REPORT ON GEOTECHNICAL STUDY RELATIVE TO ESTABLISHING A COMMUNITY GRAVEL BORROW PIT FOR BURWASH LANDING AND DESTRUCTION BAY, YUKON FEBRUARY, 1983 CG10047





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Prepared for DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT, CANADA Ottawa, Ontario

> Prepared by HARDY ASSOCIATES (1978) LTD. Calgary, Alberta

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SUMMARY

A detailed geotechnical investigation of three existing gravel pit reserves along the Alaska Highway (YTG #10981, DIAND #11574 and YTG #10983) was undertaken, to provide information on the basis of which to establish a community borrow pit for the use of Burwash Landing and Destruction Bay, Yukon. It is intended that the chosen pit will satisfy the concrete aggregate and gravel fill requirements of the two communities.

Following a review of existing information, a comprehensive drilling and laboratory testing program was carried out. In all, 45 boreholes were drilled and sampled within the three deposits. Laboratory testing consisted of moisture content determinations and, on selected samples, visual petrographic analysis, sieve analysis, and Los Angeles abrasion and sulphate soundness tests. Borehole logs and laboratory test results are presented.

Principle findings of the study are as follows:

- a) The M.P. 1086.2 site is a low volume deposit of fair to poor quality aggregate. With a 3:1 gravel-overburden stripping ratio, development does not appear warranted unless the overburden is used as fill material.
- b) Reserves for the M.P. 1087.6 deposit are estimated at 22 300 m³ proven and 81 500 m³ probable, of good quality aggregate. This will be suitable for most construction purposes, with crushing and screening required to produce concrete aggregate.
- c) At M.P. 1095.1 proven reserves are 90 000 m³ of good quality aggregate, greater than 200 000 m³ probable. Again though suitable for most purposes, the gravel will require crushing to produce concrete aggregate.



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It is concluded that, while additional testing is needed in the southern section (when improved access is available), the borrow reserve at M.P. 1095.1 (YTG #10983) is most suitable for development as a large volume, good quality, gravel pit for the use of the two communities.



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1.0 INTRODUCTION

Hardy Associates (1978) Ltd. was retained by the Department of Indian Affairs and Northern Development to carry out necessary geotechnical testing and assessment studies in connection with establishing a community gravel pit for Burwash Landing and Destruction Bay, Yukon. Authorization to proceed with the study was given on November 16, 1982 by Mr. G. N. Faulkner, Assistant Deputy Minister, Northern Affairs. Completed contract documents for the work were returned to Mr. G.Y. Williams, DIAND Contract Services Division, on December 13, 1982.

1.1 SCOPE OF STUDY

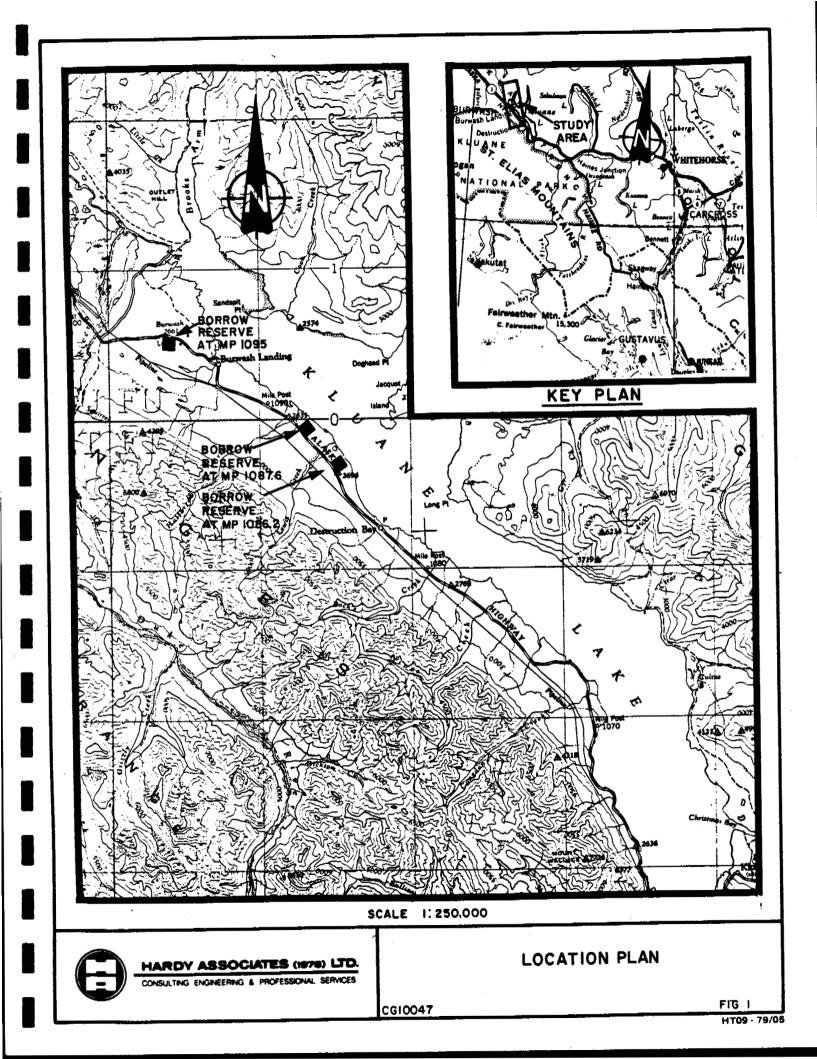
The prime objective of the study was to evaluate three existing borrow pit reserves, in connection with establishing a community borrow pit for the use of Burwash Landing and Destruction Bay. The chosen pit is to satisfy the demands for concrete aggregate and gravel fill for both communities. The three reserves are located adjacent to the Alaska Highway, between MP's 1086 and 1096 (Figure 1).

1.2 TERMS OF REFERENCE

Terms of reference for the study, as established in our Contract No. 82-348 with Department of Indian Affairs and Northern Development, were to:

 Carry out a detailed field drilling program at the following existing borrow pit reserves;

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- a) YTG Gravel Pit #10981 M.P. 1086.2 (KMP 1737.9)
- b) DIAND Gravel Pit #11574 M.P. 1087.6 (KMP 1740.2)
- c) YTG Gravel Pit #10983 M.P. 1095.1 (KMP 1752.2)
- 2. Conduct testing on representative samples to confirm the quality of the material in each pit and its suitability for various uses.
- 3. Prepare and submit a brief report, discussing the study methodology and presenting its results, providing an assessment of available aggregate volumes and suitability for various community uses, and presenting recommendations for pit development.

2.0 GEOLOGICAL SETTING

2.1 RELIEF AND TOPOGRAPHY

Physiographically, the borrow reserve sites lie in the Shakwak Trench, along the northeast side of the Kluane Ranges, St. Elias Mountains (Bostock, 1969). The M.P. 1086.2 and 1095.1 sites have undulating topography and slope gently to the north towards Kluane Lake, while the topography of borrow reserve at M.P. 1087.6 is hummocky, with a maximum relief of approximately 8 m to 10 m. Elevations of the three sites range from 821 m above sea level (asl) to 806 m asl (Figure 1).

2.2 BEDROCK GEOLOGY

According to Rampton (1981):

"The eugeosynclinal sequence of the Kluane Ranges and adjacent areas north of the Slims River consists primarily of -5-



argillite, volcanic, and greenstone rocks of Permo-Triassic age."

2.3 SURFICIAL GEOLOGY

The surficial geology of the Burwash Landing/Destruction Bay area is shown on Figure 2 (after Rampton, 1979a; 1979b).

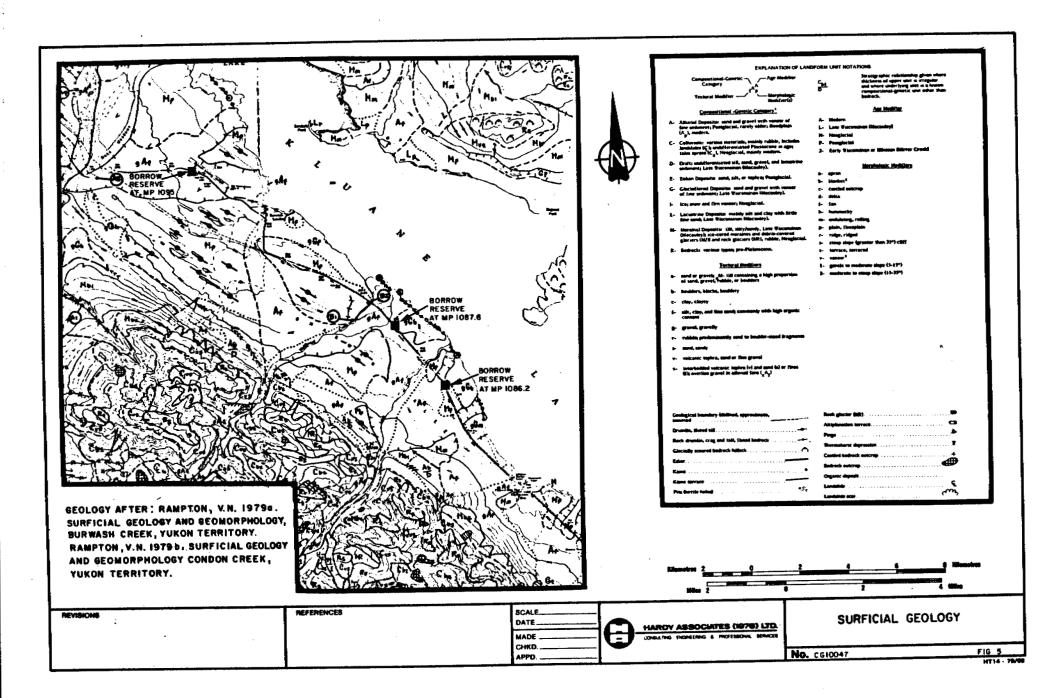
The Alaska Highway in this area follows the base of the Kluane Ranges, St. Elias Mountains, across a series of large coalescing alluvial fans which overlie glaciofluvial and morainal deposits (Rampton, 1977a; 1979b). As a result, the surficial geology is fairly complex and the three borrow reserves are all located on different surficial deposits. Thus, the borrow reserve at M.P. 1086.2 is located on a late Wisconsinan morainal deposit, which includes patches of glaciofluvial outwash material, the M.P. 1087.6 site is situated on a glaciofluvial kame terrace, and the M.P. 1095.1 site lies on a large alluvial fan of the Duke River (Figure 2).

The detailed surficial geology of the borrow sites is shown on Plates Cl to C3 (Appendix "C"), and described in Section 5.0.

2.4 DRAINAGE

The study areas slope towards Kluane Lake and have, for the most part, excellent surface drainage. Local depressional areas, however, are poorly drained and organic-infilled, for example, the extreme north-east corner of the M.P. 1086.2 site and the southern portion of the M.P. 1095.1 site. The poorly-drained organic areas are outlined on the individual site mosaics, in Appendix "C".

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2.5 PERMAFROST

The study area lies within the northern section of the discontinuous permafrost zone (Brown, 1967). Permafrost may be expected in all undisturbed areas with high ice content material occuring in the poorly drained areas. Permafrost was not encountered (to the depths drilled) in areas that have been stripped of vegetation. Low ice content permafrost can be expected in the higher, well drained, areas. During the field drilling program, permafrost was present at the M.P. 1095.1 site; no massive ice was encountered.

Expected active layer depths are in the range 0.5 m to 1.5 m, depending on material grain size and vegetation cover. Generally, coarse-grained soils with light vegetation will thaw to greater depths than fine-grained soils with heavy vegetation cover.

3.0 FIELD PROGRAM

A total of 45 boreholes was drilled on the three deposits: 15 boreholes at M.P. 1086.2, 10 holes at M.P. 1087.6 and 20 boreholes at M.P. 1095.1. Drilling was carried out between November 24 and 29, 1982. Borehole locations are shown on the photomosaic site plans (Plates Cl to C3) in Appendix "C".

3.1 METHODOLOGY

The drill rig utilized for this program was a CME 750 auger rig, supplied by Midnight Sun Drilling Ltd. of Whitehorse. Boreholes were augered and sampled under the supervision of a Hardy Associates (1978) Ltd. soil engineer. Except where

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conditions prohibited, borings were put down to a maximum depth of 6 m.

Grab samples were taken at a regular interval from each borehole for moisture profile determination and sieve analysis. Bulk samples were obtained at selected sites for more detailed laboratory testing (see Section 4.0).

3.2 RESULTS

Borehole logs are presented, on Plates Al to A45, in Appendix "A". The test drilling results for each borrow reserve are summarized and evaluated in Section 5.0.

4.0 LABORATORY TEST PROGRAM

Grab and bulk samples were retained from the boreholes and shipped to the Hardy Associates (1978) Ltd.'s Calgary laboratory for the detailed testing.

4.1 LABORATORY TEST PROCEDURES

Grab samples were taken from all test holes for sieve analysis (ASTM Cl36-82) and moisture content determinations. In addition, representative samples of coarse aggregate were tested for: petrographic analysis (ASTM C295), Los Angeles abrasion (ASTM C535-81) and soundness (ASTM C88-76).

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4.2 LABORATORY TEST RESULTS

The results of the laboratory testing program are presented on Plates Bl to B22 and Tables Bl to B5 in Appendix "B". Test descriptions and criteria for evaluating the results are also provided.

In summary, petrographic analysis of five samples from the M.P. 1087.6 and 1095.1 deposits gave PN values ranging from 100.2 to 116.2. Los Angeles abrasion tests resulted in losses (for 50 revolutions) ranging from 13.4 to 20.4 percent. Sulphate soundness testing produced losses ranging from 0.33 to 2.66 percent. Results for the individual deposits are presented in Section 5.0.

5.0 DEPOSIT EVALUATIONS

The deposits are evaluated below, in terms of their potential as sources of coarse granular aggregate, with respect to: available volumes, material type and quality, development criteria and possible community uses.

5.1 EVALUATION CRITERIA

Proven and probable reserves (and overburden volumes) have been computed for each deposit. Proven coarse aggregate volume was calculated, assuming a 100 m setback from the Alaska Highway, using average granular material thickness extrapolated over an area extending approximately 15 m in all directions from the boreholes. Overburden volume was calculated similarly. In view of the stratigraphic variability at the M.P. 1086.2 site, the calculated proven

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volume for that deposit was also reduced by a 20 percent contingency factor.

Probable reserves were calculated assuming the same proven deposit thickness and extrapolating over the area of the deposit considered, on the basis of airphoto interpretation, to be of geologically similar origin. No contingency allowance was included. In the case of the M.P. 1095.1 reserve, deposit thickness for calculation purposes was assumed to be 6 m, even though the presence of permafrost precluded drilling to this depth in all instances.

In evaluating the materials for possible community use, the granular materials classification presented on Table 1, (provided previously to us by DIAND), was used.

5.2 BORROW RESERVE AT M.P. 1086.2 (YTG #10981)

5.2.1 <u>Deposit Description</u>

This potential borrow site is located approximately 5 km northwest of Destruction Bay and 10 km southeast of Burwash Landing (Figure 1).

The site is located on Late Wisconsinan morainal deposits, which contain patches of outwash material (Rampton, 1979a). The site has undulating topography, with a maximum relief of 5 m. Drainage is good, except in the eastern part (which is low-lying). A portion of the site (in the vicinity of an existing pit) has been stripped of vegetation but the remainder is heavily treed (Plate Cl).

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TABLE 1

CLASSIFICIATION OF GRANULAR MATERIALS (after DIAND)

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SOURCE QUALITY DESCRIPTION	GENERAL DESCRIPTION OF MATERIAL	MINIMUM TECHNICAL IDENTIFICATION PARAMETERS	SUGGESTED USES OF MATERIAL
Excellent	Well graded sands and gravel, suitable for use as aggregate with a minimum of processing	Petrographic Number: 160 max. Los Angeles Abrasion Loss: 35% max. Soundness Loss (Magnesium Sulphate): 12% max., and meeting other requirements of CSA A23.1- 1973	Portland cement, and asphaltic concrete aggregate, masonry sand, concrete block, surface coarse and roofing aggregate.
Good	Well graded sands and gravels, with varying quantities of silt.	Petrographic Number: 200 max. Los Angeles Abrasion Loss: 60% max. Fines greater than 10% passing the 200 sieve can be removed with minimum of processing	Granular base and subbase. Winter sand backfill for trenches and slabs. Pads for structures. Select backfill.
Fair	Poorly graded sands and gravels, with or without substantial silt content	Petrogaphic Number: 250 max. Can be processed to meet local frost susceptibility criteria	Granular subbase. General backfill material, pads for equipment.
Poor	Poorly graded granular soils of high silt content, possibly containing very weak particles and deleter- ious materials	NIL	General non-structural fill.

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5.2.2 Field Investigation

Fifteen boreholes (BH's Cl to Cl5) were put down, on November 26 and 27, 1982. Borehole locations are shown on Plate Cl, while logs are presented on Plates Al to Al5 and laboratory test results in Appendix "B" (Plates Bl to B5).

5.2.3 <u>Material Type</u>

Coarse, poorly graded, dirty gravel was encountered in ten of the boreholes; overburden thickness ranged from 3 m to nearly 6 m. The gravel occurs at shallowest depth in the northwestern part and at slightly greater depths close to the eastern edge of the site. The overburden, probably a glacial till, ranges from clayey silt to silty and gravelly sand. Permafrost was not encountered in any of the boreholes. Only BH C14 was found to be wet at completion.

5.2.4 Available Reserves

Coarse aggregate occurs predominantly in the northwestern portion of the deposit. An area of 8400 m² was outlined by the test drilling, with an average deposit thickness of 1.3 m. On this basis, proven reserves of 11 000 m³ of coarse granular material are indicated. However, overburden thickness averages 3.8 m, giving a stripping ratio of roughly 3:1.

5.2.5 <u>Material Quality</u>

Grain size analyses were conducted on five samples from this deposit; results are presented on Plates Bl to B5 (Appendix "B"). The coarse aggregate is, in general, poorly graded and

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dirty. Fines content varies from 7 to 31 percent, with an average of 21.8 percent.

Moisture contents range from about 2 percent to 9 percent for the gravels, with an average of 5 percent. Excepting BH Cl4, with a moisture content of 22 percent, the overburden also has low moisture contents (in the 5 to 10 percent range).

Detailed testing was not carried out on material from this deposit.

5.2.6 <u>Community Uses</u>

Generally, the coarse aggregate from this deposit has a high fines content and is of fair to poor quality (Table 1). On this basis, the material is suitable for use as granular subbase, general fill and pad construction.

The overburden material consists predominantly of silty sand and silt. It is of poor quality but could possibly be useful as general non-structural fill (Table 1). The material will be difficult to work, however, and frost susceptible.

5.2.7 <u>Development Considerations</u>

This borrow reserve has excellent all-weather access, via the Alaska Highway, to both communities.

The economics of extracting the gravel, with stripping ratio of 3:1, are poor unless the overburden can be utilized for general fill purposes. In any event, extraction will be

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limited to the frost-free period, since winter development will be slow and costly (the material will be extremely difficult to rip in a frozen state).

5.3 BORROW RESERVE AT MP 1087.6 (DIAND #11574)

5.3.1 Deposit Description

This deposit is situated 7 km southeast of Burwash Landing and 8 km northwest of Destruction Bay (Figure 1).

The higher part of the site comprises a glaciofluvial kame terrace and alluvial fan deposits form the surrounding terrain. Most of the site is occupied by the kame terrace, which has up to 10 m of relief and is well drained.

As shown on Plate C2, a portion of this reserve has been excavated previously for granular borrow, and the vegetation has been partially stripped in the area around the existing pit. The undeveloped portion is sparsely to densely treed.

5.3.2 Field Investigations

Ten boreholes were drilled at this site, all to a depth of 6.0 m. Boreholes Al and A3 were located at the base of the kame terrace, on alluvial fan deposits, while BH's A2, A6, A7 and A8 were located in the bottom of the existing pit. The remainder of holes were on top of the kame terrace. Access to much of the deposit was restricted by the dense forest cover and only a limited area could be tested. Borehole locations are shown on Plate C2 (Appendix "C"), detailed logs in Appendix "A" (Plates Al6 to A25).



5.3.3 <u>Material Type</u>

Granular material was encountered in all boreholes, with overburden thickness ranging up to 2 m (average 0.45 m). Boreholes Al and A3, encountered sand and dirty gravel, while borings in the bottom of the existing pit (A2, A7 and A8) intersected 6.0 m of clean but poorly graded gravel. The remaining terrace, encountered poorly graded, generally clean, gravel, with some sand lenses; overburden averaged 0.5 m in thickness.

5.3.4 Available Volumes

The greatest potential for granular material exists in the kame terrace, already partially developed by the existing excavation. Available reserves exist in three areas:

- a) North of the existing pit.
- b) Underlying the existing pit.
- c) South of the excavation.

Test drilling to the north of the existing pit (BH's A4 and A5) proves coarse aggregate reserves of 5000 m³, assuming an average overburden thickness of 1.3 m. Estimated probable reserves for this portion of the deposit are 18 000 m³.

Boreholes A2, A6, A7 and A8, within the existing pit (area: 2100 m²), intersected greater than 6 m of clean, poorly graded, medium to coarse gravel, giving reserves of 12 600 m³, with no overburden. It is unlikely, however, that the pit will be extended below the level of the surrounding terrain, so that proven reserves from this portion of the deposit, are

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estimated at about half the above total, or 6300 m³. An additional 7200 m³ of material occurs in the vicinity of BH A6, giving probable reserves of 13 500 m³.

Boreholes A9 and A10, to the east of the existing pit, indicate greater than 6 m of coarse aggregate over an area of 1800 m², or proven reserves of approximately 11 000 m³. On the average, 60 percent of this material is expected to be gravel sized, with the remainder predominantly sand. No overburden was encountered in this area. Probable reserves are estimated in the order of 50 000 m³, extending over an area of 10 000 m². Overburden up to 1.5 m thick is expected over much of the latter area.

Total reserves for the M.P. 1087.6 deposit are 22 300 m³ proven and 81 500 m³ probable.

5.3.5 <u>Material Quality</u>

Moisture contents for this deposit are shown on the pertinent borehole logs (Plates Al6 to A25), and grain size curves are presented Plates B8 to Bl0. Generally, the aggregate is coarse and poorly graded, with a low fines content. Testing of a sample from BH A4, gave a Los Angeles abrasion loss of 13.4 percent (Plate B6), a sulphate soundness loss of 0.33 percent (Plate B7), and petrographic number (PN) of 100.2 (Table B2). The PN for a sample from BH A2 was also 100.2 (Table B1).

5.3.6 Possible Community Uses

The results of the laboratory testing indicate the aggregate from this deposit is of good quality (Table 1), suitable for

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most construction purposes. The coarseness and poor grading of the material suggest crushing will be necessary to meet the specifications for concrete aggregate. Fines may need to be added before the material can be used for road subgrades, bases or surface coarse, in the event crushing does not increase the fines content sufficiently.

5.3.7 Development Consideration

This deposit has an adequate volume of good quality material centrally located between the two communities, to warrant development.

Development should be continued from the existing excavation, both deepening and widening the work area. A 100 m buffer zone should be kept between the pit and the Alaska Highway. Overburden, where encountered, should be separated and stockpiled along the base of the kame terrace, for later use in rehabilitation and reclamation (or possibly to increase fines content of aggregate used as surface course). If possible, the topsoil should be stockpiled separately.

Extraction should ideally be timed for the summer season. Although moisture and fines contest are low enough to allow winter development, this is usually a slower and more costly process than summer development.

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5.4 BORROW RESERVE AT MP 1095.1 (YTG #10983)

5.4.1 <u>Deposit Description</u>

This borrow site is, located on the south side of the Alaska Highway, 4 km and 18 km northwest of Burwash Landing and Destruction Bay, respectively.

The deposit is situated on a portion of the Duke River alluvial fan. The site is flat to gently sloping, has a maximum of 5 m to 6 m relief, and is moderately well drained. Depressional areas on the site tend to have poor drainage. Plate C3 shows general site conditions.

Adjacent to the highway, the site has been stripped of vegetation and excavated for borrow to a shallow depth. The remainder of the study area is heavily treed, with poor access (Plate C3).

5.4.2 Field Investigations

A total of twenty boreholes (Bl to B20) was drilled, on November 27 and 28, 1982, to a maximum depth of 6.0 m. Several holes could not be completed to the full depth because of auger refusal on boulders and/or permafrost. As shown on Plate C3, boreholes are distributed mainly in the northern portion of the borrow reserve, since the heavy tree cover prevented drilling test holes further back on the site. Detailed borehole logs are presented on Plates B26 to B45.

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5.4.3 Material Type

All borings, except BH B17, encountered coarse and poorly graded, subrounded to subangular, gravel, with a low moisture and fines content, and some sand pockets. Overburden was absent in most of the holes as the site had previously been cleared and partially stripped. The extreme western portion of the deposit, which is low-lying and wet, is underlain by peat and/or silt (1.0 m to 3.0 m deep). Permafrost was encountered in many of the boreholes, particularly in the southern part where the vegetation has not been completely stripped.

5.4.4 Available Reserves

Test drilling has proven coarse aggregate in an area of roughly 20 000 m² (taking into account the 100 m setback from the Alaskan Highway). Assuming a 4.5 m minimum deposit thickness, 90 000 m³ of predominantly coarse granular material is indicated, with little or no overburden. Since a deposit thickness of at least 6 m appears likely for most of the site (but could not be proven due to permafrost), probable reserves are estimated at considerably greater than 200 000 m³. This probable volume should be treated with caution, however since drilling operations were limited to the northernmost one third of the site, due to very poor access.

5.4.5 Material Quality

Grain size curves are shown on Plates Bl1, Bl4, Bl7, Bl8, B21, B22 and B23. The aggregate is generally coarse and poorly graded, with a fines contents ranging from 1 percent to 7 percent. Material from borehole B4 had a PN of 108.3 (Table

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B3) a Los Angeles abrasion loss of 18.5 percent (Plate B12), and a sulphate soundness loss of 0.71 percent (Plate B13). Aggregate from BH B9 had a PN of 116.2 (Table B4), an abrasion loss of 18.9 percent (Plate B15) and a soundness loss of 2.66 percent (Plate B16). Finally, material from BH B14 had a PN of 111.7 (Table B5), had an abrasion loss of 20.4 percent (Plate B19) and a soundness loss of 2.42 percent (Plate B20).

5.4.6 Possible Community Uses

The results of the laboratory testing indicate the aggregate is of good quality (Table 1). The grain size curves indicate crushing and processing will be required to produce a material that is suitable for most construction requirements.

5.4.7 <u>Development Considerations</u>

This proposed borrow site has excellent access, via the Alaska Highway, to both communities and is a large volume source of good to excellent quality aggregate. Since a small borrow pit is currently located on the site, development should proceed by expansion of this existing excavation.

Landuse regulations require that a 100 m buffer zone be maintained between the development and the Alaska Highway. As a result much of the existing pit will fall into this buffer zone. Additional development should be away from this setback area.

Test drilling encountered difficulties in penetrating the frozen gravels and it is expected that excavation will meet with the same problem. Development of the pit, therefore, should be a summer operation. Permafrost is not expected to

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be encountered for the initial 4 or 5 m from the surface in the portion of the deposit that has been stripped of its surface vegetation. Expansion beyond this area will likely encounter permafrost near the ground surface, and a thaw-strip cycle method of mining in frozen ground is recommended. This involves exposing a large surface area of granular material to solar radiation to promote thawing. Excavation of unfrozen material may then be completed in layers or strips, as the thaw front progresses. Generally, coarse granular material will thaw from 0.2 m to 0.4 m per day. Site clearing well prior to development also promotes deeper thawing of the active layer.

Material obtained during a summer operation can be used directly or may be stockpiled for use during the winter months. Moisture and fines contents are generally low enough to permit winter development. However, ripping of undisturbed gravel is slower and more costly than the same process during the summer or excavating from a stockpile.

6.0 CONCLUSIONS

Findings of the study with respect to the three possible community gravel pit sites are, in summary, as follows:

- a) The M.P. 1086.2 site is a low volume deposit of fair to poor quality aggregate. With a 3:1 gravel-overburden stripping ratio, development does not appear warranted unless the overburden is used as fill material.
- b) Reserves for the M.P. 1087.6 deposit are estimated at 22 300 m³ proven and 81 500 m³ probable, of good quality aggregate. This will be suitable for most construction

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purposes, with crushing and screening required to produce concrete aggregate.

c) At M.P. 1095.1 proven reserves are 90 000 m³ of good quality aggregate, greater than 200 000 m³ probable.
 Again though suitable for most purposes, the gravel will require crushing to produce concrete aggregate.

The M.P. 1086.2 site is a small volume source of poor quality gravel, with a high stripping ratio. The study results suggest that development is probably not warranted, even if the frost susceptible overburden materials were used for fill.

Based on material quality both the M.P. 1087.6 and 1095.1 sites are candidates for development as a community gravel pit. However, proven and probably aggregate volumes at the latter are considerably in excess of those of the former. Additional testing in the southern part of the M.P. 1095.1 deposit (which presently has poor access) will likely prove out considerably greater volumes.



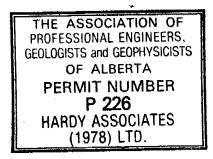
It is our conclusion that the M.P. 1095.1 borrow reserve (YTG #10983) is most suited to development as a community gravel pit for Burwash Landing and Destruction Bay. It will be necessary to set up a crushing and screening operation to produce concrete aggregate: the material may be used for fill in the pit-run state or with only limited processing.

Respectfully Submitted, HARDY ASSOCIATES (1978) LTD.

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APPENDIX "A" BOREHOLE LOGS



EXPLANATION OF TERMS AND SYMBOLS

The terms and symbols used on the borehole logs to summarize the results of field investigation and subsequent laboratory testing are described in the following pages.

It should be noted that materials, boundaries, and conditions have been established only at the borehole locations, and are not necessarily representative of subsurface conditions elsewhere across the site.

TEST DATA

Data obtained from laboratory and field testing are shown on the grid at the appropriate depth interval.

The natural moisture (water) content of the soil at the time of drilling is plotted against depth, together with the plastic and liquid limits where determined.

Abbreviations, graphic symbols, and relevant test method designations are as follows:

Ο	w	natural moisture content (ASTM D 2216)
	Wp	plastic limit (ASTM D 424)
◬	WL	liquid limit (ASTM D 423)
	NP	non plastic soil
	>	seepage
	Y	observed water level

Other abbreviations and symbols are as shown on the borehole log sheet.

DEPTH

The depth of borehole below existing ground surface is shown. Corresponding elevations sometimes are shown with respect to the datum given.

SOIL CLASSIFICATION AND DESCRIPTION

Soils are classified and described according to their engineering properties and behaviour.

The soil of each stratum is described using the Unified Soil Classification System¹ modified slightly so that an inorganic clay of "medium plasticity" is recognized.

The use of modifying adjectives may be employed to define the actual or estimated percentage range by weight of minor components. This is similar to a system developed by D.M. Burmister.²

The soil classification system is shown in greater detail on page 3.

 [&]quot;Unified Soil Classification System", Technical Memorandum 3-357 prepared for Office, Chief of Engineering, by Waterways Experiment Station, Vicksburg, Mississippi, Corps. of Engineers, U.S. Army, Vol. 1, March 1953.

American Society for Testing and Materials. Procedures for Testing Soils, "Suggested Methods of Testing for Identification of Soils", 4th Ed; pp 221-233, Dec. 1964.



SOIL SAMPLES

CONDITION - This column graphically indicates the depth and condition of the sample:



TYPE — The type of sample is indicated in this column as follows:

- A auger sample
- B block sample
- C rock core, or frozen soil core
- D drive sample
- P Pitcher tube sample
- U tube sample (usually thin-walled)
- W wash or air return sample
- O other (see report text)

PENETRATION RESISTANCE — Unless otherwise noted this column refers to the number of blows (N) of a 140 pound (63.5 kg) hammer freely dropping 30 inches (0.76 m) required to drive a 2 inch (50.8 mm) O.D. open-end sampler 0.5 feet (0.15 m) to 1.5 feet (0.45 m) into the soil, or until 100 blows have been applied, in which case, the penetration is stated. This is the standard penetration test referred to in ASTM D 1586.

OTHER TESTS

In this column are tabulated results of other laboratory tests as indicated by the following symbols:

*C	Consolidation test
Fines	Percentage by weight smaller than #200 sieve
DB	Relative density (formerly specific gravity)
k Ö	Permeability coefficient
*MA	Mechanical grain size analysis and hydrometer test (if appropriate)
рр	Pocket penetrometer strength
*q	Triaxial compression test
q _u	Unconfined compressive strength
*SB	Shearbox test
SO₄	Concentration of water-soluble sulphate
*ST	Swelling test
тν	Torvane shear strength
VS	Vane shear strength (undisturbed-remolded)
ε _f	Unit strain at failure
γ	Unit weight of soil or rock
$\boldsymbol{\gamma}_{d}$	Dry unit weight of soil or rock
ρ	Density of soil or rock
ρd	Dry density of soil or rock

* The results of these tests usually are reported separately.

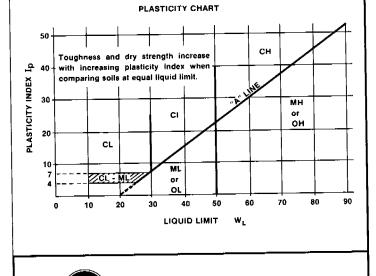
SOIL CLASSIFICATION SYSTEM (MODIFIED U.S.C.)

							LABORATO	DRY		
	MAJOR (DIVISION	GROUP SYMBOL	GRAPHIC SYMBOL	COLOR CODE	TYPICAL DESCRIPTION	CLASSIFICA CRITERI			
	HIGHLY OR	GHLY ORGANIC SOILS Pt			ORANGE	PEAT AND CTHER HIGHLY ORGANIC SOILS	STRONG COLOR OR ODOR, AND OFTEN FIBROUS TEXTURE			
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00 SIEVE	GRAVELS E THAN HALF COARSE CTION LARGER THAN NO. 4 SIEVE SIZE	CLEAN GRAVELS	GP		RED	POORLY-GRADED GRAVELS, AND GRAVEL- SAND MIXTURES, < 5% FINES	NOT MEETING ALL ABOVE REQUIREMENTS			
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RAINED SOILS LARGER THAN NO. 200 SIEVE	MORE						YELLOW	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES > 12% FINES	ATTERBERG L ABOVE "A" L Ip > 7	
COARSE-GRAINED BY WEIGHT LARGER	ASE		sw	0 0 0 0 0 P 0 0 0 0 0 0 0 0	RED	WELL-GRADED SANDS, GRAVELLY SANDS, < 5% FINES	$C_{u} = \frac{D_{60}}{D_{10}} > 4 C_{C} = \frac{(D_{10})}{D_{10}}$	$(x_{30})^2 = 1 \text{ to } 3$		
COAF HALF BY WE	SANDS SANDS MORE THAN HALF COARSE FRACTION SMALLER THAN NO. 4 SIEVE SIZE	CLEAN SANDS	SP		RED	POORLY-GRADED SANDS, OR GRAVELLY SANDS, < 5% FINES	NOT MEETING ABOVE REQUIR	EMENTS		
THAN HA	SAN SAN TION SM NO. 4 SIE	NOV SM	SM	SILTY SANDS, SAND-SILT MIXTURES		ATTERBERG LIMITS BELOW "A" LINE OR Ip < 4				
(MORE	MORE	DIRTY SANDS	sc		YELLOW	CLAYEY SANDS, SAND-CLAY MIXTURES > 12% FINES	ATTERBERG LIMITS ABOVE "A" LINE OR Ip > 7			
SIZE)	BELO	SILTS W "A" LINE ON	ML		GREEN	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY SANDS OF SLIGHT PLASTICITY	W _L < 50			
200 SIEVE	PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT CLAYS CLAYS CLAYS ABOVE "A" LINE ON PLASTICITY CHART; NEGLIGIBLE ORGANIC CONTENT		мн		BLUE	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS, FINE SANDY OR SILTY SOILS	W _L > 50			
SOILS SES NO.			CL		GREEN	INORGANIC CLAYS OF LOW PLASTICITY, GRAVELLY, SANDY, OR SILTY CLAYS, LEAN CLAYS	W _L < 30			
E-GRAINED (WEIGHT PAS			СІ		GREEN- BLUE	INORGANIC CLAYS OF MEDIUM PLASTICITY SILTY CLAYS	W _L > 30, < 50	SEE CHART BELOW		
FIN FIN			СН		BLUE	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS	w _L > 50			
THAN HAL	ORGANIC S	ILTS & ORGANIC CLAY	5 OL		GREEN	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY	w _L < 50			
(MORE T		OW "A" LINE ON STICITY CHART	он		BLUE	ORGANIC CLAYS OF HIGH PLASTICITY	W _L > 50			

1. All sleve sizes mentioned on this chart are U.S. Standard, ASTM E11.

- Boundary classifications possessing characteristics of two groups are given combined group symbols eg GW-GC is a well-graded gravel-sand mixture with clay binder between 5% and 12%.
- Soll fractions and limiting textural boundaries are in accordance with the Unified Soll Classification System, except that an inorganic clay of medium plasticity (CI) is recognized.
- The following adjectives may be employed to define percentage ranges by weight of minor components:

and	50 - 36%
some	35 - 21%
little	20 - 11%
trace	10 - 1%



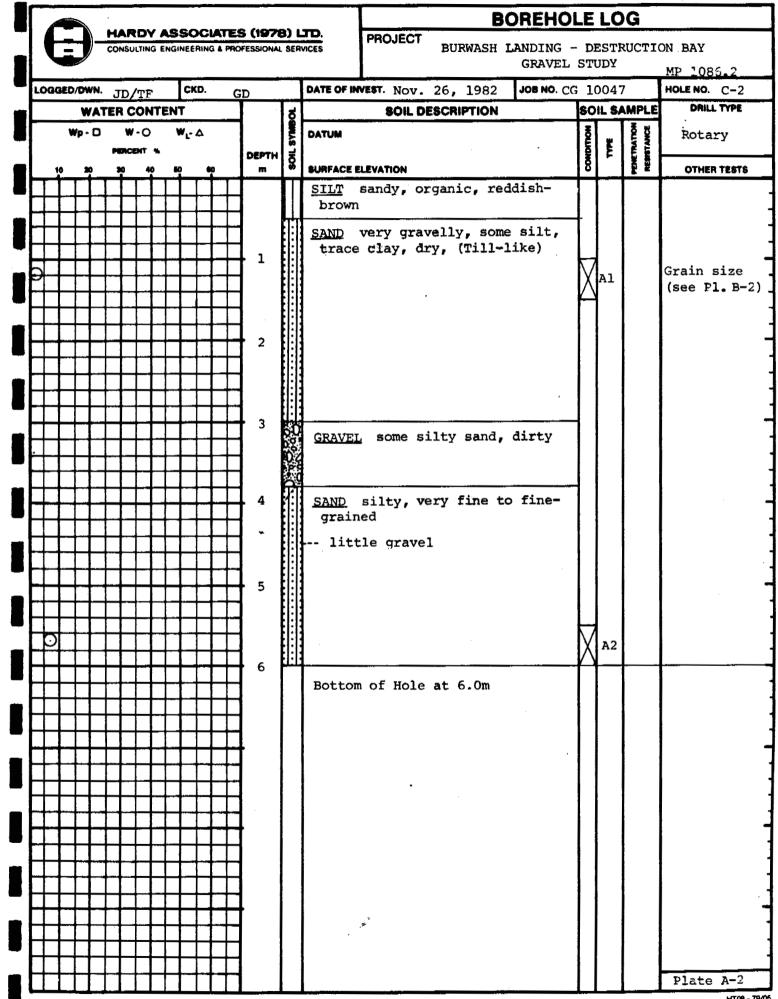
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CONSULTING ENGINEERING & PROFESSIONAL SERVICES



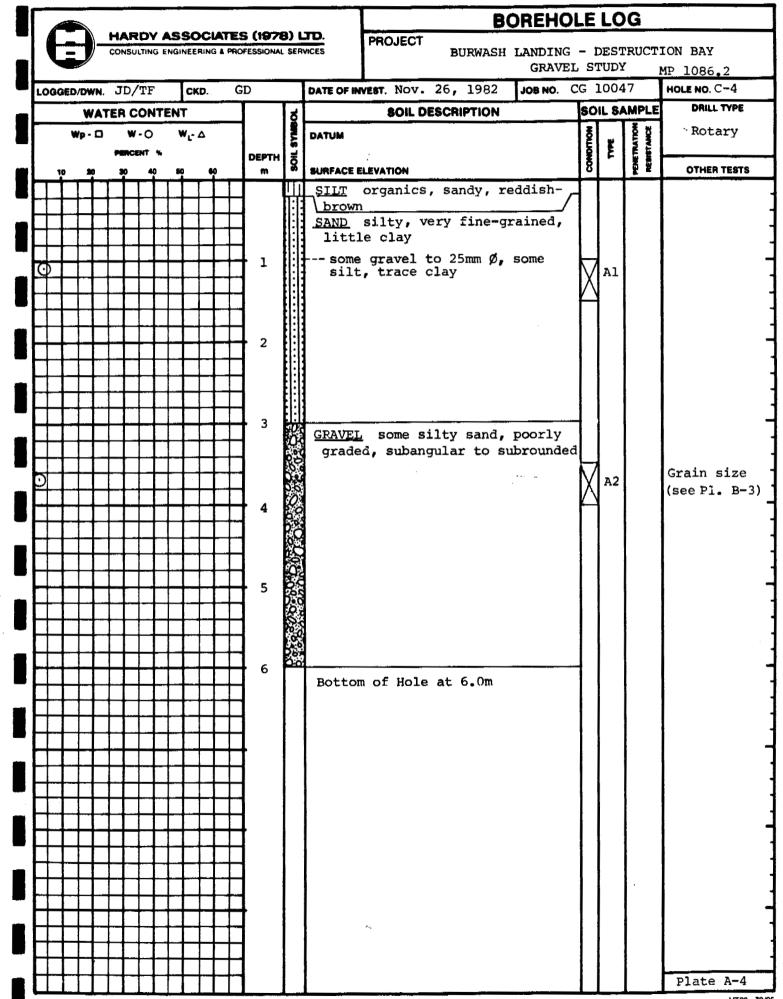
BOREHOLE LOGS M.P. 1086.2

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							-											MP 1085	
LOGGE	D/DWN.	JD	/TF		СК	D.		G	D	_	DATE OF IN		26, 1982	JOB NO. CO				HOLE NO.	C-
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	·														GRAVI	EL S	TUDY	2	MP 1086.2
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	_		ENT N			_		DEPT								CONDITION	Ĕ	PENETRATION REDISTANCE	
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			BOREH	OLE LOG	
	HARDY ASSOC		TD. PROJECT		ION BAY
	CONSULTING ENGINEERIN	NG & MUTESSIONAL SEN		EL STUDY	MP 1086_2
OGGED/DWN.	JD/TF CKD.	GD	DATE OF INVEST. NOV. 26, 1982 JOB NO.	CG 10047	HOLE NO. C-9
			SOIL DESCRIPTION	SOIL SAMPLE	
· · · · · · · · · · · · · · · · · · ·	FER CONTENT	I			Rotary
Wp - 🗖	W-0 W _L -A	1 0	DATUM	CONDITION TYPE PENETRATION	
10. 10	90000000000000000000000000000000000000		SURFACE ELEVATION		OTHER TEST
$\overline{111}$			SAND silty, brown, very fine-		
+++			grained, some clay		
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	┼┼┼╉┼╂┼	+++ 1 [[]	silty, fine-grained, trace gravel, dark brown	Al	1
			graver, dark brown		
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			1		
		-+-+-1 [[]	1		
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┽╂┼╂	╡┨┤╏╎╏┤		GRAVEL sandy, little silt,		1
			subangular		1
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d + + +	┼╉┼╂┥╏ ┿	++1 🛿		A2	
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			Bottom of Hole at 6.0m		•
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			_		BOREH	<u>)LE</u>) <u>G</u>	
Ð	CONSULTING ENGINEE				TD. PROJECT	G -	DES	TRUCT	
									MP 1086.2
OGGED/DWN.	00/11	KD.	GD		DATE OF INVEST. NOV. 26, 1982 JOB NO.				HOLE NO. C-10
WA	TER CONTENT			BOL	SOIL DESCRIPTION	50	DIL SA	AMPLE	DRILL TYPE
Wp - 🗆	W-0 W _L -		DEPTH	HL SVM	DATUM	CONDITION	Ĕ	PENETRATION REBIET ANCE	Rotary
10 30	30 40 80	9 0	m	SOIL	SURFACE ELEVATION	8		N III	OTHER TESTS
				Π	SILT sandy, brown, trace clay,				
++++	↓ ↓ ↓ ↓ ↓ ↓	┼┼┼┨			very fine to fine-grained sand	,			
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┽╉┼╊╸	┼┨╎╊┼╋╴	┼┼┽┫	_		little to some gravel, fine-				
			1		grained sand	\geq	Al		
					<u> </u>				
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			4					[
			4					1	
┼┼┼╂╴	╅╋┽╋┼╉╸	┼┼┼┨			boulders				
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						PROJECT BURWAS	H LANDING GRAVEL				
		Lava -									MP 1086.2
LOGGED/DWN.		CKD. G			DATE OF INV	EST. Nov. 26, 198		_		_	HOLE NO. C-1
	ER CONTE		4	ğ		SOIL DESCRIPTIO		150	IL 8/		
Wp - 🗅	W-O	₩ _L - Δ	DEPTH	AL SVM	DATUM			CONDITION	1.VPE	PENETRATION	Rotary
10 20	30 40	50 60	m		SURFACE EL	EVATION		8		N N	OTHER TESTS
				Ň	TOPSOII	organic, redd	ish-brown				
	╶┨╎╂┽	╉╁╋╋	4		SILT	sandy, light br	own, fine-				
┝┼╂┼╂┤	╶╂┼╉┽	╉┼╂┼	-		graine	d sand, (Till-1	ike)				
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	╺╋┼╂┦	╶╂┽╂┼	-		some	gravel, trace c	lay	∇	Al		
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			6	Ľ	Bottor	of Hole at 6.0m		T		T	
			1		BOLLOW	or note at 0.01	u				
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						PROJECT BURWASH J	LANDING - GRAVEL				
									_		MP 1086.2
LOGGED/DWN.	JD/TF	CKD.	GD		DATE OF INV	/EST. Nov. 26, 1982	JOB NO. CO				HOLE NO. C-1
WAT	ER CONT	ENT		8		SOIL DESCRIPTION		so	IL SA	MPLE	DRILL TYPE
Wp - 🗆	W -O	₩ _L - Δ			DATUM			NOL		PENETRATION RESISTANCE	Rotary
	PERCENT %		DEPTH	Ī		- FUATION		COND	TYPE	ENETH VENUE	OTHER TESTS
			m	R			hrown	Ĥ			UTHEN TESTS
┽╂┿╊╼	┝╍╋╍╅╌╂╴	┼╉┽╊╋	1	X	TOPSOI	L organic, sandy,	DIOMI				
			1	ĥ			1.0.40	1			
╧╋┼╋	┝╺┠┈┟╴┠╶	┿╋┿┦╄┿	4		SILT SOME	<pre>sandy, brown, litt clay, (Till-like)</pre>	te to				
┼╂╎╉╍	┝╋┝╋	┽╉┽╂┽	1		Bome						
┽╉┽╂╴	<u>├ </u>	┼╂┽┨┿	1								l
			1								
	┟╶┠╶┤╌┠	┼┼┼┼┼	2		trac	e gravel					
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BOREHOLE LOGS M.P. 1087.6

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LOGGED/DW	N. JD/TF CKD.	GD	DATE OF INVEST. Nov. 27, 1982 JOB NO	D CG 10047	HOLE NO. A-8
	ATER CONTENT	1	SOIL DESCRIPTION	SOIL SAMPLE	
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			<u>GRAVEL</u> poorly graded, some sand, brown		
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			fine, some sand		(see Pl. B-9)
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	<u> </u>	6	sandy, dark brown	A2	
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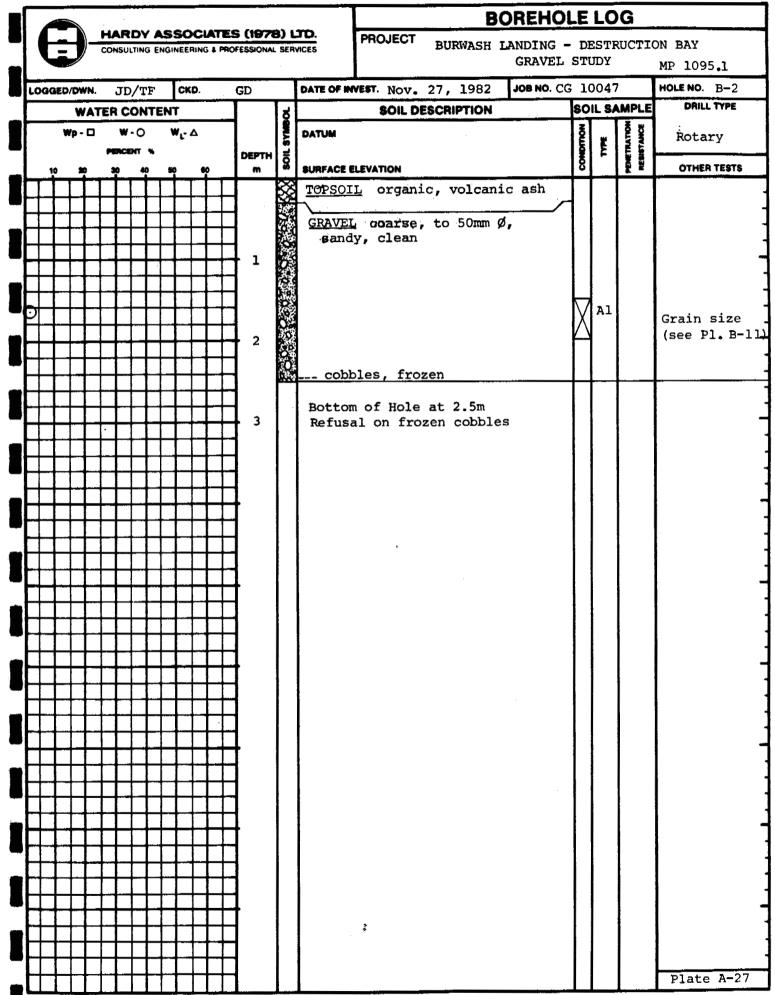
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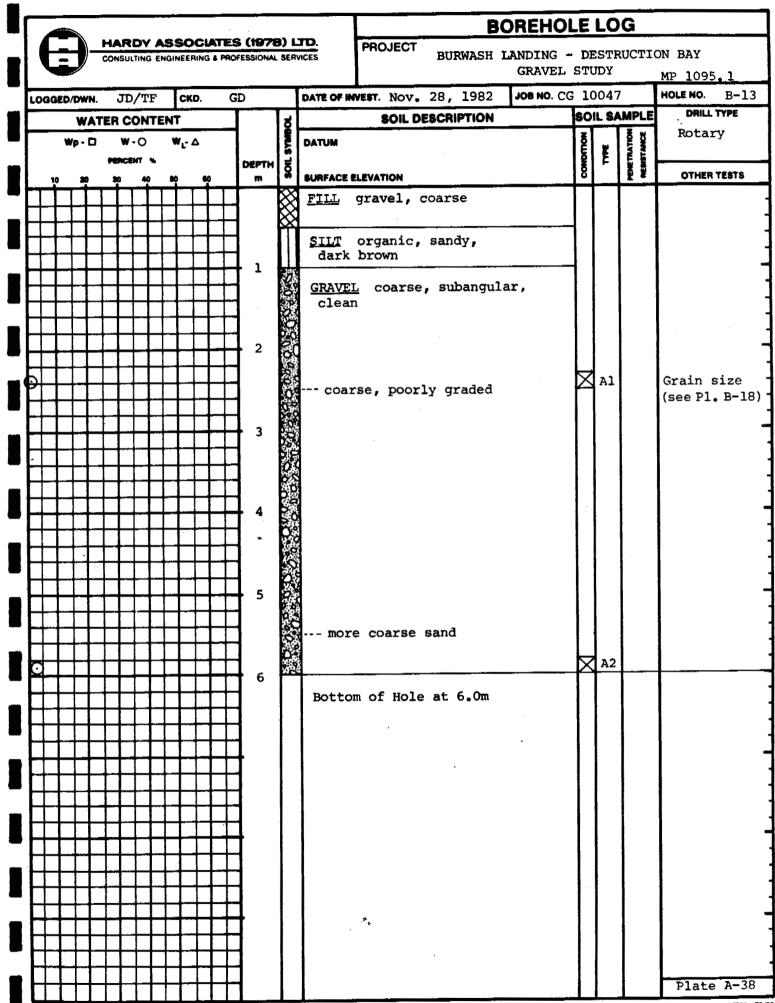
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APPENDIX "B" LABORATORY TEST RESULTS



HARDY ASSOCIATES (1978) LTD. CONSULTING ENGINEERING & PROFESSIONAL SERVICES

APPENDIX "B" LABORATORY TEST RESULTS

B.1 GRAIN SIZE ANALYSIS (ASTM C136-82)

Sieve analysis of aggregate samples provides a gradation for the bulk natural material, which may be compared with ideal curves for concrete aggregate, asphalt, etc.

B.2 LOS ANGELES ABRASION TEST (ASTM C535-81)

This test provides information on the hardness and roughness of an aggregate. A definite relationship exists between the strength of concrete and the quality of its constituent coarse aggregate, as measured by the Los Angeles Abrasion test. For most applications, a loss of less than 30 percent after 50 revolutions, is considered to indicate a good quality aggregate.

B.3 SULPHATE SOUNDNESS TEST (ASTM C88-76)

This test provides an indication of any structural weakness that may be present in the aggregate. A general relationship exits between the percentage weight loss in the test with the compressive strength and freezing and thawing durability of concrete made from the aggregate. In general, coarse aggregate is considered acceptable if the weighted loss is less than 12 percent, after 5 cycles.



B.4 PETROGRAPHIC ANALYSIS (ASTM C-295)

Petrographic analysis consists of a visual examination of aggregate particles and identification on the basis of mineralogy. Particles are assigned a rating on the basis of the known soundness or deleterious nature of the mineral type, a rating of 1 being the best and 10 being the worst. The weighted percentage of each mineral type is then multiplied by this rating number to produce a petrographic number (PN) for the aggregate. The following classification, recommendation by Ontario Hydro petrographers, is used in this report.

<u>PN</u>	RATING
100-110	Excellent
111-125	Good
126-140	Fair
141-155	Poor
155	Unsuitable

SUMMARY OF ROCK TYPES COARSE FRACTION

M.P. 1087.6 Borehole A-2 Depth 5.8 m - 6.0 m

	M.P. 1007.6 E		IGHTE		CENTA	GES (JENTS	<u></u>	
ROCK TYPE	CLASSIFICATION	4"	3"	. 2"	15"	1"	3/4"	· J. n. ·	3/8"	#4	Total Weighted Composition
Plutonics-acid						1.1	1.7	2.5	1.0	3.2	9.5
Greenstone-ultra basic					3.0	1.6	4.0	8.4	4.8	11.8	33.6
Carbonates	Good						1.1	1.1	0.6	1.7	4.5
Metamorphics						2.6	4.0	11.2	12.3	22.2	52.3
Volcanics	Fair									0.1	0.1
•						-					
·											
		· · · ·									
					3.0	5.3	10.8	23.2	18.7	39.0	100.0

PN = 100.2

SUMMARY OF ROCK TYPES C	COARSE FRACTION
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M.P. 1087.6 B

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Borehole A-4 Depth 3.0 m - 3.3 m

WEIGHTED PERCENTAGES OF CONSTITUENTS													
		WE					OF CON		JENTS		Total		
ROCK TYPE	CLASSIFICATION	4"	3"	2"	15"	1"	3/4"	<u>ل</u> ح"	3/8"	#4	Weighted Composition		
Plutonics-acid					2.4	3.4	3.9	3.9	3.1	4.5	21.2		
Greenstone-ultra basic	•		¥		3.6	2.2	5.2	9.5	5.6	7.8	33.9		
Carbonates	Good	•				1.1	0.8	1.4	0.4	1.0	4.7		
Metamorphics .					1.2	3.4	5.2	7.8	9.2	13.3	40.1		
Carbonatës (weathered,soft)	Fair							0.1			0.1		
			-										
							· .						
											<u></u>		
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					7.2	10.1	15.1	22.7	18.3	26.6	100.0		

PN = 100.2

SUMMARY OF ROCK TYPES COARSE FRACTION

M.P. 1095.1 Borehole B-4 Depth 5.5 m - 5.8 m

		WE	IGHTE IN				OF CON		JENTS	•	Total
ROCK TYPE	CLASSIFICATION	4 *	3"	2"	15"	1"	3/4"	1 <u>2</u> "	3/8"	#4	Weighted Composition
Plutonics-acid					1.5	3.4	4.3	3.5	4.6	4.1	21.4
Greenstone-ultra basic	Good		ý		1.5	3.6	3.8	3.3	2.9	2.6	17.7
Carbonates						1.2	1.7	1.8	0.8	0.9	6.4
Metamorphics					2.2	9.1	9.9	15.5	7.5	6.9	51.1
*											
Volcanics	Fair						0.6	1.6	0.2	0.1	2.5
Carbonates (weathered, soft)	Fall						0.1	0.3			0.4
(weathered, Volcanics soft)	Poor						0.1	0.4			0.5
]										
											f ·
	· · · · · · · · · · · · · · · · · · ·				5.2	17.3	20.5	26.4	16.0	14.6	100.0

PN = 108.3

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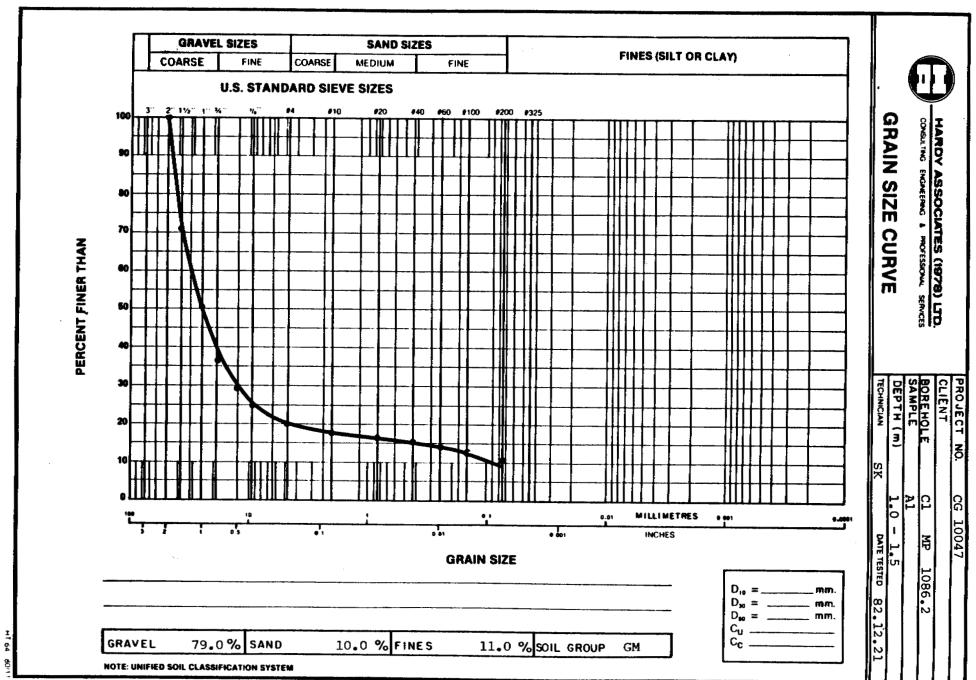
TABLE NO. B-4

SUMMARY OF ROCK TYPES COARSE FRACTION

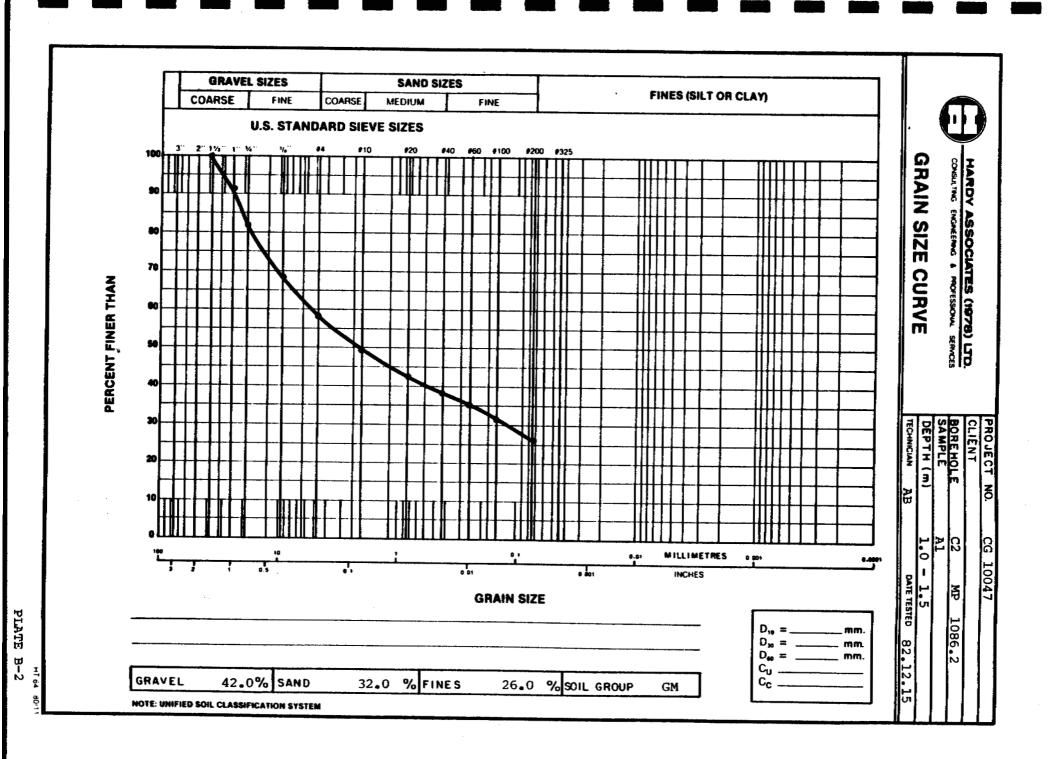
M.P. 1095.1 Borehole B-9 Depth 2.8 m - 3.0 m

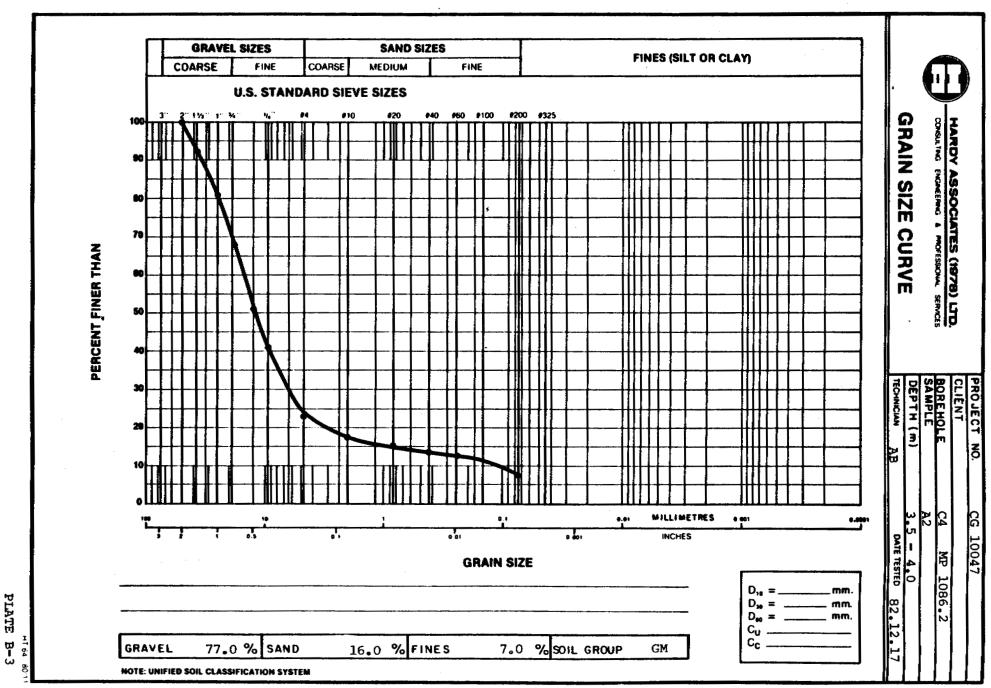
		WE					OF CON ACTION		UENTS	•	Total
ROCK TYPE	CLASSIFICATION	4 "	3"	2"	15"	1"	3/4"	<u>ب</u> چ	3/8"	#4	Weighted Composition
Plutonics-acid					1.9	0.9	3.4	4.6	4.3	4.8	19.9
Quartzite	•					0.9					0.9
Greenstone-ultra basic	Good			- - -		3.2	2.9	4.8	2.6	4.6	18.1
Carbonates					0.9	0.9	1.5	2.5	1.1	1.4	8.3
Metamorphics					0.9	4.6	5.0	12.5	9.6	14.2	46.8
Volcanics	Fair					0.9	1.2	1.0	0.8	0.7	4.6
Volcanics (slightly weathered, soft, friable	e) Poor						_	0.6	0.3	0.5	1.4
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					3.7	11.4	14.0	26.0	18.7	26.2	100.0

PN = 116.2

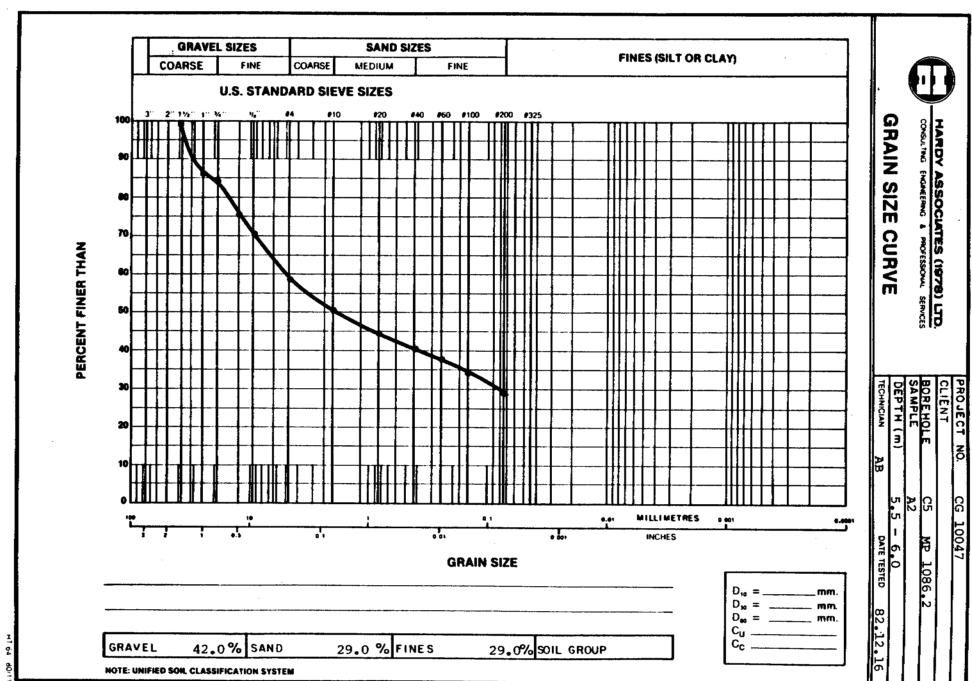






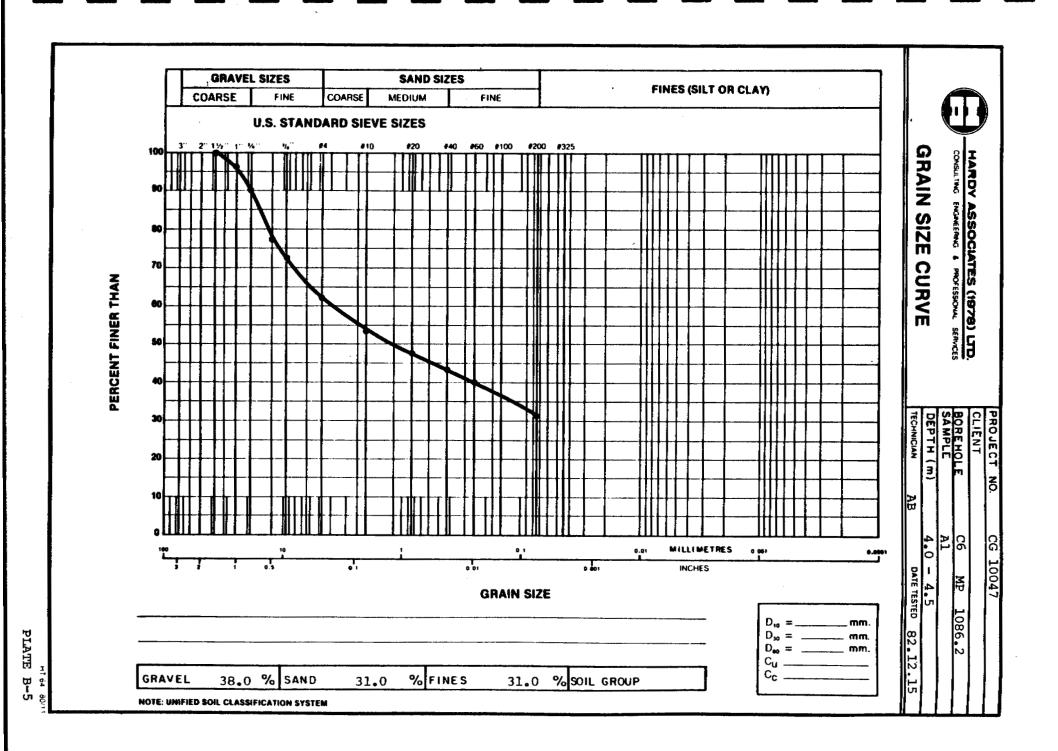


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PLATE

B-4



HARDY	ASSOCIATES (1978) LTD.	

CONSULTING ENGINEERING & PROFESSIONAL SERVICES

LOS ANGELES ABRASION TEST REPORT

OFFICE	Calgary	100	
FILE	4195-CG-		
DATE	January	31,	1983
CLIENT P.O.			
C.C.			

TO: Mr. G. Dupuy, P. Eng., Hardy Associates (1978) Ltd., 221 - 18 Street S.E., CALGARY, Alberta. T2E 6J5

PROJECT:

Burwash/Destruction Bay Gravel Samples

			Client Jan. 27/83
DING: 'A'	· · · · · · · · · · · · · · · · · · ·		
ZES		AMOUNT	
1"		1250.0	
3/4"		1251.0	
1/2"	•	1249.7	
3/8"		1249.5	
	TOTAL SAMPLE	5000.2	
500			
12	TOTAL SAMPLE	5000.2	
4988.1 ⁹	+ # 12 MATERIAL AFTER	4328.9	
	- # 12 MATERIAL AFTER	671.3	
	× 100 -	.4%	
	DATE RECEIVED	DATE RECEIVED Dec. 16/82 D IDING: 'A' I'A' 3/4" 1/2" 3/8" TOTAL SAMPLE 500 12 TOTAL SAMPLE 4988.1 9 * * * 12 MATERIAL AFTER - * 12 MATERIAL AFTER	DATE RECEIVED Dec. 16/82 DATE TESTED ATE TESTED AMOUNT 1" 1250.0 3/4" 1250.0 3/4" 1251.0 1/2" 1249.7 3/8" 1249.7 3/8" 1249.5 500 500 12 TOTAL SAMPLE 5000.2 500 - # 12 MATERIAL AFTER 4328.9 - # 12 MATERIAL AFTER 671.3 #12 * 100 - 671.3 * 100 - 13.4

COMMENTS:

Test performed in accordance with A.S.T.M. C-131

REPORT CERTIFIED

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CALGARY

DAWSON CLEEK

BURNABY

TECHNICIAN E.K.

PLATE B-6

EDMONTON + LETHBRIDGE + PRINCE GEORGE + RED DEER + WINNIPEG

ro: Ha Ge 22 CF	C. G. Dupuy ardy Associated cotechnicated 21 - 18 St ALGARY, All 22 6J5	iates (19 1 Divisio reet S.E.	78) Ltd.,		FILE: 41 DATE: Fe CLIENT P.O.: C.C.:	95-CG-100 bruary 7, - -	
TH SOURCE	URWASH LAN H A4, MP.1 B.0-3.3 D Dec./82	087.6 Typ Da		Pit Run Material ec. 16/82	SAMPLED	BY Clie	ent . 31/83
	agnesium Sul	lphate "		FINE AGGREG			
			I WAT AREAS				
PASSING	RETAINED	ORIGINAL GRADING PERCENT	Weighted AVERAGE PERCENTLOSS	PASSING	E SIZE RETAINED	ORIGINAL GRADING PERCENT	WEIGHED AVERAGI PERCENT LO
3 IN.	2 IN.			3/8 IN.	NO. 4		
2 IN.	1 - ½ IN.	7.2	-	NO. 4	NO. 8		-
1 - ½ IN.	1 IN.	10.1	0.03	NO. 8	NO. 16		-
1 IN.	3/3 IN.	15.1	0.01	NO. 16	NO. 30		-
³ 3 IN.	1/2 IN. 3/8 IN.	22.7	0.09	NO. 30	NO 50		
12 IN. 3/8 IN.	NO. 4 IN.	<u>18.3</u> 26.6	0.04	NO. 50 NO. 100	NO. 100		
	TALS	100.0	0.33		TALS	· • •	-
SIZE FRACTION			UALITATIVE EXA	MINATION OF	PLUS 34 " MATER	IAL	
3" • 2"	FINAL						
2" + 1½"	ORIGINAL						
1'2' - 1''	ORIGINAL 1		pit holes			• • • • • • • • •	1
	FINAL 1	<u>some</u>	pit notes	, and cra	cking was	opserved	· · · · · · · · · · · · · · · · · · ·
12 - 1	1	. ! _	pit holes	were obs			
1" - 34"	ORIGINAL 4		pit holes	were obs	erved.		

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219 B STREET SE CALGARY ALBERTA TE 6.5 (403) 272-8761 TWX 610-821-1388 BURNABY CALGARY DAWSON CREEK EDMINTON GRANDE PRAIRIE LETHBRIDGE PRINCE GEORGE RED DEER WINNIPEG

PLATE B-7

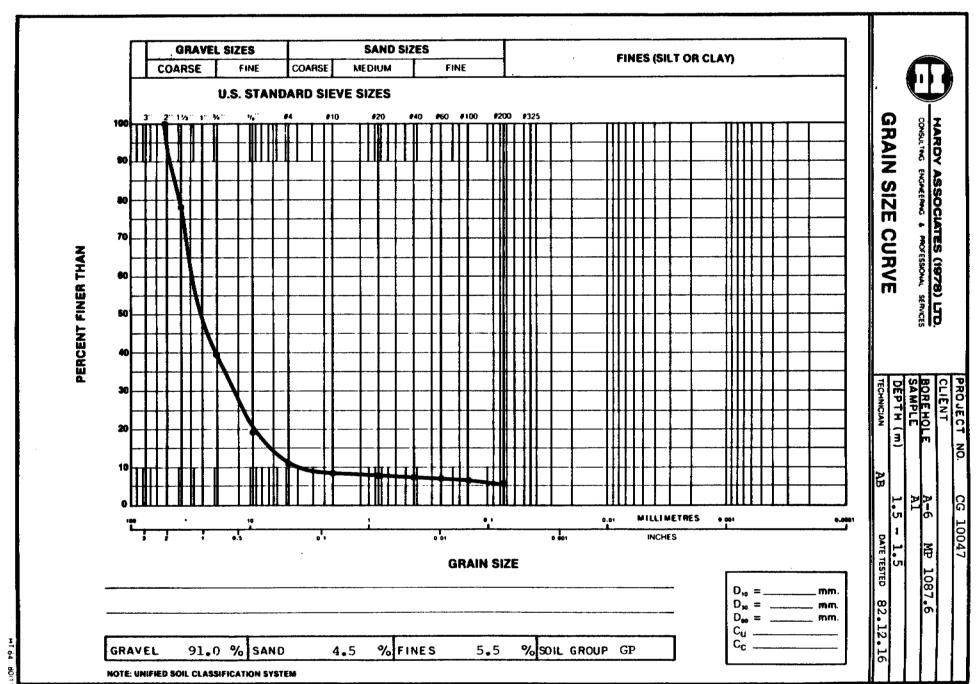
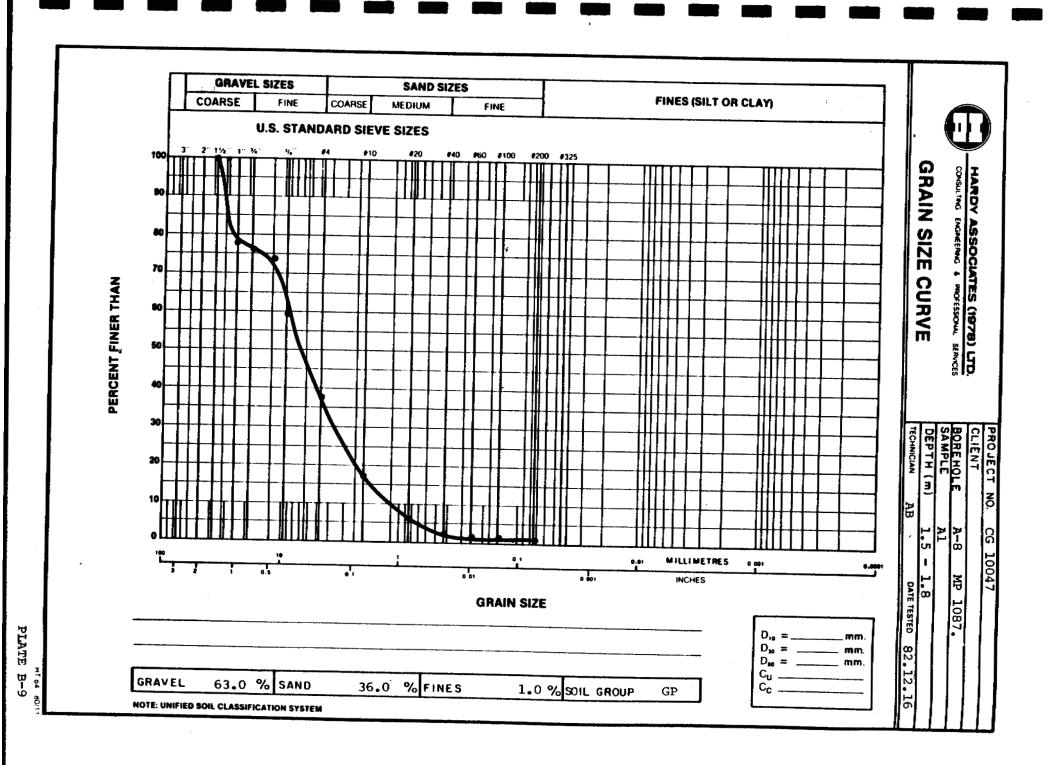
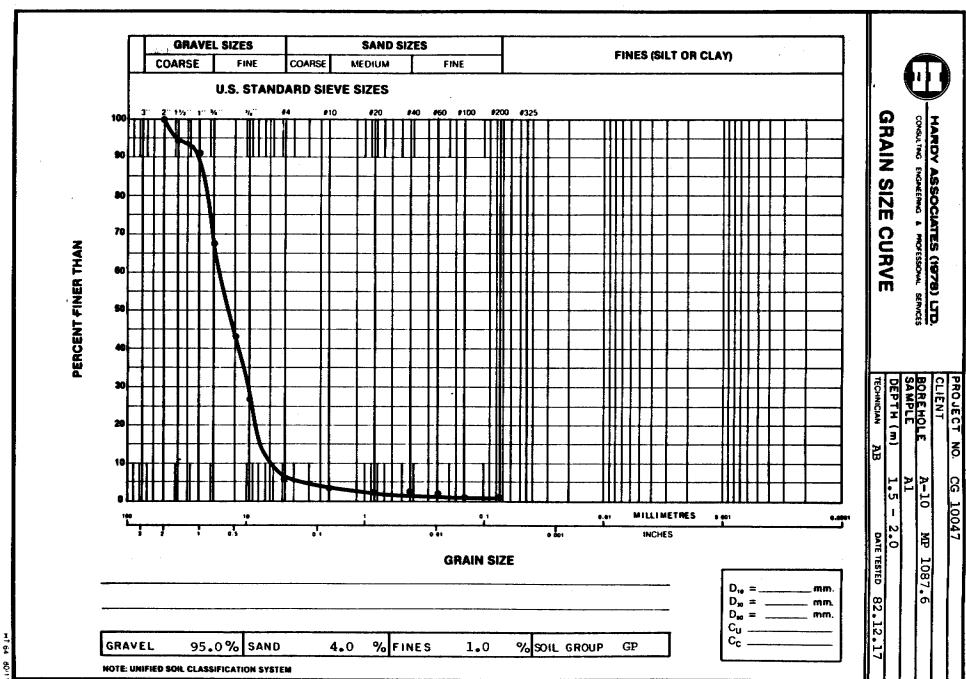


PLATE B-8





PLATE

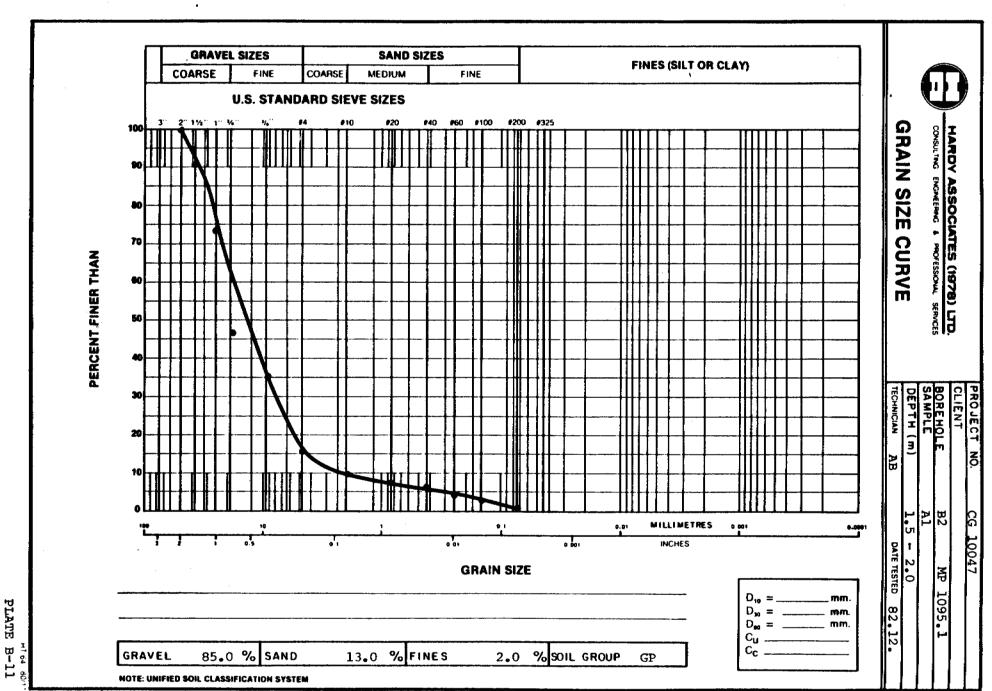
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SUMMARY OF ROCK TYPES COARSE FRACTION

M.P. 1095.1 Borehole B-14 Depth 4.0 m - 4.2 m

		WE			CENTA SIEV				JENTS	•	Total
ROCK TYPE	CLASSIFICATION	4"	3"	2"	15"	1"	3/4"	12 11	3/8"	#4	Weighted Composition
Plutonic-acid					1.3	4.4	6.1	6.8	4.7	6.7	30.0
Greenstone-ultra basic	Good				2.8	1.0	1.4	2.9	2.4	3.3	13.8
Carbonates						1.0	1.8	1.6	1.1	1.3	6.8
Metamorphics					2.8	4.8	7.8	10.1	7.6	12.7	45.8
Volcanics	Fair					0.4	0.5	0.8	0.3	0.1	2.1
Volcanics (weathered, soft)	Poor						0.1	0.6	0.3	0.5	1.5
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	1										
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	•				6.9	11.6	17.7	22.8	16.4	24.6	100.0

PN = 111.7



HARDY ASSOCIATES (1978) LTD.



CONSULTING ENGINEERING & PROFESSIONAL SERVICES

LOS ANGELES ABRASION TEST REPORT

OFFICE	Calgary	
FILE	4195-CG-1004	•
DATE	January 27,	1983
CLIENT P.O.		
C.C.		

TO: Mr. G. Dupuy, P. Eng., Hardy Associates (1978) Ltd., 221 - 18 Street S.E., CALGARY, Alberta. T2E 6J5

PROJECT: BURWASH LANDING/DESTRUCTION BAY COMMUNITY GRAVEL STUDY

TH B4 MP DURCE 5.5 - 5. ATE SAMPLED Dec./		TYPE OF SAMPLE DATE RECEIVED		AMPLED BY ATE TESTED	Client Jan. 27/83	
MAT	ERIAL GRADI	NG:*A'				
AGTUA	L 815VE 512E			AMOUNT		
	+	1"		1249,5	-	9
— l"	+	3/4"		1250.7		9
- 3/4"	+	1/2"		1250.8		9
1/2"	+	3/8"		1249.2		9
			TOTAL SAMPLE	5000,2		9
NO. OF REVOLUTIONS		500		· · · · · ·	· · · · · · · · · · · · · · · · · · ·	
NO. OF SPHERES		12	TOTAL SAMPLE	5000.2		g
WT. OF SPHERES		4987.8 ⁹	+ / 12 MATERIAL AFTER	4076.3		9
			- # 12 MATERIAL AFTER	923.9		9
	000.2 - #1	$\frac{2}{100} = \frac{923}{5000}$		<u> </u>		
			· · · · · · · · · · · · · · · · · · ·		<u> </u>	

COMMENTS:

Test performed in accordance with A.S.T.M. C-131

REPORT CERTIFIED

TECHNICIAN E.K.

PLATE B-12

BURNABY · CALGARY · DAWSON CALEK · EDMONTON · LETHBRIDGE · PRINCE GEORGE · RED DEER · WINNIPEG

	HARDY A	SSOCIATE	ES (1978)	LTD.	SOUNDNE	SS OF AG	GREGATE
J	CONSULTING EN	GINEERING & P	PROFESSIONAL SE		SULPHATE	TEST REP	ORT
0:	Mr. G. Dupu Hardy Assoc Geotechnica 221 - 18 St CALGARY, A T2E 6J5	ciates (19 al Divisio treet S.E	978) Ltd., on,		FILE: 41 DATE: Fe CLIENT P.O.: C.C.:		
ROJECT	BURWASH LA	NDING/DES	TRUCTION I	BAY COMMU	NITY GRAVE	L STUDY	
OURCE	TH B4, MP. 5.5-5.8 m	1095 .1 Typ	I E OF SAMPLE N	Pit Run Material	SAMPLED	BY Cli	ent
OURCE	TH B4, MP. 5.5-5.8 m ED Dec./82 Magnesium Su	TYP DAT	E OF SAMPLE	Material Dec. 16/82	SAMPLED 2 DATE TES	BY Cli TED Jan.	ent 31/83
OURCE	5.5-5.8 m ED Dec./82 Magnesium Su	TYP DAT	E OF SAMPLE N E RECEIVED I	Material Dec. 16/82	2 DATE TES	BY Cli TED Jan.	ent 31/83
OURCE DATE SAMPL SOLUTION	5.5-5.8 m ED Dec./82 Magnesium Su	TYP DAT	E OF SAMPLE N E RECEIVED I	Aaterial Dec. 16/82 S 5 FINE AGGREG	2 DATE TES	BY Cli TED Jan. ORIGINAL	31/83
OURCE DATE SAMPL SOLUTION	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE	TYP DAT lphate NU	E OF SAMPLE N E RECEIVED I MBER OF CYCLE	Aterial Dec. 16/82 S 5 FINE AGGREG SIEVI PASSING	2 DATE TES	TED Jan.	31/83 WEIGHED AVERAGE
OURCE DATE SAMPL SOLUTION COARSE AC	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE	TYP DAT Iphate NUI ORIGINAL GRADING	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE	Aterial Dec. 16/82 S 5 FINE AGGREG SIEVI PASSING	2 DATE TES	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS
OURCE DATE SAMPL SOLUTION COARSE AG SII PASSING	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED	TYP DAT Iphate NUI ORIGINAL GRADING	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE	Aterial Dec. 16/82 S 5 FINE AGGREG SIEVI PASSING	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8	ORIGINAL GRADING	31/83 WEIGHED AVERAGE
OURCE DATE SAMPL SOLUTION COARSE AC SII PASSING 3 IN.	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED 2 IN.	TYP DAT Iphate NUI GRADING PERCENT	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE PERCENT LOSS	Aterial Dec. 16/82 S 5 FINE AGGREG SIEVI PASSING 3/8 IN.	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8 NO. 16	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS
OURCE DATE SAMPL SOLUTION COARSE AC SII PASSING 3 IN. 2 IN.	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED 2 IN. 1 - ½ IN.	TYP DAT Iphate NUI GRADING PERCENT 5.2	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE PERCENT LOSS	Aterial Dec. 16/82 FINE AGGREG SIEVI PASSING 3/8 IN. NO. 4	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS
OURCE DATE SAMPL SOLUTION COARSE AC SII PASSING 3 IN. 2 IN. 1 - 1/2 IN.	5.5-5.8 m LED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED 2 IN. 1 - ½ IN. 1 IN.	TYP DAT Iphate NUI GRADING PERCENT 5.2 17.3	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE PERCENT LOSS	Aterial Dec. 16/82 FINE AGGREG SIEVI PASSING 3/8 IN. NO. 4 NO. 8	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8 NO. 16	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS
OURCE DATE SAMPL SOLUTION COARSE AC SII PASSING 3 IN. 2 IN. 1 - ½ IN. 1 IN.	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED 2 IN. 1 - ½ IN. 1 IN. 34 IN.	TYP DAT Iphate NUI GRADING PERCENT 5.2 17.3 20.5	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE PERCENT LOSS	Aterial Dec. 16/82 FINE AGGREG SIEVI PASSING 3/8 IN. NO. 4 NO. 8 NO. 16	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8 NO. 16 NO. 30	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS
OURCE DATE SAMPL SOLUTION COARSE AC SII PASSING 3 IN. 2 IN. 1 - 1/2 IN. 1 IN. 3/4 IN. 1/2 IN. 3/8 IN.	5.5-5.8 m ED Dec./82 Magnesium Su GREGATE EVE SIZE RETAINED 2 IN. 1 - ½ IN. 1 IN. 24 IN. ½ IN.	TYP DAT Iphate NUI GRADING PERCENT 5.2 17.3 20.5 26.4	E OF SAMPLE M E RECEIVED I MBER OF CYCLE Weighted AVERAGE PERCENT LOSS 0.02 0.01 0.41	Iaterial Dec. 16/82 S 5 FINE AGGREG SIEVI PASSING 3/8 IN. NO. 4 NO. NO. 8 NO. 16 NO. NO. 50 NO. NO.	2 DATE TES ATE E SIZE RETAINED NO. 4 NO. 8 NO. 16 NO. 30 NO. 50	ORIGINAL GRADING	31/83 WEIGHED AVERAGE PERCENT LOS

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PARTICLES	
ORIGINAL	
FINAL	
ORIGINAL	
FINAL	
ORIGINAL 22 Some cracks and pit holes were observed.	
FINAL 22 Some cracks and splitting was observed.	-
ORIGINAL 39 Some pit holes were observed.	
FINAL 39 Some cracks were observed.	
	ORIGINAL FINAL ORIGINAL FINAL ORIGINAL 22 Some cracks and pit holes were observed. FINAL 22 Some cracks and splitting was observed. ORIGINAL 39 Some pit holes were observed.

COMMENTS:

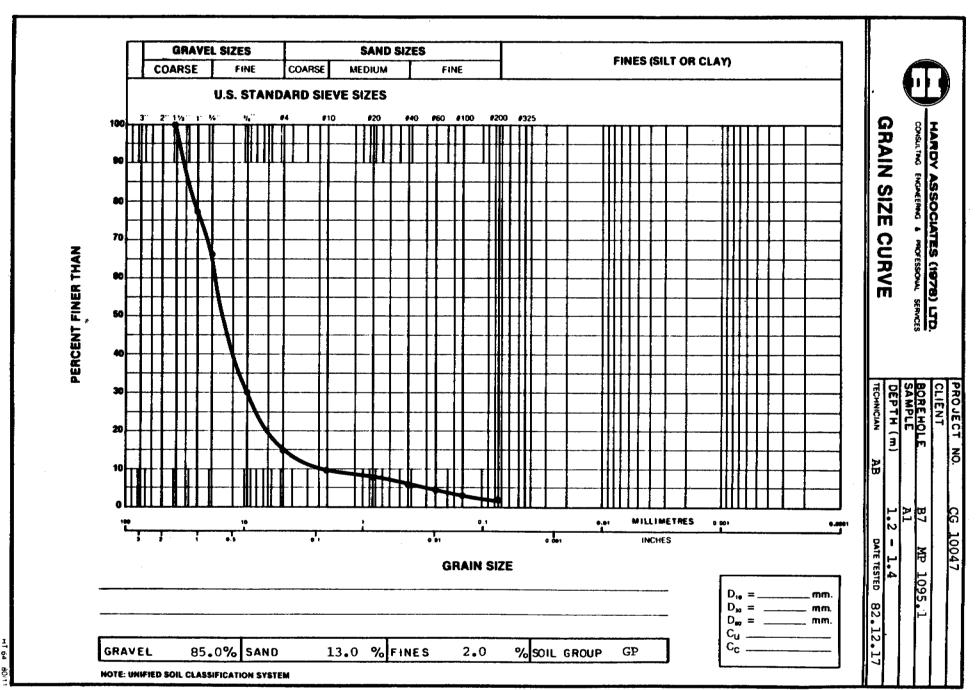
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REPORT CERTIFIED W. Dulling Set.	TECHNICIAN R.L.D.	TESTED IN ACCORDANCE WITH ASTM C88
219 18 STREET. S.A. CALGARY. BURNABY CALGARY DAWSON CREEK DMONTON	ALBERTA. TZE 6J5 (403) 272-8761 GRANDE PRAIRIE LETHBRIDGE PRINCE GEORGE	TWX 610-821-1388 RED DEER WINNIPEG HT42 - 11/79 PLATE B-13



PLATE

н^{г 64} и В-14

echnical Div - 18 Street ARY, Alberta 6J5 ASH LANDING/ 095.1, 5.0-5 -9 - 3.0 m ec./82 MATERIAL GRADIN CTUAL SIEVE SIZES 2" + 1	s (1978) Ltd vision, S.E., a. / <u>DESTRUCTION</u> 5.5 m TYPE OF SAMPLE DATE RECEIVED	BAY COMMUNITY Pit Run Material	SAMPLED BY DATE TESTED	/ Client Jan, 27/83
6J5 ASH LANDING/ 095.1, 5.0-5 -9 - 3.0 m ac./82 MATERIAL GRADIN CTUAL SIEVE SIZES 2" + 1	DESTRUCTION 5.5 m TYPE OF SAMPLE DATE RECEIVED	Pit Run Material	SAMPLED BY DATE TESTED	/ Client Jan, 27/83
095.1, 5.0-5 -9 - 3.0 m ec./82 MATERIAL GRADIN CTUAL SIEVE SIZES 2" + 1	5.5 m TYPE OF SAMPLE DATE RECEIVED	Pit Run Material	SAMPLED BY DATE TESTED	/ Client Jan, 27/83
CTUAL SIEVE 512ES 2" +]	1"			
2" +]	1"			T
			1050	
+			1252.	0
	3/4"		1249.	2
+	1/2"		1249.	0
+	3/8"		1250.	4
		TOTAL SAMPLE	5000.	6
			-	
<u></u>	± 70/.0 ¥		- 4054.	
5000.6 - #12 TOTAL SAMPLE				• %
TH B-1 and	TH B-9 mate			
	5000.6 - /1 TOTAL SAMPLE Test perfo TH B-1 and	12 4987.8 9 5000.6 - 12 * 100 = 946 TOTAL SAMPLE * 100 = 946 5000	DNS 500 12 TOTAL SAMPLE 4987.8 + / 12 MATERIAL AFTE - / 12 MATERIAL AFTE	Solution Solution 12 TOTAL SAMPLE 5000. 4987.8 + # 12 MATERIAL AFTER 4054 -# 12 MATERIAL AFTER 946. -# 13 MATERIAL AFTER 946. <

BURNABY . CALGARY . DAWSON CHEEK . EDMONTON . LETHBRIDGE . PRINCE GEORGE . RED DEER . WINNIPEG

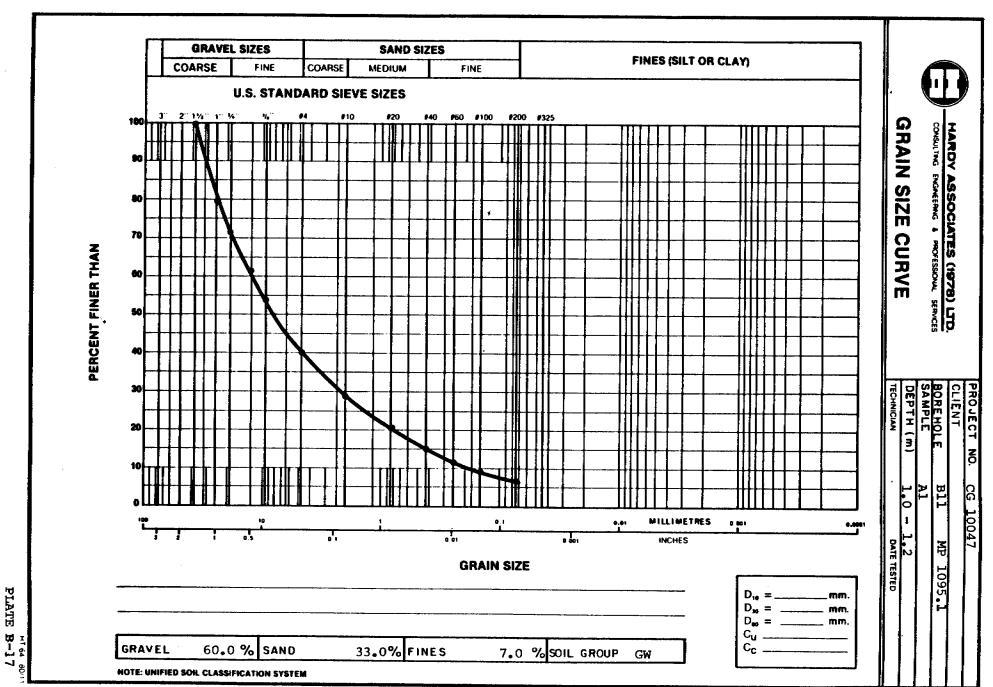
	ATES (1978) LTD.	SOUNDNESS C	OF AGGREGAT
	& PROFESSIONAL SERVICES	SULPHATE TES	T REPORT
Mr. G. Dupuy, P. Hardy Associates Geotechnical Div 221 - 18 Street CALGARY, Alberta 52E 6J5	(1978) Ltd., ision, S.E.,	FILE: 4195-(DATE: Februa CLIENT P.O.: C.C.:	
	ESTRUCTION BAY COMM	UNITY GRAVEL ST	UDY
	Pit Run TYPE OF SAMPLE Material		
SOLUTION Magnesium Sulphate	NUMBER OF CYCLES 5		

COARSE AGG	REGATE			FINE AGGREG	ATE		
SIEVE SIZE		ORIGINAL Weighted	SIEV	E SIZE	ORIGINAL	WEIGHED	
PASSING	RETAINED	GRADING PERCENT	AVERAGE PERCENT LOSS	PASSING	RETAINED	GRADING PERCENT_	AVERAGE
3 IN.	2 IN.			3/8 IN.	NO. 4		-
2 IN.	1 - 1/2 IN.	3.7	-	NO. 4	NO. 8		_
1 - ½ IN.	1 IN.	11.4	0.08	NO. 8	NO. 16		-
1 IN.	3∕₄ IN.	14.0	0.06	NO. 16	NO. 30		-
3/4 IN.	1/2 IN.	26.0	0.73	NO. 30	NO. 50		-
½ IN.	3/8 IN.	18.7	0.82	NO. 50	NO. 100		-
3/8 IN.	NO. 4 IN.	26.2	0.97	NO. 100			
TO	TALS	100.0	2,66	TO	TALS	-	-

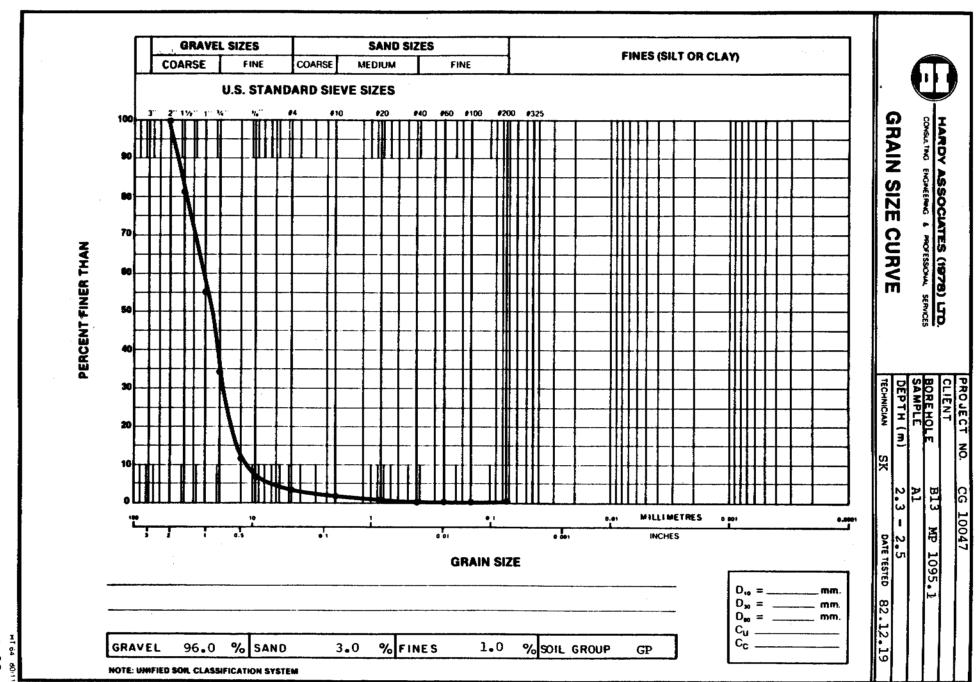
SIZE FRACTION	NO. PARTICLES	QUALITATIVE EXAMINATION OF PLUS 34" MATERIAL
3" - 2"	ORIGINAL	
3 • 2	FINAL	
2" - 1½"	ORIGINAL	
	FINAL	
1 1/2" - 1"	ORIGINAL 16	Some cracking was observed.
	FINAL 16	Some pit holes, flaking and cracking was observed.
1" - ¾"	ORIGINAL 44	Some cracking was observed.
·/4	FINAL 44	Some pit holes, flaking, and cracking was observe

COMMENTS: TH #1 & TH #9 material was combined to make up Soundness Test Sample.

E.						
REPORT CERTIFIED	(, TET .	# TECHNICIAN	R.L.D.		l	ESTED N ACCORDANCE VITH ASTM C88
219 18 STREET, SA BURNABY CALGARY DAWSON CREEK	CALGARY.	ALBERTA. GRANDE PRAIRIE	TZE BJ5 LETHBRIDGE	(403) 272-8761 PRINCE GEORGE	TWX RED DEER	610-821-1388 WINNIPEG



PLATE



PLATE

B-18

	GINEERING & PROFESSI		LOS ANGELES ABRASION TEST REPORT			
Mr. G. Dupuy Hardy Associ 221 - 18 Str CALGARY, Alb T2E 6J5	ates (1978) Lto eet S.E.,	đ.,	OFFICE FILE DATE CLIENT P.O. C.C.	Calgary 4195-CG-10047 Jan. 31, 1983		
		DN BAY COMMUNITY	GRAVEL	STUDY		
TH B-14, MP 1095. URCE 4.0 - 4.2 m TE SAMPLED Dec./82	L TYPE OF SAMPL DATE RECEIVED	Dec 16/82	SAMPLED BY DATE TESTED	Jan. 27/83		
			· · · · · · · · · · · · · · · · · · ·	·····		
MATERIAL G	RADING: YA'		18 Status - Jun - 18 - 18 - 19			
ACTUAL SIEVE	SIZES		AMOUNT	r		
- 1 1/2" *	l"		1252.1			
- 1" +	3/4"		1250.9			
- 3/4" +	1/2"	•	1249.8			
1/2" +	3/8"		1247.9			
		TOTAL SAMPLE	5000.7			
NO. OF REVOLUTIONS	500					
NO. OF SPHERES	12	TOTAL SAMPLE	5000.7			
WT. OF SPHERES	4987.7 9	+ # 12 MATERIAL AFTER	3981.5			
		- / 12 MATERIAL AFTER	1019.2			
LOSS - 5000.7		<u>20.4</u> 0.7 × 100 =20.4	4	%		

COMMENTS:

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Test performed in accordance with A.S.T.M. C-131

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TECHNICIAN

E.K.

LETHBRIDGE . PRINCE GEORGE . RED DEER

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EDMONTON

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DAWSON CREEK

REPORT CERTIFIED

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BURNABY

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CALGARY

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PLATE B-19

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CONSULTING ENGINEERING & PROFESSIONAL SERVICES

SOUNDNESS OF AGGREGATE

SULPHATE TEST REPORT

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Mr. G. Dupuy, P. Eng., Hardy Associates (1978) Ltd., Geotechnical Division, 221 - 18 Street S.E., CALGARY, Alberta. T2E 6J5

FILE: 4195-CG-10047 DATE: February 7, 1983 CLIENT P.O.: -C.C.: -

PROJECT BURWASH LANDING/DESTRUCTION BAY COMMUNITY GRAVEL STUDY

TH B14, MP. 1095.1 SOURCE 4.0-4.2 m DATE SAMPLED Dec./82

TO:

1 Pit Run TYPE OF SAMPLE Material DATE RECEIVED Dec. 16/82

SAMPLED BY DATE TESTED

Client Feb. 1/83

COARSE AGG	REGATE			FINE AGGREG	ATE		
SIEVE SIZE		ORIGINAL Weighted		SIEVE SIZE		ORIGINAL	WEIGHED
PASSING	RETAINED	GRADING PERCENT	AVERAGE PERCENT LOSS	PASSING	RETAINED	GRADING PERCENT	AVERAGE
3 IN.	2 IN.			3/8 IN.	NO. 4		
2 IN.	1 - ½ IN.	6.9	-	NO. 4	NO. 8		_
1 - ½ IN.	1 IN.	11.6	0.24	NO. 8	NO. 16		-
1 IN.	3/4 IN.	17.7	0.57	NO. 16	NO. 30		-
3/4 IN.	1/2 IN.	22.8	0.17	NO. 30	NO. 50		
½ IN.	3/8 IN.	16.4	0 42	NO. 50	NO. 100		_
3/8 IN.	NO. 4 IN.	24.6	1.02	NO. 100			-
TO	TALS	100.0	2.42	TO	TALS	-	

SIZE FRACTION	NO. PARTICLES	QUALITATIVE EXAMINATION OF PLUS 34 " MATERIAL
3" - 2"	ORIGINAL	
3 - 2	FINAL	
2" - 1½"	ORIGINAL	
	FINAL	
11/2" - 1"	ORIGINAL 17	Some pit holes were observed .
	FINAL 17	Some pit holes and cracking was observed,
1." - ¾"	ORIGINAL 42	Some pit holes and cracking was observed .
14	FINAL 41	Some pit holes, splitting, and flaking was observed.

COMMENTS:

SP.			*				ESTED N ACCORDANCE
REPORT CERTIF	W. W.	Ingenty, EE	TECHNICIAN	R.L.D.			VITH ASTM C88
+	8 STREET.	CALGARY, CALGARY, CREEK MONTON	ALBERTA. GRANDE PRAIRIE	TZE 6J5	(403) 272-8761 PRINCE GEORGE	TWX RED DEER	610-821-1388 WINNIPEG
		·					HT42 - 11/79

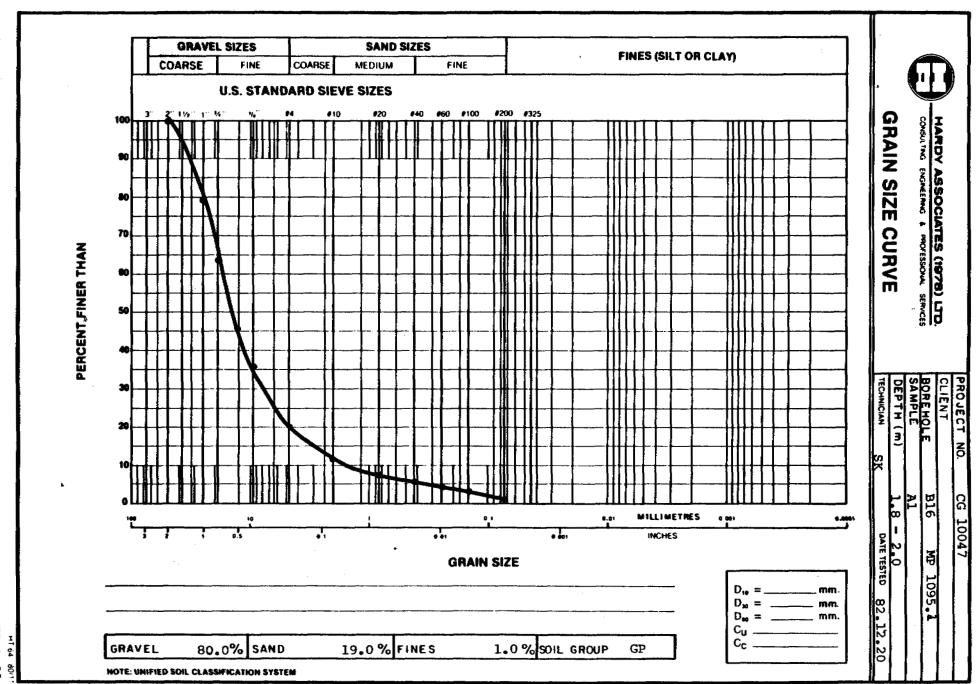
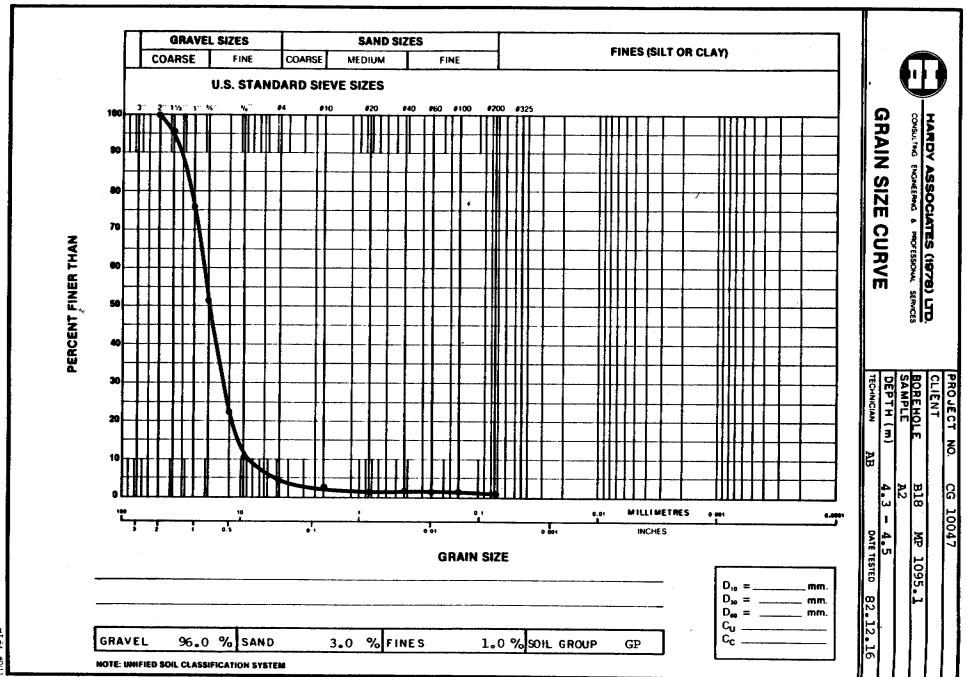


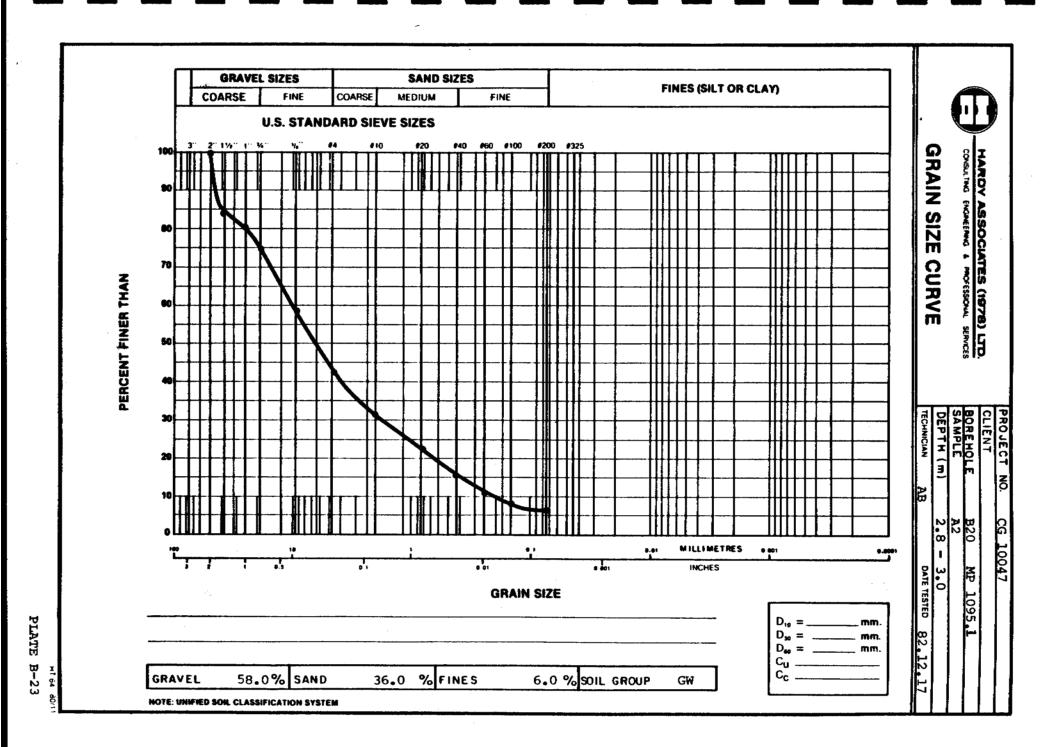
PLATE B-

64 ост В-21



PLATE

B-22





APPENDIX "C" BORROW RESERVE SITE PLANS

