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The Use and Value of Urban Geology in Canada: A Case Study in the National Capital Region

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Article abstract

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Following this forum Natural Resources Canada's Audit and Evaluation Branch undertook an impact study that examined the usefulness and value of benefits of basic types of geoscience information in urban and regional planning and development. The evaluation study of the National Capital Region Project determined that geoscience documents are used extensively and provide an authoritative standard forwork. They are particularly useful in pre·liminary project planning, geotechnical engineering for major facilities, environmental impact assessments, public safety planning, and as a multi-disciplinary research tool and field guide. The estimated value of benefits includes a 5%-20% reduction in the cost of civil/environmental engineering design and planning study work, and considerable monetary savings in derived or indirect benefits, amounting to annual savings of several million dollars. Recent tech·nological advances increase the possible range of applications, especially for those who have traditionally been users of geological maps.

The Use and Value of Urban Geology in Canada: A Case Study in the National Capital Region

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SUMMARY

In response to a request to increase its activities in environmental geology and to collaborate with the provinces, the Geological Survey of Canada (GSC) initiated a project in 1993 to provide geoscience information for urban and regional planning and development in eastern Ontario and western Quebec. Prior to the launch of the project, representatives from various levels of government, private consultants, environmentalists, universities and the general public were invited to a forum to discuss the need for and usefulness of urban geological information. The participants confirmed the importance of urban geological information and supported a co-ordinating role for the GSC.

Following this forum Natural Resources Canada's Audit and Evaluation Branch undertook an impact study that examined the usefulness and value of benefits of basic types of geoscience information in urban and regional planning and development. The evaluation study of the National Capital Region Project determined that geoscience documents are used extensively and provide an authoritative standard for work. They are particularly useful in preliminary project planning, geotechnical engineering for major facilities, environmental impact assessments, public safety planning, and as a multi-disciplinary research tool and field guide. The estimated value of benefits includes a 5%-20% reduction in the cost of civil/environmental engineering design and planning study work, and considerable monetary savings in derived or indirect benefits, amounting to annual savings of several million dollars. Recent technological advances increase the possible range of applications, especially for those who have traditionally been users of geological maps.

RÉSUMÉ

Suite à une requête adressée à la Commission géologique du Canada pour qu'elle augmente ses activités en géologie de l'environnement et qu'elle collabore plus étroitement avec les provinces, celle-ci a lancé, en 1993, un projet visant à fournir de l'information géoscientifique pour l'aménagement urbain et régional dans l'Est ontarien et l'Ouest québécois. Lors du lancement du projet, on a invité des représentants des différents paliers de gouvernements, des experts-conseils, des environnementalistes, des universitaires et des gens du publique en général, pour discuter de la pertinence du projet de géologie urbaine. Les participants ont souligné de façon unanime l'importance des données géologiques en aménagement du territoire et ont appuyé le rôle de coordonnateur de la Commission géologique en ce domaine.

Dans un deuxième temps, la Direction de la vérification et de l'évaluation du Ministère des Ressources naturelles Canada a entrepris une étude d'impact pour déterminer l'utilité et la valeur des données géoscientifiques fondamentales dans l'aménagement régional. L'étude du cas de la Capitale nationale a démontré que les documents géoscientifiques sont utilisés de façon extensive et fournissent des normes officielles acceptées. Les données sont particulièrement utiles pour la planification des projets, les travaux d'ingénierie pour les installations publiques, pour les études d'impact sur l'environnement, pour la sécurité publique et enfin servent d'outil de recherche multidisciplinaire et de guide sur le terrain. La valeur estimée des bénéfices inclut une réduction de 5%-20% des coûts dans la planification des études de génie civil et environnemental, ainsi que des économies indirectes pouvant atteindre plusieurs millions de dollars annuellement. Les développements récents en informatique permettent d'étendre l'utilisation des données géoscientifiques à de nouveaux domaines, bénéficiant principalement, aux utilisateurs traditionnels des cartes géologiques.

INTRODUCTION

Urban geology in Canada is a century old, as reported by Scott (1998): "...in May 1899 recognition of the significance and importance of geology to urban centres was manifest by the presentation of a paper (Ami, 1900) on the geology of the principal cities of eastern Canada to a meeting of the Royal Society of Canada." Despite the early contributions by Ami, few systematic studies, with the objective of providing information to assist in municipal planning and development, were made during the following 60 years (Scott, 1998). It was only at the end of the 1960s and during the 1970s, that public awareness of environmental issues led to a sudden increase in programs and publications on environmental/urban geology. This sudden awareness of the importance of earth sciences in environmental planning was summarized in a presentation by J.E. Harrison at the 28th Canadian Geotechnical Conference, in 1975: "Had I been writing this introduction 4 or 5 years ago I would have spent several paragraphs justifying the role of geology in urban planning. Today, with McHarg's *Design with Nature* (1969) 6 years old and Legget's *Cities and Geology* (1973) enjoying wide circulation, there is a growing acceptance of the philosophy that an understanding of the materials and processes of the natural environment is the starting point for good urban planning."

Despite the perceived acceptance of the role of earth sciences in urban planning, Mathewson and Font (1974) showed that basic earth science was more often ignored than used in the planning process. The reasons for not using earth science data were identified as: the required information did not exist, the access to it was difficult, and the information was not in a form compatible to the user's need. In response to these information needs, the Geological Survey of Canada (GSC) initiated, in 1970, a project to develop a computerized system to facilitate the compilation, processing and display of earth science information, and to provide planners, engineers and administrators with geoscience information required for the orderly and efficient development of urban centres (Bélanger and Harrison, 1980). The Urban Geology Automated Information System (UGAIS) (Bélanger, 1975a,b) was used in 1971-1972 to compile more than 110,000 engineering drill hole records for 26 major urban centres in Canada (Scott, 1998). The Regional Geoscience Information: Ottawa-Hull report (Bélanger and Harrison, 1980) and accompanying maps were used extensively in the National Capital area, but the electronic data bases of the UGAIS that were sent to the other cities and provinces were used only marginally, due to the difficulties of processing computer files at that time (Bélanger, 1998).

The arrival of personal computers, and the rapid evolution of hardware and software in the 1980s and 1990s completely changed the approach for compiling, processing and releasing geoscience information, and contributed to a revival of urban geology initiatives. In the early 1990s, in response to concerns expressed by the Canadian public regarding environmental problems, the GSC was asked to increase its activities and collaborate with the provinces on projects concerning environmental geology issues. One of the requests voiced by local governments and the private sector was for the updating of the geoscience data base of the National Capital area. By the time a new urban geology project was launched in 1993, the GSC had already automated its map production through the use of Geographic Information Systems (GIS), and most data sets were available in digital format. Similarly, following a trend observed throughout the world (deMulder,1990), many of the regional and municipal administrations of Canada were making use of automated systems to store and retrieve information for planning purposes.

A recent survey of the 27 data bases compiled by the GSC in 1972 showed that:

- Four data bases are maintained locally (Kitchener-Waterloo, Toronto, Montreal and St. John's).
- Four data bases were transformed to PC-compatible formats and re-released by the GSC (Vancouver, Winnipeg, Hamilton, and Ottawa), and these data bases will be available on the Internet through the GSC Web site.
- All the Ontario data bases were transformed to a PC-compatible format and the originals are kept by the Ontario Geological Survey (OGS) (Thunder Bay, Sault Ste. Marie, Sudbury, Windsor, London, St. Catharines-Niagara, and Oshawa).
- Seven data bases are still available on microfiche at the GSC (Edmonton, Calgary, Regina, Chicoutimi, Fredericton, Halifax and Moncton). Plans are to enter the information on computer and release the data bases on the Internet.
- The five remaining data bases are not readily available (Victoria, Trois-Rivières, Shawinigan, Sherbrooke and Saint John): of those data bases, only the Victoria one was reported as existing in archives.

In order to assess the need for a new urban geology project and evaluate its impact from the user's perspective, Natural Resources Canada decided to consult various groups of people who could be possible users of geoscience information. The project was first discussed at a user's forum, held prior to the launch of the project. As a follow-up to a recommendation from an evaluation of the GSC programs by the Audit and Evaluation Branch(AEB) of Natural Resources Canada, the project was also selected as a subject of an evaluation study on the use and value of geoscience information, based on extensive interviews with a wide range of users of geological information. The use and value of urban geology in Canada presented here is based on feedback obtained from these two consultations.

THE USER FORUM

Since the release of the Regional Geoscience Information: Ottawa-Hull report and data base for the Ottawa-Hull project (Bélanger and Harrison, 1976 and 1980), the GSC has continued to receive feedback from engineering firms, local governments, environmental groups, and individuals, underlining the usefulness of the report and the necessity of updating the data base. These users deplored the fact that the report went out of print within only a few months of its release. The wide acceptance of the urban geology report indicated that there was a need for geoscience information not only for regional planning purposes, but also to serve as background information for private firms when planning engineering works or conducting environmental impact studies.

In March 1994, before going ahead with the update of the regional geoscience data base and maps of the Ottawa-Hull region, the GSC invited 35 representatives from geoscience consulting companies, local and regional municipalities, provincial and federal governments, and universities to discuss the needs for a new urban geology project and the type of information required by users. The participants were divided into discussion groups and, with the help of facilitators, were asked to provide feedback on the following points:

1. What role should the Geological Survey of Canada play in urban geology?
2. Does the Ottawa-Hull urban geology project respond to a need?
3. Who are the users of earth science data, generated by the Ottawa-Hull urban geology project?
4. Is the type of information provided by the GSC adequate?
5. Are the limits of the proposed Ottawa-Hull study area adequate?
6. Data base:
   - What type of information should the urban geology data base contain?
   - Are the sources of information adequate?
   - What should be the format of the data base?
   - Should the data base be updated?
   - What should be the role of the GSC?
   - How should the data base be released?
7. Maps:
   - Are the legends of bedrock and surficial geology maps adequate?
   - Should the GSC produce derived, integrated or other types of maps?
   - Should the maps be released on paper, in digital format or both?
   - If digital, what format?
8. Should the GSC be involved in hydrogeology studies in urbanized areas?
9. Is there a need for any other type of documents?

The opinions expressed in each group at the user forum were compiled and summarized as follows:

The Need for an Urban Geology Project

- Geoscience information forms the

basis for regional planning, zoning and regulations by the various levels of government. Geoscience information is also required in environmental studies such as waste management, development of regional infrastructure, inventory of natural resources, hydrology, and geological hazards.

• An urban geology project would provide the opportunity to compile all the geoscience information available for the National Capital region and release the information in a standard format that could be accessible by all users, including the private sector, the various levels of governments, universities, and the general public.

The Role of the GSC

• The GSC should co-ordinate the urban geology project, but there should be co-operation with other governments (regional, provincial, federal) and the private sector to avoid duplication, and to arrive at a consensus on the standardization of formats and type of information.

• The private firms and local governments do not have the resources to enter the geoscience information into computers, but they would like to participate in the project by providing all their data, if the GSC is able to compile the information and serve as the main repository for the geoscience data base.

• The GSC should publicize the Ottawa-Hull urban geology project by informing the private sector, governments, and the general public in order to promote co-operation and generate interest in the project.

Type of Information Required

• The Ottawa-Hull urban geology project should compile and release all the available information for the area. This includes the nature, thickness and properties of the bedrock and surficial materials, aquifers, geochemistry and geotechnical properties of materials.

• There is a need for site-specific information such as stratigraphic logs from drill holes and regional compilations such as bedrock and surficial geology maps. Documents and maps derived from the geoscience data base are also required, such as drift thickness, bedrock topography and stratigraphic cross sections. Ideally, the project should provide 3-D models of the regional geology.

• The data base containing borehole information should be released in digital form, on PC-compatible diskettes or CDs, in a format as universal as possible. Maps and regional compilations should be available in digital form, with the possibility of producing print copies on demand.

• Users, including governments and private firms, want information as detailed and specific as possible and at a scale as large as possible, mainly for surficial materials. The GSC would not compete with private firms when releasing detailed site-specific information, as the purpose of each type of document is different. The information released by the GSC is meant to serve as background information and must not replace engineering testings, which carry legal implications.

Compilation and Distribution Procedure

• Most of the existing private engineering files are manual and the firms do not have the resources to enter the data in computers, especially backlog information. The engineering firms would welcome GSC personnel to compile their reports into digital format. As an incentive, the GSC would give a computerized copy of the consultant's data base in digital format to the consultants.

• The data base should indicate only the generic provenance of the information contained in the data base to protect the agency providing the data, unless specified otherwise by the provider.

• All the documents produced by the Ottawa-Hull urban geology project should be released to the general public. The fees for the publications should not be prohibitive and should be proportionate to the disbursement incurred by the GSC.

EVALUATION STUDY BY NATURAL RESOURCES CANADA

In 1995, as part of an examination of the impact of all GSC programs, GSC work in urban geology was made the subject of an evaluation study. The study was directed by the Audit and Evaluation Branch (AEB) of Natural Resources Canada, whose responsibilities include examination of departmental programs and evaluation of their continued relevance, cost-effectiveness, impacts, and success in meeting departmental objectives. The AEB, in consultation with the GSC, decided to follow a case study approach and selected the area covered by the GSC's Ottawa-Hull urban geology project (Fig. 1). More specifically, its objective was to "examine the use and value of the basic types of geological mapping products in the urban-regional planning and development process as exemplified in the eastern Ontario-western Quebec area" (Moore, 1998). The study was intended to address not only NRCan concerns but also many of the design concerns and objectives of those managing the Ottawa-Hull urban geology project as well.

The evaluation study was carried out in two parts. The first developed a broad overview of the use of these maps and data through interviews with those involved in the geological and technical aspects of urban-regional development: included were GSC and academic geoscientists and engineers, geotechnical/environmental consultants, and a literature review. The second part of the study was a more detailed examination of the use of geoscientific maps and data by the more intensive users of this information, and was based on interviews of 12 geotechnical and environmental engineering consulting firms in eastern Ontario-western Quebec. Findings of the second part are given in the next section. The complete report can be obtained from the Audit and Evaluation Branch, Natural Resources Canada (Moore, 1998).

GEOSCIENCE MAPS AND DATA

The original intent of the evaluation study was to examine the use of the maps and data contained in the standard GSC reference source for the National Capital Region, *Regional Geoscience Information: Ottawa-Hull* (Bélanger and Harrison, 1980), which contains a series of surficial and bedrock geological maps and related data files. This material has been entered into digital format. After several interviews it became readily apparent, however, that the range of materials covered would have to be extended.

Analysis of the relative importance of sources was complicated not only by the wider than expected range of source materials used, but also because these maps were frequently highly interrelated. Current federal and provincial geological mapping products were often found to be interdependent in origin and content, being based on earlier geological maps and studies. Furthermore, maps produced by other natural resource mapping agencies, such as maps produced by soil surveys and forestry agencies, were frequently derived in part from geological maps. Thus, unravelling the lines of attribution to a particular piece of geoscience work could prove quite a complex task.

USERS OF GEOLOGICAL INFORMATION

The survey demonstrated that the direct users of geoscience information were divided among:

- The three levels of government that are responsible for managing or conducting research on natural resources.
- The geotechnical and environmental consulting firms that serve them directly or indirectly (through the civil engineering firms who design major facilities).
- Educational and research bodies, especially universities.

The most intensive direct users were the consulting firms. Local governments were more often indirect users because they did not possess the technical expertise and rely on the consulting firms for these needs.

There were also users of products derived from geoscience maps and data. These derived products included soils surveys, forestry research, land management, and land use and zoning maps used by urban and regional planners and private developers. This category of users was not interviewed. A study of the use of soil survey maps in Ontario demonstrated the potentially great impact of these derived products (Acton *et al.*, 1986).

PURPOSES FOR USE

Preliminary Project Planning

For many, if not most, geotechnical and environmental consulting firms, geoscience documents provide the major source material for preliminary project design work. Firms use these maps to determine the type of field work required for a particular project or study, *e.g.*, frequency and depth of drilling, other soil or water samples to be collected and the types of analyses needed, likely types of construction methods or precautions, construction materials and structures suitable for the site conditions. Their role in estimating work requirements for geotechnical and environmental consulting contract bids can be the critical difference in completing a project within estimated cost and time, or not. As an example, a depth of drift map indicates the depth of drilling required to reach bedrock. Since drilling is expensive, an underestimate of depth would lead to cost overruns and losses for the contractor. Many firms could not conceive of conducting their work without referring to GSC or OGS geological maps.

Geotechnical Engineering for Public Systems and Major Facilities

Geological maps have been found most helpful for geotechnical and design engineering purposes where only generalized regional geological information is required. Location selection studies for either sites or routes for public activities or major private facilities are probably the most important category of application. In these cases, typically geological and other geographic criteria are established to screen the region for possible sites by eliminating those that do not meet the selection criteria.

Examples of this application include:

- Locating a landfill facility

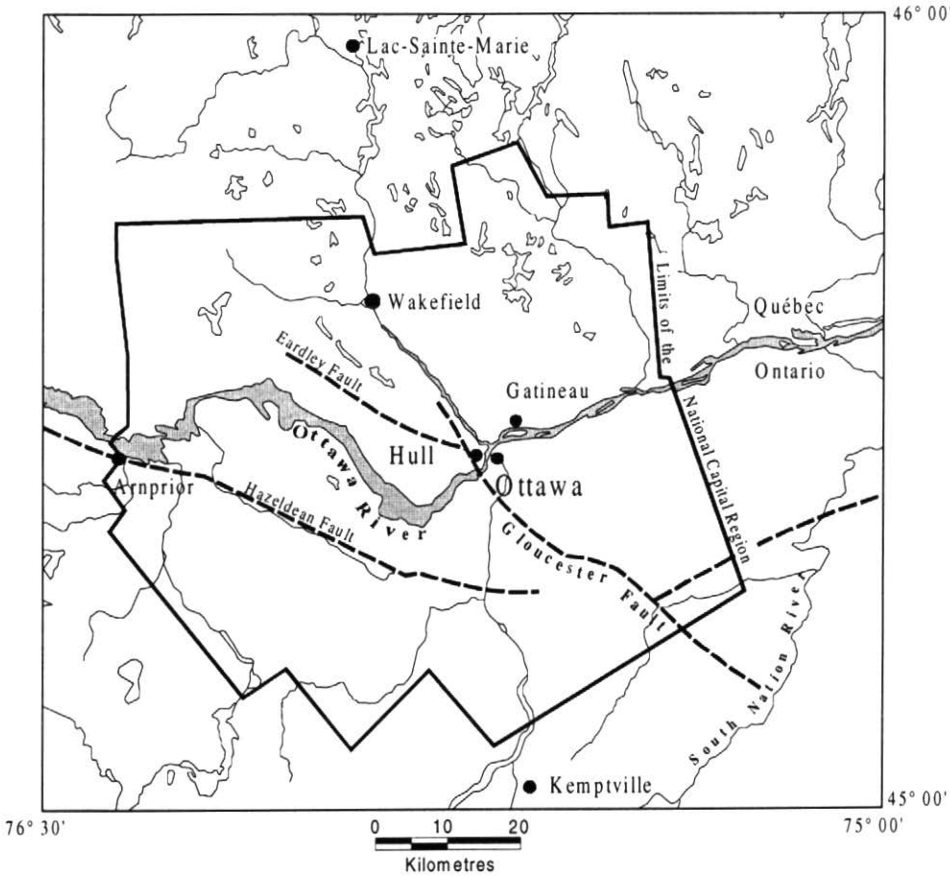

Figure 1 Extent of theOttawa-Hull urban geology project.

- Budgeting for municipal water system maintenance
- Research on a city water supply system
- Estimating costs for conducting a water system maintenance program
- Establishing accurate cost estimates for engineering work and ensuring satisfactory engineering design.

In the case of the water system research, the National Research Council (NRC) used the GSC's surficial maps in locating a geological environment suitable for studying the effects on city water pipes that had been buried in clays containing salt water. The objective of the NRC research project was to determine a means of detecting and reducing corrosion damage of water pipes.

Environmental Impact Assessment and Related Public Health Planning

Recently, geoscience maps have found increasing applications in remedial work related to public safety and public health. They are a primary source of information required for determining the appropriate course of action when toxic chemicals such as chlorinated or hydrocarbon compounds have spilled and possibly leached into the ground and entered the ground water. The presence of clays can reduce the risk of ground water pollution, while permeable deposits can require major remedial work. Environment-related work has risen from negligible levels 12 years ago to constitute an estimated 50% of the local consulting industry's business today.

Public Safety Hazard-Related Planning

Geoscience maps have also been used in studies related to public safety hazards. It is critical to understand ground stability, and geoscience maps can provide information on the geological materials, their history, and their properties. This aspect is particularly important in the Ottawa-Hull study area owing to the presence of sensitive marine clays that are susceptible to landslides and differential settlement.

Another example is the potential risks related to earthquakes. The amount of damage from earthquakes commonly is dependent on local geological conditions. Seismic risk can be established for an area, but the effect of a seismic disturbance will vary with specific surface and bedrock materials. Insurance companies have recently contracted geoscience consultants to conduct studies to establish the relative risk to specific areas by combining information from surficial and bedrock maps with information on seismic activity. This information, together with information on structures, is critical in establishing reasonable insurance rates (Risk Management Solutions, 1995).

An Information Infrastructure for Public Good Planning

Public agencies are extremely reliant on geological maps for major land use, public facility, and route selection decisions. They need comprehensive coverage of a wide variety of geological information for established and sometimes unexpected purposes related to the public good. Public agencies seek to provide an infrastructure of knowledge critical to adequately manage the natural resources in a region, to protect public health and safety, and to facilitate the more efficient functioning of the economy.

As a form of capital investment, geological maps enable useful studies to be conducted at far less cost than otherwise. In fact some important studies could not be conducted at all were it not for the existence of geological maps. A case in point is the study of aggregate resources in Regional Municipality of Ottawa-Carleton, in which it was estimated that the costs would have tripled without the publicly available geological maps. If the maps had been in digital format, time requirements and costs would have been further reduced.

A Multi-Disciplinary Research Tool and Field Reference Guide

Geological maps are also used as a reference guide in field work, not only for updating maps and understanding the geological characteristics of an area, but for correlative work in related disciplines, *e.g.*, for conducting soil surveys, forest management and research projects on ecology, and other studies of the natural environment. Because surficial and bedrock geology provide both the foundation material of which the natural environment is composed and the basic framework on which the natural environment is built, they have proven to be particularly useful in natural environment management and research studies.

A number of users estimated that the GSC surficial geology maps in the Ottawa-Carleton area reduced the time required for soil surveys by 1 year, or approximately 15% of the cost of producing a map. Surficial geology has been used by Ontario government forestry researchers in defining forest management regions, and as an explanatory variable in predicting the likelihood of forest fires.

An Accepted Authoritative Standard

The overriding reason given for the wide use of geological maps was that they provided a consistent and dependable context within which to conduct and guide work. The use of the same or a similar legend and classification system for large geographic areas was mentioned by many as a deciding factor in selecting a particular map or map series for use. It should be noted that these maps also provide a useful and especially authoritative standard that can be, and often is, included in submissions to regulatory agencies and as evidence in court cases.

MONETARY BENEFITS FROM THE USE OF GEOLOGICAL INFORMATION

General Considerations in the Measurement of Benefits

Attributing monetary value to the use of geoscience products presents many challenges. Most applications require a large consideration for the public good or general welfare of society particularly, protection of public health and safety through regulatory controls over building and pipeline construction, provision of public services such as highway transportation, and use of crown land and resources for the long-term value to society. Establishing value for these public uses of geoscience information is not straightforward, requiring many assumptions. The estimates obtained thus can be controversial. However, a reasonable and conservative approach to valuation was taken, and thus the valuation provides a useful perspective on the benefits actually received from use of these maps.

It is important to take a longer-term perspective in identifying the benefits of geological maps. Specific applications of the maps will vary with the public concerns or tasks at a point in time. A shorter-term perspective would miss some important applications.

Estimated Value of Benefits

Estimates of the value of using geological maps and data are divided into firmer, direct benefits, and indirect or derived benefits. The estimates of direct benefits are based on the opinions of the users of the geological information materials. The number of those interviewed for the eastern Ontario-western Quebec study area was not large but constituted a high percentage of the total population of users, especially after weighting the responses by the volume of work undertaken by their organizations. Most of the larger consulting firms were covered, as well as a cross section of the smaller firms. This means that there was at least a 67% to 75% coverage of the volume of business. Estimates of time and cost savings were very similar for both private firms and public agencies.

Estimates given to this study on the annual volume of geoscience-related contract business undertaken in the study area of eastern Ontario-western Quebec varied widely; however, estimates made by some of the larger consulting firms place the figure for geotechnical engineering, land use planning, and environmental impact type work at \$50-\$60M per year. This includes most but not all of the work contracted by public agencies, since they conduct little engineering and planning work themselves; however, the value of the work conducted by public agency staff is so small that it would serve to firm up the upper limit of the estimated range.

Direct Benefits: Engineering Design and Planning Applications

The direct or operational benefits of using publicly available geoscience materials in civil/environmental engineering design and planning study work were estimated by many private and public sector users to have reduced the costs of completing their tasks by 5% to 20%. In the case of geotechnical/environmental engineering and planning firms, that estimate translates into a savings of \$2.5M (*i.e.*, .05 x \$50M) to \$12.0 (*i.e.*, .20 x \$60M) per year for the study area. In the case of planning, design and maintenance work undertaken by municipal and other governmental resource agencies in forestry and agriculture and management of aggregate resources for highway departments, similar rates of operational savings were estimated. Direct or operational savings are more likely to be in the range of \$1-\$1.5M per year, with major projects (*e.g.*, transportation systems planning) bringing the figure to the higher level in particular years.

These figures include a wide range of uses from project cost estimation, planning of field work/determination of appropriate tests, to site or route selection. They are all exercises that can be based largely on existing geoscience maps and data bases. It was difficult to distinguish the estimated benefits between these different applications, which could vary from project to project.

Table 1 presents six examples of savings and other benefits provided by the use of geoscience information in the eastern Ontario-western Quebec study area. These examples came from interviews with those involved in carrying out specific projects.

Derived or Indirect Benefits: Land Use Controls and Construction

Monetary benefits derived from the results of civil/environmental engineering design and regulatory work (*e.g.*, the construction of highways, facilities, land use, and public servicing) should also be included. While these benefits are typically only partly attributable to the use of the public geoscience information, they are considerable. An aggregate benefit figure would be difficult to establish, but an order of magnitude can be estimated from a series of examples.

- The cost of damage that can be related to geological characteristics or conditions of a site frequently exceeds millions of dollars. Several examples of remedial work costing several tens of thousands of dollars were recorded during the evaluation study.
- There are also real-time benefits in the ability to quickly survey and locate other areas of risk once an emergency such as a pipeline break, explosion or landslide has occurred. Speed can be critical in lessening or eliminating damage in these other locations of risk, *e.g.*, along natural gas, water and sewer pipelines, highways, railways, aquifers *etc.*
- Many of the benefits of the use of geological maps and data bases are realized through the land use/environmental controls and building codes used by public agencies for the protection and general welfare of society. The published geoscience resources are almost indispensable to these applications. They are virtually the only source of any reliable generalized information on hydrogeology, building site stability, and other information on the location and characteristics of surface materials and bedrock so important in determining appropriate land uses. The maps also have value as standards for reference in regulatory submissions and hearings, *e.g.*, natural gas pipeline submissions.
- The determination of the magnitude of all of the benefits that can be attributed to the use of geological maps and data bases rests on the ability to construct likely alternative courses of action in their absence. Some users stated that they would have gone ahead without GSC maps, using their background understanding, and accepting the risks involved. Given the magnitude of these known losses and risks involved, even at a conservatively estimated 1% level of attribution, the geoscience information would enable hundreds of thousands of dollars of savings per year.
- There is also an all-pervasive and even more elusive application for these geoscience materials: their educational use. The economic benefits of these applications have not been separated from the others already estimated. They would, however, serve to strengthen the estimates.

SURVEY OF PRIVATE CONSULTING COMPANIES

Once the overview was established during the first part of the evaluation study, the second step in the study was a more systematic and detailed examination of the use of geoscientific maps and data by the more intensive users of this information, the geotechnical and environmental engineering consulting industry of eastern Ontario-western Quebec. This was accomplished through a structured survey of 12 geotechnical and environmental engineering firms in the region. The survey was conducted *via* face-to-face and telephone interviews based on an interview guide.

The 12 companies reported a total of approximately 304 employees. They estimated their total volume of business at \$21.5M per year, of which approximately \$18M was for work in the three categories covered by the study: land use planning and regulation-related work; design and engineering work; and environment-related work. These firms conducted approximately 3430 projects

Table 1 Examples of economic impacts from use of GSC-OGS geoscientific information.

PROJECT	Purposes & Applications of Geoscientific Information	Costs for Engineering/Surveying/Planning or Design Projects			Related Construction Costs	Indirect Benefits or Savings Identified
		Geotechnical & Envr. Part	Est. Direct Savings (%)	Project Total		
1. A City Water and Sewer System: Geotechnical Design	identification of design restrictions imposed by surficial materials	$100k	$25k @ 20%	$100k	$3M	$100k for a less costly design concept
2. Transitway West extension	environmental impact, depth to bedrock, surficial materials & their physical/chemical qualities	$1.2M	$100k @ 50%	$3.7M	$30M	basis for sounder & more stable design; protection of aquifers & soil
Transitway to 1995		$15M est.	$750k @ 5%	$45M est.	$372M	
3. Soil Surveys in Eastern Ontario	identifying parent materials for mapping soil classes	$500k	$100k @ 20%	$500k	n/a	better basis for land use restirctions/ authority for real estate value
4. Aggregate Mapping in Eastern Ontario	distribution and qualities of aggregate	$10-20k	$20-40k @ 66%	$10-20k	n/a	better basis for land/resource use restrictions
5. South Nation River Land Slide Study	establishment of site risks for landslides	$5-10k	$5-10k @ 50%	$5-10k	n/a	$13M damage from last landslide
6. Solid Waste Disposal Site Selection Study	elimination of geologically unsuitable areas	$18k	$12k @ 66%	$250k	not known	protection of aquifers & soil

per year, of which 2850 were in the three selected categories of work.

Estimates provided by individual companies for total consulting fees or contracts for geotechnical, environmental assessment and environmental geoscience-related consulting work in the eastern Ontario and western Quebec region varied widely; however, they supported an overall estimate of approximately $50 to $60 million for all geotechnical and environmental work in the entire geographical region.

As a means of determining the relative importance or usefulness of particular items of geological information to the users, a rating scale was developed by averaging the ratings of individual companies. A numerical score was assigned to each user's response as follows:

- very important/very useful 3
- important/useful 2
- less important/less useful 1
- not important/not useful 0

Overall Importance of Urban Geology Maps and Data Bases

The importance of urban geology information for each of the three major categories of work was rated between "important" and "very important," with scores of 2.2 for land use planning and regulation-related work; 2.1 for design and engineering work; and 2.4 for environment-related work.

Use of Urban Geology Maps and Data Bases

The most useful GSC products, in the opinions of the 12 participating companies, are surficial geology maps at scale 1:125,000 and 1:50,000 (scores 2.1 and 2.8, respectively), bedrock geology maps (score 2.4), and drift thickness trend maps at 1:50,000 (score 2.2). The scores for the surficial geology and drift thickness trend maps indicate that maps of scale 1:50,000 are more useful than those at 1:125,000. Only one company out of the 12 interviewed was using digital versions of the existing maps.

The lack of familiarity with certain GSC products, expressed by one-third of companies interviewed, suggests that GSC could improve its marketing and promotion of urban geology products, and also notify companies of the existence of its web site.

In terms of other urban geology products, most companies used various products from the Ontario Geological Survey and found them "useful." Other products widely used are air photographs (both federal and provincial) and provincial water-well records.

Geoscience Information Purposes

Among a number of identified purposes, GSC products were considered most useful for initial orientation and screening (score 2.4), conceptual understanding (score 2.3), and selection of methodology or techniques required for field work (score 2.2). This rating order was confirmed by a direct question on the most important use.

All companies agreed that interaction with the organization that provided the maps is not normally necessary during a project.

Role of the GSC, Its Products and Services

Eleven companies considered the GSC's contribution to urban geology information in the Ottawa Valley region to be "important" or "very important." One company indicated that it had used the GSC in the past (for consultation or services), "for solutions to specific/unique/uncommon problems." Nine companies indicated that the fact that a product or service came from the GSC made a difference because of its name, reputation or standard.

In terms of the consequences of the unavailability of GSC maps or data bases, eight out of 12 companies indicated that they would have gone to another source of existing information as a first option. Three others would have relied much more on their own company's maps, data bases and files from other projects. Several companies noted that, in the absence of GSC mapping, they would put more emphasis on organizing internal company data from previous projects.

All companies indicated that these alternatives to the existence and use of GSC maps would result in an increase in their costs. There would be increases in costs to prepare proposals, and increases in project costs. These additional project costs would be passed on to their clients.

Respondents felt that GSC urban geology maps increased competition in the consulting industry by creating a level playing field, since the information is available to everybody. They did not feel that the maps affected profitability, because cost increases for contracts would be passed on to the client. All companies agreed that the GSC information makes it easier to prepare proposals; it improves accuracy and reduces uncertainty in estimating project costs.

In terms of the role that the information plays in the final project results, the consequences depend on the purpose. For site-specific projects, there was general agreement that GSC information plays very little role in the final project results. For regional studies and for site or route selection, however, the information does have an impact on final project results.

User Opinions of the GSC's Ottawa Valley Urban Geology Project

Most companies thought that it would be worthwhile for the GSC to convert its products to digital format, and to add new drill hole data as it becomes available.

Most companies expressed satisfaction with the timing of release of information, the level of detail of information, the level of consultation, and their strength of relationship with the GSC.

Among the new products planned for the Ottawa Valley region, the *engineering data base* was considered the most useful new product (score 2.8), followed by *surficial geology* maps at 1:50,000 (score 2.6), *hydrogeology* maps(score 2.5), *drift thickness trend* maps at 1:50,000 (score 2.3), and *bedrock topography* maps at 1:50,000 (score 2.3). Products considered the least useful were *drainage basin* maps (score 0.9), and *hazards* maps (score 1.0).

All companies responded that it would be useful to preview these products on the Internet prior to ordering. Concerning the medium for distribution of these products, paper and CD-ROM were considered essential media. Only one company selected diskette as a preferred medium.

Asked what should the GSC's role be in urban geology, most companies felt that the GSC should continue with the role that it is currently playing; that is, as one company described, to provide base information on the geology of the area, and to identify problems that companies are likely to encounter.

SUMMARY AND CONCLUSIONS

Both the user forum on the urban geology project and the later evaluation study on its impact have brought about a better understanding of the needs of users of geoscience information, and helped to clarify the importance and role of the GSC-produced geoscience information in environmental studies. The user forum revealed extensive uses for geoscience information, and a broad client base, encompassing five major user groups (governments, private consultants, environmentalists, academe, and the general public), with applications going far beyond the original objective of providing geoscience information for government land use planning purposes, zoning and regulation. Geoscience information is now used extensively in the National Capital area for environmental impact studies related to waste management, development of regional infrastructure, tapping of natural resources, and geological hazards.

The user forum demonstrated that the private sector welcomes site-specific information and regional compilations published at the largest possible scale. Consulting companies do not see the release of site-specific data by the GSC as being in competition with them. They consider GSC publications to be background information and not replacements for engineering testing or other specific types of environmental studies, which may carry legal implications.

The evaluation study on the applications of geoscience maps and data in an urban-regional development context demonstrates well the value of these maps and data bases, confirming the role of government in their production and the fact that these geoscience maps and data are well worth their costs. Primarily the maps save time in the design phase of projects or for land use-related planning or research projects where only generalized information is required. This can result in substantial savings in that the design phase is less expensive and the project can be completed sooner. Earlier completion can mean earlier use of the facility and therefore earlier returns from it, for example, transportation cost savings, income from sales or production or services. Secondarily, the use of the maps can also reduce the risk of error in work undertaken by keeping plans and designs within the geological-environmental constraints.

The maps provide frameworks for many types of work. The multiple applications cannot always be foreseen: for example, the now extensive use in environmental impact work. The fact that geology is the foundation on which and in which the natural and human systems operate gives the geological maps potentially broad applications and long shelf lives. Recent advances in GIS technology increase the possible range of applications largely because they are now technically and financially more feasible. In this light the study noted the potential for increased co-operative and collaborative work in future with those who have not traditionally been users of geological maps. Geological maps can now be simplified or tailored to the requirements of those working outside the geoscience area.

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