CANADIAN GEOSCIENCE COUNCIL

Report of the Review Committee on the Minerals Geoscience Program of the Geological Survey of Canada

submitted by

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Executive Summary

0.1. Introduction

This report presents the findings of an external Review Committee that investigated the Minerals Geoscience Program (MGP) at the Geological Survey of Canada (GSC) between July 1999 and February 2000. The members of the committee were selected by the Canadian Geoscience Council, in collaboration with the GSC. The committee was asked to conduct an overview of scientific activities, assess the adequacy of publications and research infrastructure, examine how research projects are planned and implemented, and provide its ideas on future initiatives and opportunities.

The MGP has the main responsibility within the GSC for conducting minerals research and providing minerals advice to the federal government. The GSC, which is Canada's oldest scientific organization, grew rapidly after World War Two and reached its peak in size, energy and influence in the mid-1980's. During the last six years, however, the GSC has suffered a 32% decline in funding and funding for the MGP has been cut by almost 50%. The reasons for this sharp downsizing are varied and include government-wide policies, such as Program Review and a new federal science policy, a major departmental reorganization, and the termination of the federal-provincial Mineral Development Agreements program. The GSC has adopted a range of measures to lessen the impact but the result of this sharp cutback in funding has been a serious decline in the amount of scientific research being performed.

The Review Committee reviewed the policy trail that defines the responsibility for the GSC, in general, and the MGP, in particular. Despite recent departmental and sectoral policy documents that are so broad and general that they no longer specify a minerals geoscience function, it is clear to the committee that the GSC retains both a statutory and policy imperative for a strong minerals geoscience program.

The Review Committee believes that redirection and rebuilding of the MGP is necessary, as a consequence of the reductions, if the GSC is to continue to make a meaningful contribution to the health of the Canadian minerals industry. This rebuilding will be difficult without additional funding. In addition to more funding, the Review Committee believes that a viable and strong MGP must be rebuilt through enhanced integration and synergy with other GSC programs, notably the Bedrock Geoscience (Mapping) and the Surficial Geoscience (Mapping) Programs. It is the Review Committee's view that future projects to address minerals objectives should be multidisciplinary and draw on relevant expertise across the existing Divisions in GSC. Much of the focus of this report is aimed at defining appropriate priorities for the MGP and identifying ways in which the GSC and the MGP can best implement change in order to continue to fulfill an important national function.

0.2. Overview of Scientific Activities

The GSC is part of the Earth Sciences Sector (ESS) of the Department of Natural Resources (NRCan). The MGP is the part of the GSC that is focused on Canada's non-hydrocarbon mineral

resources. It is delivered dominantly by scientists in the Mineral Resources Division although scientists in three other divisions also contribute to the program. The stated goals are:

- to assist the minerals industry to sustain employment and prosperous mining communities;
- to provide the federal government with required geoscience information for policy formulation and implementation; and
- to promote the international technological capability of the exploration services industry.

The key strategies within the MGP for pursuing these goals are:

- Mineral Deposit Research
- Mineral Resource Assessment
- Mineral Exploration Research
- Mineralogy and Chemistry Laboratories
- International Projects

Project selection has been largely proposal-driven and will become even more so under a new Proposal Driven System (PDS) that is currently being instituted. The PDS is viewed by the committee as a necessary step in achieving the operational changes required to refocus the GSC programs, align them with corporate strategic priorities, and match the funding available. Those changes are discussed later in this summary.

The MGP is divided into four subprograms, which are closely aligned with the key strategies above. Elements of the subprograms, comprising projects or groups of projects, encompass a range of projects and scientific activities. Approximately 30 active subprogram elements, including laboratories, have been designated as contributing to the MGP. Because of the budget cutbacks, the MGP has been left with more ongoing projects than it can fund or adequately support. One of the tasks faced by the Review Committee has been to review these projects and activities, and to evaluate and rank them according to a standard set of criteria. The Review Committee found that, for the purposes of evaluating the scope and relevance of the MGP program, the subprograms were too broad to provide a useful framework at the activity level, while subprogram elements were generally too detailed. For the purposes of documenting and evaluating the types of science activities within the program, the committee identified 20 scientific "program areas" and "activities" that make a similar contribution to the program and the strategic goals and objectives, and that can logically be considered together. Following an assessment of the relevance, uniqueness, current delivery levels, and adequacy of each activity, a priority ranking of activities was carried out by considering three questions about each:

1) Is it a core function of the GSC, as the national geological survey?
2) Can only the GSC do it?
3) Does it contribute to the MGP mission?

The results of this analysis allowed the committee to suggest a relative prioritization of activities currently carried out within the MGP. It felt that this prioritization might provide a useful resource to GSC managers in the event that decisions need to be made about the continuation of various program activities in an environment of reduced funding.

The activities assigned the highest priority by the committee are:

- **Digital databases**, which form the basis of the GSC's knowledge base to meet the present and future needs of its clients. The lack of a systematic system for archiving all data into corporate databases is viewed by the Review Committee as a serious gap.
- **EXTECH-type mineral deposits research**, which has been widely praised because of its collaborative style, its tight management structure and its ability to meet goals in a timely manner, and which has a socio-economic basis through its strong community involvement. The committee has concluded that projects of this type should be encouraged and receive priority funding.
- **Regional geochemical and surficial surveys**, which provide basic data that is highly relevant to a wide variety of users and is becoming increasingly important as environmental baseline information.
- **Regional airborne geophysical surveys**, which are an essential component of modern geoscientific mapping and provide basic regional information. A systematic mapping program is best coordinated under a national program to develop a consistent national database.
- **Regional metallogeny studies**, which provide the basis for assessment of the resource inventory to meet Government needs and stimulate private sector exploration. These are carried out, particularly in the northern territories, in conjunction with regional multidisciplinary mapping projects. The Review Committee is of the opinion that these studies are an essential part of a national minerals program. Their level of activity has declined recently, which is a matter of concern.

The Committee attached a slightly lower priority to the following activities because parts could be performed outside the GSC. However, these are still important components of the MGP mandate:

- **Analytical laboratory services**, which provide high quality, specialized geochemical analyses that most scientists within the survey consider essential for their work. The committee concluded that the laboratories are generally well equipped, but that their operational integrity is being threatened by inadequate levels of technical support and capital replacement. Given the funding shortfall, the committee believes that decisions will have to be made about which analytical services should be maintained, which can be provided by alternative means (e.g., outsourcing, collaboration with universities) and which should be terminated.
- **Thematic mineral deposit studies**, which are very important to Canada at a regional and national scale. The GSC is a recognized world leader in this type of work. However, its capacity to perform this function has been hit hard by downsizing and little or no capability now exists for many deposit types, a matter of particular urgency in the northern territories. Strengthening this activity could play a key role in government efforts to arrest the continuing decline of the Canadian minerals industry.
- **Rock collections**, which comprise the archive of rock and mineral specimens collected during field work, as well as the national meteorite collection. These are an important national resource for future research and reference.
- **International mineral deposit research, and technology and knowledge transfer**, which provide opportunities to apply information gained from overseas research into major ore deposits to Canadian deposits. Overseas projects aimed at supporting export of Canadian

knowledge and technology are consistent with ESS goals, but could be largely performed by the private service sector.

- **Laboratory technology development**, which is focused on new analytical methods to aid in exploration and environmental geochemistry, is considered by the committee to be particularly useful.

Three other activities are considered by the committee to be worthy of continued strong support, but are rated somewhat lower than the others because they are being, or could be, conducted elsewhere in Canada. These are:

- **Genetic mineral deposit research**, which should not be a primary focus of MGP research programs. However, there is a significant opportunity to pursue these investigations as adjunct research to larger multidisciplinary projects that are more closely aligned with strategic priorities.
- **Geochemical and surficial process research**, which consist mainly of drift dispersal studies that are of particular importance in the northern territories.
- **Environmental process research**, an area in which MGP has taken a leadership role in the study of the movement of metals in solution and that is of great importance to other government departments.

The Committee is of the view that several other MGP activities that did not rate as highly in terms of relevance to a national role should either be better integrated into the core program or terminated.

0.3. Publications

The GSC has a well-deserved international reputation for the scientific excellence of its geoscience research, and this is also true of mineral geoscience research. Overall, MGP scientists are highly productive with a publication rate equal to or greater than that of many university departments. To ensure more timely release of information to clients, the GSC is encouraged to speed data dissemination and reduce publication costs by use of modern digital technologies, especially the Internet. Coupled with this is a need to adopt a more corporate approach to data acquired through GSC programs. Specifically, the MGP should develop an explicit policy that all data generated by GSC project work belong to the GSC, ensure that it is all captured in corporate archival databases, and develop procedures to release these corporate databases to the public as soon as is practical after the accuracy of the data has been verified.

The Review Committee found less tangible evidence regarding the relevance of MGP products to its clients. While there is clear evidence of the uptake and application of some GSC outputs, a significant proportion of MGP publications are now in the national and international literature, where their impact and uptake is less certain. Closer attention by the GSC to the needs of its clients and closer monitoring of the uptake and application of its outputs will ensure that the GSC continues to provide a relevant, high-quality program.

0.4. Research Infrastructure

0.4.1. Analytical Laboratories

The mineralogical and geochemical analytical laboratories in the MGP represent a very large component of the MGP budget in terms of salaries (25% of MRD staff) and capital expenditures and operating and maintenance expenses (15% of program resources). The Committee recognizes the importance of the labs to the research projects, but feels that the MGP research program must focus on field-based rather than laboratory-based research.

The MGP laboratories appear to be very comprehensive, well maintained, and generally fully functional. Most are equipped with current, but not state-of-the-art technology (e.g., quadripole ICP-MS vs. magnetic-sector multi-collector ICP-MS). The principal exception is the Sensitive High Resolution Ion Probe (SHRIMP) facility, which is maintained by the Continental Geoscience Division (CGD).

The top priority for analytical activities in the MGP should be to provide specialized services that are not available elsewhere, and that require (further) in-house development and/or a high degree of communication between scientist and analyst, or direct (hands-on) analysis by the scientist (e.g., certain microbeam analytical methods). The GSC should actively seek university partnerships to address cutting-edge analytical needs. Analytical research priorities should be determined in the context of program needs, focusing on collaborative research that is closely aligned with the strategic goals and objectives of the MGP.

0.4.2. Information Technology

The Review committee concluded that computer facilities are generally adequate, but that there appears to be a lack of access to IT support and GIS expertise. In addition, it appears that the need for support in this area is a corporate necessity and not a divisional or program need. The requirements of individual projects should be addressed at the project planning stage.

0.5. Strategic Planning and Management

The GSC is evolving from a project proposal system, driven largely by individual scientists and contained largely within Divisions, to a more open and competitive approach under the new PDS. The Review Committee recommends that the GSC use the implementation of the new system to re-focus the program in a multi-disciplinary and cross-Divisional approach to projects.

The committee strongly recommends, as a matter of urgency, the development of a long-term strategic plan for minerals geoscience in the GSC, based on national needs and priorities. The strategic plan should be used to evaluate *ad hoc* short-term opportunities for collaborative or co-funded research that have the potential to distort and fragment the research effort unless aligned with strategic directions.

The strategic plan should be used as a basis for rationalizing the current program into fewer, better-funded projects with a more balanced ratio of salary to operational funding levels. The GSC should use this opportunity to terminate those projects and activities that do not clearly align with corporate priorities and to capture “stranded assets” resulting from recent downsizing.

Concurrent with the introduction of the new PDS, the Review Committee recommends that GSC review its Divisional organizational structure with the intent of simplifying the management and

reporting structures. Any new management structure should recognize and support the project as the most effective mechanism for delivery of team-based research outputs. The Committee commends the extension of "best practices" observed in some MGP projects to all future projects. These "best practice" characteristics include scoping and planning of projects, especially outputs, in consultation with stakeholders and clients, as well as monitoring, reporting, and evaluation. The GSC should support and encourage the development of team-based, multi-disciplinary research and broaden the current reward/promotion criteria to recognize productivity and excellence in all contributions to the GSC program.

0.5.1. Future Initiatives and Opportunities

The Review Committee believes that the process of change that has taken place in the MGP in recent years is not over and is not reversible. It seems likely that scientists who are able to identify new research opportunities that are aligned with the broader Departmental and Sectoral policies will continue to find new and challenging opportunities for their research. The committee sees future initiatives and challenges in four important areas.

0.5.2. Changing Needs of the Minerals Industry

Canada's share of world production in most metals has been falling steadily for two or three decades and the country has lost its former position as the leading global metal producer. This trend appears to be increasing at an alarming rate because new mines are not being found at a sufficient rate to offset the closure of the major deposits that have sustained the Canadian minerals industry in the past. Increasing levels of Canadian exploration (and development) funds as well as expertise are being directed overseas as Canadian companies have adopted a global approach to exploration and mining. At a time when positive action is needed to reverse these trends, federal policies have resulted in a cutback on the necessary research funds.

There is a need for increased research to support future exploration in areas covered by thick overburden, water, ice or barren rocks. This will require deeper geophysical penetration, more sophisticated geological and geophysical interpretation, a better understanding of glacial and fluvial history, more sensitive geochemical analyses, and improved mineral deposit models. The scientific leadership needed for this effort must, in the committee's view, be fostered at the national level, within the GSC. Regional metallogenic studies, EXTECH-style projects, and northern development will be particularly important in future mineral programs. The northern territories will continue to provide enormous opportunities for new minerals programs within the MGP.

0.5.3. Increased Emphasis on Collaboration

The broad spectrum of knowledge and the multi-disciplinary approach to modern science requires a collaborative approach. Synergies resulting from the melding of diverse areas of expertise have been responsible for significant advances in science. Although collaborative research has always played a role in GSC research programs, it has blossomed in recent years, prompted in part by the need to work jointly with Provincial and Territorial surveys in order to work in their jurisdictions. The Review Committee has concluded that this collaboration with sister surveys, university researchers and industry must increase in order to make better use of the shrinking resources and to capture the best research available.

0.5.4. New and Emerging Technology

The committee sees two areas of clear opportunity presented by new technology. One of these is better analytical capability for an increased range of elements at lower concentrations. New geochemical applications could be particularly significant in, for example, detecting geochemical dispersion in bedrock or the surficial environment, tracing metal transport in the environment, developing sophisticated methods for tracing indicator minerals in surficial materials, and developing more detailed ore deposit models from case studies.

The second area of opportunity is in the field of information technology. The importance of the growth of computers in science cannot be overestimated. Computer technology is constantly providing new opportunities for data accumulation, processing, analysis, visualization, publication, and archiving. There is tremendous opportunity for the MGP to conduct sophisticated data analysis and to incorporate large volumes of related data in ways that are beyond the means of many of their clients.

0.5.5. Applying Existing Skills in New Directions

MGP scientists have expert knowledge and skills that can be applied in areas other than mineral deposit research. The geochemical expertise that is critical for exploring the surficial environment for new mineral deposits can be applied to understanding the environmental effects of metal transport in other areas. The committee feels that application of MGP data to environmental matters will be an increasingly important part of the program. It is critical that good science be brought to bear on the environmental issues raised by metals in the environment and that this science be communicated, not only to the geoscience community, but also to those concerned with public health and safety.

0.6. Summary of Recommendations (numbered as in main text)

0.6.1. Mandate and Resources

1 GSC management should continue to strongly support and promote the national need for a minerals geoscience program at the federal level.

51 The MGP must assume a national leadership role with respect to Canada's mineral deposit science to ensure that the country's mineral endowment is sufficiently well understood to allow successful exploration for the difficult mineral deposit targets that must replace diminishing reserves in the future. New programs should target, in particular, regional metallogenic and thematic studies in the northern territories.

2 The size and impact of the MGP needs to be enhanced through additional funding and/or enhanced integration and synergy with other GSC programs, notably the Bedrock Geoscience (Mapping) and the Surficial Geoscience (Mapping) Programs, and through greater cooperation with Provincial and Territorial geological surveys under the framework of the Intergovernmental Geoscience Accord.

0.6.2. Strategic Planning

36 A long-term strategic MGP plan based on national needs and priorities should be developed as a matter of urgency.

37 The strategic plan, in conjunction with the introduction of the PDS, should drive a cultural change in the GSC that harnesses existing resources to deliver excellent multi-disciplinary and cross-disciplinary scientific research results to meet the changing needs of government, industry and the community.

38 Future projects to address minerals objectives should be multi-disciplinary and draw on relevant expertise from across the existing Divisions in the GSC, and from Provincial and Territorial geological surveys.

39 The MGP should include regional metallogenic studies as an integral component of bedrock mapping programs; and ensure that regional airborne geophysical surveys form an integral part of the regional mapping and metallogenic studies.

49 The MGP should consider using a high-level industry advisory committee, composed of representatives of major and junior companies actively engaged in Canadian exploration, to review and comment on the strategic direction of programs on an annual basis.

0.6.3. Rationalization of Program

41 The strategic plan should be used as a basis for reviewing and rationalizing the current MGP into fewer, better funded projects with a more balanced ratio of salary to operational funding levels. The committee believes that a target salary:operations ratio of less than 70:30 should be sought across the MGP. The rationalization should: a) terminate projects and activities that do not meet strategic directions or are of low priority; b) examine the distribution of expertise between GSC divisions to maximize effective use of resources; c) aggregate small-scale projects with similar objectives into larger projects to take advantage of multi-disciplinary input and synergies of scale; and d) capture any stranded assets resulting from the recent program review and direct them towards project areas where they can make an effective contribution to the program's strategic priorities.

0.6.4. Management

40 In conjunction with the implementation of the new PDS, MRD should review its organizational structure with the intent of simplifying the management and reporting structures. Any new management structure should recognize and support the project as the most effective mechanism for delivery of team-based research outputs.

46 The current communication strategies, both within the MRD and between other GSC divisions contributing to the MGP, should be reviewed to determine if internal communication can be made more effective. In particular, managers should review and, where necessary, improve mechanisms for downward feedback to ensure an effective and transparent flow of information to staff.

47 Strategies such as "Team Briefing" and regular, informal forum-style meetings between the GSC executive and staff should be implemented to provide an opportunity for communication on current issues.

0.6.5. Project Management

43 Scientific project managers should receive better technical and secretarial support for routine functions (financial management, certain reporting, logistics, etc.). This would allow scientists

to focus on the management of the scientific program and to interface with clients and stakeholders. This support could take the form of part-time or shared (across several projects), full-time technical and administrative support directly to major projects. Consideration should be given to whether or not this can be achieved by deployment of staff from central functions to divisions and major projects.

44 The use of "best practice" in project management, including scoping, monitoring, reporting, and evaluation, should be extended to all projects.

0.6.6. Staff Rejuvenation and Promotion

42 The staff rejuvenation program in the MGP should be accelerated urgently through strategic hiring of younger scientists in priority areas.

45 The development of team-based, multi-disciplinary research should be supported and encouraged and the current criteria for promotion and advancement should be expanded to recognize the value placed by the organization on multi-disciplinary teams and productivity and excellence in all contributions to the GSC program.

0.6.7. Databases

14 As part of the corporate information management strategy, the MGP should conduct a review and audit of all data collected by the MGP to determine which data should be stored in structured corporate databases.

15 The MGP should immediately develop and implement structured databases, with consistent standards and structures, within the GSC corporate database framework, and institute a policy and program of corporate archiving and timely public release of all data in these databases.

0.6.8. Information Technology

34 Technical support should be provided on a GSC-wide basis to maintain computing and network hardware, and network and database software to meet project needs. Except where dictated by specific project needs, IT hardware and software should conform to standard GSC-wide minimum specifications and configurations to maximize the efficiency of IT support and ensure compatibility and transfer of information across the GSC.

35 The GIS, database and geomathematical needs of projects should be determined when projects are planned and designed, and adequate specialist and technical support in these areas should be made available from across all GSC divisions.

54 The MGP should continue to look for ways to extract new understanding from existing data through the application of information technology, and should ensure that scientists possess a high degree of computer literacy and are provided with necessary Information Technology support. The GSC should also design and participate in programs that take maximum advantage of this technology.

0.6.9. External Communications

48 The MGP should ensure continuous and comprehensive communication of their program and project plans with the Provinces and Territories in which they occur.

50 The MGP should broaden communication with its clients and stakeholders and undertake evaluation of its major projects. Evaluations should seek feedback and rank the relative importance of types of projects and products to key clients and stakeholders.

0.6.10. Delivery of Outputs

13 The GSC should develop an explicit corporate policy that all data generated by GSC project work belong to the GSC, and should develop a corporate information management strategy that includes a requirement that all data be released to the public as soon as is practical after the accuracy of the data has been verified.

26 The MGP should attempt to speed data dissemination and lower publication costs by releasing open-file information digitally on CD-ROM and by providing databases on an ftp server that is accessible using standard web browsers (e.g., Internet Explorer, Netscape). It should also advertise the availability of new open-file information on an e-mail LIST server.

27 The MGP should regularly undertake market surveys of its clients to gain direct information on the relevance, quality, and timeliness of its publications. In addition, closer monitoring of the uptake through sales figures of its products would provide another useful measure.

0.6.11. Mineral Deposit Studies

16 Metallogenic studies should be significantly increased with a focus on achieving better integration with regional multidisciplinary projects and national thematic databases.

17 Thematic mineral deposits activity should be significantly increased with a focus on achieving better integration with regional multidisciplinary projects and national thematic databases.

18 Mineral deposits scientists should be reassigned where necessary to provide needed metallogenic expertise to regional mapping projects and to ensure that critical gaps in expertise in thematic mineral deposits research are filled.

52 The GSC should seek to expand the capacity of the MGP to meet the increasing demand from industry for more sophisticated geological and exploration models (vs. genetic models) through greater cooperation and sharing of resources with university researchers.

19 Genetic mineral deposit research, which is an important component of MGP activities, should be carried out as a secondary, not primary, focus of mineral deposits research projects. Inquiry into genetic models should not be the principal driver for new mineral deposits research programs.

20 The EXTECH program should be expanded from its present focus on mining camps that are running low on reserves, to former metal-producing camps that have been closed for some time but might contain more deeply buried mineralization, and well-mineralized districts that have never achieved commercial production because of insufficient reserves or inadequate grade.

0.6.12. Research Infrastructure

28 The MGP should review the needs for additional technical staff to ensure efficient and effective operation of those laboratories deemed essential for the support of the scientific program.

29 A strategic capital replacement program for essential laboratory facilities should be designed and implemented to maintain state-of-the-art analytical facilities in support of the GSC core program.

30 A transparent corporate approach to assigning priorities for laboratory access and allocation of analytical resources and services based on the needs of approved projects should be implemented with the specific objective of improving cross-divisional access to all laboratory facilities in the GSC.

31 Simultaneous with a review of required laboratory services across the GSC (see below), the management of and operating arrangements for the laboratories should be reviewed with a view to achieving greater synergy and increasing efficiencies through sharing of facilities and staff resources across divisional boundaries.

32 A review of laboratory needs and management arrangements to support the science program should be undertaken. This review should consider current and future program needs, including analytical methods not currently employed at the GSC. Existing laboratory facilities (and future needs) should be considered in terms of the following categories: a) essential to core MGP programs and must be maintained in-house; b) important to the program but can be contracted out to commercial laboratories; c) important to the program but usage does not warrant in-house capability, and capacity exists at universities or other research agencies through partnership or contract; d) no longer important to the program and/or regularly required and should be terminated.

33 Based on the above analysis, a program of outsourcing of analytical services should be instigated and an outsourcing management plan should be implemented that contains regular monitoring and review of arrangements and quality assurance procedures. This plan should include elements of commercial outsourcing of geochemical analyses as well as building partnerships with research analysts in university laboratories for specialized analytical needs that cannot be met in-house.

53 The GSC should continue to develop and monitor cutting-edge analytical technology and be capable of applying this technology to the practical needs of the program.

0.6.13. Geophysics

5 Support for regional geophysical surveys should be increased to ensure that they are available for strategic deployment in support of regional mapping and metallogeny.

6 Consideration should be given to amalgamating the gamma-ray and magnetic survey groups with a view to providing a strengthened airborne mapping group with responsibility for implementation of airborne geophysical surveys in support of mapping-based minerals programs, and research into data interpretation, visualization, and integration.

7 Research into the application, processing, visualization, and interpretation of magnetic, gravity, and seismic imaging methods for bedrock and surficial geological mapping (including rock property studies), especially into resolving 3D geometry of regions under cover, should be given greater emphasis in future programs.

8 An independent evaluation of the borehole geophysics program should be commissioned in consultation with users to determine the extent to which it still meets the mission of the MGP and the needs of clients, and to allow prioritization of this activity within the MGP.

0.6.14. Regional Geochemistry

9 Regional geochemical and terrain surveys should be maintained at present levels or increased and funding models developed that allow geochemical and terrain surveys to be deployed according to strategic priorities rather than by the availability of outside funding.

10 Research in drift dispersal studies should continue at present levels, and opportunities should be sought for establishing better synergies within the MGP and aligning the work with program priorities.

11 Geochemistry technology development should continue at present levels, but opportunities should be sought for establishing better synergies within the MGP and aligning the work with program priorities.

0.6.15. Environmental Geochemistry

23 The MGP should encourage the collection of geoscientific datasets that serve the dual role of providing environmental baselines and applications for mineral exploration.

24 Environmental process research should be increased because of the growing importance of this field. .

25 A strategic plan should be developed for environmental baseline study and monitoring and environmental research in the context of expressed client needs, and should include aggressive plans to market MGP expertise to regulatory bodies across government.

55 The GSC should expand its environmental programs to take advantage of the expertise that already exists within the MGP in the geochemistry of metals and metal transport mechanisms.

0.6.16. Rock Collections

12 Maintenance of the Survey's rock and mineral collections must continue to be adequately funded to ensure proper archiving and preservation of these valuable national resources.

0.6.17. Geomathematics

3 The geomathematical service activities should be aggressively marketed throughout the MGP, particularly to proponents of new projects in the PDS, and targets for corporate contributions should be set and met.

4 Geomathematical research activities that do not directly contribute to corporate objectives should be curtailed.

0.6.18. International

21 Involvement in international projects should be maintained at their present levels on a full-cost recovery basis.

22 Opportunities for MGP scientists to observe and study mineral deposits abroad for the purpose of acquiring knowledge that can be applied in the Canadian context should be continued, and the knowledge gained though international activity should be transferred to the Provincial/Territorial, industrial, and academic sectors in a timely fashion.

1. Introduction

1.1. Review Committee

In late 1998, the Canadian Geoscience Council was invited by the Assistant Deputy Minister of the *Earth Sciences Sector* (ESS) of *Natural Resources Canada* (NRCan), Dr. M.D. Everell, to review the science-related activities of the *Minerals Geoscience Program* (MGP), part of the *Geological Survey of Canada* (GSC). The review commenced in July 1999 after agreement on the terms of reference and the membership of the Review Committee.

The Review Committee was composed of:

- **Mr. Robert J. Cathro**, P. Eng., retired mineral exploration consultant, Bowen Island, British Columbia. (Chair)
- **Dr. A. Lynton Jaques**, Chief Scientist (Minerals), Minerals Division, Australian Geological Survey Organization, Canberra, Australia
- **Dr. C. Michael Lesher**, Professor of Economic Geology and NSERC Senior Industrial Research Chair in Mineral Exploration Research, Laurentian University, Sudbury, Ontario
- **Dr. H. Scott Swinden**, Executive Director, Minerals & Energy Branch, Nova Scotia Department of Natural Resources, Halifax, Nova Scotia

This report presents the findings, conclusions, and recommendations of the Review Committee.

1.2. Terms of Reference

The Review Committee was specifically asked to:

1) Determine and document the current level and type of **scientific activities** within the MGP.
2) Assess the **relevance and adequacy** of these activities to (a) users in industry, university and government sectors, and (b) the sectoral and department national responsibilities and mandates.
3) Assess the **timeliness, relevance, quality and quantity of publications** arising from the science activities within the MGP.
4) Assess the **range, adequacy and quality of research infrastructure** available to support the science activities within the MGP.
5) Examine the **methods and procedures used in originating, implementing, assigning priorities and managing research projects** within the MGP.
6) Identify **new potential initiatives and opportunities** for the MGP.

1.3. Schedule of Activities

Prior to beginning the review, the GSC provided the Review Committee with background documents outlining the strategic and business plans of the organization and summarizing the

activities, personnel, budget, and structure of the MGP. Following its initial evaluation of this material, the committee prepared a list of questions that was distributed to all the scientists engaged in the program. These questions were intended to provide MGP scientists with a sense of the information that the committee would be seeking and to focus discussion on key issues. The committee also requested that summary descriptions be prepared for each current project in the MGP.

The committee convened in Ottawa from 22 to 27 September 1999, during which time it met on three occasions with the managers of the MGP, conducted interviews with 51 scientists (**Table 1.1**) and inspected some of the laboratory facilities in the GSC headquarters. The committee made it clear during the interviews that it would be pleased to receive written submissions, and detailed responses were subsequently received from 21 scientists.

Table 1.1 Divisional breakdown of scientists who contribute full or part time to the MGP and were interviewed by the Review Committee

Division	Number of Scientists
Mineral Resources Division (MRD)	38
Terrain Sciences Division (TSD)	6
Continental Geoscience Division (CGD)	3
GSC – Québec	4
Total	**51**

Committee members also solicited advice from senior GSC managers as well as scientists and managers in industry, academia, and Provincial and Territorial surveys. All written and oral contributions were accepted on the condition of confidentiality in order to encourage candor.

During its Ottawa visit, the committee learned that the existing project proposal and approval process detailed in the background documents was in the process of being replaced with a new proposal-driven process, known in the GSC as "PDS" for *Proposal Driven System*. This proposal-based research project approval system is aligned with the strategic directions of ESS and NRCan. Part of the formal proposal evaluation process is the use of Prograd™. Both the new and old systems are discussed in **Section 6**.

After the meeting in Ottawa, the Review Committee sought additional information from the GSC to address the Terms of Reference. More meetings were held in Ottawa on 08 (at St. Joe's Confessional) and 09 December 1999, by all committee members except Dr. Jaques, to clarify areas of uncertainty and discuss a preliminary draft of the report with GSC management.

1.4. Structure and Organization of the Report

This report comprises an Executive Summary, which summarizes the report and itemizes the recommendations, an Introductory chapter, which provides some background information, and individual chapters addressing each of the Terms of Reference.

The report was written in Microsoft® Word2000© for Windows98/2000© and is designed to be viewed in Word (*.doc version) or in Internet Explorer *.htm version). All Tables were created as Word tables or are inserted as bitmapped Pictures, not as links to Excel spreadsheets. Depending on how the Word program is configured, some of the tables and figures may only be visible in *Print Layout* or *Web Layout* modes. The Table of Contents and references to Sections, Figures, and Tables in the text (marked in blue bold type) are *hyperlinked* to the corresponding sections of the text. When viewing the document in Word, moving the cursor over hyperlink will change it from an "I" to a pointed hand and clicking the *left* mouse button will move to the corresponding section or table in the text.

1.5. Background

1.5.1. History

Founded in 1842, twenty-five years before Confederation, the GSC is Canada's oldest scientific organization. It was created to conduct a geological survey by the Legislature of the Province of Canada (formed in 1840 by the union of Upper and Lower Canada, roughly those parts of present-day Ontario and Quebec lying within the St. Lawrence-Great Lakes drainage basin). The main objective was to produce "a report of our national wealth and resources" in order to establish a viable mineral industry, a key component of an industrial strategy designed to turn Canada into more than an agricultural colony dependent on exports of lumber and wheat.

The GSC achieved its founding goal in a most remarkable fashion, helping to turn the nation into a major world producer of metals and minerals, and transforming itself into a national geological survey that has been the envy of the world. Throughout its history, the GSC has given the highest priority to identifying, documenting, and contributing to the development of the nation's mineral wealth. In recent years, this responsibility has been carried out mostly within the MGP.

During the period of rapid economic growth that followed World War Two, the GSC's mandate expanded significantly to respond to changing national priorities. Some of the changes that affected the MGP include:

- There was an increase in emphasis on providing scientific information for policy decisions after 1966, when the Department of Mines became part of the new Department of Energy, Mines, and Resources (EMR). Concern about resource adequacy in the late 1960's led to national resource assessments.
- The energy crisis in the early 1970's led to an increased focus on nuclear power and the establishment of a significant effort directed at uranium, including the Uranium Reconnaissance Program.
- As land use became a major policy concern in the late 1970's, the GSC was directed to undertake regional non-renewable resource appraisals in support of aboriginal land claims negotiations and the establishment of new national parks. The latter led to the development of the Mineral and Energy Resource Assessment (MERA) process, which continues to be an important responsibility.
- When regional development became a priority of the federal government in the mid 1970's, the newly created Department of Regional Economic Expansion undertook funding of a number of geoscience activities to stimulate mineral exploration. These programs eventually

evolved into a series of Federal-Provincial Mineral Development Agreements (MDAs), which gave both the GSC and the Provincial surveys the opportunity to hire new expertise in mineral deposits. Between 1984 and 1995, the GSC received about 10 per cent of its budget from MDAs.

Until about 1993, the GSC continued to perform its traditional studies of the national mineral endowment, largely through regional scale mapping, geophysical and geochemical surveys, and research into the metallogeny and origin of Canadian mineral deposits. Much of that research was performed in collaboration with geologists working in the Provincial and Territorial geological surveys, universities and the minerals industry through projects such as the *Exploration Technology* (EXTECH) and *National Mapping* (NATMAP) Programs. Since 1993, however, the federal government has increasingly removed itself from programs related to resources that lie within provincial responsibility, including minerals, and this has led to a significant decline in GSC activities that supply research and information services to the minerals industry. For that reason, this review is most timely.

1.5.2. Recent Program Influences

The last outside review of the entire GSC minerals program occurred in 1984, when the CGC formed a review committee (the Naldrett Committee, of which the current Chair was a member) to investigate the state of mineral deposit research within the GSC. Its report was published as GSC Paper 86-2, Part 2. The Naldrett Committee recommended several ways in which the GSC could better focus its efforts and increase its collaboration with other agencies and industry, many of which were adopted. Subsequently, reviews have been conducted of two components of the MGP: the exploration geochemistry program (published as GSC Paper 91-13) and the geophysics program (published in 1991 as Open File 2366).

The peak budget years occurred in the early 1990s; in 1993, for example, the GSC had a budget of about $110 million. In recent years, however, there has been a severe decline in resources allocated to mineral deposit research and all other mineral-related activities within the GSC, resulting in a significant reduction in the size and nature of the GSC minerals program. Some activities and specialties have all but disappeared. Several seemingly unrelated factors have been blamed:

- **Mineral Development Agreements**: In 1995, the federal government decided not to renew the minerals-related regional development programs with the Provincial and Territorial governments. The MDAs funded 17% of the MGP and 12% of the GSC's mapping activities at the time and their phasing-out had a profound impact on the delivery of the MGP.
- **Program Review**: Also in 1995, the federal government embarked on a thorough review of all programs with a view to reducing the size and cost of government. Because of the demographic profile within MGP and the manner in which it was downsized, which relied more on voluntary retirements than on strategic planning, some research teams maintained their core strengths, some lost key positions, and some were terminated. The process has resulted in an increase in the ratio of salaries to operations & maintenance from 72:28 to 76:24. Although efforts were made to offset the loss of MDA funding with external funding, the combined effect of the above events has left the MGP with diminished ability to fund fieldwork and little flexibility to develop new programs or participate in "partnered opportunity" programs such as Geoconnections or Resource Innovation Initiatives (RII). This

has led to a situation where the scientists and their ability to obtain external funding, rather than strategic goals, are driving the program.

- **Management Vacancies**: Over half of the scientists who were interviewed stressed the serious negative impact on the MGP caused by the lack of a permanent Director of the MRD during the critical period between early 1995 and early 1999. The vacancies resulted from delays in hiring replacements and by absences due to training programs. Interim arrangements included the temporary assumption of more senior management responsibilities by a number of MRD scientists, which ensured that business planning and program operations were able to continue. However, the committee gained the distinct impression that the program suffered from a lack of continuity in leadership and direction during this vital period.
- **Reorganization**: The GSC has been subject to two significant reorganizations, the amalgamation of EMR and the Canadian Forest Service into NRCan in 1993 and the amalgamation of the GSC and Geomatics Canada in 1995. Prior to the reorganizations, the head of the GSC was also the program leader, and represented the Survey at the ADM level. Following the reorganization, the GSC is represented at its senior program level by three Executives, two Directors General and a Chief Scientist, who, along with their counterparts in other organizations in ESS, report to the ADM.
- **New Federal Science Policy**: In 1996, the government enacted a new policy titled '*Science and Technology for a New Century: A Federal Strategy*'. This provided new policy directions to all federal science organizations, including the GSC. Federal Science and Technology activities are now focused on three main goals: advancement of knowledge, sustainable job creation and economic growth, and improved quality of life. In attempting to address the full scope of science needs in this broadened Government agenda, the relative emphasis on traditional strengths like the MGP and other core GSC activities has diminished.

The cumulative damage, both direct and collateral, caused by these recent impacts is well illustrated by comparing budget levels and scientific staffing levels at the beginning and end of this period (**Tables 1.2** and **1.3**).

Table 1.2 Change in **GSC Science Program** funding between fiscal year 1994/1995 and fiscal year 1999/2000 ($000).

Program	Funding Components	1994-1995	1999-2000	% Change
Marine	Abase/OERD/MDA	6719	4866	-27.6
Hydrocarbon	Abase/OERD/MDA	8492	5691	-33.0
Minerals	**Abase/OERD/MDA**	**11003**	**5536**	**-49.7**
Mapping, Bedrock, & Surficial	Abase/OERD/MDA/NATMAP	20926	13890	-33.6
Environmental/Hazards	Abase/OERD/MDA/MITE	10772	9290	-13.8
Total Science Program Spending		**57912**	**39273**	**-32.2**

Data provided by GSC. 94-95 includes NATMAP ($1280), OERD, MDA, IPP, and distributed revenue ($823K), excludes: Capital, Employee Benefits Plan (EBP), Green Plan, and Grants & Contributions. 94-95 Source: GSC Year-End financial report 1994-95 Table XVIII-A and B, and GSC Notionals 94-95. 99-00

Source: GSC Notionals 99-00. NATMAP and Metals in the Environment funds indicated. Revenues and Special Purpose Accounts not included. Abbreviations in Section 8.

Table 1.3 Change in **Minerals Program** salary and operating & maintenance funding between fiscal year 1994-1995 and fiscal year 1999-2000 ($000).

	1994-1995		1998-1999		1999-2000	
	Amount	**Proportion**	**Amount**	**Proportion**	**Amount**	**Proportion**
Minerals Program						
"Minerals" Salary	7610	**69%**	notional	N/A	notional	N/A
"Minerals" O&M	3393	**31%**	notional	N/A	notional	N/A
Total "Minerals"	**11003**		**5718**		**5536**	
Mineral Resources Division						
MRD Abase salary	8069		5595		N/A	
MDA salary	266		0		N/A	
Student salary	206		in total		N/A	
IPP salary	42		0		N/A	
Total MRD Salary	**8583**	**72%**	**5595**	**76%**	N/A	N/A
Abase O&M	1854		1686		N/A	
MDA O&M	1250		0		N/A	
IPP O&M	248		0		N/A	
Total MRD O&M	**3352**	**28%**	**1723**	**24%**	N/A	N/A

Data provided by GSC. Source: 94-95: GSC Year End Financial Report. 98-99: ESS Year End Financial Report (last year for which final expenditure figures are available). MRD delivers 95% of the Minerals Program, its salary to operating ratio reflects spending on the Minerals Program. Between FY95 and FY98 the Salary:O&M ratio has increased from 72:28 to 76:24. Opening budgets are notional only, and subject to transfer between salary and O&M. Budgets given here include distributed revenues and MITE funding, but do not include Special Purpose Accounts.

2. Organizational Constraints

2.1. Position of the MGP within MRG, GSC, ESS, and NRCan

The GSC is one of three operational components of the Earth Sciences Sector (ESS) of NRCan, the others being Geomatics Canada and the Polar Continental Shelf Project.

The GSC is organized into two operational **branches**, *Minerals and Regional Geoscience* (MRG) and *Sedimentary and Marine Geoscience* (SMG), each of which is headed by a Director General, and seven **divisions**, each of which is headed by a Director. Three of the divisions are based in Ottawa, whereas the others are located at regional centers in Dartmouth, Quebec City, Calgary, and Vancouver/Pat Bay (**Table 2.1**).

Beginning in the mid-1980's, the operational path began to separate from the organizational path, outlined above, as the concept of **programs** and **subprograms** was developed. As a result of this, the present system of modified matrix management emerged, with the scientific work of the GSC conducted within six programs (**Table 2.2**):

Table 2.1. *Organizational* location of MGP within MRG, GSC, ESS, and NRCan

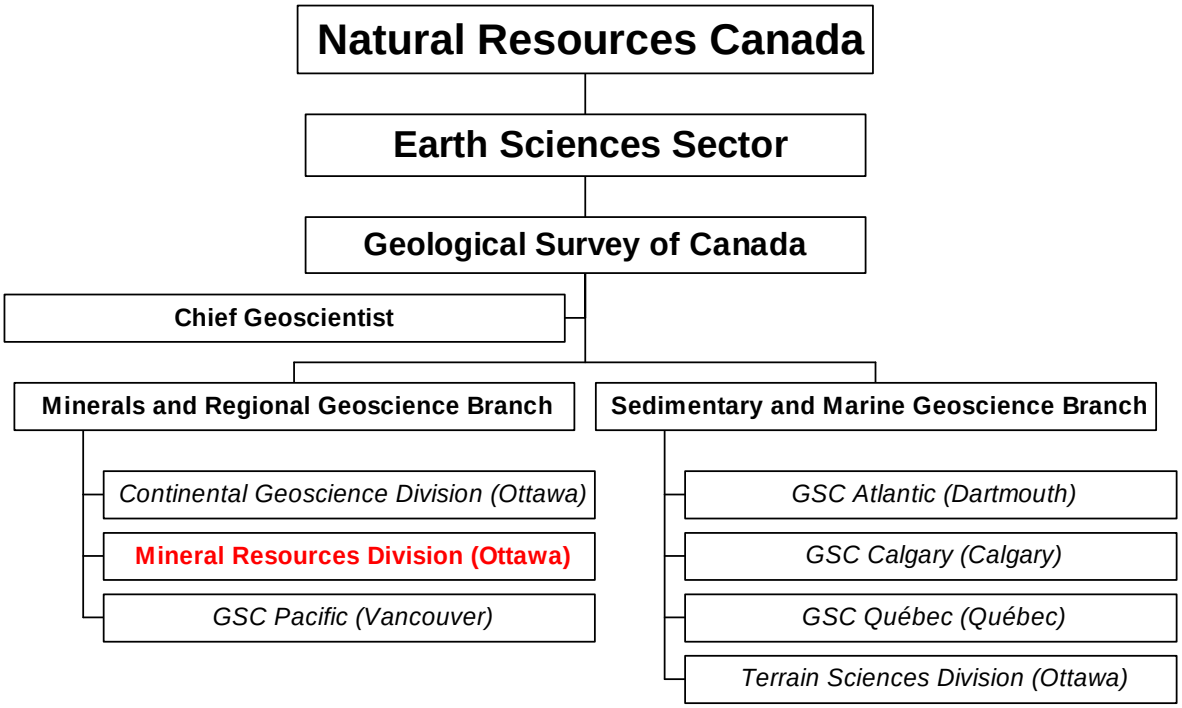
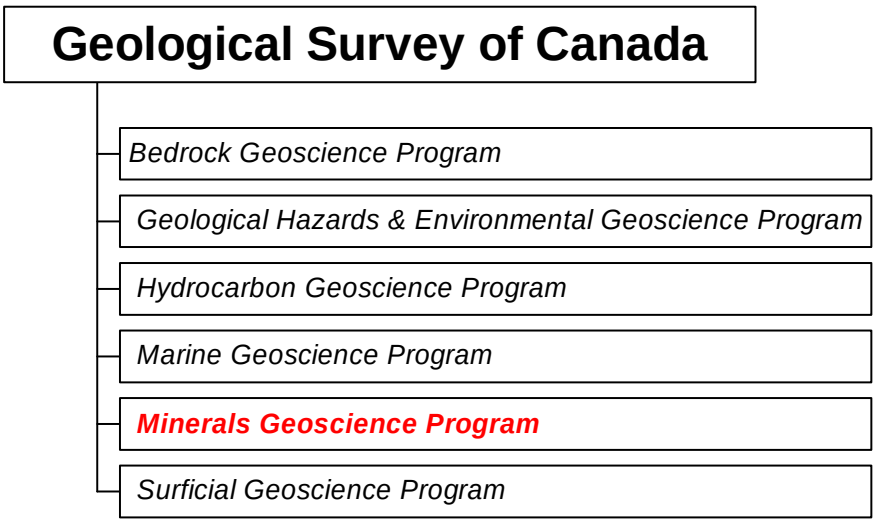


Table 2.2. *Operational* location of MGP within the GSC



Program development and delivery is the responsibility of the seven *divisions*, each of which has responsibilities in more than one *program*. Conversely, no *program* is the sole responsibility of any one *division*. Each division prepares an annual Business Plan, which outlines the objectives and deliverables in both program and management terms and is the division's principal accountability document. The Review Committee found that scientists were not always aware of the relative roles of the Divisions versus the Programs. The committee concluded that the program concept, although perhaps useful as a management and communication tool, does not seem to have had a significant impact on the way that staff view their work and their place in the corporate body.

In the past, the project proposal and selection process was driven largely by individual scientists and was contained largely within Divisions. Most projects were developed in response to broad objectives outlined in the Five Year Strategic Plan, to regional needs determined in consultation with Provincial and Territorial governments, and to scientific priorities. The broad diversity of stakeholder interests and funding sources made this approval process quite complicated.

2.2. Mandates

The GSC currently operates within a framework of various mission statements, mandates, visions, and roles, a framework that has undergone substantial change during the government reorganizations of the 1990's, which were described earlier. Because these changes were so extensive and so recent, the Review Committee felt that a thorough review was needed to determine what the current goals and objectives are and how they vary from the traditional GSC role.

According to the *1996-2001 GSC Strategic Plan for Geoscience*, the survey has positioned itself to meet the goals and objectives of the *1996 Federal Strategy for Science and Technology*, which include sustainable job creation and economic growth, the advancement of knowledge, and the improvement of quality of life. Sustainable development was defined by the World Commission

on Environment and Development (the Bruntland Commission) in 1987 as: "development that meets the needs of the present without comprising the ability of future generations to meet their own needs".

The statutory responsibility of the GSC to carry out minerals-related work is clearly defined in the *1966 Resources and Technical Surveys Act,* which directs the Minister to:

> **"make detailed investigations of mining camps and areas containing economic minerals or deposits of other economic substances"** and **"make a full and scientific examination of the geological structure and mineralogy of Canada"** by preparing **"maps, plans, sections, diagrams, drawings, documents, and data"**

The same Act directs the minister to carry out other research to:

> **"aid the mining and metallurgical industry of Canada"**

and to maintain collections that:

> **"afford a knowledge of the geology and mineralogy and the mining and metallurgical resources and industries of Canada".**

The 1994 *Department of Natural Resources Act,* which set up the new department within which the GSC is administered, is less specific with respect to program responsibility in the minerals area. It directs the Minister to:

> **"have regard to the sustainable development of Canada's natural resources and the integrated management thereof,"** to **"assist in the development and promotion of Canadian scientific and technological capabilities,"** and the **"promotion of market access for Canada's natural resources products and technical surveys industries, both domestically and internationally."**

The definitive discussion of sustainable development in the context of minerals is found in the 1996 *Minerals and Metals Policy of the Government of Canada.* This document defines the sustainable development of minerals as:

1) finding, extracting, producing, adding value to, using, re-using, recycling, and, when necessary, disposing of mineral and metal products in the most efficient, competitive, and environmentally responsible manner possible, utilizing best practices;
2) respecting the needs and values of all resource users, and considering those needs and values in government decision-making;
3) maintaining or enhancing the quality of life and the environment for present and future generations; and
4) securing the involvement and participation of stakeholders, individuals, and communities in decision-making.

The term "sustainable development", when used in this context, clearly encompasses both the discovery of new resources and attention to the environment. The Review Committee believes that the reference to sustainable development in the Department of Natural Resources Act provides a clear mandate for the GSC to maintain a minerals-related program.

The GSC has gone to considerable lengths in recent years to redefine its mission and mandate in modern terms and to demonstrate links between projects, programs, and GSC/ESS/NRCan goals and objectives. The committee felt it was important to try and understand the links between the mandates and missions statements at various levels within the Department, and the relationship between these and the statutory responsibility of the GSC. This is particularly crucial in the context of the government's strategic decision in the early- to mid-1990's to withdraw from some minerals-related programs, partly reflecting the redefinition of the Federal role with respect to mining as outlined in the *1996 Minerals and Metals Policy*. That policy, while acknowledging the importance of a comprehensive geoscience knowledge base and citing the importance of EXTECH and other elements of the MGP, emphasizes the Federal role in promoting a competitive business climate, sound environmental stewardship, and protection of aboriginal communities.

At the Departmental level, NRCan goals and objectives are too broad to specifically refer to minerals (or even to geoscience), but they nonetheless provide ample opportunity for minerals-related programming. This is illustrated in the *1999-2002 ESS Business Plan*, addressing NRCan Policy goals:

- **to enable Canadians to make balanced decisions regarding natural resources;**
- **to maintain the economic and social benefits derived from natural resources for present and future generations; and**
- **to minimize the environmental impacts of natural resource development.**

ESS requires a component of mineral resource information and knowledge to meet these goals and strategies for various types of geoscience programs, including minerals.

Nor does the ESS mission statement, as expressed in the ESS document "*Strategic Directions for 2000-2005, An Overview of the Strategic Plan*" specifically reference program areas where activity is required to meet its mandate:

> **"The Earth Sciences Sector will provide innovative, timely, and reliable geomatics and geoscience knowledge, advice, products, and services to meet client needs"**

However, the new ESS goals and objectives, as outlined in the above cited overview of the 2000-2005 ESS Strategic Plan, are closely aligned with the Departmental goals (as they should be) and provide specific objectives for ESS that can be related back to programs. The responsibility to carry out minerals-related geoscience programs to help develop and sustain economic and social benefits of mineral development is stated unequivocally in the implementation strategies (see, for example, the implementation strategies for program areas 1.5 and 2.1). It is clear to the Review Committee that the GSC has a responsibility to provide minerals-related information, knowledge, and expertise that can only be derived from its own programs. This is essential if ESS is to fulfill its stated objectives relating to geoscience knowledge, resource assessments, resource exploration, industry support, aboriginal capacity and land claims, and environmental policies.

The mandate to provide this information is found within the *1996-2001 GSC Strategic Plan*:

> **"To provide Canada with a comprehensive geoscience knowledge base contributing to economic growth, sustainable development, health and safety, and environmental protection by acquiring, interpreting, and disseminating geoscience information concerning Canada's landmass and offshore territory."**

However, the GSC recognizes that it shares responsibility for geoscience knowledge for the public good with the Provincial and Territorial geological surveys. The different, but complementary, roles and responsibilities of the various surveys are defined by the 1996 *Intergovernmental Geoscience Accord*. The role of the GSC is described as follows:

> **"The GSC carries out national geoscience programs to define the geology and resources of Canada. These programs are typically thematically based, and national or broadly regional in scope and significance. They are operated across Canada, and include aspects of fundamental research, technology development, and information transfer not contained in the programs of all of the provincial and territorial survey organizations. In addition to its activities on land, the GSC operates marine and coastal studies that are unique among the geological survey organizations. The GSC also has a lead role in representing Canada in international geoscience activities."**

The MGP is specifically provided for by the *1996-2001 GSC Strategic Plan*, which defines its goals as follows:

> **"The ultimate goals of the Minerals Geoscience Program are to assist the industry to discover the resources required to sustain Canada's position as one of the world's leading mineral producers, to ensure that the government has the geoscience knowledge that it requires to formulate and implement minerals-related policies in matters of federal jurisdiction, and to promote the technological capability of the Canadian exploration industry in an increasingly competitive global market."**

All of the above provide ample evidence that there is both a statutory and a policy imperative for a strong MGP within the GSC, and that a policy trail exists which shows how minerals-related programs play into the wider strategic plans of the department and its national responsibilities. However, the Review Committee notes with deep concern that recent mandates, particularly at Department and Sector levels, have used language that appears to de-emphasize the specific responsibility for minerals programs. Based on what it heard from both managers and scientific staff, the Committee is concerned that this reflects a corporate shift within the GSC away from programs that address Canada's mineral resources. Such a shift would be alarming, and the Committee, and all of the clients who were consulted, strongly believe that there is and should be a mandate for the GSC to deliver a national minerals program.

In summary, although recent NRCan mandates and mission statements are written in language that tends to hide or downplay it, a clear and unequivocal policy trail is set out in both legislation and policy that defines the need, and federal responsibility, for a national minerals program.

Recommendation 1. ***GSC management should continue to strongly support and promote the national need for a minerals geoscience program at the federal level.***

Recommendation 2. **The size and impact of the MGP needs to be enhanced through additional funding and/or enhanced integration and synergy with other GSC programs, notably the Bedrock Geoscience (Mapping) and the Surficial Geoscience (Mapping) Programs, and through greater cooperation with Provincial and Territory geological surveys under the framework of the Intergovernmental Geoscience Accord.**

3. Overview of Scientific Activities

This chapter reviews both the current levels and types of scientific activities in the MGP (**Term of Reference #1**), as well as the relevance and adequacy of these activities to a) users in industry, university and government sectors, and b) the sectoral and departmental national responsibilities and mandates (**Term of Reference #2**).

The MGP encompasses scientific activities focused on Canada's non-hydrocarbon mineral resources. The program is intended to maintain **"a critical mass of expertise in the field of mineral deposits geology, exploration geochemistry and geophysics, analytical chemistry, and mineralogy"** (*1998-1999 GSC Program Plans*).

The GSC operational plan derives from the *Strategic Plan*, which sets out the goals, objectives, and general schedules of operations in five-year blocks. The GSC is more than halfway through its current strategic plan, which covers the period 1996 to 2001. The operational plan is refined annually through consultation with the Provincial and Territorial governments and other stakeholder groups. The results are incorporated into the annual *Program Plan*, which, along with the *Business Plan*, is the activity document for the year.

The appropriateness of each MGP activity can be evaluated against the stated goals of the MGP, as set out in the *1996-2001 GSC Strategic Plan for Geoscience*:

- Assist the industry to discover ore reserves required to sustain employment and prosperity in Canada's mining communities and minerals industry, and to increase metal export revenues.
- Ensure that the federal government has the geoscience information it requires to formulate and implement minerals-related policies in areas of federal jurisdiction.
- Promote the technological capability of the Canadian exploration services industry in an increasingly competitive global market.

The MGP is delivered by scientists in four Divisions. The majority of staff and fiscal resources for the program reside in the MRD, but the TSD, CGD, and GSC-Québec also contribute to the program. Broadly stated, the key strategies to pursue those goals are:

- **Mineral Deposit Research** - to pursue a national program of thematic studies of significant deposit types for Canada's principal trading commodities in order to develop more precise guidelines for exploration, and to establish a more quantitative basis for assessing resource potential.
- **Mineral Exploration Research** - to focus on those areas where the GSC has unique capabilities or a critical mass of expertise. There will be an emphasis on partnerships and cost-shared research to promote technology transfer.
- **Mineral Resource Assessments** - to be undertaken, as required, to respond to federal government policy and legislation.
- **State-of-the-Art Laboratories** - to be maintained for mineralogy, analytical chemistry and petrophysics in order to meet increasingly complex demands both in traditional program areas and in environmental applications.

- **International Perspective** - to be enhanced to keep abreast of the increasingly global outlook of the Canadian exploration industry. The GSC will continue to assist Canadian firms to obtain a foothold in foreign markets although these opportunities will be pursued on a cost-recoverable basis. These activities will also provide scientific benefits and improve knowledge of foreign mineral potential for GSC scientists.

3.1. Scientific Priorities

The Strategic Plan places emphasis on the development of better deposit models based on an understanding of ore-forming processes and sound documentation of deposit characteristics. The current emphasis is on volcanic-associated massive Cu-Zn-(Pb) sulphide (VMS) deposits and, to a lesser degree, sedimentary exhalative (SEDEX) Pb-Zn-Cu deposits, mesothermal gold deposits, magmatic PGE-(Cu) and Ni-Cu-(PGE) sulphide deposits, and diamond deposits. Another priority is to identify prospective terrains for deposit types that are either unknown or poorly represented in Canada.

In exploration geochemistry, the focus is on improving the analytical methodologies associated with selective extractions of soils and sediments, and the use of water as a sample medium. Research in drift prospecting is directed toward diamond exploration. The priority for both borehole geophysics and gamma-ray spectrometry is the development of exploration applications using a case study approach. Other topics include seismic imaging and better documentation of petrophysical and other rock properties.

There is a stated intent to concentrate on thematic research of significant deposit types and to use GSC expertise to advance mineral exploration technology. There is to be an increased shift to multidisciplinary research, as exemplified by the NATMAP and EXTECH projects. GSC projects are to be increasingly undertaken in collaboration with other geological surveys, and thematic studies of igneous, sedimentary, metamorphic processes are to emphasize a regional or tectonic context. The GSC is to increasingly balance its expertise and laboratory functions with those of the universities and provincial surveys. Finally, traditional publications are to be phased out in favor of more economical on-demand printing and electronic dissemination.

Each of the subprogram elements encompasses a range of projects and scientific activities, Within each subprogram, various ‘subprogram elements’ comprising projects or groups of projects are identified. There is considerable diversity in the size and resources allocated to these subprogram elements and, typically, individual scientists are involved in more than one project. According to information supplied to the review committee, approximately 30 active subprogram elements, including laboratories, have been designated as contributing to the MGP.

Although the subprogram framework is helpful for attempting to document and assess the scientific activities within the program, the Review Committee found that it does not provide a useful context for documenting and assessing the types of scientific activities. Subprograms are too broad to provide a useful framework at the activity level, whereas subprogram elements are generally too detailed. Therefore, for the purposes of documenting and evaluating the types of science activities within the program, the committee attempted to identify scientific “program areas” and “activities” that make a similar contribution to the program and the strategic goals and objectives, and that can logically be considered together. The "program areas" and "activities" identified by the committee are shown in **Table 3.1**.

Table 3.1. Table of MGP program areas, activities, subprogram elements, users, program relevance, uniqueness, current delivery levels, adequacy, and suggested future directions.

Program Area	**Analytical**
Activity	**Service**
Subprogram Element	electron optical (EPMA, SEM); stable isotope ratio mass spectrometry (Québec); fluid inclusion microthermometry (Québec); analytical chemistry (XRF, ICP-MS, IC); sedimentology (terrain sciences)
Users	exclusively in-house
Program Relevance	considerable demand for high quality, reliable geochemical analyses in many parts of the program; considered essential by staff users; relevance in context of mandates is related to relevance of program elements that use service; some of the more routine work (e.g., XRF, ICP-MS) could be outsourced to commercial labs if cost effective
Uniqueness	none of the MGP service facilities are unique in Canada, but demand for and cost effectiveness of analytical work may be high enough to justify maintaining them if this does not compromise provision of analyses that are not available commercially; some hands-on instruments are essential to have in-house (e.g., electron probe, SEM); only the CGP SHRIMP is unique in Canada
Current Levels	levels are less that in past because of loss of support staff, resulting in slower throughput; lost ability to perform some analyses (e.g., PGE, semi-metals); level of activity seems appropriate for demand; significant resources are going into this activity compared to field programs
Adequacy	range of analytical facilities available for service functions is good to excellent; instrumentation is good to excellent; resources for staffing and maintenance are inadequate; specialized analytical services (e.g., low-level PGE and semi-metals) are no longer available in-house and have limited availability externally; inadequate access to geochronology is a cross-divisional problem
Future Directions	maintain EPMA and SEM; focus on highly specialized services (low-level REE / HFSE, low-level PGE, semi-metals); actively seek opportunities for partnerships with university labs for specialized analytical services; some analytical services (e.g., routine work) could potentially be outsourced if cost-effective; ensure that geochronological services are available across divisional boundaries
Program Area	**Analytical**
Activity	**Development**
Subprogram Element	mainly ICP-MS; no instrumentation development
Users	exclusively in-house

Program Relevance	highly relevant to needs of users – when new analytical needs are identified, program responds to need; provides a necessary service and is highly supported by in-house users; relevance in context of mandates is related to relevance of program elements that use service
Uniqueness	some of the MGP development facilities are unique in Canada (e.g., selective leach techniques); most could be done elsewhere if necessary
Current Levels	levels seem to be adequate for demand with no indication that ability to respond to demand has diminished; not a large effort at present;
Adequacy	ability to respond to most needs is adequate; there are indications that some abilities have been lost and resources don't exist to redevelop
Future Directions	maintain analytical development capabilities; seek university partnerships for development needs that can't be met in-house; provide better support for maintenance and capitalization of equipment

Program Area	**Analytical**
Activity	**Research**
Subprogram Element	geochemical research; stable isotope ratio mass spectrometry (Ottawa and Québec); SHRIMP (not part of the MGP but critical to MGP programs)
Users	almost exclusively in-house; academia (rarely)
Program Relevance	high level of expertise with specialized/targeted research interests; does not cover all research lab needs; relevance to sectoral and departmental mandates and strategic program is low to moderate; some research could potentially be done externally through collaboration; provides users with the opportunity for collaborative work with analysts; some research presents an intrinsically valuable opportunity for scientists to maintain expertise and currency in their field
Uniqueness	only the CGP SHRIMP facility is unique to Canada; all other analytical facilities are available elsewhere (universities & commercial)
Current Levels	staffed at minimum level and lacking technical support; program and output dependent on expertise and interests of research scientists; level of activity within labs is appropriate
Adequacy	adequate to meet needs of existing program elements;
Future Directions	focus on collaborative and integrated research that addresses strategic directions; explore options for external collaboration with academic research facilities to foster collaboration; continue to ensure that pure research is not carried out at the expense of service functions

Program Area	**Geomathematics**
Activity	**Service**
Subprogram Element	spatial data analysis and integration; remote sensing
Users	in-house

Program Relevance	potentially relevant to in-house users to maximize value of data sets in multi-disciplinary projects; has made valued contribution to a number of projects but seems to be underutilized in this capacity relative to resources; relevant to sectoral and departmental mandates in the context of maximizing use of data; some processing could potentially be contracted out;
Uniqueness	not unique in Canada
Current Levels	level has not been seriously impaired by downsizing but demand for services has increased; support for major multidisciplinary projects could be increased to improve overall output
Adequacy	resources available for service support across the MGP are inadequate – this group could make a significantly greater impact on the corporate agenda
Future Directions	PDS should require this group to interact more effectively with other groups; encourage group to market skills within the organization

Program Area	**Geomathematics**
Activity	**Research**
Subprogram Element	quantitative techniques – mineral exploration and geologic hazard; geostatistical applications in groundwater and mineral resources
Users	academia; industry(?)
Program Relevance	work is judged relevant by external clients and research community; relevance is less clear in terms of sectoral and departmental mandates as it is not applied as much within the department; overall, relevance of research is low to moderate
Uniqueness	leading research but not unique
Current Levels	level of activity seems to be high in the academic arena external to the GSC; not clear that this level of activity is warranted to fulfill the GSC agenda
Adequacy	work being done is more than adequate to meet corporate responsibilities; work being done is clearly well regarded science but some research is not well integrated into core program; could be improved by greater emphasis on problem solving
Future Directions	eliminate individual research activities, which are not an MGP mandate and are better done in universities; focus on collaboration with other groups in the GSC and on solving problems in core program

Program Area	**Geophysics**
Activity	**Surveys**
Subprogram Element	NATGAM and AGRS
Users	in-house; provincial surveys; industry; other external clients

Program Relevance	extremely relevant to geological mapping, exploration, and environmental work; extremely relevant to sectoral and departmental mandates; overall relevance is high
Uniqueness	only the GSC can do this type of work
Current Levels	overall level of activity is low to moderate compared to both previous levels and needs of clients; capacity to do this has been lost
Adequacy	adequate quality but inadequate resources to meet needs;
Future Directions	important now and will be more so in future; increase support and activity

Program Area	**Geophysics**
Activity	**Research**
Subprogram Element	petrophysics; downhole seismic imaging; terrain geophysics
Users	provinces / territories (Terrain Geophysics); industry
Program Relevance	very relevant to needs of clients who require better remote sensing methods for ore finding and/or physical properties of rocks; relevance to sectoral and departmental mandates is less clear; this seems to be a matter of critical mass and opportunity within the GSC, but could perhaps be more appropriately done outside(?); useful and potentially a valuable tool; petrophysics work is largely external and relevance to much of minerals program seems marginal;
Uniqueness	some parts are unique, but the private sector is a leader in many of these techniques
Current Levels	level of research has not declined significantly in downsizing; moderate level of activity but appropriate to level of support from industry; could this be efficiently done outside the GSC?
Adequacy	present work is more than adequate to meet identified internal needs; high quality, but much of program not well integrated into other projects and lacks synergy with remainder of the MGP
Future Directions	integrate with core program with a focus on rock properties and modelling of potential field and other geophysical data where appropriate; discontinue remainder

Program Area	**Geophysics**
Activity	**Technology Development**
Subprogram Element	borehole geophysics
Users	industry
Program Relevance	relevance to industry end-users not well established in course of review; relevance to sectoral and departmental mandates not clear – not generally well integrated into departmental programs although has contributed to some major projects (e.g., Bathurst EXTECH); overall moderate
Uniqueness	uniqueness and degree of overlap with private service sector not clear; need for rock property measurements in regional projects

Current Levels	level of activity doesn't seem to have declined significantly; seems to be a level of activity suitable to meet needs of clients; overall moderate
Adequacy	more than adequate to meet needs; needs to be re-evaluated in terms of departmental mission
Future Directions	commission an independent evaluation of this program against MGP strategic directions in consultation with users

Program Area	**Geochemistry / Terrain Sciences**
Activity	**Surveys**
Subprogram Element	NGR; NATMAP / regional till geochemistry
Users	in-house; industry; provinces; environmental
Program Relevance	data continue to be very relevant to a variety of users; relevance to sectoral and departmental mandates is high – unique national coordinating role; reduced impact on departmental mandates through lack of funding for strategic "public good" programs and present need to seek external funding on opportunity basis; ability to impact may suffer as a result of continuing application of old technology; becoming increasingly useful as environmental baseline
Uniqueness	only the GSC can do this type of work; unique role to maintain national database
Current Levels	output levels dependent on operational funding available; seems to have maintained level of activity through downsizing; lack of operational funding to undertake surveys
Adequacy	adequate to meet identified needs, but will likely become more important in the future;
Future Directions	maintain staff levels and increase operational funding to contract surveys; develop funding models to allow priorities to be set strategically, not on availability of external funding

Program Area	**Geochemistry / Terrain Sciences**
Activity	**Research**
Subprogram Element	drift dispersal
Users	provinces, territories, industry
Program Relevance	very relevant to users – drift dispersal is fundamental to interpreting regional surveys and dispersal patterns; relevant to sectoral and departmental mandates; cross jurisdictional and thematic; the GSC is best placed to do this work, especially in the territories
Uniqueness	not unique in Canada - provincial surveys, industry, and universities are also undertaking similar research; can probably only be done in the territories by the GSC
Current Levels	level is generally moderate and appropriate
Adequacy	adequate to meet needs at present
Future Directions	concentrate research in the territories; seek provincial / university partnerships for work in other jurisdictions

Program Area	**Geochemistry / Terrain Sciences**
Activity	**Technology Development**
Subprogram Element	Analytical Method Development
Users	industry, academia
Program Relevance	strong external customer base with clear relevance to industry needs; international reputation is high – gets good reviews; relevance to departmental and sectoral mandates is not as clear – some R&D could be undertaken in private sector; not easily integrated into other minerals activities
Uniqueness	high level of expertise and some parts appear to be unique in Canada; potential for overlap with private sector exists in some research areas
Current Levels	moderately low level of activity; dominantly in one lab and presently focused on enzyme leach
Adequacy	adequate to meet internal needs
Future Directions	continue current level of activity; consider refocusing activities to align with strategic priorities

Program Area	**Collections / Databases**
Activity	**Rock**
Subprogram Element	National Collections
Users	in-house; provinces
Program Relevance	relevance high to users and department as national archive and database
Uniqueness	only the GSC can do this type of work
Current Levels	level seems to be high; staff feel that level is not sufficiently high to meet archiving mandate
Adequacy	appears to be marginal
Future Directions	increase level of activity slightly; ensure that collections are properly archived and preserved

Program Area	**Collections / Databases**
Activity	**Digital**
Subprogram Element	All geochemical
Users	in-house; all clients
Program Relevance	relevance to all users is extremely high;
Uniqueness	only the GSC can do this type of work
Current Levels	level of corporate database archiving seems to be low; haven't successfully made the transition from paper to digital files; every rock analysis should be archived; every analyzed sample should have location and lithology

Adequacy	inadequate; going to need more resources as multi-disciplinary studies become more common
Future Directions	greatly increase level of activity; build corporate understanding of the importance of archiving digital materials

Program Area	**Mineral Deposits Research**
Activity	**Regional Metallogeny**
Subprogram Element	NATMAP (ancient Pacific margin, Keewatin); MERA
Users	territories; provinces (?); industry
Program Relevance	relevance to users is high, especially in the territories where GSC has responsibilities; less so in provinces which typically have their own metallogenic expertise, although there is a need for trans-provincial work and information transfer on a national scale; especially relevant as part of multi-disciplinary studies; GSC is uniquely positioned to do this work in the territories or regionally (trans-provincial)
Uniqueness	the GSC is uniquely positioned to play a leadership role in this type of work
Current Levels	level of activity is low compared to past levels and demands of mapping projects in the territories
Adequacy	increasingly inadequate as multi-disciplinary studies become more common
Future Directions	greatly increase level of activity; use metallogenic projects as an opportunity to broaden deposit skills of scientists

Program Area	**Mineral Deposits Research**
Activity	**Thematic Mineral Deposits Studies**
Subprogram Element	VMS; SEDEX; kimberlites, carbonatites, and mantle processes; magmatic PGE-Cu-Ni; Au
Users	provinces / territories; industry
Program Relevance	highly relevant to users – provides important context and technology transfer for provincial mineral deposits geologists; relevant to sectoral and departmental mandates regarding thematic programs of regional and/or national scope; overall high
Uniqueness	not unique - similar work is being done in universities and provincial surveys, often on a larger scale with more support from industry; however, the GSC is uniquely positioned to do this type of work at a regional or national scale
Current Levels	much lower following downsizing; program covers some deposit types but not all major types; significant capability has been lost;
Adequacy	fully capable for VMS and SEDEX, barely adequate for Au, PGE, Cu, Ni, and diamonds; although some capability exists for most deposit types important to Canada, inadequate overall as many deposit themes cannot be covered because of lost capability
Future Directions	increase level of activity in strategic areas; develop a strategic plan for ensuring adequate coverage in important deposit areas; reassign staff if necessary to cover gaps

Program Area	**Mineral Deposits Research**
Activity	**Genetic Mineral Deposit Studies**
Subprogram Element	VMS; SEDEX; PGE; impact-induced hydrothermal alteration and ore deposits (Sudbury)
Users	provinces / territories; industry; academia
Program Relevance	low to moderate to most users; industry generally more interested in descriptive rather than genetic models; high in academic areas; low to moderate to sectoral and departmental mandates; genetic modelling is fundamental to most academic research and can be done in universities; has intrinsic value in keeping GSC scientists at leading edge of research
Uniqueness	not unique - some elements are of very high quality, but most of the work could (and would) be done by university researchers
Current Levels	level has declined significantly with loss of corporate expertise; present level is moderate
Adequacy	probably adequate for VMS and SEDEX.; barely adequate but very thin for Au, Ni, diamonds; inadequate for others
Future Directions	ensure that genetic studies are secondary, not primary, focus of programs and underpin regional metallogenic studies; continue only in the context of adjunct research to strategic goals of program; provide opportunities to integrate with multi-disciplinary projects; discontinue projects whose prime focus is basic research that could (should) be done by universities

Program Area	**Mineral Deposits Research**
Activity	**EXTECH**
Subprogram Element	EXTECH II – Bathurst; EXTECH III – Yellowknife
Users	provinces / territories; industry;
Program Relevance	highly relevant to all users – multidisciplinary and a good vehicle for integrating various elements of the minerals program; highly relevant to sectoral and departmental mandates; highly valued by industry and by provinces/territories because of technology transfer and collaborative nature
Uniqueness	the GSC is uniquely positioned to play a leadership role in this type of work
Current Levels	level has been steady with one major project at a time; present level is moderate and will need to grow
Adequacy	scope for expansion, especially into areas where EXTECH doesn't presently operate (i.e., dormant mining camps, frontier high potential exploration areas)
Future Directions	increase level of activity in strategic areas

Program Area	**International**
Activity	**Economic Development**
Subprogram Element	PASMA; World Minerals database
Users	foreign countries; industry

Program Relevance	relevant to and consistent with goals of ESS in terms of international competitiveness and export of expertise; supports Canadian mining services industry but less relevant to exploration sector in international settings; helps broaden base for thematic studies; participation of the GSC staff in overseas projects can potentially divert resources from internal needs
Uniqueness	the GSC expertise is not unique; private service sector is well positioned to undertake PASMA-type projects
Current Levels	seems to be maintained at a fairly low level; projects are opportunistic and not looking to grow
Adequacy	adequate at present; should resist the urge to expand this area
Future Directions	maintain present level of activity

Program Area	**International**
Activity	**Reverse Knowledge Transfer**
Subprogram Element	PASMA; opportunistic stand-alone international projects
Users	in-house; provinces / territories
Program Relevance	relevant to GSC scientists and Canadian industry if it helps interpret or promote Canadian deposits; relevant to sectoral and departmental mandate for national scope, information transfer; helps broaden base for thematic studies
Uniqueness	not unique, but follows on above
Current Levels	a few instances mentioned, but generally at a low level
Adequacy	adequate at present
Future Directions	maintain present level of activity

Program Area	**Environmental**
Activity	**Baseline**
Subprogram Element	environmental geochemistry – Hg, Cd; groundwater hydrogeology / hydrogeochemistry
Users	in-house; provinces / territories; environmental
Program Relevance	very high to all users; very relevant to sectoral and departmental mandates; unique role in national standards and database
Uniqueness	the GSC is uniquely positioned
Current Levels	level seems to be moderate but growing; abundant of NGR data; Hg project
Adequacy	barely adequate at present; requirement for baseline data will probably increase in the future
Future Directions	increase level of activity; develop strategic priorities from expressed client needs

Program Area	**Environmental**
Activity	**Process Research**

Subprogram Element	MITE; environmental geochemistry – Hg, Cd; clay mineralogy
Users	provinces / territories; environmental
Program Relevance	very relevant to users; relevant to sectoral and departmental mandates; relevant to skills of the MRD because mineral deposits skills are valuable and applicable
Uniqueness	not unique, but the GSC may be uniquely positioned to play a leadership role in this type of work
Current Levels	low, but off to a good start and growing
Adequacy	resources probably barely adequate at present; demand likely to increase in future
Future Directions	increase level of activity

The following discussion is intended to supplement the information in **Table 3.1**, present information and observations that are not easily tabulated, and summarize recommendations and conclusions resulting from the committee's analysis of this information.

3.2. Analytical Program Area

A more comprehensive discussion of analytical laboratories under the topics of Technical Support, Capital Replacement, Integrated Management, and Rationalization, including a detailed inventory of equipment, and Recommendations is contained in **Section 6**.

3.2.1. Analytical Service Activity

The analytical service activity encompasses the work of all of the analytical labs supporting the MGP projects. The laboratories are the major support function provided to scientific programs in-house and represent a significant commitment of both staff (about 25% of the MRD) and resources (~15% of the program).

Most scientific staff consider the availability of high quality geochemical analyses provided by the GSC laboratories to be essential for their work. Because many of the analyses are specialized and carried out by methods developed in-house on a needs basis, the argument was made by both analysts and project geoscientists that a similar level of service could not be obtained cost-effectively from outside sources. Nonetheless, not all of the present analytical needs of the MGP are met by existing labs, and high-volume, routine analyses (e.g., NGR) are typically contracted to commercial laboratories.

The committee believes that the MGP analytical facilities are generally well equipped, and provide valuable service to MGP scientists at a level that is appropriate to demand. The committee also notes that the decline in technical support for labs has resulted in a loss of service to the program. The labs are not all adequately staffed to meet demands for service and some specialized functions have been forgone because of budget restrictions (e.g., low-level PGE and semi-metals). The Review Committee believes that none of the MGP analytical facilities is unique in Canada and a significant proportion of the analytical demands that they presently service could potentially be met by outside laboratories if required. The committee notes that previous comparisons have shown the use of the GSC labs to be more cost-effective than contracting out to commercial laboratories.

The committee believes that it is important to maintain a level of analytical service capability that can meet the needs of project scientists. It is the committee's view that the highest priorities for laboratory support are maintenance of hands-on facilities such as EPMA and SEM, and specialized geochemical analyses that require in-house method development and close analyst-scientist communication. The committee also believes that cost-efficiency must be a key criterion in evaluating which analyses are carried out in-house and which are eventually outsourced.

3.2.2. Analytical Development Activity

There is a relatively small, but important, scientific activity related to new analytical methods to meet the needs of the program. It includes the development of analyses at particularly low concentrations and new analytical approaches for difficult materials or other complications.

Project scientists were strongly in agreement that this capability is a critical component of the MGP lab support that cannot be obtained commercially. There appears to be adequate capacity in the labs to meet this need at present. Increased demand in future may strain the capacity to carry out this work, in which case external sources of specialized analyses may have to be aggressively sought. The committee agrees that this development work has been important to some programs. However, such work is not necessarily unique to the GSC and much high quality analytical development work also goes on in universities. There may be opportunities for increased partnerships with research labs outside the GSC to carry out at least some of the necessary development work.

3.2.3. Analytical Research Activity

Scientists in most labs maintain a program of research in addition to the service function of the lab. Scientists argue that maintenance of this component of their work is essential for the labs to stay current, and for the scientists to maintain their skills. The Review Committee accepts these arguments, and notes that in the service labs, at least, analysts clearly recognize that internal research projects should not compromise the service function of the lab.

The program also maintains some labs that are primarily research rather than service labs. Work in these labs is often carried out in collaboration with other scientists in-house or with external partners, and provides access to cutting-edge data and analytical methods. Examples include the stable isotope labs and the SHRIMP (which is part of the CGD, not the MGP).

The committee recognizes that the work that is carried out in the MGP research labs is of high quality and that the information that comes out of these labs is well used by scientists. However, only the SHRIMP is unique in Canada, and most of the analytical research *could* be done in universities if necessary.

3.3. Geomathematics Program Area

3.3.1. Geomathematics Service Activity

For many years, the geomathematics group has been at the cutting edge of research into mathematical data handling, geospatial analysis, and predictive mathematical models. Members of this group have been increasingly involved in internal application of these techniques to data analysis, most recently to the EXTECH II and MITE programs. Where this service has been integrated in other scientific programs, it appears that to have made a valuable contribution. However, it appears that this does not occur often enough and some MGP scientists highlighted a lack of mathematical and information technology support as a problem.

The Review Committee feels that this activity has the potential to make significant contributions to many parts of the MGP, but that not enough effort has been made to integrate it into the rest of the MGP.

Recommendation 3. ***The geomathematical service activities should be aggressively marketed throughout the MGP, particularly to proponents of new projects in the PDS, and targets for corporate contributions should be set and met.***

3.3.2. Geomathematics Research Activity

The geomathematics group, although small, is internationally recognized for its research work in quantitative predictive techniques, mineral exploration and geologic hazard assessment, and geostatistical applications in groundwater and mineral resources. Unfortunately, this work seems to be much better recognized externally that internally within the GSC and there is a low level of integration with strategic priorities or ongoing projects.

Recommendation 4. ***Geomathematical research activities that do not directly contribute to corporate objectives should be curtailed.***

3.4. Geophysics Program Area

3.4.1. Geophysics Survey Activity

Regional geophysical surveys, such as those carried out under the NATGAM program and the potential field surveys program in the CGD, are considered by the Review Committee to be core activities of the GSC. They are very relevant to a wide variety of clients and can be done only by the GSC. The committee notes that significant capacity to carry out regional geophysical surveys has been lost, especially in terms of the resources to fund surveys on anything more than an opportunistic basis, and that this has resulted in a decreased ability to target this work strategically. The committee feels that the GSC presently lacks adequate capacity to serve the needs in this area.

In particular, the need to obtain outside funding can mean that resources are deployed in areas where companies are prepared to make funds available, rather than those that address strategic needs of the survey.

The committee feels that there may be synergies and other benefits that could result from integration of the airborne magnetic and gamma-ray groups with an increased focus on integrated regional surveys in support of the minerals program.

Recommendation 5. ***Support for regional geophysical surveys should be increased to ensure that they are available for strategic deployment in support of regional mapping and metallogeny.***

Recommendation 6. ***Consideration should be given to amalgamating the gamma-ray and magnetic survey groups with a view to providing a strengthened airborne mapping group with responsibility for implementation of airborne geophysical surveys in support of mapping-based minerals programs, and research into data interpretation, visualization, and integration.***

3.4.2. Geophysics Research Activity

The MGP includes research into methods of applying geophysics to problems of interest to the program. The research includes such varied applications as physical properties, seismic imaging of orebodies, and 3-D imaging of surficial materials for engineering geology, groundwater, and other applications. The Review Committee recognizes the quality of this work and acknowledges that all of this work is very relevant to specific clients. The GSC is uniquely positioned to carry out some of this work, for example the brokering role with respect to the seismic imaging work, which

is of considerable interest to industry. The committee also feels that the level of activity in this area is appropriate to meet identified needs, but noted that at least some of this work could be carried out in the private sector or academia. Despite the high quality of the work and the interest it generates with clients, it is not well integrated with the rest of the program and there appear to be few instances of synergies developed with other activities.

Given the importance of regional magnetic, gamma-ray, and gravity surveys as a core activity, the Review Committee believes that the focus of geophysical research should be into new applications, processing, visualization, and interpretation of such data. The magnetic, gravity and seismic imaging methods, which enable mapping of overburden, Quaternary geology, bedrock lithology, structure, and alteration, are likely to be increasingly important in the future with the focus on mapping the '3D' geometry of geologically complex terranes under cover. Studies of rock properties are critical to enabling more effective application of potential field data. The committee has concluded that research into the application of geophysical methods at the regional scale should be strengthened at the expense of site-specific investigations that could be undertaken by service companies in the private sector.

Recommendation 7. ***Research into the application, processing, visualization, and interpretation of magnetic, gravity, and seismic imaging methods for bedrock and surficial geological mapping (including rock property studies), especially into resolving 3D geometry of regions under cover, should be given greater emphasis in future programs.***

3.4.3. Geophysics Technology Development Activity

The work of the borehole geophysics group in the development of new exploration tools and techniques is well known and well regarded. Although impacted by the recent program review, the group retains a core mass of personnel to continue to carry out this work at an adequate level to meet current needs. The Review Committee acknowledges the quality of the work done by this group and the contribution that it made to the EXTECH II program, in particular. However, it is concerned that, overall, the work of the group is primarily directed toward exploration technology and techniques applied at the prospect or mine scale and as such is not integrated well with other MGP programs that are focused at regional scales (mineral provinces, districts or camps). The committee has no real context within which to evaluate the relevance of the work to clients, or of its impact on the industry. An independent review should be undertaken to determine whether this program still fulfils a need in the Canadian industry, or whether it is best continued by the private sector geophysical service companies.

Recommendation 8. ***An independent evaluation of the borehole geophysics program should be commissioned in consultation with users to determine the extent to which it still meets the mission of the MGP and the needs of clients, and to allow prioritization of this activity within the MGP.***

3.5. Geochemistry / Terrain Sciences Program Area

3.5.1. Geochemistry / Terrain Sciences Survey Activity

The Review Committee considers that regional geochemical and surficial surveys are core scientific functions of the GSC, particularly in the northern territories. These are activities that only the GSC can do on a regional scale, although it is acknowledged that some Provincial surveys have regional terrain science capabilities within their own jurisdictions. Regional surveys provide data that is highly relevant to a wide variety of users and both geochemical and terrain science data are increasingly useful sources of environmental baseline information. The strategic value of the National Geochemical Reconnaissance Program (NGR) program has been recognized in a cost-benefit study by Queen's University Centre for Resource Studies in 1996 which noted that, although the NGR had resulted in the discovery of new mineral deposits, the major (legacy) benefits of the program would be baseline geochemical data for environmental monitoring and public health issues.

The MGP has been able to maintain an adequate level of activity in these areas, but the NGR, in particular, currently relies on outside funding to such an extent that its priorities are set by the available funding rather than by strategic priorities. The committee strongly endorses the efforts to ensure that data from one NGR survey to the next are comparable to maximize the benefits of a uniform baseline dataset. However, the Review Committee noted that the program needs to take full advantage of advances in analytical technology and the demands of new clients for alternative sampling media and methods. The committee considers that the NGR represents a core component of the MGP's strategic program and should be funded appropriately.

Recommendation 9. ***Regional geochemical and terrain surveys should be maintained at present levels or increased and funding models developed that allow geochemical and terrain surveys to be deployed according to strategic priorities rather than by the availability of outside funding.***

3.5.2. Geochemistry / Terrain Sciences Research Activity

The principal research activity is drift dispersal studies carried out by the Terrain Sciences Division. This work is highly relevant to clients and the GSC is uniquely placed to do it, particularly in the territories. This work is presently proceeding at a moderate level in the MGP, which the committee considers to be appropriate. The Review Committee also notes the need for ongoing research into the nature and distribution of appropriate sampling media for geochemical surveys, and for the visualization of multi-element geochemical data in conjunction with other datasets, both as baseline data and to identify metallogenically prospective terranes. At the same time, there is a role in defining parameters for modern multi-element sampling programs and for accompanying regional orientation surveys to assist more cost-effective exploration by industry, especially in frontier provinces.

Recommendation 10. ***Research in drift dispersal studies should continue at present levels, and opportunities should be sought for establishing better synergies within the MGP and aligning the work with program priorities.***

3.5.3. Geochemistry Technology Development Activity

The Analytical Method Development laboratory is focused on exploration and environmental geochemistry. The Review Committee feels that this lab produces results of real value to the exploration industry, and to the environmental work of the MGP. The results are also very relevant to the industry clients that it principally serves and have been successfully transferred to the private sector, where they are of wide benefit. This program appears to be unique in Canada. Internally, it appears to be integrated with the environmental programs better than the minerals programs.

Recommendation 11. Geochemistry technology development should continue at present levels, but opportunities should be sought for establishing better synergies within the MGP and aligning the work with program priorities.

3.6. Collections & Databases Program Area

3.6.1. Rock Collection Activity

The GSC collection of rock and mineral specimens consists of an archive of samples collected during the course of field projects throughout the country, as well as the national meteorite and mineral collections. This collection is a national treasure, vital to scientific staff and the public, and its maintenance is a function that can only be performed by the GSC . The level of activity in this area seems to be marginally adequate at present, although the committee heard some concerns that the activity may not be able to meet the continuing needs of collections archiving and maintenance into the future.

Recommendation 12. Maintenance of the Survey's rock and mineral collections must continue to be adequately funded to ensure proper archiving and preservation of these valuable national resources.

3.6.2. Database Activity

Although it was not identified as a separate scientific activity within the MGP program, the lack of systematic archiving of geochemical data obtained in the course of minerals research was raised as a serious gap by many scientists during interviews. This is a matter of serious concern to the Review Committee, which observed that the NGR and the NATGAM are the only activity areas within the MGP that have a good record of storing, archiving and retrieving data to meet client orders. Anecdotal evidence suggests that there is no requirement that all data acquired by individual scientists be incorporated into corporate databases, nor that it be released in a timely fashion. Considering that the rapid digitization of the world has brought vast improvements in the way that data is archived and disseminated, the committee feels that the MGP is not taking advantage of available opportunities in this area at the present time and is not fulfilling its obligation to rapidly publish data acquired at public expense (see **Section 4.1**). Urgent attention is required to bring the archiving of the MGP's geochemical data into the digital era.

The Committee also noted that other data collected by MGP scientists are not systematically stored in structured databases to enable the full benefit of the data to be extracted through integration with other datasets in Geographic Information Systems (GIS) and other spatial data

analysis systems. The EXTECH and certain other regional projects have demonstrated how integration of multi-disciplinary data can provide new insights into geological problems, commonly beyond the original purpose for which the individual data were collected.

Recommendation 13. ***The GSC should develop an explicit corporate policy that all data generated by GSC project work belong to the GSC and should develop a corporate information management strategy that includes a requirement that all data be released to the public as soon as is practical after the accuracy of the data has been verified.***

Recommendation 14. ***As part of the corporate information management strategy the MGP should conduct a review and audit of all data collected by the MGP to determine which data should be stored in structured corporate databases.***

Recommendation 15. ***The MGP should immediately develop and implement structured databases, with consistent standards and structures, within the GSC corporate database framework, and institute a policy and program of corporate archiving and timely public release of all data in these databases.***

3.7. Mineral Deposits Research Program Area

3.7.1. Regional Metallogeny Survey Activity

The MGP carries out regional metallogenic studies, principally in the northern territories but also in the provinces, in conjunction with integrated multidisciplinary projects such as those operated under NATMAP. Such studies involve documenting and interpreting the mineral endowment of an area in the context of its regional geological framework. Most provinces have some capability for metallogenic studies relevant to their jurisdictions.

The level of regional metallogenic activity in the MGP has declined as a result of the demise of the MDAs, in particular, as well as downsizing related to program review. The Review Committee believes that regional metallogenic studies, particularly in the territories, is a core function of the MGP. It is critically important that metallogenic activities be carried out as part of multidisciplinary mapping projects. The GSC is uniquely placed to provide this work in the territories and can play a key role in metallogenic studies of regional scope that encompass more than one province or territory. The committee also feels that the PDS should provide increasing opportunities for participation by MGP scientists in regional multidisciplinary projects and that this should help to develop synergies that seem to be presently lacking between mapping geologists and mineral deposits geologists.

The Review Committee is of the opinion that there will be an increasing need for this activity in the future. With a smaller complement of staff attempting to cover a wide range of mineral deposits science, there will be increasing demands for scientists to cover a broader spectrum of mineral deposits expertise than is sometimes the case at present. This being the case, assignment of MGP researchers to a metallogenic project could provide opportunities for needed professional development, a chance to broaden expertise, and an opportunity to apply their expert knowledge to relatively unfamiliar areas of mineral deposits science.

Recommendation 16. Metallogenic studies should be significantly increased with a focus on achieving better integration with regional multidisciplinary projects and national thematic databases.

3.7.2. Thematic Mineral Deposit Research Activity

Although excellent work on individual deposits or camps is being done at a local scale by provincial surveys and university-based research groups, the GSC is uniquely placed to do thematic studies involving commodities or deposit types at a regional or national scale. GSC scientists bring a broad perspective and wide knowledge of particular deposit types that is particularly valuable as a resource to scientists in provincial/territorial surveys and industry.

The GSC has traditionally maintained a broad-based capability and expertise in commodities and deposit types, with a critical mass in many scientific areas that are important to Canada. However, the demise of the MDAs and downsizing related to program review has had the effect of significantly reducing the research strength for all deposit types except VMS and SEDEX. Single researchers continue to do excellent work in the areas of Au, PGE-Ni-Cu, and diamonds. However, little or no capability remains to exercise national responsibilities for most of the remaining deposit types and/or commodities. **Because thematic mineral deposit research is so fundamental to the role of the MGP, the Review Committee made a special effort to measure how serious the decline in resources has become and whether the MGP has the resources to meet the national needs.**

The committee has identified a number of important aspects of the state of mineral deposit expertise within the present MGP:

1) The program's present strength resides in the area of high temperature hydrothermal deposits. There is resident world-class expertise for most deposit types of importance to Canada and to the North with the exception of W-Cu-Sn skarns, which still represent a significant reserve and exploration potential, particularly in the north. Expertise is very thin for porphyry type deposits. However, the expertise exists to allow all of these deposit types to be covered.
2) There is substantially less capability to deal with the wide range of magmatic deposits, low-temperature hydrothermal, and very low temperature deposits, although marginal capability does exist for some deposit types. The MGP would be hard pressed to provide an adequate level of expertise to deal with national needs related to most of these deposits.
3) There is very little capability to deal with alluvial deposits.

Given the diversity and importance of Canada's mineral endowment, the level of activity and range of capability within the MGP has now fallen to an inadequate level. The Review Committee believes that the GSC must urgently begin to rebalance its capability in the area of thematic mineral deposits activity. This might mean reassigning some staff to areas of the science that have not been their traditional specialty.

Recommendation 17. Thematic mineral deposits activity should be significantly increased with a focus on achieving better integration with regional multidisciplinary projects and national thematic databases.

Recommendation 18. Mineral deposits scientists should be reassigned where necessary to provide needed metallogenic expertise to regional mapping projects and to ensure that critical gaps in expertise in thematic mineral deposits research are filled.

3.7.3. Genetic Mineral Deposit Research Activity

The Review Committee recognizes that, for many scientists, inquiries into the genetic processes of mineral deposits are the most scientifically satisfying aspect of their research. GSC scientists have built considerable capacity in this area for a few deposit types, and have traditionally made significant global contributions to mineral deposits science through their investigations. Research of this type has provided major advances in our understanding of Canadian ore deposits and of Canada's undiscovered mineral potential. The committee, therefore, accepts the relevance of, and need for, a component of fundamental research into mineralizing environments and systems in the MGP. It keeps scientists current in their field, contributes to regional metallogenic and thematic deposit models, and maintains the scientific profile of the GSC. The committee noted that the MGP minerals scientists have been proactive in sharing their conclusions and genetic models with industry through short courses, lectures, and workshops, and applauds these initiatives.

However, the Review Committee does not necessarily view genetic studies as a core business function of the MGP. Such work is not unique to the GSC and the issue then becomes one of a matter of judgment as to the level of resources that the GSC should commit to this type of research, and to what extent this type of research could and should be undertaken through universities. The capacity of the GSC to do this sort of work has been damaged by the downsizing resulting from program review, with the result that the capacity to do genetic research on mineral deposits only remains for a very few deposit types. The committee believes that genetic research for its own sake should not be a primary focus of MGP research programs and that future genetic research should be more clearly and closely aligned with strategic priorities.

Recommendation 19. Genetic mineral deposit research is an important component of MGP activities, but should be carried out as a secondary, not primary, focus of mineral deposits research projects. Inquiry into genetic models should not be the principal driver for new mineral deposits research programs.

3.7.4. EXTECH Program

The Review Committee strongly supports the EXTECH model for multidisciplinary research focused on mineral resources. The MGP has worked hard to develop a process for identifying opportunities, and implementing and monitoring the impacts of these programs. It is now in a position to operate programs based on this model efficiently and effectively.

The EXTECH programs are highly valued by industry and by the provinces/territories where they take place. The GSC is uniquely placed to play a leadership role in their continuation. The committee believes that the EXTECH model should be continued and could be successfully expanded to reach beyond the "dying mining camp" model that has been the principal driver for program identification to date. EXTECH-type programs could have a significant impact in both inactive former mining camps and in frontier areas with significant potential, if targeted strategically.

Recommendation 20. ***The EXTECH program should be expanded from its present focus on mining camps that are running low on reserves, to former metal-producing camps that have been closed for some time but might contain more deeply buried mineralization, and well-mineralized districts that have never achieved commercial production because of insufficient reserves or inadequate grade.***

3.8. International Program Area

3.8.1. International Economic Development Activity

The GSC has engaged in a small number of projects in developing countries to assist with economic development and to provide opportunities for the Canadian mining service companies. Recent projects in Brazil and Argentina have been well received by both the host countries and the Canadian companies. These programs provide only minor benefit to the Canadian mining exploration sector, which is able to function quite successfully in the vanguard of this important field without any public sector support.

Another component of the GSC's international programs is the development of a worldwide database of geology and mineral deposits. This project has strong industry support and is potentially of high value to all GSC clients, including the contributing nations.

International development projects are entirely externally funded. However, they do utilize GSC human resources that are, thereby, not deployed within Canada. This is work that the GSC is well, although not uniquely, qualified to do, and it addresses the international mandate that is explicit in strategic and business plans for the GSC and the MGP. To a considerable extent, the projects are opportunistic. The activity has been carried out at a relatively low level, which the Review Committee views as appropriate. The benefits to Canada justify continuation of these activities at their present levels, but they divert resources from the other parts of the MGP program. Therefore, the GSC is urged to resist the temptation to expand this area of operation and, instead, encourage greater participation by the private sector.

Recommendation 21. ***Involvement in international projects should be maintained at their present levels on a full-cost recovery basis.***

3.8.2. International Reverse Knowledge Transfer Activity

Because of their opportunity to work in international settings, GSC scientists acquire knowledge and concepts that can then be applied in the Canadian context. The Review Committee acknowledges the importance of this knowledge transfer, and urges the GSC to ensure that its scientists continue to be provided with opportunities to study mineral deposits abroad. The GSC should also ensure that full advantage is gained from this opportunity by insisting that the knowledge is disseminated within Canada in a timely fashion.

Recommendation 22. ***Opportunities for MGP scientists to observe and study mineral deposits abroad for the purpose of acquiring knowledge that can be applied in the Canadian context should be continued, and the knowledge gained though international activity should be transferred to the***

Provincial/Territorial, industrial, and academic sectors in a timely fashion.

3.9. Environmental Program Area

3.9.1. Environmental Baseline Activity

Much of the data collected by MGP programs, particularly geochemical, gamma-ray, and surficial data, are assuming an increasing importance as baseline data for environmental assessments of new projects and of the relative impact of human activities on the environment. In particular, the close proximity of human activities such as mining to surficial and near-surface waters in much of Canada requires high quality baseline data and a high level of understanding of surficial processes to enable both wise decision-making in response to development and sound environmental monitoring and management. The level of this activity within the GSC has been growing in recent years, which the Review Committee views as appropriate, as it believes that information of this type collected in the public interest will assume increasing importance in the future.

Recommendation 23. The MGP should encourage the collection of geoscientific datasets that serve the dual role of providing environmental baselines and applications for mineral exploration.

3.9.2. Environmental Process Research Activity

Beyond recording baseline data, the MGP has recently taken a leadership role in interpreting processes related to the flux of metals and other substances in the environment. Although this is not an area of research that is unique to the GSC, it follows naturally, in some cases, from the collection of baseline data. It is important and interesting research, and mineral deposits scientists and aqueous geochemists are uniquely qualified to do this work as the study of the movement of metals in solution is their stock-in-trade. Also, the application of this knowledge is often required in other government departments, to which the GSC has better access than the private sector.

The Review Committee supports the growth of research efforts in this area, and believes that the MGP is off to a good start in this relatively new area and that there will be a growing need for this information. The committee feels that the GSC must aggressively market its environmental knowledge and programs across government, to ensure that this science is considered in decision-making by all regulatory bodies. However, while the Review Committee recognizes that much of this activity is driven by client (government) needs, it believes that there is substantial benefit in growing this area of research in the context of a strategic plan.

Recommendation 24. Environmental process research will be an area of future need in which activity should be increased.

Recommendation 25. A strategic plan should be developed for environmental baseline study and monitoring and environmental research in the context of expressed client needs, and should include aggressive plans to market MGP expertise to regulatory bodies across government.

4. Timeliness, Relevance, Quality, and Quantity of Scientific Publications

This chapter reviews publications arising from the science activities within the MGP (**Term of Reference #3**). As noted in **Section 2.2**, an important mandate of the GSC is to prepare “maps, plans, sections, diagrams, drawings, documents, and data." The Review Committee interprets this to mean that the MGP should deliver high quality, accurate geoscience information in a timely fashion and in a format that is easily used by its clients. The clients for MGP outputs include federal and provincial governments, the mineral exploration and mining industry, consultants, the research community, and the general public.

4.1. Timeliness

Although there are many examples of geoscience information being used many years after it has been generated, information is most valuable when it is new because of its stimulating effect on exploration and research activities. Although no information was made available to the committee regarding the time interval between the inception of MGP projects and the dissemination of the information, it is clear that there is still a wide range in the timeliness of release of information. The Review Committee noted that some MGP scientists are routinely diligent about timely dissemination of their work, and that some projects have a history of quick data release. The committee concluded that more timely reporting of results is one of the positive effects of partnered programs, because relatively inflexible reporting deadlines are set by external funding agencies and partners well in advance. However, timely release of project results is still not as prevalent as it should be and some of the work done in the MGP has not been delivered in a very timely fashion. There appear to be several reasons for this:

- As a consequence of downsizing, some MGP geoscientists are trying to cover too many areas and have too little time available to write up their work.
- The publication time for major internal GSC publications such as the Bulletin series has increased. Although of a high standard, these may take up to 2 years to produce.
- Some MGP geoscientists have become involved in editing and contributing to multi-author short course volumes and monographs, some which have experienced long publication (i.e., preparation) delays.
- The present criteria for promotion are *perceived* to favor publication in peer-reviewed, internationally-circulated scientific journals, which may take up to two years for review and publication. This discourages publication in rapid GSC publications, such as GSC Open File reports, which can be produced in a few months.
- Some scientists appear to view the data they generate as proprietary and appear to be unwilling to release it into the public domain until they have published it externally.

The Review Committee feels strongly that all data generated at public expense should be made available in an open-file format as soon as it has been verified as being correct. This approach maximizes the uptake of the government-funded research, especially while the data are current,

and also generates a return to the community through the use of the data by industry and/or government clients.

The Review Committee noted with approval that the MGP has taken some steps towards releasing project results in a CD-ROM format. This has the advantages of cost effectiveness and timeliness, and allows bundling of text, graphic images, and supporting data in a format that ensures maximum usefulness for all clients. The committee encourages the MGP to actively seek opportunities for this form of data release and to ensure that scientists take full advantage of the release capabilities that this medium offers to provide for maximum dissemination of both data and interpretations.

Publication costs can be reduced considerably by making the data available via the Internet. Most GSC publications are released to clients at the cost of transfer. In the case of printed publications, the transfer costs are high and require the expenditure by GSC of "sunk costs" in printing. The use of the Internet reduces the cost of transfer, benefiting both the GSC and the end-user. In addition, the extended delays associated with traditional publication methods indicates that clients would be better served by the use of the Internet to more rapidly disseminate products. The availability of new open-file data should be advertised on an e-mail LIST server.

Recommendation 26. ***The MGP should attempt to speed data dissemination and lower publication costs by releasing open-file information digitally on CD-ROM and by providing databases on an ftp server that is accessible using standard web browsers (e.g., Internet Explorer, Netscape). It should also advertise the availability of new open-file information on an e-mail LIST server.***

4.2. Relevance

Many clients are interested only in raw data and prefer to interpret it themselves, commonly with their own data included. An increasing number are also interested in receiving value-added interpretations as long as the primary data are available separately.

In general, MGP publications have been and continue to be relevant to a wide variety of end users. Some MGP publications, such as the resource assessments for Parks Canada and the EXTECH projects, which have been commissioned by government and/or industry sponsors, are obviously relevant and have a direct impact on the end-user in the short to medium term. Such short-term commissioned research provides a firm basis to assess the relevance of part of the GSC's program, in general, and the MGP program, in particular.

Publications representing other activities in the MGP have equally high relevance, but may suffer from a lag in effective uptake and application. This applies particularly to the regional geological, geophysical, and geochemical datasets that are acquired as part of a systematic national program to provide basic geoscientific information. Data acquired under the NGR program, for example, provide baseline data for environmental studies and monitoring, but have also led directly to the discovery of new mineral deposits. For example, the Brewery Creek mine in Yukon was discovered in 1992 on the basis of NGR data acquired in 1988. It is clear that the value of a strategic program such as this can only be judged in the longer term. The Review Committee

regards such national and regional datasets as core outputs of a national geological survey and has concluded that their relevance to environmental and land resource management will increase.

The relevance of some other MGP publications with respect to the corporate mandate and goals, particularly those reporting the results of fundamental research, is not as easily measured, and the extent to which these publications add value to the GSC core program is a matter of judgment. However, in a rapidly changing global economic environment, there are large rewards for leadership in effective application of new concepts and exploration techniques and MGP publications have provided major advances in our understanding. They provide a contribution to the scientific literature that is useful in its own right and may serve as a building block for further scientific advances by others that are important to MGP clients. The Review Committee, therefore, accepts the relevance of and need for providing its scientists with the opportunity to contribute to the scientific literature.

The Review Committee has concluded that the GSC reward system should place greater emphasis on the relevance of outputs to its key stakeholders and clients than is apparent in the present system. Whereas there is clear evidence of the quality of MGP publications (see below), there is little information on the importance that MGP clients attach to the products, or even the level of uptake of the information contained in the publication. An additional measure of the quality (and relevance) of its products could be obtained through client satisfaction surveys, but there is no evidence that MGP consults its clients to obtain feedback on the relevance of its products.

Recommendation 27. The MGP should regularly undertake market surveys of its clients to gain direct information on the relevance, quality, and timeliness of its publications. In addition, closer monitoring of the uptake through sales figures of its products would provide another useful measure.

4.3. Quality

The quality of MGP publications is generally excellent, as are the contributions of individual researchers that appear in external outlets (journals, monographs, short-course notes). Much of the work being published by MGP scientists is cutting-edge science and is making a significant contribution to our knowledge of the geological, exploration, and environmental settings of mineral deposits in Canada and elsewhere in the world.

Although one of the best measures of the quality of MGP publications is the high esteem in which contributions to Current Research are held within the Canadian geoscience community, it is also possible to assess the quality by examining the external scientific journals in which the work has appeared. Although no statistics have been compiled, perusal of the list of publications provided by the MGP indicates that its work has been published in such prestigious (highly cited) journals as:

Nature
Geology
Journal of Geophysical Research
Journal of Petrology
Earth and Planetary Science Letters
Contributions to Mineralogy and Petrology
Economic Geology

In addition, a wide variety of other peer-reviewed, internationally-circulated journals was also noted, including:

AAPG Bulletin
Analyst
American Mineralogist
Applied Geochemistry
Applied Spectroscopy
Bulletin of Volcanology
Canadian Institute of Mining and Metallurgy Bulletin
Canadian Journal of Applied Spectroscopy
Canadian Journal of Earth Sciences
Canadian Journal of Remote Sensing
Canadian Mineralogist
Chemical Geology
Computers and Geosciences
Earth Science Reviews
Environmental Geology
Environmental Science and Technology
Environmental Toxicology and Chemistry
European Journal of Mineralogy
Geological Society of America Bulletin
Geophysics
International Journal of Environmental Analytical Chemistry
Institution of Mining and Metallurgy Transactions
International Geology Review
Journal of Analytical Atomic Spectrometry
Journal of Analytical Chemistry
Journal of Environmental and Engineering Geophysics
Journal of Exploration and Mining Geology
Journal of Geochemical Exploration
Journal of Geology
Journal of Sedimentary Research
Marine Chemistry
Mathematical Geology
Mineralium Deposita
Mineralogical Magazine
Neues Jahrbuch für Mineralogie
Nonrenewable Resources
Ore Geology Reviews
Powder Diffraction
Sedimentary Geology
Spectrochimica Acta
Spectroscopy
Tectonophysics
Water, Air, and Soil Pollution
Water Resources Research

In addition, major MGP-edited volumes such as *Mineral Deposit Modeling* (GAC Special Paper 40), *Geology of Canadian Mineral Deposit Types* (DNAG Volume XX), *Volcanic-Associated Massive Sulfide Deposits: Processes and Examples in Modern and Ancient Settings* (SEG Reviews in Economic Geology 8) and *The Kidd Creek Volume* (SEG Monograph 10) are excellent contributions. This impressive and diverse list of publications provides clear evidence of the quality of MGP products.

4.4. Quantity

Over the past five years (1995-1999), MGP scientists have produced 1453 publications (**Table 4.1**), including 591 journal articles/book chapters/short-course chapters (~41%), 395 abstracts (~27%), 327 Current Research and Open-File Reports (~23%), and 140 other GSC products (maps, bulletins, databases, etc.) (~10%). These publications are distributed in the areas of mineral exploration research (~55%), mineral deposits research (~25%), mineralogy and chemistry (~11%), bedrock and surficial geoscience (~8%), international activities (~1%), and mineral resource assessment (<<1%). This works out to an average of ~290 publications per year or ~7 per scientist (assuming ~40 scientists). The Mineral Exploration Research group was most productive (ave. ~18 per year), followed by the Mineral Deposits Research group (ave. ~10 per year), the Mineralogy and Chemistry group (ave. ~5 per year), the Bedrock Surficial Geoscience group (ave.

~3 per year), the International Activities group (ave. ~3 per year), and the Mineral Assessment group (ave. ~1 per year).

Overall, this is a very respectable publication rate that is equal to or greater than many university departments. Perusal of the publication lists provided by the MGP indicates that some scientists have greatly exceeded these averages, whereas others are well below. An analysis of the productivity of individual scientists is beyond the scope of this review. However, it is important to realize that some disparities are normal because a five-year period is not long enough to average the lengthy time cycle for mineral deposits research projects. These typically involve field work, sample collection, sample processing, petrographic work, mineralogical analysis, geochemical analysis, isotopic analysis, geochronological analysis, data interpretation and visualization, and write-up. Nor does this short period take into consideration the long time periods required to edit review volumes. Nevertheless, it is obvious that some of the scientists have consistently better publication records than others.

Despite this good publication record, however, it is quite clear from a comparison between the amount of data published and the amount of data reported to have been generated in the analytical laboratories, that much of the data generated in the MGP laboratories is not published. This shortfall, which has been acknowledged by both the scientists and the analysts, is unfortunate and wasteful. The MGP laboratories generate some of the highest quality data available in Canada and since it is being paid for by Canadian taxpayers, *all* of it should be published.

The publication list presented above indicates that the bulk (more than two-thirds) of GSC's publications are in the national and international literature rather than in GSC publications. Basic survey publications (i.e., maps, databases, bulletins etc) comprise only 10% of MGP publications. The Review Committee could find little evidence, other than anecdotal, that this span of publications adequately meets its clients needs. Information presented to the committee suggests that the current GSC reward system favors publication in international journals over digital data compilations and internal (GSC) publications.

Table 4.1. Summary of MGP publications for the period 1995-1999.

	1995					1996					1997					1998					1999				
SubProgram	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**
MDR	21	5	24	34	84	21	17	21	18	77	9	1	24	44	78	6	2	42	7	57	28	3	25	15	71
MRA																					1				
IA		1			1							3			3		2	2	1	5			1	4	5
MER	37	4	40	75	156	27	29	75	53	184	24	21	56	63	164	21	20	62	34	137	25	28	73	30	156
M&C	3		21		24	4		20	9	33			24	5	29	1		20	2	23	3		48	1	52
BSG	23		3		26	22	2	1		25	21	2	6		29	24		2		26	6		1		7
Total	**84**	**10**	**88**	**109**	**291**	**74**	**48**	**117**	**80**	**319**	**54**	**27**	**110**	**112**	**303**	**52**	**24**	**128**	**44**	**248**	**63**	**31**	**148**	**50**	**292**

	1995-1999					Average per Year					Average per Person-Year*					Person-Years*	%
SubProgram	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**	**CR**	**OR**	**J/B**	**A**	**Total**		
MDR	85	28	136	118	367	17.0	5.6	27.2	23.6	73.4	1.8	0.6	2.9	2.5	7.7	**9.5**	26.0
MRA	1				1	0.2				0.2	0.2				0.2	**1**	0.3
IA	0	6	3	5	14	0.0	1.2	0.6	1.0	2.8	0.0	0.4	0.2	0.3	0.9	**3**	0.0
MER	134	102	306	255	797	26.8	20.4	61.2	51.0	159.4	1.5	1.1	3.4	2.8	8.8	**18.2**	41.0
M&C	11		133	17	161	2.2		26.6	3.4	32.2	0.4		5.1	0.7	6.2	**5**	3.4
BSG	96	4	13		113	19.2	0.8	2.6		22.6	6.4	0.3	0.9		7.5	**3**	29.4
Total	**327**	**140**	**591**	**395**	**1453**	**65.4**	**28.0**	**118.2**	**79.0**	**290.6**	**1.6**	**0.7**	**3.0**	**2.0**	**7.3**	**40**	**100.0**
%	22.5	9.6	40.7	27.2	100	22.5	9.6	40.7	27.2	100	22.5	9.6	40.7	27.2	100		

MDR = Mineral Deposits Research
MRA = Mineral Resource Assessment
IA = International Activities
MER = Mineral Exploration Research
M&C = Mineralogy and Chemistry
BSG = Bedrock Surficial Geoscience

CR = Currrent Research
OR = Open-File Reports
J/B = Journal Papers and Book Chapters
A = Abstracts

***Person-Year** = estimated average number of scientific staff publishing in this area each year

5. Research Infrastructure

This chapter reviews the range, adequacy and quality of research infrastructure available to support the science activities within the MGP (**Term of Reference #4**). It expands on the discussion of laboratory activities in **Section 3**.

5.1. Analytical Laboratories

GSC analytical laboratories within the MRD play an important role in supporting many of the MGP programs as well as the analytical needs of other GSC programs. A wide variety of mineralogical, geochemical, isotopic, and geochronological data are heavily used in mineral deposit studies, thematic mineral deposits research, mineral resource assessments, multi-disciplinary programs such as EXTECH, regional geochemical surveys, and regional environmental studies. Most of these data are of very high quality, suitable for research and publication. Some regional geochemical analyses, which generally do not require research quality and which sometimes exceed the capacity of the GSC laboratories, are contracted out to commercial laboratories. In addition to providing data to GSC scientists, the analytical laboratories undertake research into geochemical exploration techniques, commonly in partnership (generally involving in-kind or cash contributions from the private sector).

The MGP includes the operation of several analytical laboratories containing a variety of instrumentation, the major components of which are listed with age and condition in **Tables 5.1 to 5.7**.

Table 5.1. Major equipment in Analytical Chemistry Section of MRD (Dec 1999)

Equipment	Serial No.	Cost $ 000	Year	Condition	Comments
Philips PW 1404 XRF spectrometer	DY749	270	1985	4	Simultaneous, vacuum problems, needs replacement
LECO RMC100 H_2O analyzer	107	45	1986	3	
LECO S analyzer	1100	41	1986	5	backup only
LECO RMC100 H_2O analyzer	130	38	1988	2	
Perkin Elmer ETV ICP sampler	5563	0	1990	3	
Diane ion chromatograph	904010	64	1991	5	Pyro-hydrolysis needs replacement
Perkin Elmer flame AA	037N3031504	51	1992	2	
Milestone microwave oven	121033	20	1993	2	
P-E Optima 3000 ICP OES	069N4842002	200	1993	2	
LECO C/S analyzer	3233	75	1994	2	
Radiometer-Copenhagen auto-titrator	S4C90132R007N009	34	1996	1	
Milestone Hg analyzer	9711253	40	1997	2	
P-E Elan 6000 ICP MS	5419812	200	1999	1	
P-E Elan 6000 DRC ICP MS	0059902	200	2000	1	
Merkentek UV laser		55	2000	1	on order
Major estimated capital		**1333**			
Minor estimated capital		**767**			
Total major and minor capital		**2100**			

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.2. Major equipment in Stable Isotope Geochemistry Laboratory of MRD (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
Finnigan 252 IRMS mass spectrometer	8425	375	1990	2	
Multiport-Trapping Box Inlet		40		2	accessory
Gilson Autosampler		10		2	accessory
Nuclide analyzer (IRMS mass spec)	n/a	80	1980	3/5	Built 1980, brought to GSC in 1984
High vacuum preparation lines	n/s	60	1980	2/3	Built 1980, brought to GSC in 1984
MILES laser extraction system	n/a	70	1990	2	custom built
CO2 laser system	28492	156	1990	3	from Geochron 1999
Finnegan 252 IRMS mass spec.	8502	400*	1995	2	*new cost. Purchased used in 1998
Carlo Erba elemental analyzer	940084	32.5	1995	2	Purchased used 1998
Automated CG gas sampling bench	B9501145	60	1995	2	Purchased used 1998
Other minor capital: Zeiss microscope, analytical balance, micro balance, disc mill		72	1998	2/3	
Total estimated capital		**1335**			

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.3. Major equipment in Analytical Method Development Laboratory of MRD (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
P-E 5000 AA and HGA 500 graphite furnace and AS-40 autosampler	125225	120	1979	4/5	Original 5000 refurbished in 1993. GFAAS barely functional. Replace
JY-38 ICP ES sequential spectrometer	83395	120	1984	3/4	Functional, needs to be upgraded
PE 3030B flame AA	124044	32	1984	3/5	Operable, parts no longer available.
PDV 2000 anodic stripping voltammeter	89110	19	1989	3/5	Parts not available, O/S only for old 286 system.
Chelation concentration module, sampler and fraction collector		42	1992	3/4	Pump components are no longer available.
VG PQ2 ICP MS and IR laser	SLOT961	470	1993	3/4	Not current. Significant downtime due to age.
Shimadzu TOC analyzer		20	1993	3	Old O/S, no upgrade.
Mandel Alkalinity titrator	MS9K5-503	15	1994	3/5	Prototype, old DOS O/S, no upgrades.
Direct insertion nebulizer	129403CM	25	1996	2	pump replaced 1999 (12.4K)
Tekran Hg gas analyzer	0033	80	1996	2	requires upgrading
Clean room Class 100		430	1996	1	
UV digestion system	97019	11	1997	2	
PE Optima 3000DV ICP-ES	069N7021502	200	1997	2	
Ultrasonic nebulizer	109815AT+E	23	1998	2	
Hydride generator		7	1999	1	
Subpur acid distillation system	9908055	15	2000	1	
Other minor capital: e.g., shakers, still, furnaces, microwave, centrifuges etc.		300	1980 to 1990	2-5	old equipment, many smaller items in need of replacement.
Total estimated capital		**1929**			

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.4. Major equipment in Microprobe and SEM Laboratory of MRD (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
Edwards coater			1983	3	
Camebax microprobe 4 vertical spectrometer WDS		524	1984	3	needs mechanical controls upgrade
Video system		21	1994		
EOS image system		4	1994		
Mac O/SBSE system		19	1995		
CL tube		6	1997		
Olympus microscope		8	1985	3	
Sputter coater		8	1987	3	
Cambridge S200 SEM		138	1987	3	has new EDS 2000
with 4Pi EDS and Image analysis		42	2000		
Nikon microscope		12	1988	3	
Cameca SX50 4 vertical spectrometer		732	1990	1	fully automated
with WDS Autofocus system		10	1992		
SX operating system		97	1997		
Denton coater		20	1993	3	needs new vacuum system
Cambridge S360 SEM		360	1993	2	
with EDS Cambridge CL Imager		13	1996		
Offline stage		20	1993	4	needs upgrade
UPS power supply		40	1996	2	On power grid at input.
Data servers		15	1997	2	digital data and image delivery to clients
Other minor capital: chillers, trim saw, binocular microscopes, water alarms.					
Total estimated capital		**2269**			

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.5. Major equipment in X-Ray Laboratory of MRD (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
Darkroom		15	pre 83	3	
Precession cameras		23	pre 83	4	
Film reader		5	pre 83	2	
Philips PW1710 XRD controller		48	1984	5	not supported, significant downtime on sampler
Philips PW1820 diffractometer		72	1989	4	
Philips PW1830 generator		35	1989	2	
Philips PW1729 generator		35	1989	2	Debye-Scherrer and precession cameras
Philips PW 1730 generator		35	1989		
Safety enclosures		12	1990		
JADE pattern identification software		8	1994	4	needs V5
and upgrade V4		5	1997		
PDF-2 Data Set		11	1999	1	current data set
		2	2000		
Other Capital: shaker, balance, furnace, ultrasonic bath, polarizing microscope, binocular.					
Total estimated capital		**428**			

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.6. Major equipment in Sample Preparation Laboratory of MRD (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
Rock saws (6)		40		2	
Custom wire saw (1)		40*	1995	2	built in-house
2 grinding, 3 polishing laps			pre-83	3	
2 Franz separators, 1 superpanner			pre-83	3	
Other preparation equipment: cleaner, ovens, shatterbox, camera system				3	

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Table 5.7. Major equipment in Instrument Development Shop (Dec 1999)

Equipment	Serial No.	Cost $000	Year	Condition	Comments
Milling machines, 1 with two-axis control				3/5	two obsolete
Lathes (6)				3/5	two obsolete
Other capital: grinders, drill press, sheet metal benders, welding.					

Condition: **1** = state-of-the-art, **2** = current, well-maintained, and fully functional, **3** = old, but well maintained and fully functional, **4** = functional but significant downtime, needs to be replaced soon, **5** = poorly-maintained (parts not available) and/or barely functional, needs to be replaced immediately. Abbreviations in **Appendix**.

Overall, the quality of the instrumentation and the state of the facilities are excellent. Few of the instruments are truly *cutting-edge* (e.g., quadripole ICP-MS vs. magnetic sector multi-collector ICP-MS), but many are top-quality *current generation* research instruments. The only obvious exception is the Sensitive High-Resolution Ion Microprobe (SHRIMP), maintained by CGD, which represents cutting edge analytical technology.

Although the committee understands that the SHRIMP is not assigned to the MGP, precise U-Pb dating by ion probe has very important applications in mineral deposits research. The effective application of strategic research facilities like the SHRIMP is a high priority and provides a focus for some important aspects of cross-divisional relationships, as they affect the needs of the program. There are several areas where improvements can be made to current practices in the interests of making best use of existing laboratories and ensuring that the GSC continues to have access to very high quality laboratory facilities. These are discussed below.

5.2. Technical Support

Many oral and written submissions to the Review Committee from GSC research scientists expressed a need for increased technical support for the laboratories, to relieve them of the need to undertake sample preparation and other routine technical functions. It was noted that budget reductions over recent years significantly reduced the amount of technical support available to scientific staff.

Although efficiencies are likely to be gained from increasing support staff, the need for more laboratory support must be balanced against the need for new appointments of scientific staff. As long as funding constraints force the GSC to limit hiring, the Review Committee feels that replacing lost technical support in labs, although important in some areas, is a lesser priority than rejuvenating the scientific staff.

Table 5.8 summarizes the relative priorities for MGP staff replacement, based on submissions (both written and oral) to the Review Committee by staff in the MGP, input from GSC managers, and the Review Committee's own assessment. The Committee's ranking is based on its assessment of what would best increase the quantity and quality of MGP outputs and ensure the continuing relevance of the MGP to national priorities.

Table 5.8. Summary of relative priorities for MGP by staff, management, and the review committee

	Staff Ranking	Management Ranking	Committee Ranking
Add young scientists	1	1	1
Increase technical staff	3	3	2
Rationalization of laboratory operations		4	3
Maintain analytical facilities	2	2	4
Increase administrative staff		5	5

Recommendation 28. The MGP should review the needs for additional technical staff to ensure efficient and effective operation of those laboratories deemed essential for the support of the scientific program.

5.3. Capital Replacement Program

There is a wide range of analytical instrumentation and facilities at GSC (**Tables 5.1 to 5.7**). Many of the instruments are current generation (e.g., Elan 6000DRC ICP-MS), some are aging but functional (e.g., Cameca SX-50 electron probe), and some are obsolete (e.g., Philips PW 1404 XRF spectrometer). Maintaining the mineral laboratory infrastructure represents a major past and continuing commitment of resources (**Table 5.9**).

Table 5.9. Summary of capital requests and expenditures for analytical instrumentation and facilities for Mineral Resources Division.

Year	Requested ($000)	Spent ($000)	Percentage
1994-1995	2171*	1294	40.4
1995-1996	1186	644	45.7
1996-1997	1056	724	31.4
1997-1998	541	366	32.3
1998-1999	1298	836	35.6
1999-2000	1131	578	48.9

Notes: Approximately 60% of instrumentation and facilities services the MGP. Deficits are not cumulative; capital shortfalls include both deferred and new initiatives.*1994 includes Digital Cartography initiative.

However, budget cutbacks in recent years have reduced the funds available for maintenance, upgrades, and replacement. In order to maintain current capacity in analytical methods and to benefit from the efficiency gains generated by ongoing improvements in data quality, throughput, and automation associated with new instrumentation, a program of regular upgrading and replacement needs to be in place. Although capital replacement plans are reportedly developed by all laboratories on an annual basis, it appears that implementation is more often than not compromised by budget restrictions.

Recommendation 29. ***A strategic capital replacement program for essential laboratory facilities should be designed and implemented to maintain state-of-the-art analytical facilities in support of the GSC core program.***

5.4. Integrated Management of Laboratory Facilities

Most of the GSC laboratories are created, assigned to, and managed within the Divisions that they mostly service, which has the advantage of ensuring that the laboratories meet the needs of the immediate research programs. However, this policy does not appear to provide a consistent level of access to the facilities by researchers from outside the host Division and results in uneven support of the laboratories. Some scientific staff expressed the view that access to some analytical facilities is often determined more by the research interests of the lab staff, rather than by prioritization of needs against the corporate strategic plan. Implementation of the PDS should provide a firmer basis for establishing priorities for delivery of analytical services and research to meet project requirements. All activities should be fully justified and consistent with the corporate strategic plan to ensure that the highest priority needs are met.

Recommendation 30. ***A transparent corporate approach to assigning priorities for laboratory access and allocation of analytical resources and services based on the needs of approved projects should be implemented with the specific objective of improving cross-divisional access to all laboratory facilities in the GSC.***

Recommendation 31. ***Simultaneous with a review of required laboratory services across the GSC (see below), the management of and operating arrangements for the laboratories should be reviewed with a view to achieving greater synergy and increasing efficiencies through sharing of facilities and staff resources across divisional boundaries.***

5.5. Rationalization of Laboratories

The GSC geochemical laboratories are, in general, well maintained, functional and efficient. However, sufficient funding to maintain and eventually replace all of the current equipment is not available now, and may not be available in the immediate future. It is possible that, as equipment deteriorates with time, decisions will have to be made about capital replacement, requiring choices about which analytical services will be maintained and which will be met by alternate delivery mechanisms. Inevitably, a choice must be made between maintaining all of the present instrumentation at an inadequate level, or focusing on those instruments that are essential and outsourcing some work to universities and commercial laboratories.

Some of the geochemical analytical services that have been maintained in the recent past (REE and HFSE by ICP-MS) are those that are, or could be, available externally. Ironically, some of those that have been reduced or eliminated (e.g., low-level PGE analyses by ICP-MS, semi-metal analysis by hydride-generation AAS) are precisely those that cannot be easily obtained externally. Some facilities require hands-on operation (e.g., SEM, electron probe microanalyzer) and there is a good argument for maintaining these facilities based on the full-time need for such data in the GSC program, However, others (e.g., routine AAS and ICP-MS) *could* be done externally, especially if the GSC worked with the external operators to establish the analytical protocols, quality controls, and quality assurances. Indeed, there is presently a considerable surplus of analytical capacity in most commercial laboratories, many of which have analytical equipment identical to, and in some cases superior to, that housed at the GSC.

Given the high level of resources that are presently dedicated to these laboratories and that will be needed in the future, it would be appropriate for the MGP to begin to identify analytical services that may not be supported internally in the future and prepare for alternate delivery mechanisms.

Recommendation 32. ***A review of laboratory needs and management arrangements to support the science program should be undertaken. This review should consider current and future program needs, including analytical methods not currently employed at GSC. Existing laboratory facilities (and future needs) should be considered in terms of the following categories: a) essential to core MGP programs and must be maintained in-house; b) important to the program but can be contracted out to commercial laboratories; c) important to the program but usage does not warrant in-house capability, and capacity exists at universities or other research agencies through partnership or contract; d) no longer important to the program and/or regularly required and should be terminated.***

Recommendation 33. ***Based on the above analysis, a program of outsourcing of analytical services should be instigated and an outsourcing management plan should be implemented that contains regular monitoring and review of arrangements and quality assurance procedures. This plan should include elements of commercial outsourcing of geochemical analyses as well as building partnerships with research analysts in university laboratories for specialized analytical needs that cannot be met in-house.***

5.6. Information Technology and Other Facilities

The GSC has excellent library and map information facilities. The quality of PCs and workstations appears to be adequate, but many staff criticized the inadequate level of technical support to maintain and/or upgrade the computing facilities. Like other programs, the MGP has resident pockets of expertise in GIS and geospatial applications (e.g., World Map project, geomathematics group). Nevertheless, many individual scientists expressed frustration with the lack of IT support and lack of access to IT and GIS expertise. GIS and structures (relational) databases are basic tools for the integration, analysis, and visualization of geospatial and other geoscientific data in modern formats. The need for support in this area is uniformly present throughout the scientific program and is a corporate necessity, not a divisional or program need. The needs of individual projects should be addressed within the project planning phase, with resources allocated on a priority basis to meet agreed specific needs.

Recommendation 34. ***Technical support should be provided on a GSC-wide basis to maintain computing and network hardware, and network and database software to meet project needs. Except where dictated by specific project needs, IT hardware and software should conform to standard GSC-wide minimum specifications and configurations to maximize the efficiency of IT support and ensure compatibility and transfer of information across the GSC.***

Recommendation 35. ***The GIS, database and geomathematical needs of projects should be determined when projects are planned and designed, and adequate specialist and technical support in these areas should be made available from across all GSC divisions.***

6. Originating, Implementing, Prioritizing, and Managing Research Projects

This chapter reviews the methods and procedures that have been used in originating, implementing, assigning priorities, and managing research projects within the MGP (**Term of Reference #5**).

In the past, the MGP has been delivered through projects that were mostly developed within the MRD. Project planning was commonly bottom-driven and the principal drivers cited for new project development have been the broad strategic plans, bilateral needs determined through consultation with the Provinces and Territories, and scientific priorities defined through internal and multilateral workshops. The MGP appears to be doing a satisfactory job of aligning its projects with departmental and sectoral goals and objectives, and documenting the timeliness, deliverables and criteria for success.

Staff and budgets are managed though a combination of division and subdivision managers and project coordinators. Performance and outputs are monitored through a combination of the Annual Review Process and the GSC Project Management Information System. Performance against milestones is monitored and reported in semi-annual reports through the Sector Management Team. Reports on some projects are posted on the GSC website three times per year. The MRD has recently commenced evaluation of the impacts of its major projects.

Substantial changes have taken place in recent years, and are presently taking place though initiatives under the ESS Management Plan and the move to a PDS. The committee's comments are directed toward the following areas:

- Strategic and business planning, program development, and priority setting
- Project resources
- Project management
- Internal communication
- Client communication
- Evaluation

6.1. Strategic and Business Planning, Program Development, and Priority Setting

6.1.1. Policy Framework

The MGP is developed within a framework defined by the following mandates, which were discussed in detail in **Section 2.2.**):

The government's key priorities, as outlined in "*Science and Technology for a New Century*";

- NRCan's policy goals and objectives, notably WINS (*Winning in the Knowledge-based Economy*);

- ESS's strategic goals and objectives, particularly those developed in response to the *Science and Technology Capacity Study*; and
- The *Intergovernmental Geoscience Accord*, which defines the respective Federal and Provincial roles in geoscience.

Recent strategic planning for the MGP is described in the GSC's 1996-2001 Strategic Plan. This plan outlines the Government policy objectives that drive the strategic plan and sets forth a number of guiding principles by which the GSC will meet new needs. The strategic plan strongly emphasizes the GSC's collaborative role, and sets out detailed plans for working with Provinces and Territories, universities, other government departments, and industry. The strategic plan also highlights the GSC's role to represent Canada internationally. The Strategic Plan identifies five general strategies for the MGP, to which the four MGP sub-program elements are closely aligned:

- Explain how mineral deposits are formed;
- Focus mineral exploration research to take advantage of unique GSC capabilities;
- Conduct mineral resource assessments for policy and land-use planning needs;
- Maintain state-of-the-art laboratories; and
- Develop an international perspective.

The details of how the MGP intends to address these strategic directions are found in the ESS and MGP Business Plans. ESS identifies four Business Lines by which it variously addresses the NRCan goals and objectives:

- Science and Technology;
- Knowledge infrastructure;
- Development of federal policy and regulations; and
- Promotion of Canada's international interests.

At the Sector level (1999-2002 ESS Business Plan), objectives are identified under each Business Line and deliverables are identified that address the NRCan policy goals and objectives. At the Division level (e.g., 1999-00 to 2001-02 MRD Business Plan), projects are identified against each of the applicable ESS objectives; deliverables and performance indicators are provided at the project level. The deliverables in the two sets of Business Plans, although displaying some degree of conformity, are not easily matched in detail.

The Review Committee noted that there is a discontinuity between the very high level of strategic planning for the GSC as a whole and the business planning at the Division level. The GSC's strategic directions encompass a wide range of activities and it is clear that the MRD has little difficulty in justifying its various projects within the framework of these strategic directions. However, the committee believes that for effective business planning at the project level, an element of strategic planning is also needed to identify priority areas, allocate the program's resources on a strategic basis, and provide rationale for refocusing activities and staff, where appropriate.

The Review Committee was given a draft of ESS goals and objectives that will drive the organization's strategic and business planning over the next planning period. The goals align

closely with the NRCan goals, as they must, and the objectives provide, in the committee's view, a good starting point for more detailed strategic planning.

Within the framework of organizational strategic planning through 1999, and Sector/Division business planning, new project development took place almost entirely through a "bottom-up" process where project proposals were initiated and developed by individual and/or groups of scientists. These were then reviewed, evaluated, and prioritized by Division management. Approval was based upon scientific criteria and availability of resources.

The Review Committee noted that, historically, initiation of project proposals within the MGP has been driven by a number of factors. These include the availability of a critical mass of expertise, personal scientific interest, opportunity for funding within a larger project, ongoing relationships by scientists with geographic or scientific areas, and the availability of partners. One common theme in interviews was that the lack of operational funding, particularly within MRD, has made access to external funds a key driver in new project directions. Few, if any, interviewees cited organizational or program strategic goals as drivers for new programs. When asked, most expressed the opinion that they could easily cast any project within their field of expertise in the context of the MGP strategic goals. It was apparent to the committee that many staff failed to either identify with or effectively link their project with broad NRCan/ESS policy goals and objectives.

Many submissions to the Review Committee, both during the interviews and in written submissions, expressed both confidence and pride in this process and the "bottom-driven organizational culture" that empowered staff both in terms of the science undertaken by the organization and in ensuring excellence in its endeavors. At the same time, many submissions were also critical of the lack of strategic direction and leadership.

The current bottom-driven approach for proposals contributes to staff engagement, to scientific excellence, and the "scientific culture" of the organization. This culture, which can be defined as the cumulative sum of policies, practices, and traditions of the GSC, and of the MRD in particular, is dominated by self-direction and independent research. Such a process can, in the absence of clearly defined strategic corporate priorities for assessment of such proposals, lead to a program that depends more on the research interests and expertise of the current staff than the current needs of the program stakeholders and clients. In other words, the projects may be of high scientific quality, but of limited direct relevance. **While this may have served the GSC well in the past, the Review Committee believes that cultural change is needed for the GSC to respond effectively to the current fiscal environment and continue to meet the GSC mission.**

The Review Committee has concluded that the MGP is producing a wide range of high quality science outputs of relevance to government, the exploration and mining industry, the minerals service industry, and the community. Notwithstanding this, the Review Committee has identified a number of areas where the program is clearly in difficulty:

- It is too broad and fragmented with too many projects; in other words, it is spread too thinly;
- Many (if not most) internally funded projects lack adequate resources, especially technical support, to be fully effective;
- The program is being unduly influenced (driven) by short-term tactical issues and opportunities rather than longer-term strategic interests;

- The program includes some projects or activities, especially technology and applications, that could be undertaken by the private sector or by universities; and
- The program does not fully realize the potential synergies within the MRD, and especially with other GSC Divisions, to achieve an integrated and cost-effective strategic program with greater impact.

A number of factors have combined to contribute to the above situation:

- There is a gap between the broad NRCan policy goals and objectives, and specific project outputs and outcomes;
- There is a lack of clearly defined strategic priorities for the MGP;
- There is a serious shortage of funding;
- Strategic priorities are not always aligned with short-term opportunities offered by external funding;
- Stable management was absent within the MRD for almost five years; and
- There are barriers (real and perceived) between GSC Branches, Divisions and Programs.

Irrespective of the level of future funding, the strategic direction of the MGP needs to become more focused to meet the changing needs of government, industry and the community, and to take advantage of opportunities resulting from these changes. The views of the Review Committee on future initiatives and opportunities are outlined in **Section 7**.

Recommendation 36. A long-term strategic MGP plan based on national needs and priorities should be developed as a matter of urgency.

Recommendation 37. The strategic plan, in conjunction with the introduction of the PDS, should drive a cultural change in the GSC that harnesses existing resources to deliver excellent multi-disciplinary and cross-disciplinary scientific research results to meet the changing needs of government, industry and the community.

6.1.2. Cross-Divisional Links and Program Delivery

Although the MRD has primary responsibility for delivery of the MGP, significant contributions are delivered through other Divisions. This cross-divisional approach has the benefit of providing critical skills, such as surficial geology and geochemistry that reside in other divisions. However, in order to develop and fund projects in this environment, clearly defined strategic direction and strategic priority setting are required at the Branch level. Although consultative mechanisms are in place at the Director level to determine priorities and to allocate resources, submissions to the Review Committee indicated that divisional structures have created barriers to deployment of resources, especially for research expertise and facilities in high demand, such as geochronology. Clearer definition of strategic directions and priorities at the corporate and Branch level would help overcome the competition for resources generated by the bottom-up bidding process and terminate lower priority activities. The PDS is intended to provide a firmer basis for assessing project proposals against strategic directions and corporate priorities. This system may also help to move the culture of the organization away from self-direction and independent research to one that

values and encourages multi-disciplinary, team-based projects developed in close consultation and cooperation with Provincial and Territorial partners and industry stakeholders and clients.

The MRD currently operates on both project- and discipline-based lines for research and also as a cost-center for the laboratories. The Review Committee recognizes the importance of maintaining long-term strategic research in key disciplines, but this can equally be done on a project basis. Funding on a project-by-project basis forces more regular review, not only of the quality and timeliness of the outputs but, more importantly, of the relevance and justification for continued research in that discipline. The committee also recognizes that the development of new understanding, applications, approaches, and methodologies in geoscience is an important role in government research. These are often subsequently adopted and implemented on a routine basis both in GSC programs and by its clients and partners. Decisions need to be made on a regular basis on whether continued research in that field has higher priority than new avenues of research. This may be the case for several lines of research currently being undertaken in the MGP.

The distribution of certain activities amongst the different divisions reflects previous program arrangements. For example, the airborne gamma-ray mapping group has historically been associated with the MRD and its precursors, reflecting the past focus on the use of gamma-ray spectrometry in mineral exploration, especially for uranium. However, gamma-ray mapping also has important applications in terrain (land resource) and soil mapping as well as bedrock mapping in areas of outcrop. Airborne magnetic surveys, on the other hand, have historically been conducted through the CGD. Combined magnetic and gamma-ray surveys are much more cost-effective than those undertaken separately. Similarly, there is an overlap of skills in the acquisition, processing, and integration of airborne geophysical data. There may be synergies to be gained from integration of airborne gamma-ray and magnetic mapping programs and section staff, i.e. the Airborne Geophysics Section in the MRD and the Regional Geophysics Section in the CGD.

NATMAP has been an important mapping vehicle for both surficial and bedrock mapping in the GSC. This program has been highly successful in providing a new generation of high quality maps and in providing new insights into regional geology. NATMAP projects are multi-disciplinary and vary considerably, from project to project, according to the geology and objectives identified in consultation with Provincial and Territorial partners. Regional metallogenic studies have been a component of some, but not all, NATMAP projects. NATMAP (or an equivalent regional geological mapping program) is the logical vehicle for providing both the synergies of common logistics and also a modern geological framework for the metallogenic investigations. Regional metallogenic mapping and assessment should be an integral part of all regional bedrock mapping programs. Moreover, there is sufficient evidence from EXTECH and other regional mapping projects to show that airborne geophysical surveys are a fundamental component of modern geological mapping, especially in areas of poor outcrop. Thus, new geophysical datasets should form an essential part of the regional mapping program and the geophysical requirements of the NATMAP and EXTECH programs should be important drivers in setting priorities for geophysical acquisition, for both the NATGAM and magnetic mapping programs.

Recommendation 38. Future projects to address minerals objectives should be multi-disciplinary and draw on relevant expertise from across the existing Divisions in the GSC, and from Provincial and Territorial geological surveys.

Recommendation 39. The MGP should include regional metallogenic studies as a integral component of bedrock mapping programs; and ensure that regional airborne geophysical surveys form an integral part of the regional mapping and metallogenic studies.

6.1.3. Divisional Management Arrangements

The present management structure in the MRD (and perhaps in other Divisions) comprises a mixture of discipline/function-based and project-based managers. For example, line management is through sections and subsections whereas program outputs are delivered primarily through projects. **It is widely recognized internationally that the project provides a flexible vehicle for team-based research and the delivery of outputs. Research at government institutions and universities is being increasingly undertaken by multi-disciplinary teams headed by a project leader or manager. This move to the use of the project as the main operational unit means that funding and accountability for research outputs and outcomes is devolved to the project team and its manager**. The new PDS should lead to a more project-centric organization with at least three advantages:

- It should ensure that only those projects meeting stringent corporate guidelines are funded;
- It should overcome organizational and, especially, cultural barriers; and
- It should ensure funding for the most worthwhile and relevant science across the whole GSC.

The Review Committee believes that a review of the present management structure in MRD and across other Divisions is desirable once the PDS is implemented to ensure the most effective and efficient management of the MGP. While responsibility for the delivery of planned project outputs to time and budget must rest primarily with the project manager, the Review Committee recognizes that the longer-term needs of staff, especially mentoring and career development, need to be provided for outside the project. The proposed review of the management structure would focus primarily on whether management is best achieved through continuing the present discipline-based subprograms and sections, or whether a more streamlined management arrangement (relying more on project management with project managers reporting to a small number of divisional submanagers) is more efficient.

Recommendation 40. In conjunction with the implementation of the new PDS, MRD should review its organizational structure with the intent of simplifying the management and reporting structures. Any new management structure should recognize and support the project as the most effective mechanism for delivery of team-based research outputs.

6.2. Project Resources

The MGP budget is provided primarily through appropriations to the MRD and totaled a notional $5.536 million in 1999-2000 (see **Table 1.3**). An additional $1.419M was obtained in 1998-1999 from external sources through cost-recovery activities, including revenue from sale of products, provision of contract services, and from other government and industry co-funding of projects.

Budgets were allocated on the basis of strategic program funding levels to individual divisions, which then allocated funding to projects and cost centers based on annual project review, new proposals accepted, and zero-based consumable and operational costs for laboratories. Staff are assigned to projects on a full or part-time basis as required by the needs of the project. Coordination of project staff rests with the project manager, using a team approach, Accountability based on individual performance rests with the Section or Subdivision Head.

The Minerals and Regional Geoscience Branch has set a target of 15% of Abase funding for external funding for the Divisions. The level of external funding varies significantly from project to project with some, such as international projects PASMA and Brazil, being fully funded externally, whereas others are funded entirely from Abase funds.

The Review Committee recognizes that operational funding for MRD staff involved in NATMAP and other projects carried by other GSC Divisions may, in some cases, be provided by the project. It also recognizes the value of external funding and collaborative projects such as the EXTECH projects and the MERA projects co-funded by Parks Canada and the Department of Indian Affairs and Northern Development (DIAND). Nevertheless, the committee has concerns regarding the limited funding available to major strategic, regionally-based programs such as the NGR and NATGAM projects, which provide basic information to underpin resource exploration and provide baseline data for environmental management. The lack of sufficient Abase funding to continue a long-term strategic program has forced a change to a more tactical approach that is highly influenced by and very dependent on the level of external funding. This issue has been recognized by the GSC, and the need for the development of a longer-term research agenda was identified as the first of five strategic initiatives in the 1999-2000 MRD Business Plan. The critical issue is how to balance between ensuring delivery of a strategically important program over the long-term and capitalizing on short-term opportunities for funding or partnerships in addressing immediate issues. The Review Committee suggests that this can best be addressed through the development of a long-range strategic research plan based on national needs and priorities.

The Review Committee believes that it would be preferable to curtail certain lower priority projects in favor of maintaining strategic, flagship projects at a viable level. An issue of particular concern is that continued under-funding of major strategic programs may already be reducing their impact on key client groups and that this may lead to their degradation and demise in the longer term. Although the number of projects is too large and the level of funding has been substantially reduced, there has not been a commensurate decrease in the range of work undertaken by the MGP. It would be preferable to complete a smaller number of fully funded projects on schedule than attempt to undertake a larger program with inadequate resources. From the evidence presented, the committee believes that there are still a significant number of smaller, thematic and/or discipline-based research projects that do not appear to be well integrated in the core program. It is critically important that the MGP conduct a rigorous reappraisal of all existing projects against the program's strategic directions, with the objective of eliminating projects that do not address the program's priorities. This would allow the MGP to focus resources on a smaller number of projects that are closely aligned with strategic priorities.

The Review Committee believes that there is a need to invest in leading-edge and high-risk Research and Development in the expectation that the new tools and knowledge may be later applied to major GSC projects. However, a significant hindrance to investment in this type of research, which was identified in the MRD Futures document and the 1999-2000 Business Plan, may be the program's "stranded assets", i.e. assets that were acquired to support the pre-program

review level of activity, but which do not now comprise a critical mass capable of sustaining an independent level of program activity. The continuing cost of stranded assets may preclude strategic advancement of the program into new areas. Management should vigorously explore opportunities to identify and deploy these "stranded assets" to strategic (flagship) projects. There may be scope to develop a more integrated program across divisions, thereby creating synergies through sharing of critical skills and the possibility of redeployment of staff to support strategic projects. This would also ensure that "stranded assets" are effectively captured and linked within the broader GSC program.

Staff comments overwhelmingly indicated that the highest priority should be placed on the appointment of younger staff at all levels. The lack of younger staff to provide future expertise and knowledge in the MGP has been recognized in the MRD 'Futures" document and 1999-2000 Business Plan, which nominated rejuvenation of the staff profile through strategic hiring as one of five strategic initiatives. The Review Committee endorses the ESS Strategic Plan for recruiting, retaining, and rejuvenating human resources outlined in the 1999-2000 Business Plan and notes that 2 of the 25 new staff appointments will be made in the MGP. However, the need for immediate rejuvenation is so pressing that adding a larger number of new scientists must be made a high priority.

Recommendation 41. ***The strategic plan should be used as a basis for reviewing and rationalizing the current MGP into fewer, better funded projects with a more balanced ratio of salary to operational funding levels. The committee believes that a salary:operations ratio of less than 70:30 should be sought across the MGP. The rationalisation should: a) terminate projects and activities that do meet strategic directions or are of low priority; b) examine the distribution of expertise between GSC divisions to maximize effective use of resources; c) aggregate small-scale projects with similar objectives into larger projects to take advantage of multi-disciplinary input and synergies of scale; and d) capture any stranded assets resulting from the recent program review and direct them towards project areas where they can make an effective contribution to the program's strategic priorities.***

Recommendation 42. ***The staff rejuvenation program in the MGP should be accelerated urgently through strategic hiring of younger scientists in priority areas.***

6.3. Project Management

The MGP is delivered through activities that range from large multi-disciplinary projects such as those carried out under EXTECH, through medium-sized contract R&D projects, to small discipline-based research projects. Some projects employ project management principles and elements of best practice, including:

- Needs analysis with stake-holder and client involvement in planning;

- Effective scoping of project with definition of outputs;
- Project planning with achievable milestones;
- Risk management;
- Monitoring;
- Reporting and communication; and
- Evaluation.

However, some parts of the MGP appear to operate more on the basis of ongoing function or discipline/research interest than on a project basis, and lack clearly defined objectives, outputs, and time frame. Key project outputs and milestones are listed in the annual Business Plan.

A common theme in staff comments to the Review Committee was the contention that the amount of time spent on project (and organizational) management was both excessive and increasing, and that some of the planning that did not lead to implementation appeared to be "process for process sake." There are clearly increasing demands for accountability entailing greater planning, monitoring, and reporting to government and to clients and stakeholders. The Review Committee recognizes these as part of the operating environment in modern government and sees obtaining an effective balance of the management overhead and productivity gains as a challenge for GSC management.

Recommendation 43. Scientific project managers should receive better technical and secretarial support for routine functions (financial management, certain reporting, logistics, etc.). This would allow scientists to focus on the management of the scientific program and to interface with clients and stakeholders. This support could take the form of part-time or shared (across several projects), full-time technical and administrative support directly to major projects. Consideration should be given to whether or not this can be achieved by deployment of staff from central functions to divisions and major projects.

The reward and recognition of high performing staff is intimately linked with productivity. A number of staff submissions indicated that the present reward and promotion system, which is based on individual research achievement and publication, is too narrow, does not encourage participation in multi-disciplinary teams, and discourages and perhaps penalizes scientists involved in production of digital publications and datasets. The Review Committee believes that the management and reward systems must support and reinforce the modern paradigm of team-based multi-disciplinary research and recommends a broadening of the GSC reward system to recognize excellence and productivity in areas other than those currently emphasized in the reward system.

Recommendation 44. The use of “best practice” in project management, including scoping, monitoring, reporting, and evaluation should be extended to all projects.

Recommendation 45. The development of team-based, multi-disciplinary research should be supported and encouraged, and the current criteria for promotion and advancement should be expanded to recognize the value placed by the organization on multi-disciplinary teams and productivity and excellence in all contributions to the GSC program.

6.4. Internal Communication

Internal communication at the GSC is achieved through e-mail, subdivision and divisional staff meetings, and project meetings. The Review Committee observed no major impediments to communication in the MGP, and noted that communication is very effective within some research groups and projects. However, several submissions to the Review Committee indicated that there are deficiencies in internal communication in certain areas, most noticeably between divisions but also between senior management and staff, between project leaders/scientists and laboratories, and between scientists.

A number of submissions highlighted a concern with the quality of communication between management and staff. Several submissions specifically expressed the view that professional staff are not generally aware of the extent to which their upward feedback was incorporated in decision making by senior management. Comments were made to the effect that “feedback tends to flow upwards, but not downward”, “managers don’t have time to look to staff as they are too occupied with the demands of the Tower”, and “managers are increasingly preoccupied with dealing with bureaucracy and are always managing up rather then down”. These comments suggest to the committee that there is at least a perception among staff of a communication discontinuity between management and professional staff, and, in particular, a problem with downward feedback within the organization.

Communication within organizations as large as the GSC, and even within the MGP, poses significant challenges. However in times of change, effective and transparent communication between all levels of the organization is critical. The Review Committee is of the view that improved communication may help overcome the lack of understanding of, and alignment with, corporate priorities, and assist in the better coordination and integration of research and other activities. Improved internal communication would also help ensure that the GSC captures and shares the benefits of knowledge and research development across the whole organization.

Improved communication within the organization can also result in direct scientific benefits. For example, the Review Committee was told about cases where the results of leading-edge research were regularly given externally as short courses to industry and other government clients, but not given within the GSC. The 1999-2000 ESS Business Plan lists internal communication as a priority for ESS management. The 1998-1999 to 2000-2001 MRD Business Plan identified implementation of a transparent communication system in MRD as a management priority.

Recommendation 46. The current communication strategies, both within the MRD and between other GSC divisions contributing to the MGP, should be reviewed to determine if internal communication can be made more effective. In particular, managers should review and, where necessary, improve mechanisms for

downward feedback to ensure an effective and transparent flow of information to staff.

Recommendation 47. Strategies such as "Team Briefing" and regular, informal forum-style meetings between the GSC executive and staff should be implemented to provide an opportunity for communication on current issues.

6.5. Client Communication

For large projects, particularly those that have a component of external funding, clear lines of systematic communication are usually mandated by the clients. This communication can take the form of regular reports, workshops, field trips, posters, and presentations. The evidence presented to the committee showed that for projects like EXTECH II, the international projects, and the world map project, to name a few, the client communication was generally very good and well received. Similar good communication at the working level seems to be a feature of most multi-disciplinary and externally-funded projects. As well, many MGP scientists go out of their way to present their knowledge and results to industry clients through workshops, field trips and short courses. This aspect of the MGP's client communication seems to be working very well indeed and the committee applauds the effort that has been expended on this area by scientists.

The committee also heard evidence of increasing communication, both within and external to government, with non-traditional clients in such diverse fields as health, environment, parks and transportation. This is commendable and the committee encourages the MGP to proactively seek out new clients for its knowledge and information. The committee also believes that MGP scientists have generally good communication with colleagues in the scientific community, through written papers, scientific presentations, and joint supervision of students.

An excellent framework for communication and collaboration with Provincial and Territorial surveys is set out in the bilateral accords signed under the aegis of the Intergovernmental Geoscience Accord. Likewise, mechanisms for high-level communication with the Provincial and Territorial surveys are well developed through the National Geological Surveys Committee, which provides an opportunity for a significant amount of input into GSC program planning. However, evidence from interviews and from discussions with Provincial/Territorial Survey colleagues, suggest that the quality of communication between the GSC and individual Provincial and Territorial surveys is often a function of individual relationships, rather than a philosophical commitment to communicate with sister surveys. There are still too many instances of individual GSC scientists planning and, in some cases, implementing research programs without adequate contact with their Provincial/Territorial counterparts. Provincial/Territorial surveys, by and large, are not familiar with the MGP, the exception being the work of individual MGP scientists who have been active in the jurisdiction and have made a point to contact Provincial/Territorial workers. It is imperative that Provincial and Territorial surveys, with their specific mandate for minerals in their jurisdiction, be fully consulted and offered collaboration by MGP scientists. There is still considerable room for improvement in communication in this area.

One other area where lines of communication do not appear to be as well developed as they should be is with the senior mineral industry officials. The Review Committee recognizes that the GSC routinely consults with specific members of industry and other clients (for example, the S&T Capacities Study, NATMAP projects, and the formative consultations for EXTECH II and III).

However, it was not clear that an adequate overall level of communication is routinely practiced with respect to the whole program. The committee feels that a systematic, periodic review of the strategic directions of MGP programs and projects by senior representatives of the mineral exploration and production industry would provide valuable input during priority setting and program planning.

Recommendation 48. ***The MGP should ensure continuous and comprehensive communication of their program and project plans with the Provinces and Territories in which they occur.***

Recommendation 49. ***The MGP should consider using a high-level industry advisory committee, composed of representatives of major and junior companies actively engaged in Canadian exploration, to review and comment on the strategic direction of programs on an annual basis.***

6.6. Evaluation

The ESS and MRD Business Plans contain information on Deliverables and Performance Indicators for each project. Evaluation is reported in the following forms:

- Performance against milestones is reported at the middle and end of each year;
- Evaluation against performance indicators is conducted annually or at the completion of projects;
- Divisional performance for the preceding year is reported in the annual Divisional Business Plan;
- Reports on quality projects are posted on the web three times per year; and
- Most projects are evaluated internally.

However, ESS policy is to encourage assessments by clients and stakeholders. The ESS Business Development section recently issued "*Guidelines for Client Satisfaction Measurement Activity*" as a basis for evaluation and instituted training in measurement of client satisfaction. Formal external evaluations have been conducted recently for a number of GSC programs as part of the ESS Science and Technology socioeconomic impact assessment. Under this program of evaluations, the NGR program, the Industrial Partners Program (IPP) and EXTECH II have all been evaluated externally and developed as case studies. The NGR assessment was a cost-benefit study whereas the IPP assessment included an evaluation of the economic impact of the program using a probability-based method. The assessment of the multi-disciplinary EXTECH II project evaluated a number of factors including wealth and job creation, improvements to exploration technology, contribution to geoscientific knowledge, non-traditional applications of geoscience, training of personnel, the degree of integration of federal, provincial and university programs, and the degree of collaboration. The evaluation rated EXTECH II as a very effective project and respondents unanimously recommended continuing the EXTECH model.

The evaluation procedures both currently in place and presently being implemented provide a firm basis for evaluation of programs and selected projects. However, given the limited resources available for the scientific program, full external evaluation is only warranted for large projects. The Review Committee believes that continued communication and feedback from the clients and stakeholders, both during the definition and development of the project and during its implementation, should ensure both the relevance and quality of the project and its products.

Recommendation 50. ***The MGP should broaden communication with its clients and stakeholders and undertake evaluation of its major projects. Evaluations should seek feedback and rank the relative importance of types of projects and products to key clients and stakeholders.***

7. Future Initiatives and Opportunities

This chapter provides the views of the Review Committee on potential future initiatives and opportunities for the MGP (**Term of Reference #6**)

The MGP has been undergoing major changes to its mandate, capabilities, and operations for several years. These changes have had serious negative impacts on the ability of the MGP to fulfill its responsibilities in the manner it has done previously. However, this process of change has also brought new opportunities. Although the program has lost significant resources (both human and financial), it retains a core of highly skilled, knowledgeable, and dedicated professional and support staff. The challenge now is to identify the opportunities for new or redirected initiatives that will make the best use of the knowledge and skills of the staff that remain, while being consistent with the mandate of the program.

MGP scientists presented the committee with a wide range of ideas about new directions for research in the minerals program. In general terms, the thinking behind these "new directions" tended to be rather linear, focused narrowly along new developments in the researchers' particular fields of interest rather than "outside the box" thinking in recognition of changing conditions or needs. Some of the more specific examples included:

- mineralogical and process-related trace-element signatures for finding deposits
- temporal relationships between distribution of SEDEX and VMS deposits
- chemical evolution of oceans from Archean to present
- control of anoxic oceans and the sulfur cycle on sulfide preservation and formation on the seafloor of ancient oceans
- genetic relationships between rifting, magmatism, heat flow, hydrothermal activity, and the formation of seafloor sulfide deposits
- tectonic controls of hydrothermal vents and associated mineral deposits
- syn-ore and pre-ore hydrothermal alteration associated with SEDEX deposits
- zonation of minerals, isotopes and elements in hydrothermal sediments
- chemical and isotopic composition of fluids hosting deposits
- pathways and processes by which metals are leached from sulphide deposits
- systematic, reconnaissance-scale indicator mineral surveys
- synchrotron radiation for mineral characterization and X-ray diffraction
- cathodoluminescence spectrometry
- XRF microprobe mineral analysis
- micro-XRD
- modeling of paleo-basinal fluids, including hydrodynamic modeling
- microanalysis of paleo-fluids
- dating of diagenetic minerals
- dating of duration of mineralization
- improved integration of airborne and ground geophysics across GSC divisional boundaries
- increased nuclear monitoring
- intensified and diversified indicator mineral surveys
- application of new understanding of regional glacial geology

- development of more comprehensive algorithms/software for 3-D visualization and modeling of potential field data
- the effectiveness of new analytical tools (multi-collector ICP-MS) in making isotope geochemistry a more useful discriminator of responses due to ore and non-ore processes
- spatial prediction models for identifying exploration targets and hazard areas
- better mineral potential maps
- predicting acid mine drainage and absorption
- standardized national and international databases
- process of magma degassing
- providing "robust linkages" between various models for arc mineral deposits
- natural dispersion of toxic elements in the environment
- continuous-flow MS and micro-analysis (laser-based, SIMS)
- gas chromatographic separation/automated preparation for stable isotope analysis of solids
- quantitative modeling of fluid flow

Some of the more general examples included the field of land management; environmental assessment and management; and geoscience information management.

The Review Committee believes that the process of change that has taken place in the MGP in recent years is not over and is not reversible. It seems likely that scientists who are able to identify new research opportunities that are aligned with the broader Departmental and Sectoral policies will continue to find new and challenging opportunities for their research. The committee sees new potential research initiatives and opportunities for the MGP in four important areas, which are discussed individually below:

- Opportunities arising from the changing needs of the mineral industry
- Opportunities arising from the increased emphasis on collaboration
- Opportunities presented by new and emerging technology
- Opportunities to apply existing skills in new directions

7.1. Opportunities Arising from the Changing Needs of the Mineral Industry

Most of Canada that is favorably situated in relation to cheap transportation and energy, and is not restricted from secure mineral title by competing land uses, has now reached a fairly mature level of mineral development. An analysis of the economic and employment benefit to Canada of domestic vs. foreign mining and exploration activities is beyond the scope of this review, but is largely self-evident and provides the basis for the mandates reviewed in **Section 2.2**.

Notwithstanding the recent discovery of Voisey's Bay, it seems safe to say that *most* of the easy discoveries, such as mineral deposits that outcropped, were surrounded by prominent gossans, or were found as obvious extensions of known deposits, have already been made. Likewise, modern, sophisticated exploration has already been performed in most of the older mining camps, leading to the discovery of many hidden orebodies in camps such as Keno Hill (YK), Flin Flon–Snow Lake (MB), Noranda (QC), Sudbury (ON), and Bathurst (NB). Discoveries of new giant camps such as Hemlo (ON), Voisey's Bay (NF), and diamonds (NWT), are becoming increasingly rare.

At the same time, many of the giant mines that have contributed so much to the nation's wealth and to our knowledge of mineral deposits are nearing the end of their reserves, including Sullivan and the porphyry copper mines (BC), Polaris and the Yellowknife gold mines (NWT), Gaspé (QC), and Bathurst (NB). Canada's share of world production of many metals has been dropping steadily for two or three decades (**Figure 7.1**) and it has already lost its former position as the leading global mining nation. In addition, Canada's share of global exploration investment has also been dropping recently and Canadian exploration capital is migrating to foreign projects at an alarming rate. Positive action is necessary if the future of this important industry is to be assured.

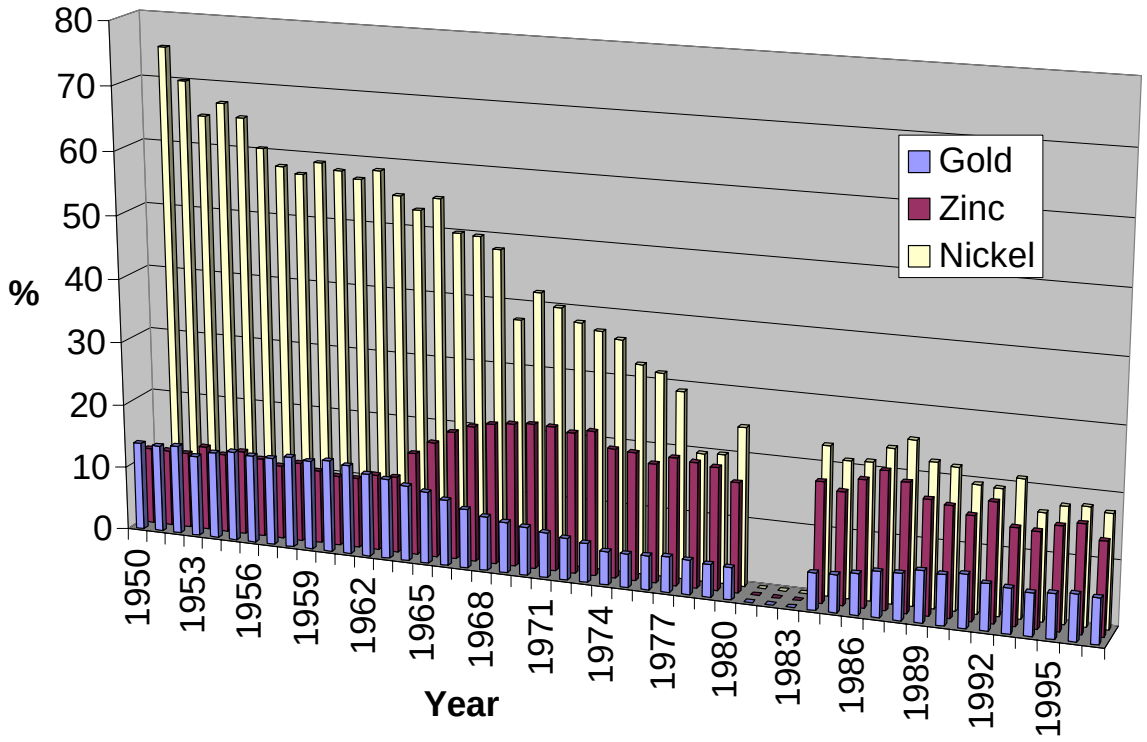


Figure 7.1. Chart showing Canadian share of global gold, zinc, and nickel production for the period 1950-1997.

Future Canadian mineral discoveries will almost certainly be made in locations that are obscured by thick overburden, water, ice, or barren rock cover, or that are deep extensions of surface mineralization. Exploring to greater depths through thick overburden and rock cover will require deeper geophysical penetration and more sophisticated geological and geophysical interpretation. This effort will also require a better understanding of the geological architecture of the Canadian landmass, especially its glacial and fluvial overburden history; more sensitive geochemical and geophysical tests for hidden mineralization; and improved mineral deposit models. The scientific leadership and many of the critical components of any national strategy to provide for the future of the minerals industry must, in the committee's view, be provided by the GSC. For reasons stated elsewhere in this report, it is clearly understood by all clients of all Canadian geological surveys that understanding the mineral endowment of the nation at regional and national scales can only be

accomplished by the GSC. The depth of geoscientific understanding that is required to effectively explore for increasingly difficult mineral deposit targets must be fostered at the national level, and effectively utilized in local settings.

The MGP has a critical role to play in the future of the mineral industry in Canada, but it appears that it will have to play this role in the context of decreased resources and an increased need for collaboration. The Review Committee believes that regional metallogenic studies, EXTECH-style projects, and northern development will be particularly important in the future minerals programs.

The GSC has a particular responsibility for minerals programs related to mineral exploration in the Territories. Territorial geological surveys generally have less capability than Provincial surveys for in-depth minerals work within their jurisdictions. Nevertheless, new information is required to encourage and support exploration in vast, remote, and inhospitable regions, and to support sound decision-making. Any northern development strategy must contain a strong component of mineral development, and geoscientific studies will be urgently required as part of this strategy. Realistically, only the GSC can provide the leadership for this work. It is the strongly held view of the Review Committee that the northern territories will continue to provide enormous opportunities for new minerals programs within the MGP.

Recommendation 51. ***The MGP must assume a national leadership role with respect to Canada's mineral deposit science to ensure that the country's mineral endowment is sufficiently well understood to allow successful exploration for the difficult mineral deposit targets that must replace diminishing reserves in the future. New programs should target, in particular, regional metallogenic and thematic studies in the northern territories.***

7.2. Opportunities Arising from Increased Emphasis on Collaboration

For most scientists, collaboration is a way of life and synergies resulting from the melding of diverse areas of expertise have been responsible for significant advances in scientific thought. Although collaborative research has always played a role in GSC research programs, it has blossomed in recent years. This has been particularly true in the MGP, prompted in part by the need to collaborate with Provincial and Territorial surveys in order to work in their jurisdictions, as set out in the Intergovernmental Geoscience Accord, and by the decline in available operational resources.

Collaboration with Industry and Provincial/Territorial Surveys: Multidisciplinary research programs such as EXTECH and NATMAP have been an important part of the MGP in recent years and the Review Committee feels strongly that these should be expanded. These large, multidisciplinary projects are developed in cooperation with Provincial and Territorial surveys and the mineral industry, serve a variety of clients, have self-evident relevance, and are uniquely coordinated by the GSC. The committee believes that the EXTECH model should be expanded from its present focus on mining camps with diminished reserves to a) *former metal-producing camps* that have been closed for some time, but might contain more deeply buried mineralization (e.g., Buchans, NF; Raglan, NWT), and b) *well-mineralized districts* that have never achieved commercial production because of insufficient reserves or inadequate grade (e.g., Muskox ultramafic complex, NWT; Selwyn Basin SEDEX district, YK-NWT-BC).

This approach can be applied to regional metallogenic studies of poorly studied districts where the geological environment is considered to be sufficiently prospective. The objective of such projects is to reduce the exploration risks posed by poor geological knowledge, especially of covered areas.. A feature of the EXTECH and many NATMAP projects has been the strong integration of geophysical, geological and geochemical data, commonly with the acquisition of new data sets. The active participation of industry representatives in these projects can ensure that industry interests are maximized and that relevant information possessed by industry as a result of their work is integrated in the final product. The Committee feels that comprehensive multi-disciplinary data sets provide a strong base for conducting metallogenic studies. Release of integrated packages of data in modern (GIS) format, coupled with new knowledge and insights into geological evolution and metallogenic environments provide an important stimulus to exploration, even in districts where present exploration interest is low.

Collaboration with Universities: Collaboration with university researchers has been an important aspect of many GSC scientific programs in the past, and the Review Committee feels that this should be increased in the future. Although some MGP projects have been interacting extensively with universities, some have not. Because of downsizing, the MGP no longer has the depth of expertise to cover, by itself, the wide range of mineral deposit types that occur in Canada or are of interest to Canadian mining companies. The same situation has occurred in Canadian universities, where an entire generation of world-class scientific expertise in mineral deposit geology has not been replaced. Collaboration with universities would benefit the GSC by providing expertise in areas not covered by MGP; it would benefit universities by providing expertise in areas covered by MGP; and it would benefit both by avoiding duplication of effort and analytical facilities and by increasing opportunities for external funding. Most importantly, by covering gaps in expertise and by providing critical mass, collaboration with universities would permit the MGP, in particular, and the GSC, in general, to focus more on MGP's strategic objectives, as opposed to purely opportunistic research that responds to available funding opportunities.

Recommendation 52. The GSC should seek to expand the capacity of the MGP to meet the increasing demand from industry for more sophisticated geological and exploration models (vs. genetic models) through greater cooperation and sharing of resources with university researchers.

7.3. Opportunities Presented by New and Emerging Technology

Technology exerts a major influence on all activities within the MGP. The Review Committee feels that clear opportunities have been presented by new technology development in at least two areas.

Analytical Geochemistry: As many scientists pointed out to the committee, major advances in scientific understanding and in practical applications of science have arisen in recent years from new technology that allows better analytical capability for an increased range of elements at lower concentrations. New geochemical applications could be particularly significant in, for example, detecting geochemical dispersion in bedrock or the surficial environment, tracing metal transport in the environment, developing sophisticated methods for tracing indicator minerals in surficial materials, and developing more detailed descriptive (and genetic) ore deposit models from case studies.

Recommendation 53. The GSC should continue to develop and monitor cutting-edge analytical technology and be able to apply this technology to the practical needs of the program.

Information Technology (IT): The importance of the growth in the use of computers in science cannot be overestimated. Computer technology is constantly providing new opportunities for data accumulation, processing, analysis, visualization, publication, and archiving. It is critically important that any scientific organization be able to maintain a very high standard of IT capability and that a high level of support be available in this area. GIS provides tremendous opportunities for the MGP to conduct sophisticated data analysis and to incorporate large volumes of related data in ways that are beyond the means of many of their clients. New generation software will provide increased capacity for the integration and modeling of large, complex geospatial datasets and the formulation of options for decision makers. The Internet technologies offer opportunity for on-line access to such data by traditional and new clients, and for on-line decision support systems employing geospatial data by exploration companies, land management agencies, and local communities. The GSC, as the custodian of key national geoscientific datasets, is positioned to play an important role in the provision of geoscientific information to a wider range of clients with differing needs.

Recommendation 54. The MGP should continue to look for ways to extract new understanding from existing data through the application of information technology, and should ensure that scientists possess a high degree of computer literacy and are provided with necessary Information Technology support. The GSC should also design and participate in programs that take maximum advantage of this technology.

7.4. Opportunities to Apply Existing Skills in New Directions

Scientists who contribute to the MGP have expert knowledge and skills that can be applied in areas other than mineral deposit research. As was pointed out by a number of interviewees, the same processes that transport and deposit metals in orebodies, and that distribute the evidence of buried mineralization in the surrounding rocks and surficial materials, also govern the transport of metals and other substances throughout the modern environment. The geochemical expertise that is critical for exploring the surficial environment for new mineral deposits can be applied to understanding the environmental effects of metal transport in other areas. The MGP has already taken steps along this road with its Metals in the Environment (MITE) program and the increasing application of its regional surficial and geochemical data to environmental issues.

The Review Committee believes that application of MGP data to environmental matters will be an increasingly important part of the program. Opportunities to provide baseline geochemical data for surficial materials and to provide better understanding of the geochemistry of metals in the environment must be sought and acted upon. In the context of the MGP, this means that opportunities to apply minerals expertise to environmental problems and issues. It is critically important that good science be brought to bear on the environmental issues raised by metals in the environment and that this science be communicated, not only to the geoscience community, but

also to those concerned with environmental matters, and with public health and safety related to the presence of metals in the environment.

Recommendation 55. The GSC should expand it's environmental programs to take advantage of the expertise that already exists within the MGP in the geochemistry of metals and metal transport mechanisms.

8. Abbreviations and Acronyms

The following abbreviations and acronyms are used in this report:

Abase	line item appropriation
ADM	Assistant Deputy Minister
AGRS	Airborne Gamma-Ray Spectrometry
CGC	Canadian Geoscience Council
CGD	Continental Geoscience Division
DIAND	Department of Indian Affairs and Northern Development
DNAG	Decade of North American Geology publication series
EMR	Department of Energy, Mines, and Resources Canada
EPMA	Electron Probe Microanalyzer
EXTECH	Exploration Technology program
ESS	Earth Sciences Sector
ftp	File Transfer Protocol
GIS	Geographic Information System
GSC	Geological Survey of Canada
HFSE	High Field-Strength Element
ICP	Inductively-Coupled Plasma
ICP-AES	Inductively-Coupled Plasma Atomic Emission Spectrometer/Spectrometry
ICP-MS	Inductively-Coupled Plasma Mass Spectrometer/Spectrometry
IPP	Industry Participation Project
IT	Information Technology
MDA	Federal-Provincial Mineral Development Agreement
MERA	Mineral and Energy Resources Assessment
MGP	Minerals Geoscience Program
MITE	Metals in the Environment program
MRD	Mineral Resources Division
MRG	Minerals and Regional Geoscience branch
MS	Mass Spectrometer/Spectrometry
NATGAM	National Gamma-Ray Mapping program
NATMAP	National Mapping program
NGR	National Geochemical Reconnaissance program
NRCan	Natural Resources Canada
O&M	Operating and Maintenance
OERD	Office of Energy Research and Development
PASMA	Proyecto Apoyo al Sector Minero Argentina
PDS	Proposal Driven System
PGE	Platinum Group Element
REE	Rare Earth Element
RII	Resource Innovation Initiative
SEDEX	Sedimentary Exhalative
SEG	Society of Economic Geologists
SEM	Scanning Electron Microscope/Microscopy
SHRIMP	Sensitive High-Resolution Ion Microprobe
SIMS	Secondary Ion Mass Spectrometry
SMG	Sedimentary and Marine Geoscience branch
TIMS	Thermal Ionization Mass Spectrometer/Spectrometry
TSD	Terrain Sciences Division

VMS	Volcanic-Associated Massive Sulphide
XRD	X-Ray Diffractometer/Diffractometry
XRF	X-Ray Fluorescence Spectrometer/Spectrometry