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INSTALLATION OF WELLS AND WATER SAMPLING AT THE ABANDONED MOUNT PLEASANT LANDFILL AND IMPERIAL OIL REFINERY SITES

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INSTALLATION OF WELLS AND WATER SAMPLING AT THE ABANDONED MOUNT PLEASANT LANDFILL AND PART OF IMPERIAL OIL REFINERY SITES

PART I. MOUNT PLEASANT AND PART OF IMPERIAL OIL REFINERY SITES

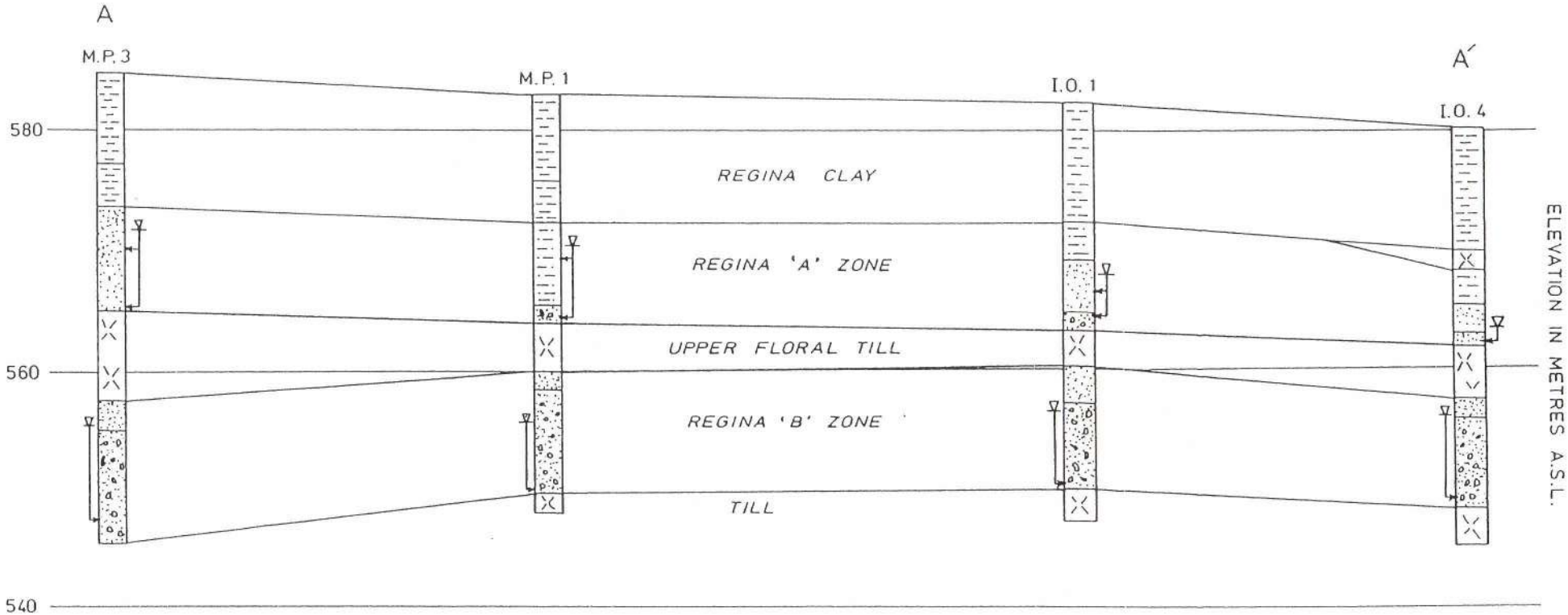
1.Ø Introduction

In November of 1983 Beckie Hydrogeologists Limited (BHL) submitted a proposal to L.D. Schnell, Director of Public Works and Engineering Department of the City of Regina for the installation and sampling of monitor wells for the abandoned Mount Pleasant (MP) landfill site and part of the old Imperial Oil (IO) refinery site. After several discussions with City personnel the Council authorized BHL to proceed with the study in December of 1984. The field program was begun in July of 1985 with the installation and sampling of the first set of monitor wells. Chemical water analyses results had to be evaluated before proceeding with additional monitor wells. Unexpected early winter weather prevented completion of the final phase of the field program in 1985 but warm weather in February allowed us to complete the field installation and sampling program early in 1986.

2.Ø Study Areas

The study area of this report covers two plots of land in the north-east part of the City of Regina. The part of the old Imperial Oil refinery site that was studied lies in a strip between Winnipeg Street and the CP rail line, and between 2nd Avenue North and 6th Avenue North. In this report the Imperial Oil site will refer to that part of the Imperial Oil refinery site studied for this report. The Mount Pleasant landfill site is situated approximately 15ØØ metres north of the Imperial Oil site adjacent to and on the west side of Winnipeg Street, north of the ring road. The area now forms the Mount Pleasant Park complex. See Figure 1 for location of the two sites investigated.

CITY OF REGINA
NORTH - SOUTH CROSS - SECTION A-A´
THROUGH MOUNT PLEASANT AND IMPERIAL OIL SITES



LEGEND

- CLAY
- SAND
- GRAVEL
- TILL

STATIC WATER LEVEL

SCREENED SECTION

NOTE: See figure 1 for location of cross - section

SCALES: Horizontal 1: 10,000
Vertical 1: 500

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FIGURE 3

thickness in the Regina area but averages about 8.5 m at both sites to a maximum of 11.9 m in two holes at the Mount Pleasant site. This stratigraphic unit is the most significant in this study because of its potential to store and act as a travel medium for contaminants. The IO site is suspected to be near the south boundary of the sand development in the Condie Moraine.

3.2.3.3.4 Surficial Stratified Drift

The Regina Clay is the surficial stratigraphic unit present in both areas investigated. It is a highly plastic, brown, mainly oxidized , and fractured clay. At the Imperial Oil site it averages about 10.7 m in thickness. At the Mount Pleasant site it averaged 9.2 m in thickness. A cross section of the Aquifer through both sites can be seen in Figure 3.

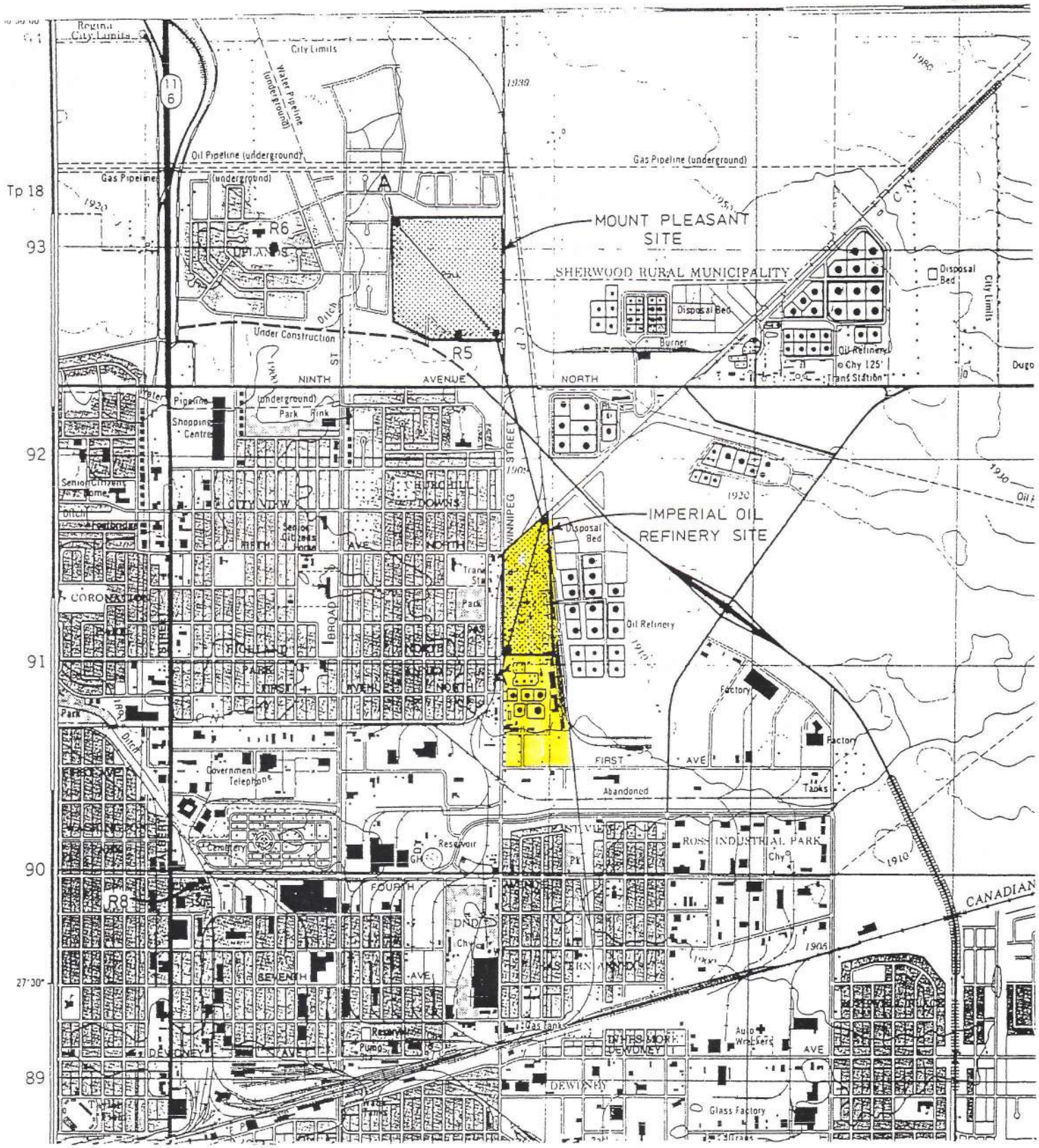
4.Ø Program Objectives

The objective of the program was to determine if leachate is entering the Regina A Zone Aquifer at the Mount Pleasant Landfill and Imperial Oil refining sites. The program proposed was a phased sequence involving the installation of thirty-two (32) monitor wells to check in the A Zone of the Regina Aquifer and eight (8) additional monitor wells to check in the B Zone of the Regina Aquifer. The monitor wells were installed to check the piezometric head and water quality in the A and B Zones of the Regina Aquifer.

5.Ø Field Program Completed

5.1 Installation of Regina B Zone Monitor Wells

The monitor well installation and sampling program which began in July of 1985 was conducted in three stages at both sites. The first stage involved utilization of a conventional rotary drill rig to drill and E-log a testhole into the B Zone of the Regina Aquifer and install a monitor well near the bottom of the saturated section. The testhole was to determine stratigraphy, identify the base of the A Zone Aquifer, and determine the thickness of the separating glacial till layer. This information was used to determine the depths of subsequent A Zone Aquifer monitor wells. Difficult drilling conditions in coarse gravel prevented penetration of the B Zone at all sites but the main objective .. to get a sample of water near the bottom of and



SCALE 1: 25,000

0 500 1000 metres

CITY OF REGINA

DIAGRAM SHOWING LOCATIONS

OF MOUNT PLEASANT AND IMPERIAL OIL

MONITOR SITES AND CROSS-SECTION A-A'

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FIGURE 1

3.Ø Physical Environment

3.1 Climate

The climate of the study area can be summarized as follows: Average annual precipitation is 4Ø3 mm with 3Ø % as snow and 7Ø % as rain. Extreme temperatures vary from -5Ø C in winter to 43.3 C in the summer. Prevailing winds are west to north-west and east to south-east and calm condiions exist only 2.8 % of the time.

3.2 Geology

3.2.1 Introduction

The geological setting of the study areas is similar and has been previously discussed and demonstrated by the Saskatchewan Research Council (SRC) with maps and cross sections by Christiansen (1961, 1971, 1979), Meneley and Christiansen (1975), and G. van der Kamp and H. Maathuis (1985). Lissey (1962) prepared a detailed report for the City of Regina.

This report is based on the geological framework of the Regina area as described by Christiansen (1979) and modified by van der Kamp and Maathuis (1985).

3.2.2 Bedrock Stratigraphy

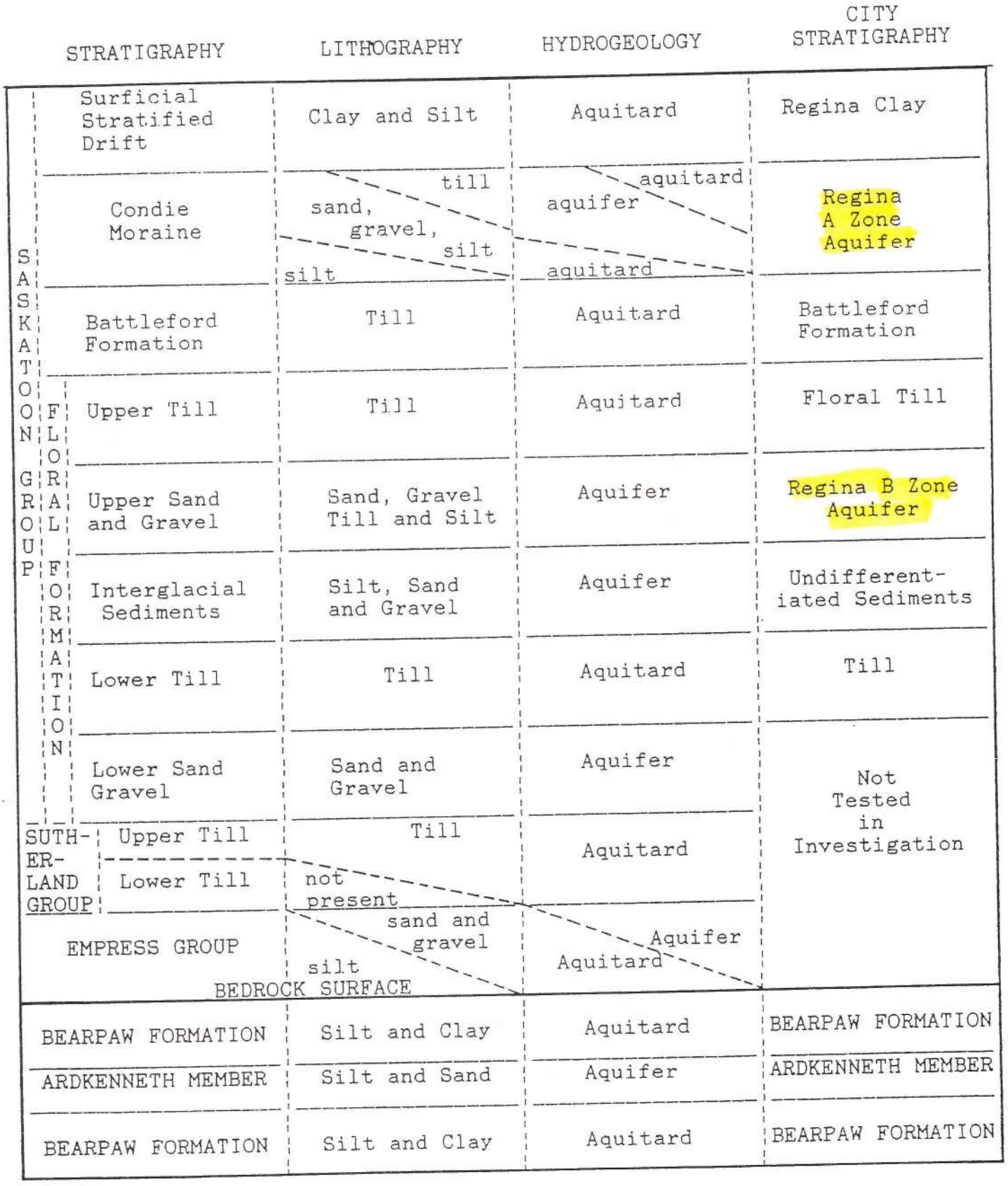
The Bearpaw Formation of the Cretaceous Period, forms the bedrock surface in the study area. This Formation consists of grey, marine, non-calcareous silts and clays, which could be up to 24Ø metres thick. Locally the Bearpaw may include the Ardkenneth Member, a sand interbed.

3.2.3 Quaternary Stratigraphy

In the study area this includes the Empress Group, Sutherland Group and Saskatoon Group as can be noted on Figure 2 showing the stratigraphic units comparing the nomenclature used by the City of Regina and that of the Saskatchewan Research Council.

3.2.3.1 Empress Group

The Empress Group is composed of sand, gravel, silt, and clay of fluvial, lacustrine, and colluvial origin. This unit was not encountered in any testholes drilled on the project but was encountered in the nearby New Grade study area. The unit lies between overlying till of Quaternary age and the underlying Cretaceous marine sediments.



Schematic geological and hydrogeological setting of the Regina area. (Stratigraphy after Christiansen, 1979a)

Figure 2

3.2.3.2 Sutherland Group

In the study area Christiansen (1979) has shown this unit, consists of Ø to 64 metres of dense glacial till with minor amounts of stratified drift. All of the testholes for this program were terminated above this unit.

3.2.3.3 Saskatoon Group

This unit consists of the Floral and Battleford Formations in ascending order.

3.2.3.3.1 Floral Formation

The deepest stratigraphic unit encountered with our exploratory holes was the Lower Floral till which is an unoxidized till. This till ranges from 7 to 22 m in thickness in the Regina area.

Immediately overlying the Lower till the Upper Floral sands and gravels (called the Regina B Zone Aquifer in this report) were encountered. These oxidized sands and gravels are very extensive and vary from 32 m to as little as 1Ø m at some of the Imperial Oil sites. The City of Regina and the Consumers' Co-Operative Refineries Ltd. (CCRL) have wells developed in this aquifer zone.

The glacial till over the Floral sands and gravels is classified as the Upper Floral till and can be from 3 to 22 m thick in the Regina area. The Imperial Oil site had from 3 m to 4.3 m of the grey, hard, unoxidized till (See Maps 8 and 9 at back of report.). This till unit and the overlying Battleford till are the barriers slowing movement of contaminants into the Upper Floral or B Zone of the Regina Aquifer. Contours on the surface of this till unit can be seen on Maps 6 and 7.

3.2.3.3.2 Battleford Formation

Overlying the Upper Floral sands and gravels and/or the Upper Floral till is the Battleford Formation till and stratified till. We were not able to positively distinguish the Battleford Formation from the upper Floral till so it is included in the thickness of till over the Floral sands and gravels.

3.2.3.3.3 Condie Moraine

This unit, also known as the Regina A Zone Aquifer, consists of silt, sand, gravel, and limited glacial till. The thin overlying till stratum is thought to be from the Battleford Formation. This aquifer (Regina A Zone Aquifer) is up to 43 m in

the water level from the Regina B Zone Aquifer .. was accomplished. The geologic logs of the deepest testholes at each of the Imperial Oil and Mount Pleasant sites are included as Appendix B of this report. Annotated E-logs of the first four (4) testholes at each site are also included in Appendix B.

5.2 Monitor Well Construction Details

The monitor wells were constructed of 51 mm ID schedule 40 PVC pipe with a slotted PVC screen. The screens were covered with frac sand and capped with bentonite pellets in the B Zone. The Regina Aquifer B Zone monitor wells were then cement grout sealed into the glacial till (Upper Floral till) separating the A and B Zone Aquifers. The A Zone monitor wells were backfilled with clay cuttings to form a surface seal. The deep monitor wells were developed by airlifting and surging until a clean sample of water was returned. When conductivity of sucessive samples of the discharged water remained constant, development was stopped.

The tops of casings were cut off below ground level and enclosed in boxes at all of the Mount Pleasant sites to minimize the chance of vandalism. Before we are able to protect them, deep monitor MP-3B was filled with rocks and is not serviceable. The Imperial Oil site monitors all have threaded caps and extend about 0.5 to 0.9 metres above ground as can be seen on the construction diagram in Appendix C.

5.3 Installation of A Zone Monitor Wells

On August 19, 1985 the second stage of monitor well installations was begun. This stage consisted of the installation of fifteen (15) monitor wells into the A Zone Aquifer. There were eight (8) monitor wells installed at Mount Pleasant and seven (7) at the Imperial Oil site. These monitors were installed at the base and near the top of the saturated A Zone Aquifer with the objective of sampling water for detection of a leachate plume. The second objective was to measure the piezometric surface so the direction of groundwater flow could be determined as well as the positions of final monitor wells. The monitor wells for this stage were installed with a hollow stem auger and developed with a bailer until clean water was produced. No water was used with the hollow stem auger so the water produced had no mixing with other waters.

On February 4, 1986 the third and final stage of monitor well installations was started. In this phase a total of thirteen (13) additional shallow (A Zone) monitor wells were installed, eight (8) at Mount Pleasant and five (5) at the Imperial Oil site. The location for these final

sets of monitor wells was selected to be in the area where earlier evidence of flow direction, water quality, and stratigraphy suggested the location of a leachate plume. The objective was to again install nests of two monitors near the top and at the base of the saturated A Zone Aquifer section. The B Zone monitor wells were installed in July of 1985 so that from these testholes the base of the A Zone Aquifer could be determined. This allowed us to place the first shallow monitor at the base of the A Zone Aquifer. At three (3) of the four (4) Imperial Oil sites the saturated section of the A Zone Aquifer was so thin that one monitor well screen effectively monitored the top and the bottom of the aquifer.

5.4 Sampling of Monitor Wells

5.4.1 Sampling of A Zone Monitor Wells

All A Zone monitor wells were installed utilizing the hollow stem auger method which does not require the use of water in the installation process. Samples were collected as soon as the water bailed out of the monitor well was reasonably clean and free from mud and silt. The PVC bailer used for developing and sampling was cleaned thoroughly with distilled water prior to bailing at each monitor well and prior to collecting a sample for analyses.

Samples collected to analyze for the various parameters where treated as follows:

1) Major Ions and Physical Tests - Samples were bailed and put into 1 litre PVC containers without any preservatives or filtering. Samples were delivered to the Provincial Laboratory on the day of collection.

2) Phenols - Samples were bailed and put into 1 litre glass jars. The unfiltered samples were preserved with 5 mls of H_3PO_4 and 1 gm of $CuSO_4$. Samples were delivered to the Provincial Laboratory at a prearranged date so that the samples where analyzed within 2 days of sampling.

3) Pollution Group Analyses - A 4 litre sample was bailed, and placed unfiltered and unpreserved into a PVC container. The sample was delivered to the Provincial Laboratory on the same day as collected.

4) Heavy and Trace Metals Analyses - Samples were bailed and then filtered through 45 µm, millipore filters. All samples requiring filtering where filtered through this filter paper. The samples were contained in 1 litre PVC containers with 1Ø mls of HNO3 as a preservative. Samples were sent by courier service to the Saskatchewan Research Council within 3 days of collection.

5.4.1.5 Mercury - Samples were bailed and placed filtered in 25Ø ml glass jars using 1 ml of 5% K2Cr2O4 and 1 ml of HNO3. The samples were sent by Courier to the Saskatchewan Research Council within three days of collection. Samples from IO-6AL and IO-8AL were submitted unfiltered to the laboratory (See A-2 for results.).

5.4.1.6 Sulphide - Samples were bailed and placed filtered in 25Ø ml glass containers. The samples were preserved with NaOH pellets so that pH was greater than 13, and one (1) gm of ascorbic acid. The samples were delivred to the Saskatchewan Research Council within 3 days of collection. Samples from IO-6AL and IO-8AL were not filtered (See A-4 for results.).

5.4.1.7 Oil, Gasoline and Diesel Analyses - One litre samples were bailed and delivered in glass containers to the Public Health Laboratory on the same day as collected.

5.4.2 Sampling of B Zone Monitor Wells

All B Zone monitor wells were installed using a conventional rotary drilling rig which requires the use of water to bring up cuttings and bentonite drilling mud to keep the hole open. To minimize the chance of contamination the drilling mud was changed after penetration of the A Zone Aquifer. After the casing and screen assembly were in the hole they were backwashed with clean water. Completions were as shown on pages C-5 and C-9. Development was accomplished by air lift pumping. Discharge water was checked with a conductivity cell so that when water quality and temperature stabilized the water was considered to be representive of formation water. A sampling procedure utilizing a bailer was the same as for the A Zone aquifer. The major ions did not show any unsual constituents nor was any odor detectable so no further sampling of the B Zone monitors was undertaken.

PART II. MOUNT PLEASANT SITE

6.0 Groundwater System

The groundwater system will be briefly described in terms of aquifers, lateral groundwater flow velocity in aquifers, vertical flow velocity through aquitards and groundwater quality. More detailed consideration will be given to the Regina A Zone Aquifer which shows evidence of contamination. The regional groundwater system is adapted from van der Kamp and Maathuis (1985) (SRC Technical Report 175).

6.1 Aquifers

6.1.1 Regina B Zone Aquifer

The Regina B Zone Aquifer is very extensive with an area of about 600 square km (See Map 2 of the SRC ,1985 report). The City of Regina water wells are mainly located in the B Zone of the Regina Aquifer. This Aquifer, estimated to have 80,000 hectares of recharge area (Schneider, 1978), consists of high permeability sands and gravels and underlies this site. The SRC (1985) report indicates a hydraulic discontinuity exists in Range 19, Township 17 and 18 so all of the recharge area is not available to this site. The average transmissivity of the aquifer is 1.2 x 10E-2 m /sec (1040m /day) according to the SRC 1985 report. The thickness of the B Zone Aquifer strata in the Mount Pleasant area varied from 10.4 to 18.0 m.

The SRC 1985 report suggests the piezometric surface is "virtually flat" (See Map 4) in the study area west of the hydraulic discontinuity, except for variations of only one to two metres around local cones of depression. Direction of groundwater flow is towards pumping centers, i.e. City and CCRL wells. In the Mount Pleasant area recharge reaches the site radially by horizontal movement in the direction of pumping centres and we believe also slowly comes from the overlying Regina A Zone Aquifer (Condie Aquifer).

The SRC (1985) report suggests that rate of movement of groundwater vertically through the overlying upper Floral till and Battleford Formation is 6 to 12 cm per year assuming an effective porosity of 0.25. They further suggest water movement from the Regina A Zone Aquifer to the B Zone Aquifer may require only a few years to occur. Clifton (1985, Vol III, page 19) has indicated groundwater flow velocity in unfractured till is 15 cm/year and in

fractured till up to 200 cm/year. Laboratory tests of till samples suggest that velocities could be as low as 0.12 cm/year but we believe this is unrealistic. The high velocities have not been confirmed by the presence of leachate in water samples taken to date but demonstrate caution must be exercised.

Total dissolved solids (TDS) in the B Zone Aquifer varies as a whole from 550 to 1600 mg/L but in the Mount Pleasant area TDS varies from 1289 to 1553 mg/L.

Groundwater discharge from the aquifer is from City municipal wells and from industrial wells, most notably the CCRL and earlier the Imperial Oil refinery wells. Natural discharge from the Regina Aquifer was from springs along Wascana Creek just west of the City before pumping of wells had occured.

Calculations of rate of groundwater movement in the B Zone Aquifer are not meaningful with the data available because of a distorted water table surface due to pumping from the wells.

6.1.2 Regina A Zone Aquifer

The Regina A Zone Aquifer overlies the B Zone Aquifer at the Mount Pleasant site. Regionally the A Zone Aquifer covers about 400 km2 and overlies part of the B Zone Aquifer, SRC (1985).

The New Grade Energy (1985) Environmental Impact Statement indicates hydraulic conductivity in the A Zone Aquifer at the nearby CCRL area ranges from 1.4 x 10E-4 to 8 x 10E-3 cm/sec based on piezometer slug tests. The thickness of the A Zone Aquifer at this site varies from 7.9 to 8.8 m. The piezometric surface slopes to the south-west .. the direction of groundwater flow (See Map 1).

Recharge to the A Zone Aquifer occurs in the form of direct precipitation and percolation through the overlying Regina Clay in this area. In the Pilot Butte area there is strong recharge into the surficial gravels but some of this water discharges into surface creeks and springs such as Mallory Springs and some flows laterally to the general area of the City of Regina.

Discharge from the A Zone Aquifer was formerly by discharge into the B Zone Aquifer and springs into the Boggy and Wascana Creeks. Presently discharge from the aquifer is from wells at Boggy Creek and in the City and downward through a glacial till layer into the B Zone Aquifer. No quantitative tests were made to determine discharge into the B Zone Aquifer as it was not within the scope of the study. Determination of truly representative vertical permeablilty is difficult to make reliably even with extensive testing.

The thin section of till requires precise instrumentation and possible presence of fractures in the till makes the location of instrumentation critical unless many monitor wells are installed and tested.

6.2 Groundwater Flow Velocity

6.2.1 Expected Lateral Flow Velocity

Expected rate of groundwater movement in the A Zone Aquifer is dependent on hydraulic gradient and aquifer permeability. The hydraulic gradient at the Mount Pleasant site is about 7.9 m/km in a north-east to south-west direction (See Map 1).

These values we believe are quite indicative but we do not have any piezometers under the landfill. The landfill likely causes a local mound on the water table.

Using the value of hydraulic conductivity determined by Clifton (1985) and the above gradient one can calculate average lateral linear velocity using the following formula:

$$\text{Average linear velocity} = V = \frac{ki}{n}$$

Where K = hydraulic conductivity in cm/sec
= 1.4 x 10E-4 to 8.0 x 10E-3 cm/sec

i = hydraulic gradient
= 0.0079

n = intergranular porosity ≈ 30 %

Site MP-1:
$$V = \frac{1.4 \times 10E\text{-}4 \times 0.0079}{0.3}$$

= 3.68 x 10E-6 cm/sec
= 1.16 m/year

Site MP-2:
$$V = \frac{8 \times 10E\text{-}3 \times 0.0079}{0.3}$$

= 2.11 x 10E-4 cm/sec
= 66.5 m/year

The above lateral flow velocity calculations give an indication of possible rate of movement of groundwater and

contaminants in the groundwater. The hydraulic conductivities will vary with texture of the aquifer so the velocity will vary somewhat throughout the aquifer. Similarily, flow directions are likely to be more complex than shown on Map 1.

6.3 Aquitards

6.3.1 Expected Range of Vertical Flow Velocity Through Battleford - Condie Till

In estimating vertical flow velocity the most difficult parameter to identify is vertical hydraulic conductivity. Another parameter difficult to identify is the presence of and increase of hydraulic conductivity due to fracturing of glacial tills. Clifton (1985) conducted 3 insitu tests on piezometers at the nearby CCRL site, values of hydraulic conductivity varied from 1.9 x 10E-7 to 1.1 x 10E-8 cm/sec. These values would appear to indicate a fractured till at CCRL rather than intergranular porosity of nonfractured till. Without further testing we do not know if fractured tills exist at this site. An examination of isopach Map 8 shows the gradual thinning from north to south of this till section separating the A and B Zone Aquifers. The B Zone Aquifer has watertable conditions so downward vertical movement of groundwater is by gravity flow from the A Zone Aquifer. The head conditions vary from one place to the next in the aquifer so this also influences velocity of groundwater movement. The formula for calculating average linear velocity of groundwater (Vv) downward through the till layer is the same as for lateral movement except the hydraulic gradient is across the till section:

$$Vv = \frac{ki}{n}$$

$$\text{Vv at site MP-1} = \frac{1.9 \times 10E\text{-}7 \times 1.75}{0.2}$$

$$= 1.66 \times 10E\text{-}6 \text{ cm/sec}$$
$$= 0.52 \text{ m/year}$$

$$\text{Where } i = \frac{6.93}{3.96} = 1.75$$

$$\text{Vv at site MP-4} = \frac{1.9 \times 10E\text{-}7 \times 1.13}{0.2}$$

$$= 1.07 \times 10E\text{-}6 \text{ cm/sec}$$
$$= 0.34 \text{ m/year}$$

$$\text{Where } i = \frac{7.94}{7.01} = 1.13$$

$$\text{Vv at site MP-2} = \frac{1.9 \times 10E\text{-}7 \times 1.04}{0.2}$$

$$= 9.88 \times 10E\text{-}7 \text{ cm/sec}$$
$$= 0.31 \text{ m/year}$$

$$\text{Where } i = \frac{5.40}{5.18} = 1.04$$

These calculated rates of velocity suggest that water will travel through the separating till layer in a period of from 7.6 to 20.6 years using the highest value for hydraulic conductivity. In areas where the lower value of hydraulic conductivity applies it would take in the order of 17 times longer for water to percolate through the till layer i.e. 131 years to 358 years respectively. These latter values probably represent time required to percolate through nonfractured till.

6.4 Groundwater Quality

6.4.1 Water Quality - Regina A Zone Aquifer

6.4.1.1 Major Ion and Physical Tests

At the Mount Pleasant site there is definite evidence of leachate in monitor wells 2, 5, 7, and 8. Total dissolved solids in monitor MP-3AL is 570 mg/L (out of the plume) whereas MP-7AU is at 1648 mg/L. Similarily sulphates, total hardness and calcium show evidence of a leachate plume (Map 1). Major ion and physical tests can be noted in Appendix A. Location of the leachate plume at Mount Pleasant is in conformity with the south-west trending groundwater flow direction. At the Mount Pleasant site the leachate plume increases

major ions and physical parameters of the groundwater. Even though generally the analyses have not increased to toxic levels there is markedly reduced quality of water in the A Zone Aquifer. The phenol content in particular is offensive but one sample from MP-8AL is not conclusive . See Figure 4 for a Piper diagram of the major ions. The upper trilinear plot shows the influence of leachate by the spread between analyses in the anion triangle where MP-7AU is in the plume and MP-3AL is out of the plume so not influenced by leachate.

6.4.1.2 Pollution Group Analysis

The pollution group analysis confirms the presence of a leachate plume at the Mount Pleasant site.

At the Mount Pleasant site in the landfill generated plume area there are high levels of total phosphate at 10 mg/L. Kjeldahl nitrogen at 6 mg/L and sulfide of 2.8 mg/L, all at the MP-2AL site are much above background levels. Ammonia is also high in a number of the MP monitor wells. The total coliform noted in monitor 4AL at 23000/100 ml and the high volatile suspended solids in monitor well MP-7AL at 60333 mg/L appear anomalous so could be rechecked on later samplings.

6.4.1.3 Trace Constituents and Heavy Metal Analyses

The sulfide content at the Mount Pleasant site in monitors MP-2AL, MP-3AL, and MP-4AL again confirm the presence of leachate.

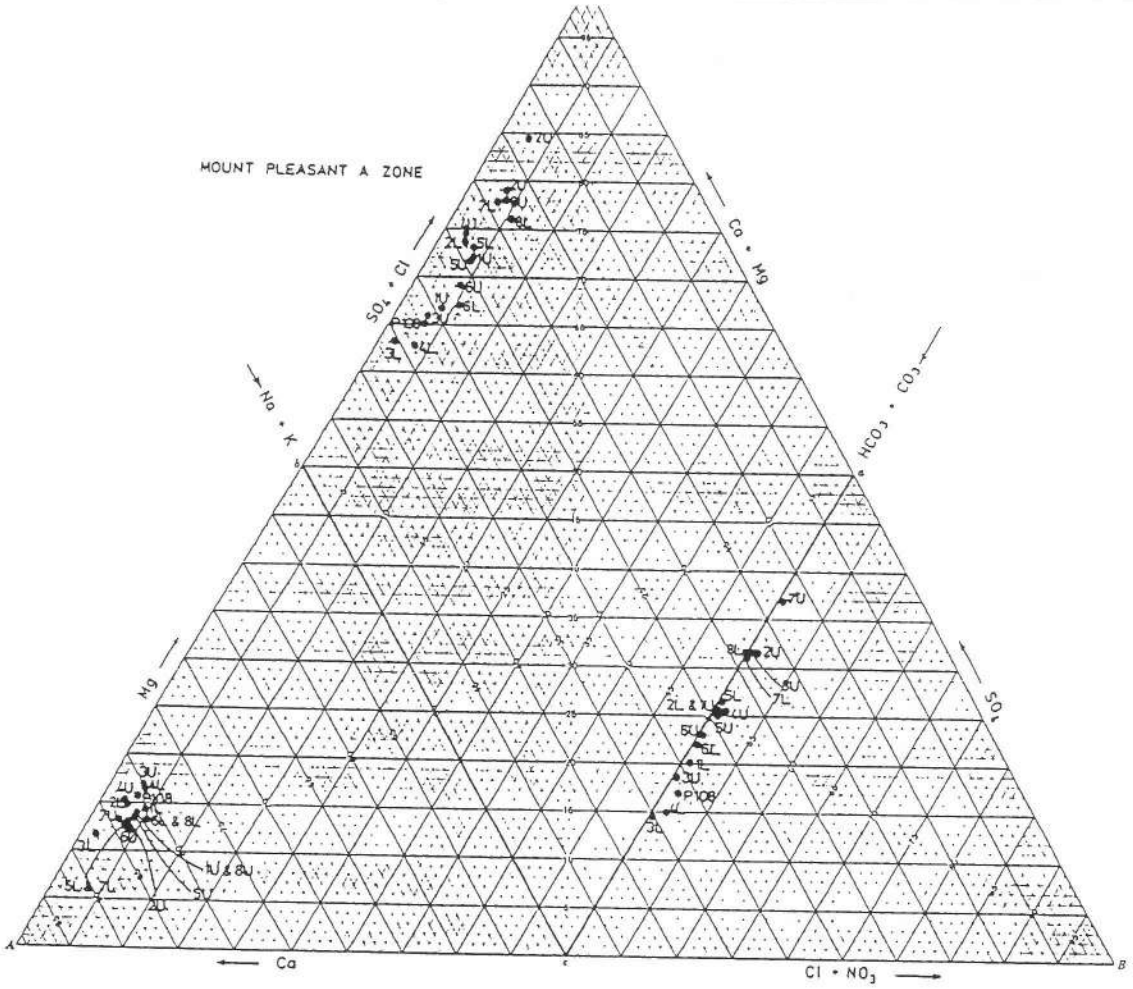
6.4.2 Water Quality - Regina B Zone Aquifer

6.4.2.1 Major Ion and Physical Tests

On the basis of samples collected and analysed for major ion and physical tests there was no evidence that any leachate was present.

7.0 Evidence of Leachate Plume

To determine if a leachate plume exists, water quality and piezometric data from the Mount Pleasant, Imperial Oil refinery, and CCRL sites were compared. By using the New Grade water quality information and maps it was possible to compare the water quality out of the zone of influence of any contaminant plumes i.e. monitors 108, 301, 305, 306, and 310. This information has been used to make a map showing possible extent of plumes using a regional picture (See Map 10). A general guide used in making this diagram was the estimated rates of lateral flow from MP and



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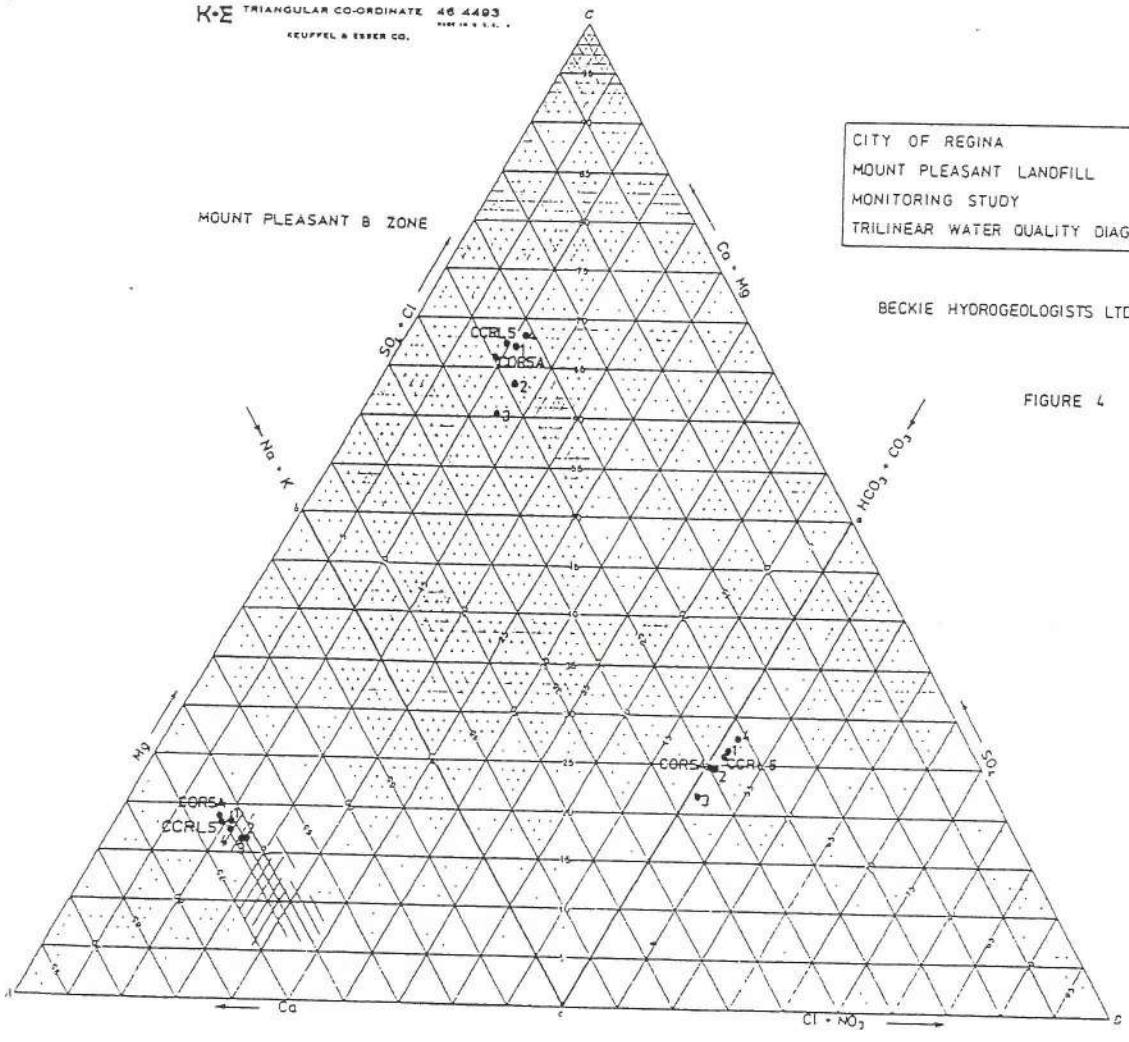

CITY OF REGINA
MOUNT PLEASANT LANDFILL
MONITORING STUDY
TRILINEAR WATER QUALITY DIAGRAM

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FIGURE 4

IO sites. Total dissolved solids of water from monitor wells out of the plumes varied from 57Ø to 85Ø mg/L.

Map 1 shows the known extent of the leachate plume at the Mount Pleasant site using the total dissolved solids parameter. The plumes extend past site boundaries but we are uncertain of the size since aquifer permeability and continuity are not known off the site.

The leachate plume shows some effects of dispersion perpendicular to direction of groundwater flow but the most concentrated area of the plume is downstream in the direction of groundwater flow from the source of contamination.

8.Ø Significance of Leachate Plume

The leachate plume is significant in that the water quality is much poorer in quality than naturally occurs in the A Zone Aquifer. The A Zone Aquifer which has intercepted the leachate acts as a source of recharge to the B Zone Aquifer. The testholes have shown that the glacial till that separates the A and B zones varies from 7 m thick at the south end to as thin as 4.Ø m thick at the south end of the Mount Pleasant site (See Map 8).

9.Ø CONCLUSIONS

1. A monitor well system has been installed into the Regina Aquifer A and B Zones at the Mount Pleasant abandoned landfill site. These monitor wells will allow a continued monitoring of water qualities and the piezometric surface at these locations.

2. The water analyses show the presence of leachate in the A Zone Aquifer. The leachate follows the direction of groundwater flow with the most concentrated leachate being immediately downstream from the presumed source.

3. There is no evidence of leachate in the B Zone Aquifer utilized by City wells.

4. Theoretical calculations, utilizing hydraulic coefficients from the CCRL sites, suggest the plume can advance laterally at rates of 1 to 66 m/year. Vertical percolation of groundwater through the underlying Upper Floral Formation till may be occuring at an estimated rate of Ø.Ø69 to Ø.52 m/year.

5. The leachate plumes extend an undetermined distance beyond the boundaries of the sites investigated. Distance travelled will depend on permeability, continuity and piezometric gradient off the site.

6. The effect on water quality in the leachate plumes has been to increase total mineral content of the water. Total solids of water in the A Zone Aquifer out of the influence of the plume is in the order of 570 to 850 mg/L and in the plumes varies from about 885 to 1648 mg/L.

10.0 RECOMMENDATIONS

1. A program should be initiated to periodically check water samples from the nearby City well in Mount Pleasant Park for phenols, sulphides, and nitrogen derivatives. In addition a request should be made to CCRL for recent analyses of water from all their production wells. These analyses should include tests for phenols and petroleum products.

2. Several more monitor wells should be installed into the B Zone Aquifer between well R5 and the leachate plume and another on the south side of the production well. Samples of water from these wells could be used to determine if contaminants are moving toward well R5. Monitor well M3B, which was vandalized, should be replaced at the same time as these recommended monitor wells are installed.

3. Slug tests should be run on the existing monitor wells and many future monitor wells if it is desired to obtain a more accurate assessment of lateral groundwater flow.

4. A program of further investigations should be undertaken to determine the extent and concentration of the leachate plume by installing additional monitor wells in the area outlined as possible extent of the plume.

5. A well or several wells could be installed into the A Zone Aquifer in the area of MP-2 and MP-7 to intercept the most concentrated leachate from the Mount Pleasant landfill site. The relatively small amount of water produced could be pumped into the sewer or used to irrigate the grass at the site in the summer. In winter months the water could be pumped into the sanitary or storm sewer system.

PART III IMPERIAL OIL SITE

11.0 Groundwater System

11.1 Aquifers

11.1.1 Regina B Zone Aquifer

The Regina B Zone Aquifer is about 600 square km as noted in 6.1.1 of this report. The part of the Imperial Oil site investigated in this study is underlain by the Regina B Zone Aquifer. When in operation Imperial Oil Refinery utilized several pump wells, located in the B Zone Aquifer in the area investigated.

Total dissolved solids (TDS) in the B Zone Aquifer varies as a whole from 550 to 1600 mg/L but in the part of the Imperial Oil site investigated TDS varies from 1319 to 1600 mg/L. A sample from IO-1B showed TDS of 777 mg/L. We don't believe this is representative and are not considering it for comparison purposes.

Calculations of rate of groundwater movement in the B Zone Aquifer are not meaningful with the data available because of a distorted water table surface due to pumping from the City and CCRL wells.

11.1.2 Regina A Zone Aquifer

The Regina A Zone Aquifer or Condie Aquifer underlies the part of the Imperial Oil Refinery site investigated and overlies the "B" Zone Aquifer.

The New Grade Energy (1985) Environmental Impact Statement indicates hydraulic conductivity in the A Zone Aquifer at the nearby CCRL area ranges from 1.4 x 10E-4 to 8 x 10E-3 cm/sec based on piezometer slug tests. The thickness of the A Zone Aquifer varies from 6.4 to 8.8 m at this part of the Imperial Oil site.

We have confirmed that the piezometric surface slopes to the south-west .. the direction of groundwater flow (See Map 3). This flow direction conforms with regional studies previously undertaken.

Recharge to the A Zone Aquifer occurs in the form of direct precipitation and percolation through the overlying Regina Clay in the areas investigated. Near Pilot Butte surficial gravels provide an excellent recharge area. Some of this water discharges into surface creeks and spring areas such as Mallory Springs and some flows laterally to the general City of Regina area. Discharge from the A Zone Aquifer is now from City water wells at Boggy Creek and downward into the B Zone Aquifer whereas before groundwater withdrawals occured from Boggy Creek wells, there was spring discharge into Boggy and Wascana creeks.

11.2 Groundwater Flow Velocity in the A Zone Aquifer

11.2.1 Expected Lateral Flow Velocity - A Zone Aquifer

Expected rate of groundwater movement in the A Zone Aquifer is dependent on hydraulic gradient and aquifer permeability. The hydraulic gradient at the Imperial Oil site is about 7.7 m/km in a north-east to south-west direction (See Map 3).

This value of gradient is representative but accurate values of aquifer permeability would require pump tests at several sites. For example near the south end of the Imperial Oil site the permeability is much lower because the aquifer is much thinner and grades from sand to silt in a southerly direction. Using the values of hydraulic conductivity determined by New Grade (1985) and the above gradient one can calculate average lateral linear velocity using the following formula:

$$\text{Average linear velocity} = V = \frac{ki}{n}$$

Where k = hydraulic conductivity in cm/sec
$= 1.4 \times 10E\text{-}4$ to $8.0 \times 10E\text{-}3$ cm/sec
i = hydraulic gradient = 0.0077
n = intergranular porosity $\approx$ 30 %

$$\text{IO-1 site: } V = \frac{1.4 \times 10E\text{-}4 \times 0.0077}{0.3}$$

$$= 3.56 \times 10E\text{-}6 \text{ cm/sec}$$

$$\text{IO-2 site: } V = \frac{8 \times 10E\text{-}3 \times 0.0077}{0.3}$$

$$= 2.03 \times 10E\text{-}4 \text{ cm/sec}$$

$\therefore$ V varies from 1.1 m/year to 64.1 m/year

The above lateral flow velocity calculations give an indication of possible rate of movement of groundwater and contaminants in the groundwater. The hydraulic conductivities will vary with texture of the aquifer so the velocity will vary somewhat throughout the aquifer. Similarily, flow directions are likely to be more complex than shown on Map 3.

11.3 Aquitards

11.3.1 Expected Range of Vertical Flow Velocity Through Battleford - Condie Till

In estimating vertical flow velocity the most difficult parameter to identify is vertical hydraulic conductivity. Another parameter difficult to identify is the presence of and increase of hydraulic conductivity due to fracturing of glacial tills. Clifton (1985) conducted 3 insitu tests on piezometers at the nearby CCRL site, values of hydraulic conductivity varied from 1.9 x 10E-7 to 1.1 x 10E-8 cm/sec. These values would appear to indicate a fractured till at CCRL rather tnan intergranular porosity of nonfractured till. Without further testing we do not know if fractured tills exist at this site. An examination of isopach Map 9 shows the till section varies from 3.04 m at the north end to 4.27 m at the south end of the part of IO site investigated. The B Zone Aquifer has watertable conditions so downward vertical movement of groundwater is by gravity flow from the A Zone Aquifer. The head conditions vary from one place to the next in the aquifer so velocity of groundwater movement is correspondingly variable. The formula for calculating average linear velocity of groundwater (Vv) downward through the till layer is the same as for lateral movement except the hydraulic gradient is across the till section:

$$Vv = \frac{ki}{n}$$

$$\text{Vv at site IO-4} = \frac{1.9 \times 10E\text{-}7 \times 0.23}{0.2}$$

$$= 2.185 \times 10E\text{-}7 \text{ cm/sec}$$
$$= 0.069 \text{ m/year}$$

Where $k = 1.9 \times 10E\text{-}7$

$$i = \frac{1}{4.27} = 0.23$$

$$n = 20\ \%$$

$$\text{Vv at site IO-2} = \frac{1.9 \times 10E\text{-}7 \times 0.74}{0.2}$$

$$= 7.03 \times 10E\text{-}7 \text{ cm/sec}$$
$$= 0.22 \text{ m/year}$$

$$\text{Where } i = \frac{2.47}{3.35} = 0.74$$

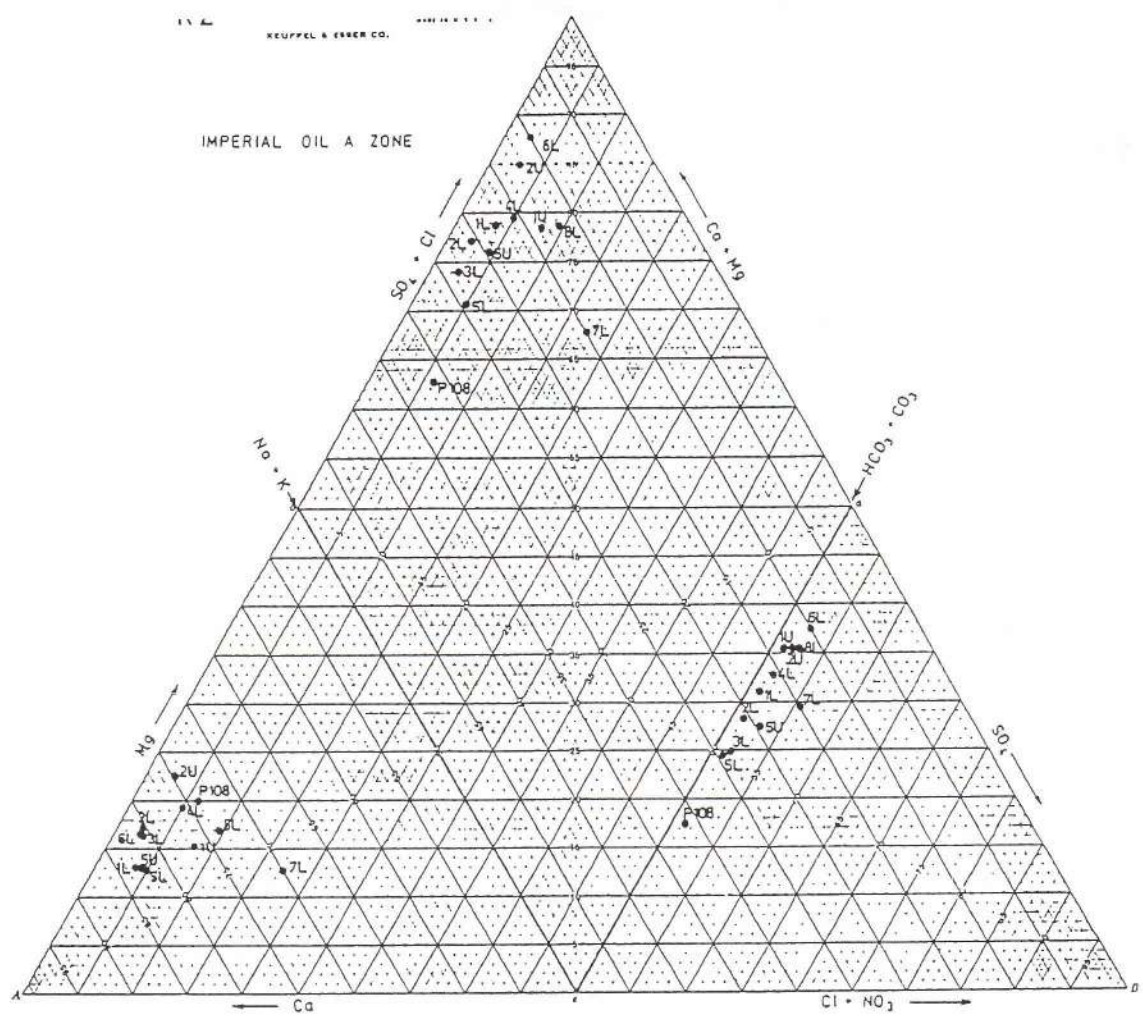
These calculated rates of velocity suggest that water could travel through the separating till layer in a period of from 15.2 to 62 years using the highest value for hydraulic conductivity. In areas where the lower value of hydraulic conductivity applies it would take in the order of 17 times longer for water to percolate through the till layer i.e. 261 years to 1071 years respectively. These latter values probably represent time required to percolate through nonfractured till.

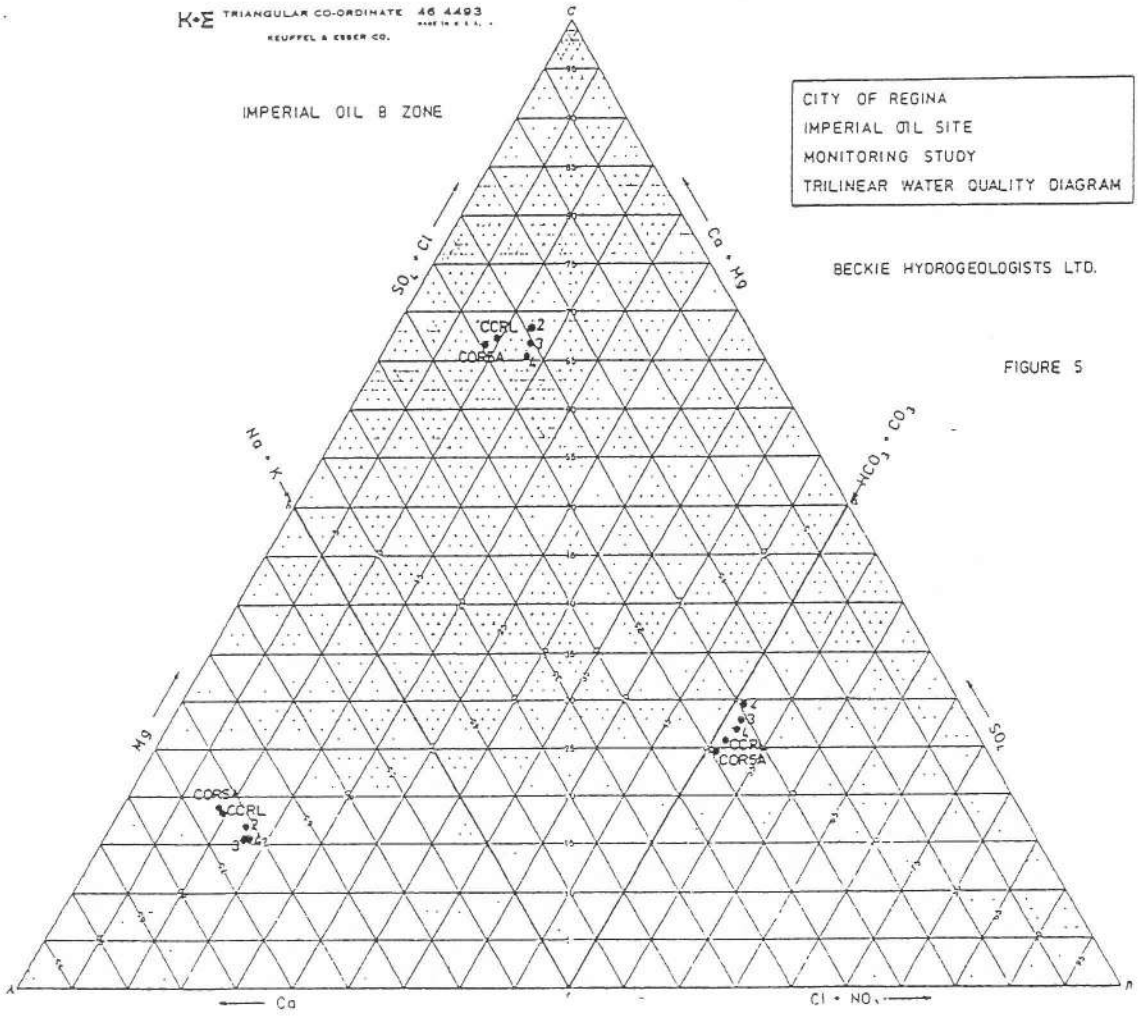
11.4 Groundwater Quality

11.4.1 Water Quality - Regina A Zone Aquifer

11.4.1.1 Major Ion and Physical Tests

At the Imperial Oil site there are possibly three separate leachate plumes evident, one as the result of Imperial Oil refinery petroleum products, two others as a consequence of the spent lime area and ponds used in conjunction with the Imperial Oil refining process (Map 2). Major ion and physical tests can be noted in Appendix A. The high levels of total solids and hardness at the IO-1AU site suggest that possibly dispersion and areas of higher permeability or the CCRL site has influenced water quality in the area. The leachate has caused increases in major ions and physical parameters of the groundwater. Individual constituents have not increased to toxic levels but there is markedly reduced quality of water in the A Zone Aquifer. The phenol content in particular is elevated at the Imperial Oil site. See Figure 5 for a Piper diagram showing percentages of major ions. The A Zone Piper diagram shows that IO-3AL and IO-5AL are not significantly influenced by leachate and that IO-6AL and IO-8AL are noticeably more mineralized because of the leachate influence.





CITY OF REGINA
IMPERIAL OIL SITE
MONITORING STUDY
TRILINEAR WATER QUALITY DIAGRAM

BECKIE HYDROGEOLOGISTS LTD.

FIGURE 5

11.4.1.2 Pollution Group Analysis

The pollution group analysis confirms the presence of a leachate plume at the Imperial Oil site.

At the Imperial Oil site the phenols are elevated in the south west-corner. At IO-7AL the phenols were found to be 1900 ugm/L, 300 ugm/L at IO-4AL, and 150 ugm/L at IO-8AL. This combined with a gasoline content of 1.1 mg/L at IO-4AL shows a substantial petroleum derived plume in this general area and this has been tentatively outlined on Map 2. This particular plume is of concern for its potential to contaminate the B Zone Aquifer. The total phosphates, kjeldahl nitrogen, and ammonia levels are all significantly above normal groundwater levels at the Imperial Oil site.

11.4.1.3 Trace Constituents and Heavy Metal Analyses

At the Imperial Oil site the sulphide content of the water in IO-6AL, IO-8AL, IO-4AL, IO-1AL, IO-2AL, and IO-3AL indicate the presence of leachate. Oil and grease were also detected in all of the monitor wells. A check for gasoline indicated 1.1 mg/L in IO-4AL. IO-4AL showed hydrocarbons of <1 mg/L because this test shows the heavy end of hydrocarbons and does not include gasoline. Samples for sulphides were not filtered for IO-6AL and IO-8AL (See A-4) so this may explain the elevated readings.

11.4.2 Water Quality - Regina B Zone Aquifer

11.4.2.1 Major Ion and Physical Tests

On the basis of samples collected and analysed for major ion and physical tests there was no evidence that any leachate was present. The analysis from a sample collected from IO-1B looks anomalous .. probably influenced by cement grout from the seal separating the upper and lower aquifer zones.

12.0 Evidence of Leachate Plumes

To determine if a leachate plume exists, water quality and piezometric data from the Mount Pleasant area, part of the Imperial Oil refinery site, and CCRL sites were compared. By using the water quality information and maps it was possible to compare the water quality out of the zone of influence of any contaminant plumes i.e. monitors 108, 301, 305, 306, and 310 at the CCRL site. This information has been used to make a map

showing possible extent of plumes using a regional picture (See Map 10). A general guide used in making this diagram was the estimated rates of lateral flow from MP and IO sites. The extent of the plumes might be significantly less if the southern extent of the aquifer is limited. Total dissolved solids of water from monitor wells out of the plumes varied from 570 to 850 mg/L.

Map 2 shows the known extent of the leachate plume using the total dissolved solids parameter and the phenol content for part of the Imperial Oil site investigated. The plumes likely extend past boundaries but we are uncertain of the size since aquifer permeability and continuity are not known off the site.

The leachate plume shows some effects of dispersion perpendicular to direction of groundwater flow but the most concentrated area of the plume is downstream in the direction of groundwater flow from the sources of contamination. The early history of site "housekeeping" practises followed at the part of the Imperial Oil site investigated would probably be difficult to establish. It is likely the lime sludge disposal on land surface and or in unlined ponds has been occurring from the earliest years so there has been in the order of 50 years for total dissolved solids plumes to develop from infiltration from this source.

13.0 Significance of Leachate Plumes

The leachate plumes are significant in that the water quality is much poorer in quality than naturally occurs in the A Zone Aquifer. The A Zone Aquifer which has intercepted the leachate acts as a source of recharge to the B Zone Aquifer. The testholes have shown that the glacial till that separates the A and B zones varies from 4 m thick at the south end to as thin as 3.0 m thick at the south end of the Imperial Oil site (See Map 9) so one cannot preclude the possibility it is absent at some locations.

14.0 CONCLUSIONS

1. A monitor well system has been installed into the Regina Aquifer A and B Zones at the part of the Imperial Oil abandoned oil refinery site investigated. These monitor wells will allow a continued monitoring of water qualities and the piezometric surface at this location.

2. The water analyses show the presence of leachate in the A Zone Aquifer. Phenol content has been detected at levels up to 1900 ugm/L in the A Zone Aquifer. These results are based on one sampling to date.

3. There is no evidence of leachate in water from the B Zone Aquifer utilized by City wells. The leachate follows the direction of groundwater flow with the most concentrated leachate being immediately downstream from the presumed source.

4. At the Imperial Oil site the glacial till layer separating the A and B Zones of the Regina Aquifer is 3.Ø to 4.3 m thick. This thin seperating till layer suggests a hole in this till is possible.

5. Theoretical calculations, utilizing hydraulic coefficients from the CCRL sites, suggest the plume can advance laterally at rates of 1 to 64 m/year. Vertical percolation of groundwater through the underlying Upper Floral Formation till may be occuring at an estimated rate of Ø.Ø69 to Ø.22 m/year so that groundwater and possibly leachate travels through this till layer in from 15.2 to 62 years from the time it enters the A Zone Aquifer if the till layer is fractured.

6. The leachate plumes extend an undetermined distance beyond the boundaries of the aquifers investigated. Distance travelled will depend on permeability, continuity and piezometric gradient off the site.

15.Ø RECOMMENDATIONS

1. A program should be initiated to periodically check water samples from City well R5 for phenols, sulphides, and nitrogen derivatives every month while the well is in use. In addition a request should be made to CCRL for recent analyses of water from all their production wells. These analyses should include tests for phenols and petroleum products.

2. The existing Imperial Oil abandoned water wells that are not cement grout sealed should be pumped and then sampled to determine if leachate is present. Any wells that are not usable should be cement grout sealed and abandoned if this has not already been done so they do not eventually rust out and allow unimpeded movement of leachate into the B Zone Aquifer. A request should be made to CCRL to check for and if not already done to plug and abandon any old wells that are open and not usable.

3. A program of further investigations covering the entire refinery area should be undertaken to pinpoint the source and to determine the full extent and concentration of the leachate plume. This could be done by installing additional monitor wells and collecting and analysing soil samples and water samples. This would also establish whether elevated phenols are also present at other locations on and off the part of the Imperial Oil site investigated.

4. A request should be made to Imperial Oil to determine if they have records of any on site disposal area. Any sites used for this purpose should be investigated in detail.

5. If further investigations confirm significant contamination and depending on the value placed on this aquifer water, consideration should be given to low producing pump wells into the A Zone Aquifer in the area of high phenols. The wells could be pumped and the water produced could be treated if necessary.

6. Tests for aquifer permeability should be undertaken using slug tests and pump tests if more accurate evaluations of potential rate and extent of movement of the leachate plume is desired. Installation of additional monitor wells and water sampling remain the most reliable indicators because of variations in aquifer characteristics.

7. We recommend the use of Dr. John Cherry a noted Canadian Hydrogeologist and expert on contamination problems to review this report and make suggestions.

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APPENDIX A

Mount Pleasant Site

MAJOR ION AND POLLUTION GROUP ANALYSES
A - ZONE AQUIFER

Monitor Wells	M.P.-1AU	M.P.-1AL	M.P.-2AU	M.P.-2AL	M.P.-3AU	M.P.-3AL	M.P.-4AU	M.P.-4AL	M.P.-5AU	M.P.-5AL	M.P.-6AU	M.P.-6AL	M.P.-7AU	M.P.-7AL	M.P.-8AU	M.P.-8AL
Lab No.	4225, 4445	4242, 4224 4447	4227, 4451	4223, 4241 4453	4229, 4443	4228, 4240 4448	4233, 4449	4231, 4239 4454	668	675, 597 2555	674	665, 595	669	670, 598 2057	667	676, 593 2058
PHYSICAL TESTS:																
pH	7.6	7.6	7.7	7.3	7.7	7.6	7.8	7.7	8.0	7.6	8.0	7.7	7.0	7.6	8.0	7.5
Total Dissolved Solids	953	738	1301	890	657	570	703	584	885	906	782	654	1648	1188	1070	1216
DISSOLVED ANIONS:																
Total Alkalinity CaCO3	324	300	330	308	276	266	228	266	304	292	257	248	285	312	275	318
Bicarbonate HCO3	395	366	403	376	337	325	278	325	371	356	350	303	348	381	336	388
Chloride Cl	4	6	10	4	2	L2	8	6	4	2	2	2	4	2	6	4
Sulphate SO4	325	194	565	315	157	107	240	113	288	320	240	190	780	500	460	510
Nitrate NO3	L1	L1	1	L1	L1	L1	L1	L1	L1	L1	L1	L1	82	L1	L1	L1
DISSOLVED CATIONS:																
Total Hardness CaCO3	584	436	828	536	432	368	476	368	564	580	472	392	1136	792	680	776
Calcium Ca	163	118	237	154	110	112	130	96	160	170	138	110	326	227	190	216
Magnesium Mg	43	34	57	42	38	21	37	31	40	38	31	28	78	54	50	57
Sodium Na	23	20	28	15	13	5	10	13	22	20	21	21	30	24	28	41
Iron Fe		0.5	5.2			1.4		0.9		#0.43		#0.21		#0.12		#0.62
Manganese Mn	0.32	0.22	0.65	0.27	0.33	0.40	0.39	0.49	0.62	0.98	0.54	0.54	1.16	0.83	0.67	0.93
POLLUTION GROUP:																
Conductivity (umhos/cm)		1128		1063		703		642		991		825		1303		1000
Biological Oxygen Demand, BOD		L50		21		L50		28		3		11		3		2
Suspended Solids, Total		2850		5650		1850		76		29720		89		62667		28840
Volatile		200		360		130		11		820		9		60333		460
Phosphate, Total		2.05		10.0		6.25		0.30		0.09		0.08		0.16		0.10
Ortho		0.08		0.07		0.08		0.19		0.08		0.10		0.09		0.10
Nitrogen, Kjeldahl		3.5		6.0		4.5		3.5		0.80		0.80		0.70		0.80
Ammonia		0.57		0.08		0.21		0.19		0.41		0.27		0.38		0.42
Nitrate		0.10		0.07		0.14		0.07		0.17		0.17		0.13		0.13
Organic Carbon		109		44		82		91		345		172		162		70
Phenols (ug/L)	2	2	2	2	2	2	2	1	0.9	L0.5	2	L0.5	2	1	2	6

NOTE: 1) For M.P.-1AU to M.P.-4AL samples were taken August 29/85
2) For M.P.-5AU to M.P.-8AL samples were taken March 3/86 except Pollution Group sampled February 25/86
3) All units expressed in mg/L unless otherwise denoted
4) AU - upper section of Regina A Zone
5) AL - lower section of Regina A Zone
6) Analyses at Public Health Laboratory in Regina unless indicated by # which means analysis was made at the SRC Laboratory in Saskatoon
7) L = less than

Mount Pleasant Site

TRACE CONSTITUENT AND METAL ANALYSES
A - ZONE AQUIFER

Monitor Well	M.P.-1AL	M.P.-2AL	M.P.-3AL	M.P.-4AL	M.P.-5AL	M.P.-6AL	M.P.-7AL	M.P.-8AL	Environment Saskatchewan Limits	
Lab. No.	11799, 11811 12073	12074, 11800	12075, 11801 11813	12076, 11802 11814	2055, 2063 2068	2056, 2604 2071	2057, 2065 2070	2058, 2062 2071		
Arsenic As	0.0056	0.0028	0.020	0.014	0.0041	0.0047	0.0055	0.010	0.05	✓
Barium Ba	0.059	0.051	0.043	0.050	0.031	0.025	0.028	0.033	1.0	
Boron B	0.23	0.20	0.19	0.15	L0.05	0.10	0.11	0.11	5.0	
Cadmium Cd	L0.001	0.002	0.002	0.002	0.001	0.001	L0.001	L0.001	0.005	✓
Chromium Cr	0.009	0.042	0.021	0.010	0.003	0.021	0.002	0.002	0.05	✓
Copper Cu	0.008	0.014	0.008	0.006	0.004	0.004	0.004	0.003	1.0	
Lead Pb	L0.005	L0.005	L0.005	L0.005	0.009	L0.005	L0.005	0.004	0.05	✓
Mercury Hg	0.07	0.07	0.07	L0.05	L0.05	L0.05	0.08	L0.05	1.0	
Manganese Mn	0.57	0.70	0.56	0.57	0.96	0.67	0.81	0.71	0.05	✓
Iron Fe	0.55	0.49	0.28	0.36	0.43	0.21	0.12	0.62	0.3	✓
Selenium Se	0.001	0.002	L0.001	L0.001	L0.001	L0.001	0.001	0.005	0.01	
Sulphide H2S	0.02	2.8	0.06	0.07	L0.001	L0.001	L0.001	L0.001	0.05	✓
Silver Ag	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	0.001	0.05	
Zinc Zn	0.20	0.19	0.12	0.16	0.21	0.17	0.11	0.18	0.5	✓

NOTE: 1) All units in mg/L except for Mercury which is ug/L
2) M.P.-1AL to M.P.-4AL sampled August 29/85
3) M.P.-5AL to M.P.-8AL sampled February 26/86
4) Analyses at Sask. Research Council in Saskatoon
5) L = less than

Imperial Oil Site

MAJOR ION AND POLLUTION GROUP ANALYSES
A - ZONE AQUIFER

Monitor Well	I.O.-1AU	I.O.-1AL	I.O.-2AU	I.O.-2AL	I.O.-3AU	I.O.-3AL	I.O-4AL	I.O.-5AU	I.O.-5AL	I.O.-6AL	I.O.-7AL	I.O.-8AL	Environment Saskatchewan Limits
Lab No.	4235, 4725	4222, 4238 4444	4221, 4724	4234, 4237 4446	4232, 4827	4230, 4236 4450	4226, 4452	666	664, 594 2059	672, 2060	673, 592 2061	671, 596	
PHYSICAL TESTS:													
pH	7.6	7.4	7.5	7.5	7.8	7.6	7.4	8.0	7.4	7.4	7.3	7.3	7.0-8.5
Total Dissolved Solids	1680	1045	2055	1182	1380	906	2080	1081	920	2738	1377	2308	1500
DISSOLVED ANIONS:													
Total Alkalinity CaCO3	324	314	370	350	368	328	474	303	315	411	364	409	500
Bicarbonate HCO3	395	383	451	427	449	400	578	370	324	501	371	499	
Chloride Cl	2[illegible]	18	36	12	14	2	30	32	16	70	76	58	250
Sulphate SO4	820	384	985	455	565	291	945	464	296	1440	555	1140	500
Nitrate NO3	L1	L1	1	L1	2	L1	4	L1	L1	L1	L1	L1	40
DISSOLVED CATIONS:													
Total Hardness CaCO3	1032	664	1652	768	928	572	1368	688	564	1980	648	1380	800
Calcium Ca	2[illegible]4	196	346	197	251	149	312	198	167	518	158	320	
Magnesium Mg	9[illegible]	46	191	67	73	49	143	47	39	168	61	141	200
Sodium Na	90	24	45	18	26	15	68	30	29	43	158	150	300
Iron Fe		4.1							*0.33	*0.21	*0.80		0.3
Manganese Mn	0.49	0.50	0.74	0.69	0.71	0.58	0.81	0.80	0.50	2.10	1.26	2.00	0.05
POLLUTION GROUP:													
Conductivity (umhos/cm)		1910		2170		1625			1030	3450	2250	2450	
Biological Oxygen Demand, BOD		23		150		66			7	*L1	6		
Suspended Solids, Total		5380		1122		4767			55000		15640	26540	
Volatile		350		113		333			1520		400	760	
Phosphate, Total		5.00		1.90		3.75			0.11	*2.0	0.10	0.06	
Ortho		0.06		0.08		0.08			0.09	*0.14	0.09	0.10	
Nitrogen, Kjeldahl		9.0		4.5		7.5			1.00	*1.4	1.80	1.90	
Ammonia		0.80		1.00		0.95			0.59	*1.1	1.26	1.25	
Nitrate		0.10		0.30		0.20			0.17	*0.18	0.03	L0.03	
Organic Carbon		32		123		100			346	*255	449	125	
Phenols (ug/L)	L2	2	L2	2	L2	2	300	10	8	L0.5	1900	150	L[illegible]

NOTE: 1) For I.O.-1AU to I.O.-4AL samples were taken August 29/85
2) For I.O.-5AU to I.O.-8AL samples were taken March 3/86 except Pollution Group sampled February 25/86
3) All units expressed in mg/L unless otherwise denoted
4) AU - upper section of Regina A Zone
5) AL - lower section of Regina A Zone
6) Analyses at Public Health Laborata unless indicated by * which means analysis was made at the SRC Laboratory in Saskatoon
7) L = less than

Imperial Oil Site

TRACE CONSTITUENT AND METAL ANALYSES
A - ZONE AQUIFER

Monitor Well	I.O.-1AL	I.O.-2AL	I.O.-3AL	I.O.-4AL	I.O.-5AL	I.O.-6AL	I.O.-7AL	I.O.-8AL	Co-op Refinery P-104	Environment Saskatchewan Limits
Lab. No.	11796, 12077 11803, 11807	11797, 12078 11804, 11808	11798, 12079 11805, 11809	12080, 11806 11810	2059, 2066 2072, 2074	2100, 2060 2075	2061, 2067 2073, 2076	2101, 2077		
Arsenic As	0.015	0.048	0.0098		0.009	0.0011	0.016		NT	0.05
Barium Ba	0.040	0.065	0.055		0.037	0.019	0.025		0.073	1.0
Boron B	0.16	0.14	0.18		0.08	0.19	0.28	Could not	0.12	5.0
Cadmium Cd	L0.001	L0.001	L0.001		L0.001	L0.001	L0.001	filter	L0.001	0.005
Chromium Cr	0.018	0.020	0.028		0.003	0.003	0.005	water.	0.012	0.05
Copper Cu	0.009	0.008	0.010		0.004	0.003	0.002		0.002	1.0
Lead Pb	L0.005	L0.005	L0.005		L0.005	L0.005	L0.005		L0.005	0.05
Mercury Hg	L0.05	L0.05	L0.011	L0.05	L0.05	L0.05	L0.05	L0.05	L0.05	1.0
Manganese Mn	0.61	1.10	0.80		0.58	1.5	1.1		0.12	0.05
Iron Fe	0.34	0.30	0.50		0.33	0.21	0.80		0.07	0.3
Selenium Se	0.001	L0.001	0.001		L0.005	L0.005	L0.005		NT	0.01
Sulphide H2S	0.11	0.34	0.30	1.4	L0.01	5.8	L0.01	0.98	L0.01	0.05
Silver Ag	L0.001	L0.001	L0.001		L0.001	L0.001	L0.001		L0.001	0.05
Zinc Zn	0.13	0.14	0.16		0.12	0.21	0.22		0.49	0.5
Oil and Grease	3	2	2	3	5	5	6	5	NT	
Gasoline	L0.050	L0.050	L0.050	1.1	L0.05	L0.05	L0.05	L0.05	NT	
Hydrocarbons	L1	L1	L1	L1	L1	L1	L1	L1.4	L1	

NOTE: 1) All units in mg/L except for Mercury which is ug/L
2) I.O.-1AL to I.O.-4AL sampled August 29/85
3) I.O.-5AL to I.O.-8AL sampled February 26/86
4) Analyses at Sask. Research Council in Saskatoon
5) L = less than

CCRL Site

GROUNDWATER QUALITY DATA 1984
A ZONE AQUIFER

SAMPLE DESCRIPTION:							
Piezometer No.	P106	P108	P109	P301	P305	P306	P310
Date Sampled (Yr/M/D)	84/11/06	84/11/06	84/11/05	84/10/04	84/11/07	84/10/12	84/10/15
Stratum	Condie	Condie	Condie	Condie	Condie	Condie	Condie
PHYSICAL PROPERTIES:							
Conductivity (uS/cm)	698	251	790	294	312	308	376
Field Temperature (C)	5	5	6.1	8.5	3.9	7	6
pH (pH units)	7.1	7.7	7.4	7.5	7.3	7.7	7.7
Total Alkalinity CaCO3	267	200	350	328	314	303	325
Total Hardness	1272	392	1712	456	472	504	496
Total Dissolved Solids	1770	657	2644	797	775	833	850
MAJOR IONS:							
Calcium Ca	339	86	444	104	98	117	110
Magnesium Mg	103	43	146	48	55	52	49
Potassium K	9.5	6	14	3.9	5.7	5.9	7.7
Sodium Na	34	22	118	34	26	32	42
Bicarbonate HCO3	326	342	439	413	383	370	397
Chloride Cl	36	8	244	4	8	12	6
Sulphate SO4	910	150	1220	194	205	216	230
ORGANIC PARAMETERS:							
Kjeldahl Nitrogen	1.1	0.6	1	1	0.8	0.5	0.8
Ammonia	0.11	0.17	0.18	0.19		0.16	0.14
Nitrate	17	L1	33	1	L1	L1	L1
Total Phosphate	0.13	0.20	0.11	0.13	0.2	0.08	0.2
Ortho Phosphate	0.06	0.08	0.06	0.07		0.07	0.04
Total Inorganic Carbon	63	70	70	76	80	68	73
Total Organic Carbon	7	L1	44	0	L1	18	9
TRACE CONSTITUENTS:							
Boron	0.1	0.08	0.08	0.1	0.16	0.12	0.11
Phosphorous	0.22	0.11	0.22	0.2	0.25	0.18	0.17
TRACE METALS:							
Silver	L0.001	0.001	0.001	0.002	L0.001	0.004	L0.001
Aluminum	0.06	0.07	0.047	0.14	0.1	0.074	0.35
Barium	0.1	0.037	0.059	0.049	0.04	0.033	0.045
Berryllium	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001
Cadmium	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001	L0.001
Cobalt	0.001	L0.001	L0.001	0.001	0.001	0.001	0.002
Chromium	0.01	0.006	0.014	0.009	0.008	0.011	0.012
Copper	0.002	0.002	0.005	0.006	0.001	0.059	0.003
Iron	0.007	0.078	0.048	0.15	0.16	0.19	0.38
Manganese	0.25	0.52	0.24	0.76	0.76	0.77	0.62
Molygdenum	0.01	0.008	0.013	0.008	0.008	0.01	0.007
Nickel	0.003	0.003	L0.001	0.006	0.001	0.007	0.005
Lead	L0.005	L0.005	L0.005	L0.005	L0.005	0.01	0.004
Titanium	L0.001	L0.001	L0.001	L0.001	0.001	L0.001	0.01
Vanadium	0.42	0.01	0.04	0.01	0.01	0.01	0.01
Tungsten	0.01	L0.005	L0.005	L0.005	L0.005	0.011	L0.005
Zinc	0.035	0.017	0.43	0.5	0.043	0.018	0.034
CHARGE BALANCE ERROR (%):	1.82	0.08	0.33	0.67	0.25	3.18	1.43
Hydrocarbons	L1	L1	L1	L1	L1	L1	L1
Phenols	L1	3	4.2	3	4	L1	7
Mercury	0.05	0.06	L0.05	0.13	L0.05	0.02	0.02
Cyanide	1	L0.1	0.08	0.8	L0.1	0.5	0.5
Sulphide			L0.01	L0.01		L0.01	L0.01

NOTE: 1) All units are in mg/L unless otherwise indicated.
2) L = less than

Mount Pleasant, Imperial Oil, CCRL,
and City of Regina Sites.

MAJOR ION ANALYSIS
B - ZONE AQUIFER

	Mount Pleasant Site				Imperial Oil Site								
Monitor Well	MP1B	MP2B	MP3B	MP4B	1016	1028	1038	1048	CCRL	CCRL Well #5	City of Regina Well #5 - A	City of Regina Well #5 - B	Environment Saskatchewan Limits
Lab. No.	3081	3085	3088	3120, 3124	3116, 3125	3119, 3123	3118, 3121	3117, 3122	9302				
PHYSICAL TESTS:													
pH	7.7	7.7	7.7	7.7	9.1	7.9	7.8	7.5	7	7.6	7.5	7.4	7.0-9.5
Total Dissolved Solids	1358	1289	1553	1462	777	1473	1300	1372	1319	1424	1331	1368	1500
DISSOLVED ANIONS:													500
Total Alkalinity, CaCO3	428	438	592	479	112	405	414	418	430	463			
Bicarbonate HCO3	522	534	722	585	78	499	556	510	525	562	548	547	
Chloride Cl	14	12	12	16	14	14	22	18	14	14	12	10	250
Sulphate SO4	480	415	456	550	476	585	600	495	450	485	432	486	500
Nitrate NO3	11	11	11	11	11	11	11	11	11	11	11	11	40
DISSOLVED CATIONS:													800
Total Hardness CaCO3	764	672	764	784	349	772	828	692	736	768			
Calcium Ca	185	157	172	178	45	171	194	160	138	168	170	157	
Magnesium Mg	86	72	91	84	59	84	84	71	95	93	97	97	200
Sodium Na	92	105	118	160	107	120	135	119	87	84	80	83	300
Iron Fe	2.3	0.4	1.4	0.8	0.3	0.2	0.5	0.3	0.16	0.2	0.10	0.10	0.3
Manganese Mn	1.9	1.18	1.74	1.7	20.61	6.42	1.72	6.53	1.1	1.46	1.86	1.65	.05
POLLUTION GROUP:													
Ammonia NH3										0.16			
Total Kjeldahl N										0.54			

NOTE: 1) MP1B to 1048, sampled March 28 85, CCRL 9302 sampled Oct. 4/84, Eff. well #5 sampled October 25/84, City of Regina Well #5 - A sampled July 24/84, City of Regina Well #5 - B sampled June 26

2) Effl. & Ills sampled by others

3) All units expressed in mg/L except pH which is unitless

4) Analyzed at Public Health Lab in Regina

5) B - Regina B Zone

6) L = less than

APPENDIX B

APPENDIX B

GEOLOGIC LOGS

M.P. TH1-85

Depth in Metres	
Ø - 7.3	Clay, grey-brown, firm.
- 1Ø.7	Clay, grey, soft.
- 17.7	Silt, coarsing downwards to a fine, non-oxidized sand.
- 19.2	Gravel, fine to coarse, slightly oxidized, subangular to rounded.
- 23.2	Till, grey, very sandy, firm, some softer layers, non-oxidized.
- 24.7	Sand, medium to coarse, oxidized, rounded.
- 33.5	Gravel, fine to coarse, coarsening downwards, oxidized, subangular to rounded, loose.
- 35.1	Till, brown, sandy, clayey, hard. TD.

M.P. TH2-85

Depth in Metres	
Ø - 7.9	Clay, light brown, firm.
- 9.8	Clay, grey, soft, ozidized.
- 13.4	Silt, grey, soft, non-oxidized.
- 15.5	Sand, fine, grey, non-oxidized.
- 17.4	Silt, grey.
- 18.6	Gravel, fine to coarse, subrounded-angular, presence of till layers.
- 23.8	Till, grey, hard, sandy, non-oxidized.
- 24.7	Sand, hard, coarse.
- 41.8	Gravel, coarse, subrounded-angular. TD.

M.P. TH3-85

Depth in Metres	
Ø - 7.6	Clay, grey-brown, firm.
- 11.3	Clay, grey-brown, soft.
- 2Ø.1	Sand, fine, grey, silty, non-oxidized.
- 27.4	Till, grey, sandy, non-oxidized.
- 29.9	Sand, coarse.
- 39.6	Gravel, coarse, subrounded-angular. TD.

M.P. TH4-85

Depth in Metres	
Ø - 1.5	Clay, firm, dark brown-black.
- 8.5	Clay, hard, light brown.
- 12.2	Clay, silty, soft, light brown, oxidized.
- 20.1	Sand, very fine.
- 27.4	Till, grey, firm-hard.
- 30.5	Sand, fine-coarse.
- 39.6	Gravel, coarse. TD.

M.P. 5AL

Depth in metres	
Ø - 6.10	Clay, brown, firm, oxidized.
- 15.24	Silt, to fine sand, oxidized.
- 18.29	Sand, fine grey, non-oxidized.
- 19.81	Till, light grey, firm, non-oxidized. TD.

M.P. 6AL

Depth in metres	
Ø - 9.80	Clay, brown, firm, oxidized.
- 18.90	Silt, grading to a fine sand, grey, non-oxidized.
- 19.81	Till, light grey, firm, non-oxidized. TD.

M.P. 7AL

Depth in metres	
Ø - 9.80	Clay, brown, firm, oxidized.
- 19.81	Silt, to fine sand, grey, non-oxidized.
- 21.34	Till, light grey, firm, non-oxidized. TD.

M.P. 8AL

Depth in metres	
Ø - 9.80	Clay, brown, firm, oxidized.
- 19.81	Silt, to fine sand, grey, non-oxidized.
- 21.34	Till, light grey, firm, non-oxidized. TD.

I.O. TH1-85

Depth in Metres	
Ø - 1Ø.1	Clay, soft, light brown-grey.
- 11.6	Silt, consolidated, clay present.
- 13.1	Silt, soft, grey, loose, non-oxidized.
- 17.4	Sand, fine, grey, loose, non-oxidized.
- 18.9	Gravel, fine, slightly oxidized.
- 21.9	Till, firm, grey, silty, clayey, non-oxidized.
- 25.Ø	Sand, fine-coarse, subangular-rounded.
- 32.3	Gravel, fine-coarse, subangular-rounded.
- 35.1	Till, light grey, silty, clayey, non-oxidized. TD.

I.O. TH2-85

Depth in Metres	
Ø - 1Ø.7	Clay, firm, brown-grey, non-oxidized.
- 15.2	Silt, clayey, soft, consolidated, non-oxidized.
- 18.6	Silt, loose, fine sand present, non-oxidized, coarser downward.
- 19.2	Sand, fine-coarse, some gravel.
- 22.6	Till, hard, dark grey, non-oxidized.
- 24.4	Sand, medium-coarse, oxidized.
- 34.4	Gravel, fine-coarse, oxidized, subangular-rounded.
- 36.6	Till, firm, light grey, non-oxidized. TD.

I.O. TH3-85

Depth in Metres	
Ø - 1Ø.4	Clay, brown, firm, non-oxidized.
- 13.7	Silt, grey,consolidated, clayey, soft.
- 18.6	Silt, grey, coarsening downwards, non-oxidized.
- 18.9	Sand, fine to coarse, some grae, non-oxidized.
- 22.6	Till, hard, dark grey, silty.
- 25.Ø	Sand, fine to coarse, oxidized.
- 32.3	Gravel, fine to coarse, subangular to subrounded, oxidized.
- 35.1	Till, light grey, very silty. TD.

I.O. TH4-85

Depth in Metres	
Ø - 1Ø.4	Clay, brown, firm, oxidized.
- 11.9	Till, dark grey, firm, non-oxidized.
- 14.9	Silt, semi-consolidated, clayey, soft.
- 17.1	Sand, fine, slightly oxidized, loose.
- 18.3	Sand, fine to coarse, some gravel.
- 22.6	Till, dark grey, hard, non-oxidized.
- 24.4	Sand, coarse oxidized.
- 32.Ø	Gravel, fine to coarse, subangular to rounded, oxidized.
- 35.1	Till, light grey, firm, non-oxidized. TD.

I.O. 5AL

Depth in metres	
Ø - 9.14	Clay, brown, firm, oxidized.
- 15.24	Silty clay, soft.
- 18.9Ø	Silt and fine sand, light grey, non-oxidized.
- 19.81	Till, light grey, firm, non-oxidized. TD.

I.O 6AL

Depth in metres	
Ø - 1Ø.4Ø	Clay, brown, firm, oxidized.
- 17.98	Silt to fine sand, light grey, non-oxidized.
- 19.81	Till, light grey, firm, non-oxidized. TD.

I.O. 7AL

Depth in metres	
Ø - 9.75	Clay, brown, firm, oxidized.
- 17.68	Silt, silty sand, light grey, non-oxidized.
- 19.81	Till, light grey, firm, non-oxidized. TD.

I.O. 8AL

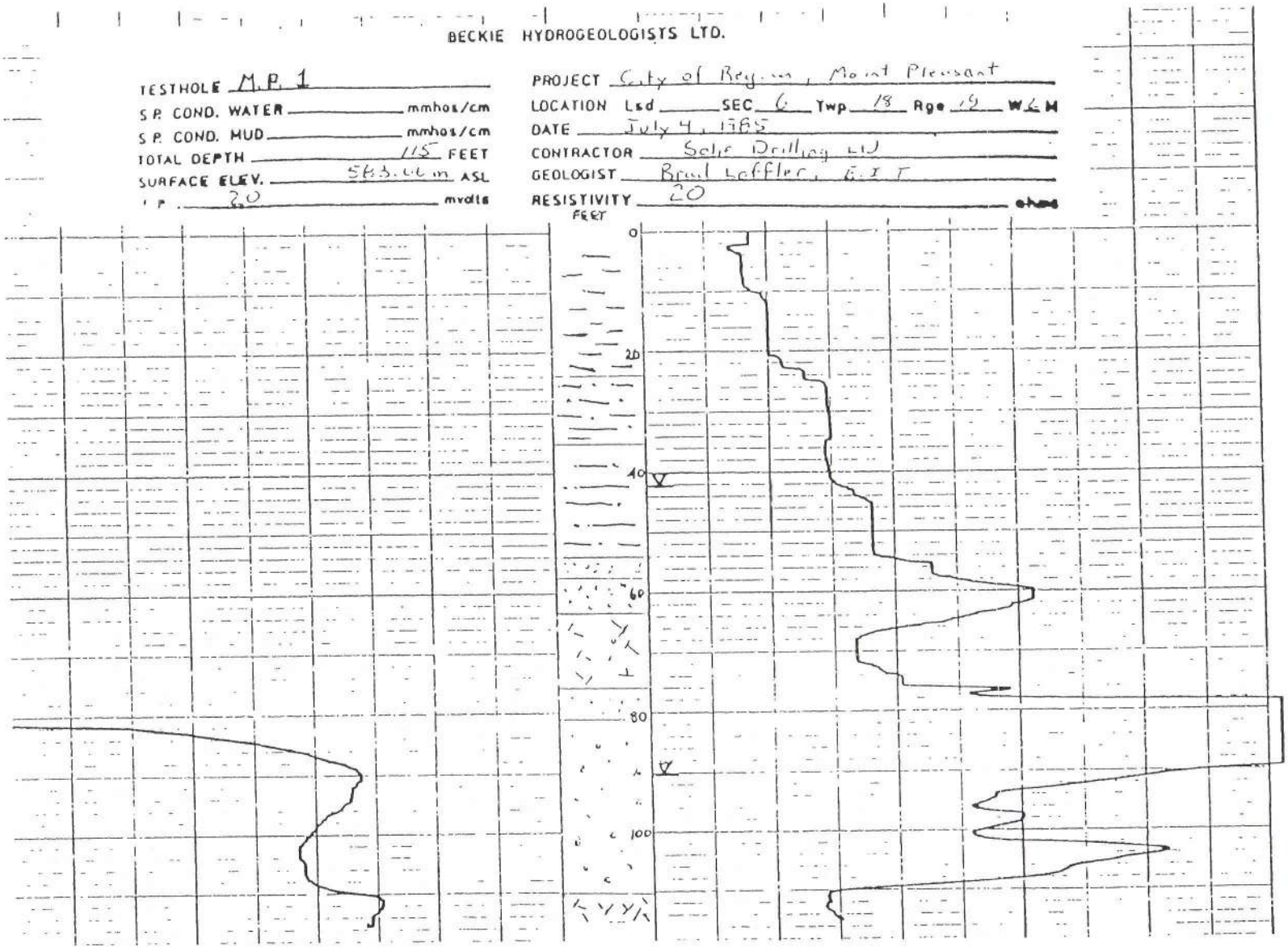
Depth in metres	
Ø - 12.19	Clay, brown, firm, oxidized.
- 17.37	Silt, coarsening downwards to fine sand.
- 2Ø.42	Till, light grey, firm, non-oxidized. TD.

NOTE: Observation wells for I.O. 5AL - 8AL were installed using an auger rig.

BECKIE HYDROGEOLOGISTS LTD.

TESTHOLE M.P. 1
S.P. COND. WATER _____ mmhos/cm
S.P. COND. MUD _____ mmhos/cm
TOTAL DEPTH 115 FEET
SURFACE ELEV. 583.66 m ASL
I.P. 2.0 mvolts

PROJECT City of Regina, Mount Pleasant
LOCATION Lsd ____ SEC 6 Twp 18 Rge 19 W 2 M
DATE July 4, 1985
CONTRACTOR Self Drilling Ltd
GEOLOGIST Brad Leffler, E.I.T.
RESISTIVITY 20 ohms



Beckie Hydrogeologists Ltd.

TESTHOLE M.W.2

S.P. COND. WATER _____ mmhos/cm

S.P. COND. MUD _____ mmhos/cm

TOTAL DEPTH 137 FEET

SURFACE ELEV. 591.96 m ASL

S.P. 20 mvolts

PROJECT City of [illegible], Ind. Pk at

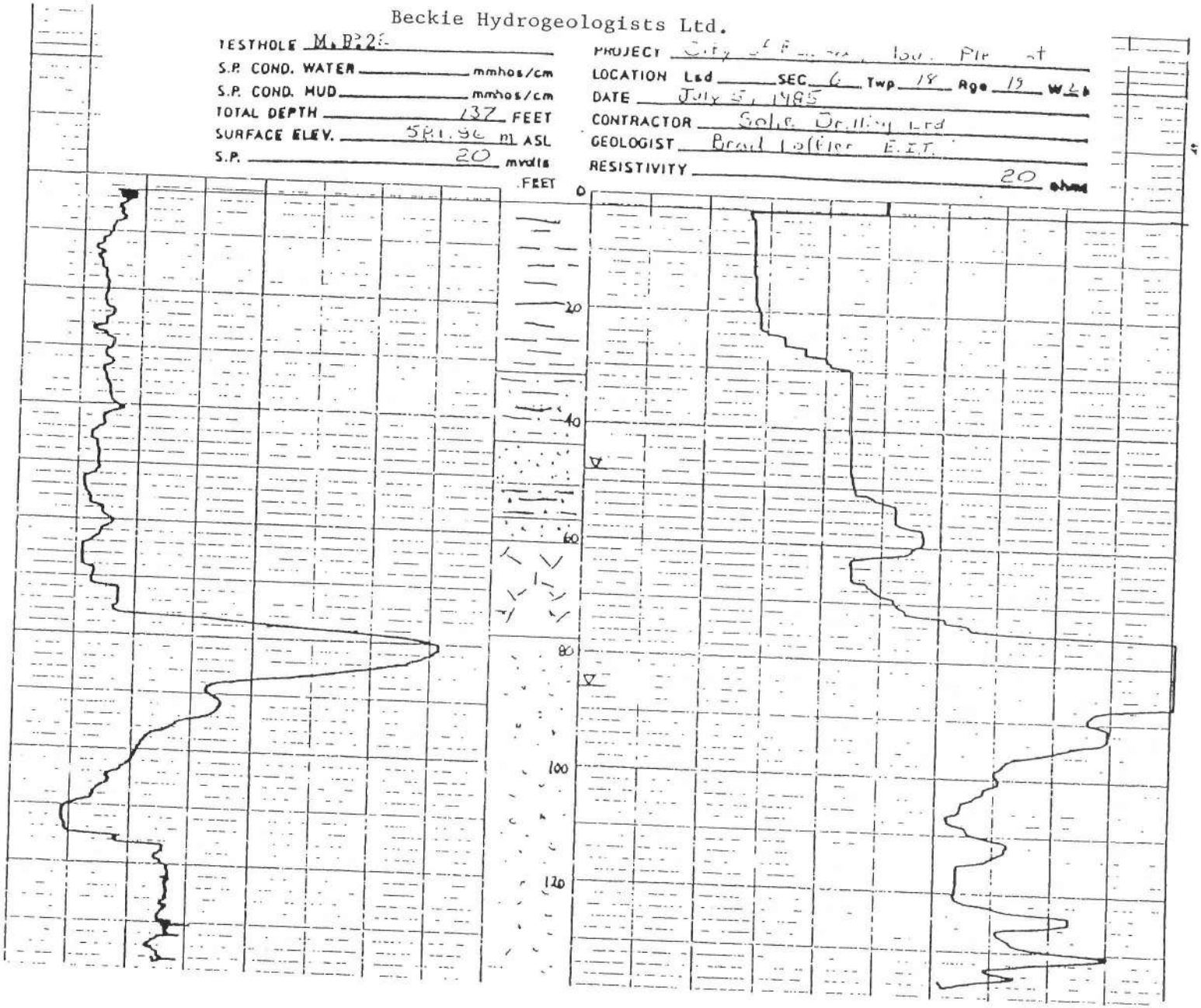
LOCATION Lsd _____ SEC 6 Twp 18 Age 19 W of

DATE July 5, 1985

CONTRACTOR Sol-E Drilling Ltd

GEOLOGIST Brad Loffler E.I.T.

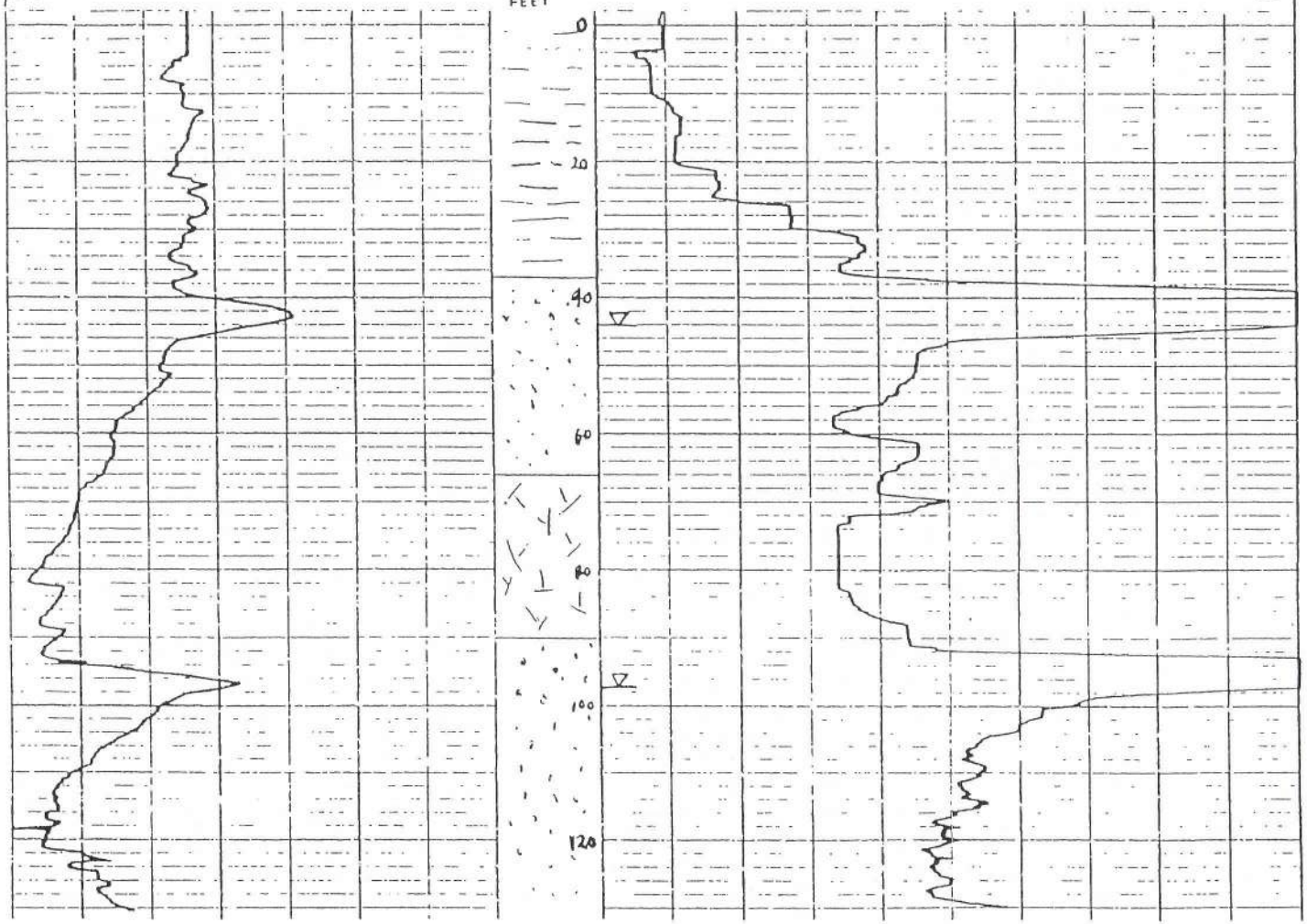
RESISTIVITY 20 ohms

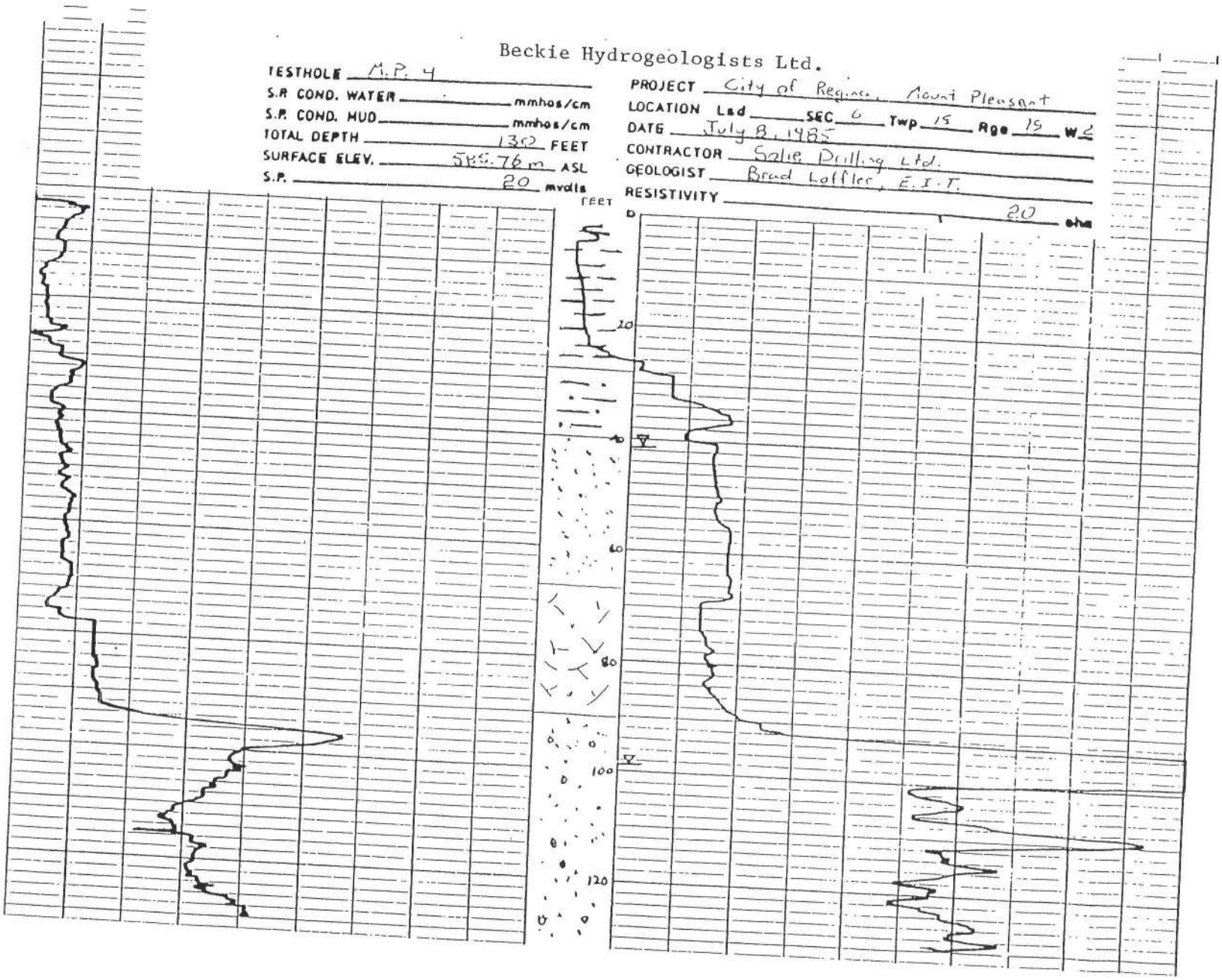


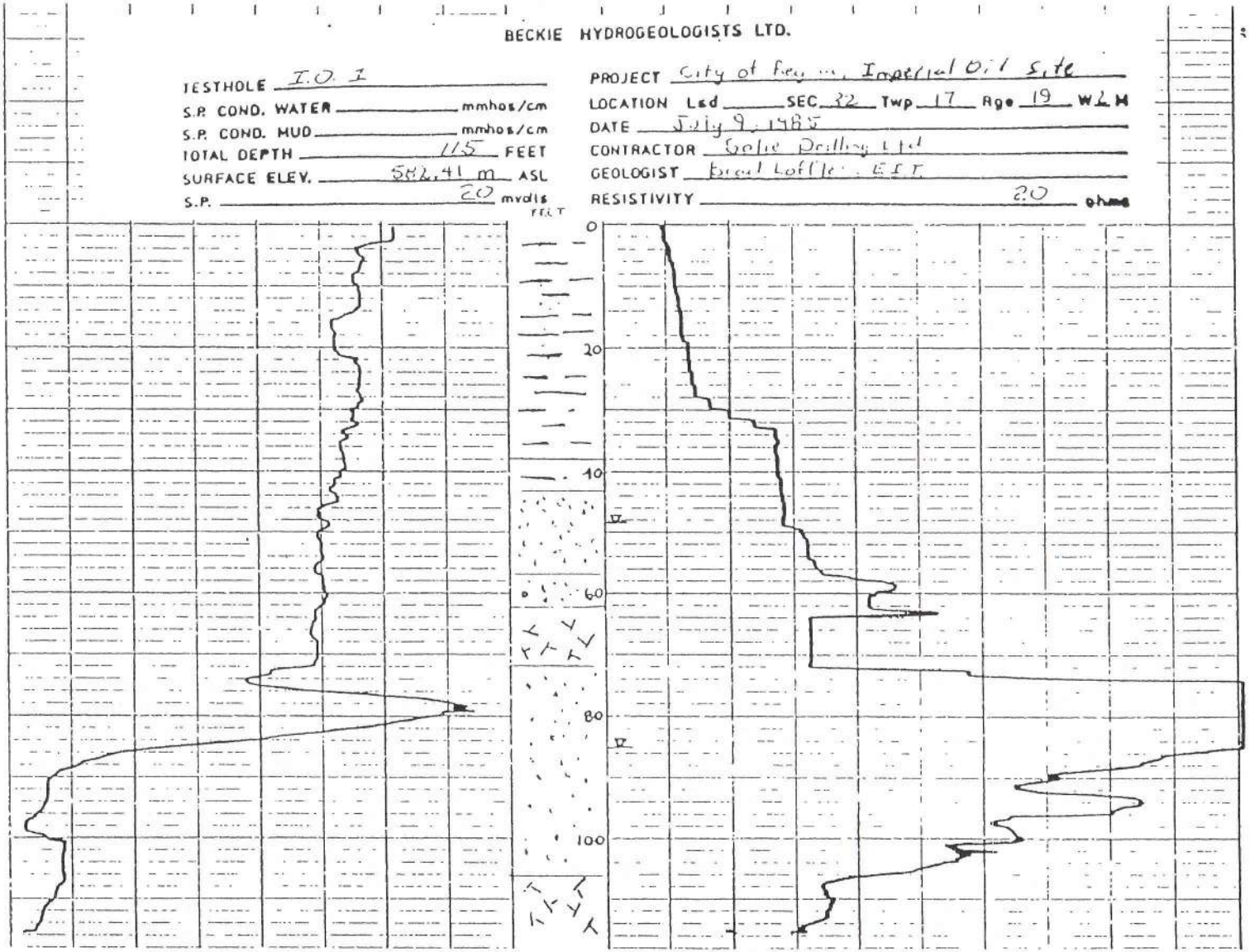
BECKIE HYDROGEOLOGISTS LTD.

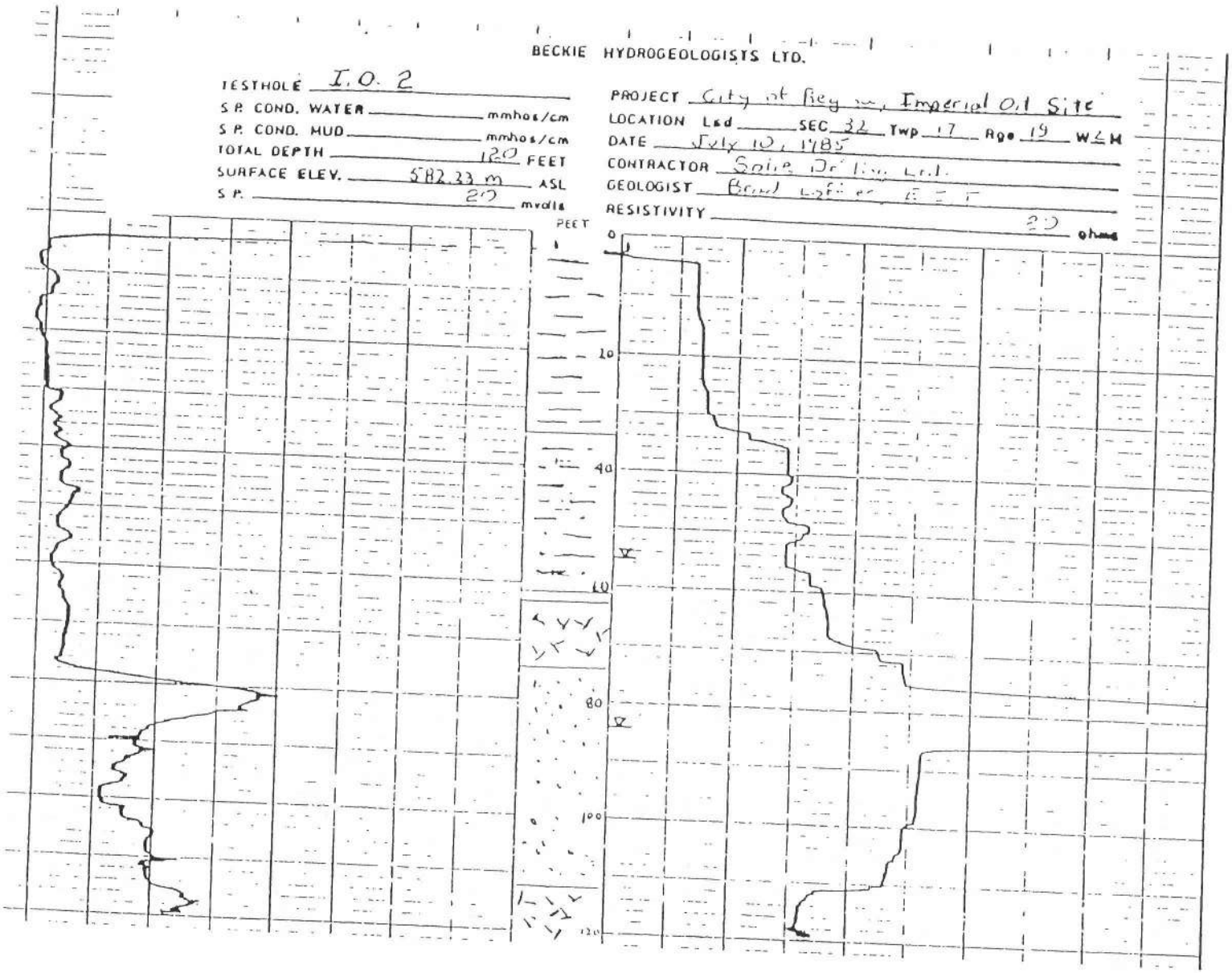
TESTHOLE M.P. 3
S.P. COND. WATER ____ mmhos/cm
S.P. COND. MUD ____ mmhos/cm
TOTAL DEPTH 120 FEET
SURFACE ELEV. 584.89 m ASL
S.P. 2.0 mvolts

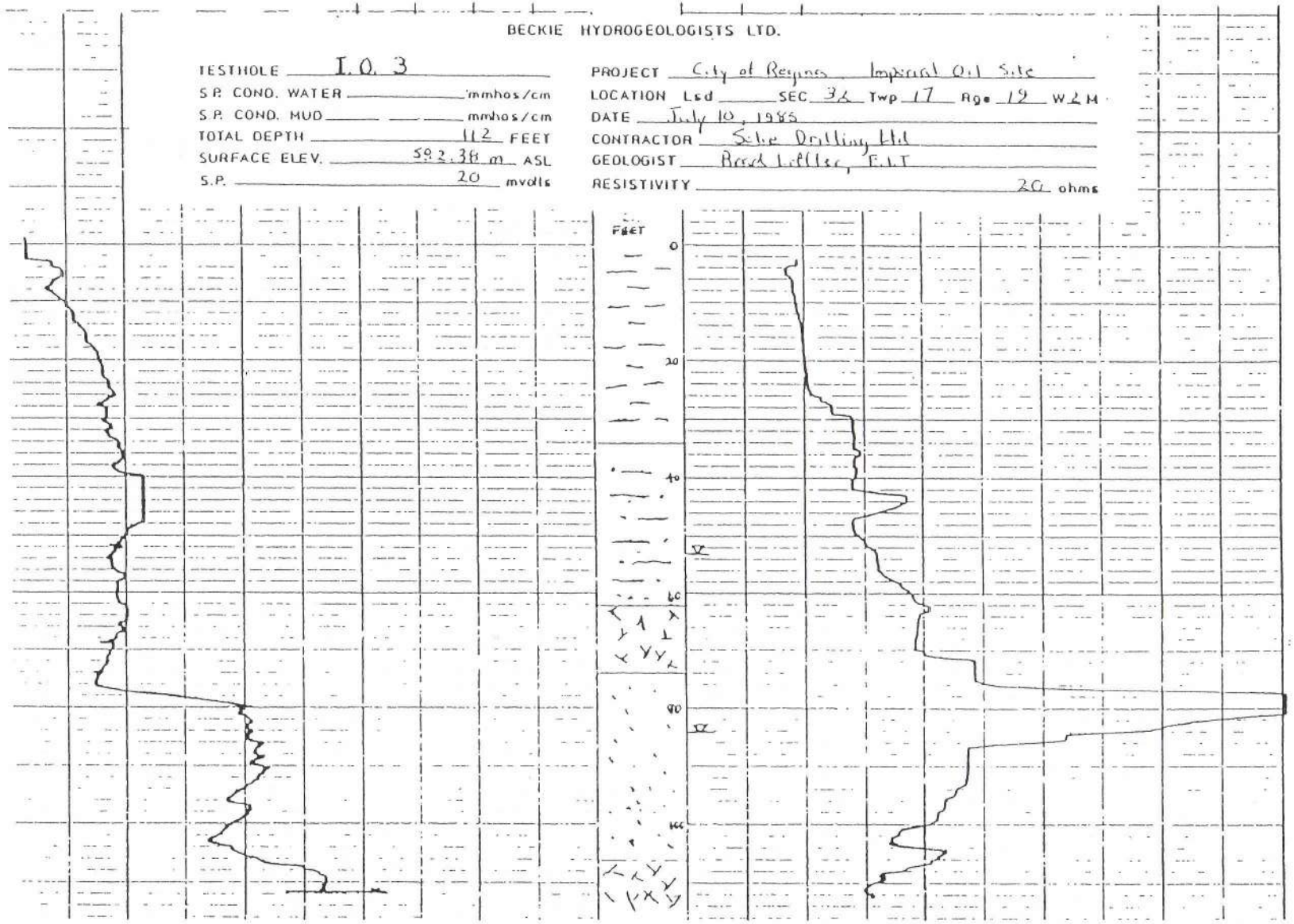
PROJECT City of Regina, Mount Pleasant
LOCATION Lsd ____ SEC 6 Twp 18 Rge 19 W2
DATE July 8, 1985
CONTRACTOR Solie Drilling Ltd.
GEOLOGIST Brad Loffler, E.I.T.
RESISTIVITY 2.0 ohm

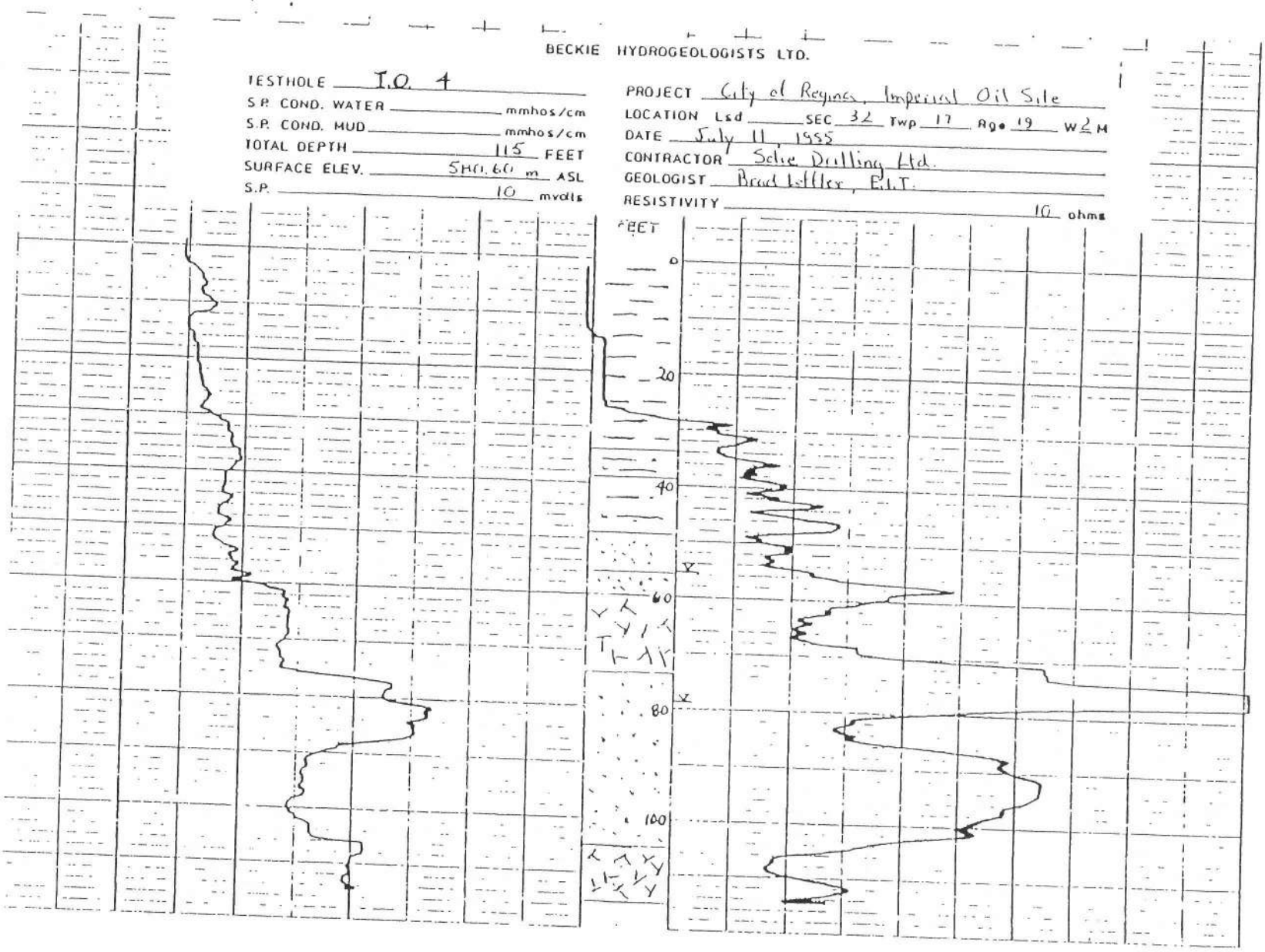



Beckie Hydrogeologists Ltd.
TESTHOLE M.P. 4
S.R COND. WATER mmhos/cm
S.P. COND. MUD mmhos/cm
TOTAL DEPTH 130 FEET
SURFACE ELEV. SRS: 76 m ASL
S.P. 20 mvolts
PROJECT City of Regina, Mount Pleasant
LOCATION Lsd SEC 6 Twp 15 Rge 19 W 2
DATE July 8, 1985
CONTRACTOR Solie Drilling Ltd.
GEOLOGIST Brad Loffler, E.I.T.
RESISTIVITY 20 ohm
FEET
0
10
40
60
80
100
120


BECKIE HYDROGEOLOGISTS LTD.
TESTHOLE I.O. 1
S.P. COND. WATER ____ mmhos/cm
S.P. COND. MUD ____ mmhos/cm
TOTAL DEPTH 115 FEET
SURFACE ELEV. 582.41 m ASL
S.P. 20 mvdis
PROJECT City of Fort Mc. Imperial Oil Site
LOCATION Lsd ____ SEC 32 Twp 17 Rge 19 W4M
DATE July 9, 1985
CONTRACTOR Solie Drilling Ltd
GEOLOGIST Brad Loffler, EIT
RESISTIVITY 20 ohms
FEET
0
20
40
60
80
100

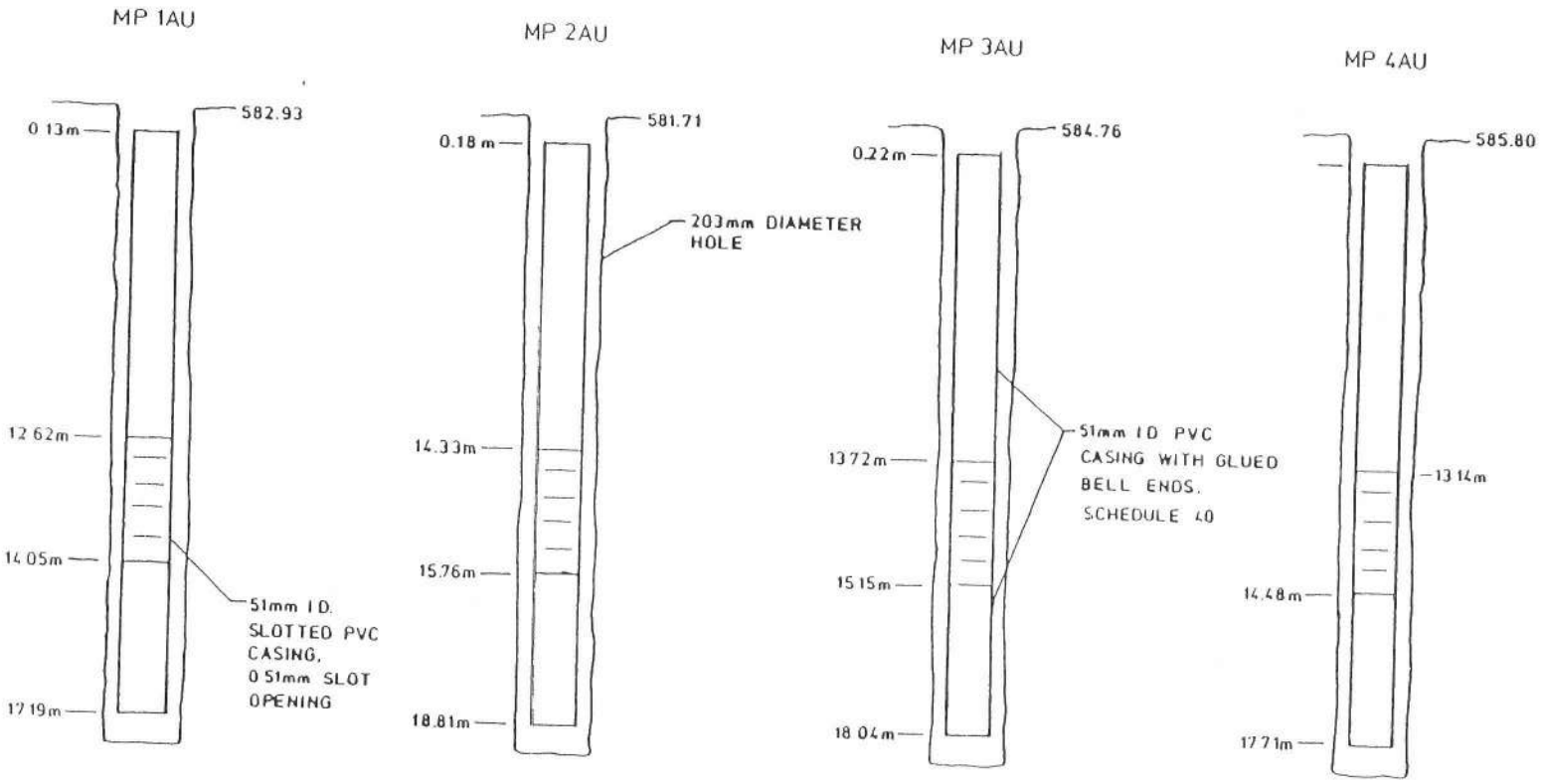

BECKIE HYDROGEOLOGISTS LTD.
TESTHOLE I.O. 2
S.P. COND. WATER ____ mmhos/cm
S.P. COND. MUD ____ mmhos/cm
TOTAL DEPTH 120 FEET
SURFACE ELEV. 582.33 m ASL
S.P. 20 mvolts
PROJECT City of Regina, Imperial Oil Site
LOCATION Lsd ____ SEC 32 Twp 17 Rge 19 W2M
DATE July 10, 1985
CONTRACTOR Soil Drilling Ltd.
GEOLOGIST Brad Lafleur, E.I.T.
RESISTIVITY 20 ohms
FEET
0
20
40
60
80
100
120


BECKIE HYDROGEOLOGISTS LTD.
TESTHOLE I.O. 3
S.P. COND. WATER ____ mmhos/cm
S.P. COND. MUD ____ mmhos/cm
TOTAL DEPTH 112 FEET
SURFACE ELEV. 593.38 m ASL
S.P. 20 mvolts
PROJECT City of Regina Imperial Oil Site
LOCATION Lsd ____ SEC 32 Twp 17 Rge 19 W2M
DATE July 10, 1985
CONTRACTOR Schie Drilling Ltd
GEOLOGIST Reed Lidlier, E.I.T
RESISTIVITY 20 ohms
FEET
0
20
40
60
80
100


BECKIE HYDROGEOLOGISTS LTD.
TESTHOLE I.O. 4
S.P. COND. WATER mmhos/cm
S.P. COND. MUD mmhos/cm
TOTAL DEPTH 115 FEET
SURFACE ELEV. 580.60 m ASL
S.P. 10 mvolts
PROJECT City of Regina, Imperial Oil Site
LOCATION Lsd SEC 32 Twp 17 Rge 19 W2M
DATE July 11, 1955
CONTRACTOR Selco Drilling Ltd.
GEOLOGIST Broad Loffler, P.Eng.
RESISTIVITY 10 ohms
FEET
0
20
40
60
80
100

APPENDIX C

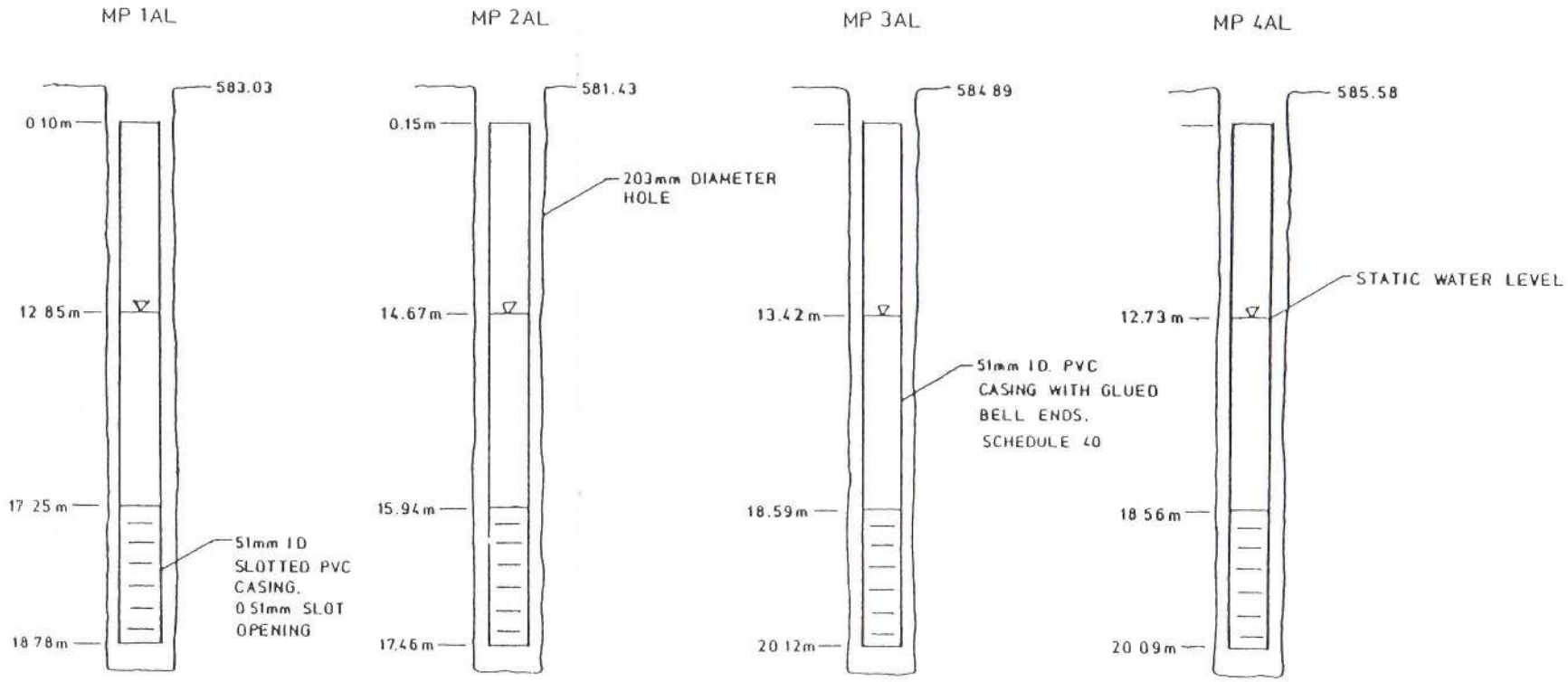
CITY OF REGINA
MOUNT PLEASANT PARK
CONSTRUCTION DETAILS OF OBSERVATION WELLS
A-ZONE AQUIFER
AUGUST 1985



NOTE : DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD.

CITY OF REGINA
MOUNT PLEASANT PARK
CONSTRUCTION DETAILS OF OBSERVATION WELLS
A-ZONE AQUIFER
AUGUST 1985



NOTE : DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD.

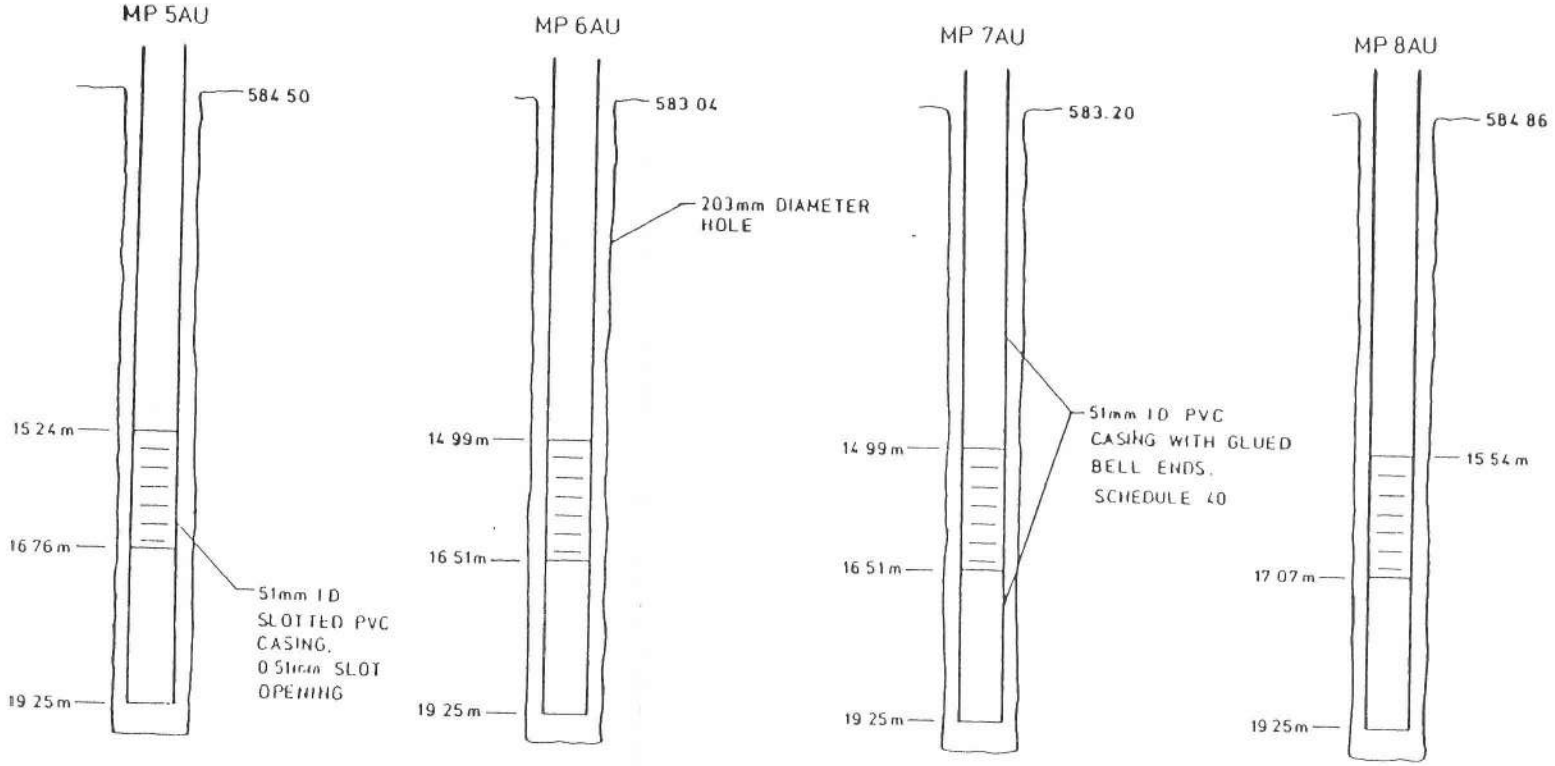
CITY OF REGINA

MOUNT PLEASANT PARK

CONSTRUCTION DETAILS OF OBSERVATION WELLS

A-ZONE AQUIFER

FEBRUARY 1986



NOTE : DIAGRAM NOT TO SCALE.
DEPTHS IN METRES BELOW GROUND

BECKIE HYDROGEOLOGISTS LTD

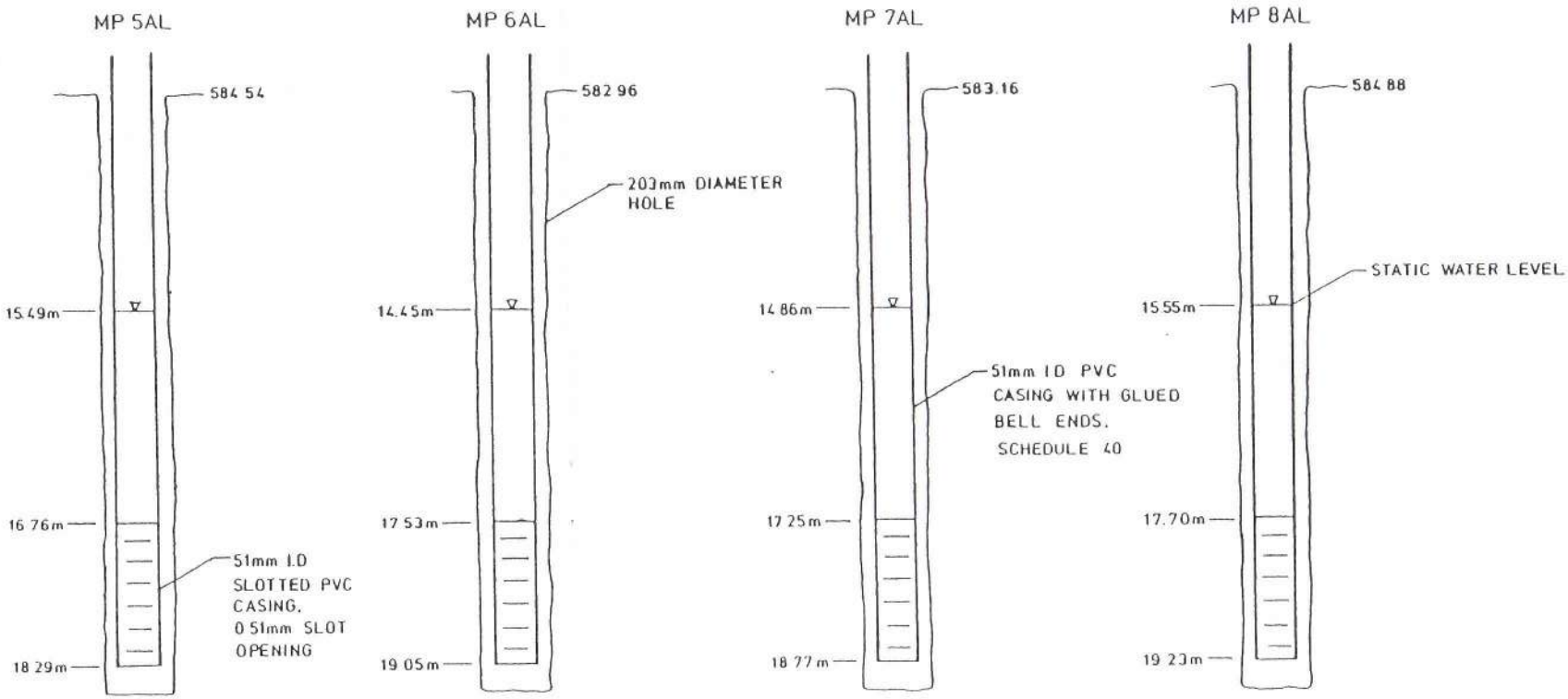
CITY OF REGINA

MOUNT PLEASANT PARK

CONSTRUCTION DETAILS OF OBSERVATION WELLS

A-ZONE AQUIFER

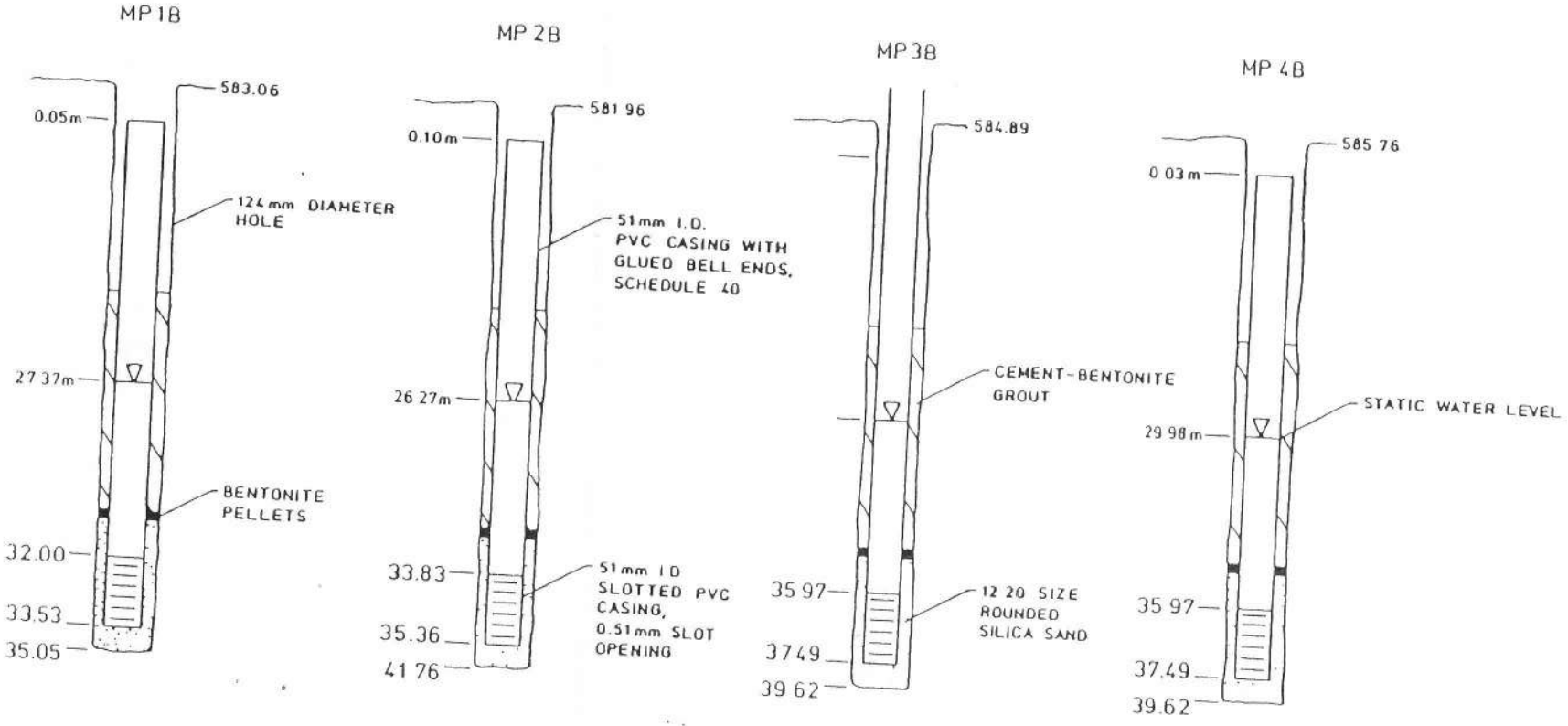
FEBRUARY 1986



NOTE · DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD

CITY OF REGINA
MOUNT PLEASANT PARK
CONSTRUCTION DETAILS OF OBSERVATION WELLS
B-ZONE AQUIFER
JULY 1985

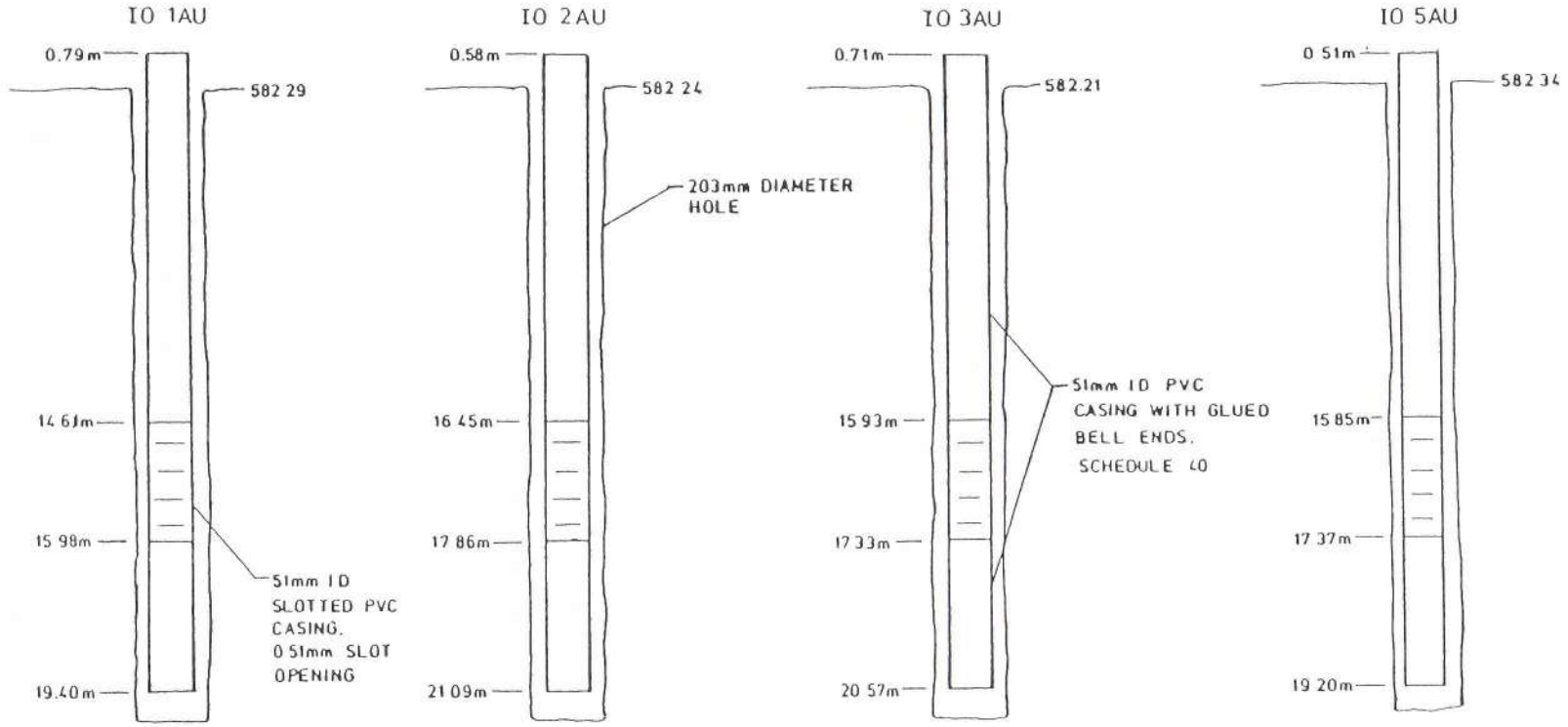


NOTE · Diagram not to scale.
Depths in metres below ground

BECKIE HYDROGEOLOGISTS LTD

C-5

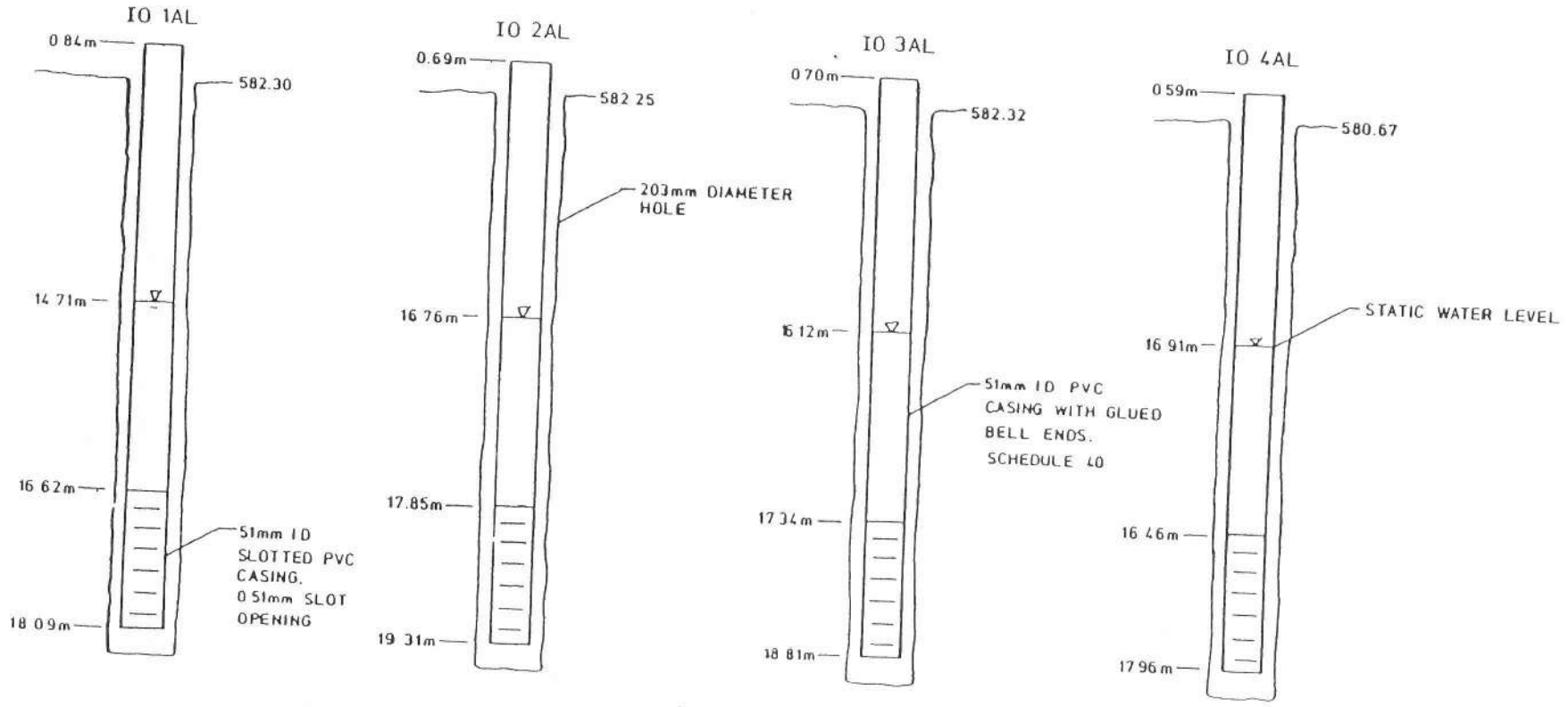
CITY OF REGINA
IMPERIAL OIL SITE
CONSTRUCTION DETAILS OF OBSERVATION WELLS
A-ZONE AQUIFER
AUGUST 1985



NOTE · DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD

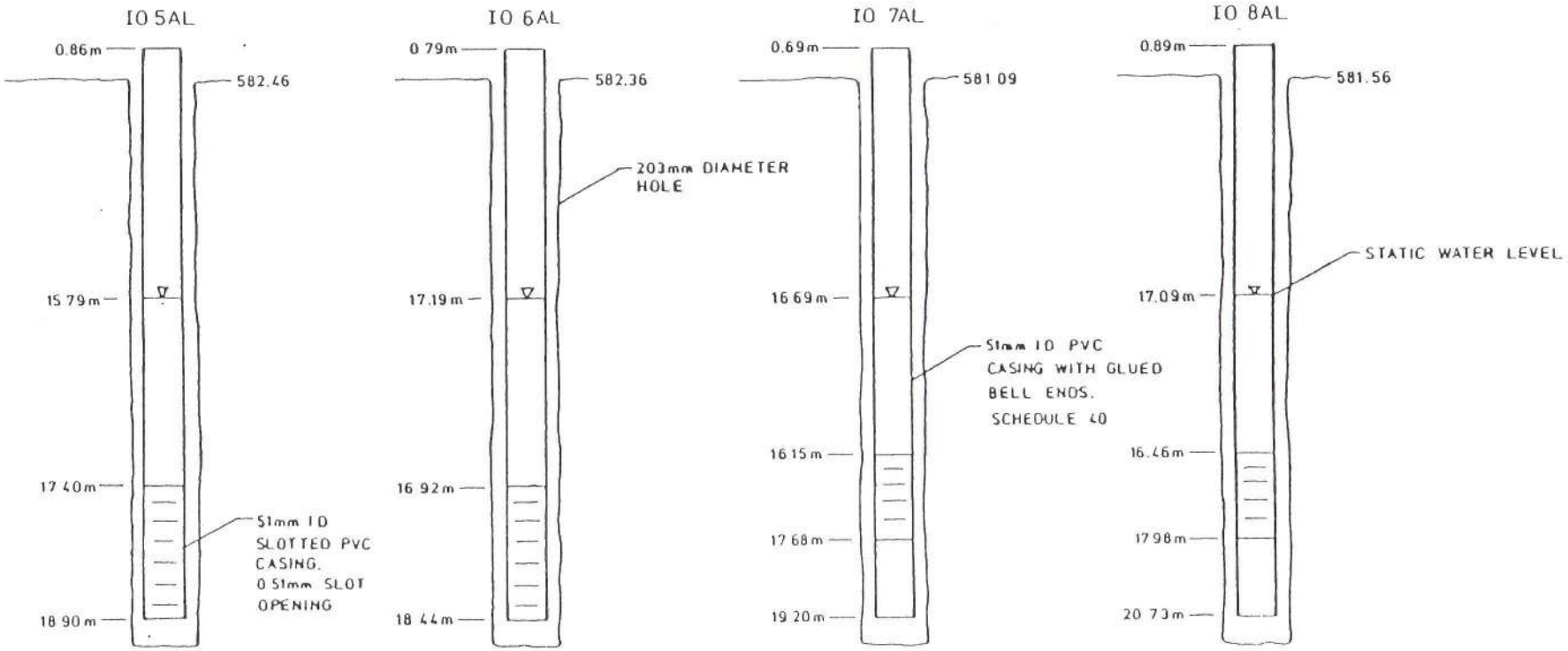
CITY OF REGINA
IMPERIAL OIL SITE
CONSTRUCTION DETAILS OF OBSERVATION WELLS
A-ZONE AQUIFER
AUGUST 1985



NOTE DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD

CITY OF REGINA
IMPERIAL OIL SITE
CONSTRUCTION DETAILS OF OBSERVATION WELLS
A-ZONE AQUIFER
FEBRUARY 1986



C-8

NOTE : DIAGRAM NOT TO SCALE.
DEPTH IN METERS BELOW GROUND.

BECKIE HYDROGEOLOGISTS LTD

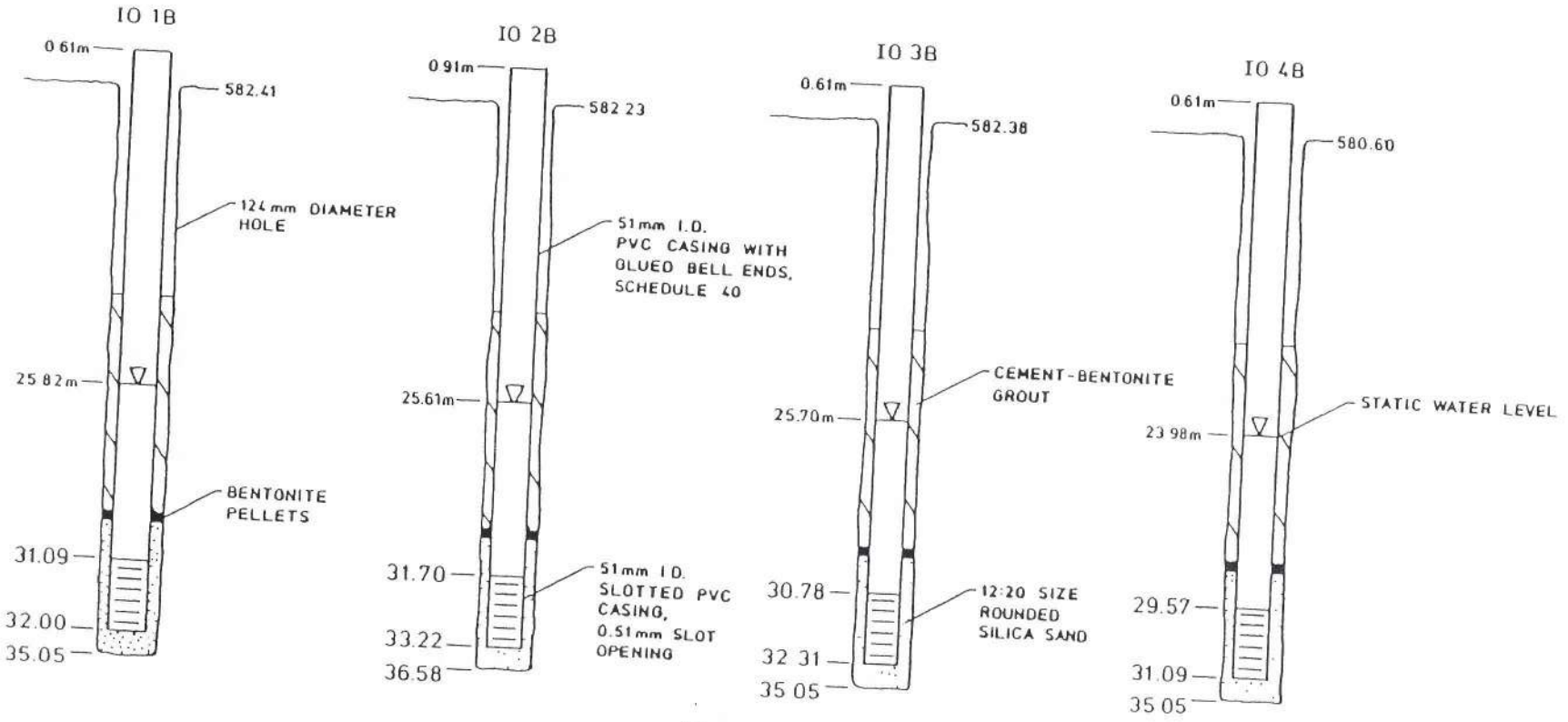
CITY OF REGINA

IMPERIAL OIL SITE

CONSTRUCTION DETAILS OF OBSERVATION WELLS

B-ZONE AQUIFER

JULY 1985



NOTE : Diagram not to scale.

Depths in metres below ground.

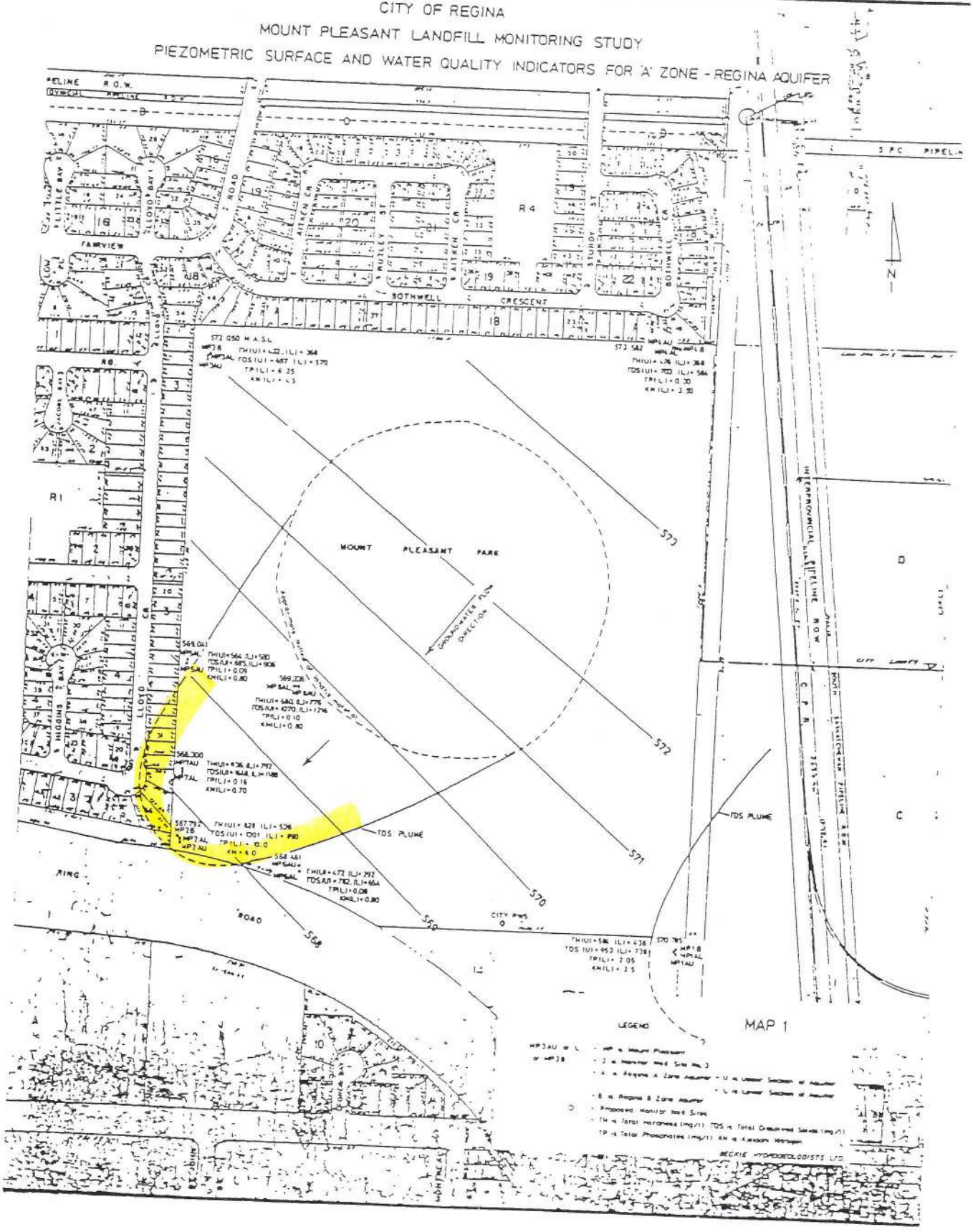
BECKIE HYDROGEOLOGISTS LTD.

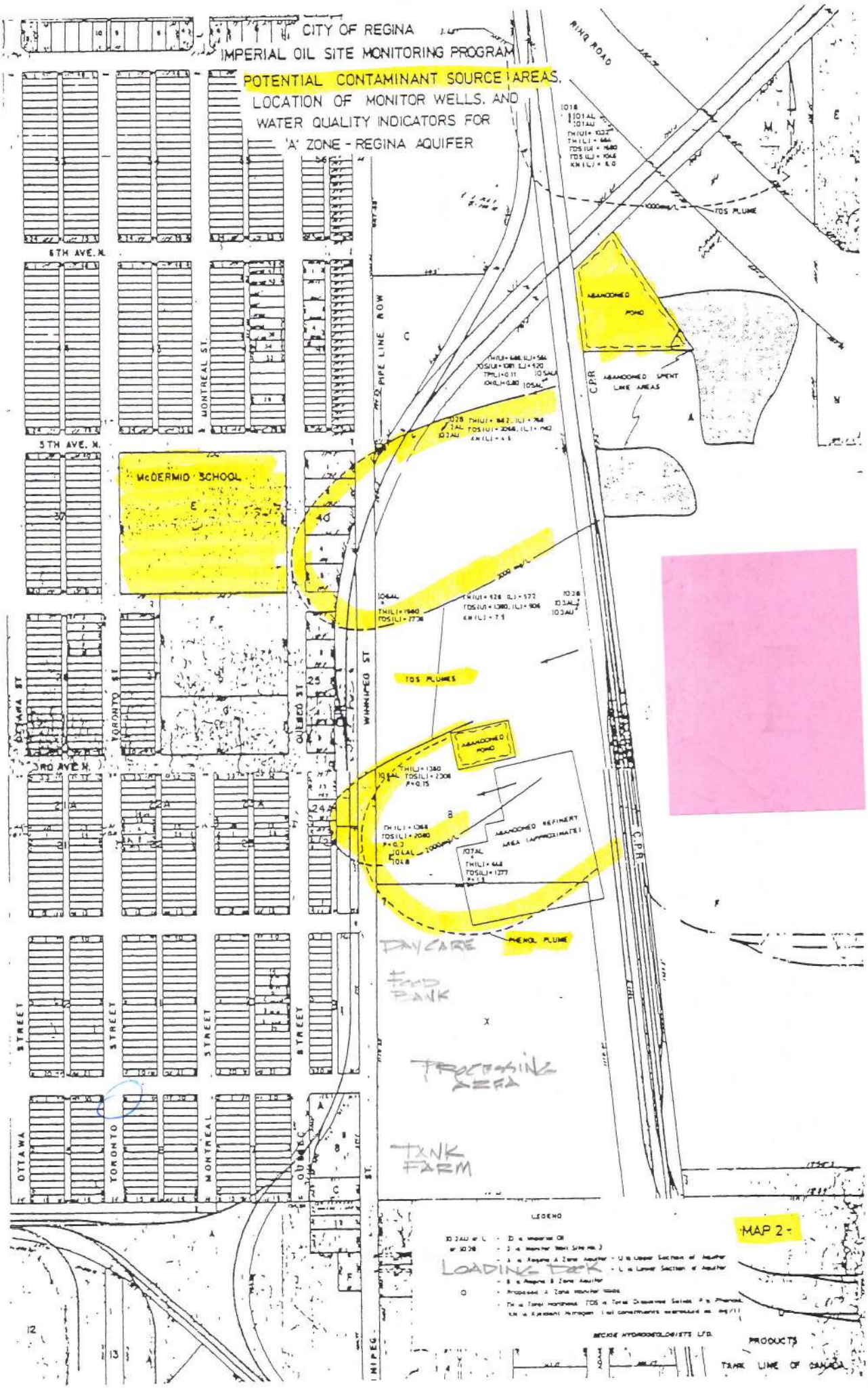
MAPS

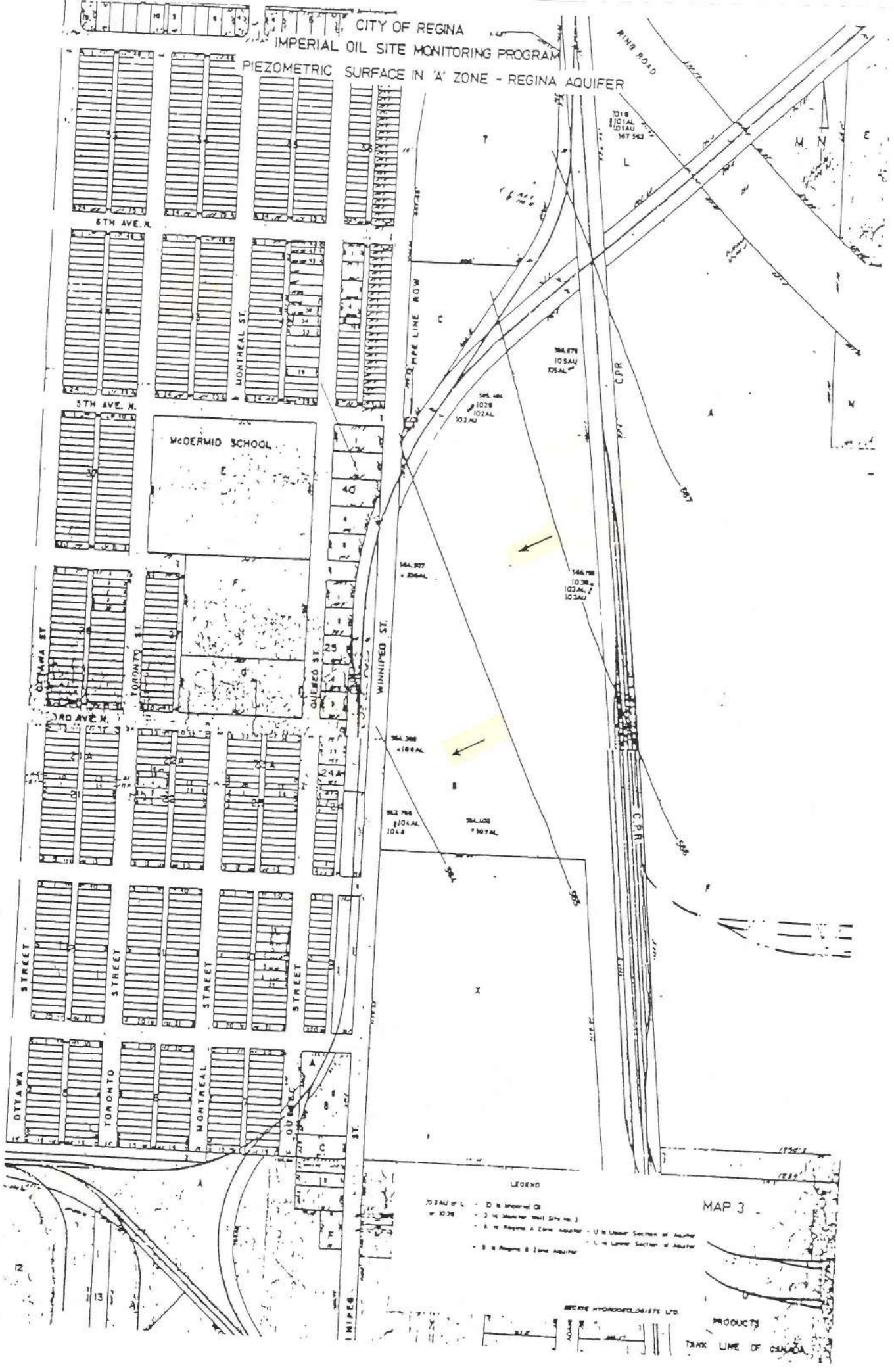
CITY OF REGINA

MOUNT PLEASANT LANDFILL MONITORING STUDY

PIEZOMETRIC SURFACE AND WATER QUALITY INDICATORS FOR 'A' ZONE - REGINA AQUIFER



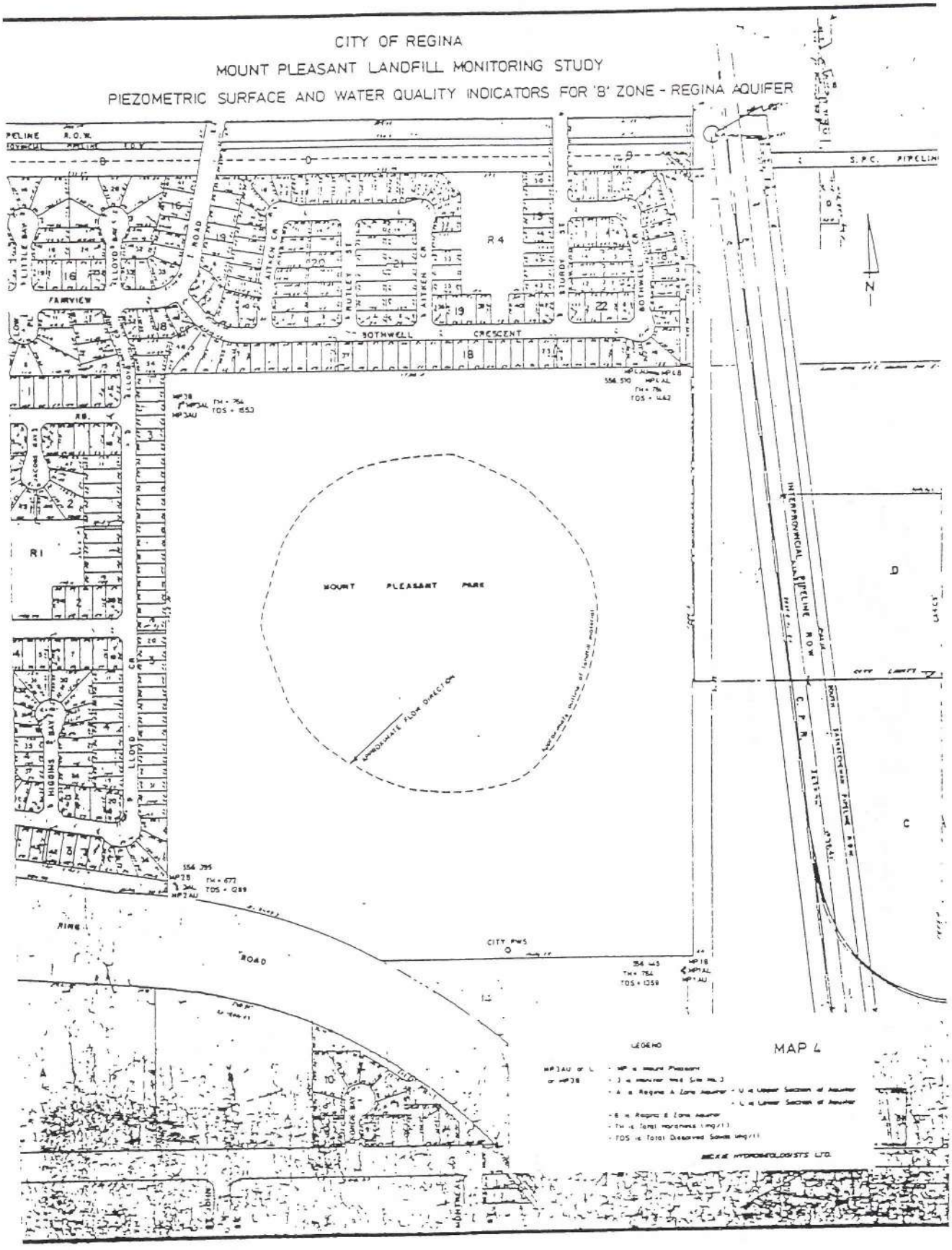

CITY OF REGINA
IMPERIAL OIL SITE MONITORING PROGRAM
POTENTIAL CONTAMINANT SOURCE AREAS, LOCATION OF MONITOR WELLS, AND WATER QUALITY INDICATORS FOR 'A' ZONE - REGINA AQUIFER
RING ROAD
TDS PLUME
ABANDONED POND
ABANDONED SPENT LIME AREAS
C.P.R.
6TH AVE. N.
5TH AVE. N.
4TH AVE. N.
3RD AVE. N.
McDERMID SCHOOL
MONTREAL ST.
PIPE LINE R.O.W.
OTTAWA ST
TORONTO ST
QUEBEC ST
WINNIPEG ST
TDS PLUMES
ABANDONED POND
ABANDONED REFINERY AREA (APPROXIMATE)
PHENOL PLUME
DAYCARE
FOOD BANK
TRUCKING AREA
TANK FARM
LOADING DOCK
LEGEND
MAP 2
PRODUCTS


CITY OF REGINA
IMPERIAL OIL SITE MONITORING PROGRAM
PIEZOMETRIC SURFACE IN 'A' ZONE - REGINA AQUIFER
RING ROAD
6TH AVE. N.
5TH AVE. N.
4TH AVE. N.
McDERMID SCHOOL
MONTREAL ST.
PIPE LINE ROW
CPR
OTTAWA ST
TORONTO ST.
QUEBEC ST.
WINNIPEG ST.
OTTAWA STREET
TORONTO STREET
MONTREAL STREET
QUEBEC STREET
WINNIPEG ST.
LEGEND
MAP 3
PRODUCTS
TANK LINE OF CANADA

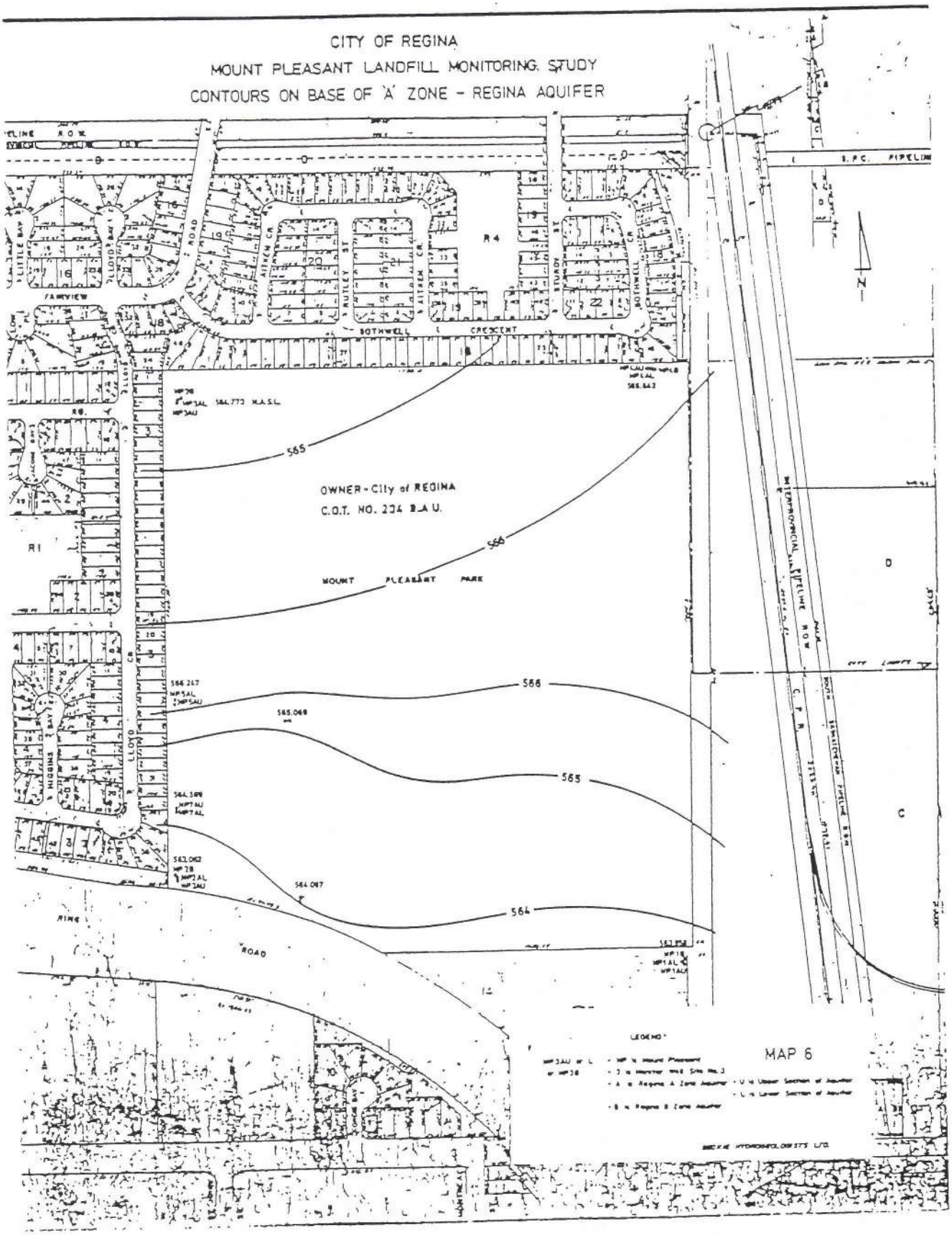
CITY OF REGINA

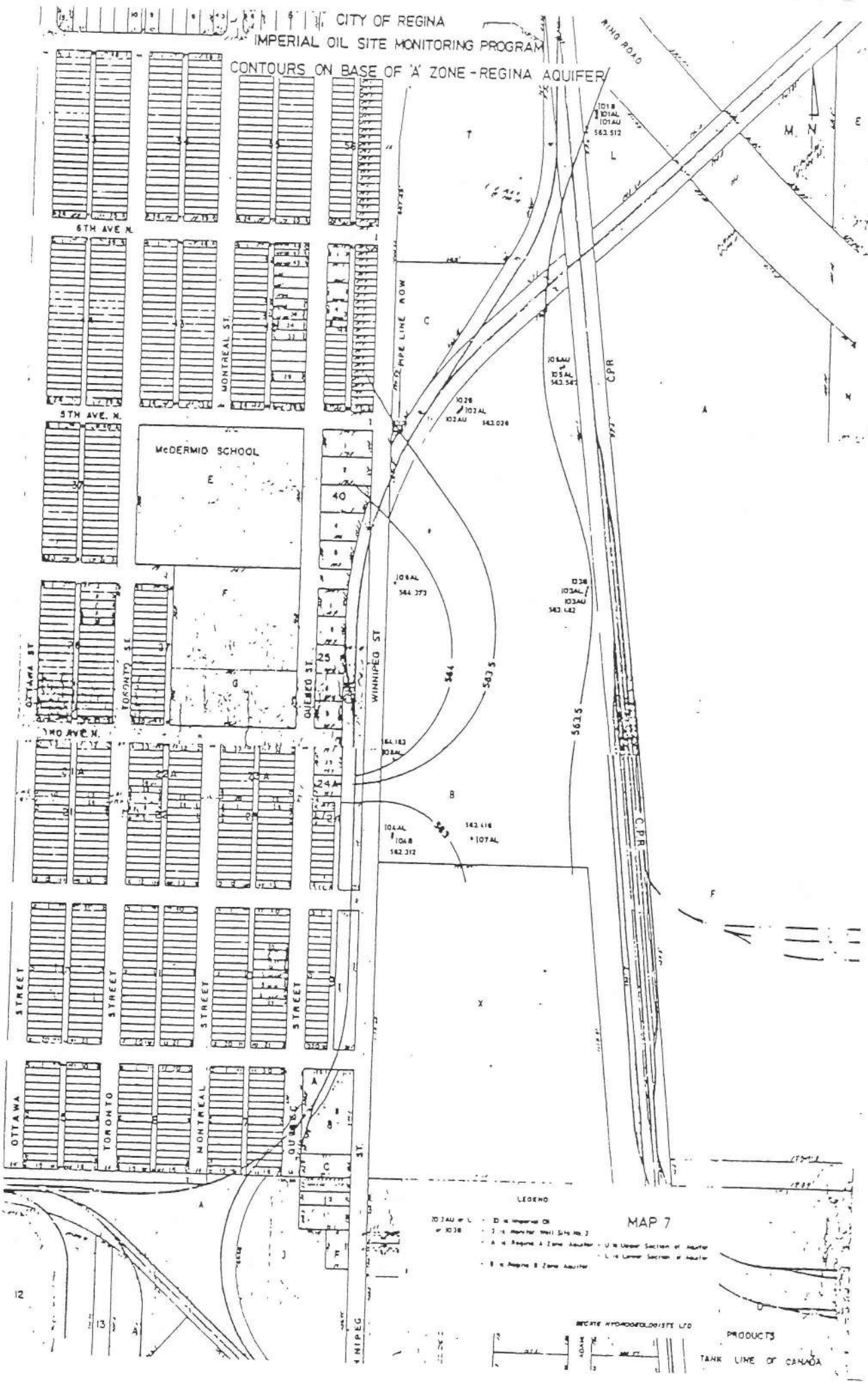
MOUNT PLEASANT LANDFILL MONITORING STUDY

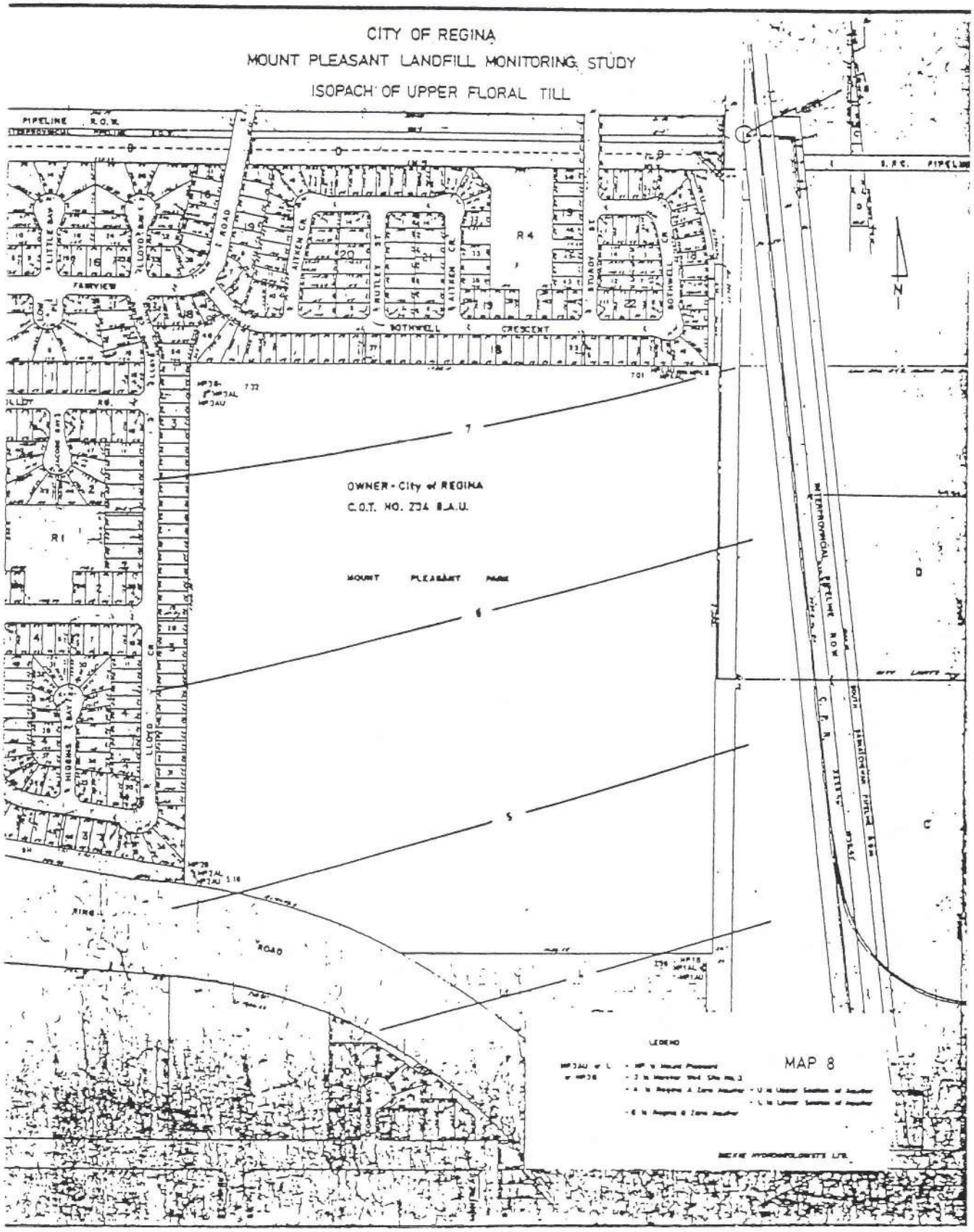
PIEZOMETRIC SURFACE AND WATER QUALITY INDICATORS FOR '8' ZONE - REGINA AQUIFER

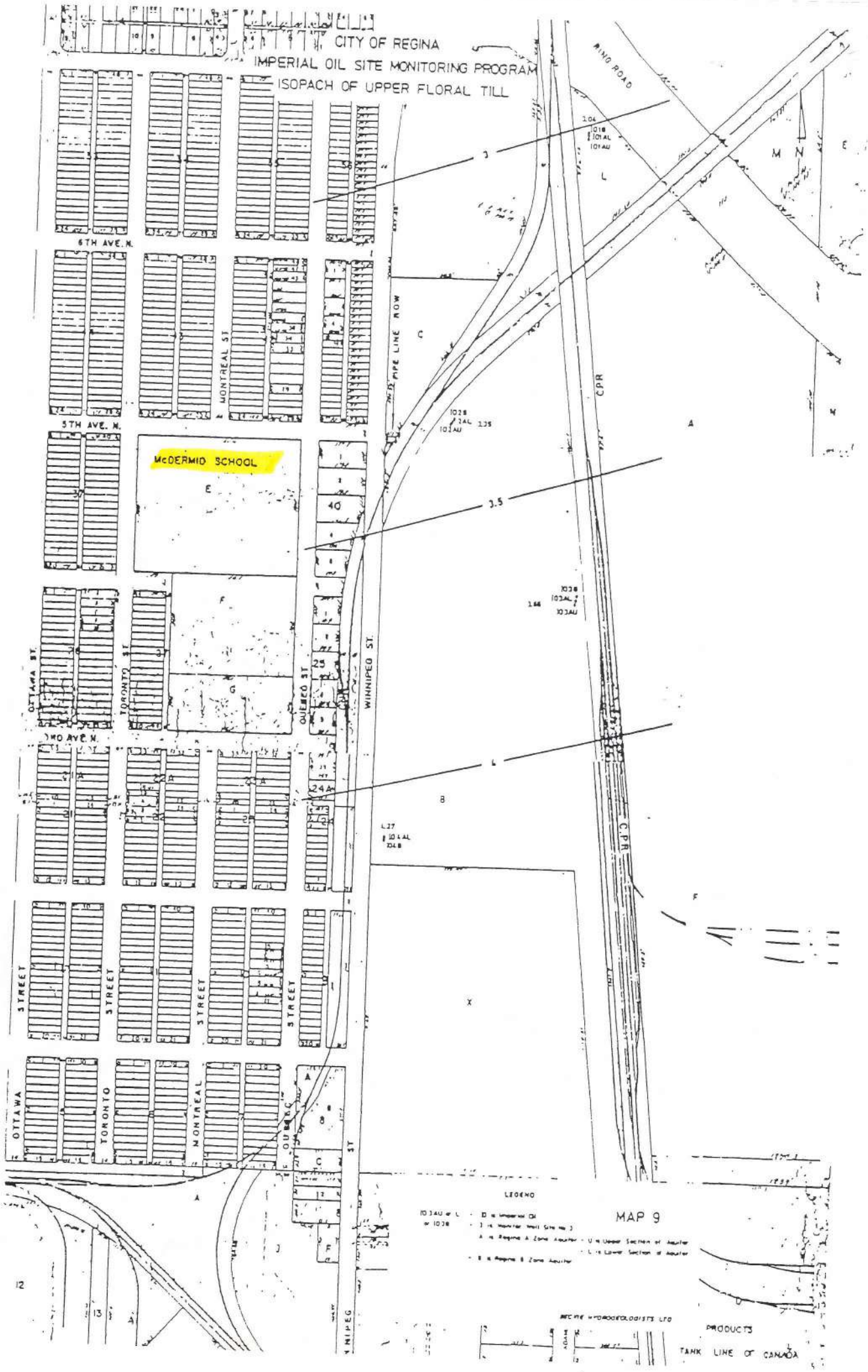


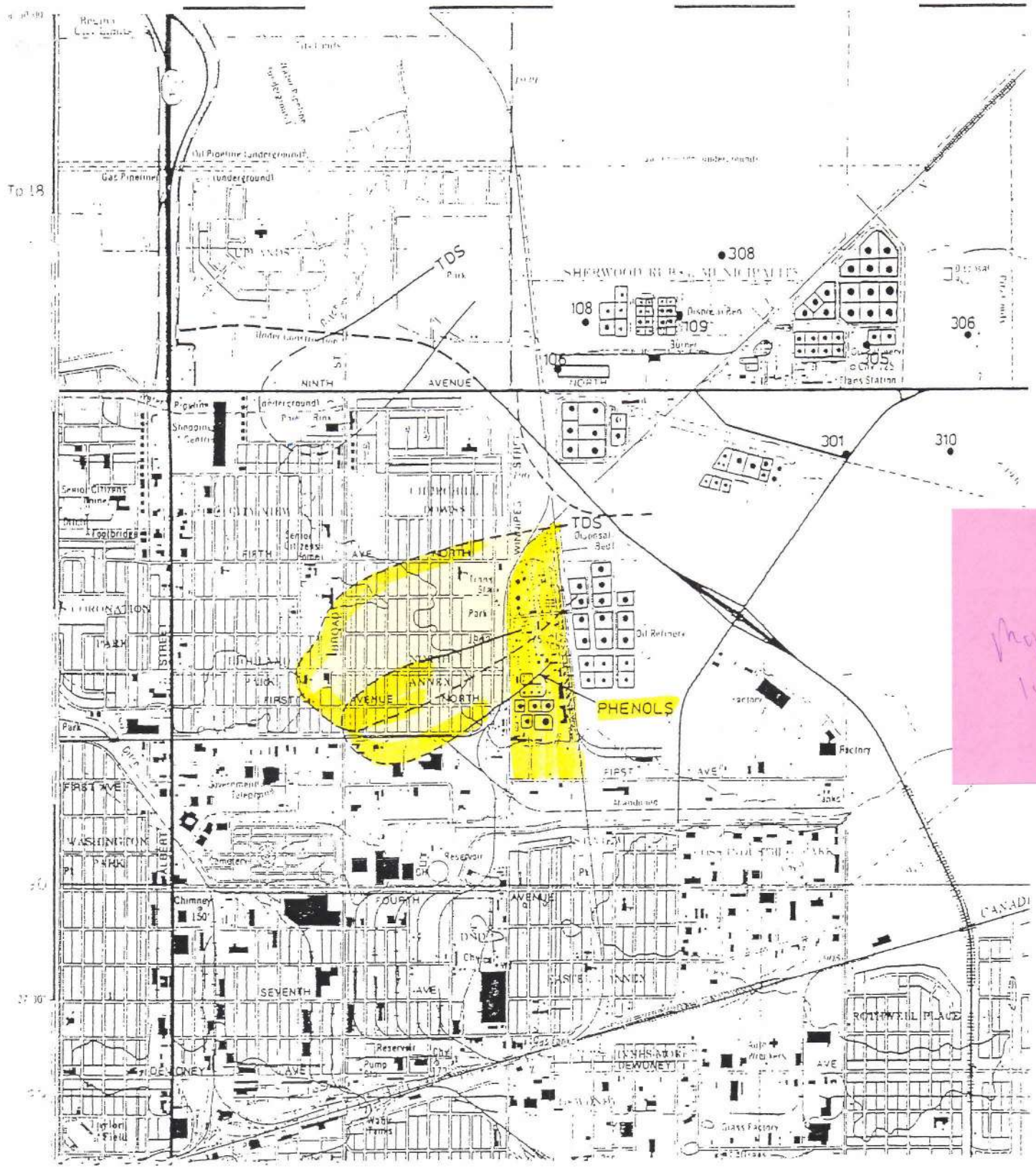

CITY OF REGINA
IMPERIAL OIL SITE MONITORING PROGRAM
PIEZOMETRIC SURFACE AND WATER QUALITY
INDICATORS FOR 'B' ZONE - REGINA AQUIFER
RING ROAD
6TH AVE. N.
5TH AVE. N.
4TH AVE. N.
McDERMID SCHOOL
MONTREAL ST.
PIPE LINE ROW
C.P.R.
QUEBEC ST.
WINNIPEG ST.
OTTAWA ST.
TORONTO ST.
MONTREAL ST.
OTTAWA STREET
TORONTO STREET
MONTREAL STREET
QUEBEC STREET
WINNIPEG ST.
GROUNDWATER FLOW
LEGEND
MAP 5
PRODUCTS
TANK LINE OF CANADA


CITY OF REGINA
MOUNT PLEASANT LANDFILL MONITORING STUDY
CONTOURS ON BASE OF 'A' ZONE - REGINA AQUIFER
565
566
568
565
564
OWNER - City of REGINA
C.O.T. NO. 224 B.A.U.
MOUNT PLEASANT PARK
R4
R1
MAP 6


CITY OF REGINA
IMPERIAL OIL SITE MONITORING PROGRAM
CONTOURS ON BASE OF 'A' ZONE - REGINA AQUIFER
RING ROAD
6TH AVE N.
5TH AVE N.
4TH AVE N.
McDERMID SCHOOL
MONTREAL ST.
PIPE LINE ROW
CPR
OTTAWA ST
TORONTO ST
QUEBEC ST
WINNIPEG ST
OTTAWA
TORONTO
MONTREAL
QUEBEC ST.
WINNIPEG
12
13
LEGEND
MAP 7
PRODUCTS
TANK LINE OF CANADA


CITY OF REGINA
MOUNT PLEASANT LANDFILL MONITORING STUDY
ISOPACH OF UPPER FLORAL TILL
PIPELINE R.O.W.
B.A.C. PIPELINE
R4
R1
BOTHWELL CRESCENT
AITKEN CR.
BUTLEY ST.
STUDLEY ST.
FAIRVIEW
LLOYD
HIGGINS BAY
OWNER - City of REGINA
C.O.T. NO. 2224 B.A.U.
MOUNT PLEASANT PARK
INTERPROVINCIAL PIPELINE R.O.W.
C.P.R.
RING ROAD
LEGEND
MAP 8


CITY OF REGINA
IMPERIAL OIL SITE MONITORING PROGRAM
ISOPACH OF UPPER FLORAL TILL
RING ROAD
6TH AVE. N.
5TH AVE. N.
4TH AVE. N.
MONTREAL ST
PIPE LINE ROW
CPR
McDERMID SCHOOL
OTTAWA ST.
TORONTO ST.
QUEBEC ST.
WINNIPEG ST.
3 STREET
OTTAWA
TORONTO
MONTREAL
QUEBEC
WINNIPEG ST
3.5
LEGEND
MAP 9
PRODUCTS
TANK LINE OF CANADA



LEGEND

310
● CCRL MONITOR WELLS

NOTE:
(1) Aquifer extent and texture are unknown beyond study areas.

(2) Extent of plumes depends on (1).

SCALE 1: 25,000

0 500 1000 metres

CITY OF REGINA

GROUNDWATER MONITORING PROGRAM

MAP SHOWING POSSIBLE EXTENT OF LEACHATE PLUMES IN 'A' ZONE OF REGINA AQUIFER

BECKIE HYDROGEOLOGISTS LTD.

MAP 10