GEOLOGICAL SURVEY OF CANADA

OPEN FILE 4734

Survey of Expert Opinion on Permafrost and Geotechnical Issues for Northern Pipelines

D.E. Lawrence

2004

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Foreword

In the winter of 2002/2003, a survey was undertaken on geotechnical and permafrost issues related to northern hydrocarbon pipelines. The survey of experts in government agencies, industry and academia was part of an initiative to identify knowledge gaps, and to assist in focusing research activities and project/funding proposals to address these gaps. The timing of the survey coincided with the federal government's early preparations for the anticipated environmental and regulatory approvals of a likely Mackenzie Valley gas pipeline.

In addition, the Earth Science Sector of Natural Resources Canada (ESS/NRCan) was beginning the implementation of its issues driven and results-based S&T strategy. The survey was thus also intended to serve the transition to the new ESS program structure, and to help, through stakeholder and client feedback, target ESS research activities and outputs. As such the questionnaire sought comments on ESS's Geological Survey of Canada (GSC) products and services relevant to the issues under discussion.

Comments that appear in this report are generally the unedited responses from survey participants, or the opinion of the report's author. They do not necessarily represent the opinions of ESS.

For confidentiality purposes the specific individuals or agencies that provided responses have not been explicitly identified for each comment. While this anonymity has been preserved, the initial survey distribution list is included.

Margo Burgess
ESS/GSC
July, 2004

Northern Pipelines
Survey of Expert Opinion
on
Permafrost and Geotechnical Issues
and the use of
GSC Products and Services

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Executive Summary

A survey was undertaken in the latter part of 2002 and early 2003 to solicit opinions on the critical geotechnical and permafrost issues related to northern hydrocarbon development, principally pipelines. This survey of experts in government, industry and regulatory agencies is part of an initiative designed to identify knowledge gaps that could interfere with the orderly assessment and development of northern projects.

Identification of critical issues and gaps in the knowledge base will assist in focusing research activities required for the design, construction and operation of northern pipelines and their environmental and technical assessment.

There was general agreement that progress has been made since the early 1970s and 80s however, the major issues are largely the same. Major issues relate to adequacy of data on soil thermal regimes, behaviour of permafrost soils (both thaw and heave), pipe/soil interaction, route selection, stream crossings, resource development and environmental concerns. The major new issue not rigorously debated in earlier project reviews, is the effect of climatic warming.

Respondents further noted that additional quality base line data would be required for design input and for prediction of terrain response to man made and natural influences. Since the 1970s and 80s and in the absence of major northern hydrocarbon development, the level of research activity and data collection has been substantially reduced. The level of activity must now be increased in order to respond in a meaningful and responsible manner to new proposals.

Most respondents see the Geological Survey of Canada (GSC) as the agency best positioned to undertake baseline geoscience data collection and carry out basic research on soil conditions and behaviour. Due to the reduction of personnel and resources over the past decade, some respondents expressed a lack of confidence that the GSC would be able to adequately respond to client needs, participate fully in the evaluation of northern project proposals, carry out research and as well as provide expert advice to regulatory and assessment agencies.

GSC products, maps, research and monitoring results are highly valued. It is important that they are readily accessible and in formats most used by clients. Electronic transfer of data and research results is considered to be essential.

Introduction

In the fall of 2002 a survey questionnaire was developed to solicit the opinions of researchers, regulators, consultants and pipeline owners with respect to onshore aspects of hydrocarbon development and transportation in the western Arctic. The purpose of the questionnaire generally was to identify knowledge gaps related to geotechnical and permafrost research which might have the potential to hinder the assessment, approval, development and transportation of oil and gas in the region. A secondary goal was to ascertain the degree to which GSC activities and products were useful to clients and to identify ways and means to improve these products and their delivery.

Comments that appear in this document are for the most part those of the survey participants and generally are unedited. In some instances editorial changes have been made to maintain the confidentiality of the respondent or to capture the sense of a number of similar comments. The author takes full responsibility for summarizing the comments. Opinions expressed in the document are those of the survey participants as interpreted and summarized the author; they do not necessarily agree with those of the Geological Survey of Canada.

The questionnaire comprises five multi part questions (see appendix1) laid out as follows:
Q1. Knowledge Gaps - This question attempts to identify permafrost and geotechnical issues related to hydrocarbon activity in Western Arctic and define the GSC's role in resolving issues?
Q2. Expert Advice This question is intended to evaluate the usefulness of technical advice provided by the GSC.
Q3. Cooperative undertakings, Q4. Benefits /usefulness of GSC products, and Q5. New Products and Services are intended to evaluate the extent that GSC research, activities and products were useful to clients and to identify areas where improvements could be made both in the products and their delivery.

Distribution

The questionnaire was sent via e-mail to 51 people in the following communities
University (10)
Government (14)
Regulatory agencies (11)
Engineering consultants (12)
Pipeline companies (4)

Response

Approximately half of those who received the questionnaire participated in the survey. Nineteen responses representing the opinions of 27 individuals and/or their organizations were received between mid October 2002 and mid January 2003. Two of these were nil responses. Some of the responses were the consolidation of opinions of several people and may be considered an agency or corporate position. The 17 positive responses represent the opinions of 25 individuals 23 who were recipients of the original questionnaire and 2 who received it from a secondary source. The response rates by community were approximately as follows:

Table 1. Response by Affiliation

Affiliation	**Response**	**%**
university	3/10	30%
government	4/14	29%
regulatory agency	5/11	45%
consultant	10/12	83%
pipeline company	3/4	75%
all affiliations	25/51	49%

Note: includes unsolicited responses but not the nil responses

There was mixed response to the survey. Responses ranged from limited and/or partial to detailed, considered and complete. Interest and participation was greatest in the industrial community (consultants and pipeline companies) with over a 75% response. The level of participation by government and the academic community was much lower, less than half that of industry. Regulators provided a 45% response.

Very few responses were received by 15 October, the deadline indicated in the original mail out. Many people said that they were very busy and a response would have to wait until other higher priority work was completed. In the latter part of October and November considerable time and effort was made to encourage individuals to respond (repeated e-mails and telephone calls). Without this follow-up the response rate would have been considerably lower (perhaps in the 30-40% range).

The 49% response may indicate lack of interest, lack of time or the feeling that participation would provide little return or benefit. However, many felt that it was important to examine the issues raised in the questionnaire. There was some skepticism that any concrete government action would arise from the exercise.

Survey Analysis

Each of the responses was examined, categorized, tabulated and summarized. Each point represents the comment of an individual respondent. In some cases comments have been edited to fit the format of the report or to ensure the anonymity of the respondent. A number of comments are variations on a common theme and may seem somewhat repetitious but are included so as not to miss subtle shades of meaning or intent.
In some cases information beyond the scope of this exercise was provided i.e. comments on offshore and marine environment. Generally, they have not been included in the summaries.

Question 1:

Knowledge Gaps: *(related to geotechnical and permafrost, and associated with northern hydrocarbon development in the Western Arctic).*
Please feel free to break these down by region, e.g. Mackenzie Delta, Mackenzie Valley, Yukon, or by development phase, e.g. exploration, development, transportation, supporting infrastructure.
a. In the fields of northern engineering, geotechnique and permafrost research; have the issues identified during the hydrocarbon proposals of the 1970's and '80's been resolved? To what degree? What is outstanding?
b. Have new issues surfaced? What are they?
c. What is required to resolve these issues?
d. Do you see the GSC making a contribution to resolving these issues? Elaborate – e.g. is it a major, minor, leading role or other?
e. What are the major outstanding issues, which if left unresolved, would have the potential to delay the progress of hydrocarbon development and transportation in the Western Arctic?
f. Are there knowledge gaps that hinder resolution of these issues? What do you see as the federal role, particularly GCS's in filling these gaps?

Response 1 a. Generally it is felt that progress has been made in addressing the issues identified in the 1960s and 70s and that we have benefited from an expanding knowledge base derived through the experience gained from the construction and operation of other northern projects. However, there is a need to revisit many (some say almost all) of the basic issues and problems identified earlier. Continued research is also needed to update them for different geographical regions, design scenarios and engineering issues. Considerable work still is required in many areas, grouped generally as follows:

Data and design requirements

- pipe/soil interaction in permafrost soils
- prediction and quantification of frost heave and thaw settlement
- frost heave effects and prediction for a chilled gas pipeline and infrastructure components
- identification and delineation of ice-rich permafrost and massive ice
- mapping permafrost thickness, depth, and temporal changes in more detail;

- stream, overland, and ground water hydrology in permafrost terrain
- pipeline design in permafrost
- understanding of pipe stability at high operating pressure in permafrost regions.

Rivers crossings, slopes and coastal aspects

- how to design, construct and operate river crossings for large diameter, chilled gas pipelines
- coastal erosion rates and near-shore sedimentation pose serious design issues
- slope stability, mass movement , creep and erosion of permafrost soils especially in mountainous regions and in river valleys
- pipeline river crossings and the stability of river channels
- mapping ice-scour in marine and transition-zone regions

Construction and remediation

- how to efficiently construct temporary and permanent access to pipeline rights-of-way
- long-term performance of chemical sumps and the interaction of sumps and permafrost
- improvement if the technology for winter and ice road design and operation
- contaminant transport in permafrost soils is poorly understood and needs further study
- monitoring old drilling sites and other infrastructure from the 60's, 70's
- remediation of contaminated soils
- restoration of permafrost

Response 1 b. There is general consensus that the major new issue relates to the possible effects of climate change on resource development, the environment and pipeline operation There is a need to design for the long term viability of facilities under changing conditions. In addition there are several other emerging or expanding issues that are a concern:

- long-term stability of ice-rich slopes, in terms of the deformation characteristics and ability to bear a load. The critical point being that a high-pressure gas pipeline cannot be bent to the extent of an oil line and continue to be safely operated
- horizontal directional drilling (HDD) and the extent that this technology can be applied to the construction of river crossings for large diameter pipelines
- higher pressures, refinements to pipeline design methodologies (limit states design, risk based design) may lead to different data requirements
- shoreline, near shore and offshore issues related to coast line erosion, permafrost and ice scour and the requirement to develop designs and technology to deal with them
- the requirement for good information on permafrost conditions including ground temperatures in both frozen and unfrozen soils
- greater stakeholder awareness, greater requirement for public consultation and public scrutiny of proposed projects
- increased awareness and concern regarding security issues have evolved in the past year

Response 1 c. There is also a requirement to continue to compile base line data (thermal and geotechicnal) for input into models and to facilitate design of pipelines:

- continue to develop our understanding of how climate change is affecting permafrost extent, depth and temperature, and the implications for hydrocarbon development (and pipelines in particular)
- long-term monitoring, of permafrost thermal conditions and data is essential to providing a constructive physical database for climate change modeling. This is of particular interest in the discontinuous permafrost regions.
- need to acquire good information on permafrost conditions including ground temperatures in both frozen and unfrozen soils, baseline studies and input into pipeline design and thermal models
- more study is required to evaluate the feasibility of HDD in permafrost. This could include a study of how lessons from the Colville River crossing in Alaska and large diameter HDD crossings in non-permafrost areas can be applied to larger pipe diameters in permafrost in Northern Canada
- in some cases, four to five-year field trials are required for convincing demonstration that the issues have been resolved. Computer modeling may provide considerable insight, but in the gas pipeline case, the impact of failure may be catastrophic, so the risk assessment implies a stringent design basis. There should be field experiments, like the Quill Creek test facility *(facility operated by Foothills Pipeline in the South Yukon in the early 1980s to test construction and operation modes),* specifically designed to address these issues
- studies of geological processes
- research into pipe-soil interaction studies specific to cold regions
- evaluation of resources required for construction of drilling pads and other facilities
- northern drilling waste management
- mapping of granular resources
- a need to link research to applied engineering practices. Research efforts have been made both in terms of science and in terms of engineering. However experience reveals that the two could be better linked. There would be benefit from increased research in terms of permafrost impacts and adaptation as it applies to engineering design
- South Great Slave region lacks the rigour of work done in the Mackenzie Valley. The South Great Slave area is characterized by discontinuous permafrost. These areas include the towns of Hay River and Ft Smith and the major highway linking Alberta and NWT. Current information compiled lacks detail, particularly documentation of ground and subsurface data. It is within this discontinuous zone that there are significant potential hazards for infrastructure related to climate change
- more accurate method of predicting ice thickness, freeze-up and break-up in the future is required for the planning and construction of winter roads
- expand site-specific data. Data gaps in the surficial geology may exist due to borehole sampling not reaching adequate depths or not being required for construction of older infrastructure. As well, a significant proportion of the infrastructure has changed hands (i.e. Federal to Territorial Government), and the transfer of relevant documents may be

incomplete. Geo-technical information often focuses more on soil types, moisture content, rather than the properties of ground ice, permafrost temperature and soil thermal properties

- Ground truthing is also suggested to verify and increase the confidence of the data collected as well as for forecasting

Response 1 d. There is general agreement that the GSC should provide a regional perspective on permafrost, geotechnical and ground thermal conditions and make mapped information and data easily accessible, preferably electronically. The GSC should not be involved in the work normally undertaken by industry and consultants. Specific comments include the following issues and areas of proposed GSC involvement:

- provide input on the regional effects of climate change on the environment based on initiatives such as the Mackenzie Valley IRMA* program and other permafrost mapping initiatives.

  ** A regional synthesis of the physical environment and geologic processes in the Mackenzie Valley "The physical environment of the Mackenzie Valley, Northwest Territories: a baseline for the assessment of environmental change" GSC Bulletin 547.*
- the most appropriate role for GSC is to provide input on the regional effects of climate change on the environment, based on initiatives such as the Mackenzie Valley IRMA program and other permafrost mapping initiatives. We see site/route-specific impacts as the responsibility of the individual project proponents, however GSC may be involved in providing regional, historic baseline data
- the GSC is Canada's premier geoscience agency. If it does not play a major role in ensuring the appropriate intellectual capacity for sustainable industrial development in Canada, no other agency will. A major concern, however, is the extent to which GCS's capacity in this area has been eroded over the past decade. GSC has provided a leading contribution in the discussion of climate change aspects in the region, but the expertise on specific geotechnical issues such as involved with sustainable oil and gas development is only implicit. GSC must become more proactive and engaged in geotechnical aspects of the pipeline project if its contribution is to be recognized as significant. This will probably require a great clarification of present activities and either reassignment or hiring of staff
- the following data bases should be compiled by the GSC: a. regional airborne geophysical data b. remote sensing data and c. geotechnical soils investigations
- the GSC could become more involved in the development of remote sensing applications for the measurement of slope processes
- pipe-soil interaction research, terrain mapping, ground temperature monitoring and data gathering with respect to frost heave and thaw subsidence of susceptible soils
- the GSC is in a good position to conduct studies on longer-term and regional trends (past and future) with respect to such phenomena as ground warming, thaw subsidence, coastline erosion, changes to vegetation/wildlife habitat.
- the GSC could play a major role in the areas of mapping permafrost conditions (i.e. active layer depths, ground temperatures) and in the mapping of granular resources in the north

- good background information on permafrost conditions including ground temperature (both frozen and unfrozen areas)
- the federal government needs to consolidate its efforts in the North. From a consultant's perspective, a lot of duplication of effort is seen in the Federal and Territorial governments. This duplication is particularly bad in geoscience departments. One visit to the Yellowknife Geoscience Forum brings home the fact that there are many government departments fighting over financial resources with no collaboration. Many data sets are being lost through poor management. In the GSC a concerted effort is needed to co-ordinate the activities of Continental Geoscience, Geophysical Database, Terrain Science Department, and the CS Lord Geoscience Centre.

Response 1 e. Although not directly answered by many respondents, there seems to be general agreement that unless design elements and construction procedures adequately contend with permafrost issues and associated climate change implications for a high pressure gas pipeline, a project would be at risk. Engineering solutions to technical and environmental issues must be assured. These solutions must also be cost effective and regulators must be assured of the long term viability, safety and security and of the project. Specific comments include:

- a need for geotechnical, hydrological, thermal data for input into baseline studies and statistical models for risk-based design
- a single pipe/high pressure may not be a financially viable option without more study
- delay or confirmation of the construction schedule will depend on political considerations…science will be part of the discussion but, ultimately only one of the deciding factors
- lack of understanding of the potential impacts of climatic change might have on sea ice, wave climate, permafrost and coastal erosion
- lack of knowledge of permafrost conditions, ground temperatures and granular resources may result in delays in building a pipeline in the Mackenzie Valley
- the outstanding issues relate to how to design, construct and operate pipelines in permafrost in the most cost-effective manner. They are not issues that would delay the development of hydrocarbon projects
- frost heave of chilled gas pipelines and in particular, the soil pipe interaction issue may simply revert back to the work that was done in the 70's. With the availability of higher strength pipe, higher-pressure pipelines and a better understanding of limit state design it is felt by many that the problems have been solved. However, there is still the regulatory hurdle and an understanding on the part of the locals along the valley based on the "old approach"
- a better understanding of the expected disturbance caused by pipeline construction in permafrost regions would certainly help curb some of the concerns coming from regulators and local population
- land claims (not much that the GSC can do about this)
- a much improved transportation infrastructure to the north would spur developments (again, not likely much of a role for GSC here either)

Response 1 f. The role of the GSC is seen as multi faceted. It should be a research organization but as well be the repository and distributor of regional information. This information in the form of maps, research results, databases etc must be universally available and easily accessible. The GSC must also be in a position to provide sound technical advice to regulatory agencies that review project proposals and manage resources. Generally there is a sense that, in terms of current human and financial resources, the GSC will not be able to adequately fulfill its responsibilities. There is concern that it will not be able to respond to the demands of a major hydrocarbon project. Its capacity has been diminished considerably from that of the 1970-80's while at the same time the regulatory regime has become more complex and the requirements more demanding. The GSC, as well as other government agencies have had to respond and provide advice on an ever-increasing number of project proposals. There is a feeling that without an increase in capacity the GSC would be hampered in carrying out its roles and responsibilities. Comments include the following:

- the role of the federal government is in the approval and regulation of hydrocarbon projects in the north. As GSC would be called on to provide expertise to the Regulators, it is important for it to maintain current expertise in northern engineering technology. One way to maintain and enhance this expertise would be through collaborative research work with industry
- GSC could adopt an articulate, informed and respected stance towards these issues. The GSC could conduct far-sighted, long-term, field experiments to address these issues and inform the regulatory process. But the GSC does not have much time to decide in the affirmative, if it is to establish such programs, as the regulatory process may be upon us
- firm understanding is required of physical, environmental and socio-economic effects of pipelines as these have a significant impact on routing, cost public perception and timing. The federal/GCS's role would be to further the understanding of the above, particularly in obtaining baseline data and identifying gaps for studies or research that a project proponent might be expected or required to undertake in obtaining necessary approvals
- the federal government needs to consolidate its efforts in the North. From a consultant's perspective, a lot of duplication of effort is seen in the Federal and Territorial governments. This duplication is particularly bad in geoscience departments. One visit to the Yellowknife Geoscience Forum brings home the fact that there are many government departments fighting over financial resources with no collaboration. Many data sets are being lost through poor management. In the GSC a concerted effort is needed to co-ordinate the activities of Continental Geoscience, Geophysical Database, Terrain Science Department, and the CS Lord Geoscience Centre
- the GSC is most suited to doing large regional investigations. NRC and University groups are more suited to doing localized and laboratory investigations. The federal government should be responsible for archiving and compiling geoscience information for the common good of the Canadian people rather than for targeted industry groups. The GSC should not be involved in consulting.

- shrinking GSC staff levels have dramatically affected its ability to function efficiently. Reversing the trend of declining research at the GSC could be accomplished by either employing more scientific staff, or putting projects out to bid in an open system.
- One of the GSC's roles is to bring science to potentially emotional issues. For example, much of the discussion about global warming affects on the north is based on low-technical newspaper and magazine reporting or anecdotal reports. Where is the measured information to support these Chicken Little reports? Furthermore, geologic records indicate that the western arctic was much warmer than today, during the period of 9 to 10 ka ago. Apparently many of the massive ground ice features formed at this time and in the Delta area there was widespread thermokarstic activity. Can research of these features and this time period tell us anything important about the impact of global warming?
- certainly there are knowledge gaps - centered on incomplete understanding (certainly in Canada) of the interaction of pipe and freezing ground. Even if there were only a 'small' uncertainty, with a project of this size, risk assessment demands significant expenditure. whoever pays is one thing, Canadian government. is responsible for security, safety etc
- in the areas of permafrost we are looking at an exclusively northern issue – historically the Polar Continental Shelf Project (PCSP) has been a key support role played by the federal government. By letting the capacity of PCSP decline the federal government has undermined both the government and university capacity to do northern research. In a very short period this has had a negative feedback resulting in fewer researchers working in the north and fewer researchers being trained in northern science – in a period of 5 years the number of new applications to PCSP and the number of applications with large student involvement has nose dived
- the biggest data gaps are site specific issues. GSC should not be expected to fill this gap. They would be looked at to provide overall conditions/setting. Site specific data is mostly the responsibility the proponent of project

Question 2 Expert Advice

(for consideration by regulatory agencies i.e. NEB, CEAA, DIAND, GNWT, Land and Water Boards, Environmental Impact Review Boards, etc)
a. Have the advice and/or data provided by the Terrain Sciences Division (TSD) been useful in evaluating the potential impact of northern industrial proposals being evaluated by your agency?
b. Was the level of information adequate?
c. Was this information provided in a timely manner?
d. Could we improve the manner in which our knowledge/advice are provided in the future? How?

This question was designed specifically to evaluate the effectiveness of the GSC's role in providing technical advice used principally by regulatory agencies in their environmental and engineering evaluations of northern projects. Although the way in which GSC advice is delivered and used varies from agency to agency, it is clear that the GCS's expertise in permafrost and terrain matters is highly valued and agencies depend on receiving GSC advice in a timely manner i.e. one that fits their review and assessment schedule. Because the regulators sit on the opposite side of the table from the project proponents and their consultants their point of view on issues is sometimes quite different from that of the proponent. As a result some of the issues highlighted by the regulatory agencies vary from those of the other communities.

Providing advice to regulatory agencies has changed dramatically since the 1970-80s. The current regulatory regime is more complex, more are involved and there is a statutory requirement to respond. Short turnaround times and strict scheduling have made it more difficult for the GSC. This is exacerbated by the loss of expertise and funding since the early 1990s.

Response 2

a. advise useful		**b. adequate level of information**		**c. provided in a timely manner**	
yes	no	yes	no	yes	no
5	1	2	1	2	

d. Suggestions for improvement

- TSD's first requirement - to provide good up-to-date surficial geology maps of a narrow route corridor and route ROW within it. This could provide critical and relevant advice to the various interested agencies
- essential that senior management recognize the important role TSD plays in helping the department meet its legislative responsibilities under CEAA and EA regimes and ensure that adequate resources (both funding and human) are incorporated into the GSC/TSD program to enable the department to meet its EA obligations

Question 3 Cooperative undertakings

a. Have you ever undertaken cooperative work with the GSC?
b. Was this a useful /profitable experience? Why?
c. Would you enter into such an arrangement in the future?
d. How could these arrangements be improved in the future?
e. Would you be prepared to assist in funding new TSD initiatives that would provide benefits to your organization?

Response - 3

a. co-op work experience		**b. useful/profitable**		**c. future interest in co-op undertakings**		**e. interest in future funding partnership**	
yes	no	yes	no	yes	no	yes	no
10	2	10		13		5	7

d. Suggestions for improvement

- need better presentation of GSC activities at industry-attended conferences e.g. YK Geoscience Forum, ARCSAC Conference
- cost sharing manner
- main barrier has been lack of funding for required tasks
- pay competitive rates to consultants
- don't waste time of consultants picking their brains and then awarding the contract to another firm
- don't make consultants compete with GSC for their own work.
- GSC should be more aware of business climates relating to rates, deadlines and budgets.
- government year end forces funding cycles that make it difficult to effectively plan field work - especially in the Arctic

Comments

- if GSC were working on projects of interest to us, and the client was interested in the research aspect we would consider collaboration.
- involvement with Mackenzie gas pipeline project actively pursuing ways to partner with GSC in monitoring of ground temperatures
- one opportunity that may present itself would be if the project could drill and install thermistor string (with data loggers) and the GSC monitor and collect data
- limited opportunities depending on role of GSC in a given hearing - could possibly rely on GSC staff/expertise if NRCan not otherwise involved in hearing
- assist in funding not likely but possible in a unique situation given above caveats
- interested in investigating possibility of joint funding if project fits both
- cost sharing manner could be improved
- PERD, France/Canada Pipeline Study - information to researchers and invaluable training to graduate students

- most likely and useful collaboration will involve projects of mutual interest (i.e. Delta DEM, DGPS, mapping, etc; Liard Valley studies)
- main barrier has been lack of funding for required tasks
- GSC research plays favourites - exclusive partnership is with a certain university. Only a few cases does it appear that GSC researchers seek out the most knowledgeable partners rather than "friends".
- contribution agreements a struggle - more successful model was the former research agreement systems, which operated more like a research grant.
- would support collaborative work with other pipeline companies

Question 4 Benefits/usefulness of GSC products

a. Have you used GSC or TSD data, maps, reports or research results in your work?
b. Would you likely use this type of information in the future?
c. Specify how you or your organization used them.
d. Were there shortcomings or deficiencies in any of the above?
e. How did these shortcomings limit their usefulness?
f. How could the information/products that you used have been improved?
g. Were the products and services easily accessible and was the cost reasonable?

Response - 4

a. use of GSC products		**b. likely to use in future**		**d. shortcomings**		**g. accessibility & cost**	
yes	no	yes	no	yes	no	yes	no
10		10		5	4	5	

c. How are products used?

- regional data used - suitable for introductions and regional descriptions
- surficial geology maps often used to provide preliminary routing information for pipelines and other infrastructure
- ground temperature data has been used in reports
- background information for staff analysis of Norman Wells Pipeline
- background information related to future northern pipelines
- used for soil and land resource research
- general use of published data etc
- NRCan channel cross-section survey data used, with new EC data, to analyze and depict changes in channel depth, cross-section, etc.
- background information and field research planning
- GSC maps often the starting point for projects
- background data

e. and f. Comments/Suggestions for Improvement

- some older products need to be digitized and geo-referenced before they can be compiled with more modern data
- background data has to be cheap or it is more efficient for the client to get new data from scratch
- compatibility of GSC formats are good i.e. ArcView and Mapinfo (Industry standard is ArcView and ArcInfo
- fewer GSC Current Research papers - more emphasis on public release of data
- scale is large and more detail would be advantageous
- coverage in all areas does not exist
- limit on accuracy/resolution
- mapping at lower scale (1:50,000) and ensuring no gaps in areas of proposed hydrocarbon projects or transportation corridors
- lack of data limits applicability
- need more information/data
- reduce time lag between completion of field mapping and when the desired final suficial geology map is received
- need increased stable funding for ongoing area monitoring and research, and short term funding for specific deliverables
- need collaboration by industry, government agencies, and map production to produce satisfactory new products for the area
- EC requirements for delta hydraulic modeling (<1m DEM for the delta) is not realistic via standard Govt. of Canada mapping standards
- airphotos are extremely valuable but have become prohibitively expensive
- hard copy topo maps are becoming more difficult to obtain and both maps and airphotos are too expensive - not cost recoverable if they take up too much of the available funds
- permafrost regions need more detail on ground ice (permafrost features. rather than soil/rock type and geology). Russian maps more detailed on ice
- takes too long to get Open File status
- background material to maps and reports and access to researcher would be invaluable
- sometimes reports completed after the need for them has passed
- borehole database is too vague to be used for detailed design

Question 5 New products and services

a. Are there new services or products that TSD could provide that would be useful to you?
b. Could TSD data be produced, presented released in new or revised formats that would be more useful?

Response 5

There were several general themes that are almost universally held by our clients. The GCS must have a good understanding of regional conditions and processes as this information is the

basic information that forms the starting point for conceptual and preliminary planning and design for a project. This information is also critical for locating facilities and determining routes for linear projects. The same base line data is used by regulators to evaluate a project's environmental impact and engineering viability. They also felt that it was government's role to compile and maintain regional information especially in the form of databases. Access to geothermal, geotechnical and geophysical databases and mapped information should be increasingly made available in digital formats especially formats commonly used by industry. Increase in the availability of information on the internet is recommended.
Some of the specific comments and suggestions include:

Comments/suggestions for improvement

- more access to maps in industry standard digital formats (i.e. Auto Cad)
- would like to see more products available on the web
- products most consulted are NRC Glossary of Permafrost Ground Ice Terms. GSC map of Permafrost thickness and ground temperatures; and various refereed publications on geophysical methods in permafrost mapping
- hope trend to web based GIS products continues and other large databases including geotechnical borehole data and geophysical data are added online
- I think the following Data sets should be compiled by GSC: regional airborne geophysical data; remote sensing data (in collaboration with CCRS, and YK centre for Remote Sensing; geotechnical soils investigations from the 60's to 90's
- GSC most suited to doing large regional investigations. Federal Government should be responsible for archiving and compiling geoscience information for the common good on the Canadian people rather than for targeted industry groups
- GSC should consider international developments in geoscience organizations and their relationship with consultants around the world
- conduct far-sighted, long-term, field experiments to address issues and inform the regulatory process
- more research activity is long overdue in Canada
- mapping of granular resources, additional ground temperature data. Useful formats - Excel, Quattro Pro, Arc Info, Surfer 7 and ArcView
- develop a standard risk analysis that can be used in all jurisdictions

Appendix 1. Questionnaire

Questionnaire
GSC/Terrain Sciences permafrost/geotechnical activities related to northern hydrocarbon initiatives

1. **Knowledge Gaps:** (related to geotechnical and permafrost, and associated with northern hydrocarbon development in the Western Arctic).
Please feel free to break these down by region, e.g. Mackenzie Delta, Mackenzie Valley, Yukon, or by development phase, e.g. exploration, development, transportation, supporting infrastructure.
a. In the fields of northern engineering, geotechnique and permafrost research; have the issues identified during the hydrocarbon proposals of the 1970's and '80's been resolved? To what degree? What is outstanding?
b. Have new issues surfaced? What are they?
c. What is required to resolve these issues?
d. Do you see the GSC making a contribution to resolving these issues? Elaborate – e.g. is it a major, minor, leading role or other?
e. What are the major outstanding issues, which if left unresolved, would have the potential to delay the progress of hydrocarbon development and transportation in the Western Arctic?
f. Are there knowledge gaps that hinder resolution of these issues? What do you see as the federal role, particularly GCS's in filling these gaps?

2. **Expert advice:** (for consideration by regulatory agencies i.e. NEB, CEAA, DIAND, GNWT, Land and Water Boards, Environmental Impact Review Boards, etc)
a. Have the advice and/or data provided by the TSD been useful in evaluating the potential impact of northern industrial proposals being evaluated by your agency?
b. Was the level of information adequate?
c. Was this information provided in a timely manner?
d. Could we improve the manner in which our knowledge/advice are provided in the future? How?

If you have used GSC products or services or cooperated on research projects please consider the following additional questions.

3. Cooperative undertakings:
a. Have you ever undertaken cooperative work with the GSC?
b. Was this a useful /profitable experience? Why?
c. Would you enter into such an arrangement in the future?
d. How could these arrangements be improved in the future?
e. Would you be prepared to assist in funding new TSD initiatives that would provide benefits to your organization?

4. Benefits/usefulness of GSC products:

a. Have you used GSC or TSD data, maps, reports or research results in your work?
b. Would you likely use this type of information in the future?
c. Specify how you or your organization used them.
d. Were there shortcomings or deficiencies in any of the above?
e. How did these shortcomings limit their usefulness?
f. How could the information/products that you used have been improved?
g. Were the products and services easily accessible and was the cost reasonable?

5. New products and services:

a. Are there new services or products that TSD could provide that would be useful to you?
b. Could TSD data be produced, presented released in new or revised formats that would be more useful?

Appendix 2. Distribution of Questionnaire – List of Contacts

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