ILLUSTRATIONS FROM:

AN INTERPRETIVE MANUAL FOR REPORTS ON GRANULAR DEPOSITS IN THE INUVIALUIT SETTLEMENT REGION

Prepared for:
INDIAN AND NORTHERN AFFAIRS CANADA

Part of the Inuvialuit Final Agreement Implementation Program
Task 7-Sand and Gravel

Prepared by:
FRANK THOMPSON
MARCH, 1994

0014

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1.0 INTRODUCTION

This manual is designed to help people with limited technical training use reports on granular deposits in the Inuvialuit Settlement Region. It describes, in laymans language and with the use of illustrations, how to interpret the technical data in these reports. Environmental protection measures and monitoring procedures recommended for borrow pit operations in northern climate conditions are also discussed. The focus is on sand and gravel sources of granular construction materials because these deposits present unique logistical and environmental problems not encountered in bedrock sources of granular materials. Off-shore sources of granular material are not discussed.

Although extensive, the manual is easy to use. It is divided into sections that can be used independently and, throughout, the reader is referred to other parts of the manual or other reports that provide additional information. Figures, photographs and tables are used extensively for demonstration. These illustrations, together with their captions, can be used independently of the text to understand the basics of borrow pit exploration, development and restoration. Technical terms commonly used in reports on granular deposits are presented, together with their definitions, at the end of the report.

This study is a part of the Inuvialuit Final Agreement Implementation Program: Task 7-Sand and Gravel Inventories and was authorized under contract number A7134-2-0070/01-ST. The scientific authority for the project is R. J. Gowan, Geotechnical Advisor, Natural Resources and Environment Branch, Indian and Northern Affairs Canada. The manual was prepared by F. J. Thompson of Ottawa, Ontario.

Inuvialuit Land Administration [ILA] staff and community representatives provided ideas and suggestions that formed the bases for this manual. Particular thanks go to Charles Klingenberg and William Gruben of the ILA in Tuktoyaktuk, Denis Thrasher and Vince Teddy of the Community Corporation in Tuktoyaktuk, Jane Bicknell of the ILA in Inuvik and Joey Amos of the Hunters and Trappers Association in Inuvik. Their cooperation and assistance was critical to the success of the project. The manual was improved by the suggestions of A. Judge and G. Brooks of the Geological Survey of Canada, who acted as critical reviewers.

LIST OF ILLUSTRATIONS

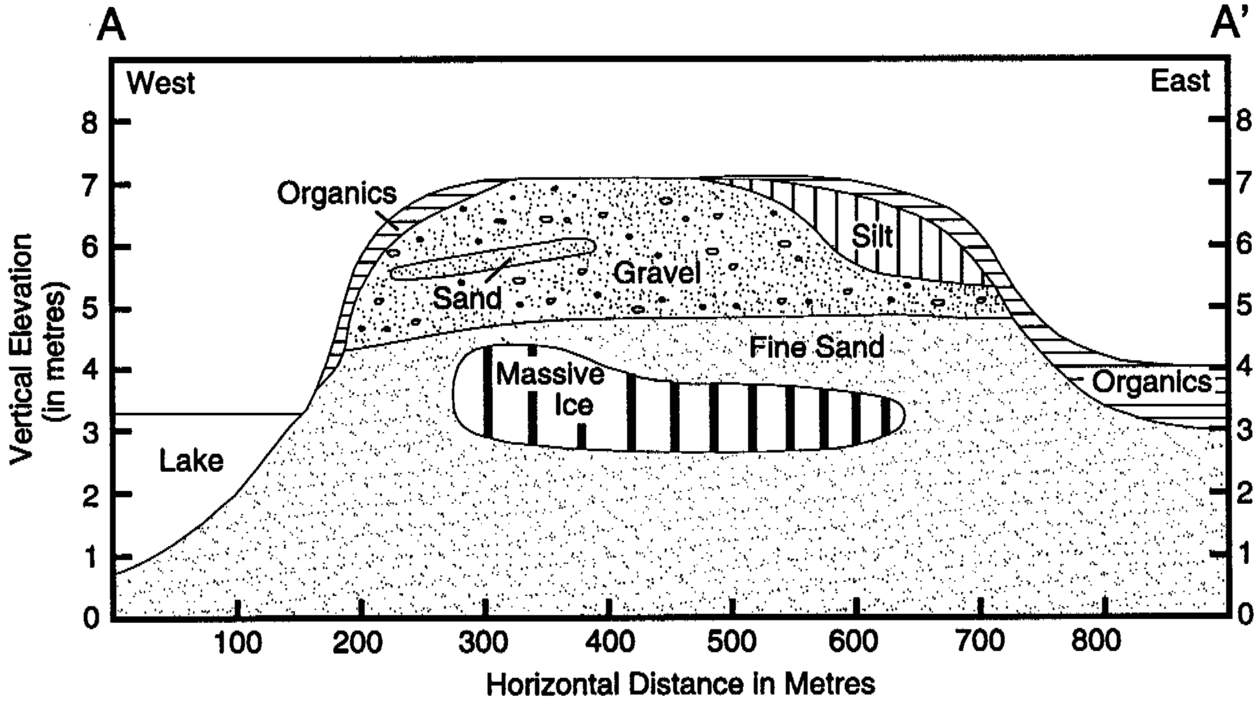


Illustration 1--Materials Encountered in Granular Deposits

This is a side view of a vertical slice through a hill showing some of the materials commonly encountered in granular deposits in the Inuvialuit Settlement Region [ISR]. The hill is about 500 metres across, 3.5 metres above the surrounding lowland and is composed primarily of gravel with some sand layers. Organics are thin and discontinuous on the hill, but thicker in low areas. Silt overlies gravel on the right [east] side of the hill. Fine sand and massive ice underlie the gravel.

This fictitious granular deposit is used for demonstration throughout the manual and is followed through stages of exploration, development and restoration [see Illustrations 2, 11, 12, 13, 17, 18, 20, 21, 22]. These illustrations are stylized for demonstration purposes and not necessarily true to scale.

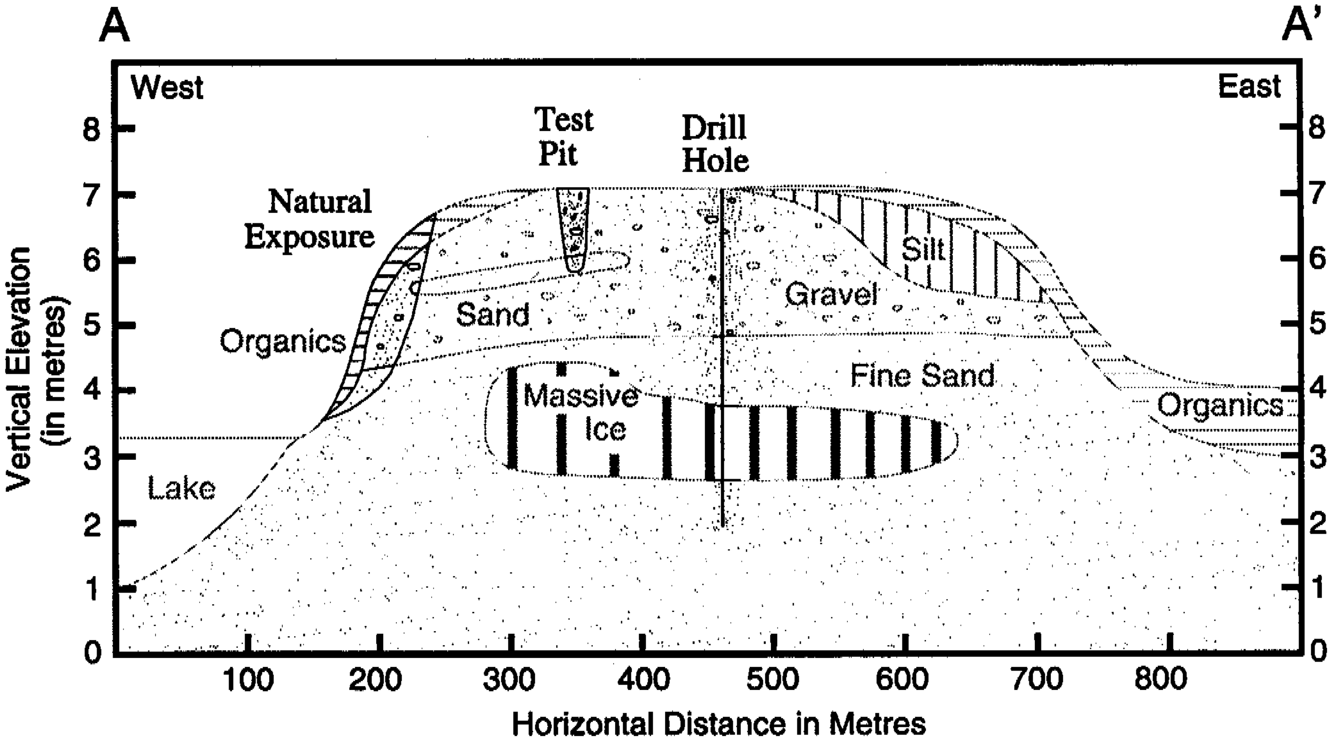


Illustration 2--Evaluating Subsurface Conditions

In our example from Illustration 1, subsurface conditions are still unknown. Previous review of geological reports and aerial photographs has indicated that this hill may contain granular material.

For the first stage of on-site exploration, the hill is examined using a natural exposure, a test pit and a drill hole. The test pit, 2 metres across by 1.5 metres deep, is excavated where there is no organic material at surface. This provides a good view of the near surface materials but is not deep enough to determine the full thickness of gravel. The natural exposure near the lake shore is about 40 metres long and 3 metres deep. It is deep enough to determine the full thickness of sand and gravel and provides a good view of the near surface materials. The drill hole is deep enough to intersect the underlying fine sand and buried ice.

In this example, the preliminary exploration indicates that there is good quality granular material in the hill, but more detailed exploration is required to determine if it is an economically viable deposit. Drilling is the most suitable exploration method to further define subsurface conditions at this site. There are no other natural exposures, and any test pits will be limited to the depth of summer thaw [less than 0.6 metres where there is organic cover at surface and 1 to 2 metres where there is no organic cover].

Results of this exploration drilling are shown in Illustrations 11, 12 and 13.

Photograph 1
A natural exposure.

Loose material was scraped off the slope to expose fresh sediments.

Photograph 2
A test pit excavated by shovel.

The surface in the foreground, where the pit is being dug, is bare of organics and vegetation.

Photograph 3
An exploration drill.

There is a thin, discontinuous cover of vegetation at surface

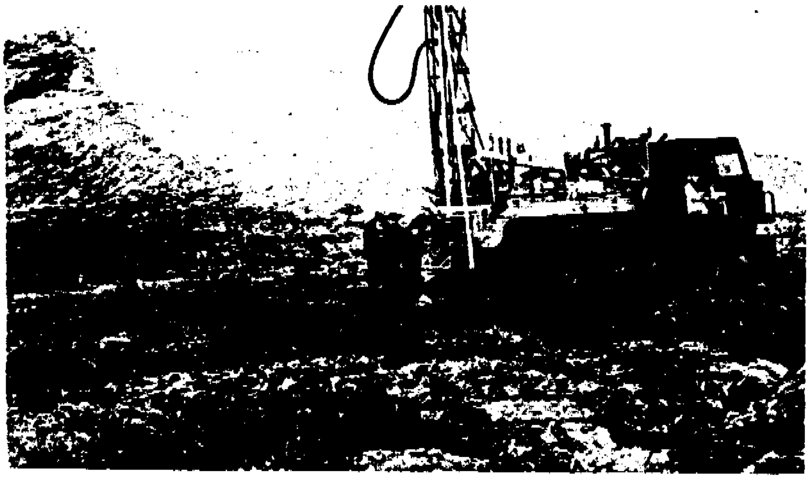


Illustration 3--Photographs of Exploration Methods

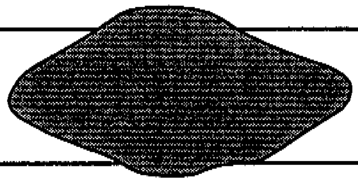
Type of Material	Size Range	Grain Size Drawn to Actual Scale
Boulder	More than 8 inches 203 millimetres	Too Large for Demonstration Purposes
Pebble	3 to 8 in. 76 to 203 mm	Too Large for Demonstration Purposes
Coarse Gravel	.75 to 3 in. 19 to 76 mm	
Fine Gravel	.19 to .75 in. 4.75 to 19 mm	
Coarse Sand	.08 to .19 in. 2.0 to 4.75 mm	
Medium Sand	.017 to .08 in. .425 to 2.0 mm	
Fine Sand	.003 to .017 in. .076 to .425 mm	
Fines (silt & clay)	Less than 0.003 inches 0.076 millimetres	Too small to be seen with the unaided eye. When wet, silt and clay are generally muddy. When dry, silt is generally dusty and clay forms a hard crust.

Illustration 4--A Graphic Illustration of Sand and Gravel Sized Grains

The terms used to describe particle size are standardized as demonstrated in this figure.

Illustration 5--The Modified Unified Classification System for Soils

In most reports, the Modified Unified Classification System for Soils is used to describe buried sediments encountered in granular deposits. It provides a standard set of abbreviations to replace a more lengthy description. A letter designation is given to the different materials [see group symbol column]. The first letter of this designation refers to type [G for gravel, S for sand, M for silt, C for clay, Pt for organics]. For clean sand and gravel the second letter of this designation refers to the grading [W for well graded, P for poorly graded]. For dirty sands and gravels the second letter refers to the type of fines [M for silty, C for clayey, F for undifferentiated fines].

Sands and gravels are defined as less than 50% fines by weight. If the course part of the sample [part courser than fines] is more than half gravel sized particles the material is called gravel, if the coarse fraction is more than half sand sized particles it is called sand. Sands and gravels are called clean if they are less than 12% fines and dirty if more than 12% fines. Silts and clays are defined as more than 50% fines by weight. The distinction between silts and clays is based on plasticity [how easily the material will flow when wet], which is determined by laboratory testing. Grading is explained in Section 5.3 and Illustration 10.

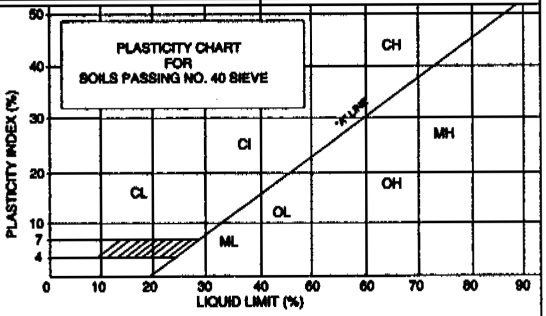
MODIFIED UNIFIED CLASSIFICATION SYSTEM FOR SOILS

MAJOR DIVISION			GROUP SYMBOL	GRAPH SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	LABORATORY CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS (MORE THAN HALF BY WEIGHT LARGER THAN 200 SIEVE)	GRAVELS MORE THAN HALF COARSE GRAINS LARGER THAN NO. 4 SIEVE	CLEAN GRAVELS (LITTLE OR NO FINES)	GW		RED	WELL GRADED GRAVELS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 4$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			GP		RED	POORLY GRADED GRAVELS, AND GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY GRAVELS (WITH SOME FINES)	GM		YELLOW	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES	CONTENT OF FINES EXCESS 12%	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			GC		YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
	SANDS MORE THAN HALF FINE GRAINS SMALLER THAN NO. 4 SIEVE	CLEAN SANDS (LITTLE OR NO FINES)	SW		RED	WELL GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES	$C_U = \frac{D_{60}}{D_{10}} > 6$ $C_C = \frac{(D_{30})^2}{D_{10} \times D_{60}} = 1$ to 3	
			SP		RED	POORLY GRADED SANDS, LITTLE OR NO FINES	NOT MEETING ABOVE REQUIREMENTS	
		DIRTY SANDS (WITH SOME FINES)	SM		YELLOW	SILTY SANDS, SAND-SILT MIXTURES	CONTENT OF FINES EXCESS 12%	ATTERBERG LIMITS BELOW "A" LINE OR P.I. LESS THAN 4
			SC		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES		ATTERBERG LIMITS ABOVE "A" LINE P.I. MORE THAN 7
FINE-GRAINED SOILS (MORE THAN HALF BY WEIGHT PASSES 200 SIEVE)	SILTS BELOW "A" LINE NEGLIGIBLE ORGANIC CONTENT	$W_L < 50\%$	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	CLASSIFICATION IS BASED UPON PLASTICITY CHART (see below)	
		$W_L > 50\%$	MH		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS		
	CLAYS ABOVE "A" LINE ON PLASTICITY CHART NEGLIGIBLE ORGANIC CONTENT	$W_L < 30\%$	CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS		
		$30\% < W_L < 50\%$	CI		GREEN-BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY, SILTY CLAYS		
		$W_L > 50\%$	CH		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS		
	ORGANIC SILTS & CLAYS BELOW "A" LINE ON CHART	$W_L < 50\%$	OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	WHENEVER THE NATURE OF THE FINE CONTENT HAS NOT BEEN DETERMINED, IT IS DESIGNATED BY THE LETTER "F", E.G. SF IS A MIXTURE OF SAND WITH SILT OR CLAY	
		$W_L > 50\%$	OH		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY		
HIGHLY ORGANIC SOILS			Pt		ORANGE	PEAT AND OTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE	

SPECIAL SYMBOLS

BEDROCK (undifferentiated)

VOLCANIC ASH



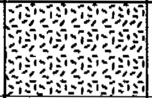
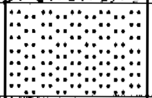
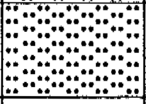
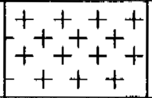
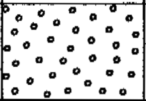
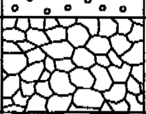
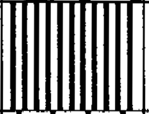
1. ALL SIEVE SIZES MENTIONED ON THE THIS CHART ARE U.S. STANDARD, A.S.T.M. E.11.
2. BOUNDARY CLASSIFICATIONS POSSESSING CHARACTERISTICS OF TWO GROUPS ARE GIVEN COMBINED GROUP SYMBOLS, E.G. GW-GC IS WELL GRADED GRAVEL SAND MIXTURE WITH CLAY BINDER BETWEEN 5% AND 12% 12%.

SOIL COMPONENTS

FRACTION	U.S. STANDARD SIEVE SIZE		DEFINING RANGES OF PERCENTAGE BY WEIGHT OF MINOR COMPONENTS	
	PASSING	RETAINED	PERCENT	DESCRIPTOR
GRAVEL coarse	76 mm	19 mm	50 - 35	and
GRAVEL fine	19 mm	No. 4		
SAND coarse	4.75 mm	2.00 mm	35 - 20	...y (eg. silty)
SAND medium	2.00 mm	425.4 µm	20 - 10	some
SAND fine	425 µm	75.4 µm		
SILT (non plastic) or CLAY (plastic)	75 µm		10 - 1	trace

SOIL COMPONENTS

Rounded or subrounded	Not rounded
cobbles 76 mm to 203 mm	ROCK FRAGMENTS > 76 mm
BOULDERS > 203 mm	ROCK > 0.76 cubic metre in volume

GROUND ICE CLASSIFICATIONS				
CATEGORY	GROUP SYMBOL	SUBGROUP SYMBOL	GRAPHIC SYMBOL	DESCRIPTION
		F		UNDIFFERENTIATED
NON-VISIBLE ICE	N	Nf		POORLY BONDED OR FRIABLE FROZEN SOIL
		Nbn		WELL BONDED FROZEN SOIL WITH NO EXCESS ICE
		Nbe		WELL BONDED FROZEN SOIL WITH EXCESS ICE. FREE WATER PRESENT WHEN SAMPLE THAWED.
VISIBLE ICE LESS THAN ONE INCH THICK	V	Vx		INDIVIDUAL ICE CRYSTALS OR INCLUSIONS
		Vc		ICE COATINGS ON PARTICLES
		Vr		RANDOM OR IRREGULARLY ORIENTED ICE FORMATIONS
		Vs		STRATIFIED OR DISTINCTLY ORIENTED ICE FORMATIONS
VISIBLE ICE GREATER THAN ONE INCH THICK	ICE	ICE+ Soil Type		ICE GREATER THAN ONE INCH THICK WITH SOIL INCLUSIONS
		ICE		ICE GREATER THAN ONE INCH THICK WITHOUT SOIL INCLUSIONS

NOTE: 1. UF signifies unfrozen ground.
2. F/UF signifies that it was not possible to determine whether the ground was frozen, or unfrozen during drilling.

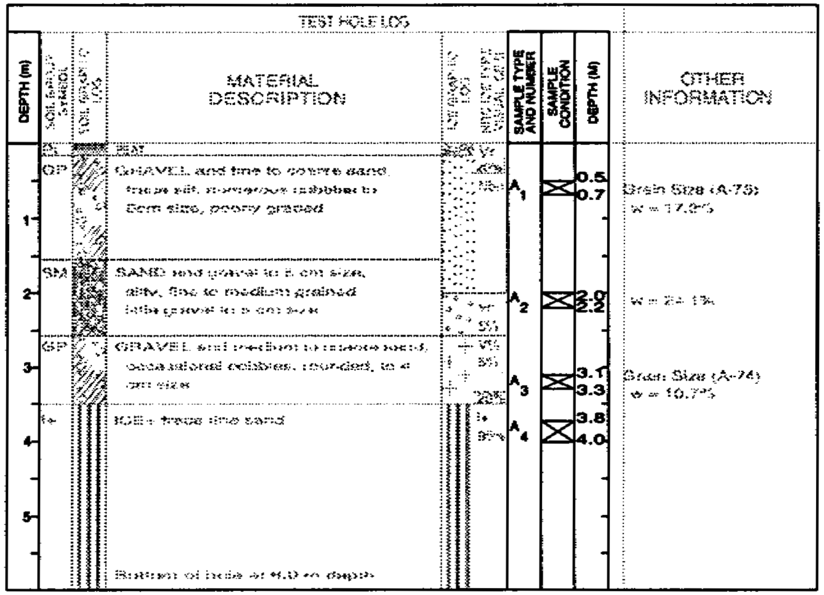
Illustration 6--The Ground Ice Classification Table

In most reports, the Ground Ice Classification Table is used to describe the ice encountered in granular deposits. A graphic symbol and letter designation is given to the different types of ice [see group and subgroup symbol columns]. The first letter of this designation indicates if the ice can be seen with the unaided eye [N for frozen soil with no visible ice and V for visible ice less than one inch thick]. Where ice is not visible the second letter of this designation refers to how hard the material is [f for poorly bonded, bn for well bonded, be for well bonded soil with excess ice]. Where ice is visible the second letter of this designation refers to distribution of the ice.

Illustration 7--Interpreting Drill Log Forms

Drill log forms are used to present the data collected in natural exposures, test pits and drill holes. Illustrations 7A to 7E demonstrate how to interpret these logs (see over). The format used is not the consistent between reports and therefore, examples from two different reports are used in each illustration.

7A-1



7A-2

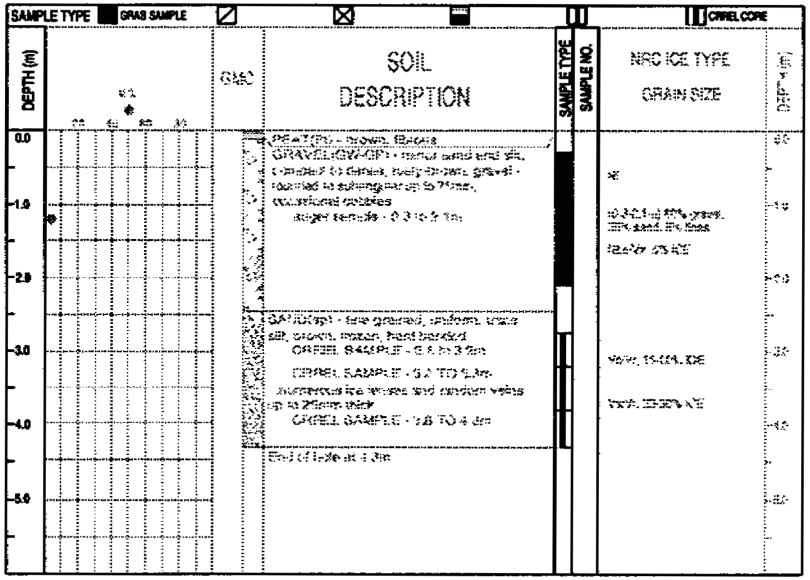
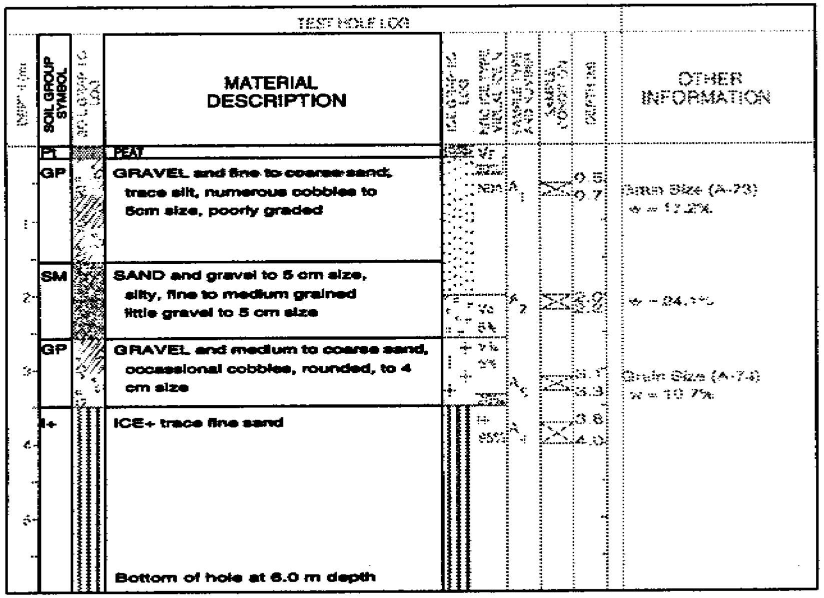


Illustration 7A--Interpreting Drill Log Forms---Depth and Sample Location

Depth from ground surface is generally presented on the left side of the log. The type and location of samples collected is shown on the right side if the log. In example 7A-2, the legend for sample type is at the top of the log.

7B-1



7B-2

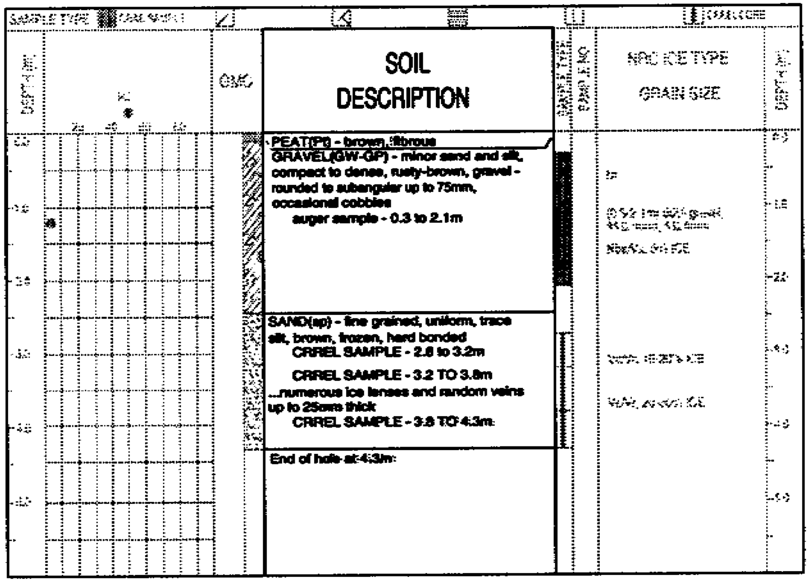
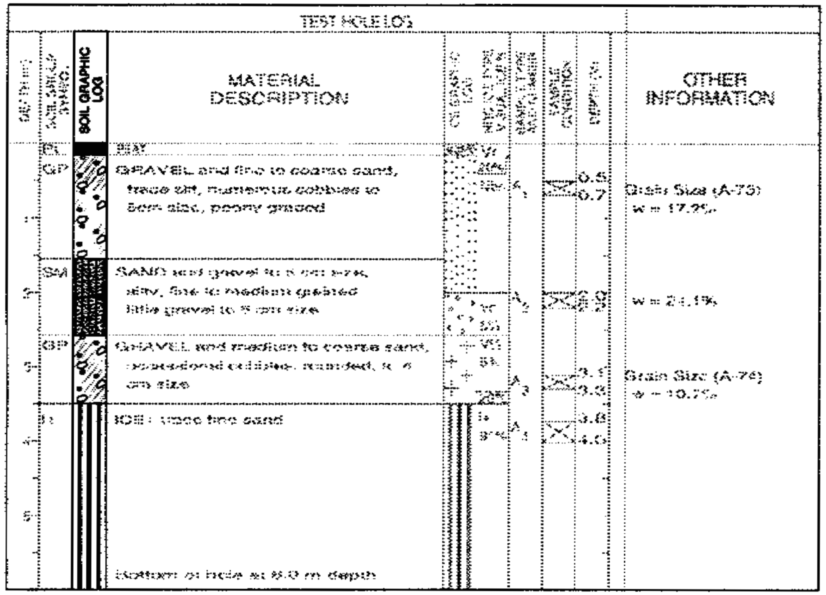


Illustration 7B--Interpreting Drill Log Forms---Written Description

The written description of buried sediments is based on the Modified Unified Classification System for Soils. In example 7B-1, the letter designation derived from the Unified Classification System is shown in the "soil group symbol" column. In example 7B-2 the Unified Classification is included with the written description, and this letter designation capitalized only where it has been confirmed by laboratory tests.

7C-1



7C-2

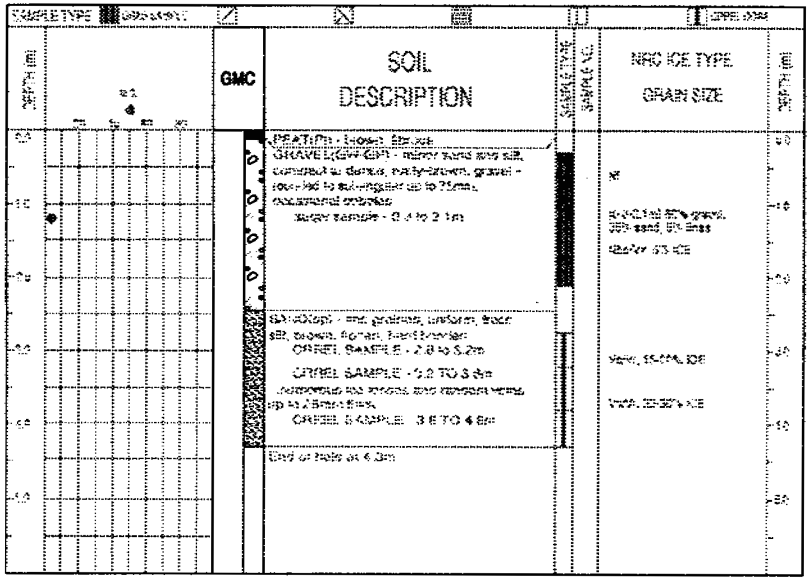
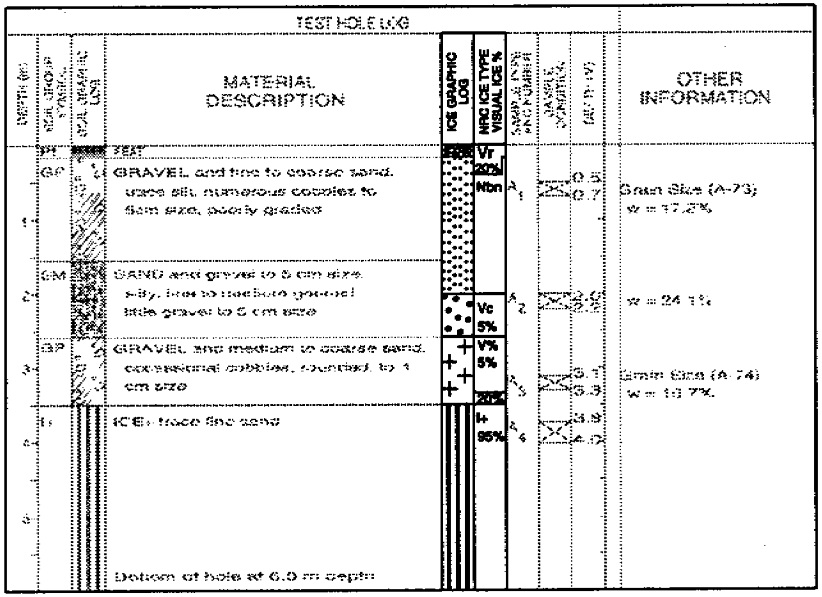


Illustration 7C--Interpreting Drill Log Forms---Graphic Log

A graphic log is generally presented to the left of the written description. The symbols used to indicate sediment type are commonly based on the Modified Unified Classification System for Soils but they are not always consistent between different reports.

7D-1



7D-2

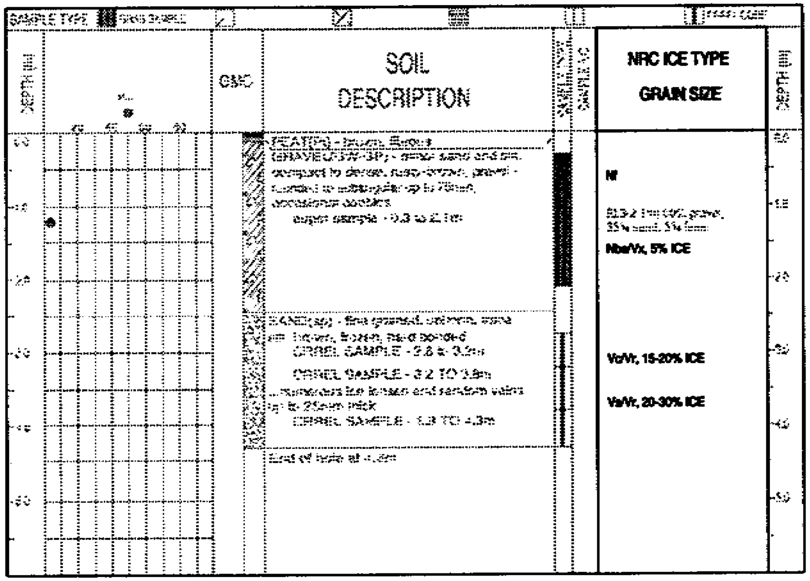
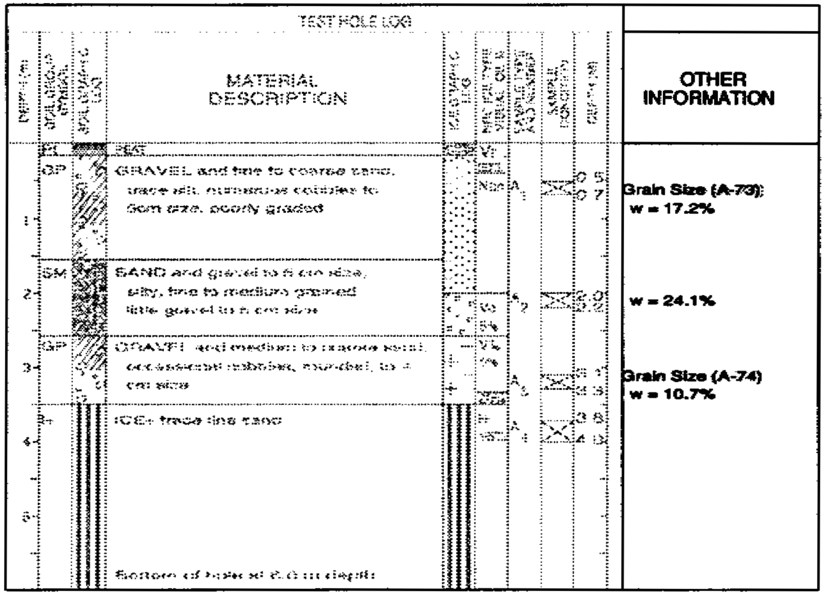


Illustration 7D--Interpreting Drill Log Forms---Ice and Ice Bonding

In both examples, the type of ice and ice bonding are recorded in the column for "NRC Ice Type". A visual estimate of ice content is also recorded in this column. The letter symbols used are based on the Ground Ice Classification Table. Example 7D-1 shows a graphic log of ice type based on the Ground Ice Classification Table.

7E-1



7E-2

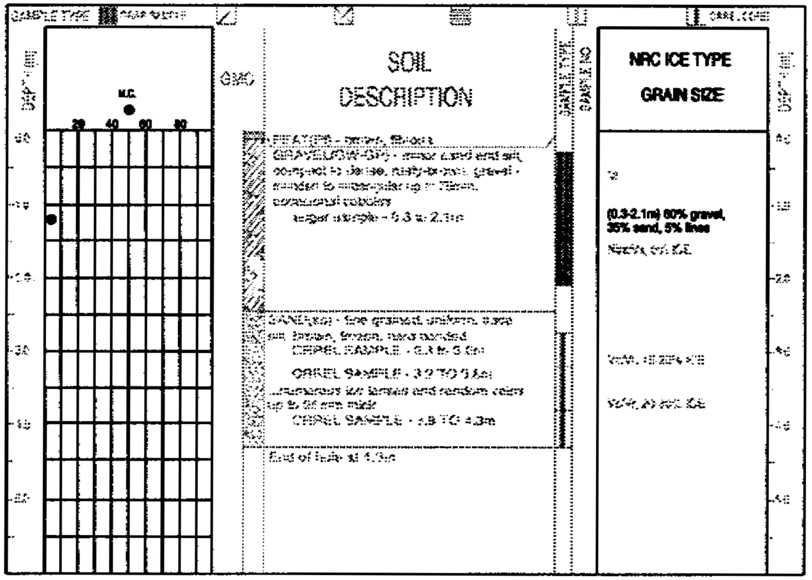


Illustration 7E--Interpreting Drill Log Forms---Laboratory Tests

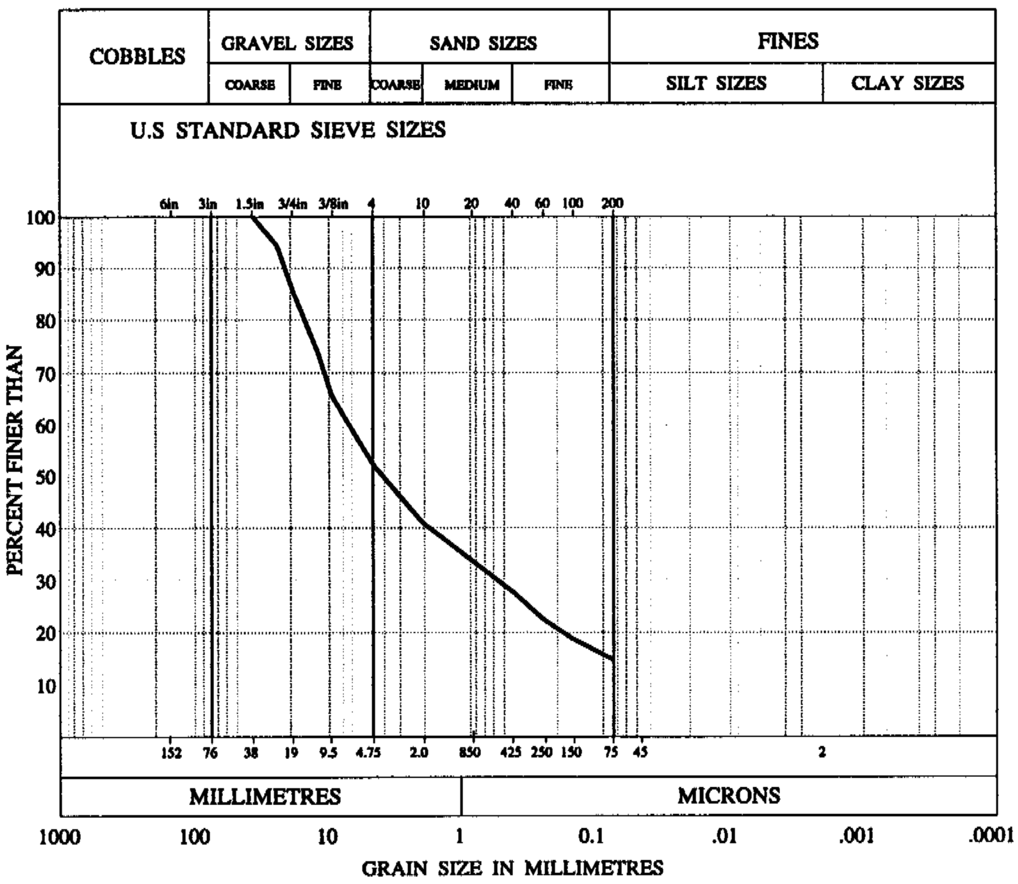
Results of some of the laboratory tests are recorded on the logs [laboratory tests are discussed in Section 5]. In example 7E-1, moisture content for each sample analyzed is recorded in the column "other information" [w=moisture content]. Grain size analysis is not recorded but page reference where this can be found in the report is noted in the column "other information". In example 7E-2, grain size analysis is presented in the column "NRC Ice Type and Grain Size" on the right side of the log. Moisture content is presented in a graphic format on the left side of the log [M.C. refers to moisture content].

Moisture content is reported as % water by weight of dry sample and is not the same as the visual estimate of ice content which is % ice by volume of soil and ice combined.

	Test	Approximate Number of Tests Required	Rationale For Test
	Moisture Content	2 tests per 3 metres of drilling/test pitting	helps to determine difficulties extracting granular material, limitations on use of granular material and potential for drainage and flood control problems.
	Grain Size Analysis	3 tests per 10 metres of drilling/test pitting	helps to determine potential uses of the granular material.
	Petrographic Analysis	1 test per 5 drillholes/test pits	helps to determine rock types in the deposit and their impact on the quality of the granular material.
Test to Determine Concrete Aggregate Suitability	Los Angeles Abrasion	1 test per 10 drillholes/test pits	indicates resistance of particles in the deposit to physical abrasion.
	Sulphate Soundness	1 test per 10 drillholes/test pits	indicates resistance of particles in the deposit to weathering.
	Alkali-Aggregate Reactivity	1 test per 10 drillholes/test pits	indicates potential for adverse reaction between the granular material and cement.
	Bulk Specific Gravity	1 test per 10 drillholes/test pits	minimum specific gravity is required for some uses such as concrete and riprap.
	Absorption	1 test per 10 drillholes/test pits	indicates potential for freeze thaw degradation
	Organic Impurities	1 test per 10 drillholes/test pits	detects the presence of any organic material.

Illustration 8--Laboratory Tests Employed to Evaluate Granular Material.

This is a summary of some of the tests commonly used to evaluate granular material in the ISR. The number of tests required is only a general guideline and is dependent on factors such as the type of deposit and amount of exploration conducted.



SUMMARY	D_{10} =	mm	GRAVEL	48. %
	D_{30} = 0.60	mm	SAND	36 %
	D_{60} = 7.5	mm	FINES	16 %

Illustration 9--Grain Size Analysis

For this laboratory test, the sample is passed through a series of screens to separate it into different sized particles [particle size is shown in Illustration 4]. The amount of material in each size range is reported as a weight % of the whole sample. This information is generally presented on a graph as shown in this illustration. The horizontal scale on the top and bottom is grain size. The vertical scale to the left side is the proportion of the sample finer than the size indicated. The steeper the slope of the graph, the more uniform the grain size of the sample. The further the graph is to right, the finer the grain size of the sample.

On the graph in this illustration, 100% of the sample is finer than 1.5 inches indicating that there are no large stones [cobbles] in the sample. Reading down the graph along the boundary between fine sand and silt indicates that 16% of the sample is finer than sand and classified as fines. In the summary box, below the graph, is a written list of what percentage of the sample is in each of the main grain size groups. Using the Modified Unified Classification System for Soils this sample would be called GF and could be described as sand and gravel with some fines.

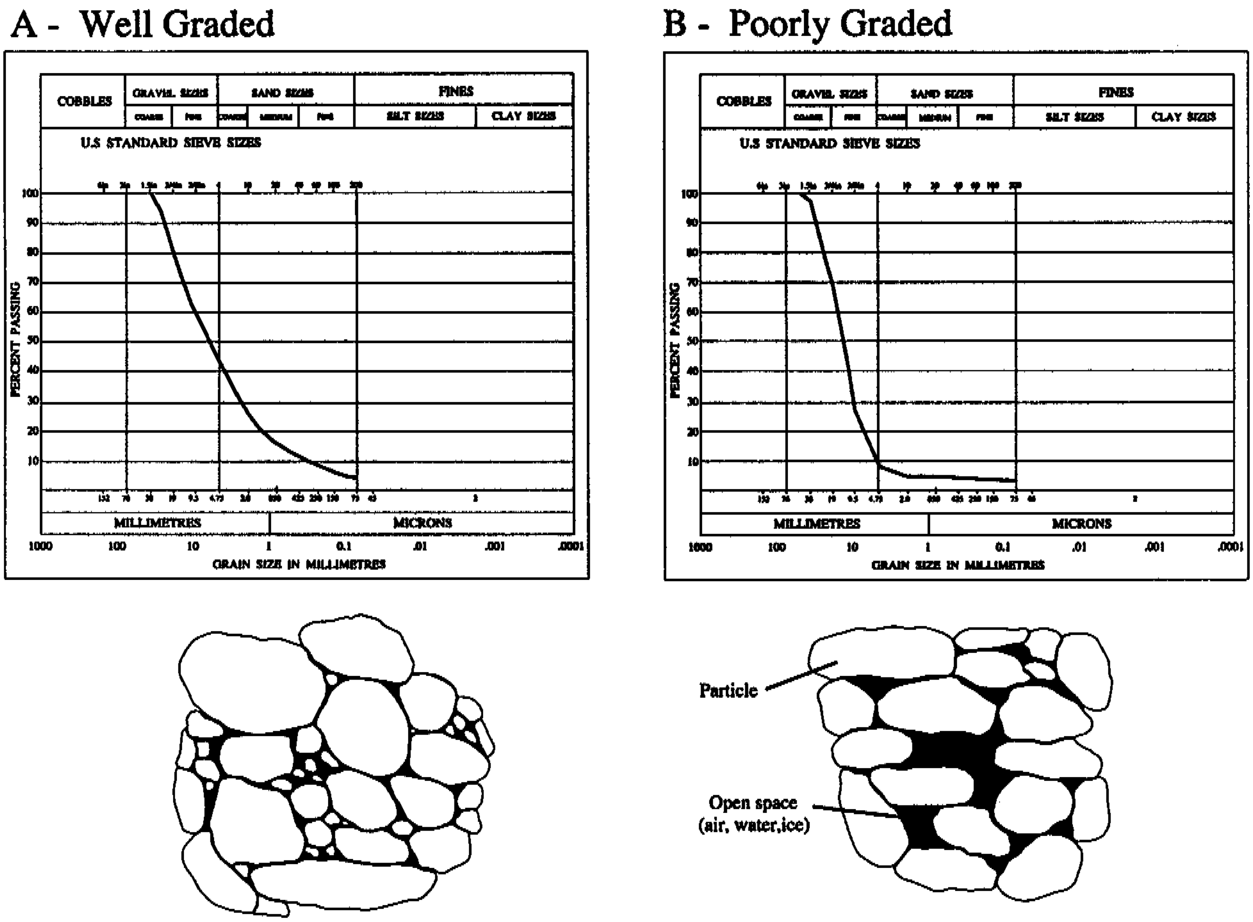


Illustration 10--Well Graded and Poorly Graded Granular Material

Well graded granular material [A] is a complete mix of grain sizes. This forms a stable base for construction purposes because smaller particles fill the spaces between larger particles minimizing any potential for compaction. Poorly graded material [B] is mostly one grain size, or has an unequal mix of grain sizes [in this example dominantly gravel sized particles]. Poorly graded material is more likely to shift or compact because spaces between grains are not filled. Therefore, poorly graded material does not form a strong pad that can be used to support heavy structures.

The grain size distribution graph for the well graded gravel shows a smooth curve from coarse gravel to fine sand. It is 56% gravel, 39% sand and 5% fines. The grain size distribution for the poorly graded gravel in this example shows a steep slope from coarse gravel to coarse sand. It is 92% gravel, 5% sand and 3% fines

Classification of Granular Materials

Class 1--Excellent quality material

- *Gradation*

  Well graded sand and gravel with less than 5% fines.
- *Moisture content*

  Ideally less than 10% but higher moisture content can be reduced by drying.
- *Technical parameters*

  PN less than 160. Los Angeles Abrasion loss less than 35%. Sulphate soundness loss [Magnesium Sulphate] less than 12%. Meets other requirements of CSA A23.1-1973.
- *Uses*

  Portland cement concrete, asphaltic concrete, masonry sand, concrete block, surface treatment and roofing aggregate. This can be used as high quality surfacing material, but sources of Class 1 material are scarce in the ISR and, therefore, commonly reserved for making concrete.

Class 2--Good quality material

- *Gradation*

  Well graded sand and gravel with less than 10% fines
- *Moisture content*

  Ideally less than 10% but higher moisture content can be reduced by drying.
- *Technical parameters*

  PN less than 200. Los Angeles Abrasion loss less than 60%. Any fines in excess of 10% can be removed with minimal processing
- *Uses*

  Pads for structures, granular base and sub-base, winter fill for trenches and slabs. Class 2 material can be used in highway construction but is commonly reserved as a source of lower quality concrete aggregate or structural fill.

Class 3--Fair quality material

- *Gradation*

  Poorly graded sand and gravel with less than 20% fines
- *Moisture content*

  Ideally less than 10% but higher moisture content can be reduced by drying.
- *Technical parameters*

  PN less than 250. Can be processed to meet local frost susceptibility criteria.
- *Uses*

  Pads for equipment, granular sub-base, general backfill. Class 3 material with a high fines content is ideal as a road surfacing material which requires the presence of a binding agent. This provides fair quality general fill for roads, foundation pads or lay-down yards.

Class 4--Poor quality material

- *Gradation*

  Poorly graded granular material with more than 20% fines
- *Moisture content*

  Ideally less than 10% but higher moisture content can be reduced by drying.
- *Technical parameters*

  None. May contain weak particles and deleterious materials.
- *Uses*

  General non-structure supporting fill.

Class 5--Bedrock, felsenmeer [broken bedrock in open area] and talus [broken bedrock at base of a slope]

Bedrock generally requires crushing before it can be used as granular material. Crushed bedrock may provide excellent sources of construction material ranging from general fill to concrete aggregate and erosion control material such as rip-rap or armour stone. Quality of the granular material is dependent primarily on the quality of the rock [see Section 5.4].

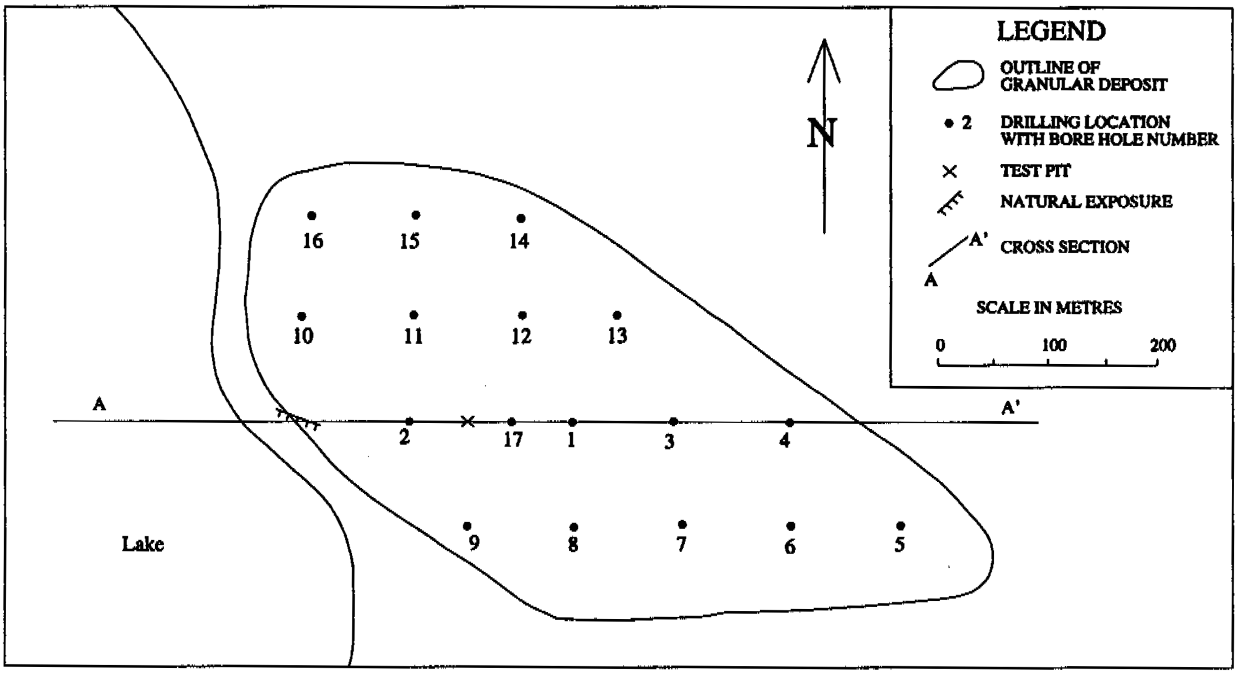


Illustration 11--Detailed Plan Map of the Granular Deposit

In our example, from Illustration 2, additional exploration drilling is conducted to further evaluate subsurface conditions. Illustration 11 is a detailed map showing the size and location of the deposit, and the locations of the natural exposure, test pit and drill holes. The north arrow shows the orientation of the map. The line of cross section A--A' shows the surface location of the vertical slice of the deposit shown in Illustration 12.

The symbols used and scale of the map are explained in the legend.

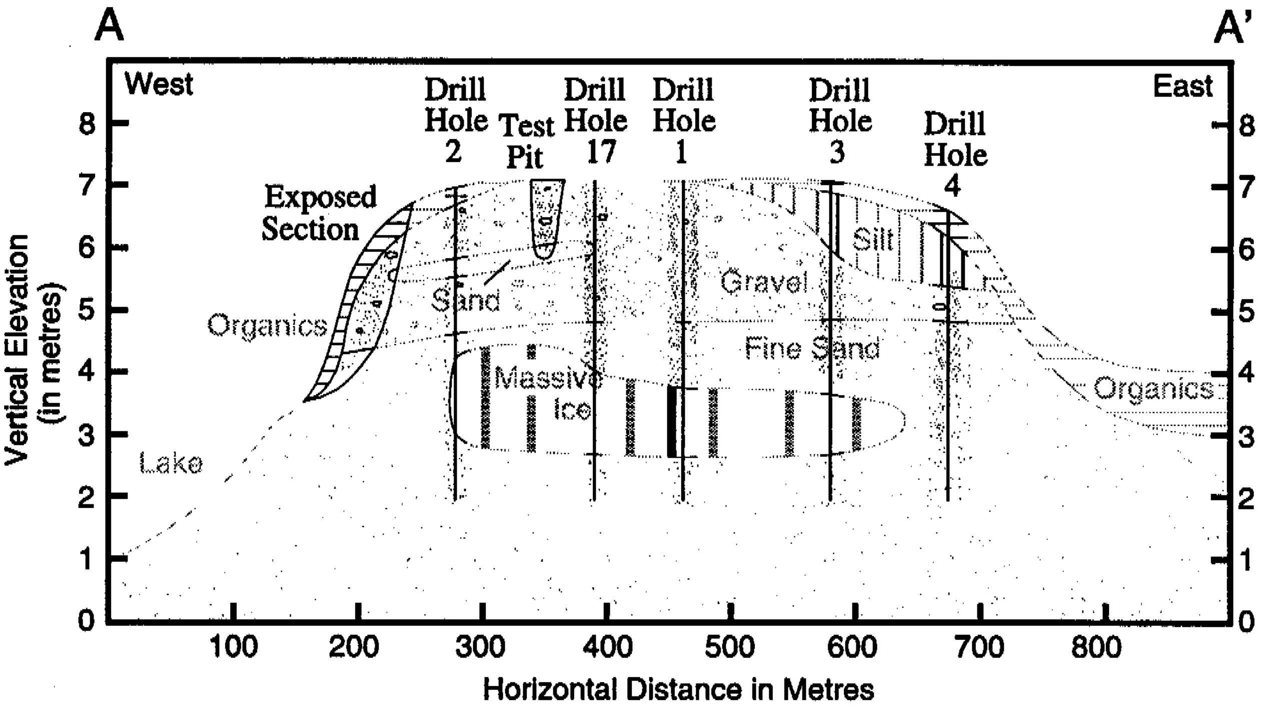


Illustration 12--Cross Section of the Granular Deposit

Results of the exploration drilling are presented in this cross section [side view of a vertical slice through the deposit]. Subsurface conditions between test sites are approximated based on the information provided at the test sites. Drill holes on 100 metre spacings generally provide sufficient information to guide borrow pit development and restoration.

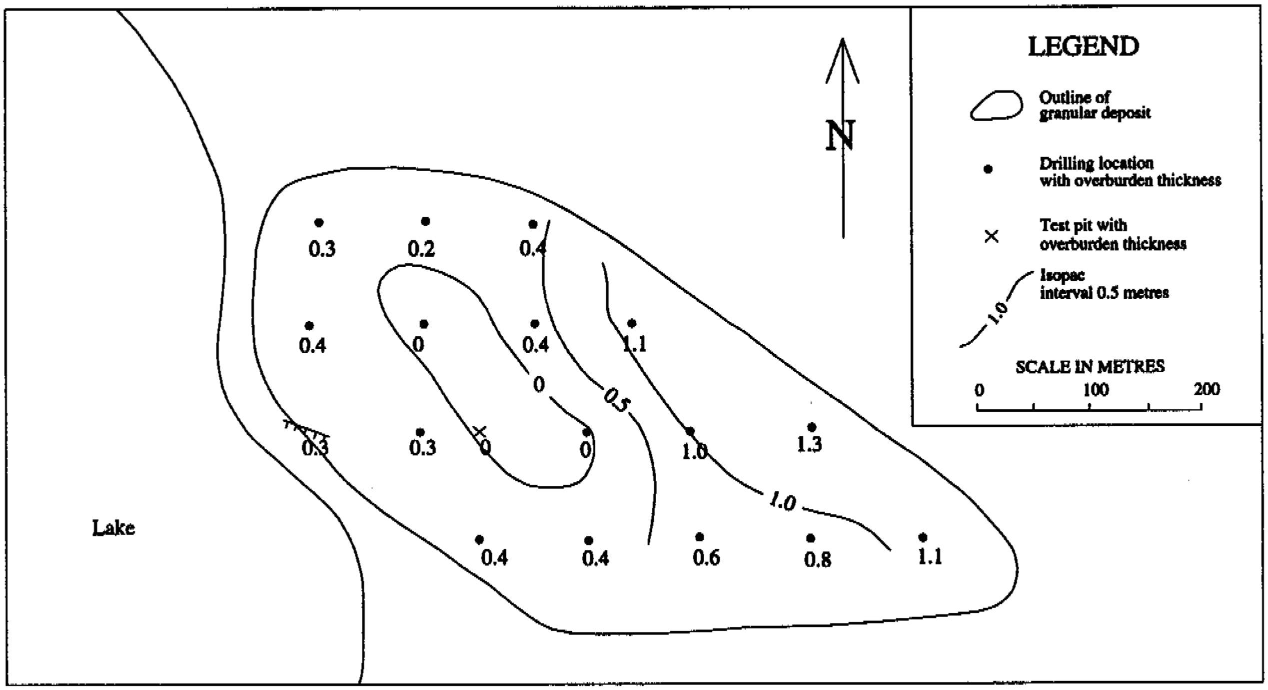


Illustration 13--Isopach Map of the Granular Deposit

This is an Isopach map showing the thickness of overburden cover [organics and silt overlying the sand and gravel] at our example granular deposit. The reported thickness of overburden is shown beside the test sites. Assumed thickness between test sites is shown by lines joining points of equal thickness. Overburden cover is thin in the central, north and west parts of the deposit but exceeds one metre on the east side of the deposit. This map provides a good visual presentation of areas of thick overburden cover where it may be economically impractical to extract the buried granular material.

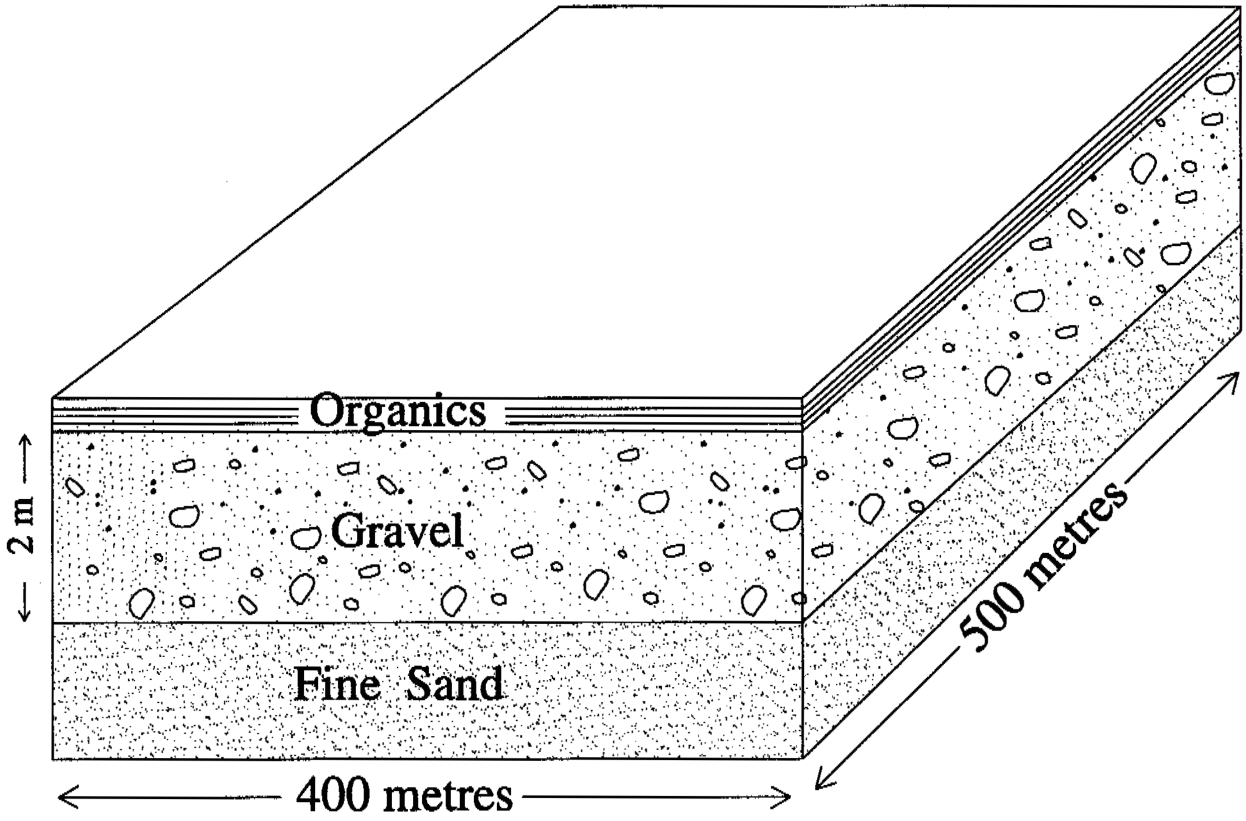


Illustration 14--Calculating Reserves of Granular Material

This is an idealized example of a deposit with surface dimensions of 400 by 500 metres. Surface area is 200,000 square metres [500 multiplied 400]. The granular material is 2 metres thick and therefore reserves are 400,000 cubic meters [200,000 multiplied 2].

In real deposits, it is neither as simple nor exact as show in this example. Deposits are irregular in outline and, thickness of granular material is variable.

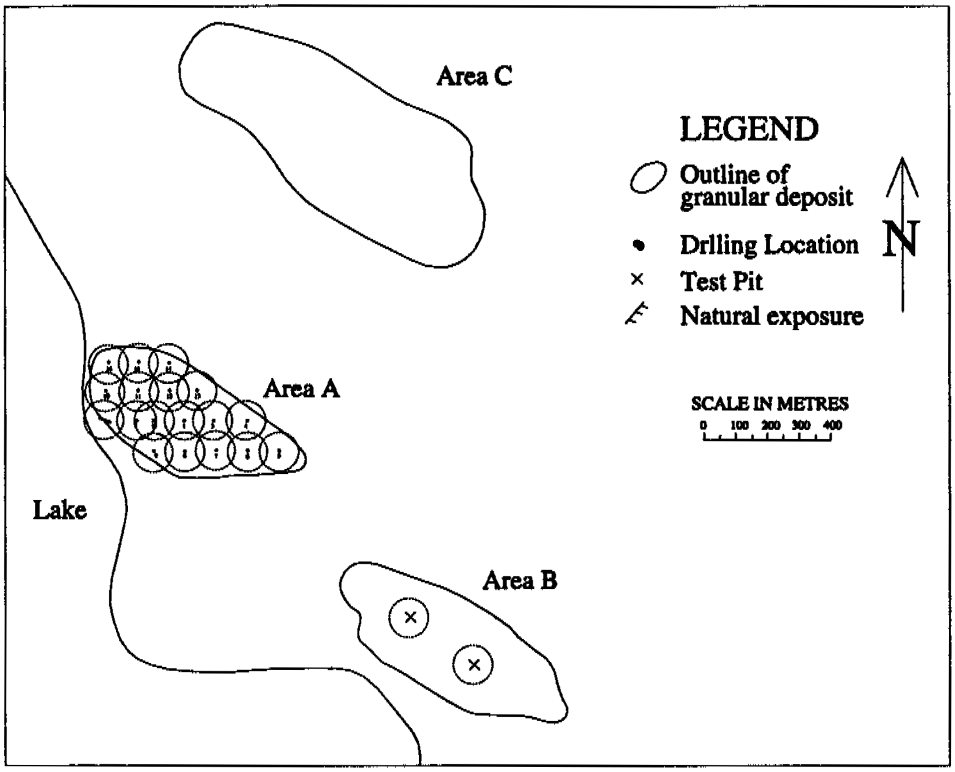


Illustration 15--Confidence Level for Estimates of Granular Reserves

This is a map of our example deposit with two nearby hills and demonstrates the difference between proven, probable and prospective reserves. For calculating reserves an area of 50 metres on all sides of a exposed section, test pit or drill hole is considered proven.

In Area A [our example deposit from Illustration 11], drill holes are about 100 metres apart. The 50 metre radius circles drawn around all test sites in this example, demonstrate that the deposit is fully tested by the drill holes. Reserves of granular material are considered **proven.**

In Area B, there are 2 test pits, both of which intersected granular material. It is expected that the rest of the hill contains similar granular material. To determine reserves, the surface area of the deposit is estimated based on studies of aerial photographs and from topographic and geological considerations. The thickness and quality of granular material is estimated based on topographic and geological considerations and from information provided by the test sites in areas A and B. The granular reserves in this hill are considered **probable.** Only the reserves within 50 metres of the test pits are considered proven.

In Area C, there has been no on-site exploration. Interpretation of aerial photographs indicates that this hill is similar in character to Areas A and B and may contain granular material. To determine reserves, the surface area of the deposit is estimated based on studies of aerial photographs and from topographic and geological considerations. The thickness and quality of the granular material in the deposit is estimated based topographic and geological considerations and from information provided by exploration in Areas A and B. Reserves of granular material in Area C are considered **prospective.**

INDIAN AND NORTHERN AFFAIRS CANADA
INUVIALUIT SETTLEMENT SAND AND GRAVEL INVENTORY AND RECOMMENDATIONS FOR DEVELOPMENT

GRANULAR RESOURCES SUPPLY SUMMARY
Inuvik

SOURCE: I401A

LOCATION: 10km N of Inuvik

REFERENCE(S): RKL 1973,Inuvik; H-BBT 1986

SETTING Hillocks bisected by streams	RELIEF 3 to 5 metres	WINTER ACCESS Tundra/ice road
LANDFORM Kame field	CONTINUITY 2 sources	SUMMER ACCESS None
AREA 1.1 sq km	DEVELOPMENT CONSTRAINTS Wildlife, poor quality	

BOREHOLES (#) 6	TEST PITS (#) 5
MOIST. CON. (#) 7	GRAINSIZE (#) 5

	OVERBURDEN	GROUND ICE
TYPE:	Silt, organics	Massive, excess
EXTENT:	All holes	Intermittent
THICK.:	Up to 0.76 m	Lenses up to 0.6 m

POTENTIAL VOLUME, cu. m. : 1,020,000

RECOVERABLE, cu. m.: 1,020,000

MATERIAL	PROVEN, cu. m.		PROBABLE, cu. m.		PROSPECTIVE, cu. m.	
	Annual	Total	Annual	Total	Annual	Total
CLASS 1						
CLASS 2						
CLASS 3			250,000	750,000	250,000	1,020,000
CLASS 4						
CLASS 5						

Illustration 16--Summary of Reserves of Granular Material in the ISR

Information on individual granular deposits in the ISR is available in summary format. This example is from a series of reports titled "Inuvialuit Settlement Sand and Gravel Inventory and Recommendations for Development" [EBA, 1987] and includes: location and access, topographic and geological setting, amount of exploration, development constraints, type and amount of granular material, type and amount of overburden, type and amount of ice.

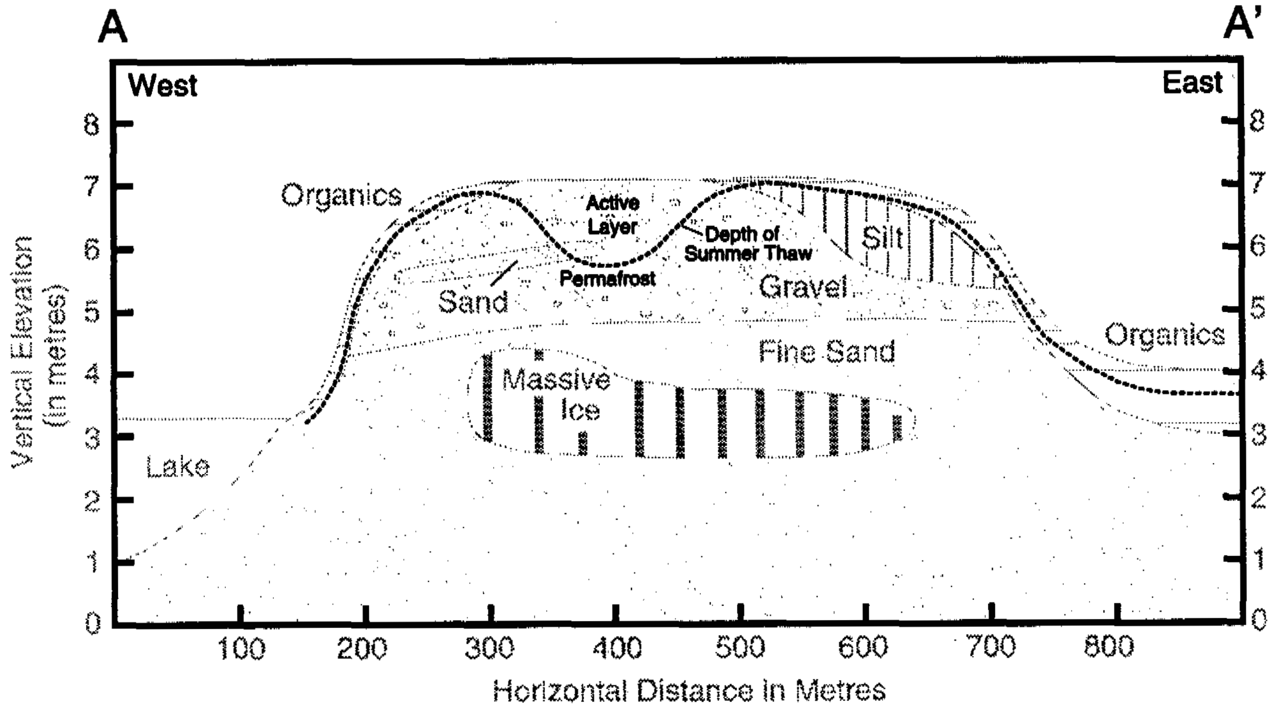


Illustration 17--Depth of Summer Thaw

With the exception of a thin layer at surface that thaws each summer, ground in the ISR is permanently frozen. Depth of summer thaw is generally 1 to 2 metres where granular material is exposed at surface and less than 0.6 metres where there is a cover of organics to provide insulation. The zone between land surface and permafrost [permanently frozen ground] that thaws each summer is called the active layer.

Extracting frozen overburden and granular material with a moisture content over 10% is difficult. Moisture content is generally lower and granular material easier to extract in the active layer of well drained granular deposits than in permanently frozen ground or poorly drained areas because some of the water is released during the summer thaw.

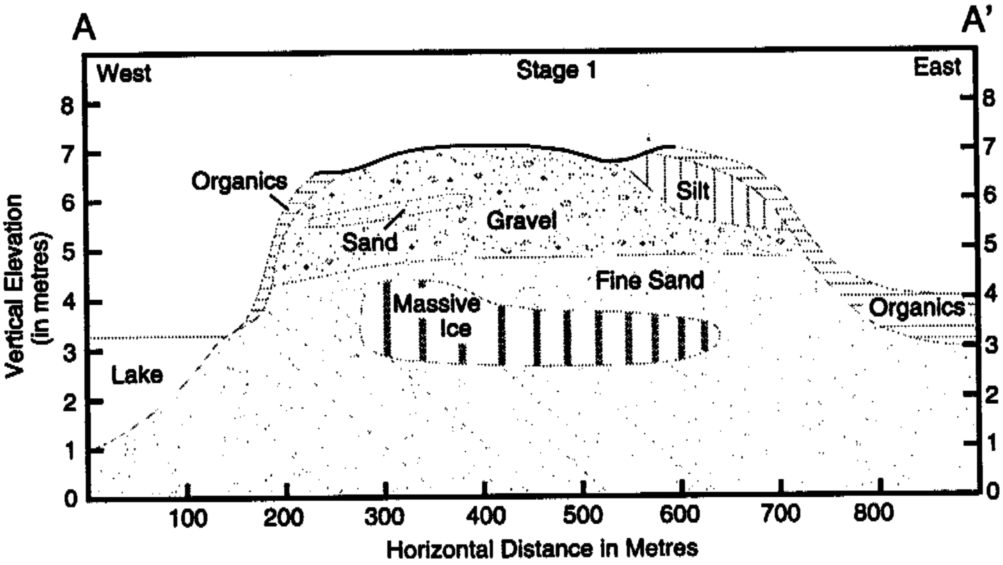
Illustration 18--Borrow Pit Development

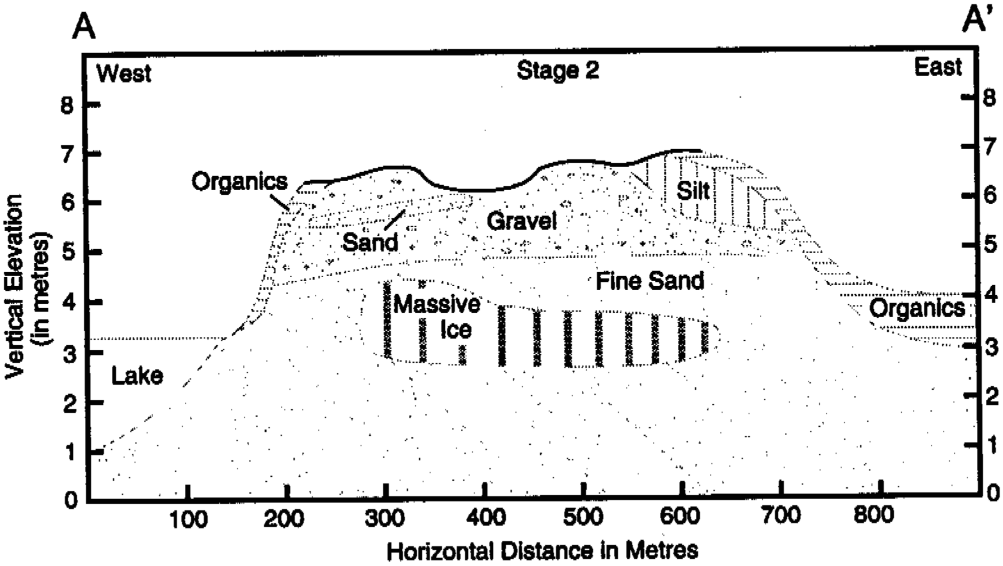
This series of diagrams shows development at our example borrow pit. This is simplified showing only three stages. In most deposits, only a part of the borrow pit would be worked at one time and development would extend over several years.

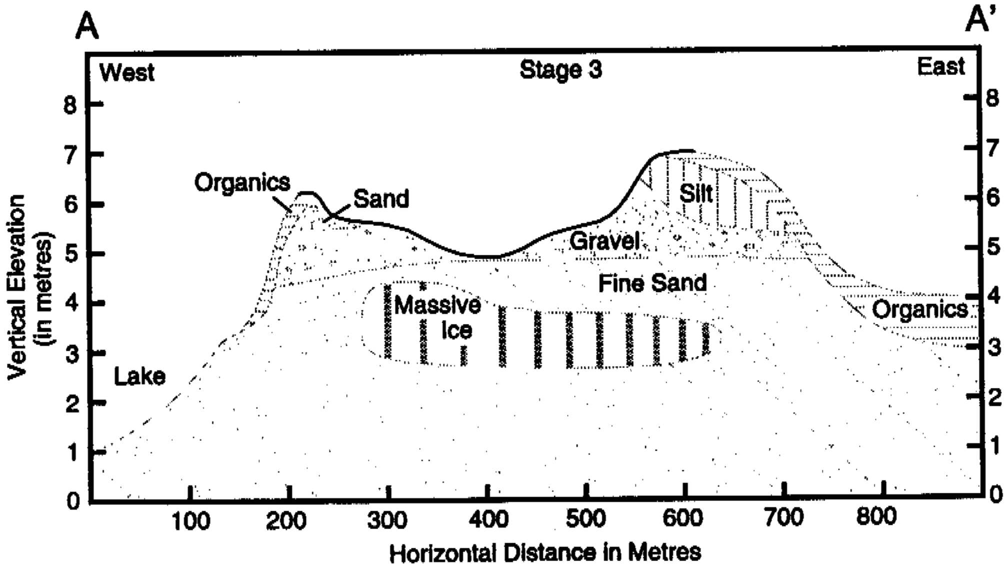
Stage 1 Organics and overburden are removed from the areas to be developed. This provides access to, and permits thaw of, the underlying granular material. Fine grained sediments, such as silt, are commonly frozen solid [hard bonded] and difficult to remove. For this reason, removing the thick overburden cover on the east side of the deposit to access the underlying granular material is economically impractical. A narrow ridge of undisturbed organics and granular material is left on the west side of the deposit to provide a protective barrier between the lake and the borrow pit.

Stage 2 Areas where the granular material is loosely bonded and easily extracted [where there was no organic cover prior to development] are exploited first. In other parts of the deposit, the frozen granular material has a higher moisture content and is more difficult to extract [hard bonded].

Stage 3 Extraction of the granular material progresses in stages. If material is to be extracted during the winter, areas stripped of organics are commonly left exposed during the summer to permit the granular material to thaw and drain to reduce moisture content and ice bonding. The following winter, 1 to 2 metres thickness of material at surface is more loosely bonded and can be extracted. If the borrow pit is worked during the summer, extraction of granular material can progress several metres in one season as unfrozen material is stripped back exposing frozen ground to thaw. The borrow pit is permanently abandoned when all of the extractable granular material has been removed [see Illustration 20 Stage 1].


A
A'
West
Stage 1
East
Organics
Sand
Gravel
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres


A
A'
West
Stage 2
East
Organics
Sand
Gravel
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres


A
A'
West
Stage 3
East
Organics
Sand
Gravel
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres

Photograph 1

Aerial view.

The thaw pond in the foreground is about 100 metres across and 2.5 metres deep. The light coloured area encircling the pit represents new vegetation growth where the organic cover and vegetation was damaged during borrow pit operations.

Photograph 2

Vegetation regrowth.

Vegetation has started to reestablish in areas where there is some organic material at surface [foreground]. There is no vegetation growth where there is no organic material [background].

Photograph 3

Thaw pond.

The vegetation underwater and the steep margins suggest that buried ice is still melting causing further deepening of the pond.

Illustration 19--Photographs of Abandoned Borrow Pits

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Illustration 20--Borrow Pit Rehabilitation

This series of diagrams shows some of the stages in rehabilitating our example borrow pit. This is an idealized example and these measures may not be required or practical in all cases.

Stage 1 The abandoned borrow pit is recontoured to leave slopes that are stable and in keeping with the natural landscape. Drainage is directed to the base of the pit. Where required, dams are constructed to prevent pit drainage from entering natural waterbodies.

Stage 2 Fine grained overburden previously removed from the pit surface [Illustration 18, Stage 1] is spread in the base of the pit. In this example, most of the overburden is placed over the east side of the pit to prevent buried ice in this area from melting.

Stage 3 Organics previously removed from the pit surface are spread on the base and slopes of the borrow pit. Organics and fine grained sediments are not placed on the west side of the abandoned pit where buried ice is too close to surface to be protected from thaw. It is expected that this ice will melt, causing the pit floor to collapse and flood.

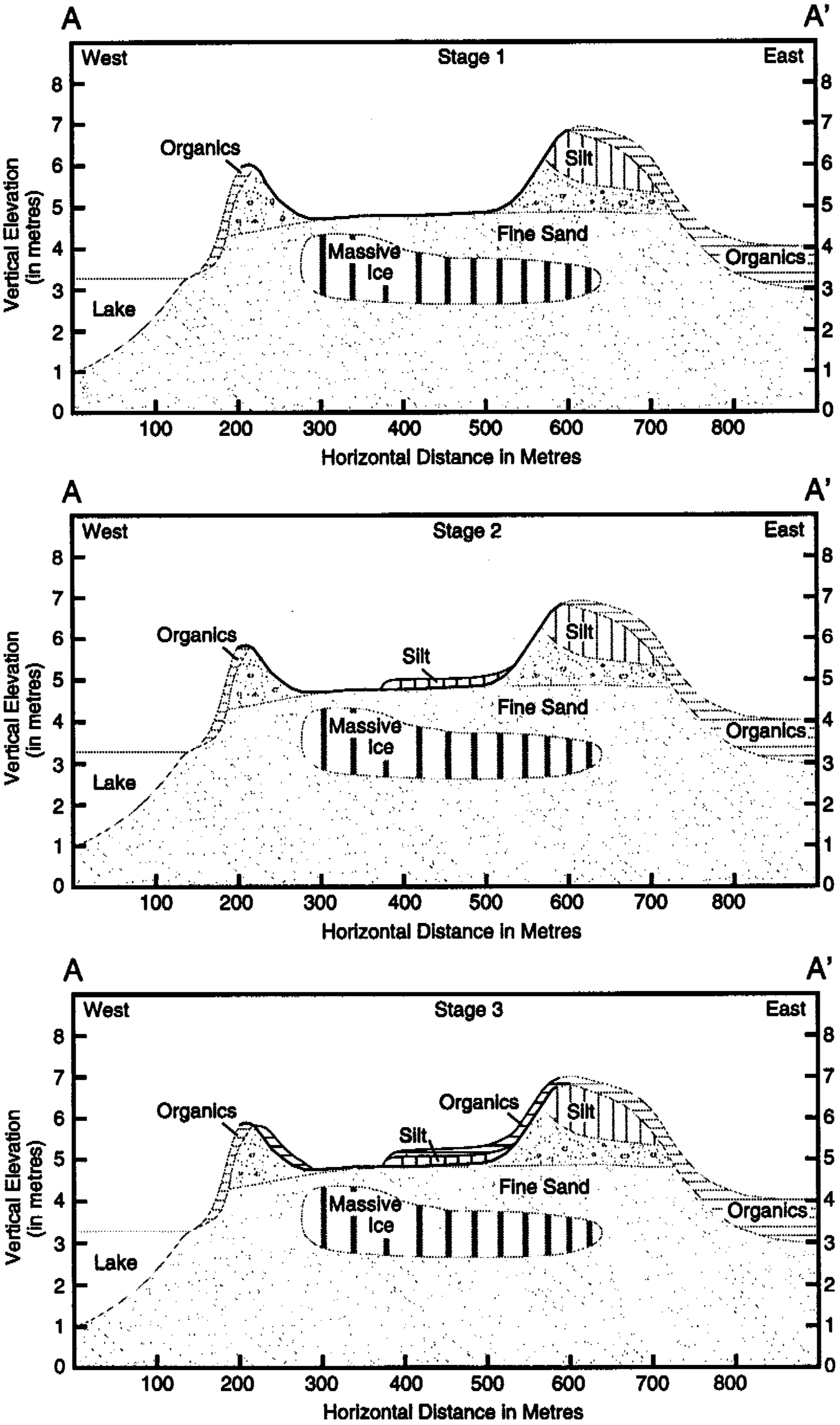

A
A'
West
Stage 1
East
Organics
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres
A
A'
West
Stage 2
East
Organics
Silt
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres
A
A'
West
Stage 3
East
Organics
Organics
Silt
Silt
Fine Sand
Massive Ice
Organics
Lake
Vertical Elevation (in metres)
Horizontal Distance in Metres

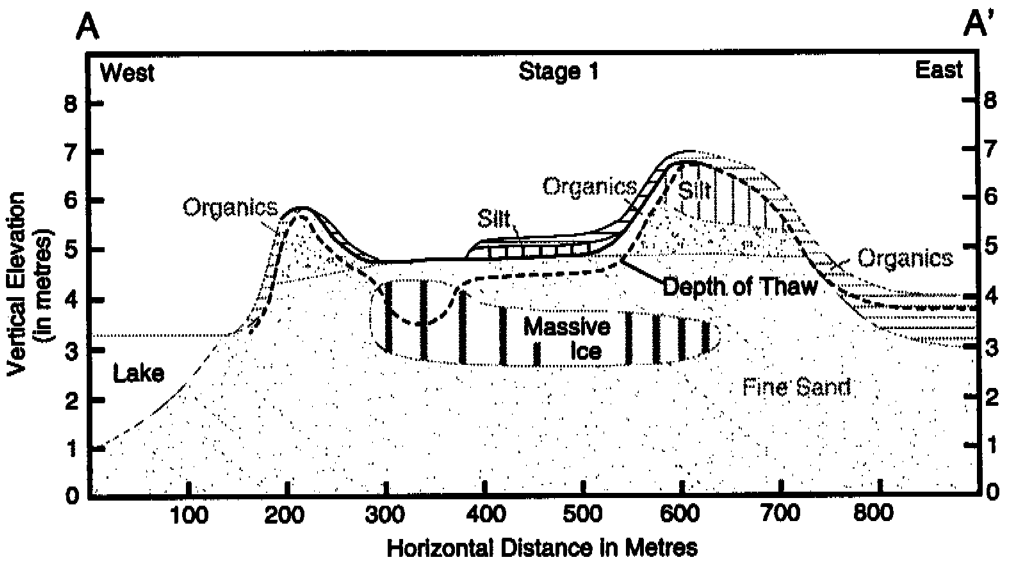
Illustration 21--Melt of Buried Ice and Formation of Thaw Ponds

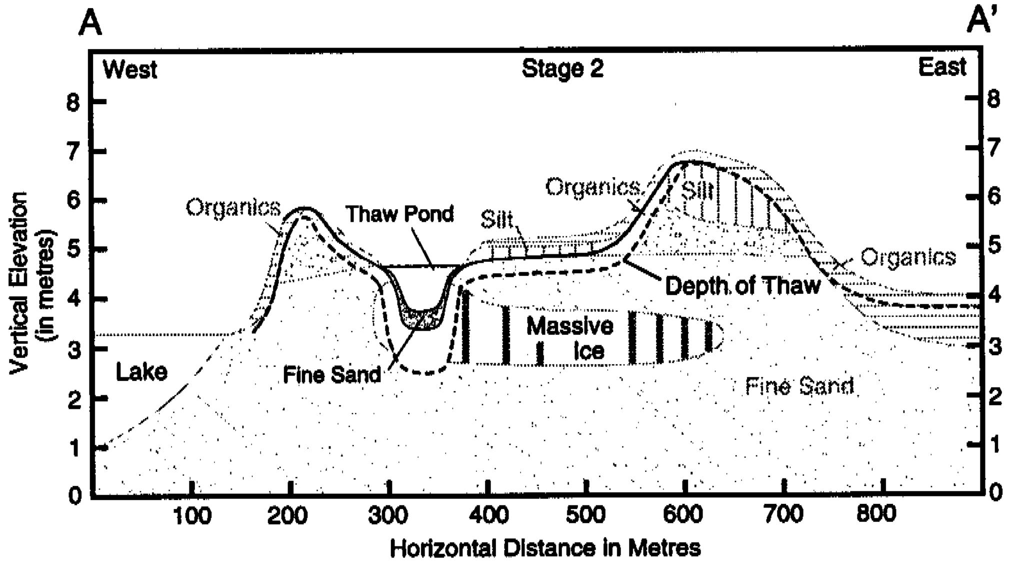
This series of diagrams shows the development of a thaw pond in our example borrow pit as buried ice melts. It may take several years for the ice to melt and the pit floor to stabilize.

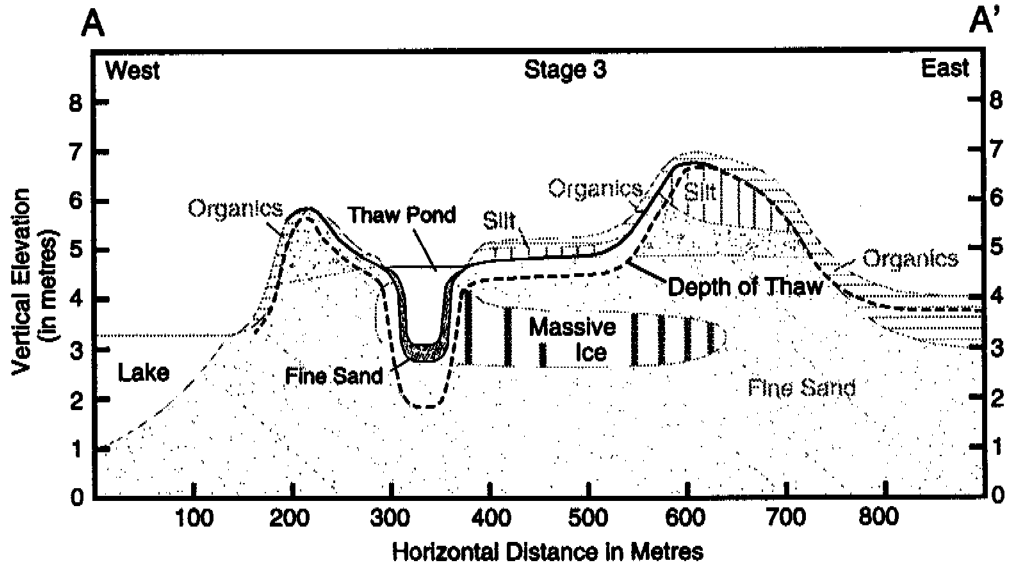
Stage 1 After restoration, the depth of summer thaw is less than 0.6 metres in undisturbed terrain, approximately 1 metre where fine grained overburden and organics have been replaced, and 1 to 2 metres where the organics have not been replaced. Buried ice under the west side of the borrow pit is exposed to melting temperatures during the summer.

Stage 2 The buried ice melts and land surface collapses forming a water filled depression [thaw pond]. Fine grained sand that was overlying the ice now lines the bottom of the pond. Depth of thaw is now 1 to 2 metres below the base of the pond and the remaining ice is exposed to thaw.

Stage 3 The remaining ice under the pond melts forming a deeper thaw pond. All of the ice under the pond has melted and the base of the pond is stable. In this example, ice on the margins of the pond is exposed to thaw and the surface area of the pond may expand as this ice melts. Growth of the pond will stop when there is sufficient cover, due to slumping of fine sand on the margins of the pond, to insulate this ice from thaw.


A
A'
West
Stage 1
East
Organics
Silt
Organics
Silt
Organics
Depth of Thaw
Massive Ice
Lake
Fine Sand
Vertical Elevation (in metres)
Horizontal Distance in Metres


A
A'
West
Stage 2
East
Organics
Thaw Pond
Silt
Organics
Silt
Organics
Depth of Thaw
Massive Ice
Lake
Fine Sand
Fine Sand
Vertical Elevation (in metres)
Horizontal Distance in Metres


A
A'
West
Stage 3
East
Organics
Thaw Pond
Silt
Organics
Silt
Organics
Depth of Thaw
Massive Ice
Lake
Fine Sand
Fine Sand
Vertical Elevation (in metres)
Horizontal Distance in Metres

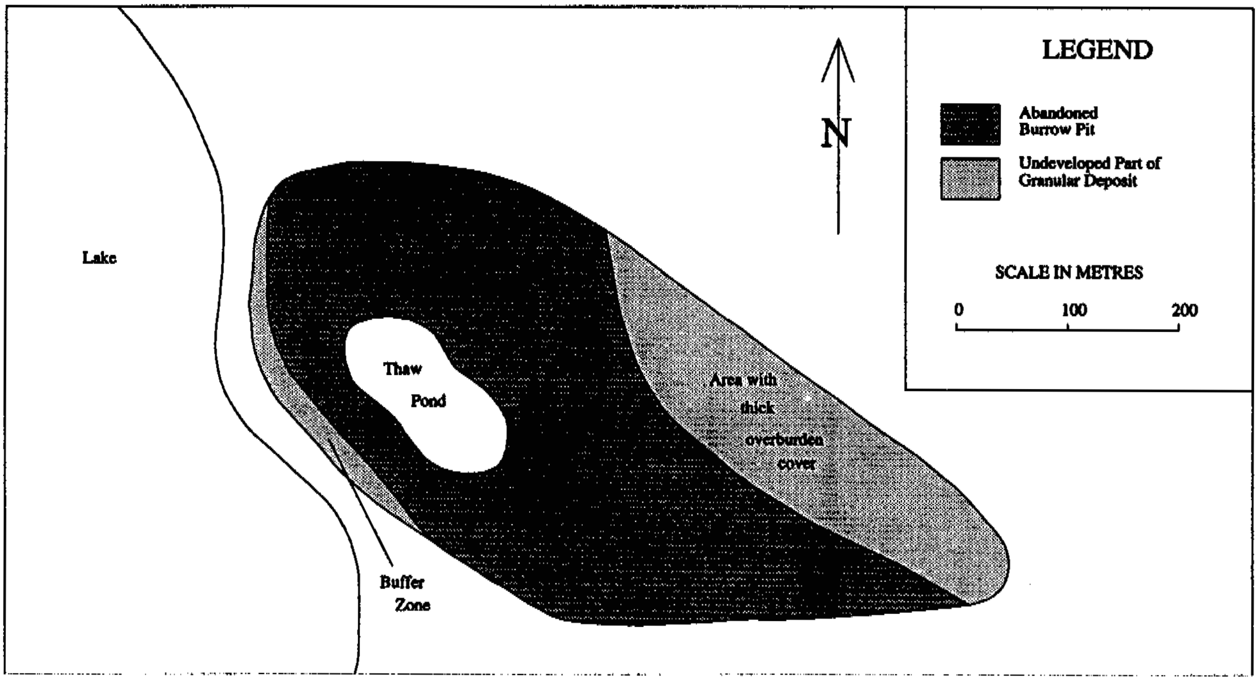


Illustration 22--Plan Map of the Abandoned Borrow Pit

This map shows conditions at our example borrow pit after it has been abandoned for several years. There a thaw pond on the west side of the pit where buried ice melted. The undisturbed buffer between the lake and the borrow pit provides a barrier to protect the lake from pit drainage that could damage fish stocks or other aquatic life. In this example, it was considered prudent to leave more than the minimum acceptable 30 meter buffer because large volumes of water were expected to be released by melt of buried ice. This ridge also provides a visual barrier between the lake and the pit. Less than 5% of the granular material available in the deposit was left in the abandoned borrow pit in order to provide this protective buffer.