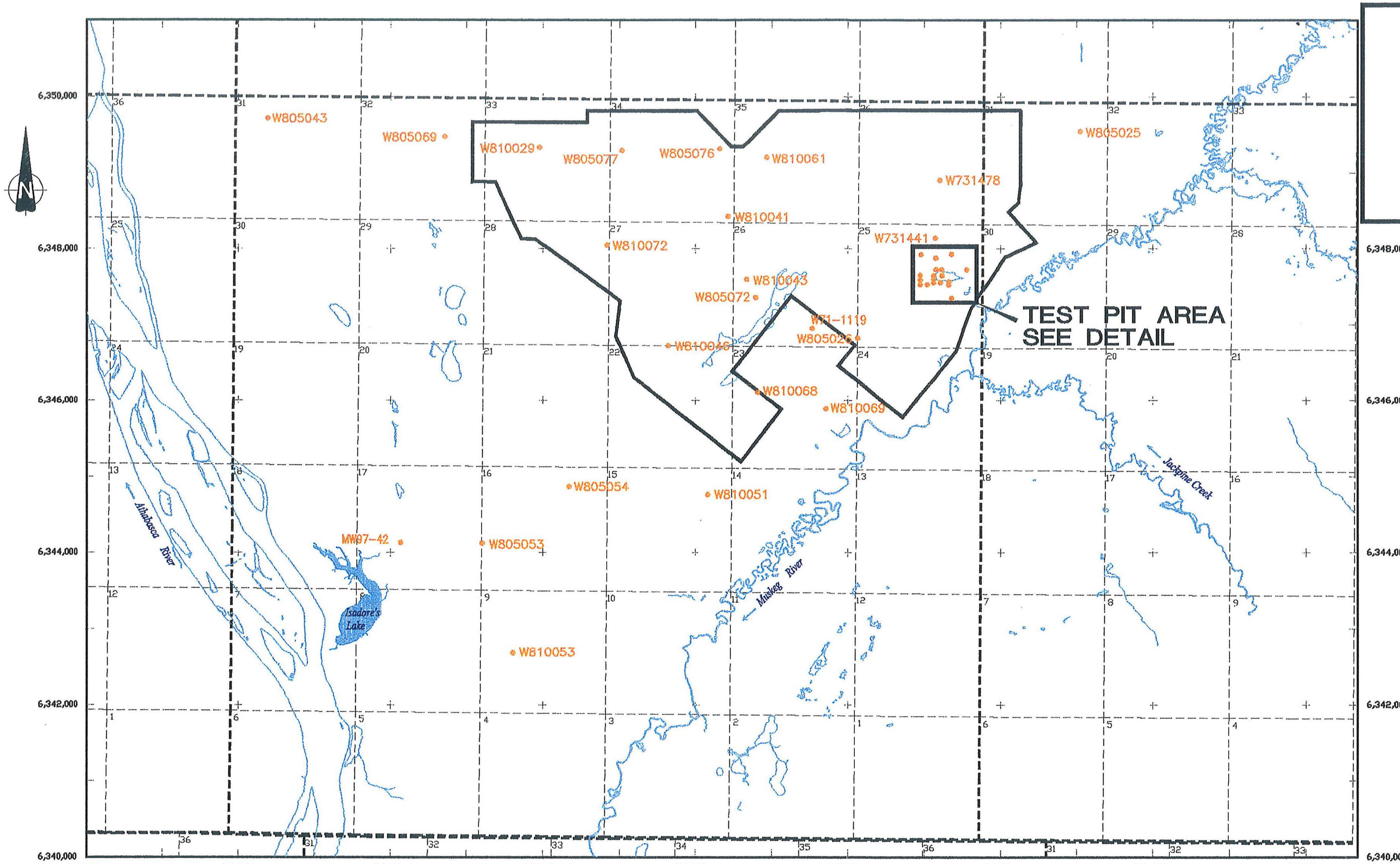
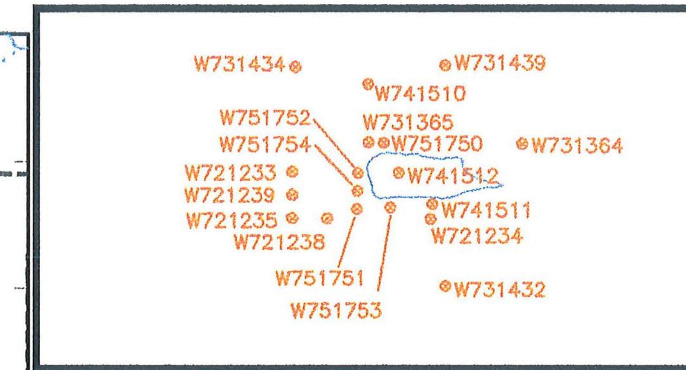
DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT17/97

PIEZOMETER LOCATIONS
DEVONIAN: METHY FORMATION

APPROVED:
FIGURE: 5

FILE: J:\4577A\13-BASE.DWG





TEST PIT AREA DETAIL

LEGEND

● W810053 PIEZOMETER LOCATION – BASAL AQUIFER

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22–JUL–97

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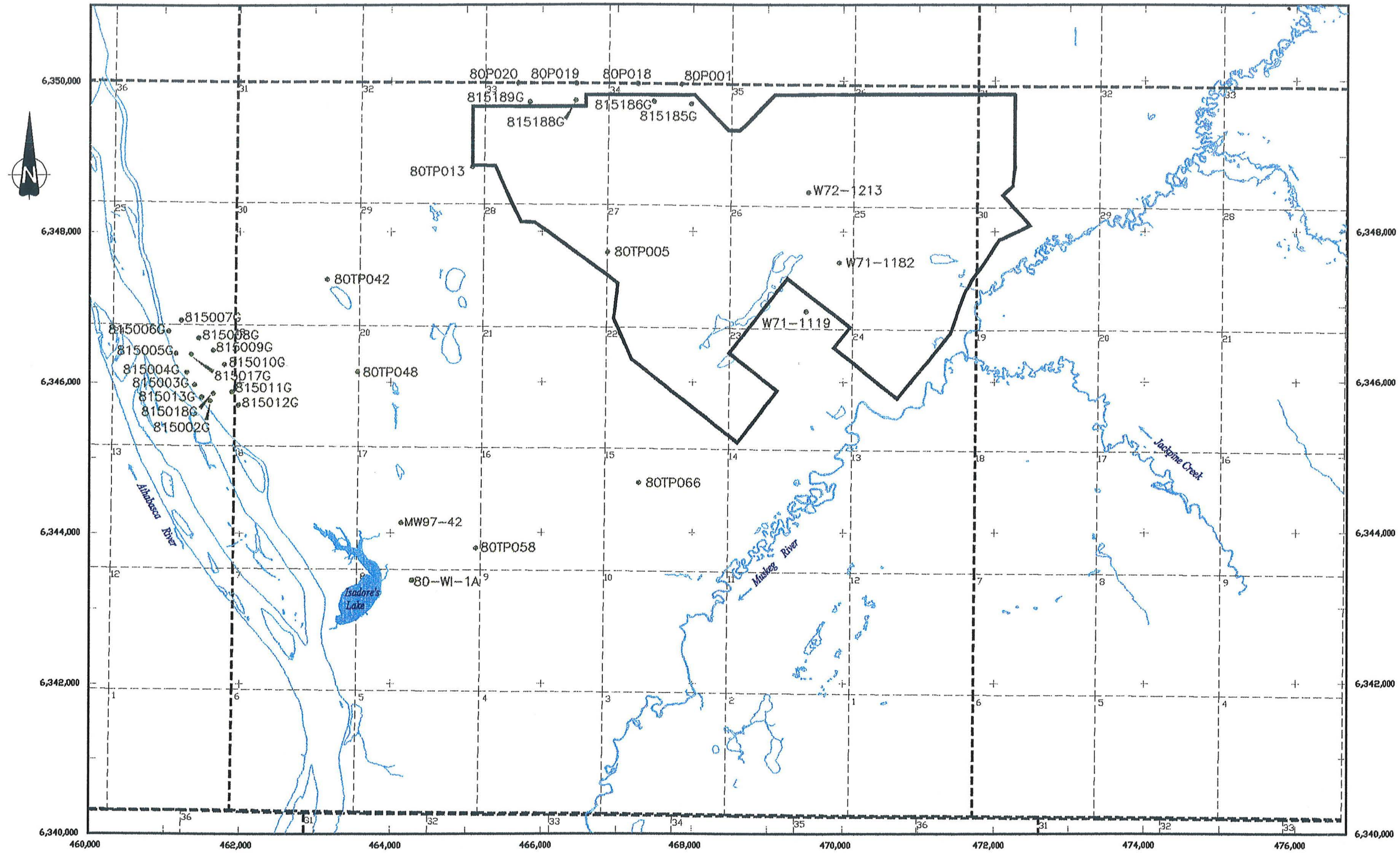
PIEZOMETER LOCATIONS
CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT17/97

APPROVED:	FIGURE:
	6

FILE: J:\4577A\13–BASE.DWG



LEGEND

• 80TP058 PIEZOMETER LOCATION – CRETACEOUS SEDIMENTS (INTRA-OREBODY OR NEAR CONTACT WITH QUATERNARY DEPOSITS)

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

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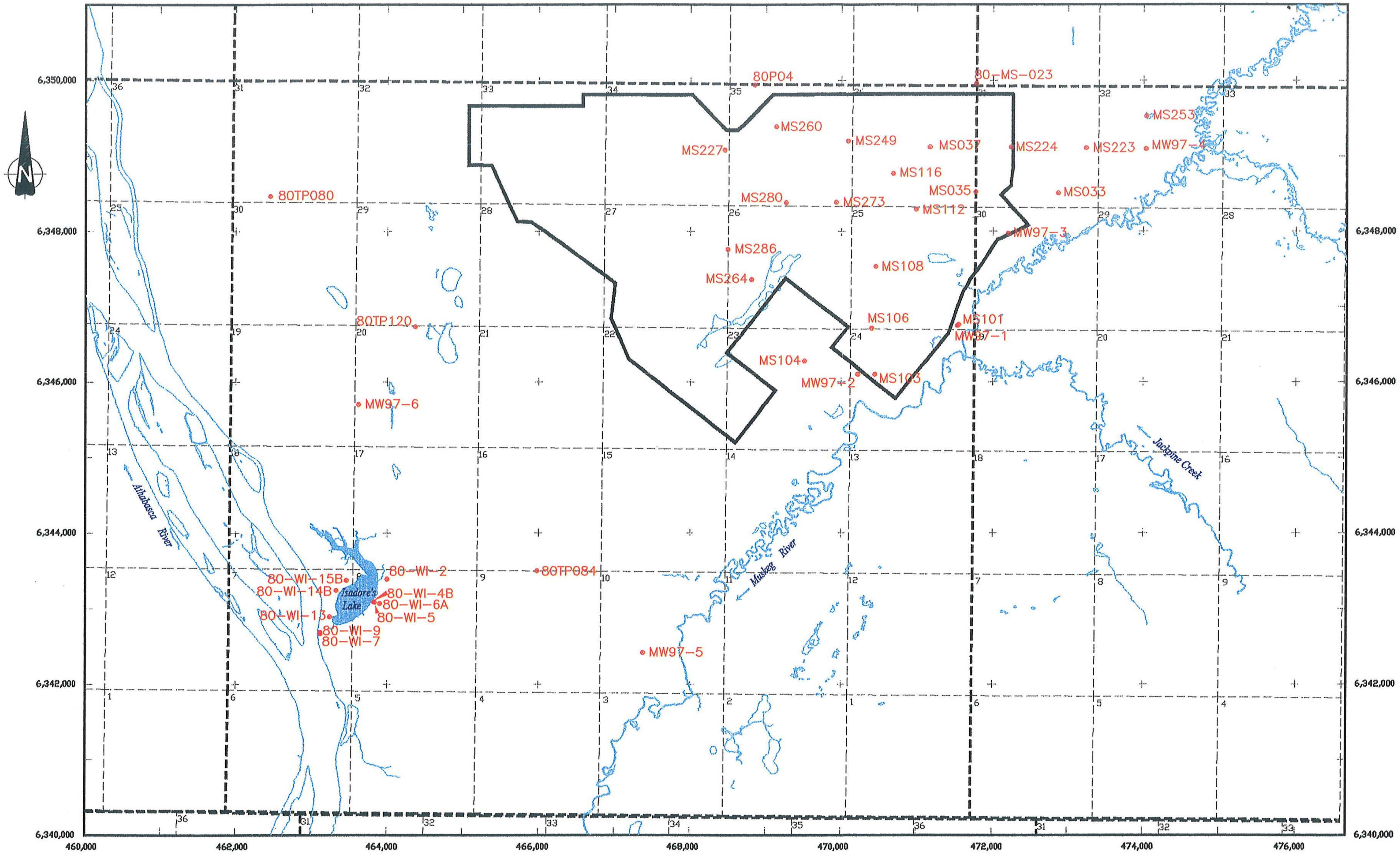
PIEZOMETER LOCATIONS
CRETACEOUS: INTRA-OREBODY AND NEAR CONTACT WITH QUATERNARY DEPOSITS

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT02/97
APPROVED:		FIGURE: 7

FILE: J:\4577A\13-BASE.DWG



LEGEND

• MW97-5 PIEZOMETER LOCATION – QUATERNARY DEPOSITS

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
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PIEZOMETER LOCATIONS
QUATERNARY DEPOSITS

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M.T.	M.T.	OCT02/97

APPROVED:	FIGURE:
	8

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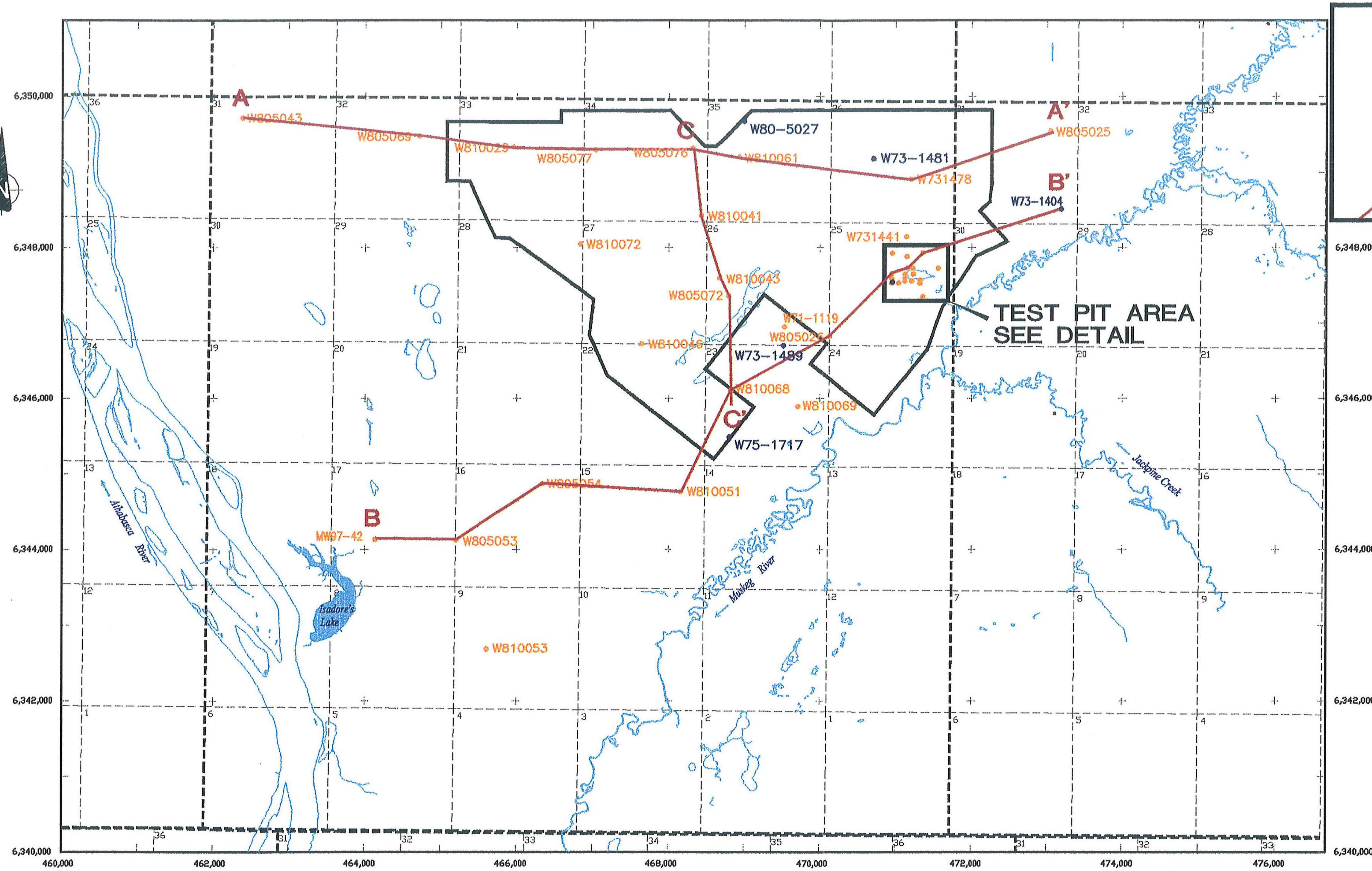

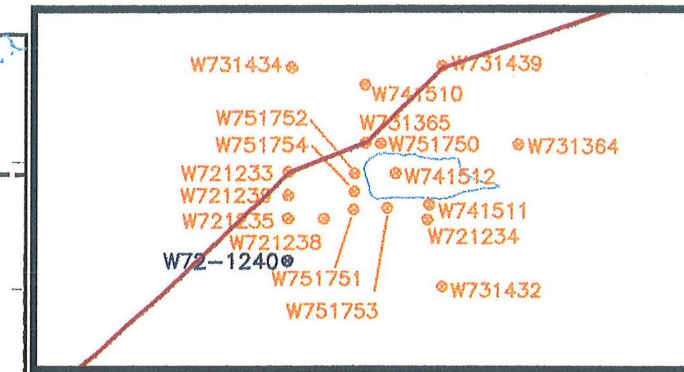

TEST PIT AREA DETAIL

LEGEND

- W810053 PIEZOMETER LOCATION – BASAL AQUIFER
- W80–5027 PIEZOMETER LOCATION – METHY FORMATION
- A — A' HYDROGEOLOGICAL CROSS-SECTION LOCATIONS

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

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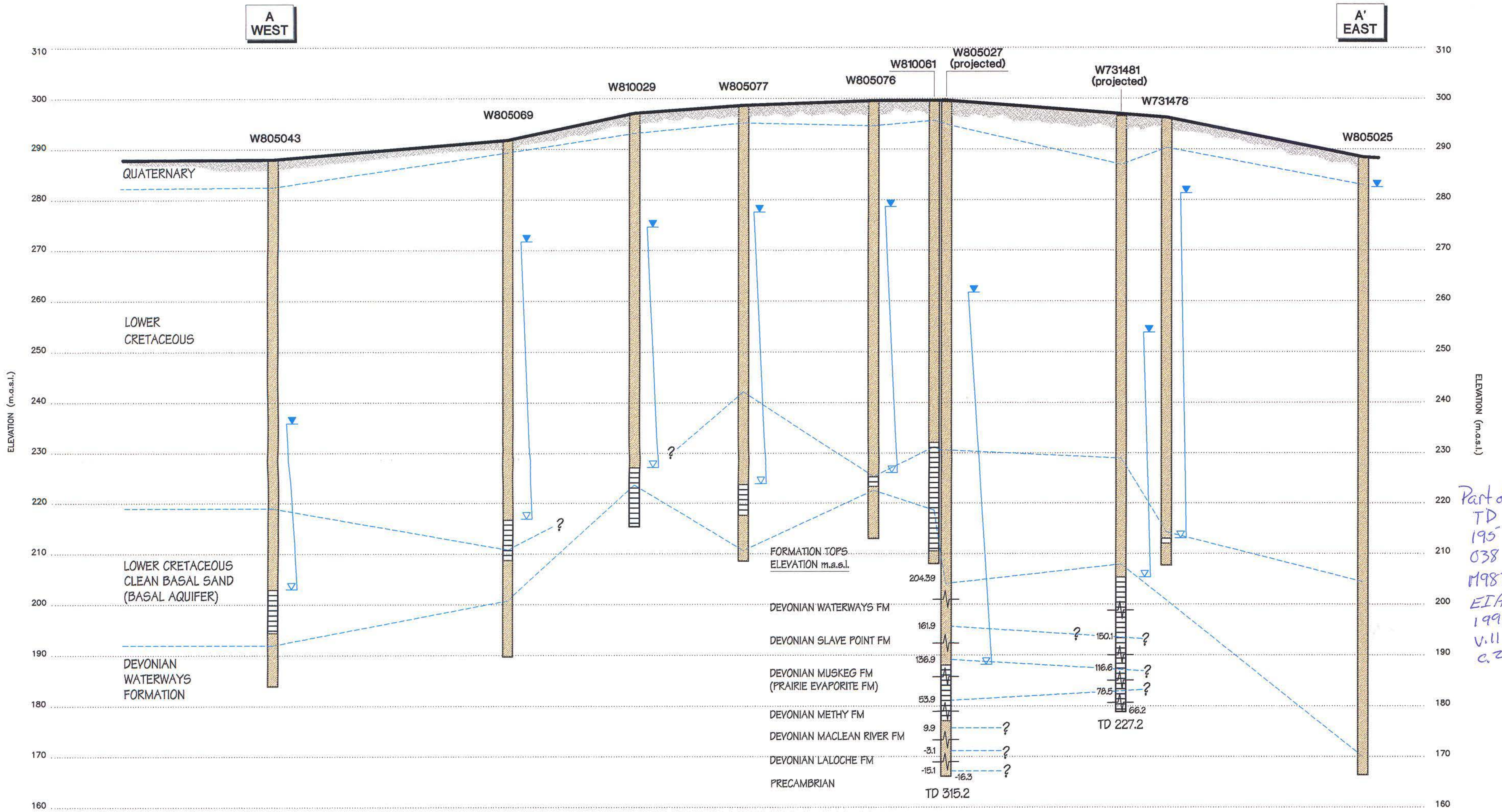
LOCATION OF SCHEMATIC HYDROGEOLOGICAL CROSS-SECTIONS

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT06/97
APPROVED:	FIGURE: 9	

FILE: J:\4577A\13-BASE.DWG



PIEZOMETER NUMBER	W5043	W5069	W810029	W5077	W5076	W810061	W805027	W731481	W731478	W805025
HYDRAULIC CONDUCTIVITY m/S	IE-05	5E-05	<IE-05	IE-04	5E-05	N/A	2E-09	9E-05	N/A	5E-08
GROUNDWATER HYDROCHEMICAL TYPE	Na-HCO_3-Cl	Na-HCO_3-Cl	N/A	Na-HCO_3-Cl	Na-HCO_3-Cl	Na-HCO_3	Na-Cl	Na-Cl	N/A	Na-HCO_3-Cl
GROUNDWATER MINERALIZATION mg/L	3973	3425	N/A	3164	2021	1430	4915	40724	N/A	2943
CHLORIDE CONCENTRATION IN GROUNDWATER mg/L	693	726	N/A	681	257	81	1160	21223	N/A	729

LEGEND

W805043 PIEZOMETER NUMBER

SCREEN OR SANDPACKED INTERVAL

BACKFILLED OR GROUTED INTERVAL

▼ STATIC GROUNDWATER SURFACE

▽ DYNAMIC GROUNDWATER SURFACE

? ANOMALOUS GROUNDWATER SURFACE ELEVATION OR UNKNOWN EXTENT OF GEOLOGICAL STRATA

N/A DENOTES INFORMATION NOT AVAILABLE OR NOT MEASURED

VERT. SCALE 1 : 6,000 (0 10 20 30m)

HOR. SCALE 1 : 30,000 (0 750 1500m)

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

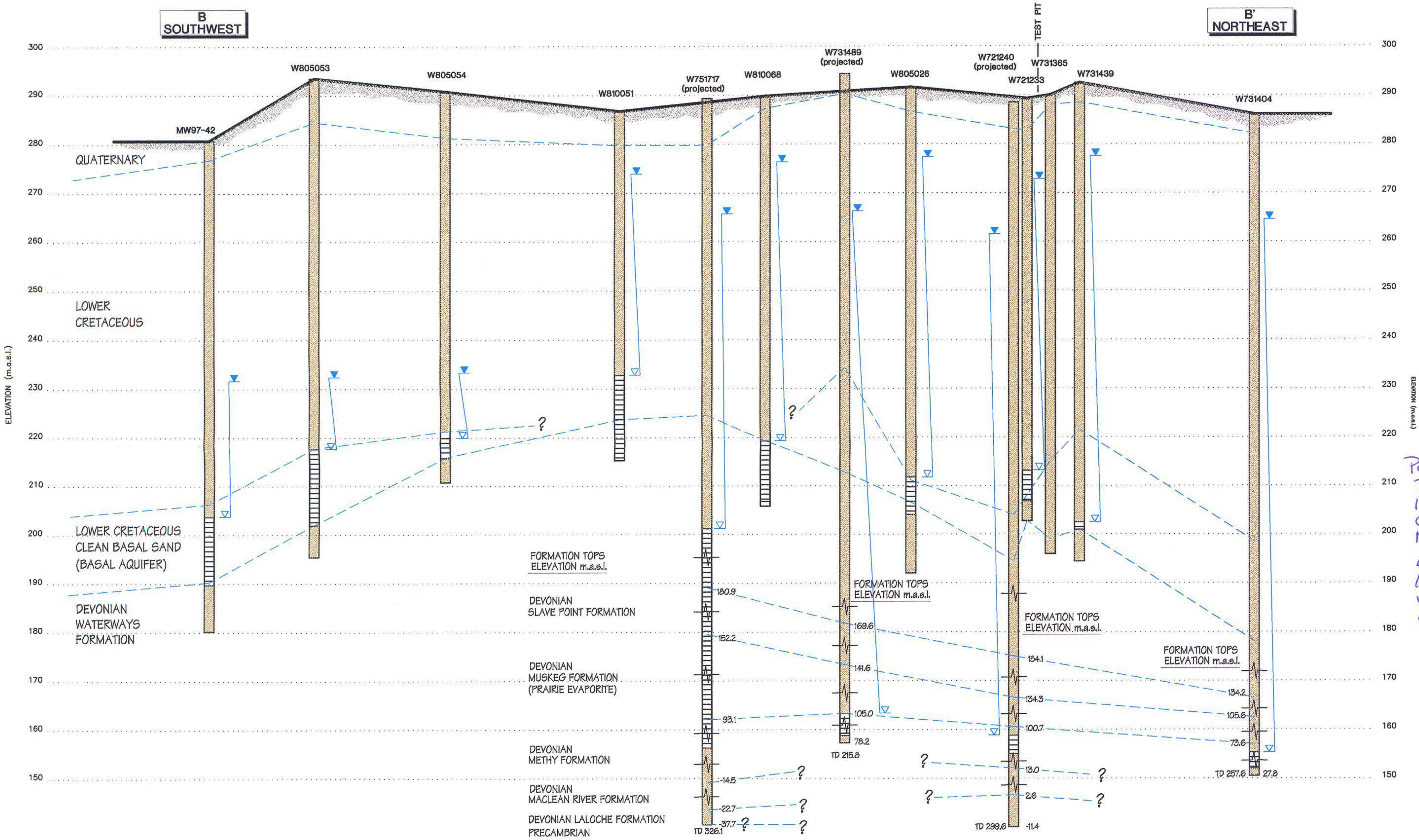
SCHEMATIC
HYDROGEOLOGICAL CROSS-SECTION A-A'

DRAWN BY: M.T. | EDITED BY: M.T. | DATE: NOV04/97

APPROVED: | FIGURE: 10

PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.

FILE: J:\4577A\SEC-AA.DWG



PIEZOMETER NUMBER	MW97-42	W805053	W805054	W810051	W751717	W810068	W731489	W805026	W721240	W721233	W731365	W731439	W731404
HYDRAULIC CONDUCTIVITY m/S	>1E-04	N/A	7E-06	4E-07	2E-08	<1E-07	>1E-04	4E-05	>1E-04	8E-05	N/A	N/A	3E-08
GROUNDWATER HYDROCHEMICAL TYPE	Na-HCO_3-Cl	Na-HCO_3-Cl	Na-HCO_3-Cl	Na-Cl-HCO_3	Na-Cl	Na-Cl-HCO_3	Na-Cl	Na-Cl-HCO_3	Na-Cl	Na-Cl-HCO_3	Na-Cl-HCO_3	Na-Cl-HCO_3	N/A
GROUNDWATER MINERALIZATION mg/L	2380	2507	2599	4360	20638	7407	13462	3907	42468	3280	3686	3653	N/A
CHLORIDE CONCENTRATION IN GROUNDWATER mg/L	548	424	346	1229	9606	2793	5735	1111	22340	1050	1028	1050	N/A

LEGEND

- W805043 — PIEZOMETER NUMBER
- SCREEN OR SANDPACKED INTERVAL
- BACKFILLED OR GROUTED INTERVAL
- STATIC GROUNDWATER SURFACE
- DYNAMIC GROUNDWATER SURFACE
- ? — ANOMALOUS GROUNDWATER SURFACE ELEVATION OR UNKNOWN EXTENT OF GEOLOGICAL STRATA
- N/A — DENOTES INFORMATION NOT AVAILABLE OR NOT MEASURED

VERT. SCALE 1 : 6,000 (0, 10, 20, 30m)

HOR. SCALE 1 : 30,000 (0, 750, 1500m)

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

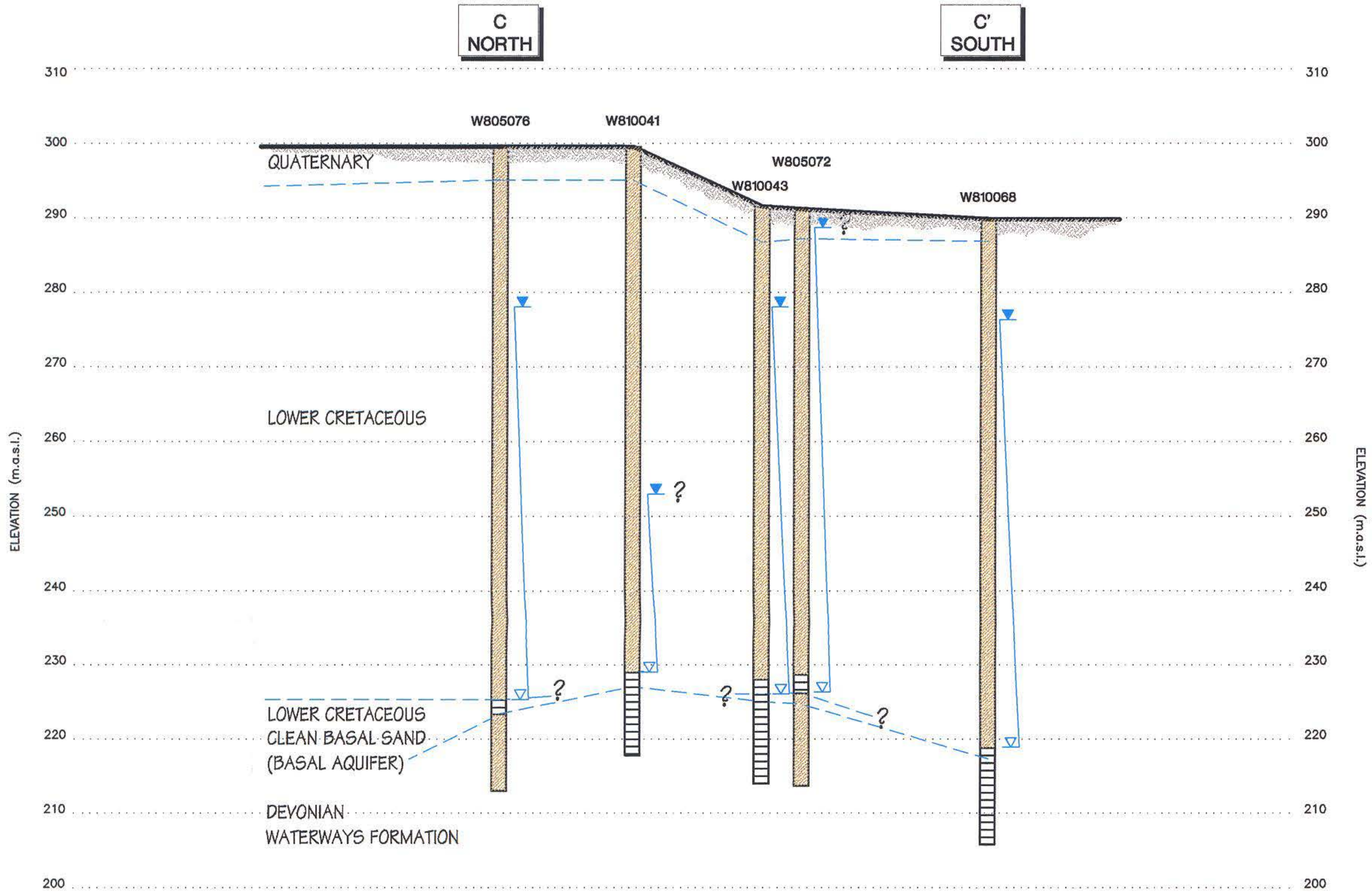
DRAWN BY: M.T. | EDITED BY: M.T. | DATE: NOV04/97

APPROVED:

FIGURE: 11

SCHEMATIC HYDROGEOLOGICAL CROSS-SECTION B-B'

FILE: J:\4577A\SEC-BB.DWG



PIEZOMETER NUMBER	W805076	W810041	W810043	W805072	W810068
HYDRAULIC CONDUCTIVITY m/S	5E-05	<1E-07	1E-06	N/A	<1E-07
GROUNDWATER HYDROCHEMICAL TYPE	Na-HCO_3-Cl	N/A	Na-Cl-HCO_3	N/A	Na-Cl-HCO_3
GROUNDWATER MINERALIZATION mg/L	2021	N/A	4516	N/A	7407
CHLORIDE CONCENTRATION IN GROUNDWATER mg/L	257	N/A	1385	N/A	2793

LEGEND

W805043 PIEZOMETER NUMBER

SCREEN OR SANDPACKED INTERVAL

BACKFILLED OR GROUTED INTERVAL

STATIC GROUNDWATER SURFACE

DYNAMIC GROUNDWATER SURFACE

? ANOMALOUS GROUNDWATER SURFACE ELEVATION OR UNKNOWN EXTENT OF GEOLOGICAL STRATA

N/A DENOTES INFORMATION NOT AVAILABLE OR NOT MEASURED

VERT. SCALE 1 : 6,000 (0 10 20 30m)

HOR. SCALE 1 : 30,000 (0 750 1500m)

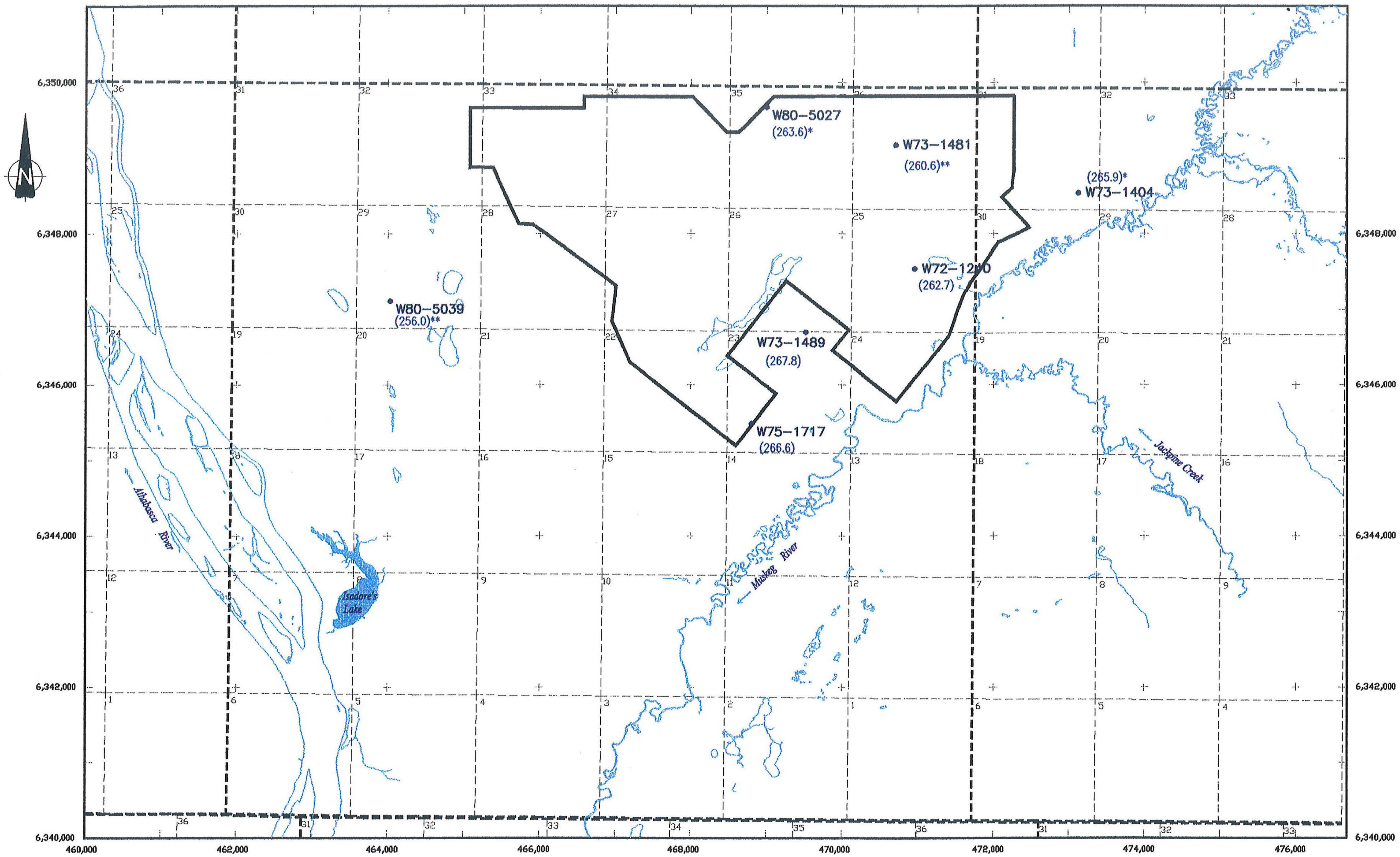
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

SCHEMATIC
HYDROGEOLOGICAL CROSS-SECTION C-C'

DRAWN BY: M.T. | EDITED BY: M.T. | DATE: NOV04/97
APPROVED: | FIGURE: 12

FILE: J:\4577A\SEC-CC.DWG



LEGEND

• W80-5039	PIEZOMETER LOCATION – METHY FORMATION
(266.6)	GROUNDWATER SURFACE ELEVATION (m.a.s.l.)
(263.6)*	DENOTES GROUNDWATER SURFACE ELEVATION (m.a.s.l.) POSSIBLY NOT STABILIZED
(256.0)**	POSSIBLY A COMPOSITE GROUNDWATER SURFACE ELEVATION (m.a.s.l.) REPRESENTING A NUMBER OF DEVONIAN FORMATIONS

NOTE: GROUNDWATER SURFACE ELEVATIONS MEASURED IN MARCH 1981.

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

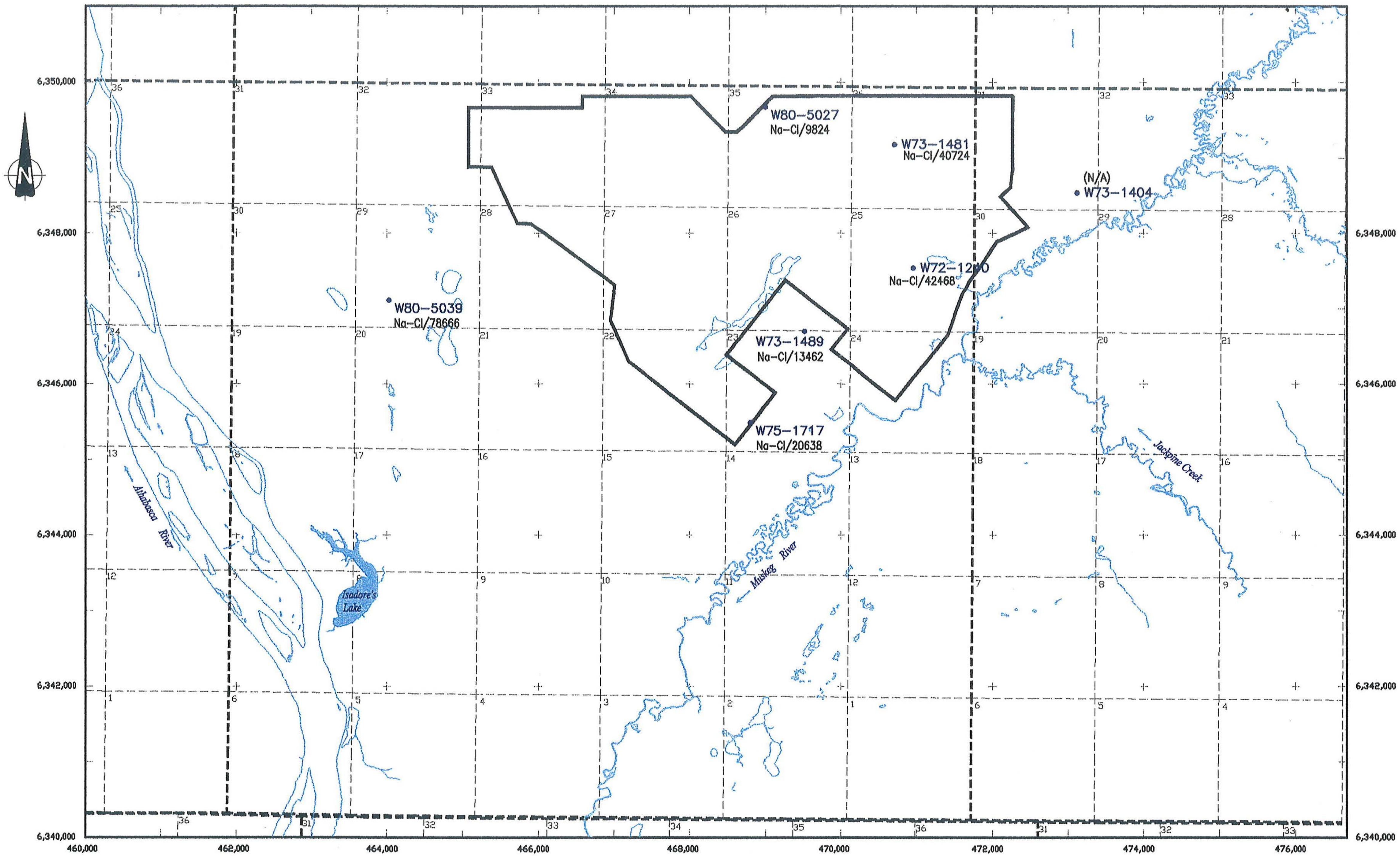
GROUNDWATER SURFACE ELEVATIONS DEVONIAN: METHY FORMATION

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT17/97

APPROVED:

FIGURE: 13

FILE: J:\4577A\13-BASE.DWG



LEGEND

• W80-5039	PIEZOMETER LOCATION – METHY FORMATION
Na-Cl/78666	HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
N/A	DENOTES INFORMATION NOT AVAILABLE

NOTES:
1. SAMPLES COLLECTED IN MARCH 1981.
2. SAMPLES W73-1481 AND W80-5039 MAY REPRESENT A COMPOSITE CHLORIDE CONCENTRATION RESULTING FROM MIXING OF GROUNDWATER ORIGINATING FROM DIFFERENT DEVONIAN FORMATIONS.

0 1.5 3.0 km
SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

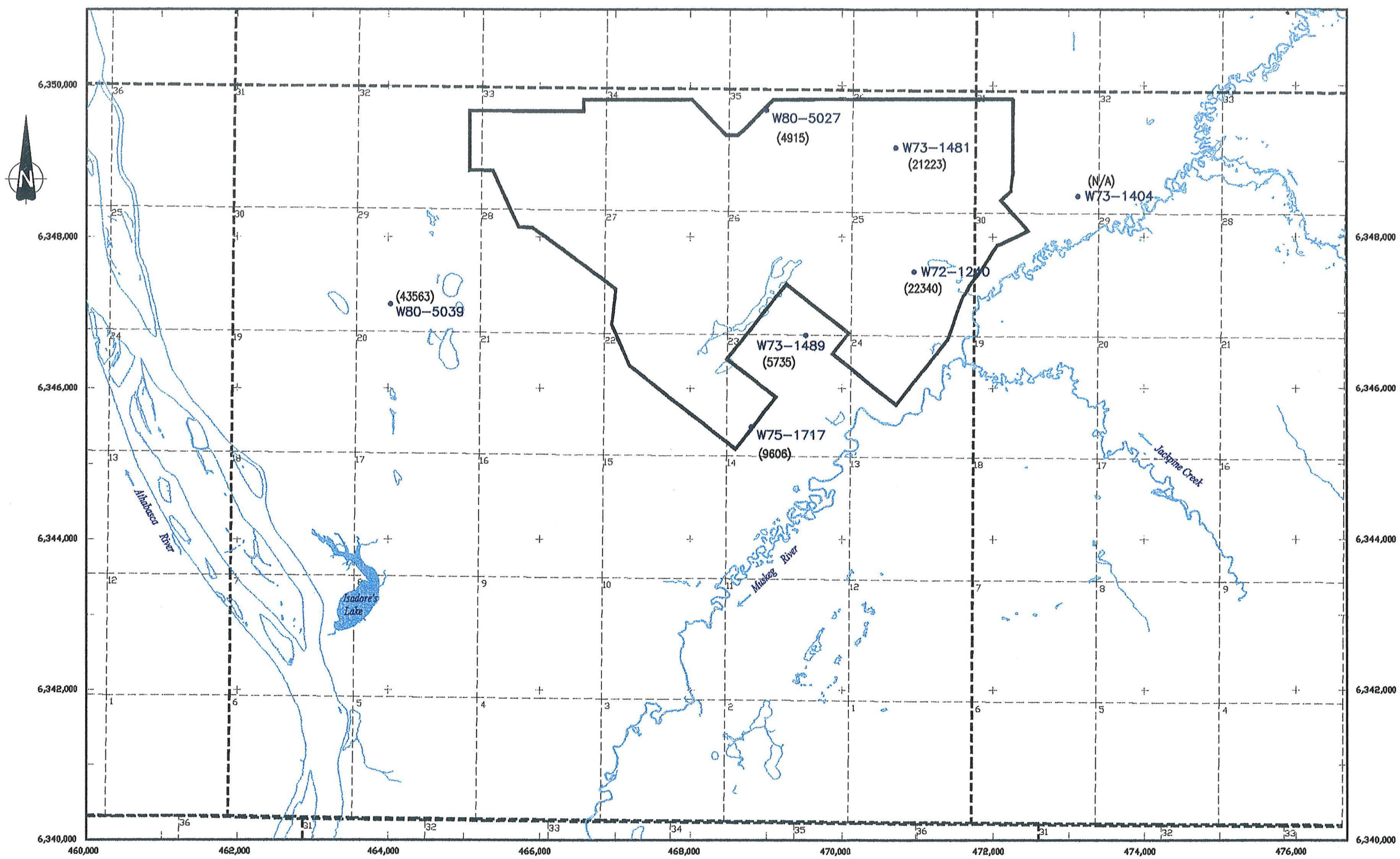
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER DEVONIAN: METHY FORMATION

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	NOV04/97
APPROVED:		FIGURE: 14

FILE: J:\4577A\13-BASE.DWG



LEGEND

• W80–5039	PIEZOMETER LOCATION – METHY FORMATION
(43563)	CHLORIDE CONCENTRATIONS IN mg/L
(N/A)	DENOTES INFORMATION NOT AVAILABLE

0 1.5 3.0 km

SCALE 1 : 60,000

NOTES:
1. SAMPLES COLLECTED IN MARCH 1981.
2. SAMPLES W73-1481 AND W80-5039 MAY REPRESENT A COMPOSITE CHLORIDE CONCENTRATION RESULTING FROM MIXING OF GROUNDWATER ORIGINATING FROM DIFFERENT DEVONIAN FORMATIONS.

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

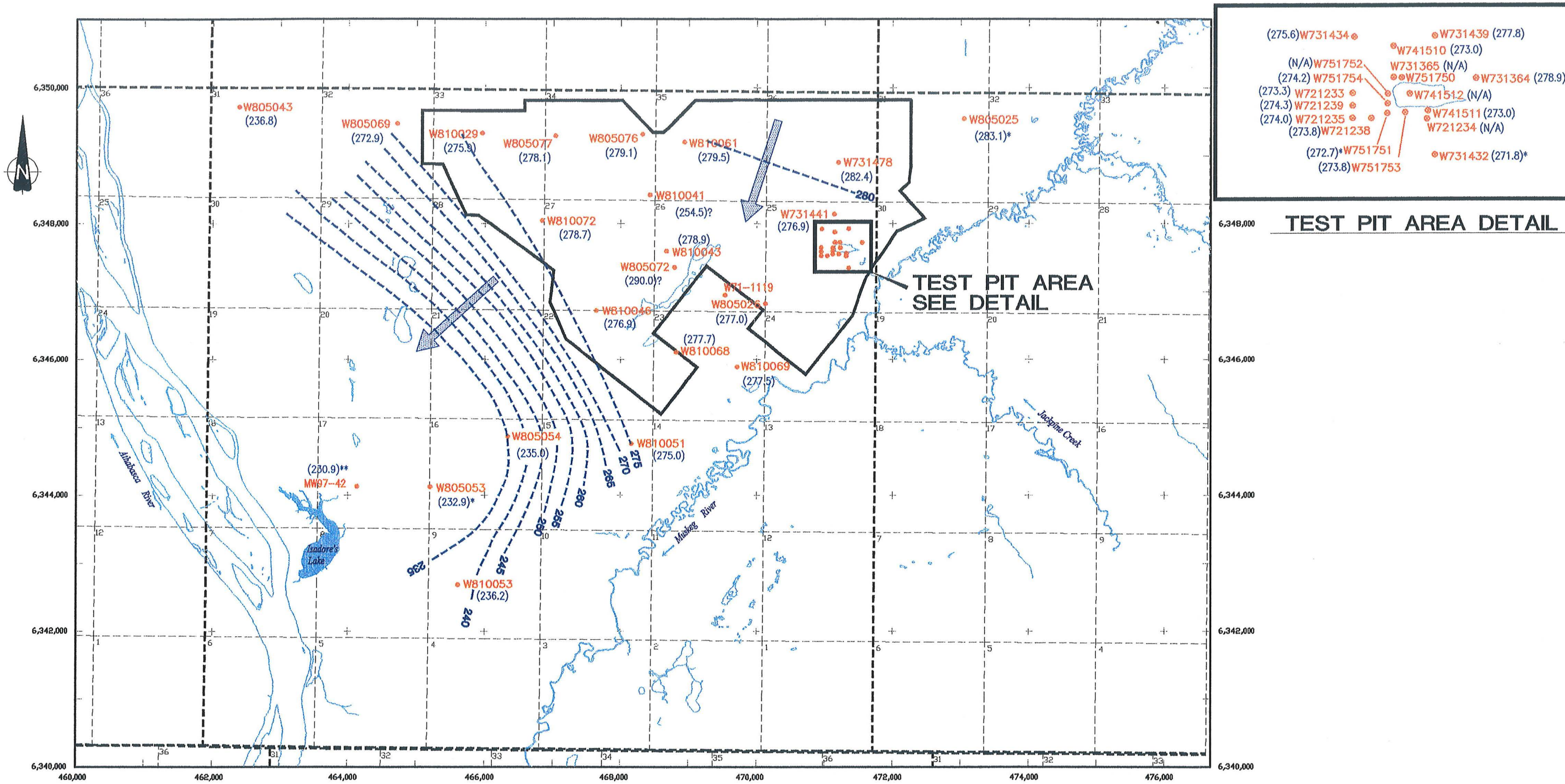
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND
ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

CHLORIDE DISTRIBUTION IN GROUNDWATER
DEVONIAN: METHY FORMATION

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT23/97
APPROVED:		FIGURE: 15

FILE: J:\4577A\13-BASE.DWG



LEGEND

• W810053	PIEZOMETER LOCATION – BASAL AQUIFER
(236.2)	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED FEBRUARY/MARCH, 1981)
(283.1)*	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED SEPTEMBER/NOVEMBER, 1980)
(230.9)**	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED APRIL, 1997)
(290.0)?	ANOMALOUS GROUNDWATER SURFACE ELEVATION (not included in the interpretation)
N/A	DENOTES INFORMATION NOT AVAILABLE
- - - - - -	APPROXIMATE PIEZOMETRIC SURFACE CONTOUR LINE (m.a.s.l.)
⟸	GENERAL GROUNDWATER FLOW DIRECTION

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

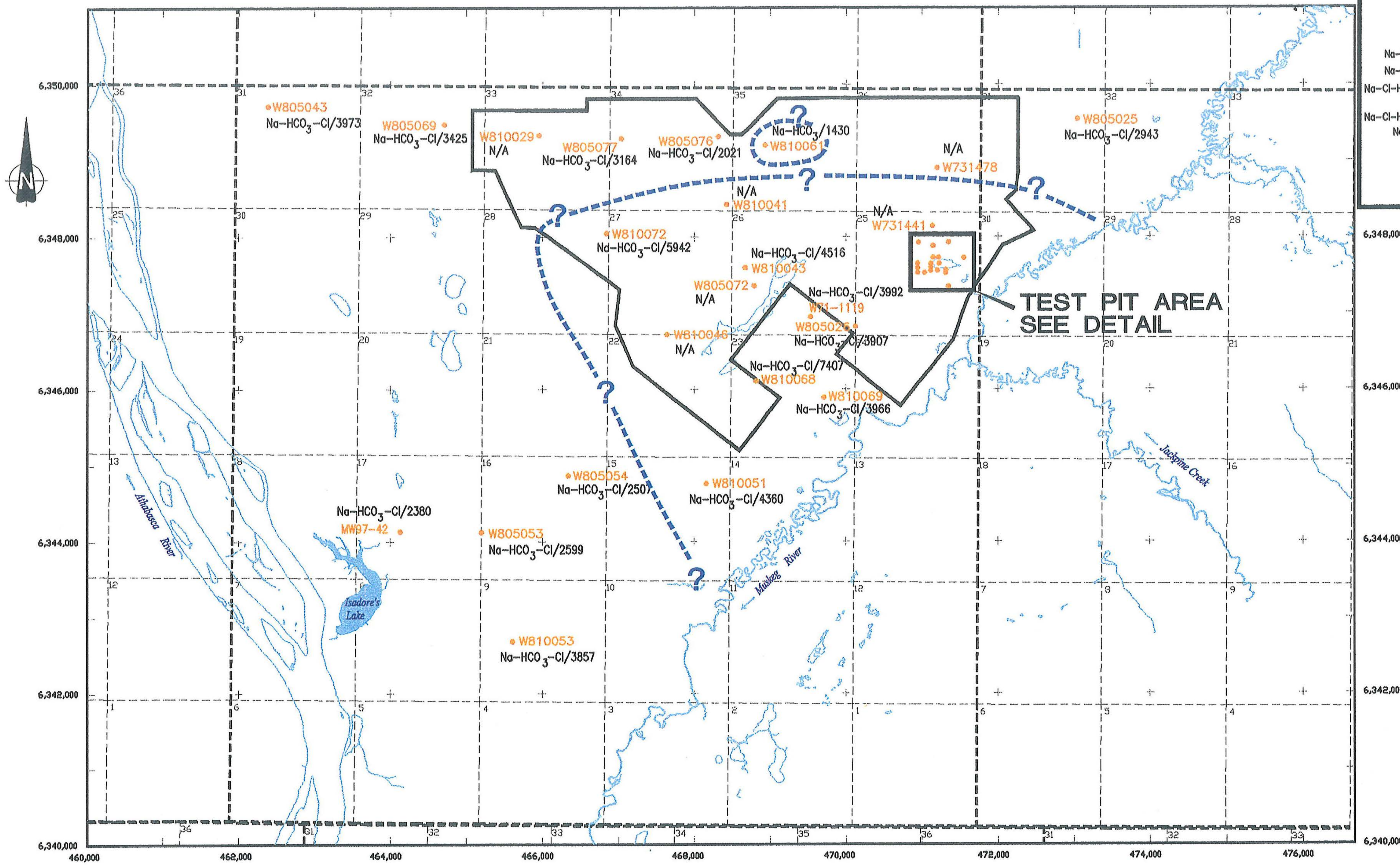
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

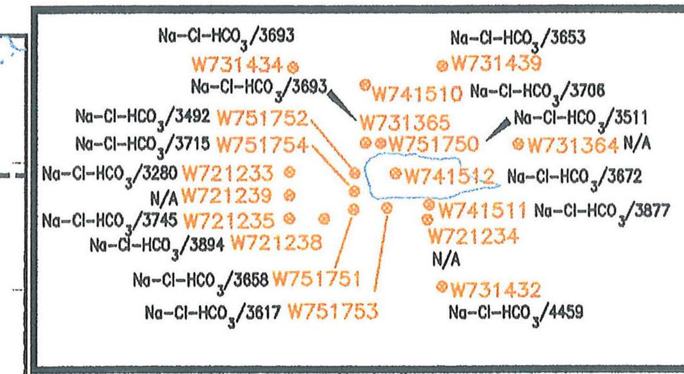
KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

PIEZOMETRIC SURFACE CONTOUR MAP
CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT17/97
APPROVED:		FIGURE: 16

FILE: J:\4577A\13-BASE.DWG





TEST PIT AREA DETAIL

NOTE: HYDROCHEMICAL DATA WAS COLLECTED DURING DIFFERENT EXPLORATION PROGRAMS (1971, 1975, 1980, 1981 AND 1997).

LEGEND

• W810053	PIEZOMETER LOCATION – BASAL AQUIFER
$Na-HCO_3-Cl/3857$	HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
N/A	DENOTES INFORMATION NOT AVAILABLE
- - - - -	APPROXIMATE BOUNDARY BETWEEN GROUNDWATER HYDROCHEMICAL TYPES

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER CRETACEOUS: BASAL AQUIFER

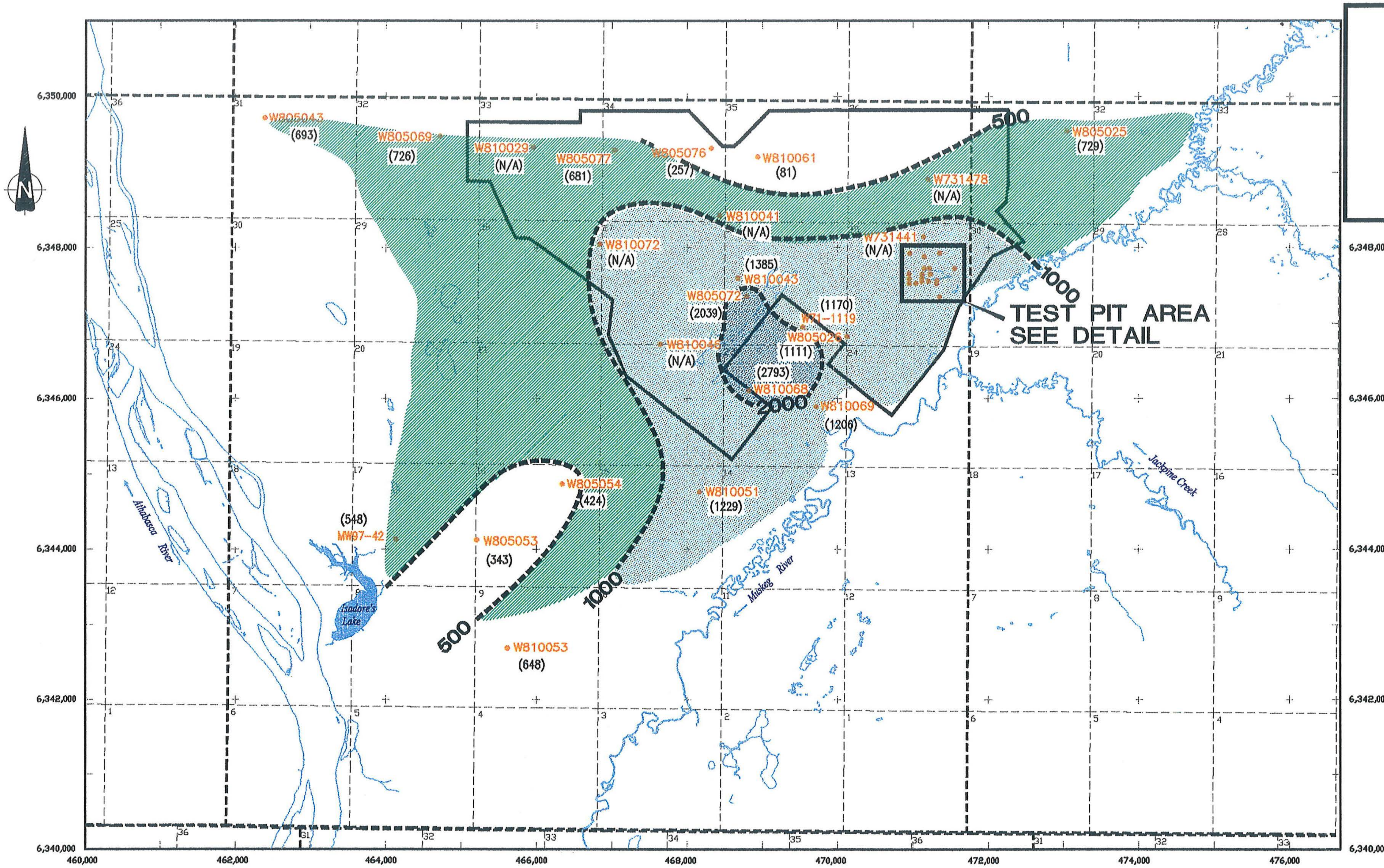
DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	NOV04/97

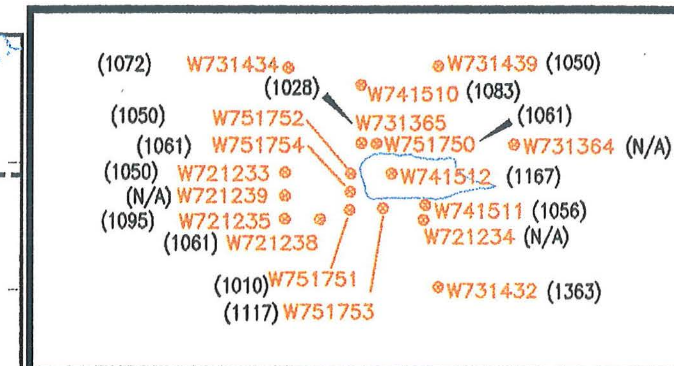
APPROVED: [signature]

FIGURE: 17

PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.

FILE: J:\4577A\13-BASE.DWG





TEST PIT AREA DETAIL

NOTE: CHLORIDE CONCENTRATIONS ORIGINATE FROM DIFFERENT EXPLORATION PROGRAMS (1971, 1975, 1976, 1980 AND 1997).

LEGEND

• W810053	PIEZOMETER LOCATION – BASAL AQUIFER
(7)	CHLORIDE CONCENTRATIONS IN mg/L
(N/A)	DENOTES INFORMATION NOT AVAILABLE
	CHLORIDE CONCENTRATION <500 mg/L
	CHLORIDE CONCENTRATION 500 – 1000 mg/L
	CHLORIDE CONCENTRATION 1000 – 2000 mg/L
	CHLORIDE CONCENTRATION >2000 mg/L

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

CHLORIDE DISTRIBUTION IN GROUNDWATER
CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	OCT23/97

APPROVED: | FIGURE: 18

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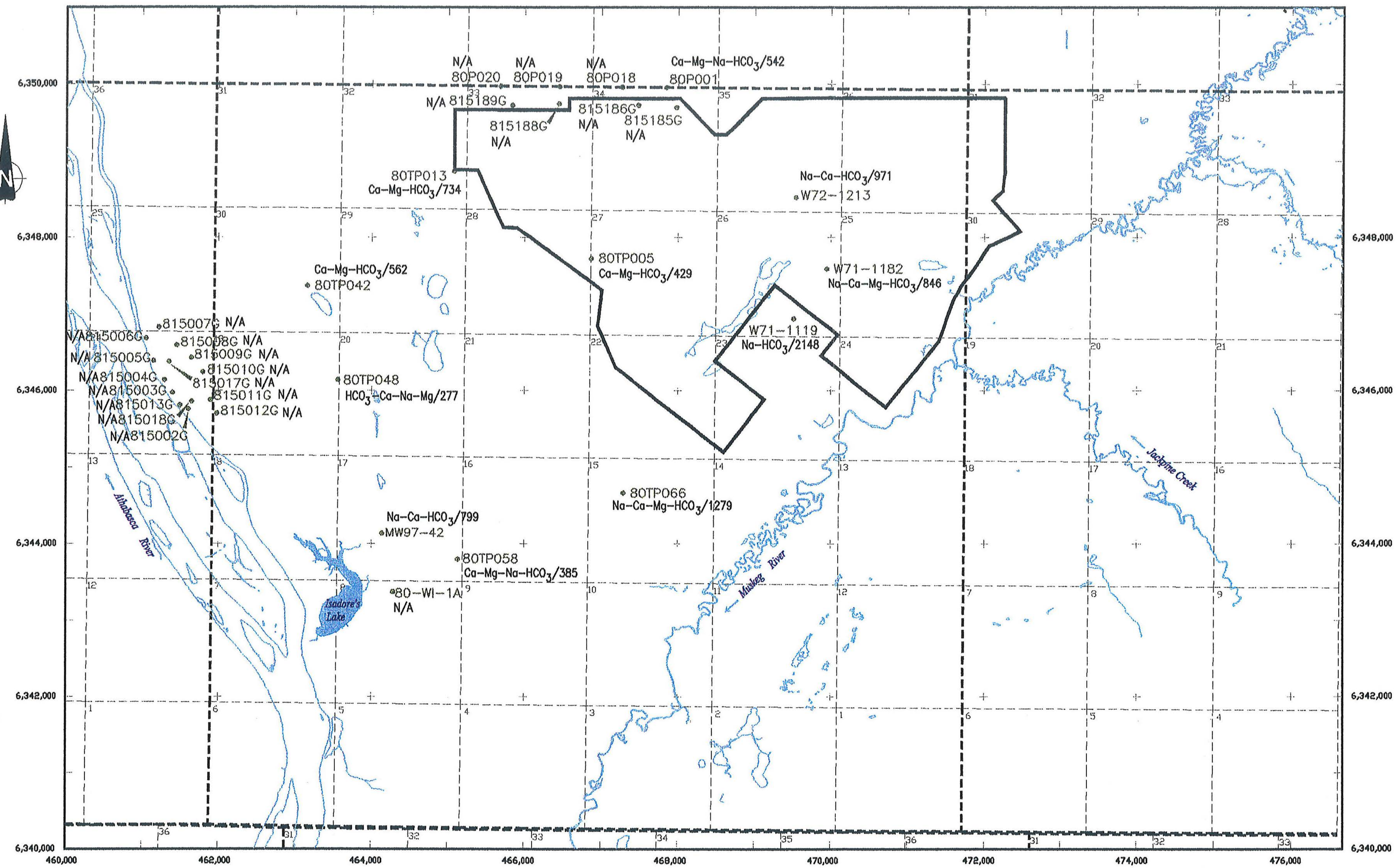
FILE: J:\4577A\13-BASE.DWG



LEGEND

- 80TP058 PIEZOMETER LOCATION – CRETACEOUS SEDIMENTS (INTRA-OREBODY OR NEAR CONTACT WITH QUATERNARY DEPOSITS)
- Na-Ca-Mg-HCO$_3$/846 HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
- N/A DENOTES INFORMATION NOT AVAILABLE

NOTES:
1. HYDROCHEMICAL DATA WAS COLLECTED DURING THE 1980 AND 1997 EXPLORATION PROGRAMS.
2. PIEZOMETERS WERE COMPLETED IN DIFFERENT LITHOLOGICAL UNITS AND AT DIFFERENT DEPTHS (1.89 – 11.87 m), THUS, DELINEATION OF HYDROCHEMICAL ZONES WAS NOT POSSIBLE.

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

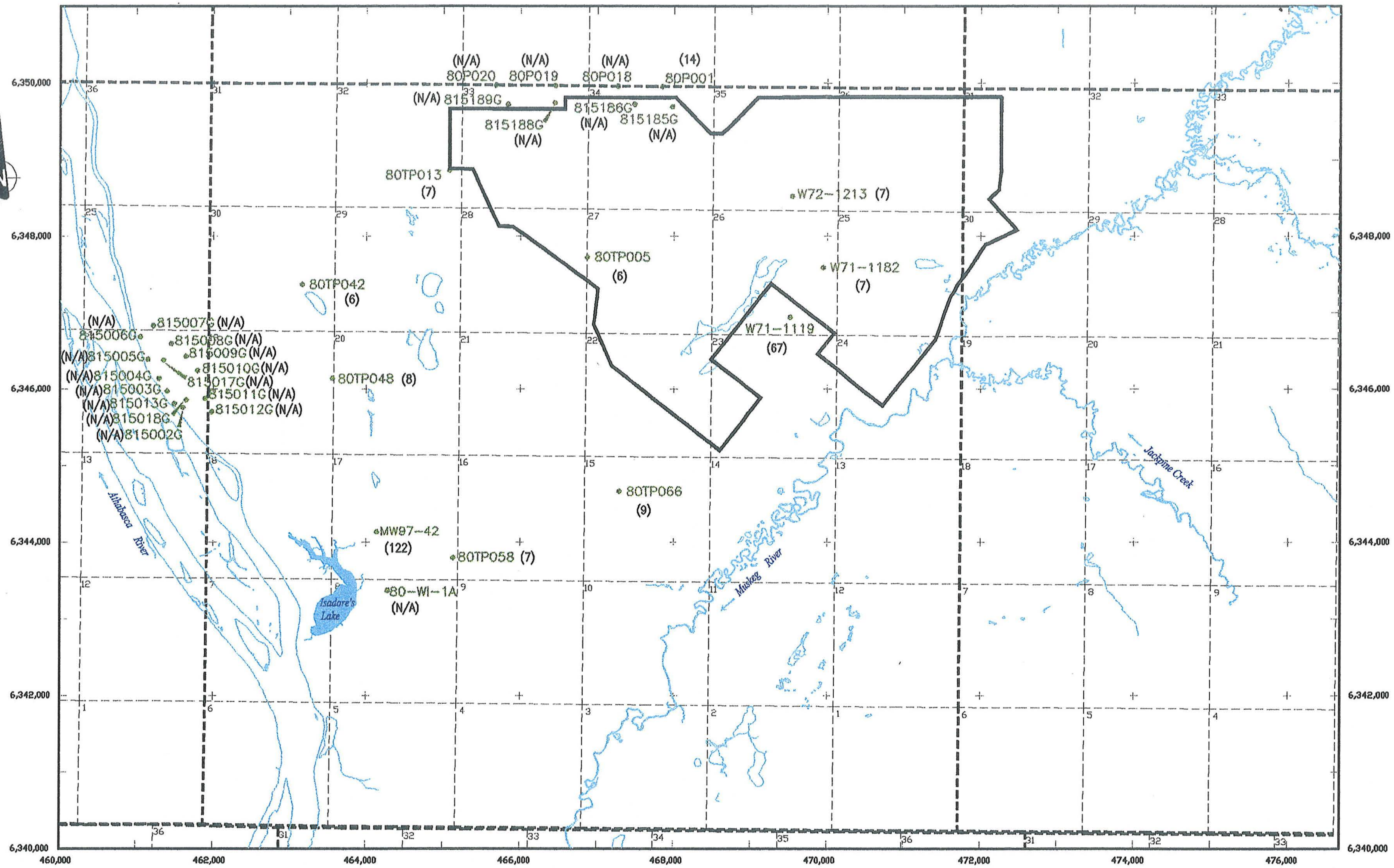
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER
CRETACEOUS: INTRA-OREBODY AND NEAR CONTACT WITH QUATERNARY DEPOSITS

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	NOV04/97
APPROVED:		FIGURE: 19

FILE: J:\4577A\13-BASE.DWG



LEGEND

- 80TP058 — PIEZOMETER LOCATION – CRETACEOUS SEDIMENTS (INTRA-OREBODY OR NEAR CONTACT WITH QUATERNARY DEPOSITS)
- (7) — CHLORIDE CONCENTRATIONS IN mg/L
- (N/A) — DENOTES INFORMATION NOT AVAILABLE

NOTE: CHLORIDE CONCENTRATIONS ORIGINATE FROM EXPLORATION PROGRAMS IN 1971, 1980 AND 1997 ONLY.

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

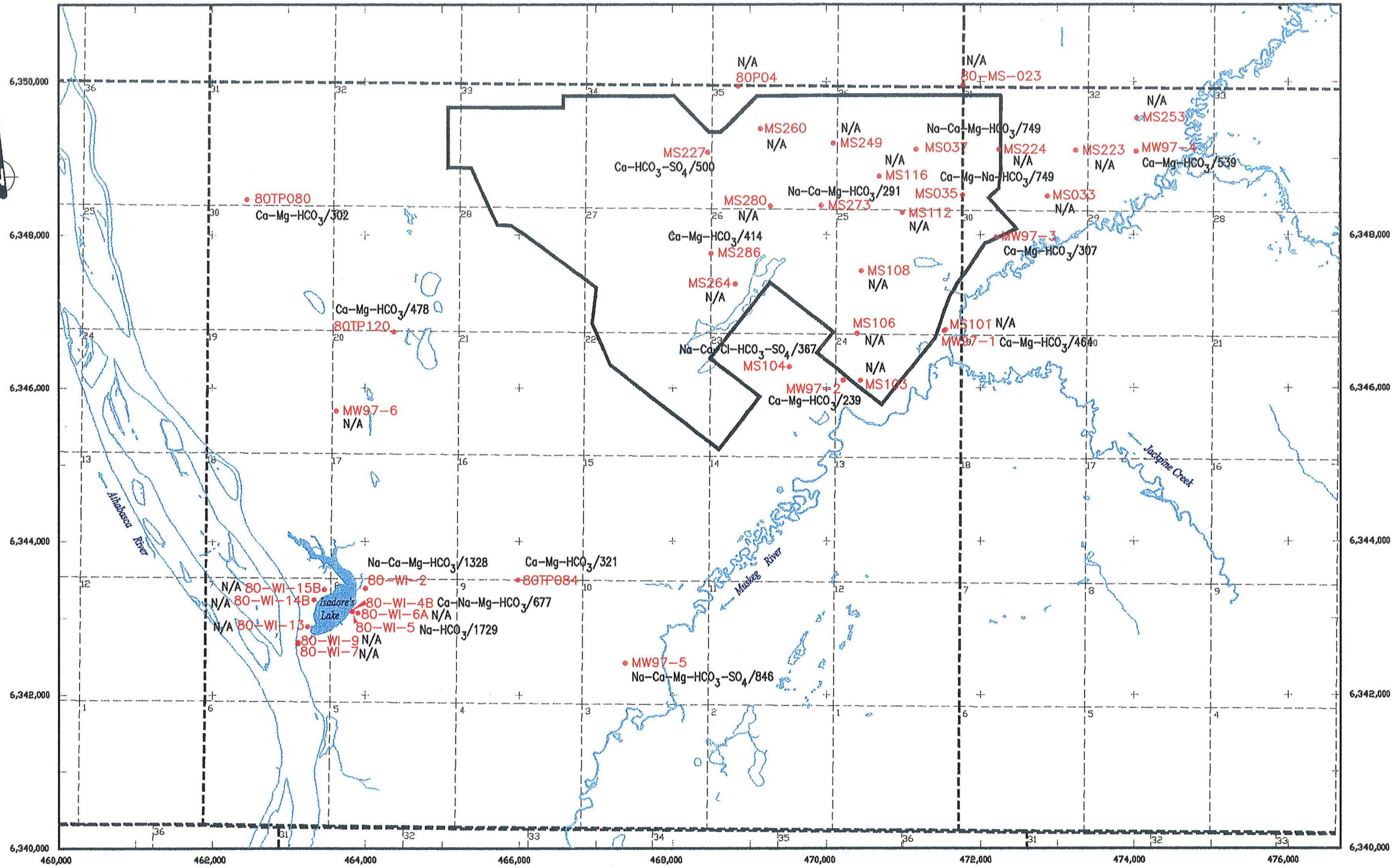
SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

CHLORIDE DISTRIBUTION IN GROUNDWATER CRETACEOUS: INTRA-OREBODY AND NEAR CONTACT WITH QUATERNARY DEPOSITS

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	SEP29/97
APPROVED:	FIGURE: 20	

FILE: J:\4577A\13-BASE.DWG



LEGEND

• MW97-5	PIEZOMETER LOCATION – QUATERNARY DEPOSITS
Na-Ca-Mg-HCO_3-SO_4/846	HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
N/A	DENOTES INFORMATION NOT AVAILABLE

NOTES:
1. HYDROCHEMICAL DATA WAS COLLECTED DURING THE 1980 AND 1997 EXPLORATION PROGRAMS.
2. PIEZOMETERS WERE COMPLETED IN DIFFERENT LITHOLOGICAL UNITS AND AT DIFFERENT DEPTHS (1.89 – 11.87 m), THUS, DELINEATION OF HYDROCHEMICAL ZONES WAS NOT POSSIBLE.

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

SHELL CANADA LIMITED
HYDROGEOLOGY BASELINE STUDY AND
ENVIRONMENTAL IMPACT ASSESSMENT LEASE 13

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER QUATERNARY DEPOSITS

DRAWN BY:	EDITED BY:	DATE:
M.T.	M.T.	NOV04/97
APPROVED:		FIGURE: 21

PREPARED SOLELY FOR THE USE OF OUR CLIENT AS SPECIFIED IN THE ACCOMPANYING REPORT. NO REPRESENTATION OF ANY KIND IS MADE TO OTHER PARTIES WITH WHICH KOMEX INTERNATIONAL LTD. HAS NOT ENTERED INTO A CONTRACT.

FILE: J:\4577A\13-BASE.DWG

APPENDIX I

AEP WELL RECORDS FOR TOWNSHIPS 94-96, RANGES 9-10, W4M

(ARCHIVAL DATA FROM THE GROUNDWATER INFORMATION CENTRE - ALBERTA ENVIRONMENTAL PROTECTION)

ALBERTA ENVIRONMENTAL PROTECTION

COMPUTER GENERATED WATER WELL DRILLER'S REPORT FORM

WELL I.D. 233856

THIS DATA MAY NOT BE FULLY CHECKED; THE PROVINCE DISCLAIMS ALL RESPONSIBILITY FOR ITS ACCURACY: Page 1 of 1

CONTRACTOR:

NAME: UNKNOWN DRILLER

ADDRESS:

LICENCE NO.: JOURNEYMAN NO.:

WELL OWNER:

NAME: SHELL&PW-3

ADDRESS:

POSTAL CODE:

WELL LOCATION: ICs: 00

~ OR LSD	SEC	TWP	RGE	W. MER
10	24	095	09	W4

LOCATION VERIFICATION METHOD: FIELD
LOCATION IN QUARTER:

LOT: BLOCK: PLAN:
WELL ELEV: 1053.51 Feet How obtain: SURVEY-TRA

FORMATION LOG DESCRIPTION:

Depth (Feet):	Lithology:
Ground ter	

DRILLING METHOD: UNKNOWN

TYPE OF WORK: NEW WELL

FLOWING WELL: No **RATE:**

GAS PRESENT: No OIL PRESENT: No

DATE OF ABANDONMENT:

MATERIAL USED:

PROPOSED USE: OBSERVATION

WELL COMPLETION DATA:

WELL FINISH: SCREEN & OPEN HOLE

TOTAL HOLE DEPTH: 103 Feet

CASING TYPE: UNKNOWN

SIZE OD: 8.63 Inch WALL THICKNESS: 0.264 Inch

BOTTOM AT: 52 Feet

PERFORATED CASING/LINER:

TYPE:

SIZE OD: Inch

WALL THICKNESS: Inch

TOP AT: 0 Feet BOTTOM AT: Feet

PERFORATED FROM: Feet TO: Feet
Feet TO: Feet
Feet TO: Feet

SIZE OF PERFORATIONS: Inch X Inch

HOW PERFORATED:

SEAL TYPE:

INTERVAL TOP: 0 Feet TO: Feet

GEOPHYSICAL LOG TAKEN:

RETAINED ON FILE:

SCREEN:

MATERIAL: STAINLESS STEEL

SIZE ID (CLEAR): Inch SLOT SIZE: Inch

INTERVAL TOP: 52 Feet TO: 73 Feet
Feet TO: Feet

INSTALLATION METHOD: ATTACHED TO RISER

TOP FITTINGS: RISER PIPE

BOTTOM FITTINGS: TAIL PIPE

PACK TYPE: SAND

GRAIN SIZE: AMOUNT:

PITLESS ADAPTER TYPE:

DROP PIPE TYPE: LENGTH: Feet DIAMETER: Inch

ADDITIONAL PUMP INFORMATION:

PRODUCTION TEST:

TEST DATE: START TIME:

Elapsed Time in Min:Sec	Depth to Water Level During Pumping	Depth to Water Level During Recovery

WATER REMOVAL RATE DURING TEST: Gal/Min

TEST DURATION: Hours Minutes

TESTING METHOD:

DEPTH OF PUMP/DRILL STEM: Feet

WATER LEVEL AT END OF TEST: Feet

NON-PUMPING(STATIC) WATER LEVEL: FEET

TOTAL DRAWDOWN: Feet

RECOMMENDED PUMPING RATE: Gal/Min

RECOMMENDED PUMP INTAKE AT: Feet

TYPE OF PUMP INSTALLED:

MODEL: H.P.:

DATE WORK STARTED:

DATE WORK COMPLETED:

DATE DATA RECEIVED: August 10, 1972

ADDITIONAL TEST AND/OR PUMP DATA:

CHEMISTRIES TAKEN: N HELD: 7 DOCUMENTS HELD: 9

WELL OWNER'S ANTICIPATED WATER REQUIREMENTS PER DAY:

COMMENTS:

(Maximum of 9 lines printed)

DATE FORM PRINTED: July 21, 1997 16:14:08 DATE DATA KEYED: March 3, 1994 GICDBASE\GIC4OPER MM

Shell PW2-2

ITJ 4B3 PHONE: 328-5322

Lab. No. 1983

Date Rec'd Sept. 21/84

Project Code No. 2

CHEMICAL WATER ANALYSIS REQUEST

PLEASE PRINT FIRMLY

This analysis will contribute to a resource data bank and be available to the public.

History

Location of Sample:

OSOWN (NAME) (STREET) (CITY, TOWN, VILLAGE)

(POSTAL CODE) (TELEPHONE)

NB* Location LSD 10 ¼ Section 24 Township 95 Range 9 W 4 Meridian

Source of Sample: (STREAM, DUGOUT, WELL TAP, ETC.)

NB* Well ☐ Depth .... meters, ... feet, Depth to Water Level .... meters, ... feet

Well Completion .... (DRILLED, DUG, SCREEN, SETTLING ETC.)

Submitted by: Yeh-Mom Chae Phone 427-6231

(ADDRESS) (POSTAL CODE)

Results to: Above ☑ or

Date of Sample: Sept. 17, 1984 Sampler's Comments: Iron precipitation

Reason for Sample: HUMAN CONSUMPTION ☐ For Interpretation Contact Local Health Unit

LIVESTOCK CONSUMPTION ☐ For Interpretation Contact Local Veterinarian

IRRIGATION ☐ For Interpretation Contact Irrigation Specialist

CHEMICAL WATER ANALYSIS REPORT

Analysis

Date Completed Oct 2/84

EC 0.53 m Siemens/cm

pH 8.4

SAR 0.17

	Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)	
Calcium	101	N.E.*	Ca
Magnesium	17	150	Mg
Hardness, Total	323	500	$CaCO_3$
Sodium	6.9	300	Na
Potassium	3.1	N.E.	K
Carbonate	14	N.E.	CO_3
Bicarbonate	368	N.E.	HCO_3
Alkalinity, Total (T. Alk.)	325	500	$CaCO_3$

	Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)	
Iron	26.8	0.3	Fe
Fluoride		1.5	F
Sulphate	2.4	500	SO_4
Chloride	2.7	250	Cl
Nitrate-Nitrogen Plus Nitrite-Nitrogen	<0.07	10.0	N
Nitrite-Nitrogen		1.0	N
Ammonium-Nitrogen	0.42	0.5	N
Total Dissolved	429	1000	

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-2

Lsd 10 Sec 24 Twp 95 R 9 W4th

Alberta Research Council

Sample source SHELL PW-2 @ 12 hours pumping @ 275 igpm SCL

Date sampled August 10, 1972 Time 11.45 pm

Major Constituents

		Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})		106	5.29	67.3
Magnesium (Mg^{++})		17	1.40	17.8
Sodium (Na^{+})				
Potassium (K^{+})	Na + K	27	1.17	14.9
Carbonate ($CO_3^{=}$)		0	0	0
Bicarbonate (HCO_3^{-})		439	7.20	91.6
Sulfate ($SO_4^{=}$)		2	0.04	0.5
Chloride (Cl^{-})		22	0.62	7.9
Nitrate ($NO_3^{=}$)				
Silica (SiO_2)				
Hydroxide (OH^{-})				
Calcium (Acidified)				
Magnesium (Acidified)				
Total dissolved solids		613 calculated		

Total Anions (epm) Total Cations (epm)

Other Constituents

Lab:		Field:
Conductivity		Temperature (C)
pH	7.4	pH
Fluoride (F^{-})		Carbonate ($CO_3^{=}$)
		Bicarbonate (HCO_3^{-})
		Hydroxide (OH^{-})
		Conductivity

1000

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-2

Lsd 10 Sec 24 Twp 95 R 9 W4th

Alberta Research Council

Sample source SHELL PW-2 @ 146 hours @ 275 igpm SCL

Date sampled August 16, 1972 Time 1.30 pm

Major Constituents

		Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})		105	5.24	65.3
Magnesium (Mg^{++})		20	1.64	20.4
Sodium (Na^{+})				
Potassium (K^{+})	Na + K	26	1.15	14.3
Carbonate ($CO_3^{=}$)		0	0	0
Bicarbonate (HCO_3^{-})		451	7.39	82.0
Sulfate ($SO_4^{=}$)		1	0.02	0.2
Chloride (Cl^{-})		22	0.62	7.7
Nitrate ($NO_3^{=}$)				
Silica (SiO_2)				
Hydroxide (OH^{-})				
Calcium (Acidified)				
Magnesium (Acidified)				
Total dissolved solids		625 calculated		

Total Anions (epm) Total Cations (epm)

Other Constituents

Lab:

Conductivity

pH 7.3

Fluoride (F^{-})

Field:

Temperature (C)

pH

Carbonate ($CO_3^{=}$)

Bicarbonate (HCO_3^{-})

Hydroxide (OH^{-})

Conductivity

1000

233856

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-2

Lsd 10 Sec 24 Twp 95 R 9 W4th

Alberta Research Council

Sample source Bailed

Date sampled July 17, 1976

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	102.0	5.09	71
Magnesium (Mg^{++})	16.4	1.35	19
Sodium (Na^{+})	15.0	0.65	9
Potassium (K^{+})	2.5	0.06	1
Carbonate ($CO_3^{=}$)	0.0	0.00	0
Bicarbonate (HCO_3^{-})	388.0	6.36	96
Sulfate ($SO_4^{=}$)	4.3	0.09	1
Chloride (Cl^{-})	6.0	0.17	3
Nitrate ($NO_3^{=}$)	1.2	0.02	0
Silica (SiO_2)	14.4		
Hydroxide (OH^{-})			
Calcium (Acidified)	101.2		
Magnesium (Acidified)	17.6		
Total dissolved solids	384		

Total Anions (epm) 6.64 Total Cations (epm) 7.16

Other Constituents

Lab:

Conductivity	600	
pH	7.6	
Fluoride (F^{-})	0.2	Mg/L

Field:

Temperature (C)	5.0	
pH	6.5	
Carbonate ($CO_3^{=}$)		
Bicarbonate (HCO_3^{-})	478	Mg/L
Hydroxide (OH^{-})		
Conductivity		

1000

MULTIELEMENT ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-2

Lsd 10 Sec 24 Twp 95 R 9 W4th

Alberta Research Council

Date sampled: July 17, 1976

Element	Value	Element	Value
Ag	<.002	Mn	.775
Au	<.003	Mo	<.006
Al	<.002	Na	14.5
As	<.038	Ni	<.010
B	.194	P	0.66
Ba	<.200	Pb	<.088
Be	.002	Se	<.060
Ca	126.5	Si	10.5
Cd	<.002	Sn	<.045
Co	<.010	Sr	.303
Cr	<.006	Te	<.065
Cu	.025	Ti	<.0009
Eu	<.015	U	<.020
Fe	33.8	V	.013
K	66.0	W	<.078
Mg	19.4	Zn	.077

NOTES:

1. All values in milligrams per liter
2. Sample bailed from well
3. Analysis done by Multielement Radio Frequency Induction Coupled Plasma Emission Spectrometer at Barringer Research Ltd., Rexdale, Ontario.

SHELL PW-2-E-78
233856

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-2

Lsd 10 Sec 24 Twp 95 R 9 W4th

Alberta Research Council

Sample source Bailed

Date sampled July 8, 1977

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	105.0	5.24	75.9
Magnesium (Mg^{++})	16.5	1.36	19.7
Sodium (Na^{+})	6.3	0.27	4.0
Potassium (K^{+})	1.3	0.03	0.5
Carbonate ($CO_3^{=}$)	0.0	0.00	0.0
Bicarbonate (HCO_3^{-})	434.0	7.11	96.7
Sulfate ($SO_4^{=}$)	8.0	0.17	2.3
Chloride (Cl^{-})	2.0	0.06	0.8
Nitrate ($NO_3^{=}$)	1.3	0.02	0.3
Silica (SiO_2)	17.1		
Hydroxide (OH^{-})			
Calcium (Acidified)	95.0		
Magnesium (Acidified)	16.1		
Total dissolved solids	444.0		

Total Anions (epm) 7.36 Total Cations (epm) 6.91

Other Constituents

Lab:			Field:	
Conductivity	670		Temperature (C)	5.0
pH	6.8		pH	6.8
Fluoride (F^{-})	0.3 ppm		Carbonate ($CO_3^{=}$)	
			Bicarbonate (HCO_3^{-})	512.0 ppm
			Hydroxide (OH^{-})	
			Conductivity	

1600

ALBERTA RESEARCH COUNCIL
WATER ANALYSIS REPORT

233856

Mer 4 Tp 95 Rge 9 Sec 24 Lsd 10

Lab no.	78 248	Date sampled (D M Y)	08 07 78
Index no.	DH 648	Date submitted	17 07 78
Well depth(ft)	103.0	Date analysed(major)	8 8 78
Water level(ft)		Date analysed(minor)	
Top open interval(ft)		Sampled by	HACKBARTH
Bottom open interval(ft)		Sample Source	WELL
Altitude(ft)		Owners name	SHELL PW-2
Bedrock elevation(ft)		Hardness(as CaCO3)	338.2
TDS(mg/l)	426.0	Alkalinity(as CaCO3)	332.0
Field Cond(micromhos/cm)		Cond(micromhos/cm@25C)	570
Field pH	6.7	Lab pH	6.9

MAJOR CONSTITUENTS

	mg/l	meq/l	% of total anion or cation
Calcium(Ca)	107.0	5.34	76.1
Magnesium(Mg)	17.3	1.42	20.3
Sodium(Na)	5.0	0.22	3.1
Potassium(K)	1.3	0.03	0.5
Carbonate(CO3)	0.0	0.00	0.0
Bicarbonate(HCO3)	415.0	6.80	99.5
Sulphate(SO4)	0.0	0.00	0.0
Chloride(Cl)	0.0	0.00	0.0
Nitrate(NO3)	2.0	0.03	0.5
Hydroxide(OH)			

Silica(SiO2)	17.2	Total anions(epm)	6.834
Calcium(Acid)	91.0	Total cations(epm)	7.014
Magnesium(Acid)	16.1	Ion balance error(%)	1.
Calculated TDS	353.9	TDS balance error(%)	-17.

MINOR CONSTITUENTS

Aluminum	0.04 ppm
Copper	0 ppb
Iodine	0 ppm
Iron	27.1 ppm
Lead	0.3 ppb
Manganese	0.60 ppm
Mercury	0.04 ppb

OTHER MEASUREMENTS

Field Temp(C)	4.00	Fluoride(F)	0.30 ppm
Field Bicarbonate(HCO3)	507 ppm		

OBSERVATION WELL NUMBER: 63

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

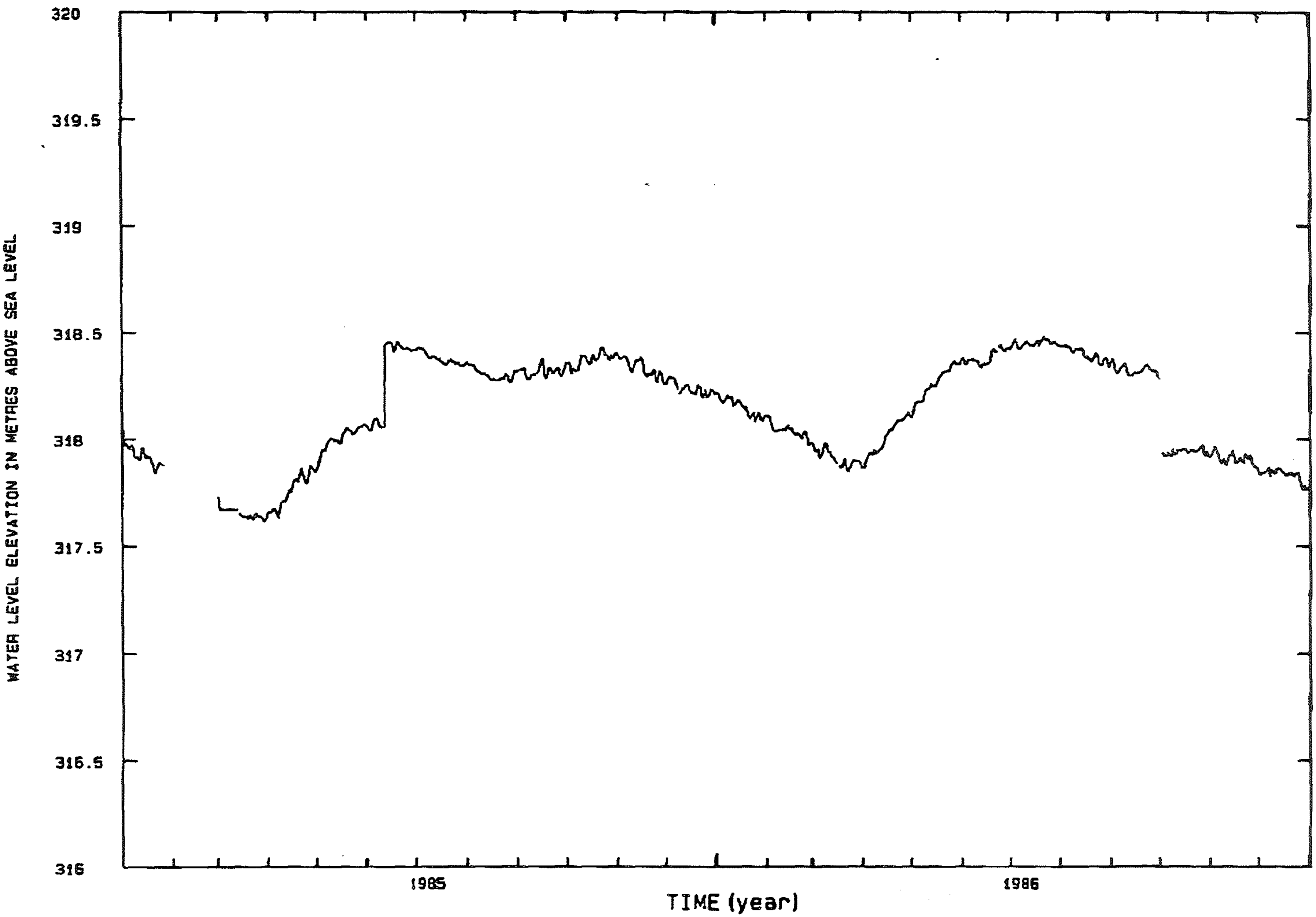
DATA START DATE: 85/ 1/ 1

NAME: FORT MCMURRAY SHELL-PW2-103

MEASURING ELEVATION: 321.11m

LOCATION: LSD 10 SEC 24 TWP 95 R 9 W 4TH

WELL COMPLETION: SLOTTED 16 - 22 m



PLOT DATE: 07-22-1997 DATA GAPS > 24 HOURS ARE NOT JOINED 1 DAYS AVERAGING

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

OBSERVATION WELL NUMBER: 63

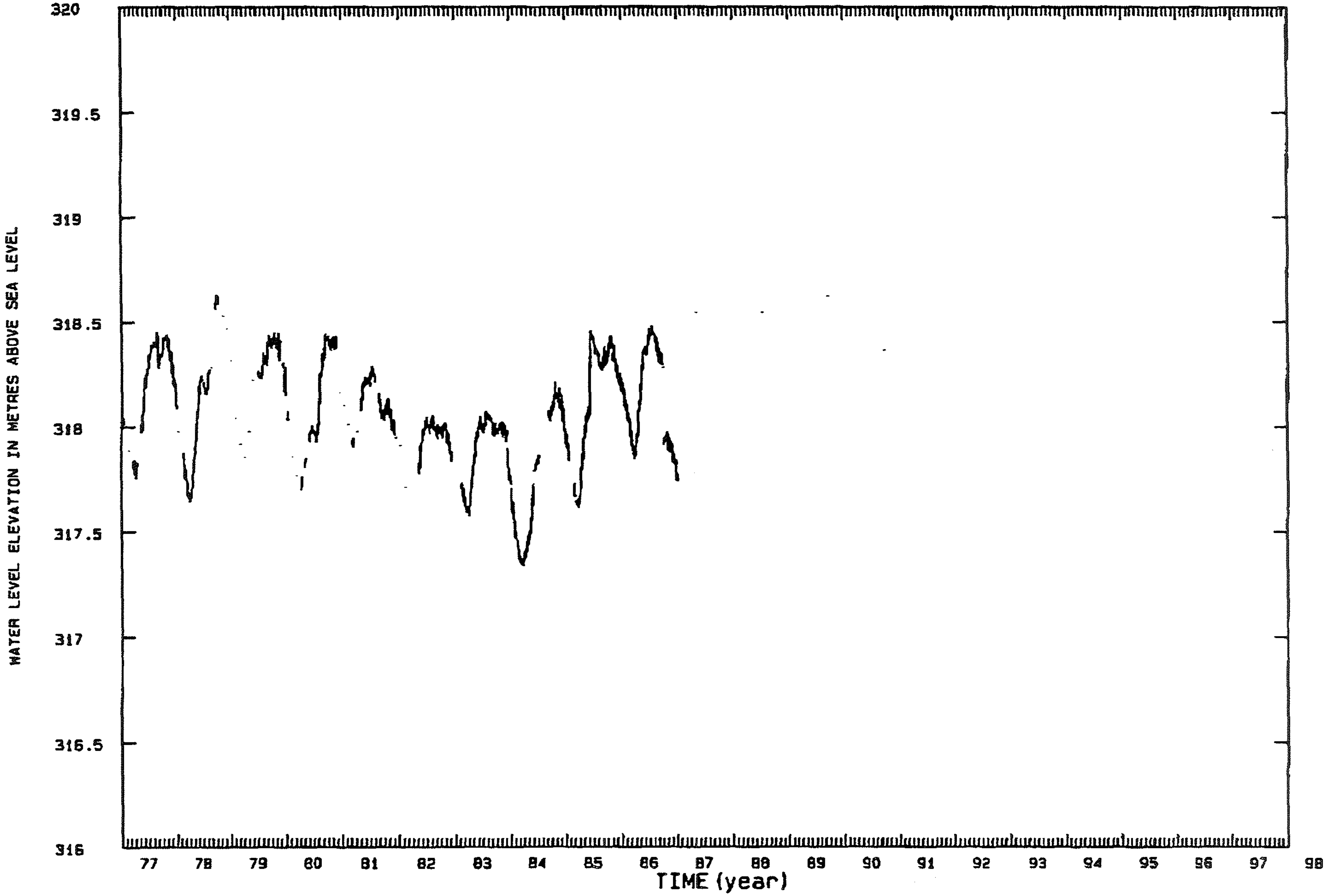
NAME: FORT MCMURRAY SHELL-PW2-103

LOCATION: LSD 10 SEC 24 TWP 95 R 9 W 4TH

DATA START DATE: 77/ 1/ 1

MEASURING ELEVATION: 321.11m

WELL COMPLETION: SLOTTED 16 - 22 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

ALBERTA ENVIRONMENTAL PROTECTION
COMPUTER GENERATED WATER WELL DRILLER'S REPORT FORM

WELL I.D. 233859

THIS DATA MAY NOT BE FULLY CHECKED; THE PROVINCE DISCLAIMS ALL RESPONSIBILITY FOR ITS ACCURACY:

Page 1 of 1

CONTRACTOR:

NAME: UNKNOWN DRILLER

ADDRESS:

LICENCE NO.: JOURNEYMAN NO.:

WELL OWNER:

NAME: SHELL#PW-4

ADDRESS:

POSTAL CODE:

WELL LOCATION: IC#: 02

¼ OR LSD	SEC	TWP	RGE	W. MER
10	25	095	10	W4

LOCATION VERIFICATION METHOD: FIELD
LOCATION IN QUARTER:

LOT: BLOCK: PLAN:
WELL ELEV: 955. Feet How obtain: ESTIMATED

FORMATION LOG DESCRIPTION:

Depth (Feet):	Lithology:
Ground to:	

DRILLING METHOD: UNKNOWN

TYPE OF WORK: NEW WELL

FLOWING WELL: No **RATE:**
GAS PRESENT: No OIL PRESENT: No
DATE OF ABANDONMENT:
MATERIAL USED:
PROPOSED USE: OBSERVATION

WELL COMPLETION DATA:

WELL FINISH: SCREEN & OPEN HOLE
TOTAL HOLE DEPTH: 301 Feet

CASING TYPE: UNKNOWN
SIZE OD: 8.63 Inch WALL THICKNESS: 0.264 Inch
BOTTOM AT: 235 Feet

PERFORATED CASING/LINER:
TYPE:
SIZE OD: Inch
WALL THICKNESS: Inch
TOP AT: 0 Feet BOTTOM AT: Feet
PERFORATED FROM: Feet TO: Feet
Feet TO: Feet
Feet TO: Feet

SIZE OF PERFORATIONS: Inch X Inch
HOW PERFORATED:

SEAL TYPE: CEMENT/GROUT
INTERVAL TOP: 0 Feet TO: 215 Feet

GEOPHYSICAL LOG TAKEN:
RETAINED ON FILE:

SCREEN:
MATERIAL: UNKNOWN
SIZE ID (CLEAR): 6.13 Inch SLOT SIZE: 0.020 Inch
INTERVAL TOP: 249 Feet TO: 270 Feet
280 Feet TO: 290 Feet

INSTALLATION METHOD: ATTACHED TO CASING
TOP FITTINGS:
BOTTOM FITTINGS:
PACK TYPE:
GRAIN SIZE: AMOUNT:

PITLESS ADAPTER TYPE:
DROP PIPE TYPE: LENGTH: Feet
DIAMETER: Inch
ADDITIONAL PUMP INFORMATION:

PRODUCTION TEST:

TEST DATE: START TIME:

Elapsed Time In Min:Sec	Depth to Water Level During Pumping	Depth to Water Level During Recovery

WATER REMOVAL RATE DURING TEST: Gal/Min
TEST DURATION: Hours Minutes
TESTING METHOD:
DEPTH OF PUMP/DRILL STEM: Feet
WATER LEVEL AT END OF TEST: Feet
NON-PUMPING(STATIC) WATER LEVEL: FEET
TOTAL DRAWDOWN: Feet

RECOMMENDED PUMPING RATE: Gal/Min
RECOMMENDED PUMP INTAKE AT: Feet
TYPE OF PUMP INSTALLED:
MODEL: H.P.:

DATE WORK STARTED:
DATE WORK COMPLETED:
DATE DATA RECEIVED: February 2, 1975
ADDITIONAL TEST AND/OR PUMP DATA:
CHEMISTRIES TAKEN: N HELD: 7 DOCUMENTS HELD: 8
WELL OWNER'S ANTICIPATED WATER REQUIREMENTS PER DAY:

COMMENTS:
(Maximum of 8 lines printed)

DATE FORM PRINTED: July 21, 1997 14:25:26 **DATE DATA KEYED:** March 3, 1994 DATA\GWICDATA\GIC4 MM

SHELL PW-4-E-77
233859

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-4

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source SHELL PW-4 (SCL)

Date sampled February 2, 1975 Time

Major Constituents

		Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})		19	0.95	
Magnesium (Mg^{++})		25	2.06	
Sodium (Na^{+})	Na + K	1130	49.17	
Potassium (K^{+})				
Carbonate ($CO_3^{=}$)		0	0	
Bicarbonate (HCO_3^{-})		1327	21.75	
Sulfate ($SO_4^{=}$)		39	0.81	
Chloride (Cl^{-})		1050	29.62	
Nitrate ($NO_3^{=}$)				
Silica (SiO_2)				
Hydroxide (OH^{-})				
Calcium (Acidified)				
Magnesium (Acidified)				
Total dissolved solids		3590 calculated		

Total Anions (epm) Total Cations (epm)

Other Constituents

Lab:		Field:
Conductivity		Temperature (C)
pH	8.18	pH
Fluoride (F^{-})		Carbonate ($CO_3^{=}$)
Iron	0	Bicarbonate (HCO_3^{-})
H_2S	0	Hydroxide (OH^{-})
		Conductivity

1002

233859

MULTIELEMENT ANALYSIS

OBSERVATION WELL NUMBER SHELL FW-4

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Date sampled: July 16, 1976

Element	Value	Element	Value
Ag	<.002	Mn	.100
Au	<.003	Mo	<.006
Al	0.22	Na	1028
As	<.038	Ni	<.010
B	1.67	P	<.110
Ba	<.200	Pb	<.088
Be	<.001	Se	<.060
Ca	58.2	Si	2.76
Cd	<.002	Sn	<.045
Co	<.010	Sr	1.45
Cr	<.006	Te	<.065
Cu	.019	Ti	<.0009
Eu	<.015	U	<.020
Fe	0.79	V	0.009
K	99	W	<.078
Mg	28.9	Zn	0.077

NOTES:

1. All values in milligrams per liter
2. Sample bailed from well
3. Analysis done by Multielement Radio Frequency Induction Coupled Plasma Emission Spectrometer at Barringer Research Ltd., Rexdale, Ontario.

SHELL PW-4-E-77
233859

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-4

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source Balled

Date sampled July 16, 1976

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	58.0	2.89	5
Magnesium (Mg^{++})	31.0	2.55	5
Sodium (Na^{+})	1113.0	48.41	89
Potassium (K^{+})	15.8	0.40	1
Carbonate ($CO_3^{=}$)	0.0	0.00	0
Bicarbonate (HCO_3^{-})	1388.0	22.75	44
Sulfate ($SO_4^{=}$)	36.7	0.76	2
Chloride (Cl^{-})	1010.0	28.48	55
Nitrate ($NO_3^{=}$)	1.0	0.02	0
Silica (SiO_2)	4.0		
Hydroxide (OH^{-})			
Calcium (Acidified)	60.5		
Magnesium (Acidified)	33.0		
Total dissolved solids	7910		

Total Anions (epm) 52.01 Total Cations (epm) 54.26

Other Constituents

Lab:			Field:		
Conductivity	5200		Temperature (C)	6.0	
pH	7.5		pH	7.2	
Fluoride (F^{-})	1.5	Mg/L	Carbonate ($CO_3^{=}$)		
			Bicarbonate (HCO_3^{-})	1449	Mg/L
			Hydroxide (OH^{-})		
			Conductivity		

233859

SHELL PW-4-E-78

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL PW-4

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source Bailed

Date sampled July 8, 1977

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	51.0	2.54	4.8
Magnesium (Mg^{++})	29.0	2.39	4.5
Sodium (Na^{+})	1088.0	47.32	89.8
Potassium (K^{+})	16.3	0.42	0.8
Carbonate ($CO_3^{=}$)	0.0	0.00	0.0
Bicarbonate (HCO_3^{-})	1430.0	23.44	44.1
Sulfate ($SO_4^{=}$)	27.8	0.58	1.1
Chloride (Cl^{-})	1032.0	29.10	54.8
Nitrate ($NO_3^{=}$)	0.2	0.00	0.0
Silica (SiO_2)	4.6		
Hydroxide (OH^{-})			
Calcium (Acidified)	48.0		
Magnesium (Acidified)	27.0		
Total dissolved solids	2928.0		

Total Anions (epm) 53.12 Total Cations (epm) 52.67

Other Constituents

Lab:		Field:	
Conductivity	5500	Temperature (C)	7.0
pH	7.4	pH	7.5
Fluoride (F^{-})	2.3 ppm	Carbonate ($CO_3^{=}$)	
		Bicarbonate (HCO_3^{-})	1449.0 ppm
		Hydroxide (OH^{-})	
		Conductivity	

233859

ALBERTA RESEARCH COUNCIL
WATER ANALYSIS REPORT

Mer 4 Tp 95 Rge 10 Sec 25 Lsd 10

			D M Y
Lab no.	78 247	Date sampled	08 07 78
Index no.	DH 647	Date submitted	17 07 78
well depth(ft)	310.0	Date analysed(major)	8 8 78
water level(ft)	301	Date analysed(minor)	
Top open interval(ft)		Sampled by	HACKBARTH
Bottom open interval(ft)		Sample Source	WELL
Altitude(ft)		Owners name	SHELL PW.4
Bedrock elevation(ft)		Hardness(as CaCO3)	214.3
TDS(mg/l)	2850.0	Alkalinity(as CaCO3)	1103.2
Field Cond(micromhos/cm)		Cond(micromhos/cm@25C)	4560
Field pH	7.5	Lab pH	7.5

MAJOR CONSTITUENTS

	mg/l	meq/l	% of total anion or cation
Calcium(Ca)	43.0	2.15	4.3
Magnesium(Mg)	26.0	2.14	4.2
Sodium(Na)	1050.0	45.67	90.7
Potassium(K)	16.3	0.42	0.8
Carbonate(CO3)	0.0	0.00	0.0
Bicarbonate(HCO3)	1379.0	22.60	42.9
Sulphate(SO4)	28.5	0.59	1.1
Chloride(Cl)	1045.0	29.47	55.9
Nitrate(NO3)	0.8	0.01	0.0
Hydroxide(OH)			

Silica(SiO2)	4.6	Total anions(epm)	52.679
Calcium(Acid)	27.0	Total cations(epm)	50.375
Magnesium(Acid)	20.0	Ion balance error(%)	2.
Calculated TDS	2892.3	TDS balance error(%)	1.

MINOR CONSTITUENTS

Aluminum	0.04 ppm
Copper	2.25 ppm
Iodine	0.03 ppm
Iron	.6 ppm
Lead	0.3 ppb
Manganese	0.06 ppm
Mercury	0.36 ppb

OTHER MEASUREMENTS

Field Temp(C)	6.00	Fluoride(F)	1.80 ppm
Field Bicarbonate(HCO3)	1400 ppm		

Lab. No. 1945

Date Rec'd Sept. 21/84

Project Code No. 2

CHEMICAL WATER ANALYSIS REQUEST

PLEASE PRINT FIRMLY

This analysis will contribute to a resource data bank and be available to the public.

History

Location of Sample:

OSOWN (NAME) (STREET) (CITY, TOWN, VILLAGE)

(POSTAL CODE) (TELEPHONE)

NB* Location LSD 10 ¼ Section 25 Township 95 Range 10 W 4 Meridian

Source of Sample: (STREAM, DUGOUT, WELL, TAP, ETC.)

NB* Well ☐ Depth ....meters, ...feet, Depth to Water Level ....meters, ...feet

Well Completion (DRILLED, DUG, SCREEN, SETTLING ETC.)

Submitted by: Yeh-Moon Chae Phone 427-6231

(ADDRESS) (POSTAL CODE)

Results to: Above ☑ or

Date of Sample: Sept. 15, 1984 Sampler's Comments:

Reason for Sample:
- HUMAN CONSUMPTION ☐ For Interpretation Contact Local Health Unit
- LIVESTOCK CONSUMPTION ☐ For Interpretation Contact Local Veterinarian
- IRRIGATION ☐ For Interpretation Contact Irrigation Specialist

CHEMICAL WATER ANALYSIS REPORT

Analysis Date Completed Oct 2/84

EC 3.84 m Siemens/cm

pH 9.9

SAR 151

	Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)	
Calcium	1	N.E.*	Ca
Magnesium	0.6	150	Mg
Hardness, Total	5	500	$CaCO_3$
Sodium	777	300	Na
Potassium	27	N.E.	K
Carbonate	186	N.E.	CO_3
Bicarbonate	298	N.E.	HCO_3
Alkalinity, Total (T. Alk.)	555	600	$CaCO_3$

	Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)	
Iron	0.05	0.3	Fe
Fluoride		1.5	F
Sulphate	2.4	500	SO_4
Chloride	868	250	Cl
Nitrate-Nitrogen Plus Nitrite-Nitrogen	<0.07	10.0	N
Nitrite-Nitrogen		1.0	N
Ammonium-Nitrogen	12.6	0.5	N
Total Dissolved Solids (TDS)	2026	1000	

History

Location of Sample:

OSOWN
(NAME) (STREET) (CITY, TOWN, VILLAGE)

(POSTAL CODE) (TELEPHONE)

NB* Location LSD 10 ¼ Section 25 Township 95 Range 10 W 4 Meridian

Source of Sample: .... (STREAM, DUGOUT, WELL, TAP, ETC.)

NB* Well ☐ Depth .... meters, ... feet, Depth to Water Level .... meters, ... feet

Well Completion .... (DRILLED, DUG, SCREEN, SETTLING ETC.)

Submitted by: Yek-Moon Chae Phone 427-6231

(ADDRESS) (POSTAL CODE)

Results to: Above ☑ or ....

Date of Sample: Sept. 15, 1984 Sampler's Comments: Fine black particles Precipitation?

Reason for Sample: HUMAN CONSUMPTION ☐ For Interpretation Contact Local Health Unit

LIVESTOCK CONSUMPTION ☐ For Interpretation Contact Local Veterinarian

IRRIGATION ☐ For Interpretation Contact Irrigation Specialist

CHEMICAL WATER ANALYSIS REPORT

Analysis

Date Completed Oct 2/84 EC 5-11 m Siemens/cm

pH 8-15 SAR 27-6

	Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)			Sample Results mg/L (ppm)	Canadian Drinking Water Standards mg/L (ppm)	
Calcium	5-8	N.E.*	Ca	Iron	0-15	0.3	Fe
Magnesium	30	150	Mg	Fluoride		1.5	F
Hardness, Total	270	500	$CaCO_3$	Sulphate	34	500	SO_4
Sodium	1042	300	Na	Chloride	993	250	Cl
Potassium	16	N.E.	K	Nitrate-Nitrogen Plus Nitrite-Nitrogen	<0.07	10.0	N
Carbonate	0	N.E.	CO_3	Nitrite-Nitrogen		1.0	N
Bicarbonate	1414	N.E.	HCO_3	Ammonium-Nitrogen	2-66	0.5	N
Alkalinity, Total (T. Alk.)	1159	500	$CaCO_3$	Total Dissolved Solids (TDS)	2872	1000	

Laboratory Comments:

no visible particles

NB*—Land Location and Well Depths must be given for all groundwater samples.

NE*—Not Established.

D. N. GRAVELAND
BRANCH HEAD FOR

WHITE - Submittee; YELLOW - File; PINK - Municipal Engineering; BLUE - Hydrogeology Branch

OBSERVATION WELL NUMBER: 65

NAME: FORT MCMURRAY SHELL-PW4-301

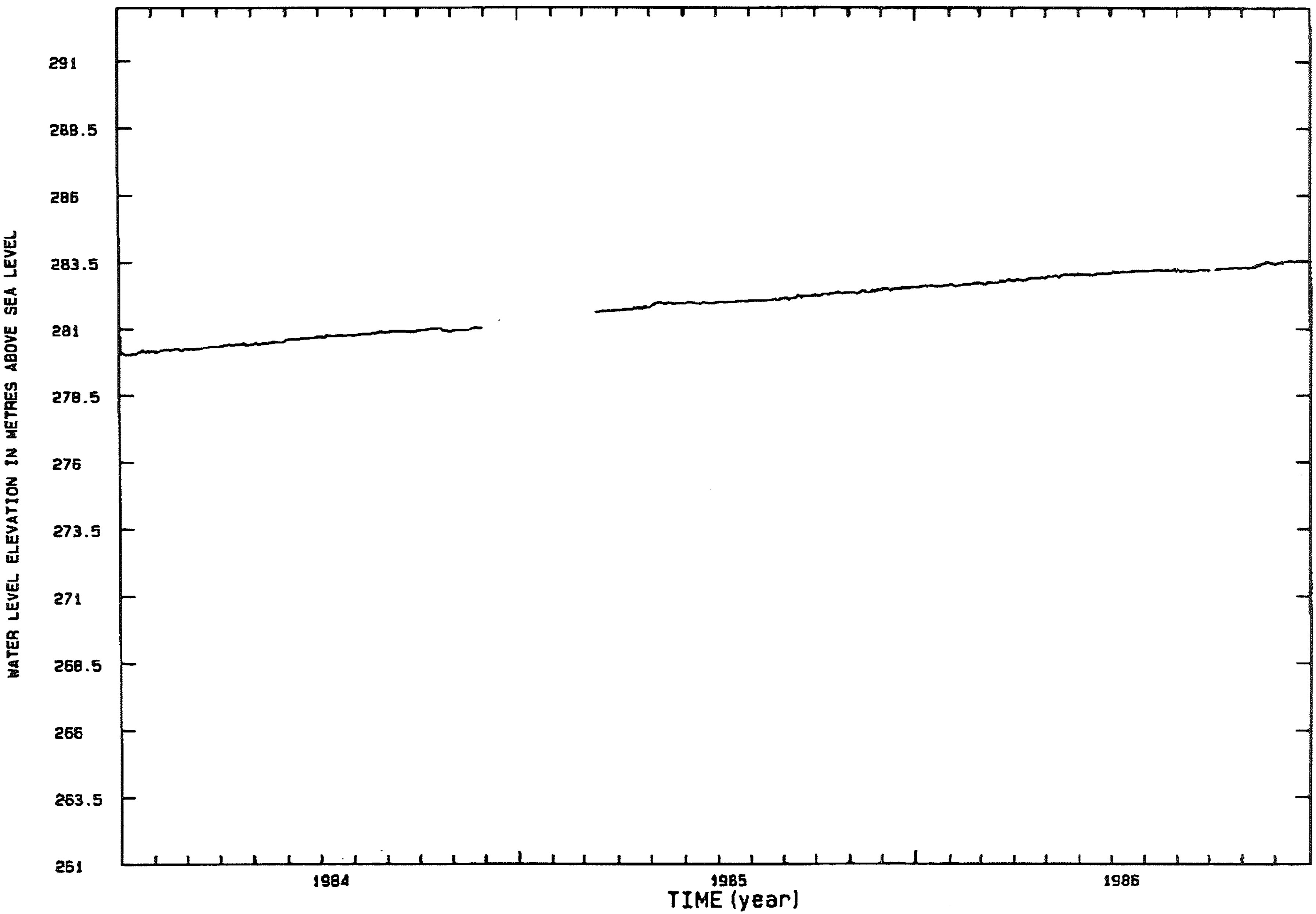
LOCATION: LSD 10 SEC 25 TWP 95 R 10 W 4TH

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

DATA START DATE: 84/ 1/ 1

MEASURING ELEVATION: 291.08m

WELL COMPLETION: SCREEN 74.9-82.3; 85.4-88.4 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

OBSERVATION WELL NUMBER: 65

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

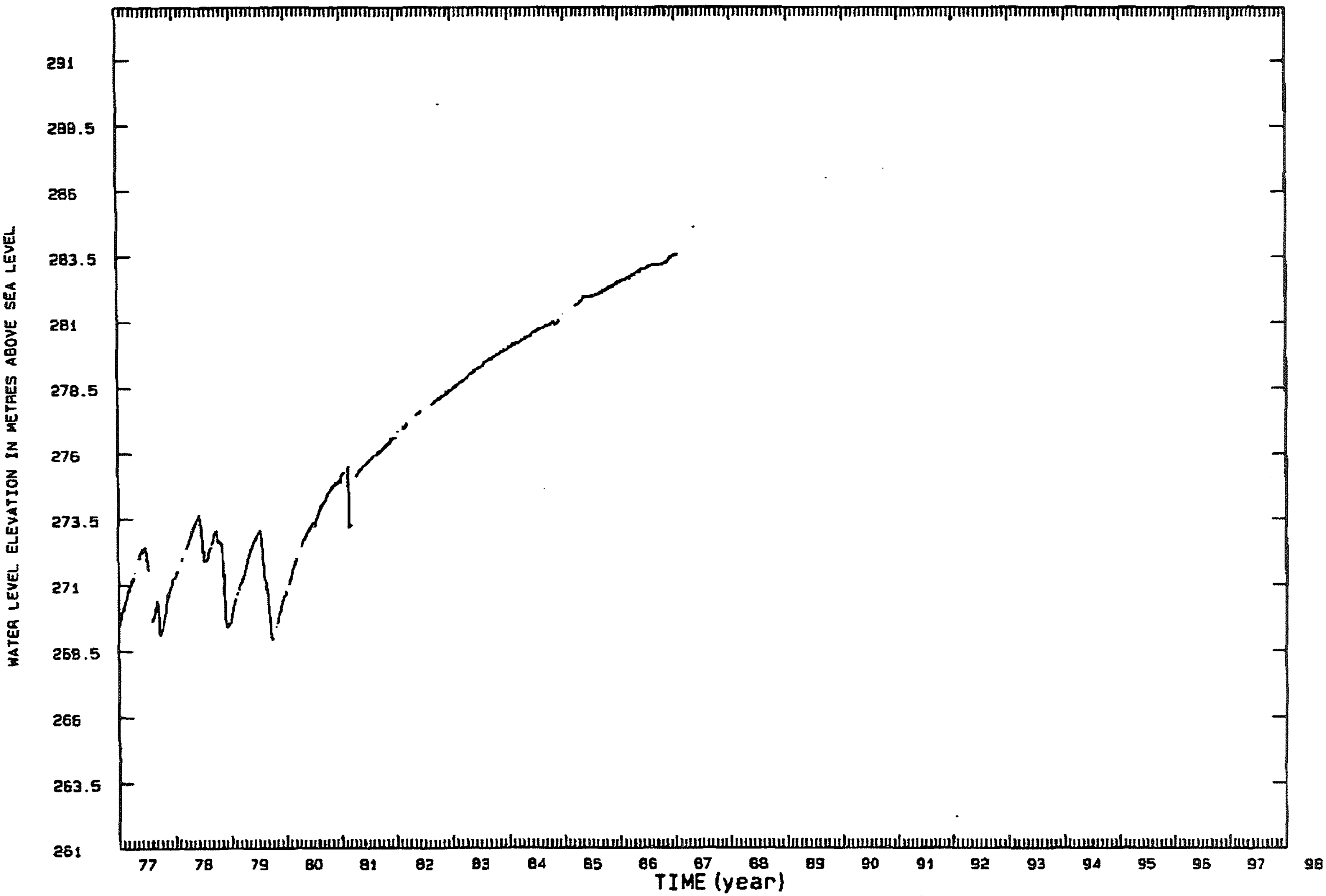
DATA START DATE: 77/ 1/ 1

NAME: FORT MCMURRAY SHELL-PW4-301

MEASURING ELEVATION: 291.08m

LOCATION: LSD 10 SEC 25 TWP 95 R 10 W 4TH

WELL COMPLETION: SCREEN 74.9-82.3; 85.4-88.4 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

ALBERTA ENVIRONMENTAL PROTECTION

COMPUTER GENERATED WATER WELL DRILLER'S REPORT FORM

WELL I.D. 233860

Page 1 of

THIS DATA MAY NOT BE FULLY CHECKED; THE PROVINCE DISCLAIMS ALL RESPONSIBILITY FOR ITS ACCURACY:

CONTRACTOR:

NAME: UNKNOWN DRILLER

ADDRESS:

LICENCE NO.: JOURNEYMAN NO.:

WELL OWNER:

NAME: SHELL#OBS-7

ADDRESS:

POSTAL CODE:

WELL LOCATION: IC#: 03

¼ OR LSD	SEC	TWP	RGE	W. MER
10	25	095	10	W4

LOCATION VERIFICATION METHOD: FIELD
LOCATION IN QUARTER:

LOT: BLOCK: PLAN:
WELL ELEV: 953. Feet How obtain: ESTIMATED

FORMATION LOG DESCRIPTION:

Depth (Feet):	Lithology:
Ground to:	
310	Unknown
380	Greenish Gray Calcareous Shale
405	Argillaceous Limestone
445	Gray Soft Shale
475	Limestone
480	Gray Soft Shale
500	Silty Limestone
510	Dolomite
565	See Comments
575	See Comments
590	See Comments
595	Gray Soft Shale
615	Dolomite
640	Limestone
643	Unknown
983	Lost Circulation

DRILLING METHOD: UNKNOWN

TYPE OF WORK: NEW WELL

FLOWING WELL: No **RATE:**

GAS PRESENT: No OIL PRESENT: No

DATE OF ABANDONMENT:

MATERIAL USED:

PROPOSED USE: OBSERVATION

WELL COMPLETION DATA:

WELL FINISH: OPEN HOLE
TOTAL HOLE DEPTH: 983 Feet

CASING TYPE: UNKNOWN
SIZE OD: 5.50 Inch WALL THICKNESS: Inch
BOTTOM AT: 367 Feet

PERFORATED CASING/LINER:
TYPE:
SIZE OD: Inch
WALL THICKNESS: Inch
TOP AT: 0 Feet BOTTOM AT: Feet
PERFORATED FROM: Feet TO: Feet
Feet TO: Feet
Feet TO: Feet

SIZE OF PERFORATIONS: Inch X Inch
HOW PERFORATED:

SEAL TYPE:
INTERVAL TOP: 0 Feet TO: Feet

GEOPHYSICAL LOG TAKEN:
RETAINED ON FILE:

SCREEN:
MATERIAL:
SIZE ID (CLEAR): Inch SLOT SIZE: Inch
INTERVAL TOP: Feet TO: Feet
Feet TO: Feet

INSTALLATION METHOD:
TOP FITTINGS:
BOTTOM FITTINGS:

PACK TYPE:
GRAIN SIZE: AMOUNT:

PITLESS ADAPTER TYPE:
DROP PIPE TYPE: LENGTH: Feet
DIAMETER: Inch
ADDITIONAL PUMP INFORMATION:

PRODUCTION TEST:

TEST DATE: **START TIME:**

Elapsed Time in Min:Sec	Depth to Water Level During Pumping	Depth to Water Level During Recovery

WATER REMOVAL RATE DURING TEST: Gal/Min
TEST DURATION: Hours Minutes
TESTING METHOD:
DEPTH OF PUMP/DRILL STEM: Feet
WATER LEVEL AT END OF TEST: Feet
NON-PUMPING(STATIC) WATER LEVEL: FEET
TOTAL DRAWDOWN: Feet

RECOMMENDED PUMPING RATE: Gal/Min
RECOMMENDED PUMP INTAKE AT: Feet
TYPE OF PUMP INSTALLED:
MODEL: H.P.:

DATE WORK STARTED:

DATE WORK COMPLETED:

DATE DATA RECEIVED: August 17, 1972

COMMENTS: SEE FILE FOR DETIALED LOG. NB: WELL WAS DRILLED TO 983' AND PLUGGED BACK TO 750'

(Maximum of 9 lines printed)

ADDITIONAL TEST AND/OR PUMP DATA:

CHEMISTRIES TAKEN: N HELD: 5 DOCUMENTS HELD: 8

WELL OWNER'S ANTICIPATED WATER REQUIREMENTS PER DAY:

DATE FORM PRINTED: July 21, 1997 14:25:15 **DATE DATA KEYED:** August 6, 1996 DATA\GWICDATA\GIC4 DC

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL OBS-7

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source SHELL OBS-7 (SCL)

Date sampled August 17, 1972

Major Constituents

		Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})		1032	51.50	13.7
Magnesium (Mg^{++})		271	22.29	6.0
Sodium (Na^{+})				
Potassium (K^{+})	Na + K	6960	302.63	80.4
Carbonate ($CO_3^{=}$)		0	0	0
Bicarbonate (HCO_3^{-})		390	6.39	1.7
Sulfate ($SO_4^{=}$)		2944	61.32	16.3
Chloride (Cl^{-})		10947	308.71	82.0
Nitrate ($NO_3^{=}$)				
Silica (SiO_2)				
Hydroxide (OH^{-})				
Calcium (Acidified)				
Magnesium (Acidified)				
Total dissolved solids		22544 calculated		

Total Anions (epm) Total Cations (epm)

Other Constituents

Lab:

Conductivity	
pH	7.1
Fluoride (F^{-})	
H_2S	None

Field:

Temperature (C)

pH

Carbonate ($CO_3^{=}$)

Bicarbonate (HCO_3^{-})

Hydroxide (OH^{-})

Conductivity

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL OBS-7

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source Bailed

Date sampled July 16, 1976

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	5.5	0.27	4
Magnesium (Mg^{++})	2.3	0.19	3
Sodium (Na^{+})	158.0	6.87	92
Potassium (K^{+})	5.0	0.13	2
Carbonate ($CO_3^{=}$)	7.2	0.24	3
Bicarbonate (HCO_3^{-})	142.0	2.33	32
Sulfate ($SO_4^{=}$)	13.6	0.28	4
Chloride (Cl^{-})	160.0	4.51	61
Nitrate ($NO_3^{=}$)	0.3	0.00	0
Silica (SiO_2)	0.1		
Hydroxide (OH^{-})			
Calcium (Acidified)	5.4		
Magnesium (Acidified)	2.5		
Total dissolved solids	380		

Total Anions (epm) 7.37 Total Cations (epm) 7.46

Other Constituents

Lab:			Field:		
Conductivity	730		Temperature (C)	6.0	
pH	8.4		pH	9.0	
Fluoride (F^{-})	0.6	Mg/L	Carbonate ($CO_3^{=}$)	53	Mg/L
			Bicarbonate (HCO_3^{-})	68	Mg/L
			Hydroxide (OH^{-})		
			Conductivity		

1103

SHELL OBS-7-E-78

MULTIELEMENT ANALYSIS

OBSERVATION WELL NUMBER SHELL OBS-7

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Date sampled: July 16, 1976

Element	Value	Element	Value
Ag	<.002	Mn	<.001
Au	<.003	Mo	<.006
Al	<.002	Na	144
As	<.038	Ni	<.010
B	.334	P	<.110
Ba	<.200	Pb	<.088
Be	<.001	Se	<.060
Ca	7.30	Si	.40
Cd	<.002	Sn	<.045
Co	<.010	Sr	.130
Cr	<.006	Te	<.065
Cu	.008	Ti	<.0009
Eu	<.015	U	<.020
Fe	.033	V	<.0008
K	<.150	W	<.078
Mg	2.38	Zn	<.002

NOTES:

1. All values in milligrams per liter
2. Sample bailed from well
3. Analysis done by Multielement Radio Frequency Induction Coupled Plasma Emission Spectrometer at Barringer Research Ltd., Rexdale, Ontario.

1C03

SHELL OBS-7-F-78

WATER ANALYSIS

OBSERVATION WELL NUMBER SHELL OBS-7

Lsd 10 Sec 25 Twp 95 R 10 W4th

Alberta Research Council

Sample source Bailed

Date sampled July 8, 1977

Major Constituents

	Mg/L	Meq/L	Percent Cations or Anions
Calcium (Ca^{++})	8.8	0.44	2.5
Magnesium (Mg^{++})	8.6	0.71	4.0
Sodium (Na^{+})	378.0	15.44	92.0
Potassium (K^{+})	10.8	0.28	1.5
Carbonate ($CO_3^{=}$)	7.2	0.24	1.3
Bicarbonate (HCO_3^{-})	224.0	3.67	20.1
Sulfate ($SO_4^{=}$)	28.1	0.59	3.2
Chloride (Cl^{-})	488.0	13.76	75.3
Nitrate (NO_3^{-})	0.7	0.01	0.1
Silica (SiO_2)	0.4		
Hydroxide (OH^{-})			
Calcium (Acidified)	8.3		
Magnesium (Acidified)	8.5		
Total dissolved solids	1036.0		

Total Anions (epm) 18.27 Total Cations (epm) 17.87

Other Constituents

Lab:		Field:	
Conductivity	2000	Temperature (C)	7.0
pH	8.5	pH	
Fluoride (F^{-})	1.2 ppm	Carbonate ($CO_3^{=}$)	24.0 ppm
		Bicarbonate (HCO_3^{-})	195.0 ppm
		Hydroxide (OH^{-})	
		Conductivity	

/CO.

ALBERTA RESEARCH COUNCIL
WATER ANALYSIS REPORT

Mer 4 Tp 95 Rge 10 Sec 25 Lsd 10

			D M Y
Lab no.	78 246	Date sampled	08 07 78
Index no.	DH 646	Date submitted	17 07 78
Well depth(ft)	387.0	Date analysed(major)	8 8 78
Water level(ft)		Date analysed(minor)	
Top open interval(ft)		Sampled by	HACKBARTH
Bottom open interval(ft)		Sample Source	WELL
Altitude(ft)		Owners name	SHELLOBS-7
Bedrock elevation(ft)		Hardness(as CaCO3)	119.7
TDS(mg/l)	1742.0	Alkalinity(as CaCO3)	275.2
Field Cond(micromhos/cm)		Cond(micromhos/cm@25C)	3030
Field pH	8.4	Lab pH	7.8

MAJOR CONSTITUENTS

	mg/l	meq/l	% of total anion or cation
Calcium(Ca)	15.0	0.75	2.5
Magnesium(Mg)	20.0	1.65	5.5
Sodium(Na)	619.0	26.92	90.5
Potassium(K)	17.1	0.44	1.5
Carbonate(CO3)	0.0	0.00	0.0
Bicarbonate(HCO3)	344.0	5.64	17.7
Sulphate(SO4)	36.3	0.76	2.4
Chloride(Cl)	905.0	25.52	79.9
Nitrate(NO3)	1.7	0.03	0.1
Hydroxide(OH)			

Silica(SiO2)	1.2	Total anions(epm)	31.943
Calcium(Acid)	14.4	Total cations(epm)	29.757
Magnesium(Acid)	18.7	Ion balance error(%)	4.
Calculated TDS	1784.4	TDS balance error(%)	2.

MINOR CONSTITUENTS

Aluminum	0.04 ppm
Copper	0 ppb
Iodine	0.03 ppm
Iron	0 ppm
Lead	0 ppb
Manganese	0.03 ppm
Mercury	0.52 ppb

OTHER MEASUREMENTS

Field Temp(C)	6.00	Fluoride(F)	1.00 ppm
Field Carbonate(CO3)	14 ppm		
Field Bicarbonate(HCO3)	307 ppm		

/c 03

OBSERVATION WELL NUMBER: 64

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

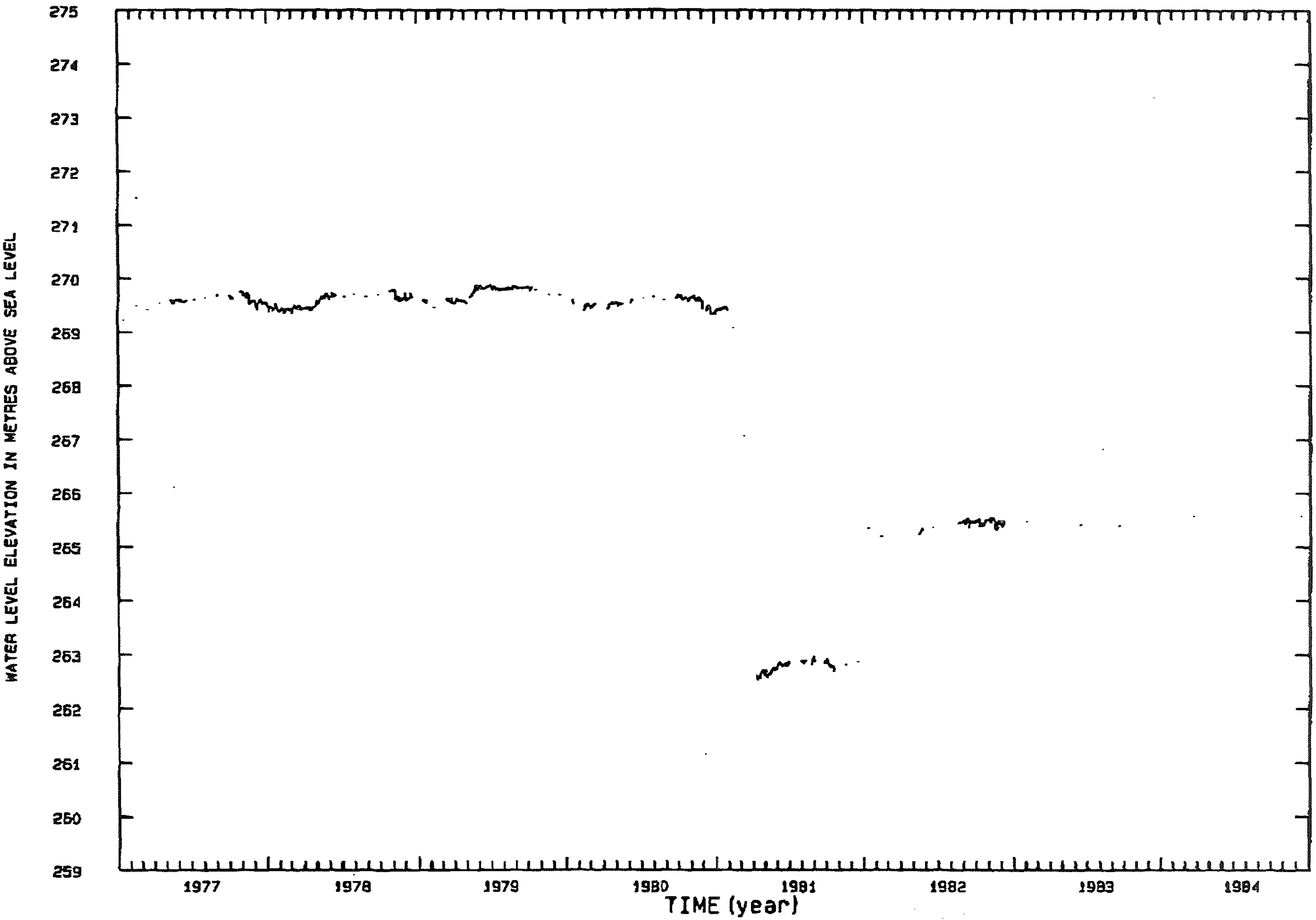
DATA START DATE: 77/ 3/ 1

NAME: FORT MCMURRAY SHELL-OBS-7-750

MEASURING ELEVATION: 290.48m

LOCATION: LSD 10 SEC 25 TWP 95 R 10 W 4TH

WELL COMPLETION: OPEN 112 - 229 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

OBSERVATION WELL NUMBER: 64

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

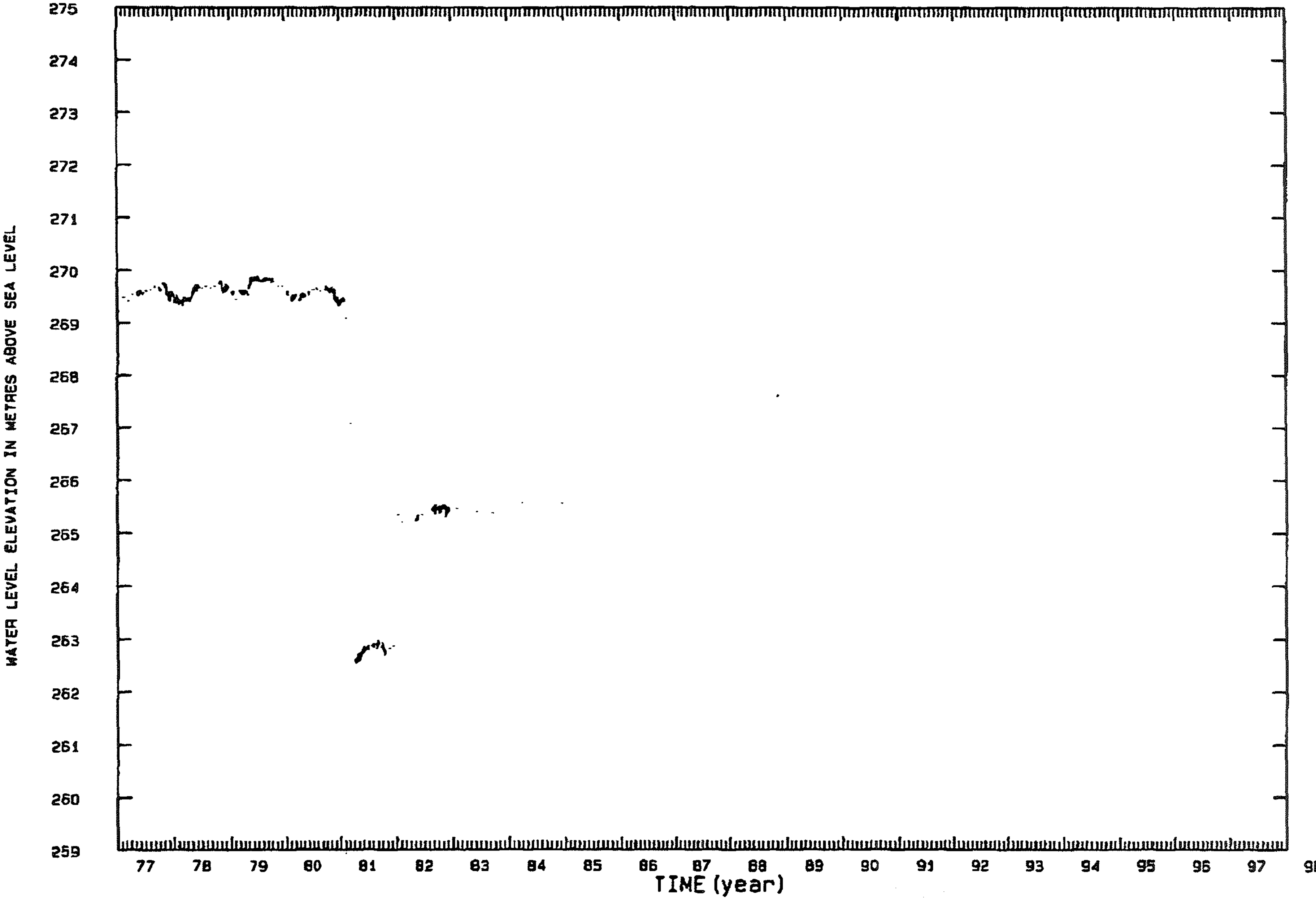
DATA START DATE: 77/ 1/ 1

NAME: FORT MCMURRAY SHELL-OBS-7-750

MEASURING ELEVATION: 290.48m

LOCATION: LSD 10 SEC 25 TWP 95 R 10 W 4TH

WELL COMPLETION: OPEN 112 - 229 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

ALBERTA ENVIRONMENTAL PROTECTION
COMPUTER GENERATED WATER WELL DRILLER'S REPORT FORM

WELL I.D. 233959

THIS DATA MAY NOT BE FULLY CHECKED; THE PROVINCE DISCLAIMS ALL RESPONSIBILITY FOR ITS ACCURACY:

CONTRACTOR:
NAME: UNKNOWN DRILLER
ADDRESS:
LICENCE NO.: JOURNEYMAN NO.:

WELL OWNER:
NAME: PETROFINA#73-2
ADDRESS:
POSTAL CODE:

WELL LOCATION: IC#: 02

¼ OR LSD	SEC	TWP	RGE	W. MER
01	01	096	11	W4

LOCATION VERIFICATION METHOD: FIELD
LOCATION IN QUARTER:
LOT: BLOCK: PLAN:
WELL ELEV: 942. Feet How obtain: ESTIMATED

FORMATION LOG DESCRIPTION:

Depth (Feet)	Lithology
Ground to:	
100	Overburdan
112	Unknown
171	Tarsand
178	Clay
193	Tarsand
207	Gray Clay
227	Tarsand
239	Gray Clay
259	Tarsand
275	Clay
278	Tarsand
282	Clay
308	Water Bearing Sand
314	Unknown
322	Water Bearing Sand
329	Unknown
337	Gray Clay
344	Water Bearing Sand
352	Gray Clay
359	Green Clay

DRILLING METHOD: UNKNOWN
TYPE OF WORK: NEW WELL
FLOWING WELL: No **RATE:**
GAS PRESENT: No OIL PRESENT: No
DATE OF ABANDONMENT:
MATERIAL USED:
PROPOSED USE: OBSERVATION

WELL COMPLETION DATA:

WELL FINISH: SCREEN & OPEN HOLE
TOTAL HOLE DEPTH: 359 Feet

CASING TYPE: UNKNOWN
SIZE OD: Inch WALL THICKNESS: Inch
BOTTOM AT: Feet
PERFORATED CASING/LINER:
TYPE:
SIZE OD: Inch
WALL THICKNESS: Inch
TOP AT: 0 Feet BOTTOM AT: Feet
PERFORATED FROM: Feet TO: Feet
Feet TO: Feet
Feet TO: Feet

SIZE OF PERFORATIONS: Inch X Inch
HOW PERFORATED:
SEAL TYPE:
INTERVAL TOP: 0 Feet TO: Feet
GEOPHYSICAL LOG TAKEN: GAMMA
RETAINED ON FILE: yes GAMMA
SCREEN:
MATERIAL: UNKNOWN
SIZE ID (CLEAR): Inch SLOT SIZE: Inch
INTERVAL TOP: Feet TO: Feet
Feet TO: Feet
INSTALLATION METHOD:
TOP FITTINGS:
BOTTOM FITTINGS:
PACK TYPE: NATURAL
GRAIN SIZE: AMOUNT:

PITLESS ADAPTER TYPE:
DROP PIPE TYPE: LENGTH: Feet
DIAMETER: Inch
ADDITIONAL PUMP INFORMATION:

PRODUCTION TEST:
TEST DATE: March 30, 1974 START TIME: 11:00

Elapsed Time in Min:Sec	Depth to Water Level During Pumping (Feet)	Depth to Water Level During Recovery (Feet)
3:00	172.42	
5:00	172.82	
7:00	173.02	
10:00	173.44	
12:00	173.67	
15:00	173.85	
20:00	174.21	
25:00	174.39	
30:00	174.67	
35:00	174.81	
40:00	174.93	
50:00	175.28	
60:00	175.56	
70:00	175.73	
80:00	176.01	
90:00	176.23	
104:00	176.34	
110:00	176.57	
120:00	176.74	
135:00	176.93	
150:00	177.13	
165:00	177.33	
180:00	177.43	
240:00	178.02	
270:00	178.25	
300:00	178.84	
330:00	179.00	
360:00	179.22	
395:00	179.50	
420:00	179.79	

WATER REMOVAL RATE DURING TEST: 33 Gal/Min
TEST DURATION: 24 Hours 0 Minutes
TESTING METHOD: PUMP
DEPTH OF PUMP/DRILL STEM: Feet
WATER LEVEL AT END OF TEST: 183.1 Feet
NON-PUMPING(STATIC) WATER LEVEL: 165.0 FEET
TOTAL DRAWDOWN: 18 Feet

RECOMMENDED PUMPING RATE: Gal/Min
RECOMMENDED PUMP INTAKE AT: Feet
TYPE OF PUMP INSTALLED:
MODEL: H.P.:

DATE WORK STARTED: January 26, 1974
DATE WORK COMPLETED: February 1, 1974
DATE DATA RECEIVED:
ADDITIONAL TEST AND/OR PUMP DATA:
CHEMISTRIES TAKEN: N HELD: 3 DOCUMENTS HELD: 14
WELL OWNER'S ANTICIPATED WATER REQUIREMENTS PER DAY:

COMMENTS:
(Maximum of 8 lines printed)

DATE FORM PRINTED: July 21, 1997 14:25:37 **DATE DATA KEYED:** March 4, 1994 DATA\GWICDATA\GIC4 MM

ALBERTA ENVIRONMENTAL PROTECTION

COMPUTER GENERATED WATER WELL DRILLER'S REPORT FORM

WELL I.D. 233959

THIS DATA MAY NOT BE FULLY CHECKED; THE PROVINCE DISCLAIMS ALL RESPONSIBILITY FOR ITS ACCURACY:

CONTRACTOR:

NAME: UNKNOWN DRILLER

ADDRESS:

LICENCE NO.: JOURNEYMAN NO.:

WELL OWNER:

NAME: PETROFINA#78-2

ADDRESS:

POSTAL CODE:

WELL LOCATION: IC#:

¼ OR LSD	SEC	TWP	RGE	W. MER
01	01	096	11	W4

LOCATION VERIFICATION METHOD:
LOCATION IN QUARTER:

LOT: BLOCK: PLAN:
WELL ELEV: Feet How obtain:

FORMATION LOG DESCRIPTION:

Depth (Feet):	Lithology:
Ground to:	

DRILLING METHOD:

TYPE OF WORK:

FLOWING WELL: **RATE:**
GAS PRESENT: OIL PRESENT:
DATE OF ABANDONMENT:
MATERIAL USED:
PROPOSED USE:

WELL COMPLETION DATA:

WELL FINISH:
TOTAL HOLE DEPTH: Feet

CASING TYPE:
SIZE OD: Inch WALL THICKNESS: Inch
BOTTOM AT: Feet

PERFORATED CASING/LINER:
TYPE:
SIZE OD: Inch
WALL THICKNESS: Inch
TOP AT: Feet BOTTOM AT: Feet
PERFORATED FROM: Feet TO: Feet
Feet TO: Feet
Feet TO: Feet

SIZE OF PERFORATIONS: Inch X Inch
HOW PERFORATED:

SEAL TYPE:
INTERVAL TOP: Feet TO: Feet

GEOPHYSICAL LOG TAKEN:
RETAINED ON FILE:

SCREEN:
MATERIAL:
SIZE ID (CLEAR): Inch SLOT SIZE: Inch
INTERVAL TOP: Feet TO: Feet
Feet TO: Feet

INSTALLATION METHOD:
TOP FITTINGS:
BOTTOM FITTINGS:

PACK TYPE:
GRAIN SIZE: AMOUNT:

PITLESS ADAPTER TYPE:
DROP PIPE TYPE: LENGTH: Feet
DIAMETER: Inch
ADDITIONAL PUMP INFORMATION:

PRODUCTION TEST:

TEST DATE: March 30, 1974 START TIME: 11:00

Elapsed Time In Min:Sec	Depth to Water Level During Pumping (Feet)	Depth to Water Level During Recovery (Feet)
480:00	180.00	
540:00	180.32	
600:00	180.57	
660:00	180.82	
720:00	181.16	
840:00	181.51	
960:00	181.72	
1080:00	182.60	
1200:00	182.68	
1320:00	183.13	

WATER REMOVAL RATE DURING TEST: 33 Gal/Min
TEST DURATION: 24 Hours 0 Minutes
TESTING METHOD: PUMP
DEPTH OF PUMP/DRILL STEM: Feet
WATER LEVEL AT END OF TEST: 183.1 Feet
NON-PUMPING(STATIC) WATER LEVEL: 165.0 FEET
TOTAL DRAWDOWN: 18 Feet

RECOMMENDED PUMPING RATE: Gal/Min
RECOMMENDED PUMP INTAKE AT: Feet
TYPE OF PUMP INSTALLED:
MODEL: H.P.:

DATE WORK STARTED:
DATE WORK COMPLETED:
DATE DATA RECEIVED:

COMMENTS:
(Maximum of 8 lines printed)

ADDITIONAL TEST AND/OR PUMP DATA:
CHEMISTRIES TAKEN: HELD: DOCUMENTS HELD:
WELL OWNER'S ANTICIPATED WATER REQUIREMENTS PER DAY:

DATE FORM PRINTED: **DATE DATA KEYED:**

255457

RESEARCH COUNCIL OF ALBERTA
WATER ANALYSIS REPORT

Mer 4 Tp 96 Rge 11 Sec 1 Lsd 1

			D	M	Y
Lab no.	T 1	Date sampled	30	3	74
		Date submitted	2	4	74
Field temp	4.0	Date analysed(major)	25	4	74
Field pH		Date analysed(minor)	1	4	75
Field Cond(micromhos/cm)	4000	Sampled by	HACKBARTH		
Field Bicarbonate(HCO3)		Sample Source	PUMPTEST 3.5 HR		

Well depth(ft)	330.0	TDS(ppm)	2506.0
Water level(ft)	165.0	Hardness(as CaCO3)	142.6
Top open interval	318.0	Alkalinity(as CaCO3)	1746.0
Bottom open interval	330.0	Cond(micromhos/cm@25C)	
Altitude		Lab pH	7.7
Bedrock elevation			
Owners name	PETROFINA 73-2 OIL Co LTD.		

MAJOR CONSTITUENTS

	ppm	epm	% of total anion or cation
Calcium(Ca)	30.8	1.54	3.3
Magnesium(Mg)	16.0	1.32	2.8
Sodium(Na)	981.0	42.66	91.9
Potassium(K)	36.0	0.92	2.0
Carbonate(CO3)	0.0	0.00	0.0
Bicarbonate(HCO3)	2130.8	34.92	74.4
Sulphate(SO4)	7.0	0.15	0.3
Chloride(Cl)	420.0	11.85	25.2
Nitrate(NO3)	0.5	0.01	0.0
Phosphate(P2O5)			
Silica(SiO2)			

Total anions(epm)	46.919
Total cations(epm)	46.431
Anions:Cations(epm)	0.005
TDS balance	1.318

MINOR CONSTITUENTS

	ppm		ppm
Aluminium(Al)	0.150	Iron Total(Fe)	0.340
Antimony(Sb)		Lithium(Li)	
Arsenic(As)		Lead(Pb)	0.00620
Barium(Ba)		Manganese(Mn)	0.150
Boron(B)		Mercury(Hg)	0.00008
Bromide(Br)		Nitrogen(N)	
Chromium hex.(Cr)		Selenium(Se)	
Cobalt(Co)		Strontium(Sr)	
Copper(Cu)	0.00290	Tin(Sn)	
Fluoride(F)	1.300	Vanadium(V)	
Hydroxide(OH)		Zinc(Zn)	
Iodide(I)	0.080		

IC.02

RESEARCH COUNCIL OF ALBERTA
WATER ANALYSIS REPORT

Mer 4 Tp 96 Rge 11 Sec 1 Lsd 1

			D	M	Y
Lab no.	T 2	Date sampled	31	3	74
		Date submitted	2	4	74
Field temp	3.8	Date analysed(major)	25	4	74
Field pH		Date analysed(minor)	1	4	75
Field Cond(micromhos/cm)	4000	Sampled by	HACKBARTH		
Field Bicarbonate(HCO3)		Sample Source	PUMPTEST 22 HR		

Well depth(ft)	330.0	TDS(ppm)	2424.0
Water level(ft)	165.0	Hardness(as CaCO3)	128.9
Top open interval	318.0	Alkalinity(as CaCO3)	1730.0
Bottom open interval	330.0	Cond(micromhos/cm@25C)	
Altitude		Lab pH	8.0
Bedrock elevation			
Owners name	PETROFINA 73-2		

MAJOR CONSTITUENTS

	ppm	epm	% of total anion or cation
Calcium(Ca)	26.3	1.31	3.0
Magnesium(Mg)	15.4	1.27	2.9
Sodium(Na)	931.0	40.48	92.0
Potassium(K)	36.0	0.92	2.1
Carbonate(CO3)	0.0	0.00	0.0
Bicarbonate(HCO3)	2111.3	34.60	75.6
Sulphate(SO4)	10.0	0.21	0.5
Chloride(Cl)	388.0	10.94	23.9
Nitrate(NO3)	0.7	0.01	0.0
Phosphate(P2O5)			
Silica(SiO2)			

Total anions(epm)	45.762
Total cations(epm)	43.983
Anions:Cations(epm)	0.020
TDS balance	0.088

MINOR CONSTITUENTS

	ppm		ppm
Aluminium(Al)	0.120	Iron Total(Fe)	0.150
Antimony(Sb)		Lithium(Li)	
Arsenic(As)		Lead(Pb)	0.00620
Barium(Ba)		Manganese(Mn)	0.150
Boron(B)		Mercury(Hg)	0.00010
Bromide(Br)		Nitrogen(N)	
Chromium hex.(Cr)		Selenium(Se)	
Cobalt(Co)		Strontium(Sr)	
Copper(Cu)	0.00650	Tin(Sn)	
Fluoride(F)	1.200	Vanadium(V)	
Hydroxide(OH)		Zinc(Zn)	
Iodide(I)	0.080		

233959

Ca++	Mg++	Na+	K+		SO4--	Cl-	NO3-	CO3-- CaCO3	CO3	HCO3- CaCO3	HCO3-		
20	12	23	39		48	35.5	31.	50	30	50	61		
30.8	16	981	36		7	420	2.5	0	0	1746			
1.5	1.3	42.7	.9	46.4	.1	11.8	.02	0	0	34.9		46.9	
[illegible]	2.9	[illegible]	2.0		.2	[illegible]	.04	0	0	74.4			%
4-96-11-1-1													
49.9	27.	631	33		16	500	.3	0	0	934			
2.5	2.3	27.4	.8	33.0	.3	14.1	.01	0	0	18.7		33.1	
7.6	[illegible]	[illegible]	2.6		1.0	[illegible]	.03	0	0	56.[illegible]			%
4-96-10-9-9													
[illegible]	[illegible]	1144	21		.41	784	1.3	0	0		1310		ICO2
1.0	1.0	49.7	.5	52.2	.41	22.1	.04	0	0	32.2		34.7	
1.9	1.9	[illegible]	1.0		.8	40.5	.08	0	0	[illegible]			%
4-96-9-32-4					.4	22.1	.04	0	0		26.4	49.0	
					.9	41.1	.07	0	0		53.[illegible]		%
.04		38.8	30		90	2	.8		48	0		0	
[illegible]	[illegible]	[illegible]	[illegible]	2.2	[illegible]	1	.02	1.0		[illegible]		[illegible]	

OBSERVATION WELL NUMBER: 72

NAME: FORT MCMURRAY FINA-73-2-330

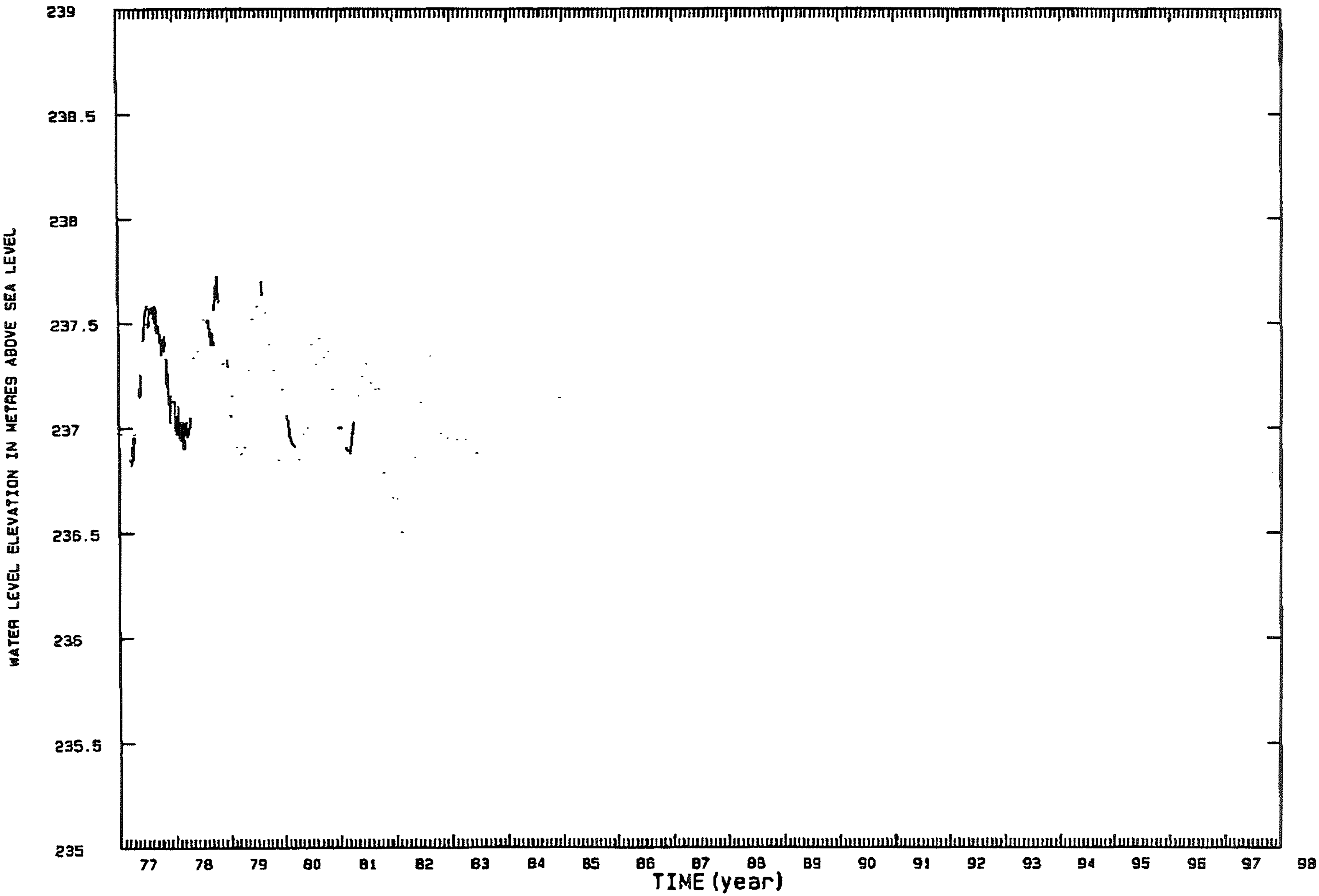
LOCATION: LSD 1 SEC 1 TWP 96 R 11 W 4TH

ALBERTA ENVIRONMENTAL PROTECTION
HYDROGRAPH

DATA START DATE: 77/ 1/ 1

MEASURING ELEVATION: 287.83m

WELL COMPLETION: SCREEN 97 - 101 m



PLOT DATE: 07-22-1997

DATA GAPS > 24 HOURS ARE NOT JOINED

1 DAYS AVERAGING

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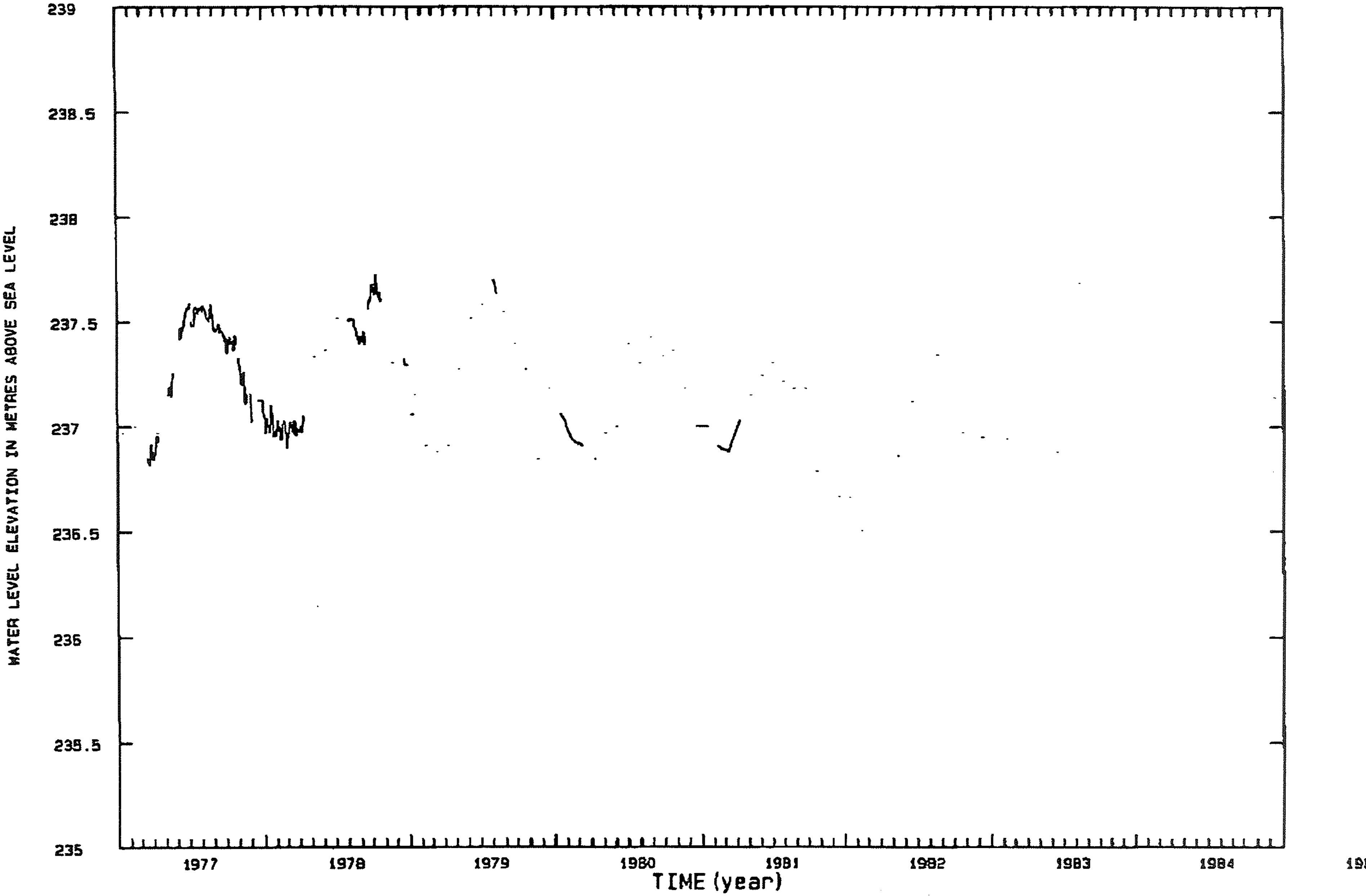

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