PARSONS LAKE GAS PLANT
PARSONS LAKE, N.W.T.

1976 GEOTECHNICAL SURVEY

PART I

PREPARED FOR

GULF OIL CANADA LIMITED
CALGARY, ALBERTA

R.M.HARDY & ASSOCIATES LTD.
CONSULTING ENGINEERING & PROFESSIONAL SERVICES
GEOTECHNICAL DIVISION

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PROPOSED GAS PLANT
GULF OIL CANADA LIMITED
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MAY, 1976
CS 3343

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1.0 INTRODUCTION

1.1 General

R. M. Hardy & Associates Ltd., Calgary, was commissioned by Gulf Oil Canada Limited to carry out a detailed geotechnical investigation at the site of a proposed gas processing plant near Parsons Lake, Northwest Territories. The objective of the 1976 Geotechnical Survey (Phase II - Site Investigation) was to provide subsurface information and soil parameters to be used during Phase I - Engineering. Phase I - Engineering will be concerned with establishing foundation design and construction criteria for the proposed gas plant and ancillary facilities.

Phase I - Site Investigation consisted of (i) a field drilling program in 1974 to assess potential granular borrow sources in the Parsons Lake-Eskimo Lakes area (Reference No. 1), and (ii) a preliminary geotechnical study in 1975 to assist with the location of a plantsite and related facilities (Reference No. 2). Both programs were carried out by other geotechnical consultants under the direction of Gulf Oil Canada Limited.

This report presents the results of the 1976 field drilling program and surficial geology study and discusses subsurface conditions relative to the February 1976 location of the gas plant and facilities (Gulf Oil Canada Limited, Drawing 1-75131-25). The study area is shown on Figure 1.1.

1.2 Scope

The scope of Phase II - Site Investigation, as outlined in the project proposal, would be (i) to provide a detailed surficial geology map for the study area, using air photos and test hole information, and (ii) to delineate subsoil conditions at the proposed locations of the gas plant and ancillary facilities, consisting of a S.T.O.L. airstrip, barge dock, staging area, transporter road, access roads, service corridor and well clusters. Additional studies would evaluate the granular borrow sources drilled in 1974 (Reference No. 1), and establish permanent survey benchmarks or monuments. A hydrologic study of the site area is to be carried out in June, 1976 by R. M. Hardy & Associates Ltd. and will be reported under separate cover.

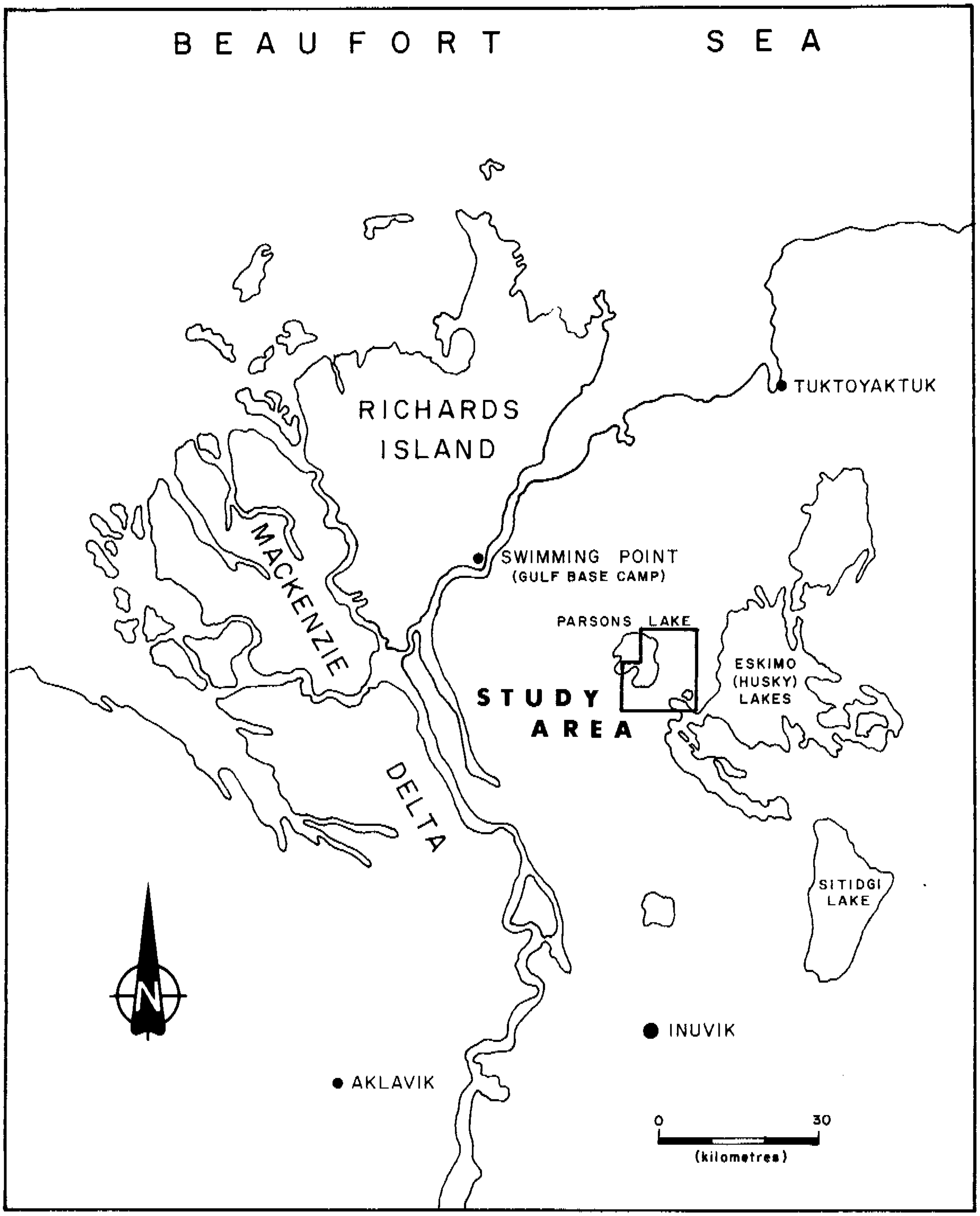


FIGURE 1.1 LOCATION OF STUDY AREA

1.2.1 Field Drilling Program

A field drilling program, comprising some two hundred test holes, would be carried out in March and early April of 1976 to obtain subsurface information in the following areas:

(i) plantsite

(ii) S.T.O.L. airstrip

(iii) barge docksite

(iv) staging area

(v) transporter road (docksite to plantsite)

(vi) access roads (plantsite to airstrip and borrow areas)

(vii) service corridor, consisting of roads and an aboveground pipeline between the well clusters and plantsite

(viii) well cluster sites

(ix) granular borrow sources

The proposed locations for the facilities to be investigated during the 1976 Geotechnical Survey are shown in Figure 1.2.

Selection and subcontracting of two drill rigs and equipment would be necessary to complete the field program within the given time constraints. Supervision of the field program and technical support would be provided by R. M. Hardy & Associates Ltd. Logistic support would be provided by Gulf Oil Canada Limited.

1.2.2 Laboratory Testing Program

Soil samples collected during the field program would be packaged and shipped to the Calgary laboratory of R. M. Hardy & Associates Ltd. Laboratory testing would include soil and ground ice classification and determination of index and engineering properties for both frozen and unfrozen soils.

Undisturbed cores would be obtained in frozen soils where the granular content is not so high as to prevent coring.

Undisturbed samples of lake sediment would be obtained at the proposed docksite, allowing strength tests to be carried out for use in dock design.

A report would be prepared describing the results of the field program and laboratory testing.

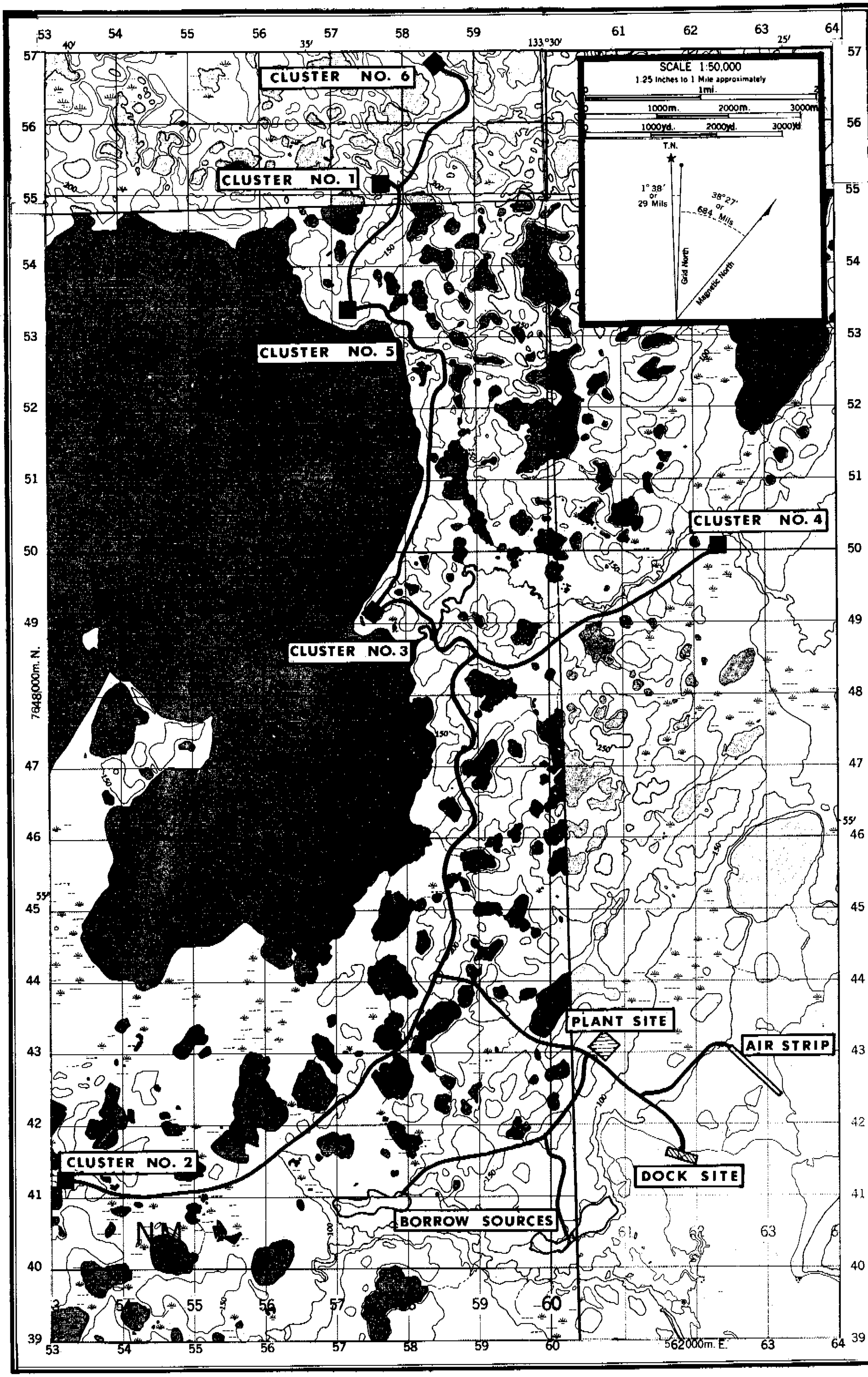


Figure 1.2 FACILITY LOCATIONS

1.3 Authorization

Authorization to proceed with the Phase II Site Investigation program was issued on February 23, 1976 in Gulf Oil Canada Limited Field Work Order 82602, authorized by Mr. F. J. Robinson, P.Eng. The study was supervised by Mr. F. J. Robinson. Logistic support for the field program was provided by Messrs. K. Woldum, E. Severson and H. Martin of Gulf Oil Canada Limited.

1.4 Personnel

Phase II-Site Investigation was organized and supervised by Mr. R. S. Tenove, M.Eng., P.Eng. as Project Engineer. The scope of the study relative to design engineering was directed by Dr. J. F. Nixon, P.Eng., Project Director.

Surficial geology mapping and layout of the field program was carried out by Mr. I. G. Jones, M.Sc., with the support of Mr. M. Stepanek, M.Sc., P.Eng.

The field drilling program was carried out by Messrs. S. Abrey, M. Rapsey, G. Lem, E.I.T. and G. Daw, E.I.T., under the supervision of Mr. T. Murray, E.I.T., and Mr. R. S. Tenove, P.Eng.

Survey control of survey movements and test holes was carried out by Messrs. A. Costin, M. Bursa and J. Ftichar.

Laboratory testing was supervised by Mr. R. Cooper, and drafting for the report was carried out by Mrs. B. Brinker and Messrs. A. Costin, M. Bursa, Y. Kunimoto and L. Bell.

Field logistical support was provided by Gulf Oil Canada Limited under the supervision of Mr. F. J. Robinson, P.Eng. and in the field by Messrs. K. Woldum, E. Severson and H. Martin.

2.0 SITE DESCRIPTION AND SURFICIAL GEOLOGY

This section discusses the physiography and surficial geology of the Parsons Lake-Eskimo Lakes area. Conditions at sites proposed for the various facilities are considered in greater detail.

2.1 Surface Conditions

2.1.1 Physiography

The topography of the map area is shown on Plate A-1 (Appendix "A"). Physiographically, it lies within the

Morainic Hills and Pitted Outwash Plains subdivisions of the "Pleistocene coastlands" region, as defined by Mackay (Reference No. 3). The Morainic Hills form a southwest-northeast trending belt of steep-sided, rounded hills located between Parsons and Eskimo Lakes. Individual hills rise to over 200 feet (61 m) a.s.l., averaging about 150 feet (45 m) a.s.l., and are separated by flat to depressional fossil thermokarst areas containing numerous ponds and small lakes. Around the shores of Parsons Lake and Eskimo Lakes are poorly drained and gently sloping lacustrine plains, at an average elevation of 5 - 10 feet (1.5 m - 3 m) a.s.l. To the east of Eskimo Lakes, a small area of steep-sided, flat "mesa-like" landforms, constituting part of the Pitted Outwash Plains, falls within the study area.

2.1.2 Hydrology

Water bodies cover 20 to 30 percent of the map area (Plate A-1). The distribution of streams draining into and out of these lakes and ponds is shown on Plate A-1 which was compiled using air photographs. Drainage courses are divided into three groups according to flow regime during the warm season (i.e. continuous, intermittent or sporadic), and degree of channel development, as observed on the air photos.

2.1.3 Permafrost

The Parsons Lake area is located within the continuous permafrost zone. Frozen ground occurs everywhere at shallow depth, except in the vicinity of the larger water bodies. Active layer thicknesses vary according to surficial material. Maximum depths of thaw range from less than 12 inches (30 cm) in organic peats and silts, to as much as 40 inches (~1 m) in sparsely-vegetated gravels and sands.

At the docksite, the permafrost table is expected to lie well below the lakebed surface, where depths of water exceed 7 to 10 feet (2 m to 3 m). In areas of shallower water, the sediment was frozen from the surface, making delineation of the permafrost table difficult.

2.1.4 Ground Ice

The test hole logs, and examination of frozen cores, collected during the 1976 field program, indicate that excess ice occurs throughout the area, as lenses, veins and pore ice. Massive segregated ice is found most commonly in glaciofluvial sediments, often at the contact between the sands and gravels, and any overlying fine-grained veneer. Ice wedges appear to be confined to the fine-grained silts, clays and peats. Massive ice also forms the core of several pingos, located in former lake basins to the south of Parsons Lake.

2.1.5 Dynamic Processes

As Rampton and Bouchard (Reference No. 4) have suggested, "permafrost-related (dynamic) processes, such as solifluction and soil creep, ice wedges formation, pingo formation and the (frost) heaving of areas formerly covered by water bodies, have a major effect upon the landscape". Slumping and other forms of slope instability are also important. The distribution of pingos, slumps and areas affected by solifluction and soil creep has been indicated on Plate A-1.

2.2 Surficial Geology

The map area is underlain at depth by silty sands, which form part of the pre-glacial Mackenzie Delta (Mackay, 1963, Reference No. 3). Resting on this deposit is a succession of glacial and post-glacial sediments of varying origin. These are discussed below in apparent chronological order, from oldest to youngest. The characteristics of each unit are summarized in Table 2.1.

TABLE 2.1

TERRAIN CLASSIFICATION		
Unit	Soil Description	Ground Ice
Organic	Peat, undifferentiated	High excess ice; ice wedges
Alluvial	Interbedded gravel and sand; minor silt	Massive ice at gravel- fine grained sediment contacts
Lacustrine	Silt with interbedded clay; minor sand. Strong organic component	High excess ice; ice wedges; pingos
Glaciofluvial	Interbedded sand and gravels; minor silt	Massive ice at gravel - fine grained sediment contacts
Morainic	Heterogeneous clay "till-like" material; very gravelly on hill tops	Massive ice at gravel - fine grained contacts

2.2.1 Morainic Deposits

In the southern part of the Morainic Hills belt, the smooth, rounded hills are composed of gravelly, clay-rich, "till-like" material. This heterogeneous deposit varies from a practically stone-free clay to a coarse gravel with very little fine material. In view of its great variability, it may be more correct to term it a "diamicton" (Reference No. 4). It is probably a terminal glacial deposit (Reference No. 3).

Excess ice contents average 20 to 30 percent in the morainic deposits. Massive ground ice occurs commonly at the contacts between gravelly material and the finer grained sediments.

2.2.2 Glaciofluvial Deposits

The relief of the Morainic Hills in the northern part of the study area is considerably more rugged. The hills in this region are composed of glaciofluvial sands and gravels, the deposition of which is believed to be related to the slow northeastward retreat of an ice front across the area (Reference No. 3). A number of small kames are present, some of which have been utilized as small scale sources of granular borrow. Massive ground ice is prevalent in the glaciofluvial material occurring most commonly at the contact with fine-grained sediments.

The Pitted Outwash Plains along the eastern margin of the map area are believed to have been deposited in a pro-glacial lake (Reference No. 3).

2.2.3 Lacustrine Deposits

The poorly-drained, former lake depressions within the Morainic Hills, as well as extensive areas around the shores of both Parsons Lake and Eskimo Lakes, are underlain by lacustrine silts with clay interbeds and minor sand. The silts frequently have an organic component, which may be dominant in the most poorly drained areas. Visible ice contents are high to very high in the lacustrine deposits, and ice wedge polygons are prominently visible on air photos. Pingos are restricted to this type of terrain.

2.2.4 Alluvial Deposits

Well graded gravels and minor sands occur in the valley of the first order stream entering Eskimo Lakes, south of Hans Bay, as floodplain deposits and as a series of depositional terraces on either side of the stream. Stratigraphically, these features consist of 3 to 60 feet (1 m to 18 m) of gravel with some sand, overlying silts and silty sands and often have a thin peat veneer. Excess ice contents are generally low but a number of massive ice bodies were intersected during drilling of test holes at these potential borrow sources (Reference No. 1).

2.2.5 Colluvial Deposits

The morainic and glaciofluvial landforms are generally overlain by a thin colluvial deposit. This consists essentially of slope washed and solifluctеd material, silts and sands, but includes, as well, some slumped material.

2.2.6 Organic Deposits

Except where it occurs as a thin surficial veneer, peat is confined to the most poorly drained valleys and depressions. Thicknesses of up to 14 feet (4.3 m) of organic material were intersected in test holes drilled during the 1976 field program. Excess ice contents are generally high in peat and ice wedges are common.

2.3 Surficial Geology Map

The surficial geology of the Parsons Lake-Eskimo Lakes area is shown on Plate A-1. This section provides details of the construction of this map, and summarizes conditions at the sites proposed for the different facilities.

2.3.1 Compilation of the Surficial Geology Map

Five major genetically-based units were mapped on aerial photographs, provided by Gulf Oil Canada Limited, employing a terrain typing system based on that developed by the Geological Survey of Canada. This system provides information on the constituent material, topography and drainage of a landform, as well as its genetic origin. The map units adopted correspond to the surficial deposits described in Section 2.2.1 with the exception of those of colluvial origin. Colluvial deposits were omitted during final compilation of the map, since this unit forms only a surficial veneer overlying the other major units. The airphoto mapping was checked by reference to the logs of test holes drilled during the 1976 field program.

2.3.2 Surface Conditions - Site Specific

The following paragraphs summarize conditions at each of the sites proposed for installation of facilities, with the exception of the barge dock. The locations of these facilities are shown on Figure 1.2.

2.3.2.1 Plantsite

The plantsite is located on top of a gently southwestward sloping, steep-sided moraine ridge. Average elevation of the site is approximately 145 feet (44 m) a.s.l., with a relief of 5 - 10 feet (1.5 - 3 m). The site appears to be well drained.

2.3.2.2 Airstrip

The S.T.O.L. airstrip is located on the lacustrine plain between the Morainic Hills and Eskimo Lakes. The site slopes gently towards the east at 1 to 2 percent, and is reasonably well drained.

2.3.2.3 Staging Area

The staging area is located immediately north of the docksite. It lies on the lacustrine plain, surrounding

Eskimo Lakes, at an elevation of 10 - 12 feet (3 m to 4 m) above the level of Hans Bay. The site appears to be well drained.

2.3.2.4 Well Cluster Sites

The well clusters are located on reasonably flat, steep-sided ridges and hills. Cluster No. 2 lies on a morainic hill, while the remaining clusters are situated on ridges composed of glaciofluvial material. All are reasonably well to well drained.

2.3.2.5 Service Corridor

General

Wherever feasible, the service corridor was located by Gulf Canada Limited along the crest of moraine and glaciofluvial ridges. Such a route will generally be well drained and somewhat less sensitive to disturbance than the lacustrine terrain. One problem is the steep grades which are encountered at the edges of the morainic and glaciofluvial landforms, where the route must descend to lacustrine terrain. Route segments between the plant-site and well clusters will be considered in turn.

Cluster No. 2 to Cluster No. 3

The route follows moraine and glaciofluvial ridges for most of its length, with generally short sections crossing lacustrine valleys and former lake beds. One 4000-foot (1220 m) long section of lacustrine sediments is traversed east of Cluster No. 2, but apparently cannot be avoided. Just south of Cluster No. 3 the route must cross the major valley of a stream flowing from Parsons Lake to Eskimo Lakes. Steep grades are encountered here and at a number of the descents to lacustrine material.

Plantsite to Cluster No. 3 - Cluster No. 2 Route

Descending from the plantsite, the route crosses a short valley section and skirts a moraine ridge, before descending to a major valley section. The lacustrine and organic sediments here are very poorly drained. Near Parsons Lake, the route traverses glaciofluvial terrain with one short lacustrine section with steep grades.

Cluster No. 3 to Cluster No. 4

This route segment initially follows glaciofluvial ridges, with a number of steep grades, before descending to the valley of Zed Creek which flows to Eskimo Lakes. The grades in this second section, which crosses glaciofluvial sands and gravels, are fairly uniform. Except for a number of minor stream crossings, the route is well drained.

Cluster No. 3 to Cluster No. 5

Immediately north of Cluster No. 3, the proposed route runs along the shore of Parsons Lake in order to avoid a series of very steep grades. The route then follows an existing winter road along the crest of a series of well drained glaciofluvial ridges. Just south of Cluster No. 5, a short section of poorly drained lacustrine and organic terrain is traversed. Steep grades exist at either end of this segment.

Cluster No. 5 to Cluster No. 1

This short route segment follows a well drained glaciofluvial ridge crest. Two deep, steep-sided gullies must be crossed.

2.3.2.6 Access and Transporter Roads

Plantsite to Docksite Road

The route crosses a shallow valley and moraine ridge, southeast of the plantsite, before descending to the lacustrine plain, north of Hans Bay. Moderately steep grades are encountered where the route crosses two abandoned strandlines. This route segment is well to fairly well drained.

Plantsite to Airstrip Road

Leaving the plantsite to docksite route one-half mile east of the plantsite, this route follows an undulating moraine ridge and descends to the lacustrine plain, upon which the airstrip is located. The ridge is well drained but a number of steep-sided gullies must be crossed.

Road from Plantsite to Borrow Sources

The route to Borrow Sources 1 and 2 follows well drained, moraine ridges throughout. No particularly steep grades are encountered. The road to Borrow Sources 3 and 4 traverses relatively poorly drained moraine terrain and encounters one steep grade as well as a number of narrow, steep-sided gullies.

3.0 FIELD PROGRAM

3.1 Scope

The proposed gas plant and ancillary facilities were located on airphotos and contour maps, during the planning stage, using the surficial geology mapping and available subsurface information. Location of study areas and alignments was to follow as closely as possible the layout on Drawing 1-75131-25, prepared by Gulf Oil Canada Limited. The locations selected are shown, superimposed on a contour map of the area, on Plate A-2 in Appendix "A", and on Figure 3.1.

The objectives of the drilling program were to confirm the accuracy of the surficial geology mapping and to obtain subsurface profiles and soil information to be used in foundation design as part of Phase I - Engineering. Soil samples were to be retained for testing in the laboratory to provide a detailed soil classification and to allow the engineering properties of the soils in both frozen and unfrozen states to be determined.

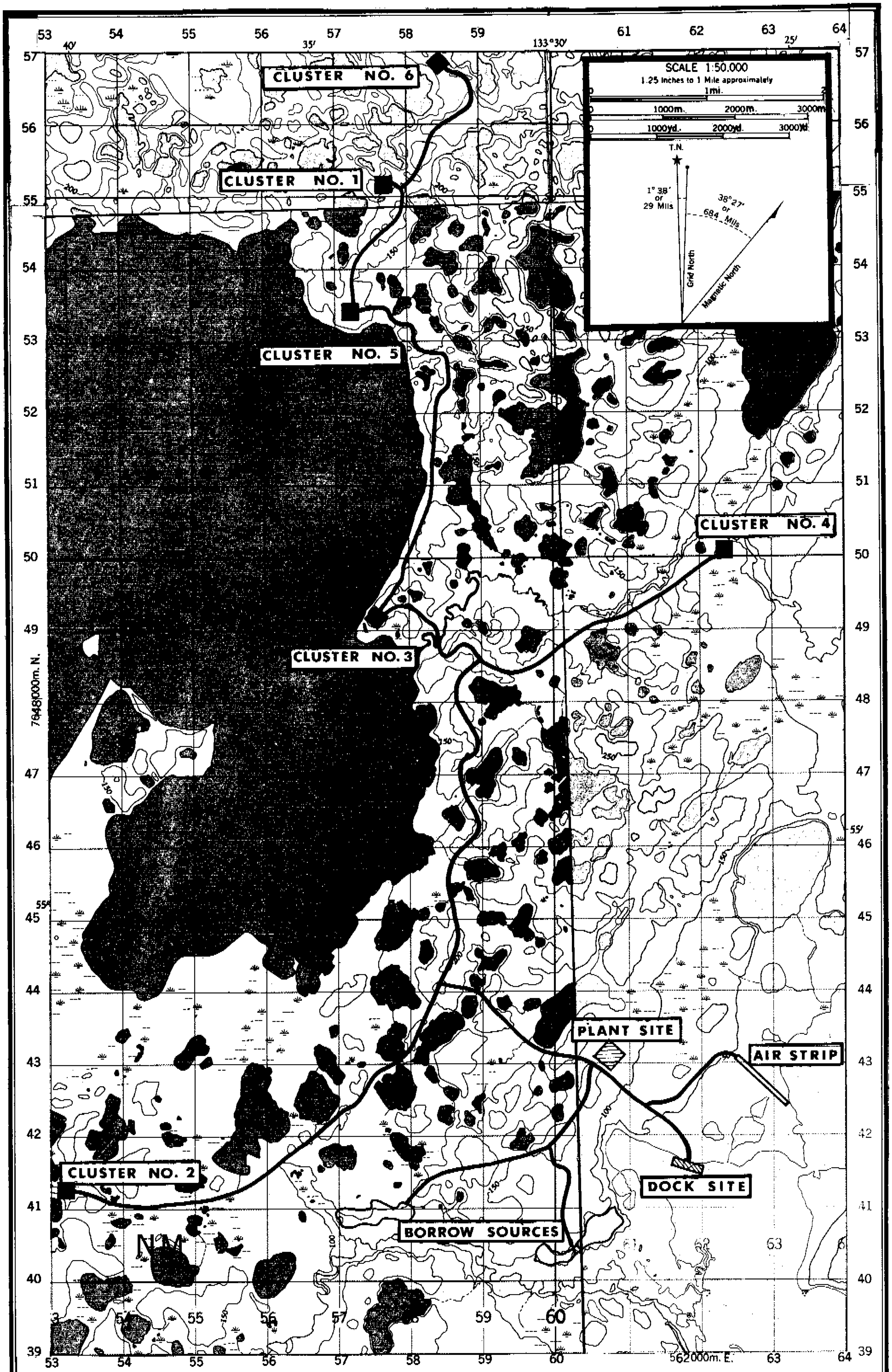


Figure 3.1 FACILITY LOCATIONS

The subsurface information requirement for each facility was determined prior to laying out test holes and is discussed below.

3.1.1 Plantsite

A plantsite measuring 1050 feet (320 m) square was selected within Location A, as delineated in Reference No. 2. Subsurface conditions within the 1050 foot (320 m) square area were first delineated broadly and then, on the basis of initial subsurface information, a smaller area of 600 to 700 feet (183 m to 213 m) square was chosen for more intensive study. Subsurface conditions, surface drainage and topography were the prime criteria for selection of the plantsite. A total of 44 test holes were drilled on a 150 foot (46 m) grid pattern as shown on Plate A-2.

In addition, several test holes were drilled on an alternate plantsite location immediately to the west.

3.1.2 S.T.O.L. Airstrip

A S.T.O.L. airstrip measuring 200 feet (60 m) wide by at least 2500 feet (760 m) in length was required, preferably located about 1 mile (1.6 km) distant from the plantsite. The site was to have a shallow gradient and traverse as few drainage courses as possible. Locations too close to Eskimo Lakes would be susceptible to ground fog conditions and were to be avoided. In addition, the orientation of the strip was to be roughly northwest-southeast so that advantage could be taken of the prevailing winds. The proposed location, shown on Drawing 1-75131-25, was on a plateau approximately 1 mile (1.6 km) northeast of the plantsite.

A field reconnaissance at the proposed airstrip site disclosed a maximum usable length of only 1700 feet (518 m) for an airstrip oriented towards the northwest. Lengthening of the airstrip would require an embankment some 800 feet (244 m) in length and 20 to 30 feet (6 m to 10 m) in height spanning an intermittent, wide drainage pattern.

Due to the northeast-southwest orientation of hills and ridges in the study area, the airstrip was relocated to the southeast in an area of glacio-lacustrine sediments where the topography is flat and wide.

The airstrip, as relocated, extends for some 4000 feet (1220 m) in usable length from the edge of Eskimo Lakes to the base of a plateau. It is oriented 312 degrees from true north. The alignment traverses a gently sloping lacustrine plain, crossing a broad drainage course and passing within several hundred feet (metres) of a small lake. The location of the S.T.O.L. airstrip is shown on Figure 3.1. A series of fourteen test holes was drilled along its centerline.

3.1.3 Docksite

The north shore of Hans Bay will be the site of a barge dock, to be used primarily for the unloading of large heavy modules to be used in plantsite construction. Prime criteria for dock location were a draft of 7 to 8 feet (2 m to 3 m) adjacent to the shore and gentle shoreline slopes for ease of access to an overland transporter road. A review of available sounding data suggested the location shown on Figure 3.1. It should be noted that sounding data were not available immediately adjacent to the shoreline.

For barge dock design, it was necessary to determine water depths, depths to permafrost and the nature of the unfrozen sediments for a distance of 100 to 150 feet (30 m to 46 m) outwards from the shoreline. Three lines of four test holes, spaced on 50-foot (15.2 m) centres, were drilled at the prime dock site location. In addition, fourteen holes, spaced at 200-foot (60 m) intervals and extending for approximately 1000 feet (305 m) on each side of the docksite, were drilled to provide additional information on water depths and sediment conditions. The area investigated covers a number of possible barge access routes to the dock, as well as possible alternative dock sites.

3.1.4 Staging Area

Adjacent to the docksite, a staging area measuring approximately 500 feet (150 m) square is required for unloading and storing equipment and materials. A series of six test holes was drilled at the proposed location as shown on Figure 3.1.

3.1.5 Transporter Road

From the docksite to the plantsite a roadway with a 35-foot (10.7 m) surface and maximum grade of 7 percent is required to transport the heavy construction modules. Several test holes were drilled along the alignment to determine soil and ice conditions.

3.1.6 Service Corridor and Access Roads

Some 20 miles (32 kilometres) of roadway with a 20-foot (6.1 m) surface are required to service the well clusters from the plantsite. The road right-of-way also serves as the alignment for a gathering system comprising an above-ground pipeline and power conduit. The pipeline will be in the order of 12 inches (30 cm) in diameter and will be elevated approximately 2 feet (60 cm) above the ground surface on pipe supports. Routing of this service corridor followed the alignment shown on Gulf Oil Canada Limited Drawing 1-75131-25. Minor realignments were carried out in the field to position the corridor on gentle slopes and avoid drainage courses where possible.

A total of fifty-seven test holes were drilled along the service corridor to a nominal depth of 25 feet (7.6 m).

A 20-foot (6.1 m) wide access road to the airstrip was also positioned to intersect the transportation road, approximately 1/2 mile (800 m) from the plantsite. In addition, a proposed access road from the plantsite to the potential granular borrow sources was investigated.

The locations of the service corridor and access roads are shown on Figure 3.1 and Plate A-2. Test hole locations are shown on Plate A-2.

3.1.7 Well Clusters

Development and production wells will be located on five or six well cluster sites in the Parsons Lake area. The locations of six well cluster sites were surveyed during the initial stages of the field program. However, the most northerly cluster site was dropped from the program in late March and soil conditions were investigated at only five sites. On all but one of the sites, exploration drilling was being conducted by Gulf Oil Canada Limited. Five test holes were drilled on each site, generally on the edge of the gravel fill pad used to support the exploration rig, camp and materials.

3.1.8 Granular Borrow Areas

A series of potential granular borrow areas, 3 miles (4.8 km) southwest of the proposed plantsite, was extensively drilled in 1974 (Reference No. 1). Sufficient test hole information exists to assess the quantity of gravel available and the likely frequency, distribution and size of large ice bodies within the most desirable borrow source areas.

Several test holes and test pits were proposed to obtain samples of the gravel for analysis of moisture and ice contents. It was also hoped that suitable samples could be obtained to evaluate the quality of the gravel with regard to concrete mix design and compaction requirements. Land use regulations prevented the excavation of test pits at this stage of the project; thus, only general subsurface information could be obtained from the six test holes drilled.

3.1.9 Survey

Five permanent benchmarks were installed to provide control for current and future surveys. Details on the location and installation of the benchmarks are given in Section 3.3. In this field program only the position of the plantsite was fixed accurately, relative to established control points.

Using the elevation of the top of the flange on the wellhead of Gulf Oil Canada Limited Well 0-27 adjacent to Parsons Lake (Elevation = 999.80), vertical control was established between the benchmarks installed. All test holes were surveyed for vertical control relative to the wellhead elevation. A horizontal survey was not carried out due to time constraints and the possibility that portions of the road and service corridor might possibly be realigned at some stage in the future. Test hole surface elevations were determined to an accuracy of ± 0.5 feet (15 cm).

Thermistor readings were taken at test holes E-14 and B-5, where thermistor strings were installed during the 1975 Field Program (Reference No. 2).

3.2 Drilling Equipment

Due to time constraints, two drilling sub-contractors were retained to drill approximately two hundred test holes as part of the 1976 Geotechnical Survey. The two companies selected to provide drilling equipment and operators were Mobile Augers and Research Ltd. of Edmonton, Alberta, and SDS Drilling Ltd. of Calgary, Alberta, (formerly Big Indian Drilling - a Division of Kenting Petrolia Drilling). The drill rigs and equipment were contracted from Inuvik and were trucked to and from the study area by Gulf Oil Canada Limited.

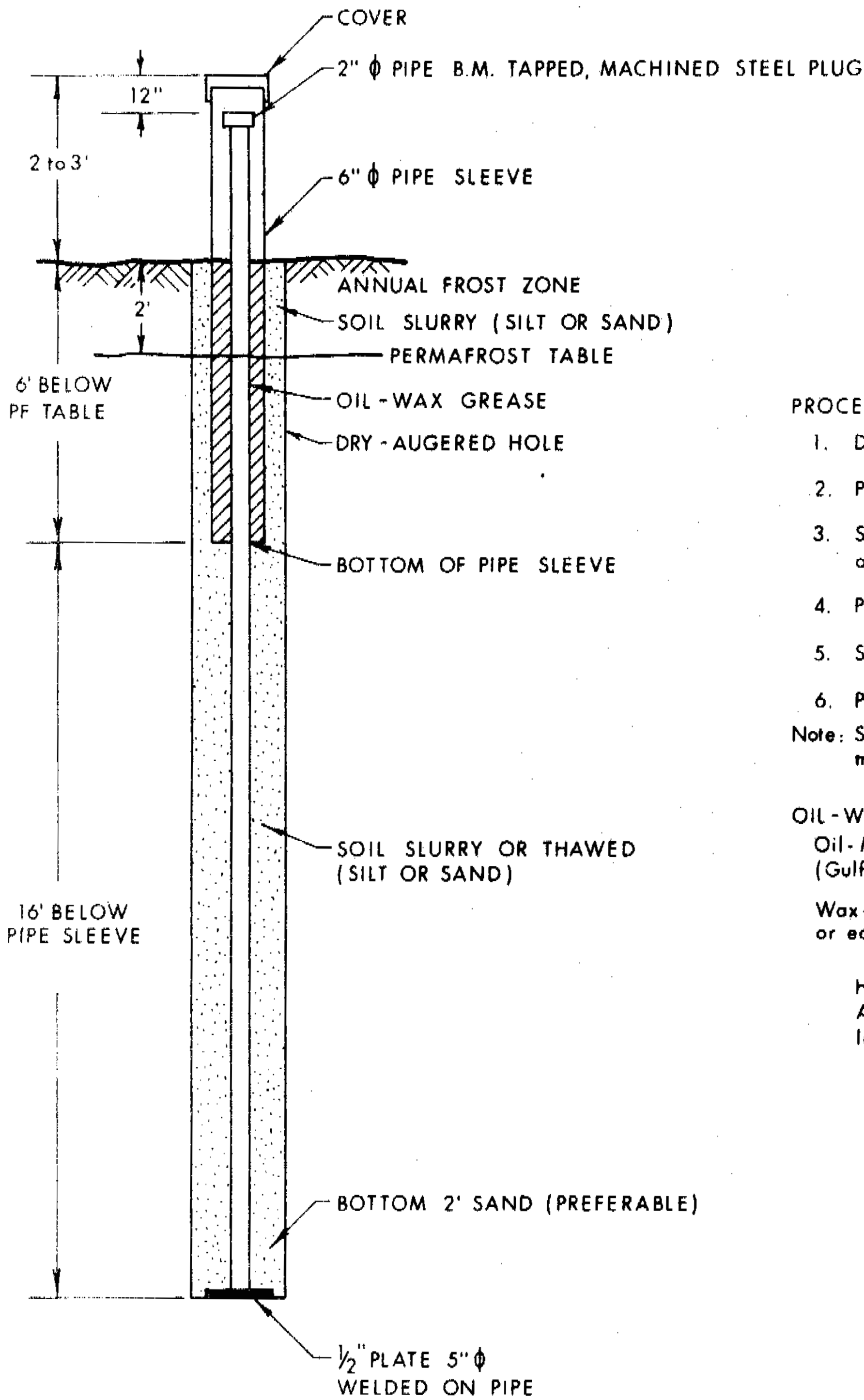
Mobile Augers and Research Ltd. provided drilling services for the 1975 Parsons Lake Study (Reference No. 2), using a helicopter portable Ranger Drill. To penetrate the subsoils encountered in the earlier study, a Mobile B-61 Auger Drill (see Figure 3.2) was supplied for the 1976 field program. The rig was track-mounted and equipped with an enclosed cab. The drilling controls and tower were not enclosed. A dry augering technique was the primary method of drilling, although a modified CRREL Barrel was frequently used to core frozen soils. Unfortunately, the coarse, granular nature of many of the soils encountered resulted in very shallow test holes using this drill rig. The B-61 was, therefore, used primarily on holes drilled through ice and water at the docksite and, upon completion of these holes, was released from the program.

The SDS Drilling Ltd. drill rig selected was a sleigh-mounted Mayhew 500 Heli-Drill (see Figure 3.2). The drill rig is equipped with a separately housed air compressor and pump and is capable of either dry or wet drilling techniques to a depth of approximately 100 feet (30 m). Both units are fully enclosed to shield equipment and personnel from the weather. The drilling assembly was skidded using a Caterpillar D-6 tractor. Again, the granular nature of the subsoils did not allow undisturbed soil samples to be obtained where soil particles larger than 0.5 inch (~12 mm) in diameter were encountered. Air drilling using insert and rock bits provided a wash sample suitable for moisture and ice content determination and soil classification. About five test holes, averaging 25 feet (7.6 m) in depth, were completed in a normal 12-hour shift.

3.3 Benchmarks

To provide horizontal and vertical control for future surveys in the Parsons Lake Study area, five permanent survey control monuments were installed during the 1976 Geotechnical Survey. The location of the benchmarks is shown on Figure 3.5 and Plate A-2.

The typical configuration of a benchmark is shown on Figure 3.3. It would have been preferable to install all benchmarks in a nominal 8 inch (20 cm) diameter drill hole. However, the gravelly nature of the soil over most of the study area prevented drilling of holes larger than 5 inches (~127 mm) in diameter for Benchmarks No. 3 and No. 5. The method of installation was to set the 2 inch (51 mm) diameter pipe, with base plate, at the bottom of the hole and backfill with a soil-water slurry to approximately 6 feet (2 m) below the ground surface. From the 6 foot (2 m) depth to



PROCEDURE

1. Dry - auger 8" ϕ min. hole to 22' deep.
2. Place 2" ϕ pipe - B.M.
3. Soil slurry (silt or sand) fill bottom 16' of hole. Allow full freezeback.
4. Place 6" pipe sleeve.
5. Slurry between hole and 6" pipe.
6. Place Oil - wax grease between 6" & 2" pipe.

Note: Sleeve size 4" diameter used where the maximum hole size was 6".

OIL - WAX GREASE

Oil - Mentor 28 or equivalent (Gulf Mineral Seal Oil)	70 %	by weight
Wax - Mikrovan 1650 or equivalent	30 %	

Heat materials to 180°F. and mix thoroughly. At about 125°F. pour into annulus and leave. Cools into a thick grease.

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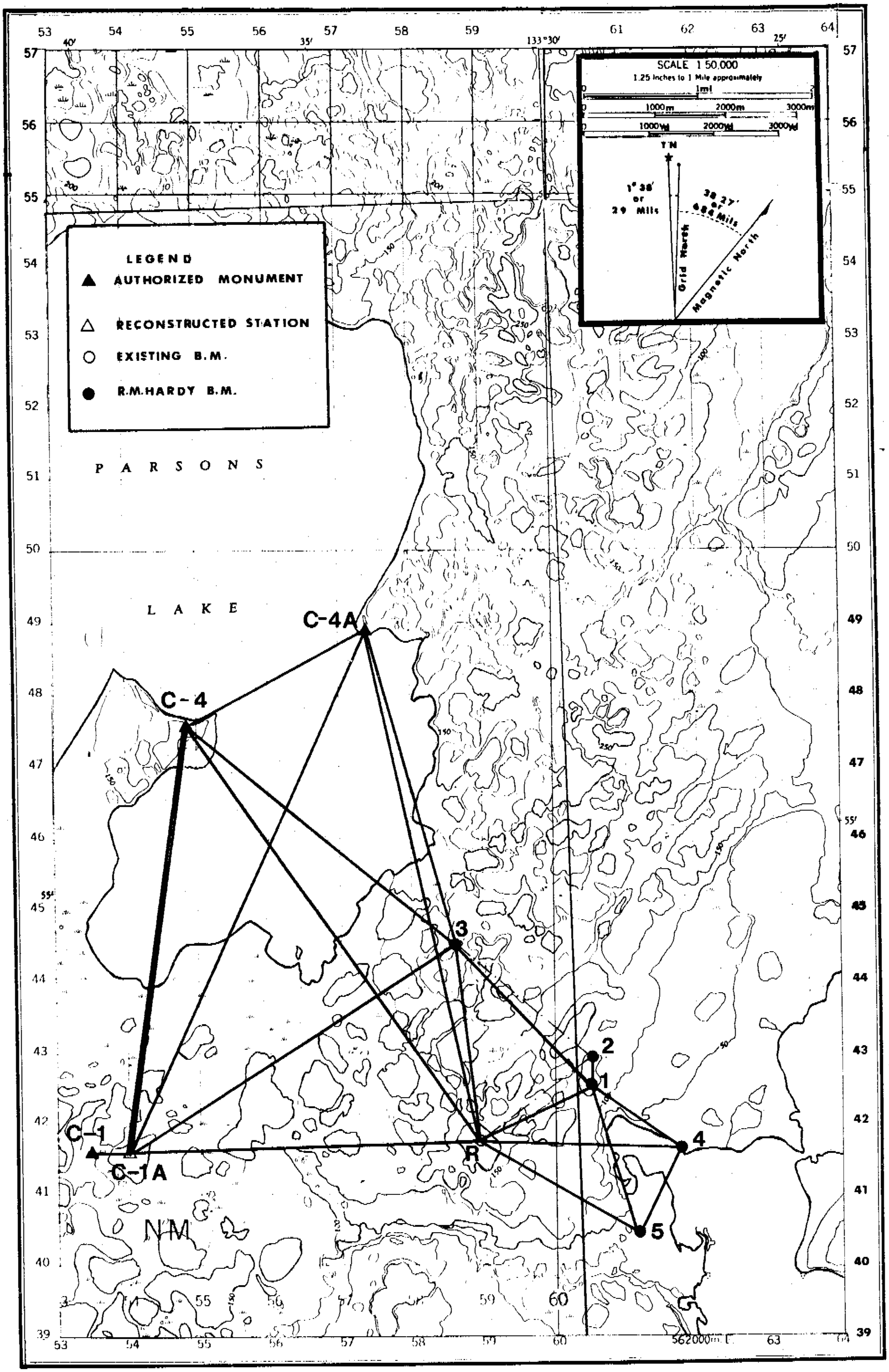
TYPICAL CONFIGURATION OF BENCHMARK IN PERMAFROST

Figure 3.3



BENCHMARK LOCATIONS

Figure 3.5

approximately 3 feet (1 m) above grade, a sleeve of 4-or 6-inch (100 mm or 150 mm) diameter casing, depending on the hole size, was set over the benchmark pipe to shield the pipe from frost effects within the active layer. The annulus outside the casing was filled level with the ground surface with a soil-water slurry. The inner annulus, between casing and pipe, was filled with an oil-wax mixture to prevent moisture accumulation and possible subsequent frost effects. The top of the benchmark pipe was fitted with a steel plug to provide a level surface. This plug was stamped R.M.H. - 1976. A photograph of one of the benchmarks is shown on Figure 3.4. Some difficulty was encountered in installing benchmarks due to vehicle availability and the lack of equipment to heat and mix the soil slurry.

The position of the survey monuments used in the 1976 triangulation survey to establish a vertical and horizontal control system in the Parsons Lake Study Area is shown on Figure 3.5.

Vertical control for future surveys relative to the benchmarks is also possible. The locations of survey monuments from previous surveys and those installed in 1976 are shown on Figure 3.5. Bearings were measured

TABLE 3.1

BENCHMARK LOCATIONS

BENCHMARK	T.P.C.S. COORDINATES		V.T.M. COORDINATES	
	NORTH (FEET)	EAST (FEET)	NORTH (METERS)	EAST (METERS)
No.1	25 082 033.5	198 065.88	7 642 493.4	560 325.6
No.2	25 081 321.6	197 978.0	7 642 710.3	560 352.3
No.3	25 087 488.73	191 818.48	7 644 372.6	558 448.7
No.4	25 078 175.5	202 187.6	7 641 534.7	561 608.3
No.5	25 074 757.6	199 922.7	7 640 493.3	560 918.2
R	25 078 229.14	192 875.02	7 641 551.1	558 770.7

and derived from bearings between monuments FD. I.P. C-4, FD. I.P. C-4A and reconstructed Pl. I.P.Mr. C-1A,obtained from C.L.S.R. 59918, September 8, 1975. A summary of benchmark coordinates is given in Table 3.1. Coordinates listed are based on the Territorial Plane Coordinate System (origin: 135° West Longitude, at the equator). U.T.M. coordinates are derived from T.P.S.C. coordinates.

A survey will be conducted during the June 1976 hydrology study to check vertical control between the benchmarks.

3.4 Sampling Equipment and Methods

Samples of frozen and unfrozen soil, in both undisturbed and disturbed states, were required to allow proper assessment of the engineering properties of the subsoils encountered, together with soil classification and index tests.

3.4.1 Frozen Soils

Frozen soils were sampled using a CRREL (Cold Regions Research & Engineering Laboratories) core barrel equipped with carbide-tipped insert teeth. Using a dry drilling method, the core barrel acts as an auger and can cut a 3 inch (76 mm) diameter core 2.5 feet (76 cm) in length which is retained in the barrel. The core is hydraulically extruded, labelled, photographed, wrapped and packaged in an insulated crate for shipment. Two frozen cores are shown on Figure 3.6. Where the sample was only to be used for moisture content determination or soil classification, it was packaged and sealed but no attempt was made to prevent thawing.

3.4.2 Unfrozen Soils

Unfrozen soils were sampled using 2-and 3-inch (51 and 76 mm) diameter split spoon samplers. These are driven into the soil using a driving method which employs 350 foot pounds (475 Nm) of energy per blow. The number of blows required to advance the sampler is recorded and the relative density and/or consistency of the soil strata can be determined (ASTM D1586-64T Standard Penetration Test). Disturbed samples were obtained and packaged for soil classification and index tests.

Relatively undisturbed samples of unfrozen ground were obtained by hydraulically pushing a 3-inch (76 mm) diameter Shelby tube into undisturbed soils. The cohesionless nature of much of the unfrozen lake sediment made retention to these samples difficult. The samples obtained were tested to evaluate the soil shear strength of the unfrozen material at the proposed barge docksite.

3.4.3 In Situ Testing

Dynamic tests were conducted at the docksite to assess the in situ relative density and/or consistency of the unfrozen sediments encountered. Standard Penetration Tests were carried out where a soil sample was also desired. A continuous profile of relative density variations with depth was obtained using a Dynamic Cone Penetration Test. A driving effort of 350 foot pounds (475 Nm) was again used. The tip of the driving rod is a solid 2 inch (51 mm) diameter cone, tapered to an angle of 60 degrees at the apex.

3.4.4 Sample Handling

All samples were packaged and transported to the Gulf Swimming Point Base Camp and then flown to Edmonton by Gulf Oil Canada Limited - PWA charter aircraft. They were then trucked to the Calgary laboratory of R. M. Hardy & Associates Ltd. Frozen samples were stored in a freezer until laboratory testing was conducted.

3.5 Timing

R. M. Hardy & Associates Ltd. was commissioned by Gulf Oil Canada Limited to conduct the 1976 Geotechnical Survey on January 26, 1976. A proposal outlining the scope and objectives of the study was submitted February 16, 1976.

Field Work Order 82602 was issued by Gulf Oil Canada Limited on February 23, 1976 authorizing the study. Approval of the land use application, with the exception of permission to excavate several test pits, was received in late February.

The field program commenced March 2, 1976 and was completed March 31, 1976. Field drilling began on March 5 and one drill rig was released from the program March 14. On March 17, the drilling was switched to a double shift operation and was completed March 27. Surveying and layout of test holes was started on March 4, 1976 and was completed March 19.

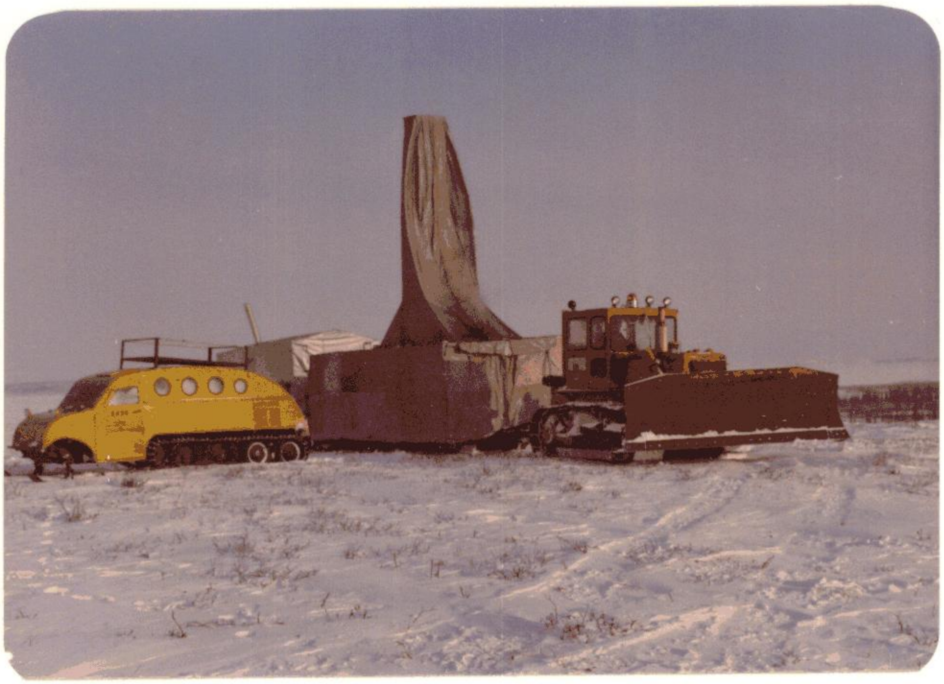
The laboratory testing program started in mid March with the first shipment of soil samples and was completed May 14, 1976.

3.6 Logistic Support

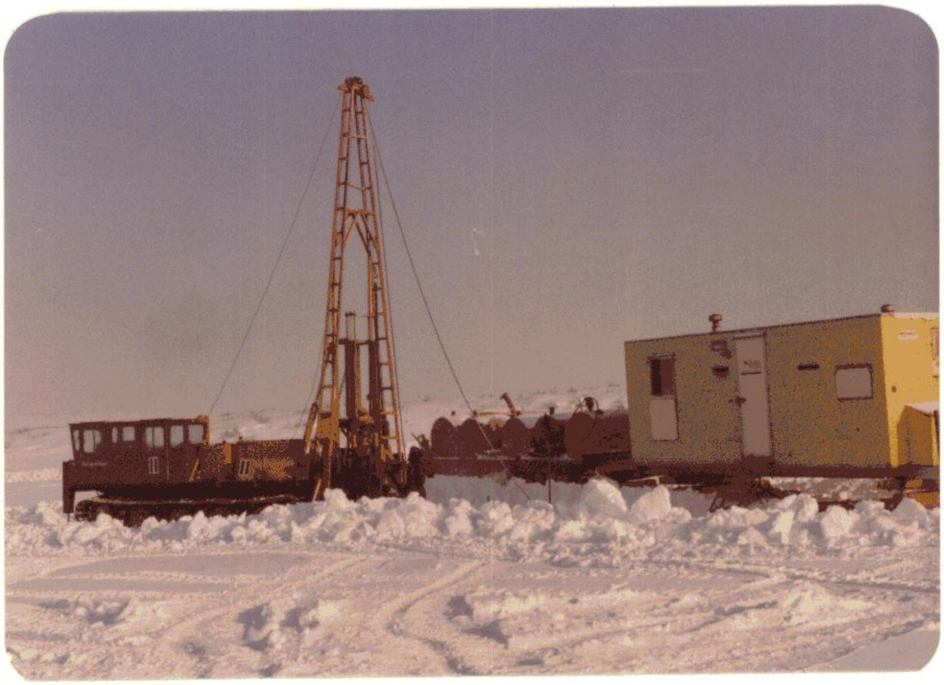
R. M. Hardy & Associates Ltd. provided supervision and technical personnel for the 1976 Geotechnical Survey as well as subcontracting the drilling equipment and personnel from Mobile Augers and Research Ltd. of Edmonton and SDS Drilling Ltd. of Calgary (renamed April, 1976).

Gulf Oil Canada Limited provided transportation to the study area via PWA charter service from Edmonton, and about the site using two gas-powered, 12-man Bombardiers. Lodging was, for the most part, in a two trailer self-contained camp set up immediately adjacent to the exploration rig camp (Adeco) at Well Cluster No. 3.

Drill rigs and equipment were transported to and from Inuvik by truck. It was necessary to use a Caterpillar D-6 to move the sleigh-mounted Helidrill as well as tow a fuel sloop. In addition, a trailer was attached to the fuel sloop for storage and maintenance of sampling equipment as well as for shelter. Temperatures during the field program were normally -20 to -25°C, with winds of 10 to 30 mph (4.5 to 13.4 m/s). Only one day was lost due to poor weather conditions.



PHOTOGRAPH No. 1
Sleigh – mounted, enclosed Heli Drill and Bombardier.



PHOTOGRAPH No. 2
B-61 Auger Rig, Fuel Sloop and Trailer.

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PHOTOS OF DRILLING EQUIPMENT

Figure 3.2

PHOTOGRAPH No. 3
Small Pingo near
Well Cluster No. 2.

PHOTOGRAPH No. 4
Benchmark Installation.

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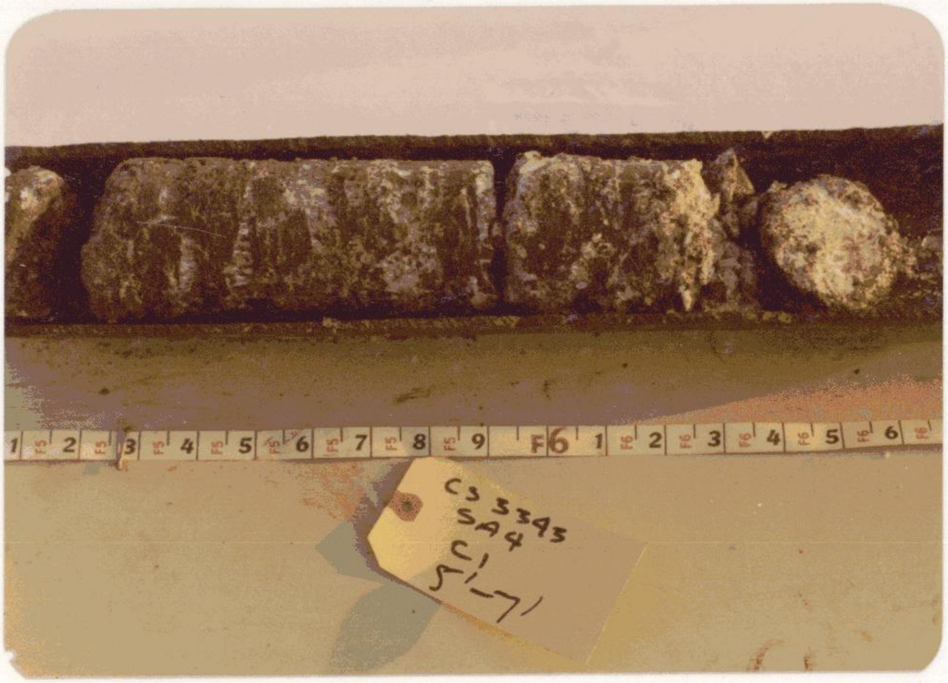
PHOTOS OF
BENCHMARK INSTALLATIONS

Figure 3.4



PHOTOGRAPH No. 5
Typical CRREL Core of Ice-rich Soil on Airstrip.

PHOTOGRAPH No. 6
CRREL Core of Massive Ice on Plant Site.

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PHOTOS OF FROZEN SOIL CORES

Figure 3.6

A communications network was established between the drill rig sites and base camp for safety reasons. The Bombardiers required periodic maintenance and eventually required the services of a mechanic, supplied by the sub-contractor. Sporadic performance of the Bombardiers necessitated use of a helicopter to complete the survey program and delayed benchmark installation until completion of the drilling program.

Soil samples were shipped to Edmonton on the Gulf charter and were then trucked to Calgary.

Messrs. K. Woldum, E. Severson and H. Martin of Gulf Oil Canada Limited organized logistic support in the field and aided the drilling program whenever possible.

4.0 LABORATORY TESTING

4.1 Test Description

The majority of soil samples retained from the field program were visually identified and tests such as Atterberg Limits and particle size analysis were conducted to aid in soil classification. The Modified Unified Classification System for Soils was used and is shown on

Plate I.1 in Appendix "I". The NRC Ice Classification System (NRC - Technical Memorandum 79) was used to describe the ground ice types present in the frozen soil samples, and is shown on Plate I.2 in Appendix "I".

Additional laboratory tests were conducted to determine the index properties of the soil types encountered, relative to foundation design. These tests include moisture content, unconfined compressive strength, unit weight, drained triaxial, frozen bulk density and thaw settlement.

Where applicable, tests were carried out using current ASTM (American Society for Testing and Materials) Standards. The ASTM Designation and definition of these tests are as follows:

4.1.1 Moisture Content (ASTM D2216-71)

The moisture content of a soil is the ratio, expressed as a percentage, of the weight of water in a given mass of soil to the weight of solid particles.

4.1.2 Atterberg Limits

4.1.2.1 Liquid Limit (D423-66)

The liquid limit of a soil is the moisture content, expressed as a percentage of the weight of oven-dried soil, at the boundary between liquid and plastic states.

4.1.2.2 Plastic Limit (D424-59)

The plastic limit of a soil is the moisture content, expressed as a percentage of the mass of oven-dried soil, at the boundary between the plastic and semi-solid states.

4.1.3 Grain Size Distribution or Particle Size Analysis (D422-63)

The grain size analysis is the quantitative determination of the distribution of particle sizes in soils. The distribution of particle sizes larger than 75 μm (retained on No. 200 sieve) is determined by sieving whereas the distribution of smaller particle sizes is determined by a sedimentation process using a hydrometer.

4.1.4 Unit Weight (D2937-71)

The unit weight or density of a soil sample obtained by hydraulically pushing a 3 inch (76 mm) thin-walled Shelby tube into undisturbed soil is determined without extruding the soil sample from the tube.

4.1.5 Unconfined Compressive Strength of Cohesive Soil (D2166-66)

The unconfined compressive strength is the load percent unit area at failure (20 percent axial strain) of an unconfined cylindrical specimen of soil. The test is carried out using strain-controlled application of the test load.

4.2 Test Results

Laboratory tests were conducted on soil samples as an aid in soil classification and to determine the index or engineering properties of the soil. All test results are shown on the test hole logs. In the case of grain size distributions, the Figure Number on which the test results are presented, is given. In addition, a summary of all laboratory tests, excluding moisture content, is given at the end of each appendix.

In frozen soils where large, discrete ice layers were present, the soil between ground ice layers was sampled. Thus, the moisture content will be that of the soil layer only. Visual ice contents given on the logs indicate the percent of ice by volume in excess of the natural pore space present in the unfrozen soil. Where the soil sample was a wash sample, it was generally impossible to differentiate between ice type subgroups and, in these instances, only an ice group and percent excess ice were recorded.

Shear strength tests and unconfined compression were conducted on selected undisturbed samples of the unfrozen sediments at the barge docksite. A drained triaxial test was conducted on a remolded sediment sample to determine effective stress parameters of the typical soil deposit encountered. In addition, a profile of soil consistency with depth was obtained by conducting dynamic cone and standard split spoon penetration tests from which approximate soil shear strengths may be derived empirically.

Frozen bulk density and thaw settlement tests were conducted on a number of frozen cores which had been retained in a frozen undisturbed state. These tests provide the settlement characteristics of a frozen soil. Samples were placed in consolidation test devices, thawed under a small load, and the resulting strain recorded. Subsequent load increments were then placed on the samples to determine the compression characteristics of the thawed soil. Thaw strain tests will be completed in early June and will be reported under separate cover. Interpretation of results will be carried out in Phase I - Engineering. Frozen bulk density results are recorded on laboratory test summary sheets.

5.0 RESULTS OF FIELD PROGRAM AND DISCUSSION OF SUBSURFACE CONDITIONS

5.1 General

In this section, the plantsite and ancillary facilities are considered, in turn, with regard to subsurface soil conditions. In addition, ground ice conditions within the soil profile at each site are considered briefly and laboratory test results discussed.

5.2 Plantsite

The site chosen for the gas processing plant is located in the southwest corner of Location A, as previously proposed (Reference No. 2). In all, forty-four test holes were drilled, on 150-foot (46 m) centres, within the 1050-foot (320 m) square grid shown on Plate A-2. The drilling was carried out in two stages. At the beginning of the 1976 Field Program, three rows of four holes were drilled to provide subsurface information upon which the selection of a detailed 600-foot (183 m) square grid could be based. The remaining test holes, within this latter detailed grid, were drilled towards the end of the program.

Two test holes were drilled on an alternative plantsite location approximately 1000 feet (305 m) to the west.

Cross sections illustrating the subsurface stratigraphy of the proposed plantsite were compiled, and are shown on Figure 5.1. Test hole logs and laboratory test results are presented in Appendix "B".

Poorly sorted, silty and clayey gravels, with sand and occasional clay and silt lenses, were intersected in all but two of the plantsite test holes. Clays, silts and organic deposits resting on the gravel stratum average 5 to 10 feet (1.5 m to 3 m) thick over the site as a whole, but 5 feet (1.5 m) or less within the detailed grid. The gravels are continuous to a depth of at least 30 feet (9 m) over much of the site.

Excess ice contents are generally low, averaging 10 to 15 percent in the gravels, and 20 to 25 percent in the overlying fine-grained sediments. Massive segregated ice bodies, up to 10 feet (3 m) thick, are, however, sometimes present at the contact between the gravel and fine-grained strata.

5.3 S.T.O.L. Airstrip

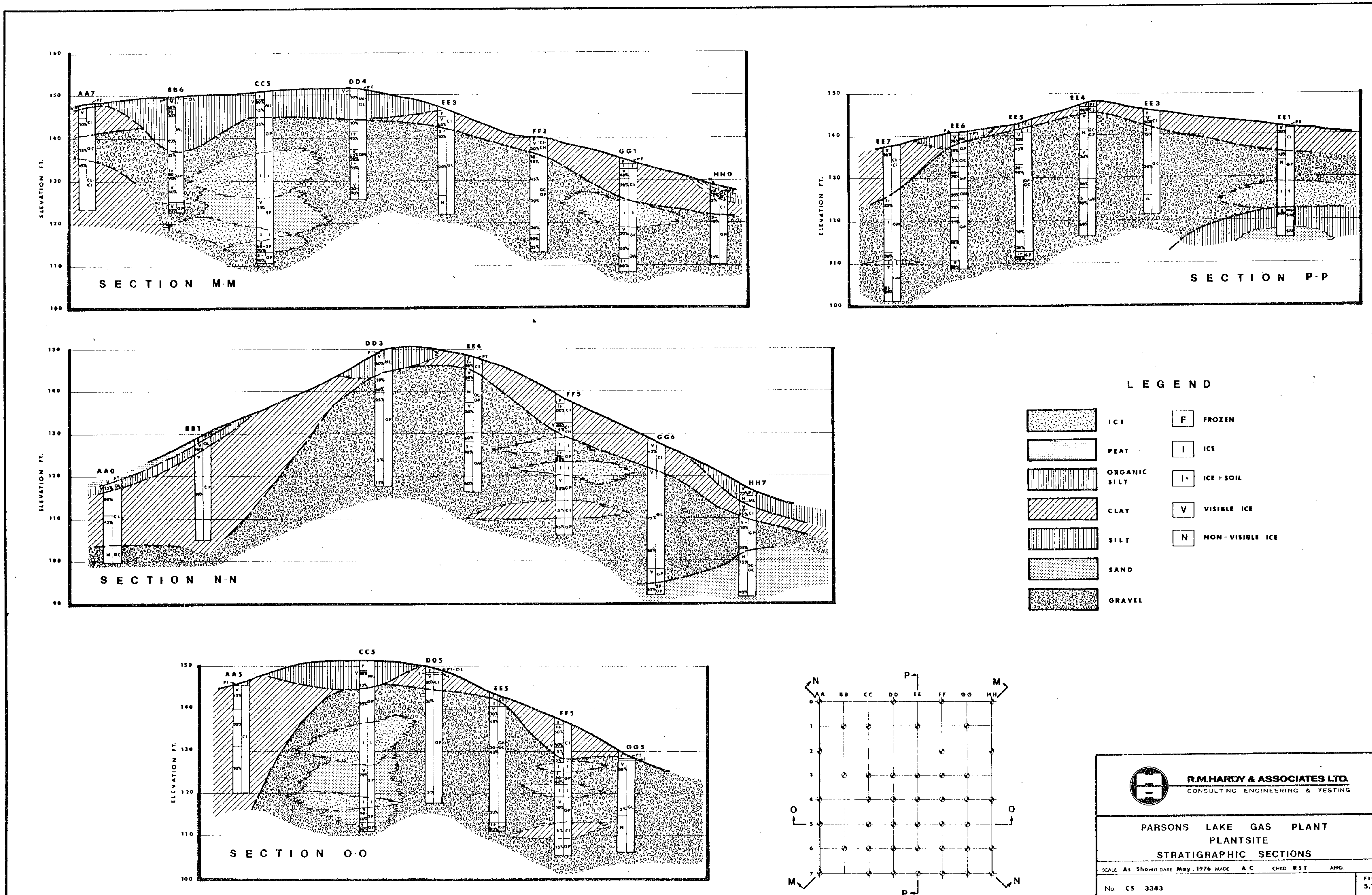
The proposed STOL airstrip is located on the lacustrine plain approximately one mile (1.6 km) east of the plantsite. The area investigated is approximately 3900 feet (1190 m) long and is oriented on an azimuth of 132 degrees. The average grade is less than two percent. A series of fourteen holes was drilled along the proposed centerline. A stratigraphic cross section is shown on Figure 5.2. Test hole logs and laboratory test results are presented in Appendix "C".

The site is underlain by up to 10 feet (3 m) of clay with low to high plastic, silty, grey layers. The clay rests on a fine-grained, silty, grey sand which is up to 20 feet (6 m) thick. The sand stratum is underlain by an apparently continuous, medium plastic, grey clay. Within the upper clay stratum, and between it and a thin peat veneer covering most of the site, are a number of silt, organic silt and silty sand lenses.

Visible ice contents range, in general, from 40 to 70 percent in the upper 10 feet (3 m) of the soil profile and decrease noticeably below 10 feet (3 m) to an average of 5 to 10 percent. Frozen bulk densities within the upper 8 feet (2.4 m) average 94 pcf (1.5 Mg/m^3) whereas below 8 feet (2.4 m) the average is 114 pcf. (1.8 Mg/m^3).

5.4 Docksite

A total of twenty-six test holes were drilled at the proposed docksite which is situated on the north shore of Hans Bay on Eskimo Lakes. Three lines of four holes were drilled, on 50 foot (15.2 m) centres, radiating out from the small spit on which the site is centred. In addition, a series of seven holes was drilled in a staggered pattern, with roughly 200-foot (61 m) spacing, for approximately 1000 feet (305 m) on either side of the spit.


SECTION M-M
SECTION P-P
SECTION N-N
SECTION O-O
ELEVATION FT.
LEGEND
ICE
PEAT
ORGANIC SILT
CLAY
SILT
SAND
GRAVEL
F FROZEN
I ICE
I+ ICE + SOIL
V VISIBLE ICE
N NON-VISIBLE ICE
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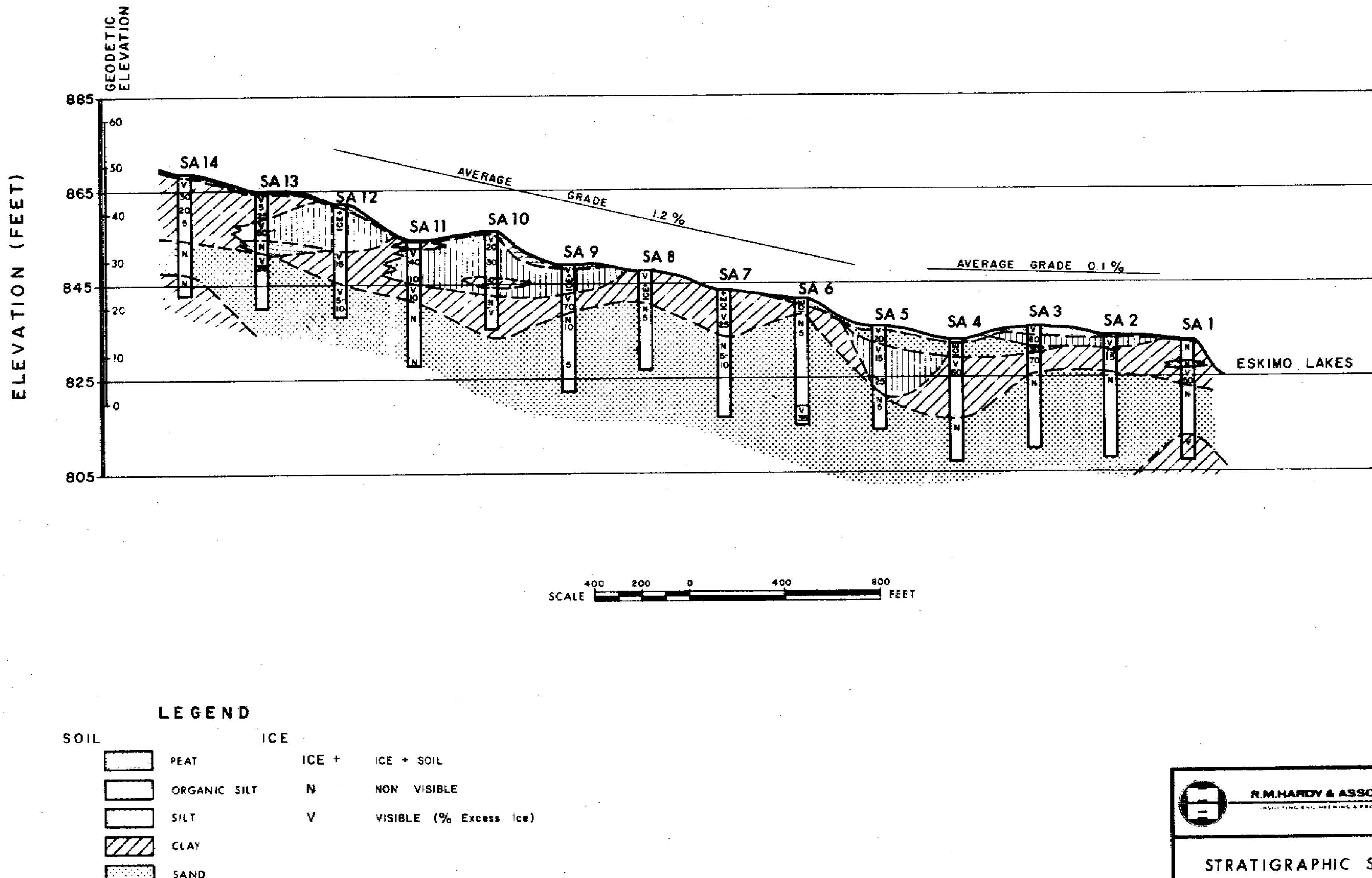
PARSONS LAKE GAS PLANT
PLANTSITE
STRATIGRAPHIC SECTIONS
SCALE As Shown DATE May, 1976 MADE A C CHKD R S T APPD.
No. CS 3343
FIG. 5.1



NOTE: Data concerning the various strata have been obtained at the borehole locations only. The soil stratigraphy between boreholes has been inferred from geological evidence and so may vary from that shown.

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STRATIGRAPHIC SECTION
S.T.O.L. AIRSTRIP

FIGURE 5.2

At the time of drilling, up to 8 feet (2.4 m) of snow covered the ice close to the shores of Hans Bay. The B-61 rig was used for the majority of holes drilled at the docksite. At eight test hole locations dynamic cone penetration tests were conducted to permit an assessment of the density of the unfrozen sediments at the site. In each instance, an adjacent hole was also augered to obtain relatively undisturbed Shelby tube samples and a soil profile. Standard Penetration Tests were carried out using a split spoon sampler as a means of empirically assessing soil shear strengths. Dynamic, in situ testing methods were used to delineate the permafrost table.

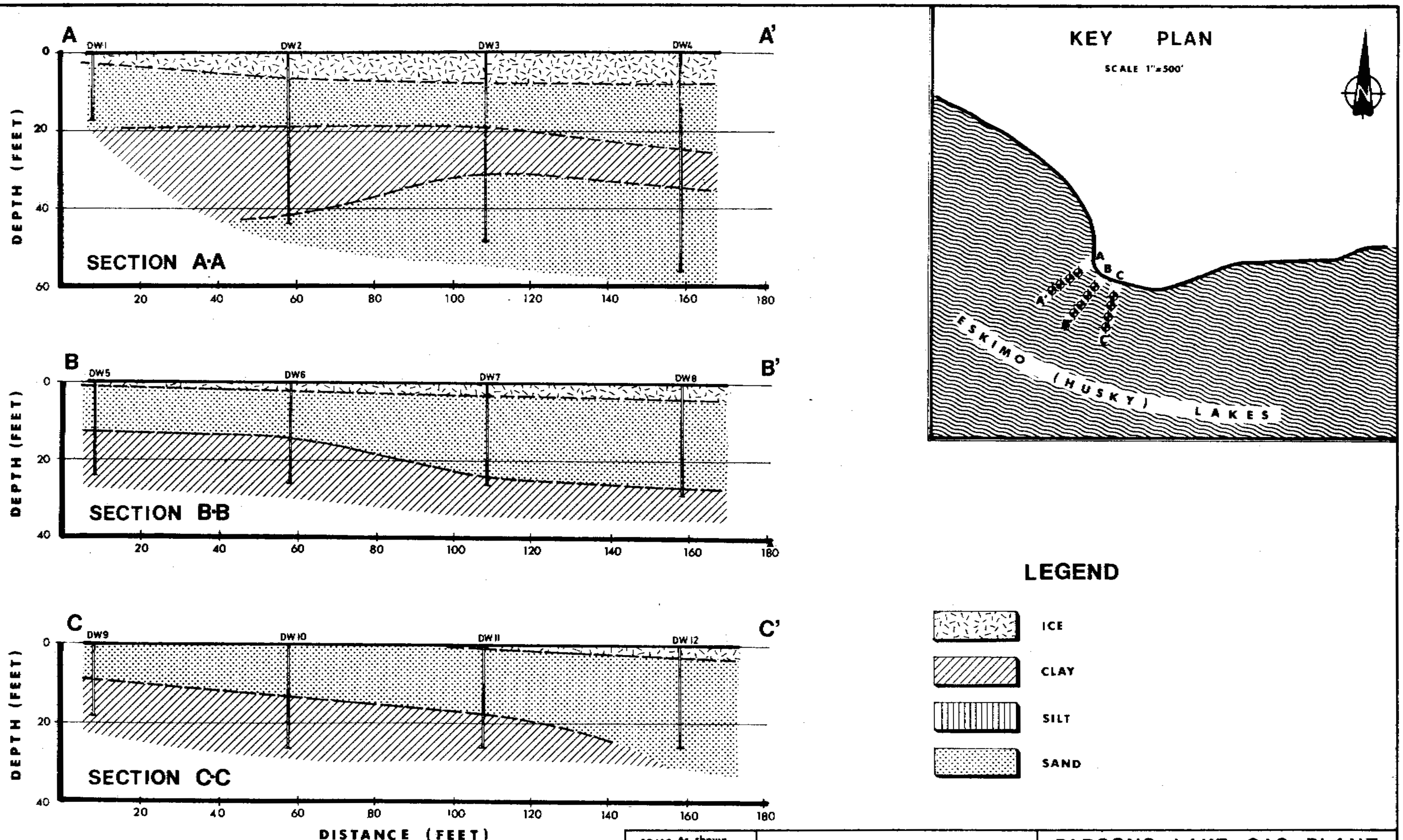
Test hole locations are shown on Plate A-2, Appendix "A". Cross sections were compiled for the three lines of test holes at the principal dock location and are illustrated on Figure 5.3. Test hole logs and laboratory test results are presented in Appendix "D".

The depths of water (ice) in the docksite test holes ranged from several inches to 14.5 feet (10-15 cm to 4.4 cm). These values are shown in Figure 5.4. Along the shoreline the water is very shallow, and shallow water also extends for a distance of approximately 100 feet (30.4 m) offshore along the eastern edge of the spit at the principal dock location.

Soundings on a closely-spaced grid, extending for approximately 500 feet (152 m) outwards from the shoreline, will be needed before a final docksite can be chosen.

The stratigraphic sequence beneath the proposed docksite is quite straightforward. Medium to high plastic clay "till-like" material, with a number of gravel lenses, overlies a well graded, silty, fine-grained sand. This latter deposit is probably the Pleistocene pre- or inter-glacial, deltaic sand described in Reference No. 3. The "till-like" material generally rests on a fine, brown to grey sand but the two deposits are sometimes separated by a high plastic clay.

Unconfined compressive strengths of the "till-like" material ranged from 2054 to 3917 psf (98.3 to 187.5 kPa). The very stiff consistency of the "till-like" stratum was confirmed in the Standard Penetration Test by 'N' values ranging from 9 to 30 blows per foot of penetration. An undrained triaxial test was carried out on a remolded mixture of three clayey soil samples from a depth of 19 to 21 feet (5.8 m to 6.4 m) in three test holes. The effective angle of internal friction for the clay was 19.5 degrees and the cohesion intercept was 5 psi (34.5 kPa) (Plate D-52).



SCALE	As shown
DATE	May 1976
MADE	A.C.
CHKD.	Y.K.
APPD.	R.T.

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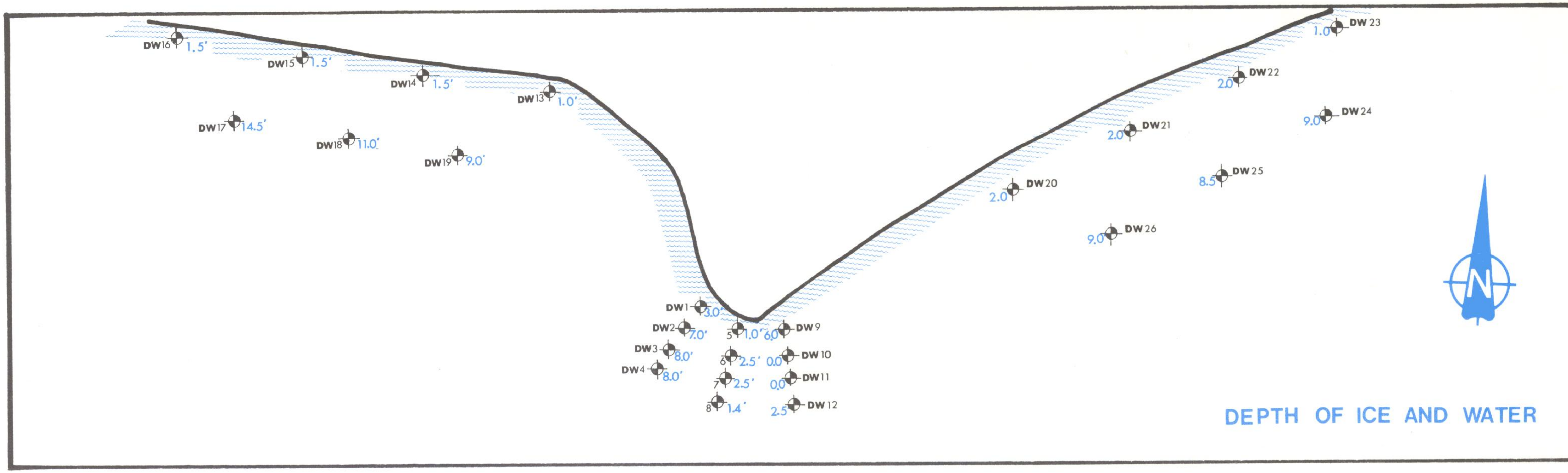
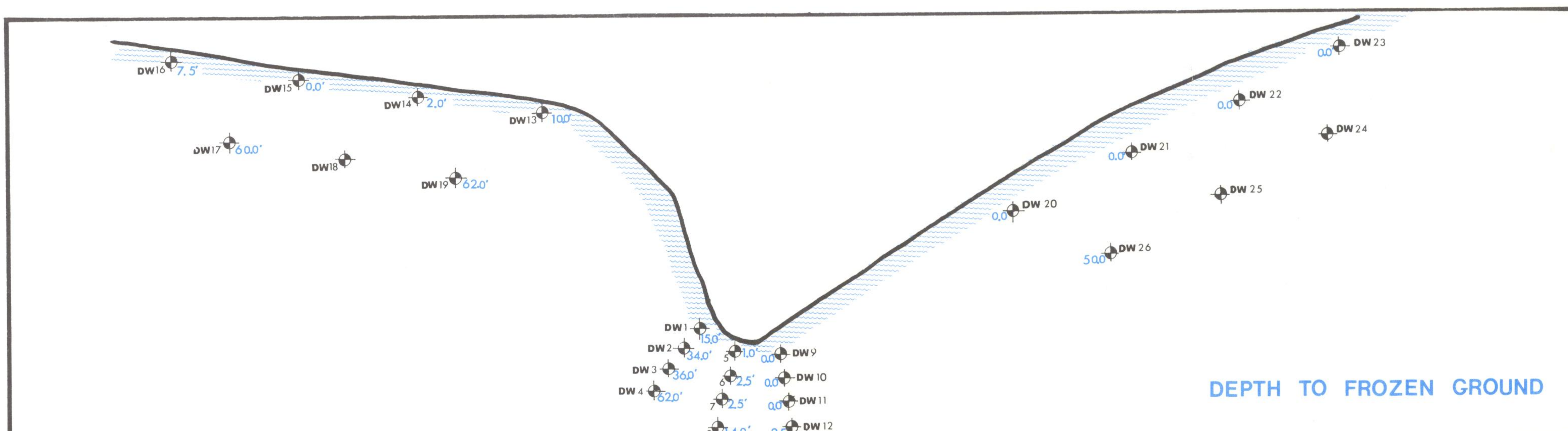
PARSONS LAKE GAS PLANT
DOCKSITE
STRATIGRAPHIC SECTIONS

No. CS 3343

FIGURE 5.3





REVISIONS	REFERENCES	SCALE 1" = 200' DATE MAY 1976 MADE DS CHKD. RT APPD.	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	PARSONS LAKE GAS PLANT DOCK SITE No. CS 3343 — 5.4

Visible ice contents were generally very low, 5 to 10 percent, and moisture contents ranged from 18 to 35 percent, varying noticeably in the more layered profiles. Frozen bulk densities increased with depth from 113 pcf (1.8 Mg/m^3) at the 6 to 10 foot (1.8 m to 3 m) depth to 130 to 135 pcf (2.1 to 2.2 Mg/m^3) at 30 feet (9.1 m).

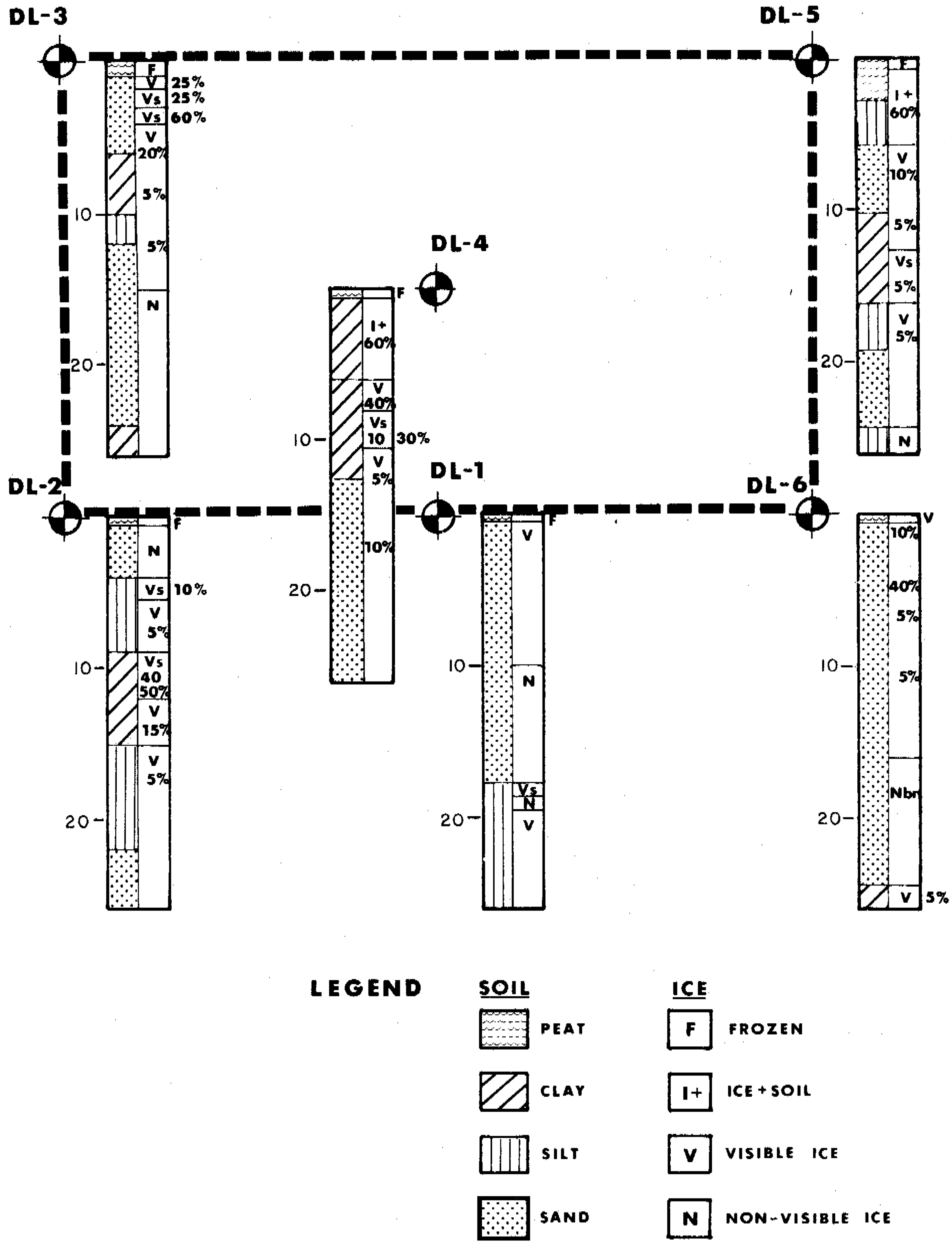
Depths to permafrost were directly related to the depth of open water. Where ice extended to the top of the sediment, the soil profile was generally frozen. In several test holes, however, a thin layer of unfrozen sediment was observed. The depth to the permafrost table increased dramatically where water was encountered beneath up to seven feet (2.1 m) of lake ice. Depths to the permafrost table at the different test hole locations are shown on Figure 5.4.

5.5 Staging Area

Immediately north of the proposed docksite, an area approximately 300 by 500 feet (91 m by 152 m) in plan was set out as a staging area for the stockpiling of equipment and materials. The site is situated on the lacustrine plain 10 to 12 feet (3 m to 3.6 m) above the level of Hans Bay and appeared to be well drained. During the 1976 field program six test holes were drilled as shown on Plate A-2.

The layout of test holes and the soil-ice profiles at the test hole locations are shown on Figure 5.5. Test hole logs and particle size analyses are presented on Plates D-27 to D-32 and D-47 to D-51 respectively, in Appendix "D".

The soil profile at this site consists of inter-bedded silty sand, sandy silt and silty clay. Depths of organic peat cover were less than 3 feet (1 m), generally 9 to 15 inches (23 cm to 38 cm). The stratigraphy is not complex, with a medium plastic clay overlying fine, dark grey to black sand. In the southern part of the area, silty sand overlies the fine grey sand and silty sand and silt overlie the clay. Moisture contents range from 22 to 35 percent and reflect very low excess ice contents ranging from 5 to 15 percent. Only in the upper 5 to 8 feet (1.5 m to 2.4 m) were ice contents excessive, frequently 50 to 60 percent. Frozen bulk densities were 85 to 97 pcf (1.4 to 1.5 Mg/m^3) in the surficial sand deposit and 92 to 122 pcf (1.5 to 2.0 Mg/m^3) in the deeper, fine-grained silt and clay strata.



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PARSONS LAKE GAS PLANT STAGING AREA

SCALE 1" = 500'	DATE May, 1976	MADE A.C.	CHKD. R.S.T.	JOB: CS 3343	FIGURE 5.5

This site is relatively well suited for the construction of a gravel pad and roads, provided adequate thicknesses of pad materials are placed to satisfy thermal and structural constraints.

5.6 Transporter Road

To transport heavy modules from the docksite to the plantsite, a roadway with a 35-foot (10.7 m) surface and grades less than 7 percent is required. The proposed alignment is slightly more than one mile (1.6 km) in length. A total of six test holes were drilled to determine the subsoil stratigraphy relative to the changes in terrain type. Test hole logs and laboratory test results are presented in Appendix "E". A sectional profile along the alignment is shown on Figure 5.6.

Initially, the transporter road crosses the lacustrine plain north of Hans Bay and is underlain by interbedded fine-grained, silty sands and low plastic grey clays. Some of the clay is gravelly and "till-like". Visible ice contents are generally low. However, greater than 50 percent excess ice was encountered in the uppermost 5 feet (1.5 m) of the profile.

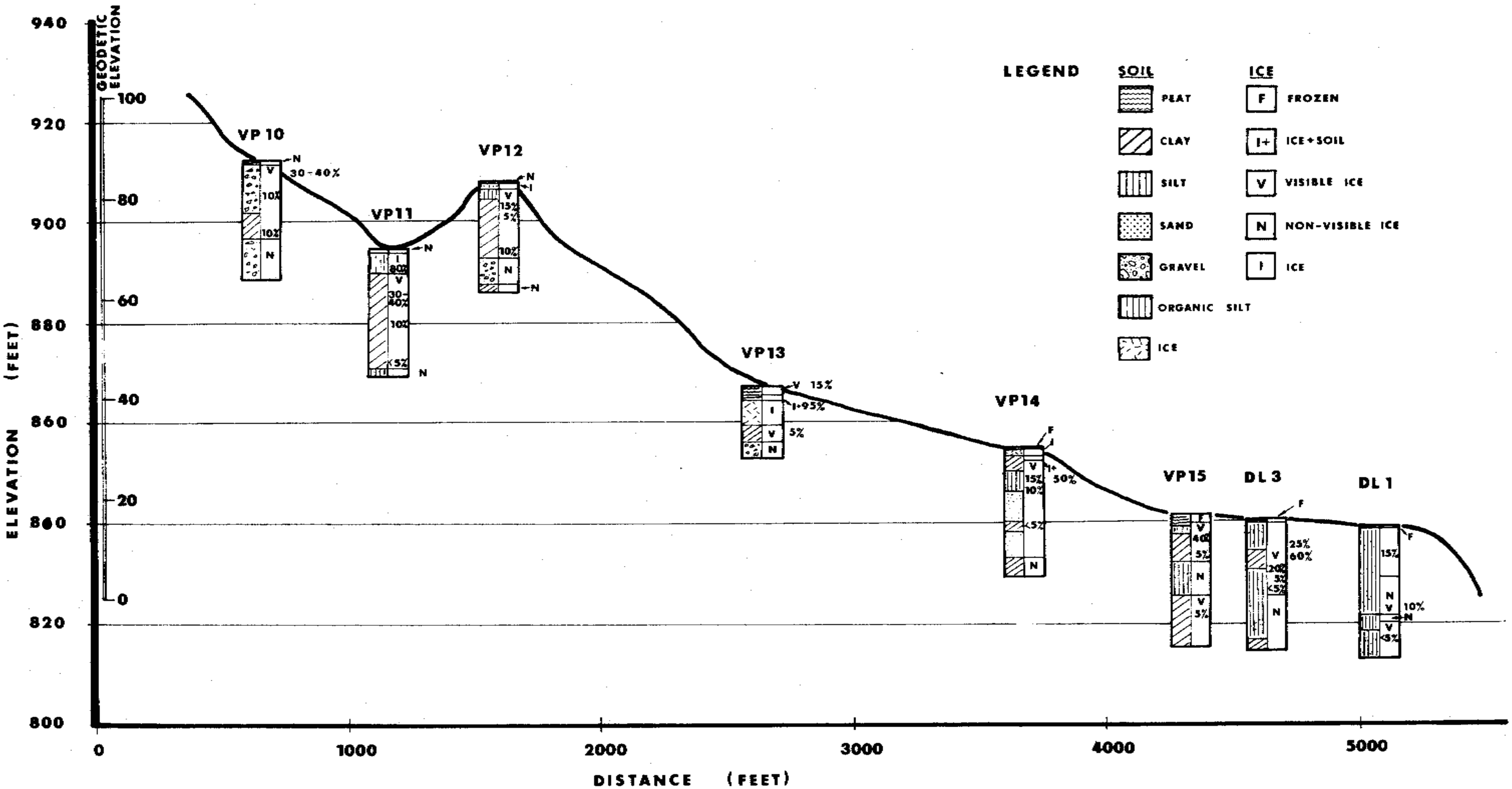
Appproaching the plantsite, the sand pinches out so that the stratigraphy consists of 20 to 30 feet (6m to 9 m) of low to medium plastic clay resting on clayey gravel. In the more poorly drained areas, the clay is in turn overlain by organic and inorganic silts. Test hole VP-10, closest to the plantsite, intersected 25 feet (7.6 m) of poorly sorted gravel with clayey lenses. Again, apart from the uppermost 5 feet (1.5 m), excess ice contents are low.

5.7 Access Roads

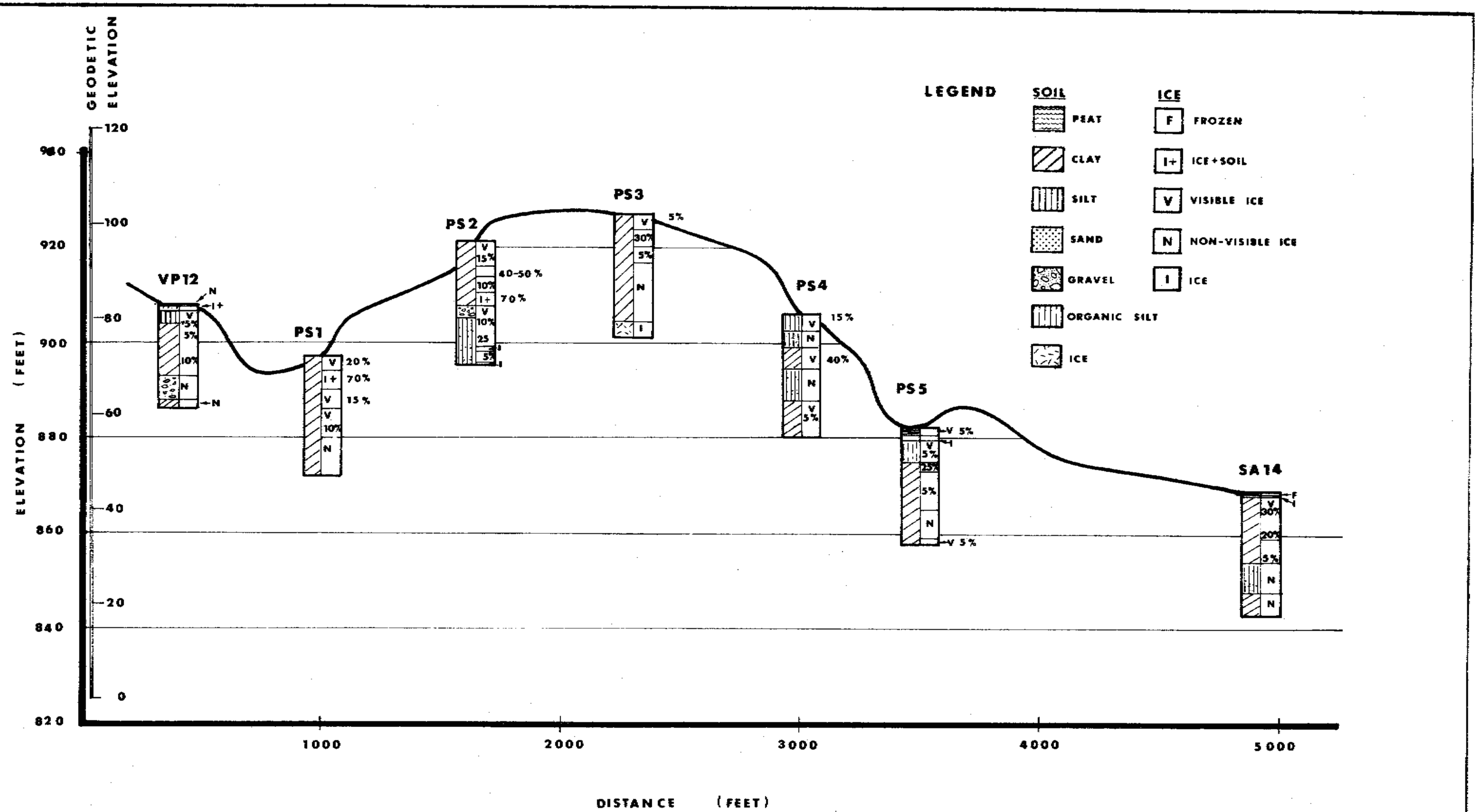
5.7.1 Airstrip from Transporter Road

The access road to the airstrip leaves the transporter road to Hans Bay about one-half mile (800 m) east of the plantsite. Five test holes were drilled along the proposed alignment. Test hole logs and laboratory test results are presented in Appendix "E". A sectional profile along the road is shown on Figure 5.7.

The access road is routed along the crest of a moraine ridge which is composed predominantly of grey-brown, low to medium plastic, "till-like" clay. Depressions in the ridge are filled with peat and organic silt, overlying the clay. Elsewhere, sand, gravel and silt lenses



SCALE AS SHOWN DATE MAY, 1976 MADE A C CHKD. R S T APPD.	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	TRANSPORTER ROAD SECTIONAL PROFILE No. CS 3343 — FIG. 5.6



SCALE	AS SHOWN
DATE	MAY 76
MADE	M.B.
CHKD.	Y.K.
APPD.	R.T.

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PARSONS LAKE GAS PLANT
S.T.O.L. AIRSTRIP ACCESS ROAD

No. CS 3343
FIG. 5.7

occur within the clay, which is apparently underlain by a fine-grained, grey sand.

Visible ice contents are very variable, ranging from less than 10 percent in the sands and gravels, to 30 to 70 percent in the clay. Massive ice layers up to 2 feet (61 cm) thick were intersected in some of the test holes.

5.7.2 Borrow Sources from the Plantsite

Access to the proposed borrow sources from the plantsite is via a road approximately three miles (4.8 km) long. It was necessary to separate the access route to Borrow Sources 1 and 2 from that to Borrow Sources 3 and 4 because of steep grades along the creek valley in which the outwash terraces were deposited. A total of ten test holes were drilled along the proposed alignment. Soil profiles and laboratory test results are presented in Appendix "E".

The north-south section of the road, leading to Borrow Sources 3 and 4, is underlain by 3 to 13 feet (1 m to 4 m) of silty clay resting on bedded gravels and sands. South from the plantsite, the clay layer becomes thicker and the underlying sediments much sandier. Test hole VP-19, located in a poorly drained area, intersected 15 feet (4.5 m) of peat resting on silty, low plastic clay. Excess ice contents are generally low except where massive segregated ice is present, close to the plantsite.

The road to Borrow Sources 1 and 2 traverses grey, low to medium plastic clays which appear to rest on sandy gravels which lie at a depth of approximately 30 foot (9 m). Test hole VP-25, drilled close to the margin of Borrow Source No. 1, intersected poorly graded gravels with silty sand lenses throughout its depth. Excess ice contents range from 20 to 60 percent, with massive segregated ice lenses occurring in the more gravelly material.

5.8 Service Corridor

Between the plantsite and well cluster sites a service corridor some 100 feet (30 m) wide is required, containing an access road, aboveground pile-supported gathering pipeline and a power conduit. The proposed alignment of the service corridor follows closely that set out on Gulf Oil Canada Limited Drawing 1-75131-25. A total of fifty-seven test holes were drilled. Soil profiles and laboratory test results are presented in Appendix "F".

5.8.1 Plantsite to Parsons Lake

Subsurface conditions within the service corridor are very variable, depending on the type of terrain traversed.

In general, the initial section of this route segment, between test holes VP-9 and VP-4, is underlain by up to 9 feet (2.7 m) of peat and organic silt, resting on a low to medium plastic, grey silty clay. Test hole VP-6 intersected interbedded sands and gravels between 3 feet and 26 feet (1 m and 8 m). Subsurface conditions beneath the remaining section of the proposed road are fairly uniform. Low to medium plastic clay with minor silt overlies fine to coarse, sandy gravel.

Excess ice contents are very high (up to 70 to 80 percent), especially in the gravels and organic sediments.

5.8.2 Cluster No. 2 to Cluster No. 3

The relief of the initial section of this route is quite variable. However, subsurface conditions are fairly uniform between Cluster No. 2 and test hole UV-12, with low to medium plastic, "till-like" clays and silt, resting on poorly sorted gravels and sands. Peat and organic silt are present in the lower, poorly drained sections. Excess ice contents are very high, averaging 60 to 70 percent, with lenses of massive ice up to 7 feet (2 m) thick.

Between test holes UV-13 and UV-27, the service corridor follows a series of glaciofluvial ridges composed of poorly sorted sands and gravels often with a veneer of organic deposits and low to medium plastic clay. In depressions the clay is much thicker. On average, 35 to 40 percent excess ice was visible, with occasional ice lenses up to 5 feet (1.6 m) thick. Ice contents appear to increase to the north.

Immediately south of Cluster No. 3, the route crosses a major drainage course. Here, peat and organic silts overlie silty, low to medium plastic clays with occasional gravel lenses. Excess ice contents average only 20 to 30 percent, but an 8 foot (2.4 m) ice lens was intersected in one test hole.

5.8.3 Cluster No. 3 to Cluster No. 4

Subsurface conditions along this route segment are reasonably uniform despite the undulating nature of the terrain. Up to 14 feet (4.3 m) of silty clay and peat overlies a poorly sorted sandy gravel.

The gravel stratum is not present in test hole UV-36 which contains clay with occasional lenses of silty sand. Excess ice contents range from less than 5 percent to about 50 percent in the gravels, and as high as 85 percent within the surficial peat and clay deposits. Massive ice layers up to 16 feet (4.9 m) thick were also encountered.

5.8.4 Cluster No. 3 to Cluster No. 5

The ridge-crest portions of this route segment are underlain by sandy gravel with a thin peat veneer. The gravel apparently rests on a silty clay "till-like" deposit. The log for test hole UV-48 suggests that this clay occurs in pockets within the glaciofluvial material. Excess ice contents range from 10 to 70 percent.

Lacustrine sands, silts and clays were intersected in test holes drilled in the low-lying and poorly drained sections of the proposed route. Less than 5 percent excess ice occurs in the sands and up to 70 percent in the clays and silts.

5.8.5 Cluster No. 5 to Cluster No. 1

Up to 15 feet (4.6 m) of silty clay and silt, underlying a 2 to 6 foot (0.6 m to 1.8 m) organic veneer, rests on poorly sorted glaciofluvial sand containing gravel lenses. Excess ice contents as high as 70 percent were encountered in the organic deposits and in some of the sands.

5.9 Well Clusters

Twenty-four test holes were drilled to investigate subsoil conditions at five well cluster sites, designated by Gulf Oil Canada Limited. The locations of the well clusters, and distribution of test holes at each cluster, are shown on Plate A-2 and Figures 5.8 to 5.12, respectively. Test hole logs and laboratory test results are presented in Appendix "G".

5.9.1 Well Cluster No. 1

This cluster is located on a glaciofluvial ridge, approximately one mile (1.6 km) north of Parsons Lake.

The stratigraphy of the site consists of a thin veneer of silt and clay overlying poorly sorted, silty sands and gravels. In two test holes, well graded sandy gravel forming part of the gravel drilling pad was intersected.

The subsoils are very ice-rich, averaging 40 to 50 percent excess ice. Massive ice layers up to 9 feet (2.7 m) thick were intersected in all five test holes.

5.9.2 Well Cluster No. 2

The site of this cluster is a low morainic hill, about 6000 feet (1830 m) south of Parsons Lake.

Subsurface conditions are straightforward with 10 to 15 feet (3 m to 4.5 m) of low to medium plastic clay resting on poorly sorted sandy gravels, with minor sand. A 1 to 2 foot (30 to 60 m) layer of peat covers much of the site.

Excess ice conditions at this site are good. With the exception of two thin ice-rich peat and clay sections, ice contents average 10 to 15 percent.

5.9.3 Well Cluster No. 3

Cluster No. 3 is located on a rounded glaciofluvial hill which forms a headland on the east shore of Parsons Lake.

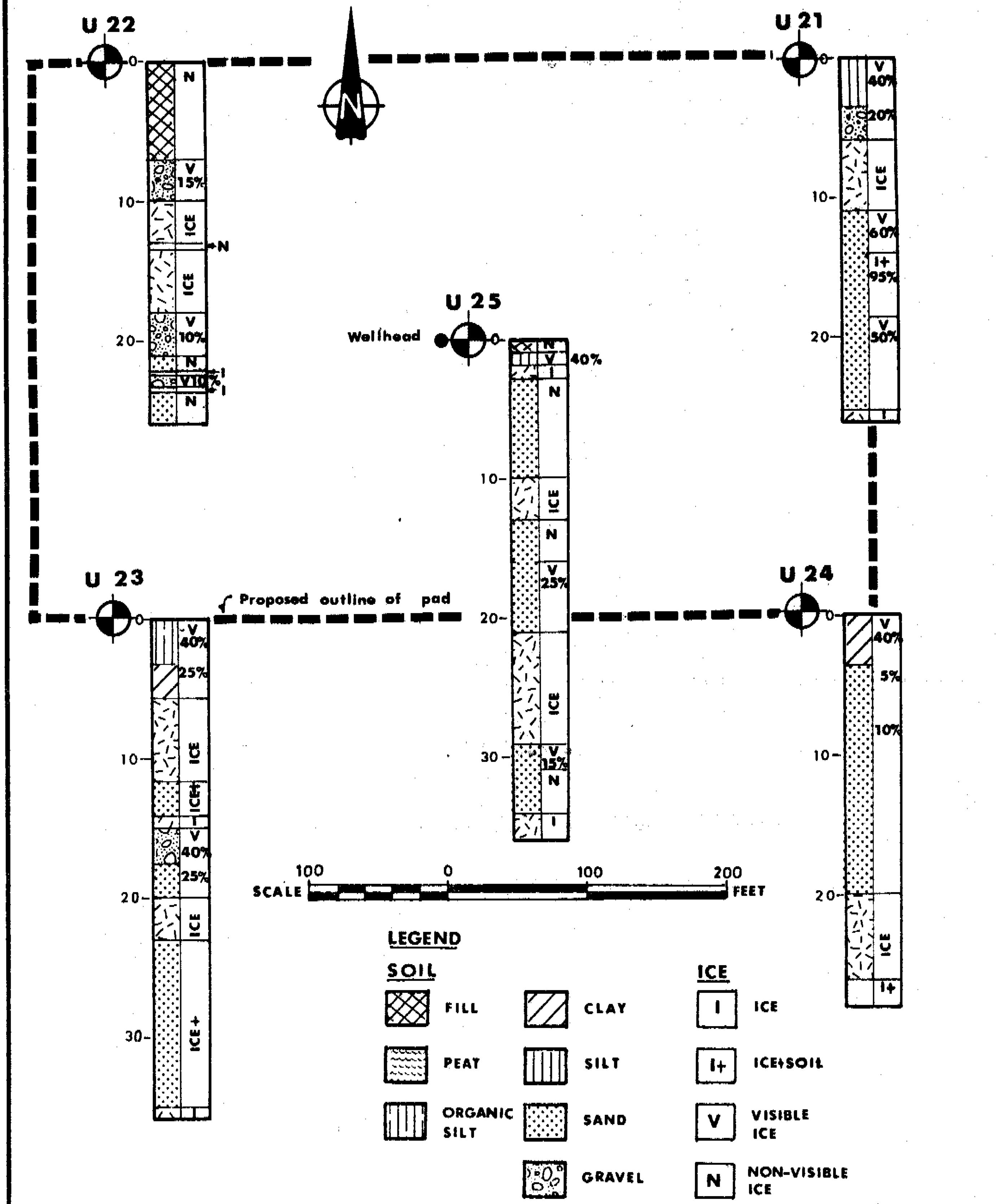
Five to ten feet (1.5 to 3 m) of organic silt and clay, with minor inorganic silt, overlies a poorly sorted silty sand at this site. In two of the test holes, the sand stratum rests on a sandy, fine to coarse gravel which appears to be underlain by sandy, low to medium plastic clay. The gravel drilling pad was intersected in one test hole.

Excess ice contents are high, averaging 40 to 50 percent. Massive ice layers up to 5 feet (1.5 m) thick are common.

5.9.4 Well Cluster No. 4

This cluster site lies in glaciofluvial terrain, about two miles (3.2 km) due east of Cluster No. 3.

The stratigraphy is relatively straightforward and consists of low to medium plastic, silty clay underlain at depth by poorly to well sorted clayey gravel. Much of the site has a thin organic silt and peat veneer.



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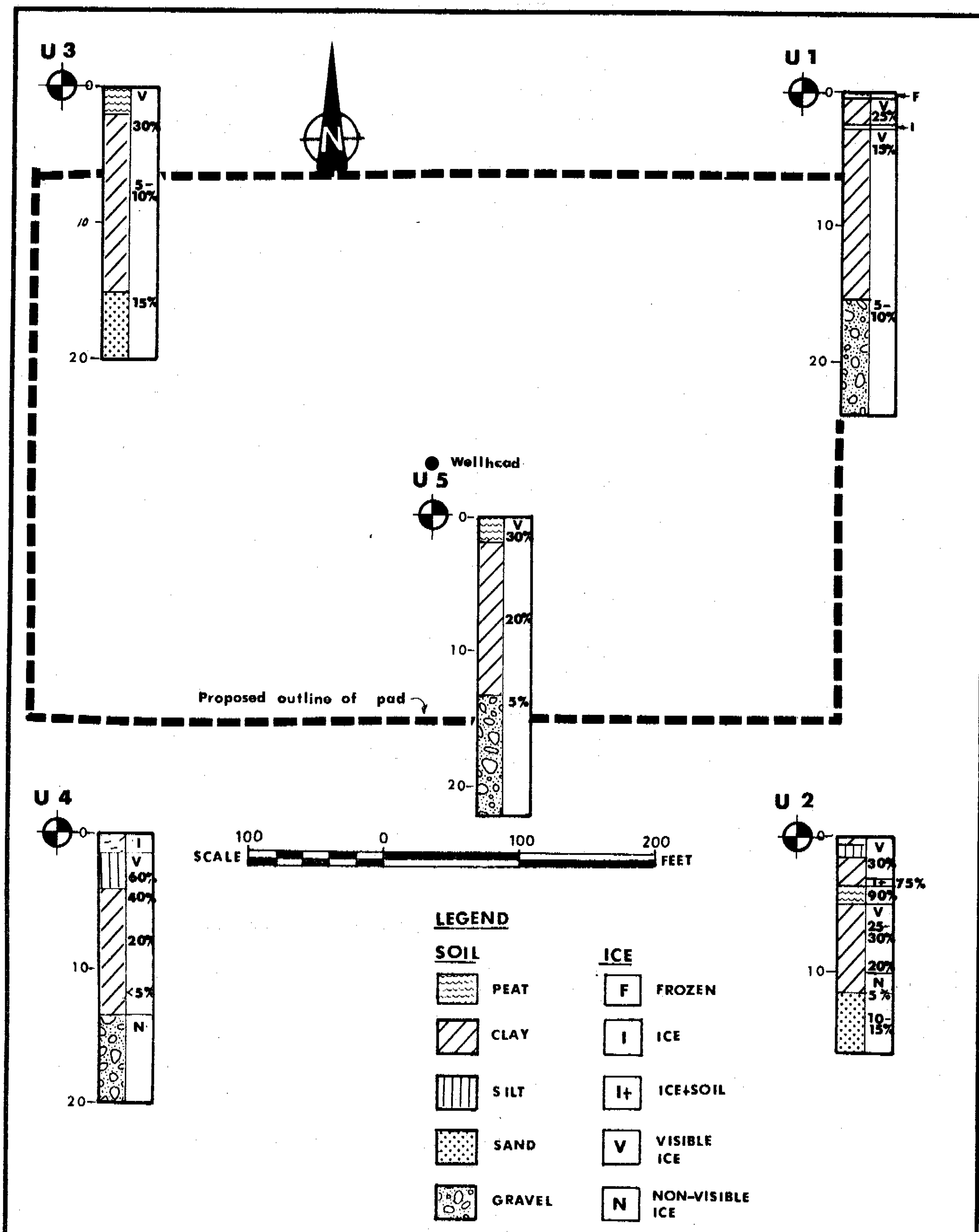
PARSONS LAKE GAS PLANT
WELL CLUSTER 1

SCALE 1" = 100'	DATE May 1976	MADE GNL	CHKD. RSI	JOB: CS 3343	FIGURE 5.8



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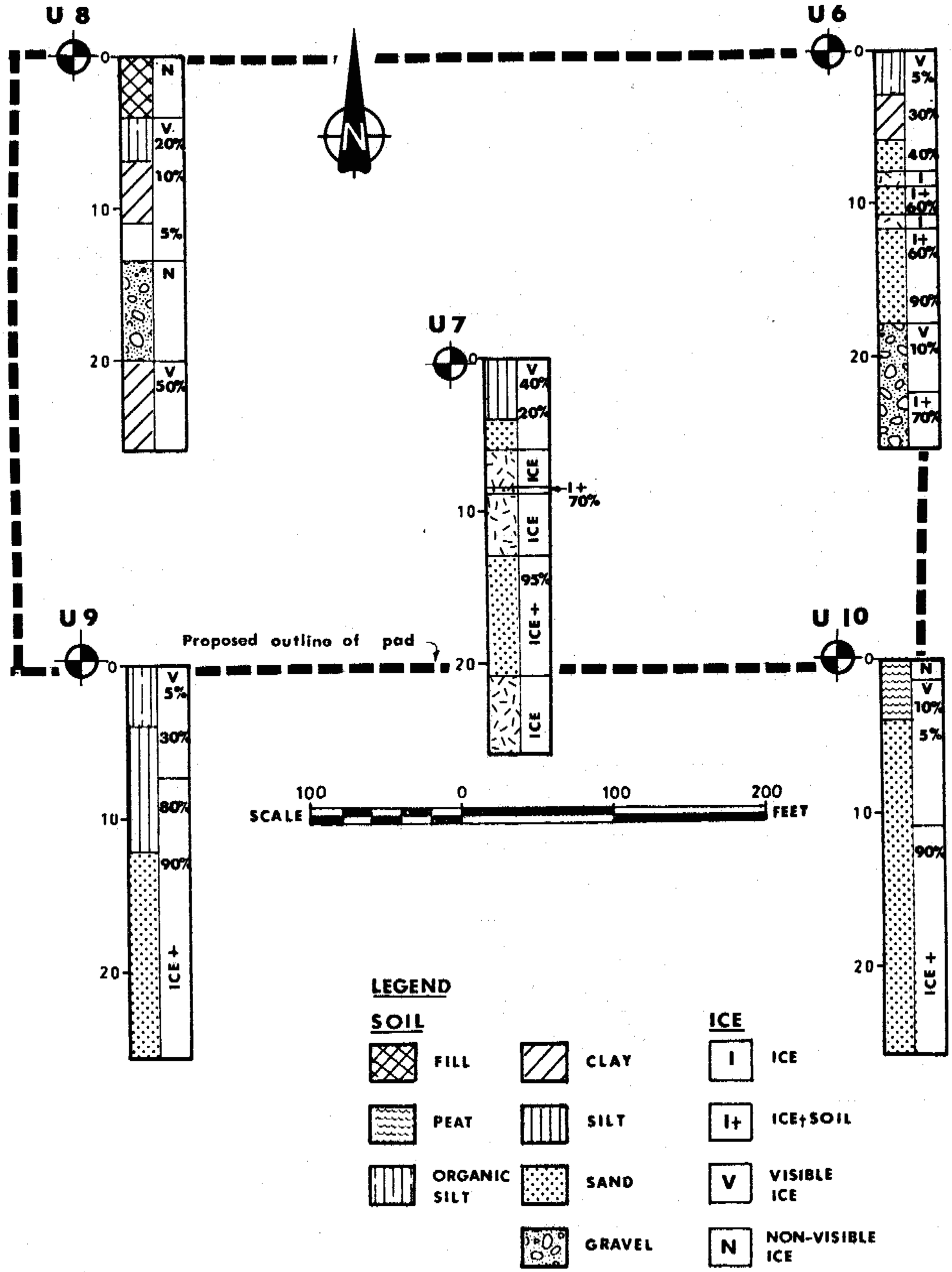
PARSONS LAKE GAS PLANT
WELL CLUSTER 2

SCALE 1" = 100'	DATE May 1976	MADE GNL	CHKD. RST	JOB: CS 3343	FIGURE 5.9



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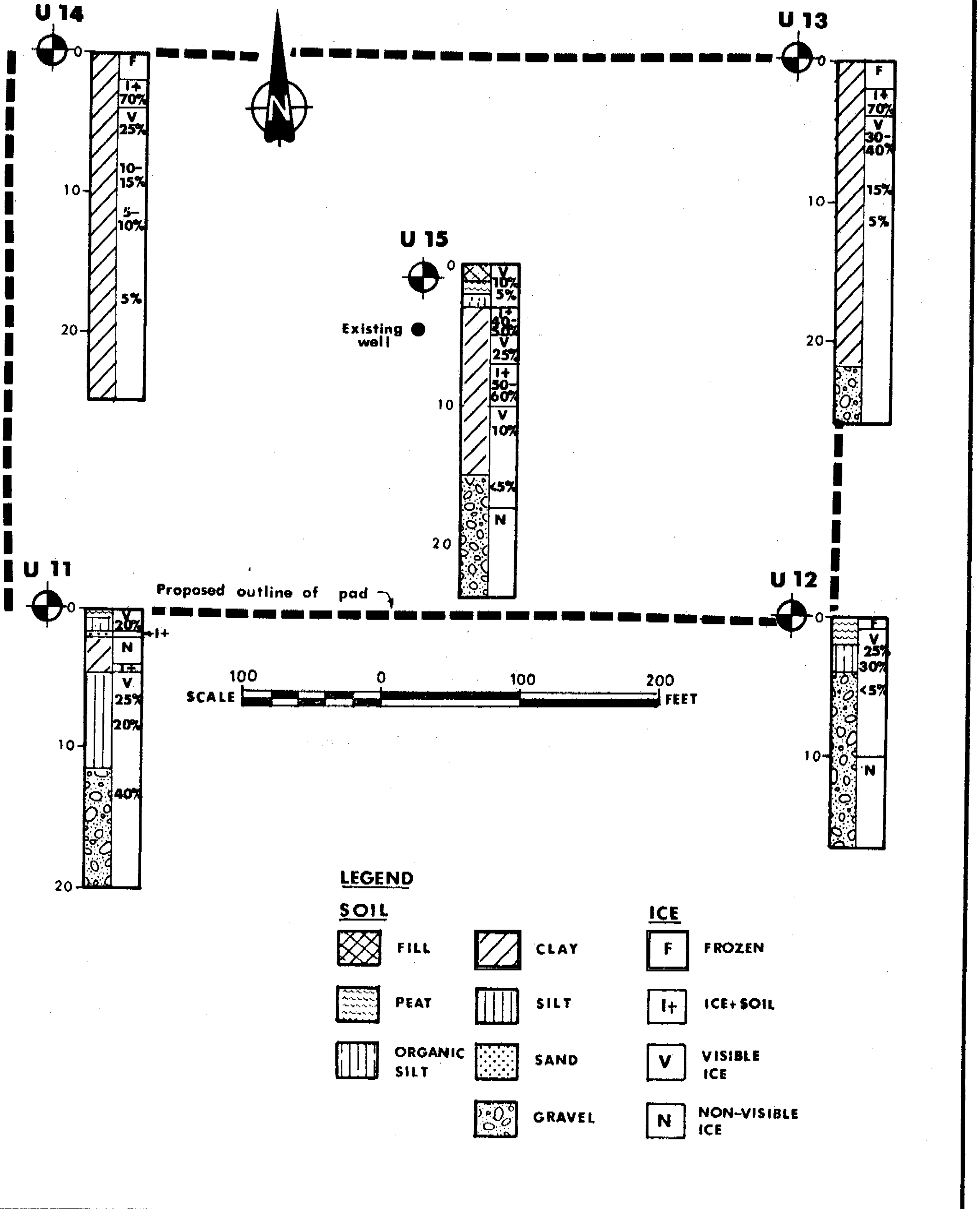
PARSONS LAKE GAS PLANT
WELL CLUSTER 3

SCALE 1" = 100'	DATE May 1976	MADE GNL	CHKD. RST	JOB: CS 3343	FIGURE 5.10



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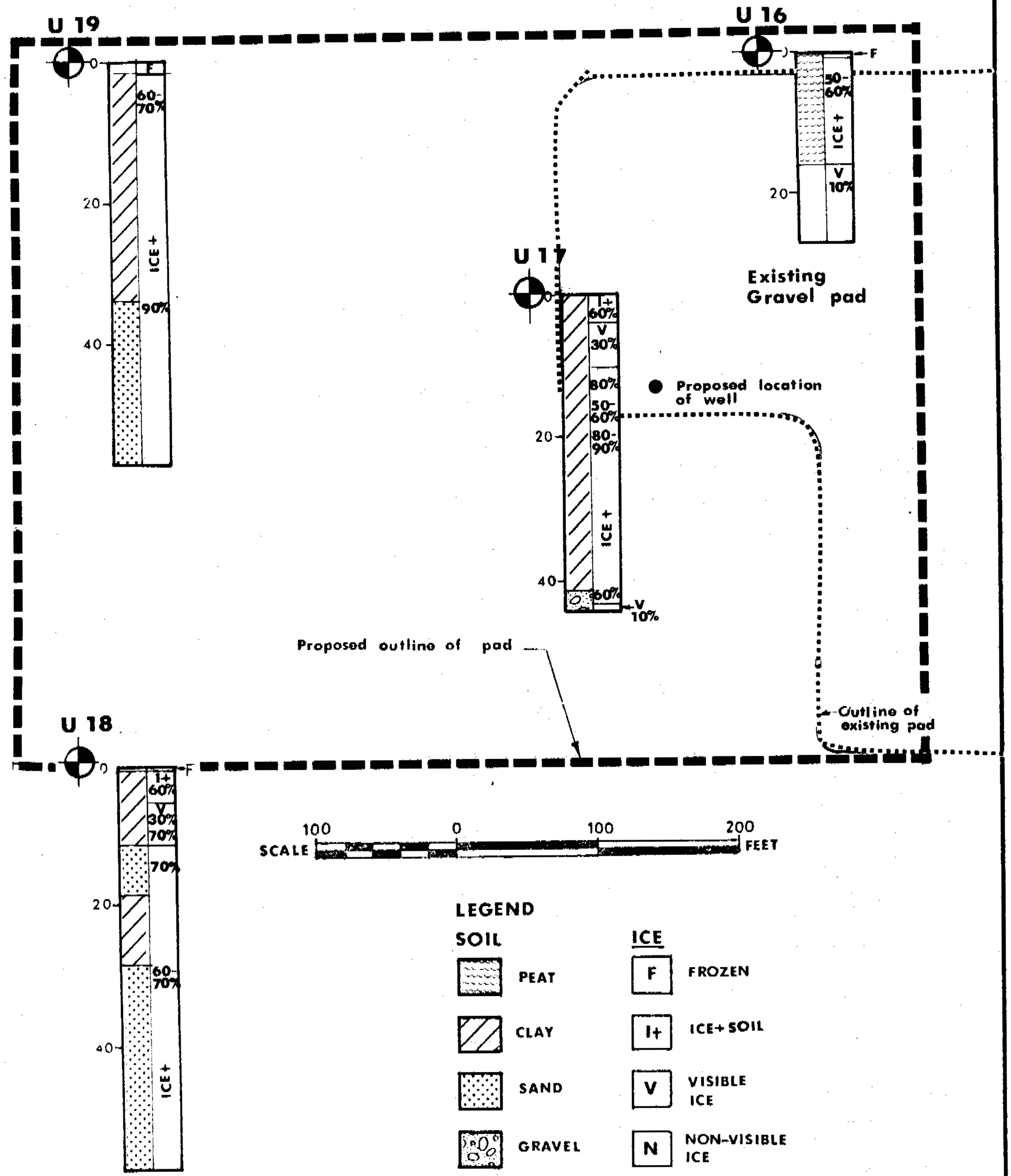
PARSONS LAKE GAS PLANT
WELL CLUSTER 4

SCALE 1" = 100'	DATE May 1976	MADE GNL	CHKD. RST	JOB: CS 3343	FIGURE 5.11



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PARSONS LAKE GAS PLANT
WELL CLUSTER 5

SCALE 1" = 100'	DATE May 1976	MADE GNL	CHKD. RST	JOB: CS 3343	FIGURE 5.12

With the exception of some thin ice-rich layers, excess ice contents at the site of Well Cluster No. 4 are low.

5.9.5 Well Cluster No. 5

Well Cluster No. 5 is located on top of an elongated hill, immediately north of Parsons Lake.

Subsurface conditions at this site are fairly straightforward. A peat and organic silt layer of variable thickness overlies silty, low to medium plastic clay. The clay stratum rests, in turn, on a fine-grained, silty sand, with some gravel lenses.

Excess ice contents are very high beneath this site, averaging 70 to 80 percent. Although no massive ice layers were encountered during drilling, highly ice-rich sediments were intersected down to the limit of drilling, at close to 60 feet (18 m) below the surface.

5.10 Granular Borrow Sources

5.10.1 General

Four potential gravel source zones were investigated in the Parsons Lake area by Klohn, Leonoff Consultants Ltd. in 1974 (Reference No. 1). In all, eleven sources were studied in Zones 1 and 2. A total of two hundred and twenty-eight test holes were then drilled in the four largest sources, located approximately two miles (3.2 km) southwest of the proposed plantsite. The report concludes that: "Sources 1, 2, 3 and 4 contain gravel and sand materials in sufficient quantities and are recommended for development in order of priority as listed. The minimum quantities of gravel and sand materials which can be removed from these sources have been estimated as follows:

Source 1	-	1,000,000	cubic yards
Source 2	-	250,000	cubic yards
Source 3	-	370,000	cubic yards
Source 4	-	200,000	cubic yards
		1,820,000	cubic yards "

The gravels were well graded, and included cobbles up to 6 inches (15 cm) in diameter and varying percentages of sand and fines. Moisture and excess ice contents were low, although some massive ground ice was encountered. The average overburden thickness was 4 feet (1.2 m).

Material handling and recovery methods are discussed in References No. 1 and No. 2.

5.10.2 Borrow Quantities

The objectives of the 1976 Geotechnical Survey were twofold. The first objective was to assess the quantity of gravel available, and the likely frequency, distribution and size of large ground ice bodies within Sources 1, 2, 3 and 4. Sufficient test hole information was presented in Reference No. 1 to permit construction of cross sections through the borrow sources. In all, fourteen cross sections were drawn as shown on Figure 5.13. The cross sections are presented in Appendix "H".

To assist in interpretation of the available subsurface data, six holes were also drilled as part of the 1976 Geotechnical Survey. These were drilled at 1974 test hole locations, as shown on Figure 5.13. With the exception of test hole BG-5, all were located adjacent to the test hole stakes of the earlier investigation. Snow depths were considerable in the area of Borrow Source No. 4, and the marker stakes could not be found. Consequently, test hole BG-5 was improperly positioned in the northern portion of Borrow Source 9 (Reference No. 1).

Test holes BG-3 and BG-4 were drilled in Source No. 1 adjacent to test holes 4 and 28 (Reference No. 1), respectively. In BG-3 a thin veneer of peat overlies 13 feet (4 m) of sandy gravel resting on silty sand, which extends to the maximum depth of drilling at 35 feet (10.7 m). The particle size distribution, Plate H-17, shows the gravel to be clean. However, it should be noted that the gravel sizes and percentages are not accurate due to fracturing caused by use of a rock bit. Moisture and excess ice contents of the gravel are in the order of 5 to 10 percent. BG-4 has a similar moisture and ice profile and intersected gravel to a depth of 37 feet (11.3 m). The gravel was overlain by 7 feet (2 m) of highly ice-rich peat.

In Source No. 2, test holes BG-1 and BG-2 were drilled adjacent to 1974 test holes 123 and 118 (Reference No. 1), respectively. Beneath a very thin peat veneer, gravel extends to depths of less than 10 feet (3 m) and is underlain by silty sands and silts. The gravel has a very low ice and moisture content. Gravel sizes up to 3 inches (76 mm) in diameter were observed and cobbles were reported by the driller. A more representative coarse gravel sample is shown on Plate H-16. This sample was obtained by reaching down into the hole rather than collecting the wash return. Test hole BG-6, in Source No. 3, was located adjacent to 1974 test hole 150 (Reference No. 1), and intersected 20 feet (6.1 m) of clean sandy gravel overlying a medium plastic clay deposit. Ice and moisture contents were very low.

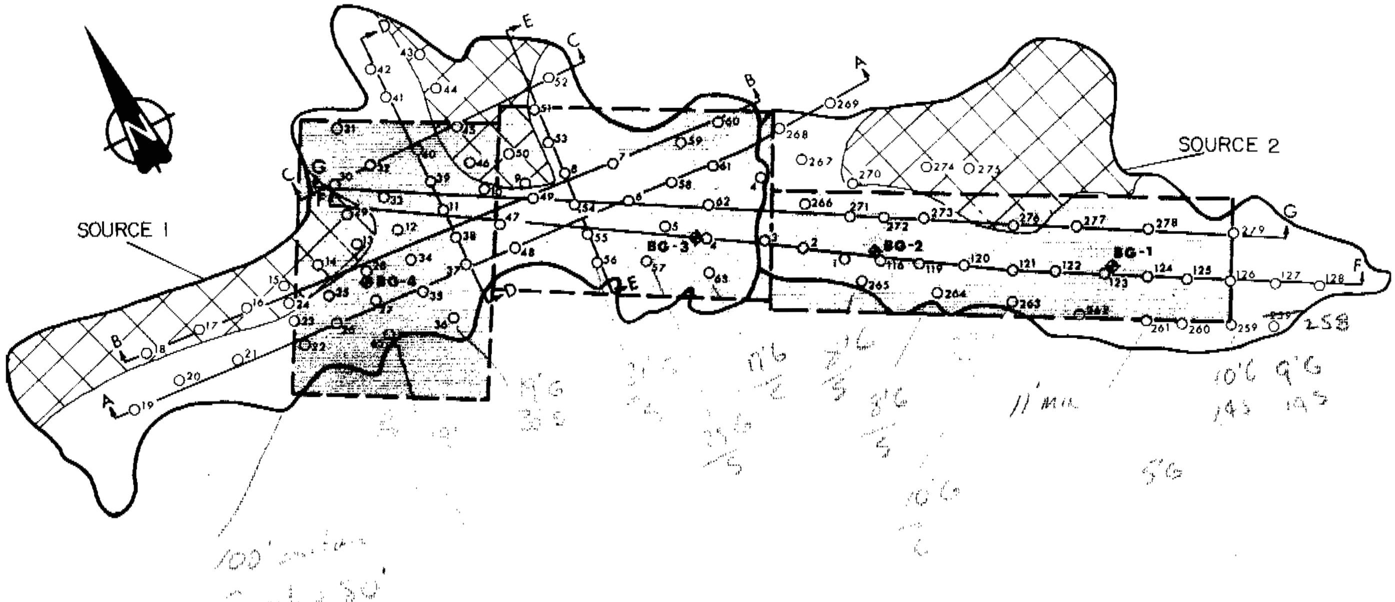
The logs of test holes BG-1 to 4 and BG-6 are shown on the cross sections constructed using existing information, and in Appendix "H". Agreement in stratigraphy is fairly good although the inability to collect undisturbed soil samples occasionally resulted in an over-emphasis of the percentage of fine sizes. Ice contents were in better agreement.

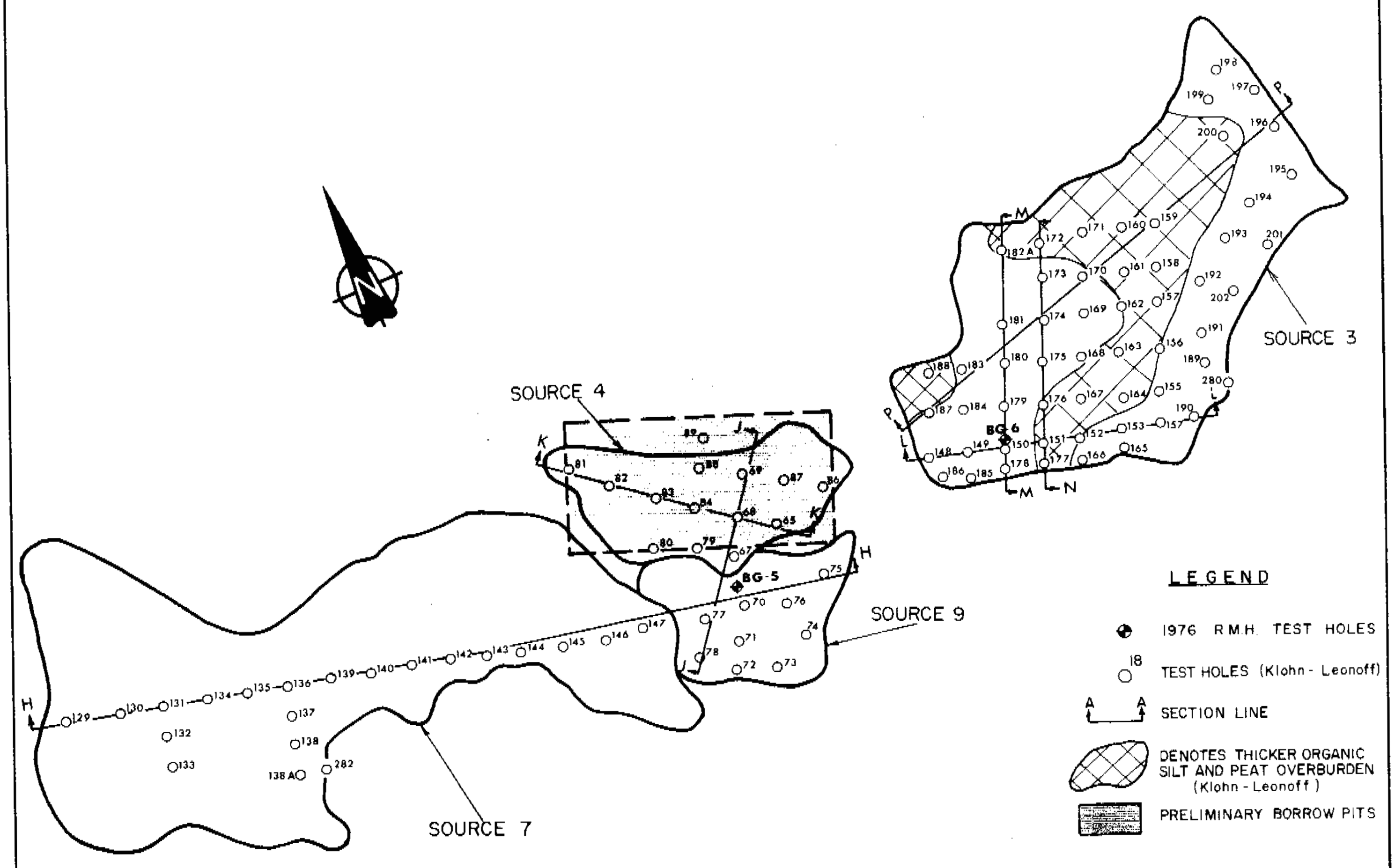
To provide an estimate of available gravel borrow quantities from Sources 1, 2, 3 and 4, four preliminary borrow pits have been located in the areas of shallowest overburden, as shown on Figure 5.13. A statistical analysis was carried out, using test hole information, to calculate available borrow quantities. Since ground surface elevations were not available at the test hole locations (Reference No. 1), the topography was assumed to be flat. Table 5.1 presents estimates of available gravel volume, assuming borrow pits of 20, 30 and 40 feet (6.1 m, 9.1 m and 12.2 m) in depth. The availability of information is indicated but, in several instances, gravel

TABLE 5.1

BORROW QUANTITIES

SOURCE NO.	SURFACE AREA (sq. yd.)	TOTAL NO. OF TEST HOLES	TEST HOLE DENSITY	NO. OF TEST HOLES DEEPER THAN 20 ft.	30 ft.	40 ft.	AVERAGE OVERBURDEN DEPTH (ft)	PIT DEPTH (ft)	TOTAL VOLUME (cu. yds.)	VOLUME SAND ?? GRAVEL (cu. yds)	GRA-VEL	ICE
A	120,000	28	1:4000 sq yds.	25	18	4	2.2	20	800,000	540,000	67.5	6.5
								30	1,200,000	740,000	61.7	6.5
								40	1,600,000	796,000	49.7	6.5
B	115,600	25	1:4600 sq yds.	23	14	3	4.2	20	750,000	472,000	62.9	7.4
								30	1,156,000	601,120	52.0	7.4
								40	1,500,000	693,000	46.2	7.4
C	140,000	26	1:5300 sq yds.	9	2	1	2.2	20	935,000	337,400	36.1	8.3
								30	1,400,000	–	–	–
								40	1,870,000	–	–	–
D	86,700	13	1:6700 sq yds.	13	7	1	3.8	20	581,000	346,800	59.7	7.1
								30	867,000	373,000	43.0	7.1
								40	1,153,000	-	-	-





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BORROW SOURCE — TEST HOLE LOCATIONS & SECTION PLAN

5.13

volumes are not given as the interpretation of the data would be misleading. Generally, the percentage of gravel is over-estimated in the calculations for a 40-foot (12.2 m) deep pit, because test holes were terminated at shallow depths when the base of the gravel stratum was penetrated.

5.10.3 Borrow Quality

The second objective of the Borrow Survey was to obtain samples suitable for gravel quality evaluation, relative to concrete mix design and construction requirements, such as gradation and moisture-density relationships. For this portion of the study it was planned to excavate a total of six test pits, in areas of minimum overburden, to a maximum depth of ten feet (3 m). Large (100-pound; 45 kg) samples would have been obtained and the stratigraphy carefully logged and photographed. Land use restrictions, however, prevented excavation of the test pits at this time. Consequently, an attempt was made to auger shallow test holes to provide gravel samples. Limited success was achieved because the large gravel sizes encountered made drilling very slow and equipment wear very costly.

Several small gravel samples were obtained. Unfortunately, these were suitable only for petrographic analysis. In each instance, the fraction passing a 3/8-inch (~9.5 mm) sieve, yet retained on a No. 4 sieve, was tested. It should be recognized that the results, which are presented in Appendix "H", represent disturbed samples, due to the fracturing action of the rock bits which had to be employed. Table 5.2 gives the chert percentages for each sample, together with comparable data from other granular borrow sources in the Mackenzie Delta area.

TABLE 5.2

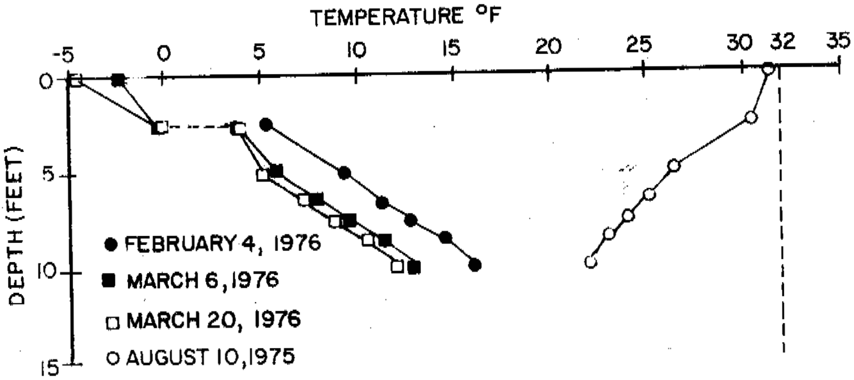
Chert Percentages, Borrow Sources

Source		Percent Chert by Weight
Parsons Lake -	Borrow Source No. 1	14.1
	Borrow Source No. 2	11.0
	Borrow Source No. 3	11.1
	Borrow Source No. 9	11.8
Tuktoyaktuk*		19
Inuvik*		6
Ya-Ya Pits*		35 to 39

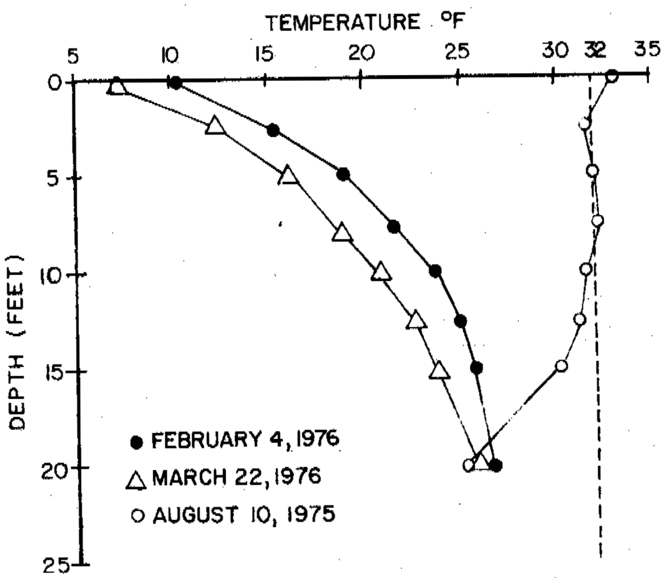
*Source: Reference No. 2

5.11 Ground Temperature Records

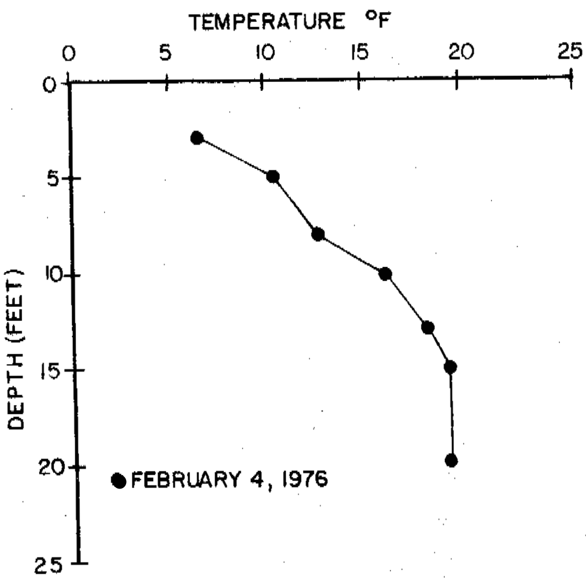
As part of the 1976 Geotechnical Survey, ground temperature data were collected from three of the four thermistor strings installed during the 1975 field program. The thermistor installations which were monitored were those installed in test holes A-4, B-5 and E-14 (Reference No. 2).



TEST HOLE B-5



TEST HOLE E-14



TEST HOLE A-4

NOTE: E-14, B-5, AND A-4 ARE TEST HOLES FROM 1975 FIELD PROGRAM, REFERENCE NO. 2. AUGUST 10 READING FROM REFERENCE NO. 2.

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GROUND TEMPERATURE PROFILES

SCALE AS SHOWN	DATE MAY, 1976	MADE AC	CHKD. R.S.T.	JOB: CS 3343	FIGURE 5.14

Readings were carried out by Mr. F. J. Robinson, P.Eng., of Gulf Oil Canada Limited on February 4, 1976 and by R. M. Hardy & Associates Ltd. field personnel during March, 1976. Ground temperature profiles are presented on Figure 5.14.

6.0 CONCLUSIONS

The 1976 field drilling program permitted an assessment to be made of subsurface conditions in the Parsons Lake Study Area. Soil samples were collected during the program for laboratory testing to determine ice and moisture contents, soil classification and engineering properties. These geotechnical data will be used in development of construction methods and optimum foundation designs during Phase I - Engineering, commencing in June 1976.

The only major omission from the program, as originally planned, was the quality assessment of the granular borrow areas as sources of material for construction, specifically in reference to concrete mix design and compaction criteria. To obtain this information, it will be necessary to excavate several test pits, and collect large representative samples for analysis.

This report discusses methods adopted and equipment used during the field program. Data collected in the field, laboratory and office are presented and summarized. It should be noted that, at this time, no recommendations or discussion are included regarding design engineering.

Thaw strain and creep tests on frozen soil cores are long-term tests. Thus, results of these tests are not reported or discussed in this report. These results will be submitted, when available, under separate cover, possibly as an appendix to the report on the hydrology study, which is to be carried out by R. M. Hardy & Associates Ltd. in June 1976.

Respectfully submitted,

R. M. HARDY & ASSOCIATES LTD.

Per: Ian G. Jones

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May, 1976
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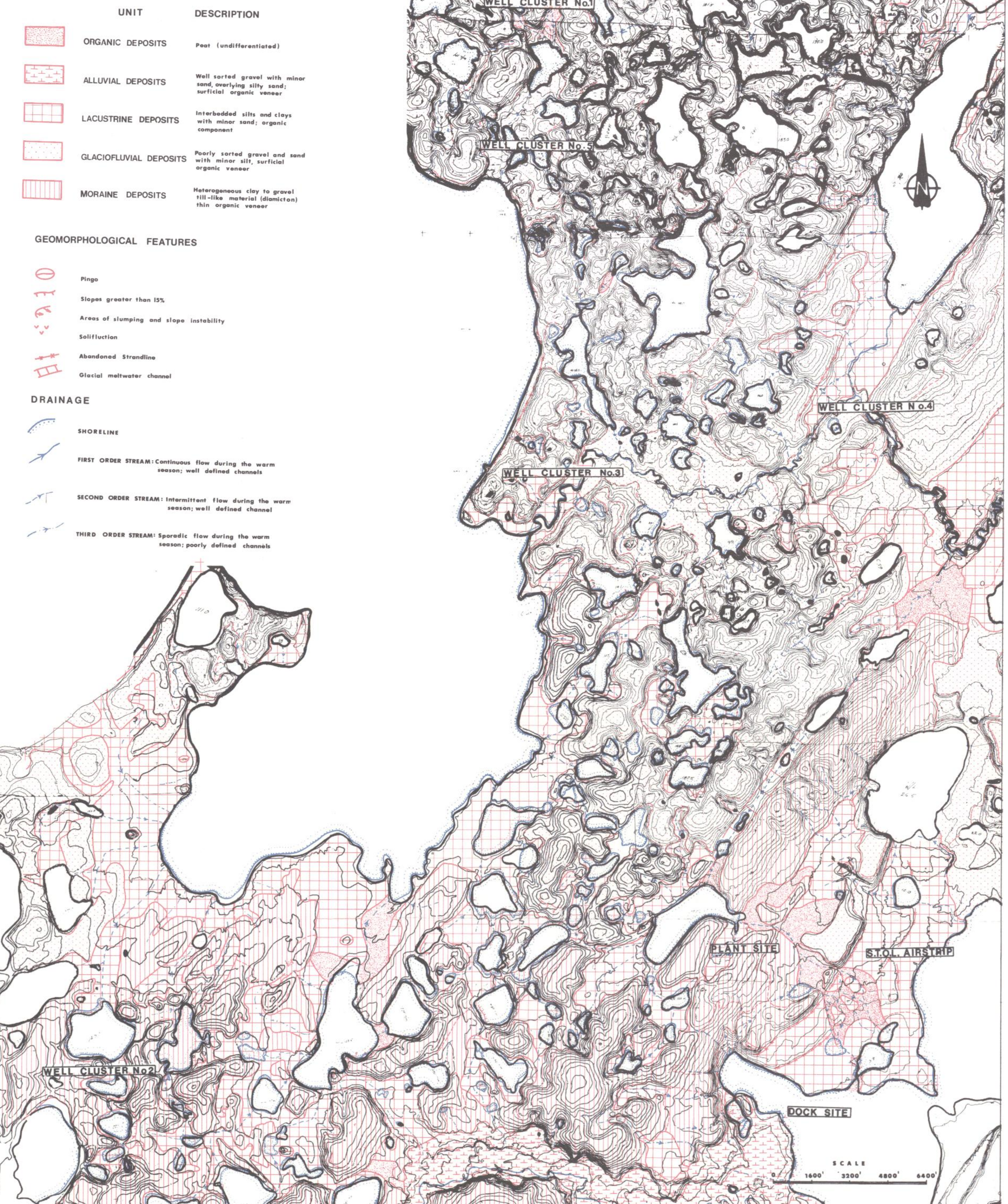

GULF OIL CANADA LIMITED
PARSONS LAKE GAS PLANT

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SURFICIAL GEOLOGY AND DRAINAGE

SCALE - AS SHOWN DATE MAY 1976 MADE MB CHKD YK APPD. RT

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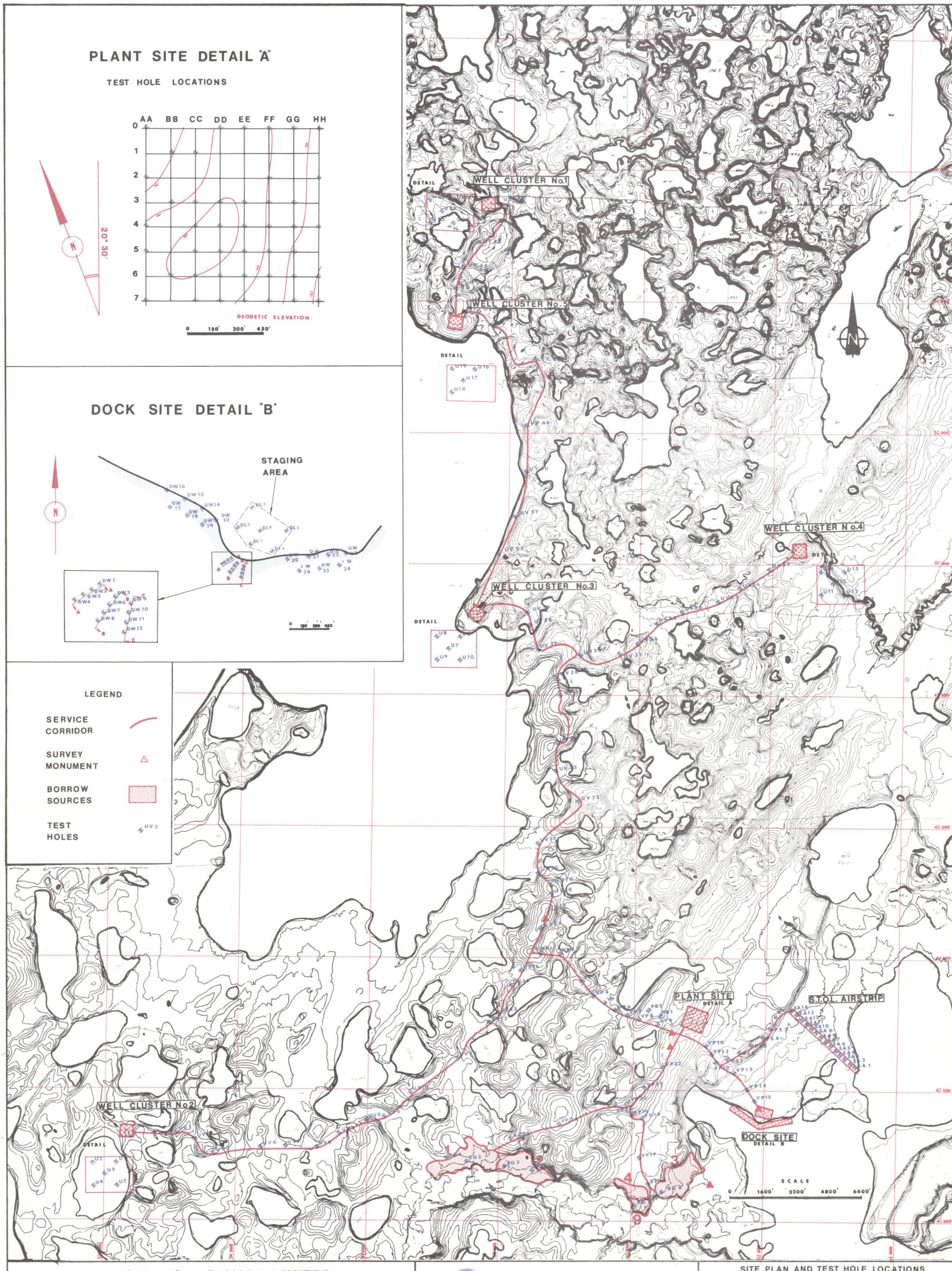

GULF OIL CANADA LIMITED PARSONS LAKE GAS PLANT	R.M.HARDY & ASSOCIATES LTD. CONSULTING ENGINEERING & TESTING	SITE PLAN AND TEST HOLE LOCATIONS SCALE AS SHOWN DATE MAY 1976 MADE MB CHKD. Y.K APPD. RT No. 3343	PL A–2