

**Land and Water Management Directorate
Department of Indian Affairs and Northern Development**

**EVALUATION OF OPTIONS FOR THE MACKENZIE VALLEY
GRANULAR RESOURCES BOREHOLE DATABASE**

1100054

September 2007



EXECUTIVE SUMMARY

EBA Engineering Consultants Ltd. (EBA) was retained under Contract #A7133-03-026 by the Land and Water Management Directorate of the Department of Indian and Northern Affairs Canada (INAC) to evaluate options for a Mackenzie Valley Granular Resources Borehole Database. Such a database is a collection of logs of boreholes and testpits drilled and excavated in the Mackenzie Valley. Currently four ESEBASE Mackenzie Delta and Valley borehole databases respectively named “INAC”, “INUV”, “NEWLOGS” and “MACKENZI” have been developed for INAC.

These four Mackenzie Delta and Valley ESEBASE borehole databases contain 12,744 borehole and testpit logs and are a significant resource tool that is used by federal and territorial government departments and the oil and gas industry. Some problems in the Mackenzie Delta and Valley ESEBASE borehole and testpit databases were identified:

- discrepancies between the number of borehole logs contained in several borehole log series in the original Geological Survey of Canada (GSC) borehole databank and the number of borehole logs contained in several borehole log series in the “MACKENZI” ESEBASE borehole database;
- some borehole program sources could not be identified; and
- borehole logs in the ESEBASE borehole and testpit databases are missing data or contain incorrect geographical location including northing and easting, soil classification and sample or completion depth.

Therefore the following recommendations are made:

It is recommended that unidentified documents associated with the borehole programs done by the federal Department of Public Works (currently Public Works and Government Services Canada) for INAC be tracked down and reviewed.

It is recommended that initially the problems mentioned in this report be corrected before a decision is made to transfer the “MACKENZI” database from a “MACKENZI” format into a “standard” ESEBASE database format. An estimate of the cost associated with each of these tasks is provided.

It is recommended that efforts be continued to create an interactive world-wide web-based Mackenzie Valley granular resources borehole database, and perhaps increase the accessibility to the database information either by avoiding proprietary licensed software or by making arrangements with the suppliers of the software so that third parties are permitted to use that software.

A review of the Beaufort Sea, Mackenzie Delta and Mackenzie Valley development history would be a useful background document to users of a Mackenzie Valley Granular Resource Borehole Database, and be of assistance in quality verification of data included in the database and tracing of information not yet included in the database.

It is recommended that this report be circulated to a select group of persons who have had involvement in the Mackenzie Valley granular resource inventory or who have had involvement in some phase of the Mackenzie Valley ESEBASE borehole database development, for further comments and completion.

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1.0 INTRODUCTION

1.1 BACKGROUND

Granular resources, such as gravel and sand, are used in the construction of building foundations and infrastructure such as airstrips, roads, rail roads and pipelines. Granular resources are also used in the construction of tank farm pads, landfills and sewage lagoons, erosion protection works, drilling platforms, dams, winter road portages and road traction provision during the winter. The requirements for granular resources by large developments such as oil and gas field developments and pipeline projects in the Mackenzie Delta and Valley have to be balanced with the requirements for granular resources by the Mackenzie Delta and Valley communities and future public infrastructure projects. Permits for the use of granular resources on crown lands in the Mackenzie Delta and Valley have to be obtained from the Department of Indian and Northern Affairs Canada (INAC). Paramount to INAC's management of the granular resources are reliable inventories and/or assessments of supply and demand.

Granular resources supply information is obtained by soil logging and testing in geotechnical investigations, geological surveys and regional resource assessments that use the drilling of boreholes, excavation of testpits, air photo interpretation and terrain reconnaissance. Additional granular resource information is acquired in geophysical programs.

Oil and gas reserves were discovered in Prudhoe Bay, Alaska, in the late 1960s and in the Mackenzie Delta in the early 1970s, and the oil and gas producers that made these discoveries commenced feasibility studies and proposals for pipeline construction to transport the oil and gas to southern markets. At the same time, the Canadian government evaluated projects to improve the infrastructure in the Mackenzie Delta and Valley, most notably an extension of the Mackenzie Highway from Fort Simpson to Tuktoyaktuk.

Many borehole programs were commissioned by the private sector to investigate subsurface conditions, identify potential granular material sources (e.g., foundations of drilling pads, camps and pipeline ditch backfill), and by the public sector to investigate subsurface conditions and identify potential granular material sources for infrastructure projects and community requirements.

INAC commissioned numerous granular resources inventories to geotechnical consultants such as Ripley Klohn and Leonoff International Limited (1972a to 1972i); Pipeline Engineering Management Canada (PEMCAN 1973a to 1973j); EBA Engineering Consultants Ltd. (EBA 1974a to 1974d and 1976a and 1976b); R.M. Hardy & Associates (1977a, 1977b, 1978, 1979 and 1980) and Hardy BBT Limited (1980). A databank of logs of more than 11,000 boreholes and testpits which were drilled or excavated in the Mackenzie Delta and Valley for the public and private sector, was compiled by Proudfoot and Lawrence (1976) for the Geological Survey of Canada (GSC), currently part of

Natural Resources Canada (NRCan). The wide variety of purposes of the borehole programs of which logs were contained in this GSC database (e.g., subsurface material characterization, borrow resource investigations, geotechnical investigations), as well as the wide variety of the borehole information sources resulted in the borehole logs in the GSC database being presented in a generalized and summarized format as compared to a “standard” geotechnical borehole log. The database also contained additional site description and geotechnical information, and somewhat different documented laboratory test results.

EBA developed the borehole and testpit database software package ESEBASE using funding from both the public sector (INAC), and the private sector (EBA) in 1986. The available information on granular resources in the Mackenzie Delta has been entered for INAC into a series of ESEBASE borehole databases: INAC (1987), INUV (1990) and NEWLOGS (1993), as part of the Northern Oil and Gas Action Program (NOGAP) and the Inuvialuit Final Agreement Implementation Plan (IFAIP). An Inuvialuit Settlement Region (ISR) world-wide web-based interactive granular resource database system that includes borehole and testpit logs, maps, reports, and some accompanying text is under development at the Land and Water Management Directorate of INAC.

EBA was requested to enter the available Mackenzie Valley borehole and testpit information into an ESEBASE database. This work was funded by INAC and Foothills Pipelines Ltd., as part of Northern Oil and Gas Action Program (NOGAP) – Project A4: Granular Resources Inventory and Management. EBA entered the borehole information contained in the GSC database in the ESEBASE borehole database MACKENZI in 1990 (EBA, 1990). MACKENZI contains 11,448 borehole and testpit logs. It was necessary to create a customized “MACKENZI” format of the ESEBASE software, since the borehole and test information contained in the GSC database was presented in a generalized and summarized format as compared to a “standard” geotechnical borehole log, contained additional site description and geotechnical information, and somewhat different documented laboratory test results.

The Land and Water Management Directorate of INAC is currently developing a world-wide web-based interactive Mackenzie Valley granular resource database system that includes borehole and testpit logs, maps, reports, and some accompanying text. The Land and Water Management Directorate of INAC is concerned that the logs in the “MACKENZI” format of ESEBASE database MACKENZI do not follow consistent geotechnical standards. EBA was retained by INAC under Contract #A7133-03-026 to evaluate the need for and costs associated with the development of a “standard” format ESEBASE Mackenzie Valley Granular Resources Borehole Database. Mr. Robert J. Gowan, P.Geol., Manager Land Programs for the Land and Water Management Directorate, was INAC’s departmental representative for this work.

1.2 SCOPE OF WORK

The scope of work for this assignment was to investigate the state of the information in the existing borehole databases. This included the following tasks:

1. Comparison of various (old and new) geotechnical borehole programs and databases and documentation of the current status and anticipated future needs;
2. A review of the pertinent background information regarding the INAC, GSC and other borehole databases for the Mackenzie Valley;
3. Consultation with INAC's representative to discuss the project scope and objectives, expected outcomes; and to discuss database requirements with other parties (GSC, pipeline/oil companies and other interested parties);
4. Development of various options and recommendations to meet INAC's (and possibly other's) needs for historical borehole information and assess the feasibility (including preliminary costing) of these options;
5. Preparation of a report describing the work undertaken, results and recommendations; and
6. Provision of 10 printed copies of the report and a single copy in digital format.

1.3 METHODOLOGY

EBA reviewed the borehole and testpit program information in the "MACKENZI", "INAC", and "NEWLOGS" ESEBASE databases. EBA did not have access to and therefore did not review other ESEBASE databases, such as the 58 boreholes containing "INUV" ESEBASE database, the information in which was entered for INAC by Hardy BBT Limited in 1990. The large amount (12,686) of borehole logs compiled in the reviewed databases did not permit a review of all logs. Information was reviewed from a few examples of each borehole series within the "INAC", and "NEWLOGS" ESEBASE databases, and information from a few examples of most borehole series within the "MACKENZI" database. The current status of the information within the ESEBASE databases seen was documented and future needs were anticipated. INAC's interactive web-based granular resource system for the Inuvialuit Settlement Region was reviewed. A draft version and later final version of the "Digital Geotechnical Database for the Mackenzie Valley/Delta Region" provided by the GSC (Smith et al. 2005) were reviewed.

A search was conducted to find pertinent background information in reports containing the borehole logs in EBA's three Mackenzie Valley ESEBASE borehole log databases. Reports were identified, using the names of the contractors, sponsors, project numbers and dates mentioned on the logs, in combination with the "Northern Granular Resources Bibliography" (a 1994 publication commissioned by INAC), EBA reports, resources from the Arctic Science and Technology Information System (ASTIS) of the Arctic Institute of North America (AINA) at the University of Calgary, and the AMICUS search engine of the Canadian National Library and Archives. The Proudfoot and Lawrence (1976) borehole log

compilation was reviewed. Ted Lawrence of the GSC was consulted on the background of the GSC database. Inquiries were made with representatives of the Department of Public Works (DPW) to locate reports pertaining to borehole programs conducted for proposed highways in the Mackenzie River Delta and Valley.

Mr. Robert J. Gowan, P.Geol., INAC's representative, was consulted in his July 2004 visit to EBA, to discuss the project scope and objectives, and expected outcomes. EBA's consultant, Dr. Fons Schellekens, visited Mr. Gowan in January 2005. Inquiries were made with environmental and geotechnical consultant company AMEC, and Gretchen Minning of GVM Geological Consultants, both working for the Mackenzie Gas Project in Calgary, and with Dr. Sharon Smith of the GSC, to find out which granular resource borehole and testpit information databases their respective organizations were using.

Options and recommendations were given to meet INAC's (and possibly other's) needs for historical borehole information, and the feasibility (including preliminary costing) of these options were assessed. The assignment was concluded with this report describing the work undertaken, results and recommendations.

2.0 MACKENZIE VALLEY BOREHOLE DATABASE INFORMATION

2.1 BOREHOLE PROGRAM DESCRIPTION

The "MACKENZI" ESEBASE database consists of 11,448 logs of boreholes and testpits, which were drilled or excavated at the request of: INAC, for the foundation evaluation of the proposed extension of the Mackenzie Highway, the foundation evaluation of the Dempster Highway and for granular resources inventories; at the request of proponents of oil and gas pipeline projects for geotechnical and granular resource investigations; and at the request of the GSC for research projects, between 1969 and 1976. The objectives of highway and pipeline borehole programs in the Mackenzie Delta and Valley were to obtain:

- geotechnical information about the quality of the highway foundation materials;
- information on the quality and quantity of granular construction or fill material; and
- foundation conditions at stream crossings.

An additional objective of pipeline borehole programs is to identify the foundation conditions for pipeline facilities such as gas processing facilities, heater stations and compressor stations.

The information gathered in each borehole or testpit program varies as a result of the wide variety in work scope, objectives, and budget of the borehole or testpit programs. Geotechnical information provided in logs of holes drilled for pipeline or highway foundations in the Canadian north may consist of soil description, soil classification, ice description, ice content, moisture content, Atterberg limits, grain size distribution, strength parameters, and organic material content. Since the budget for geotechnical testing is usually limited, a limited amount of descriptions and test data is collected for each borehole

or testpit program, and geotechnical information is not collected for each lithological unit in each borehole or testpit. In addition, the documentation style of the geotechnical information varies.

Table 1 provides for each of the borehole or testpit log series in the “MACKENZI” ESEBASE database a summary of the contractor that logged the boreholes, the sponsor that commissioned the work, the amount of boreholes drilled for a project, borehole names, type of geotechnical information obtained, location of the boreholes, year of drilling, title of the document in which the drilling program was reported and location(s) where this report can be found. In some cases, associated reports are mentioned to assist the search for the original documents. The summary of the reviewed information is based on one or two examples of each borehole or testpit series. Consulting all listed reports accompanying these projects proved to be time consuming and could not be completed within the budget constraints for this report.

The “NEWLOGS” ESEBASE database consists of 693 logs of boreholes and testpits, which were drilled or excavated at the request of the DPW for the proposed extension of the Mackenzie Highway in 1976 and 1977; for proposed oil and gas pipeline projects in 1971 and 1972, and for the Norman Wells to Zama oil pipeline in 1981 and 1982. The borehole or testpit log series in the “NEWLOGS” ESEBASE database are summarized in Table 2, using a similar procedure as was used to describe the borehole or testpit log series in the “MACKENZI” ESEBASE database in Table 1.

The “INAC” ESEBASE database consists of 545 logs of boreholes and testpits, which were drilled or excavated at the request of the DPW for the proposed extension of the Mackenzie Highway in 1976 and 1977; for proposed oil and gas pipeline projects in 1971 and 1972, and for the Norman Wells to Zama oil pipeline in 1981 and 1982. The borehole or testpit log series in the “INAC” ESEBASE database are summarized in Table 3, using a similar procedure as was used to describe the borehole or testpit log series in the “MACKENZI” ESEBASE database in Table 1 and the borehole or testpit log series in the “NEWLOGS” ESEBASE database in Table 2.

2.2 BOREHOLE PROGRAM CONTENT EVALUATION

The following conclusions can be drawn from a review of the logs in the three databases:

- The titles of most reports, associated with borehole programs could be identified;
- The number of borehole logs in each series given by Proudfoot and Lawrence 1976 is in some cases different from the number of logs contained in the ESEBASE databases;
- The reports associated with some borehole or testpit programs could not be identified (e.g., Mackenzie Highway Mile 295 to 343 done by DPW for DPW in 1972/1973);
- The sponsor and consultant name is entered wrong for the borehole series Sunoco for Arctic Geotechnical Group: the Arctic Geotechnical Group is part of EBA, which

would most likely be a contractor, and Sunoco is an oil refinery company that most likely would be a sponsor;

- Proudfoot and Lawrence list the boreholes in the Sunoco for Arctic Geotechnical Group series to be located in the Beaufort Sea, and not in the Mackenzie River Delta or Valley, which would imply that this series does not belong in this database;
- Many of the reports containing geotechnical information for pipeline projects are proprietary, difficult to obtain, and therefore difficult to consult;
- The reports associated with boreholes drilled to obtain geotechnical information for the Mackenzie Highway and Dempster Highway are stored at Public Works and Government Services Canada (PWGSC) in Gatineau;
- The location or geographic coordinates of some of the boreholes was missing;
- Some boreholes had identical spatial coordinates (northing and easting);
- The soil description of some boreholes did not match the Unified Soil Classification class assigned; and
- Some boreholes had soil descriptions or tests on samples beyond the borehole completion depth.

3.0 MACKENZIE VALLEY BOREHOLE DATABASE DEVELOPMENT

3.1 GEOTECHNICAL DATABASE DEVELOPMENT

Proudfoot and Lawrence (1976) and Lawrence and Proudfoot (1977a to 1977e) collected borehole information and designed a geotechnical databank for the GSC. This databank was stored on a magnetic tape. The purpose of this databank was to provide government departments, industry and other users easy access to an abundance of geotechnical information in the Mackenzie Delta and Valley.

INAC and Foothills commissioned EBA, after an unsolicited proposal, to develop a borehole database software package in 1990 (EBA, 1990). The borehole information of the GSC magnetic tape was entered into this new software package ESEBASE, under the database name "MACKENZI". This database "MACKENZI" still exists more or less in its original form.

The GSC recently amalgamated the borehole and testpit data of the "MACKENZI", "INAC", and "NEWLOGS" ESEBASE databases, and transferred the borehole logs from ESEBASE to Microsoft ACCESS. Subsequently, the GSC added boreholes drilled for Interprovincial Pipe Line Limited's Norman Wells to Zama Pipeline project and some borehole programs done by Hardy Associates (1978) Ltd. for Foothills and published the new database as GSC Open File Report 4924 (Smith et al. 2005). The GSC is currently adding more borehole programs done by Hardy Associates (1978) Ltd. for Foothills to the ACCESS database. The new system is user friendly and consists of the ACCESS database,

a Meta-table with all borehole information, a viewer to see borehole locations on a map, and all database files in ACCESS and ASCII text format, giving the user the opportunity to use the borehole information in spreadsheet software such as MS-Excel. This GSC database can be downloaded from the GSC web site, or can be provided on CD.

3.2 INITIAL GRANULAR RESOURCE DATABASE DEVELOPMENT

INAC commissioned a Mackenzie Valley granular materials inventory to be done in anticipation of expected increased demand for these resources for pipeline and highway construction, in addition to other (community) uses in 1972. Stage I of this inventory was done by Pipeline Engineering Management Canada (PEMCAN) Services Ltd., and involved the inventory of granular materials between Fort Simpson and Fort Good Hope (10 volumes) in 1972 and 1973 (PEMCAN 1973a to 1973j). Stage II of this inventory involved the inventory of granular materials in Hay River, NWT and in the Mackenzie Delta, including the communities Tuktoyaktuk, Inuvik, Fort McPherson and Arctic Red River (Ripley, Klohn and Leonoff International Ltd. 1973a to 1973i). Stage III of this inventory involved the inventory of granular materials between Inuvik and Fort Good Hope (EBA, 1974a to 1974d).

EBA evaluated granular resources for INAC in the Rocky Hills - Campbell Lake area and in various locations in the Mackenzie Delta in 1976. R.M. Hardy & Associates Ltd. evaluated granular resources for INAC in and around Tuktoyaktuk in 1977.

Hardy Associates (1978) Limited, which became Hardy BBT Limited conducted for INAC a number of studies on granular resources in the Lower Mackenzie Valley near Aklavik, Inuvik, Tuktoyaktuk, and elsewhere in the Inuvialuit Settlement Region between 1986 and 1991 culminating in the ESEBASE database "INUV", consisting of 58 borehole and testpit logs.

EBA developed the borehole and testpit database software package ESEBASE and converted borehole and testpit information collected by the GSC into databases in ESEBASE format, using funding from both the public sector: Supply and Service Canada, currently part of Public Works and Government Services Canada, and INAC; and the private sector, e.g., Foothills Pipelines Ltd., in 1986.

EBA compiled for INAC an inventory and recommendations for development of sand and gravel resources in the Inuvialuit Settlement Region (including Aklavik, Inuvik, Tuktoyaktuk, Paulatuk, Holman and Sachs Harbour) in 1987. The supply and demand of sand and gravel were analyzed for the Inuvialuit Settlement Region, and two volumes of borehole and testpit logs were compiled, resulting in the ESEBASE borehole database "INAC", consisting of 545 borehole and testpit logs.

Bennett (1988) compiled a computerized summary for the Lower Mackenzie Valley, including granular sources at 558 sites, covering much of the same area as the study of Hardy Associates (1978) Limited (1986). EBA and GVM Geological Consultants Ltd. 1988

compiled a summary of over 50 granular resources studies that were conducted in the upper Mackenzie Valley (Norman Wells to Fort Providence) prior to 1988.

EBA created the ESEBASE borehole database “MACKENZI” for INAC and Foothills Pipelines Ltd. as NOGAP – Project A4: Granular Resources Inventory and Management, using the databank of Proudfoot and Lawrence in 1990. MACKENZI contains 11,448 borehole and testpit logs. The information in the original databank was in generalized and summarized format as compared to a “standard” geotechnical borehole log. The database also contained additional site description and geotechnical information, and somewhat different laboratory test results. Therefore, it was necessary to create the customized “MACKENZI” borehole database of the ESEBASE software.

3.3 SIMILARITIES AND DIFFERENCES BETWEEN STANDARD AND MACKENZI FORMAT ESEBASE

Similarities and differences between “Standard” and “MACKENZI” format ESEBASE borehole databases are summarized in Table 4. Borehole logs completed in “MACKENZI” format have the potential to contain more detailed geotechnical information. However, this detailed geotechnical information is missing for most of the borehole series in the “MACKENZI” borehole database listed in Table 1.

3.4 FURTHER GRANULAR RESOURCE DATABASE DESCRIPTION

A computerized summary of the reports providing information on granular resources in the Mackenzie Valley was provided by EBA in 1991 and updated in 1992. This report catalogue database has 131 entries for the Mackenzie Valley. A workshop on granular resource requirements for proposed Mackenzie Valley pipelines was organized by INAC (Stanley Associates Engineering 1993). Paquette (1993) provided/described a report catalogue, deposit database, borehole database, and historical database, on a contract for INAC. EBA made corrections to the existing ESEBASE borehole databases, and compiled additional borehole and testpit logs in an ESEBASE borehole database “NEWLOGS” for the GSC in 1993. Howard et al. (1994) of the AINA library published a Northern Granular Resources Bibliography for the Land and Water Management Division of INAC. This bibliography contained 495 entries, and is currently being updated. Thompson (1995) described the ESEBASE program, the standard and “MACKENZI” format of ESEBASE, and the thirteen ESEBASE databases available at INAC headquarters in Ottawa in 1995.

Paquette (1993) and Thompson (1995) mention the ESEBASE databases in INAC’s holdings (see Table 5 attached). All borehole and testpit information currently available at INAC is captured in ESEBASE databases 10 (MACKENZI), 8 (N-ALASKA), 9 (DEMPSTER), 11 (INUV), 1 (INAC), 12 (PL91LOGS), 26 (BEAU93AL), 27 (HOLMAN) and 14 (SACHS) mentioned in Table 5.

INAC currently has 10 ESEBASE borehole databases containing borehole and testpit logs in northwest Canada. Four of these databases (MACKENZI, INAC, INUV and NEWLOGS) have borehole and testpit logs that were drilled or excavated in the Mackenzie

Delta and further upstream in the Mackenzie Valley. The other databases (DEMPSTER, N-ALASKA, BEAU93AL, PL91LOGS, SACHS and HOLMAN) contain logs of boreholes and testpits that were drilled or excavated in the Yukon, Beaufort Sea, east of the Mackenzie River Delta and north of the Beaufort Sea.

A world-wide web-based interactive ISR granular resource database system that includes borehole and testpit logs, maps, reports, and some accompanying text is in a far advanced stage of development at the Land and Water Management Division of INAC.

4.0 CURRENT AND FUTURE DATABASE USE AND RECOMMENDATIONS

4.1 CURRENT AND FUTURE BOREHOLE DATABASE USE

The “MACKENZI”, “INAC”, and “NEWLOGS” ESEBASE borehole databases are used by INAC in its evaluation, management and licensing of the granular resources use for large infrastructure construction projects and for communities in the Mackenzie Delta and Valley; by the Department of Transportation of the Government of the Northwest Territories in its evaluation of foundation material for highway, airstrip and barge landing construction; by the GSC in research activities and in its promotion of sustainable development of mineral resources and oil and gas exploration; and by the petroleum industry in its search for construction material required for oil and gas field exploration activities, oil and gas field developments and pipeline, plant and compressor station foundations.

Companies that own additional databases containing a considerable amount of boreholes were not identified. Imperial Oil Resources, ConocoPhillips and Shell Canada, the owners of the largest gas fields in the Mackenzie River Delta discovered in the early 1970s, recently filed proposals for the development of these gas fields and the construction of gathering pipelines and a main pipeline under the title Mackenzie Gas Project (MGP). In the MGP Environmental Impact Statement (EIS), filed with the MGP Joint Review Panel in October 2004, the description of the existing soil conditions and predictions of the project impact on the environment were to a large extent based on the information contained in the “MACKENZI”, “INAC”, and “NEWLOGS” ESEBASE databases, which the MGP proponents obtained from the GSC. Similarly, the MGP engineering design described in the applications for approvals and permits filed with the National Energy Board in October 2004 (Imperial Oil Resources Ventures Limited 2004) was based on the information contained in the “MACKENZI”, “INAC”, and “NEWLOGS” ESEBASE databases. This indicates the importance of the current Mackenzie Delta and Valley borehole database that is currently under further development at INAC and the GSC. Especially with increased competition for access to granular resources, a reliable granular resources database for the Mackenzie Delta and Valley is even more important than previously.

4.2 BOREHOLE DATABASE IMPROVEMENT

The quality and use of the current ESEBASE borehole databases can be improved by:

- Rectification of the problems mentioned above, and those mentioned in Section 2.2 would improve the database considerably;
- Enlargement of the amalgamated ESEBASE database by entering logs of Mackenzie Delta and Valley boreholes and testpits, which are not yet entered in any ESEBASE database;
- Transformation of borehole logs in “MACKENZI” format into logs in “standard” ESEBASE format, so the MACKENZI borehole information can be merged with other ESEBASE borehole databases; and
- Development of the databases in an interactive web-based database system.

The principal elements of a useful Mackenzie Delta and Valley granular resource database system design are:

- Access to a large amount of borehole logs;
- Familiarity with the geographic location of the logs;
- Query/Search capabilities of tests;
- Access to the original document(s); and
- Knowledge of the site history: what has happened to the site since the log was documented, was any of the material used, was the site buried, and did any mass movements, erosion, deposition or construction occur on the site.

In the GSC Mackenzie Delta and Valley amalgamated geotechnical borehole database the first three principal elements are well covered, and some associated document titles are provided. The web based interactive system proposed by INAC has the advantage that the last two principal borehole database elements are covered as well.

4.3 PRELIMINARY COSTING

The costs associated with the correction of the problems existing in the current databases mentioned in Section 2.2, are estimated to be in the order of \$35,000. This cost estimate is based on the assumption that the majority of the work would be done by a student, who is supervised by a professional, familiar with the existing problems.

To estimate the costs associated with the transformation of borehole logs in “MACKENZI” format to logs in “standard” ESEBASE format, a pilot project involving a limited amount of boreholes within the “MACKENZI” ESEBASE database is required. The costs of such a pilot project, performed by ESEBASE experts, is estimated to be \$30,000. Estimating the costs associated with re-entering the borehole log data from the original reports can be part of this pilot project.

INAC is in a better position to estimate the costs associated with the development of the databases in an interactive web-based database system (which includes scanned reports, links to ESEBASE borehole logs, links to maps with the location of the boreholes and

testpits, as well as introduction to and explanations of the system) than the consultants producing this report.

4.4 RECOMMENDATIONS

It is recommended that the documents associated with the borehole programs done by the DPW for the DPW be located.

It is recommended that before a decision is made to transfer the “MACKENZI” database from a “MACKENZI” format into a “standard” ESEBASE database format, the following problems in the “MACKENZI” borehole database be addressed:

- Rectification of discrepancies between the number of borehole logs contained in several borehole log series in the original borehole database and the number of borehole logs contained in several borehole log series in the “MACKENZI” ESEBASE borehole database;
- Identification of some unidentified borehole program sources; and
- Rectification of missing or contain incorrect data such as geographical location including northing and easting, soil classification and sample or completion depth in the borehole logs in the ESEBASE borehole and testpit databases.

It is recommended that efforts be continued to create an interactive world-wide web-based Mackenzie Valley borehole database, perhaps using user friendly features such as a format that does not rely on the user’s access to proprietary software (or that includes pre-signed user agreements with the software provider); presentation of the borehole and testpit logs in the database as a stand-alone package that includes a GIS viewer and links to reports; downloadable versions as well as CD packaging.

A review of the development history in the Beaufort Sea, Mackenzie Delta and Mackenzie Valley would be useful background information to users of a Mackenzie Valley Granular Resource Database, and be of assistance in quality verification of data included in the database and tracing of information not yet included in the database.

It is recommended that this report be circulated to a select group of persons who have had involvement in the Mackenzie Valley granular resource inventory or who have had involvement in some phase of the Mackenzie Valley ESEBASE borehole database development, for further comments and completion.

5.0 CLOSURE

EBA is pleased to have provided this evaluation of options for the Mackenzie Valley Granular Resources Borehole Database. Please do not hesitate to contact the undersigned should you have any questions or comments regarding this paper.

Yours truly,
EBA Engineering Consultants Ltd.

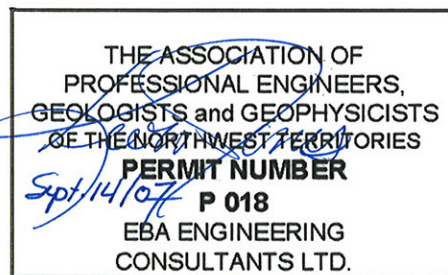


Fons Schellekens, Ph.D.
Geotechnical Specialist
fschellekens@shaw.ca



reviewed by:
K.W. Jones, P.Eng.
Senior Project Director, Arctic Region
Direct Line: 780.451.2125
kjones@eba.ca

FS:ln



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TABLES





LEGEND OF ABBREVIATIONS

All Columns	NA	Not applicable
	NI	Not investigated
	ND	No data
Column B	DPW	Department of Public Works (currently Public Works and Government Services Canada)
	DIAND	Department of Indian Affairs and Northern Development
	INAC	Indian and Northern Affairs Canada
Column H	C	Cohesion
	Cr	Consolidation ratio
	DD	Dry density
	GSD	Grain size density
	I%	Ice percentage
	ID	Ice description
	limits	Atterberg limits
	MC	Moisture content
	N	hammer blows
	ND	natural density
	Org. C	organic material content
	SD	Soil description
	USC	unified soil classification
	Column T and	ACU
Column Y	ASTIS	Arctic Science and Technology Information System (of the Arctic Institute of North America, University of Calgary)
	GSC	Geological Survey of Canada (part of Natural Resources Canada)
	UofA	University of Alberta

TABLE 1: BOREHOLE DATABASE MACKENZI

	Sponsor	Contractor	Subcontractor	# Holes		Borehole Names	Information	Project	Purpose	From	To	From Mile	To Mile	Year	Report	Author	Sponsor	Year	Location Report	Associated Report 1	Author	Sponsor	Year	Location Report	Associated Report 2	Author	Sponsor	Year	Location Report	
				Proudfoot and Lawrence	MACKENZI																									
26	Alberta Gas Trunk Line Company Limited	Acres Consulting Services	Templeton Engineering	42	41	1-12-193 to 1-16-0197; 2-17 to 14-54	SD, ID, USC, MC, limits, GSD	Pipeline	Permafrost Regression	Norman Wells, Fort Simpson	NA	NA	1970	Permafrost regression studies at Norman Wells and Fort Simpson, Northwest Territories	Templeton Engineering Company	Alberta Gas Trunk Line Company Limited	1971	ACU: TJ930 .R47 NO.991	Permafrost regression studies at Norman Wells and Fort Simpson, Northwest Territories	Templeton Engineering Company	Alberta Gas Trunk Line Company Limited	1970	ACU: TJ930 .R47 NO.973							
27	Northwest Project Study Group	Williams Brothers Canada Limited	R.M. Hardy & Associates Ltd.	77	79	CR1 to CR81	SD, MC, limits, GSD	Canol Road Assessment	Permafrost Regression	Canol Road, Norman Wells	NA	NA	1971, 1972	CANOL road study, fall, 1971: test hole logs	R.M. Hardy & Associates Ltd.	Williams Brothers Canada Limited	1971	ACU: TJ930 .R47 NO.864	Report on CANOL road study	R.M. Hardy & Associates Ltd.	Williams Brothers Canada Limited	1972	ACU: TJ930 .R47 NO.862							
28	GSC	GSC	NA	17	17	30-1602 to 88-1635; 7A to 7D, 31B, 46, 65 to 74, 76; B10 to B15B; MS1-1 to MS3-9, CCD and CCO	SD, ID, USC, MC, limits, GSD	Science	Permafrost Regression	Norman Wells area	NA	NA	1973	Local variability of ground ice occurrence at selected sites in the Mackenzie Valley	Heginbottom, J. A. and Kurfurst, P. J.	Geological Survey of Canada, Open File 476, 1977; 113 pages	1977	GSC Library 615 Booth Street, Ottawa	Mackenzie valley near surface temperature measurements, District of Mackenzie	R. A. O'Neil	Geological Survey of Canada, Open File 385; 4 pages	1976	GSC Library 615 Booth Street, Ottawa							
29	GSC	GSC (Kurfurst and Heginbottom)	NA	80	80	30-1602 to 88-1635; 7A to 7D, 31B, 46, 65 to 74, 76; B10 to B15B; MS1-1 to MS3-9, CCD and CCO	SD, ID, USC, MC, limits, GSD	Science	Ground ice variability	Various sites	NA	NA	1975	Local variability of ground ice occurrence at selected sites in the Mackenzie Valley	Heginbottom, J. A. and Kurfurst, P. J.	Geological Survey of Canada, Open File 476, 1977; 113 pages	1977	GSC Library 615 Booth Street, Ottawa												

NA = Not Applicable
 ND = No Data
 NI = Not Investigated



TABLE 2: BOREHOLE DATABASE NEWLOGS

	Sponsor	Contractor	Subcontractor	# Holes		Borehole Names	Information	Project	Purpose	From	To	From Mile	To Mile	Year	Report	Author	Sponsor	Year	Location Report	Associated Report 1	Author	Sponsor	Year	Location Report	Associated Report 2	Author	Sponsor	Year	Location Report		
				GSC	NEWLOGS																										
1	DPW	DPW	NA	127	124	96-15-1; 972-1-1 to 972-3-5; 978-6-1 to 978-6-28; 981-9-1 to 981-9-12; 983-10-1 to 983-10-8; 985-11-1 to 985-12-6; 99-17-1 to 99-18-3	SD, ID, USC, MC, limits, GSD	Mackenzie Highway	Geotechnical Investigation and borrow source identification	Inuvik	Tuktoyaktuk	970	1044	1976	Report on geotechnical investigation, mile 970 (Inuvik) to mile 1059 Tuktoyaktuk, Mackenzie Highway	DPW	DPW	1976	XQGLW (ASTIS record 35303, scanned)												
2										Inuvik area Tuktoyaktuk area	Inuvik area Tuktoyaktuk area	970 1043	995 1070	1977	Supplemental report: geotechnical investigation mile 970 (Inuvik) to mile 1059 (Tuktoyaktuk), Mackenzie Highway	DPW	DPW	1977	XQGLW (ASTIS record 55207, scanned)												
3	Alberta Gas Trunk Line Company Limited	Templeton Engineering Company	NA	249	251	TEM3 to TEM282; TEMR10 to TEMR24	SD, ID, I%, USC, MC, limits, GSD	Pipeline, Gas Arctic Project	Geotechnical Investigation	S of Poplar River	N of Hanna River	100	520	1971	The Alberta Gas Trunk Line Company Limited Gas Arctic Project data report on preliminary soils and terrain investigation program, mile 100 to 520 of proposed pipeline route	Templeton Engineering Company	Alberta Gas Trunk Line Company Limited	1971	ACU: ASTIS record 31493												
4	Gas Arctic-Northwest Project Study Group	E.W. Brooker & Associates Ltd.	NA	95	95	4761001 to 4761055; 4762040 to 4762044; 4763001 to 4763035	SD, ID, I%, USC, MC, limits	Pipeline, Gas Arctic Project	Geotechnical Investigation	N/A	N/A	N/A	N/A	1972	Geotechnical report, terrain investigation, proposed Arctic Gas Pipeline routes, Richards Island lateral and lower Mackenzie alternates, 4 volumes. EBA Job nr. E476A to E476D	E.W. Brooker & Associates Ltd.	Gas Arctic-Northwest Project Study Group	1972	ACU: ASTIS record 39774												
5	Interprovincial Pipe Line (NW) Ltd.	Hardy Associates (1978) Limited	NA	224	129	H82-46 to H203	SD, ID, I%, USC, MC	Oil Pipeline, Norman Wells - Zama	Geotechnical Investigation	Norman Wells	Zama	N/A	N/A	1982	ND	ND	ND	ND	ND												
6	Interprovincial Pipe Line (NW) Ltd.	Hardy Associates (1978) Limited	NA		96	H81-S1A to H81-S42B; H82A-S5A to H82-S30B	SD, USC, MC, C and Cr from vane tests; SD, ID, I%, USC, MC, limits	Oil Pipeline, Norman Wells - Zama	Geotechnical Investigation, stream crossings	Norman Wells	Zama	N/A	N/A	1981, 1982	Summary report on stream crossings along proposed pipeline Norman Wells, N.W.T. to Zama, Alberta: engineering data and design	Hardy Associates (1978) Limited	Interprovincial Pipe Line (NW) Ltd.	1982	ACU: ASTIS record 11819												

NA = Not Applicable
 ND = No Data
 NI = Not Investigated



TABLE 3: BOREHOLE DATABASE INAC

	Sponsor	Contractor	# Holes	Borehole Names	Information	Project	Purpose	From	To	Year	Report	Author	Sponsor	Year	Location Report	Associated Reports	Author	Sponsor	Year	Location Report
1	INAC	EBA Engineering Consultants Ltd.	7	155-2, 155-4, 155-5, 163-1, 163-2, 163-3, and 163-4	SD, ID, USC, GSD	NI	NI	NI	NI	1986	Compilation of Borehole Logs for the Mackenzie Delta Area, N.W.T. 2 Volumes (EBA report 0101-4575-D)	EBA Engineering Consultants Ltd.	INAC	1987	Indian and Northern Affairs Canada, Departmental Library, Gatineau? ASTIS record 33683	Inuvialuit Settlement Sand and Gravel Inventory and Recommendations for Development, Tuktoyaktuk. (EBA report 0101-4575-A); Inuvialuit Settlement Sand and Gravel Inventory and Recommendations for Development, Inuvik. (EBA report 0101-4575-B); and Inuvialuit Settlement Sand and Gravel Inventory and Recommendations for Development, Paulatuk. (EBA report 0101-4575-C)	EBA Engineering Consultants Ltd.	INAC	1987	ACU T31.R47 NO 173
2			63	20-1 to 28-6	SD, USC, MC, GSD															
3			24	BH-1 to BH-23	SD,USC, MC															
4			34	I-400-1 to I-407-5; I-401A1 to I-401A6; I-401AA to I-401AE; I-405A1 to I-405A3; I-400-A, I-403-P, I-404-P, I406-A	SD, ID, USC, MC, GSD															
5			98	326A-1 to 326A-98	SD, MC, USC, ID, GSD															
6			44	222A-1 to 222A-44	SD, MC, USC, ID, GSD															
7			48	2##*.# # is a number, * is A to F	SD, MC, USC, ID, GSD															
8			43	303*.*	SD, MC, USC, ID, GSD															
9			21	319-5, 319-6; 320#.#; 32#-A; 328A-#	SD, ID, USC, MC, GSD															
10			7	455-A to 455-D; 456A-A, 457A-A, 457A-B	SD, ID, USC, MC, GSD															
11			16	2##*.*	SD, ID, USC, MC, GSD															
12			48	2###.#	SD, USC, ID, MC, GSD															
13			43	2##*.*	SD, ID, USC, MC, GSD															
14			30	2##S##	SD, ID, USC, MC, GSD															
15			8	21#*S##	SD, ID, USC, MC, GSD															
16			9	2##A.#	SD, ID, USC, MC, GSD															
17			2	220-1A and 220-1B	SD, ID, USC, MC, GSD															



**TABLE 4: SIMILARITIES AND DIFFERENCES BETWEEN “STANDARD” AND MACKENZI”
FORMAT ESEBASE BOREHOLE DATABASES**

FIELDS IN BOTH STANDARD AND MACKENZI FORMAT	FIELDS ONLY IN STANDARD FORMAT	FIELDS ONLY IN MACKENZI FORMAT
Project Information		
project name	project cross reference 1	
study or project number	project cross reference 2	
borehole number	project cross reference 3	source number
drawing number		
project engineer		contractor
compiler 1	reviewer 1	
compiler 2	reviewer 2	
compiler 3	reviewer 3	
Geographic Information		
UTM units	azimuth	map numbers/letters
easting	dip	location precision
northing	central meridian	elevation precision
top of hole	station	slope angle
datum	offset reference	upslope length
	offset to left or right	downslope length
	offset	slope orientation
General Information		
drilling information	start date	burn year
finish date	start time	disturbance year
unit convention	finish time	data reliability
units	note box 1	vegetation land zone
comments	note box 2	landform description
	note box 3	proximity to water
		temperature zone
Profile Information		
depth		
boundary interface		
zone		
soil description	recovery	
median grain size	rock quality designation	texture
Unified Soil Classification	sample consistency	genetic description/origin
water level	ground ice description	thaw depth
termination depth	casing depth	

**TABLE 4: SIMILARITIES AND DIFFERENCES BETWEEN “STANDARD” AND MACKENZI”
FORMAT ESEBASE BOREHOLE DATABASES**

FIELDS IN BOTH STANDARD AND MACKENZI FORMAT	FIELDS ONLY IN STANDARD FORMAT	FIELDS ONLY IN MACKENZI FORMAT
Sample Information		
type of sample		
top of sample		
bottom of sample		
sample diameter		
sample number		
Test information		
test type	test result	
moisture content	frozen moisture content	excess water/ice content
plastic limit	bulk density	plasticity index
liquid limit	temperature	dry density
compression index	compression test result Qu	frozen density
initial void ratio E0		natural density
overburden pressure		Proctor maximum density
pre-consolidation pressure	consolidation stress	Proctor optimum moisture content
rebound index	strain at failure	pore saturation
thaw strain		specific gravity
		maximum particle size
		% passing #4 sieve
		% passing #10 sieve
		% passing #40 sieve
		finer % passing #200 sieve
		ice content percentage
		percentage organic material

TABLE 5: ESEBASE DATABASES IN INAC'S HOLDINGS

NO	DATABASE NAME	YEAR	NUMBER OF HOLES	REPORT	AUTHOR
1	INAC	1987	820		EBA
2	ERKSAK	1988	93		EBA
3	ISSERK	1988	99		EBA
4	BEAUFORT	1988	1,226		EBA
5	ERKSGC2	1989	137		EBA
6	ISSRKGC2	1989	103		EBA
7	BEAUFT89	1989	792		EBA
8	N-ALASKA	1989	593		EBA
9	DEMPSTER	1990	644		EBA
10	MACKENZI	1990	11,448		EBA
11	INUV	1990	58		Hardy BBT
12	PL91LOGS	1991	80		EBA
13	BEAU1991	1991	412		EBA
14	SACHS	1992	9		FAC
15=4	BEAU88	1993	1,226		EBA
16=3	ISSERK88	1993	99		EBA
17=2	ERKSAK88	1993	93		EBA
18=7	BEAU89	1993	792		EBA
19=6	ISSERK89	1993	103		EBA
20=5	ERKSAK89	1993	137		EBA
21=13	BEAU91	1993	412		EBA
22	BEAU93	1993	87		EBA
23=15+18+21+22	BEAU1993	1993	2503		EBA
24=17+20	ERKSAK93	1993	230		EBA
25=16+19	ISSERK93	1993	202		EBA
26=23+24+25	BEAU93AL	1993	2935		EBA
27	HOLMAN	1994	12		FAC
28 (in 1)	TUK94INC	1994	224		EBA
29 (in 10)	TUK94MAC	1994	244		EBA
30 (in 26)	TUK94NEW	1994	10		EBA
31 (in 26)	TUK94BFT	1994	109		EBA
32	NEWLOGS	1993	695		EBA

