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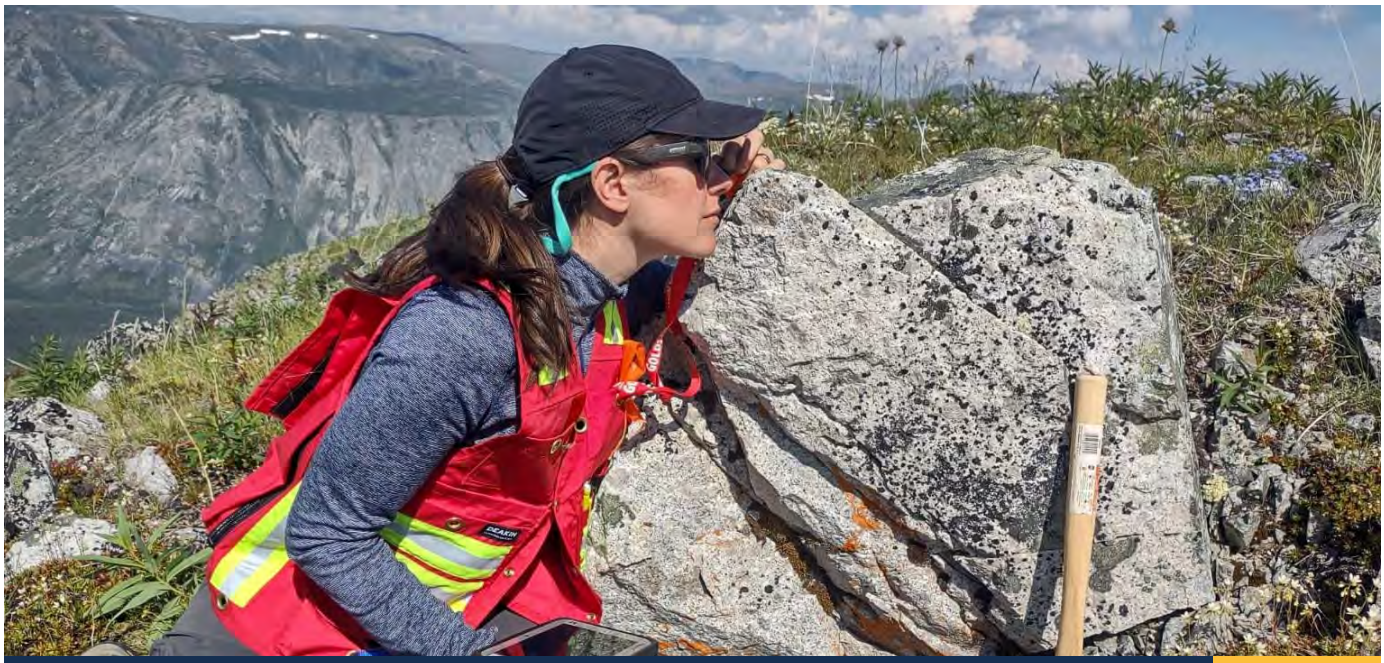

Geological Survey of Canada

Year in Review (supplemental report) 2021–22

Canada

Natural Resources Canada

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Foreword

As the Director General for the Geological Survey of Canada (GSC), it is a privilege to present this first *Geological Survey of Canada Year in Review (supplemental report): 2021-22*, a companion report to the GSC's flagship *Geological Survey of Canada Year in Review* report. This supplemental report serves as one of many public records of organizational accountability and transparency to the people of Canada.

As part of Natural Resources Canada, the Government of Canada has entrusted the GSC with a growing list of priorities and programs to serve the public good, continually updated and renewed to align with national and global needs. By undertaking priority geoscientific activities and providing authoritative research results, GSC programs are designed to support the sustainable and inclusive economic development of northern and remote communities, inform sound decision-making for land use both onshore and offshore, protect the environment, and reduce risks from natural disasters and climate change.

The GSC continues to be a world leader in geoscience because of our people. I am proud of the adaptability, perseverance, and passion of staff across the GSC, and look forward to the next year of excellence in multi-partner collaboration to achieve positive outcomes for Canadians and the world.

Daniel Lebel
Director General
Geological Survey of Canada

Table of Contents

Report overview

The Geological Survey of Canada (GSC) is Canada's national organization for public geoscience information and research. As an integral part of Natural Resources Canada's (NRCan) Lands and Minerals Sector (LMS), the mission of the GSC is to provide authoritative and cutting-edge geoscience information across Canada for the benefit of all Canadians.

In this annual Year in Review (supplemental report) 2021-22, additional information on GSC geoscience is provided that is not included in the annual *Year in Review: 2021-22 report*. In both reports, information is broadly classified into the following focus areas:

For more information on the GSC and its geoscience, visit us on the web or follow us on Twitter at @GSC_CGC.

Most GSC science programs are developed as inputs to support federal policy or are instruments of federal policy. The annexes of this report include details on

- the GSC's mandate, mission, and organizational structure (Annex 1, page 28);
- the GSC's strategic priorities and associated programs and services (Annex 2, page 35);
- how the GSC supports NRCan's departmental reporting obligations through three Performance Information Profiles (PIPs) (Annex 2, page 39);
- contact information for each of GSC's programs, projects, and activities (Annex 3, page 51); and,
- geoscience resources (Annex 4, page 96).

Through the provision of directed geoscience, the GSC continues to help ensure that Canada's lands and offshore natural resources are managed effectively and sustainably according to the best scientific knowledge, and to help keep Canadians safe.

Additional geoscience projects 2021–22

The following information is supplementary to the projects presented in the annual Year in review: 2021–22 report.

MINERALS

Supporting innovative mineral exploration techniques in complex glacial landscapes

To create a comprehensive matrix geochemical dataset of Nunavut and Manitoba trans-boundary regional till samples, Geo-Mapping for Energy and Minerals-GeoNorth (GEM-GeoNorth) combined data from nine previous GEM Open Files (approximately 1,200 samples) and new analysis results from approximately 1,000 archived regional samples in the GSC collections. By validating, updating, and transferring disparate datasets into corporate databases for Open Data Access, this project supports Open Government requirements for public access to GSC data in a machine-readable format. This access to the data, both for internal use and for the public, will allow for effective use of the data in multiple future geological and environmental research studies and mineral exploration.

Reference website: Canadian Database of Geochemical Surveys.

Leveraging unconventional geochronometry tools

To improve understanding of the formation and evolution of critical mineral deposits in Canada, Targeted Geoscience Initiative (TGI) researchers are developing new techniques based on the radioactive signatures of different minerals. The new techniques were used to successfully date biotite from the Tombstone intrusive belt (Yukon) using in situ Rb-Sr analysis, and characterized a suite of molybdenite samples using the Re-Os technique. The in situ data measured on the LA-QQQ-ICP-MS were within 1–2% of the high precision bulk N-TIMS analyses. Results of U-Pb in calcite development work constrained the timing of gold formation in Yukon relative to calcite veining and highlighted linkages with a regional intrusion-related metallogenic event, while documenting valuable evidence for U-mobility in carbonates.

LA-QQQ-ICP-MS: Inductively coupled plasma-triple-quadrupole-mass spectrometer coupled to a laser ablation system

N-TIMS: Negative Thermal Ionization Mass Spectrometry

Rb-Sr: Rubidium-strontium

Re-Os: Rhenium-osmium

U-mobility: Uranium mobility

U-Pb: Uranium-lead

Reference publication:

Pinet, N., Davis, W. J., Petts, D.C., Sack, P., Mercier-Langevin, P., Lavoie, D., and Jackson, S.E., 2022. U-Pb vein calcite dating reveals the age of Carlin-type gold zones of central Yukon, and a contemporaneity with a regional intrusion-related metallogenic event; Economic Geology vol. 117, no. 4, pp. 905–922. https://doi.org/10.5382/econgeo.4898

Determining chromium mobility and developing automated surficial geology mapping

Analysis of chromium in the environment is complicated due to its possible interspecies conversion from the time of sampling to the time of analysis. To address this, Groundwater Geoscience Program (GGP) researchers developed a water sampling and analysis methodology for chromium speciation, validated through an inter-laboratory comparison with different measurement techniques. This study of chromium mobility in water provides a methodology for chromium isotope sampling and analysis as well as a geochemical approach to metal characterization in a chromite deposit context.

In addition, GGP researchers used machine learning to develop a geological mapping pipeline of superficial formations. This machine-learning-based surficial geology mapping methodology supports development and users of modern technological approaches to remotely map hard-to-reach areas.

Deepening our understanding of orogenic gold systems

Recently published Targeted Geoscience Initiative (TGI) research focused on the geological settings and evolution of the highly prospective central Newfoundland gold belt, part of the Canadian Appalachians. A component of this research included the precise timing of faulting processes that lead to the formation of gold-containing deposits, and industry is already using this knowledge to advance targeted gold exploration, to develop a new gold mine, and to understand orogenic gold systems at large.

Reference publications:

Honsberger, I., Bleeker, W., Kamo, S.L., Sandeman, H.A.I., Evans, D.T.W., Rogers, N., van Staal, C.R., and Dunning, G.R., 2022. Latest Silurian syntectonic sedimentation and magmatism and Early Devonian orogenic gold mineralization, central Newfoundland Appalachians, Canada: setting, structure, lithogeochemistry, and high-precision U-Pb geochronology**;** Geological Society of America Bulletin, v. 134, no. 11–12, pp. 1–25. https://doi.org/10.1130/B36083.1

Honsberger, I.W., Bleeker, W., Kamo, S.L., Sutcliffe, C.N., and Sandeman, H.A.I., 2022. U-Pb geochronology of Late Silurian (Wenlock to Pridoli) volcanic and sedimentary rocks, central Newfoundland Appalachians: targeting the timing of transient extension as a prelude to Devonian orogenic gold mineralization; Atlantic Geoscience, v. 58, pp. 215–237. https://doi.org/10.4138/atlgeo.2022.009

Evaluating federal policies contributing to Canada's net-zero goals

Targeted Geoscience Initiative (TGI) researchers recently published a high-level overview of recently completed, federally funded research projects focused on critical minerals and mineral systems research, as well as ongoing collaborations with Geoscience Australia and the US Geological Survey under the Critical Minerals Mapping Initiative.

Reference publication:

Gadd, M., Lawley, C.J.M., Corrieveau, L., Houlé, M., Peter, J.M., Plouffe, A., Potter, E., Sappin, A-A., Pilote, J-L., Marquis, G., and Lebel, D., 2022. Public geoscience solutions for diversifying Canada's critical mineral production; Geological Society, London, Special Publications, v. 526, pp. 1–26. https://doi.org/10.1144/SP526-2021-190.

Extracting critical minerals from wastewater

In this project, Geoscience for New Energy Supply (GNES) researchers used Montney and Duvernay hydraulic fracturing flowback and produced water (FPW) compositional results as input for a thermodynamic study of CO_2 mineralization. The modelling results indicate that by controlling the temperature, CO_2 partial pressure and pH value of FPW, magnesium carbonate can be precipitated out separately from calcium carbonates, and as a critical element for alloying materials and future rechargeable batteries, magnesium has a much higher value than calcium. Water compositional results are also being used for a technical and economic analysis for the feasibility of lithium extraction from FPW by using various adsorbents, ion exchange materials, and membrane technologies. The partially de-metaled FPW after the CO_2 mineralization could be used for enrichment and extraction of lithium, meaning an integrated process of "CO_2 mineralization-carbonate mineral production-lithium enrichment using FPW" may help to reduce the industry's carbon footprint and produce valuable materials for Canada.

Reference publications:

Reid, M. S., Wang, X., Utting, N., and Jiang, C., 2021. Comparison of water chemistry of hydraulic-fracturing flowback water from two geological locations at the Duvernay Formation, Alberta, Canada; Geological Survey of Canada, Open File 8852, 38 p. https://doi.org/10.4095/329276

Jiang, C., Wang, X., Utting, N., Hobbs, T., and Kolbeck, C., 2021. Critical metals in hydraulic fracturing flowback and produced water from the Montney and Duvernay formations; GeoConvention 2021, pp. 1–3.

Using indicator mineral chemistry to assess critical minerals prospectivity

Tourmaline in sediment samples provides a much larger exploration target than actual porphyry copper deposits, with prospective grains dispersed up to 20 km down ice or downstream. This Targeted Geoscience Initiative (TGI) project developed a new vectoring tool using tourmaline to indicate the presence of porphyry copper mineralization for exploration in Canada. This new method was immediately adopted by a commercial heavy mineral lab and is now offered as a new service to clients globally, both in unglaciated and glaciated terrains. With the increased focus on critical minerals (specifically copper, molybdenum, and rhenium), this TGI research is supporting innovative exploration techniques in regions that are underexplored or costly to explore—for example, regions covered by thick glacial sediments or remote regions of Canada.

Reference publications:

McClenaghan, M.B., Beckett-Brown, C. E., McCurdy, M.W., and Casselman, S., in press. Stream sediment indicator mineral signatures of the Casino porphyry Cu-Au-Mo deposit, Yukon, Canada; Economic Geology.

Beckett-Brown, C. E., McDonald, A. M., McClenaghan, M.B., Plouffe, A., and Ferbey, T., 2021. Investigation of tourmaline characteristics in bedrock and surficial sediment samples from two Canadian porphyry copper systems; *in* Targeted Geoscience Initiative 5: contributions to the understanding and exploration of porphyry deposits (ed.) E. Schetselaar and A. Plouffe; Geological Survey of Canada, Bulletin 616, pp. 109–135, https://doi.org/10.4095/327989

Beckett-Brown, C.E., McDonald, A.M., and McClenaghan, M.B., in press. Recognizing tourmaline in mineralized porphyry copper systems: textures and major-element chemistry; Canadian Mineralogist, Manuscript No. CANMIN-D-22-00011.

Beckett-Brown, C. E., McDonald, A. M., and McClenaghan, M.B., in press. Trace-element characteristics of tourmaline in porphyry copper systems: development and application to discrimination; Canadian Mineralogist, Manuscript No. CANMIN-D-22-00037.

Reconstructing large mafic and ultramafic magmatic events in the Superior Province for critical metal potential

Targeted Geoscience Initiative (TGI) researchers have developed the first reconstruction of the Esker intrusive complex in the 2D and 3D spaces that illustrate the original (i.e., pre-deformation) host rock geometry of this well-endowed ultramafic to mafic mineral system. The results exhibit the actual and pre-deformation architecture of this ultramafic to mafic mineral system.

This work supports a model in which the Esker intrusive complex evolved as a series of individual intrusions that were emplaced during multiple magmatic pulses that eventually coalesced to form a composite ultramafic-mafic complex prior to being dissected and partly dismembered by post-ore shear zone deformation. These results will serve as a foundation for future research that will be undertaken in the Ring of Fire region.

Reference publication:

Laudadio, A. B., Schetselaar, E. M., Mungall, J. E., and Houlé, M. G., 2022. 3D modeling of the Esker intrusive complex, Ring of Fire intrusive suite, McFaulds Lake greenstone belt, Superior Province: implications for mineral exploration; Ore Geology Reviews, v. 145 pp. 1–23. https://doi.org/10.1016/j.oregeorev.2022.104886

Supporting future geoscientists through mapping surficial geology

One of the Geo-Mapping for Energy and Minerals-GeoNorth (GEM-GeoNorth) mandates is to train and supply geoscientists to support mineral exploration in Canada's northern regions, ensuring a sustainable future of highly qualified specialists. This GEM-GeoNorth project supported a master's thesis under the NSERC-Agnico Eagle Industrial Research Chair in Mineral Exploration at Université Laval on the surface geology of the mineralized zones around the Amaruq deposit, providing new geological knowledge on the nature and composition of surficial materials. The results are essential and directly applied to three other master's projects under the Industrial Research Chair, all of which aim to improve gold exploration methods in permafrost glacial terrain. This work will contribute to land use planning and help both the public and private sectors to identify potential mineral exploration targets.

Reference publication:

Boulianne-Verschelden, N., De Bronac de Vazelhes, V., McMartin, I., and Beaudoin, G., 2022. Surficial Geology, Amaruq deposit area, Kivalliq region, Nunavut, NTS 66-H southeast; Geological Survey of Canada, Canadian Geoscience Map 441, scale 1:50 000. https://doi.org/10.4095/329418

Supporting NRCan's legislated responsibilities for federal environmental assessments

In 2021-22, Environmental Impact Assessment Service (EIAS) staff worked with experts across the GSC to evaluate environmental assessments of 44 proposed projects, including:

- Participating in virtual Joint Review Panel Hearings for a proposed Marathon Palladium project in Ontario;
- Participating in a virtual hearing with the Canadian Nuclear Safety Commission regarding a proposed Nuclear Surface Disposal Facility in Ontario;
- Contributing to the regional environmental assessments (REA) for the Ring of Fire region (Ontario);
- Contributing to the preliminary phases of projects in the Slave Geological Province (Northwest Territories and Nunavut) and St. Lawrence River; and
- Providing input for seven designation requests coming from the Minister of Environment within extremely short timelines, as a direct result of changes to the *Impact Assessment Act (2019).*

Due to COVID-19 restrictions, many GSC experts had to pivot on short notice to provide scientific advice on geoscience virtually and in a transparent and factual manner, ensuring timely and authoritative execution of mandated responsibilities for federal environmental assessments.

Looking more closely at the diversity of types, styles, and ages of orogenic gold deposits in greenstone belts

In this project, Targeted Geoscience Initiative (TGI) researchers confirmed the hypothesis that gold is associated with early structures in the southern Abitibi belt at the Goldex mine (South Zones) and at the Kiena mine (Deep Zone), based on structural mapping, cross-cutting relationships, petrography, and U-Pb geochronology. As one of the very few, well-constrained examples of this early (i.e., post-volcanic but pre- to early main orogenic phase) gold event, this project provides industry with improved documentation and understanding of a mineralizing phase that has been documented in the past, but for which controls on ore formation and location remain only partly understood. This project also supports better exploration models based on mineralization and favourable geological structures that might have been overlooked in the past.

Reference publications:

Krushnisky, A., Mercier-Langevin, P., Ross, P.-S., Goutier, J., McNicoll, V., Moore, L., Monecke, T., Jackson, S.E., Yang, Z., Petts, D.C., and Pilote, C., 2022. Geology and controls on gold enrichment at the Horne 5 deposit and implications for the architecture of the gold-rich Horne volcanogenic massive sulfide complex, Abitibi greenstone belt, Canada; Economic Geology, online. https://doi.org/10.5382/econgeo.4978

Yergeau, D., Mercier-Langevin, P., Dubé, B., Malo, M., and Savoie, A., The Westwood deposit, southern Abitibi greenstone belt, Canada: An Archean Au-rich polymetallic magmatic-hydrothermal system—Part 1. Volcanic architecture, deformation, and metamorphism; Economic Geology, v. 117, no. 3, pp. 545–575. https://doi.org/10.5382/econgeo.4878

Yergeau, D., Mercier-Langevin, P., Dubé, B., McNicoll, V., Jackson, S., Malo, M., and Savoie, A., 2022. The Westwood deposit, southern Abitibi greenstone belt, Canada: An Archean Au-rich polymetallic magmatic-hydrothermal system—Part 2. Hydrothermal alteration, mineralization, and geological model; Economic Geology, v. 177, no. 3, p. 577–608. https://doi.org/10.5382/econgeo.4879

GEOSCIENCE FOR THE NORTH

Designing alternative mineral exploration strategies in Canada's North

GEM-GeoNorth research established that the distinctly aged (2.56 to 2.5 billion years old), which typifies the Boothia-Somerset domain and is uncommon in the Rae craton, is regionally extensive: stretching from eastern Devon Island through Boothia Peninsula to the mainland Sherman Basin, and from further southwest underlying the Nonacho Basin to Saskatchewan's Zemlak domain. Based on this evidence, GEM-GeoNorth developed a new geological model of the western Rae craton, incorporating the formation and amalgamation of a 2.56-2.5 Ga Boothia "ribbon terrane." This new model will improve mineral exploration in the remote area of Nunavut, as strategies commonly used in other areas of the Rae geological province are likely inappropriate for this regionally extensive corridor.

Reference publication:

Regis, D. and Sanborn-Barrie, M., 2022. Delimiting the extent of "Boothia terrane" crust, Nunavut: new U-Pb geochronological results; Geological Survey of Canada, Open File 8917, 1 .zip file. https://doi.org/10.4095/330703

CLIMATE CHANGE

Monitoring the changing thermal state of permafrost in the northern hemisphere

Climate Change Geoscience Program (CCGP) scientists and collaborators synthesized information on trends in permafrost temperature and active layer thickness across the northern hemisphere, including sites from GSC's permafrost monitoring network, to provide a comprehensive picture on how Canada's permafrost conditions are changing. The review also identified gaps in our understanding of the drivers of these changes and limitations of current models for prediction of future change. Further, recommendations for future research to address these gaps were offered.

This work contributes to GSC programs such as CCGP and GEM-GeoNorth. Furthermore, it ensures that GSC data and research are considered in international assessments and syntheses. Monitoring the changing thermal state of permafrost provides new information regarding impacts of climate change on permafrost environments—critical for adaption and policy development.

Reference publication:

Smith, S. L., O'Neill, H. B., Isaksen, K., Noetzli, J., and Romanovsky, V. E., 2022. The changing thermal state of permafrost; Nature Reviews Earth and Environment, v. 3, no. 1, pp. 10–23. doi:10.1038/s43017-021-00240-1.

Using machine learning to determine permafrost thaw sensitivity

Climate Change Geoscience Program researchers tested a supervised machine learning method—a deep multi-layer perceptron neural network—to predict permafrost thaw sensitivity. This project categorized the measured subsidence from Differential Interferometry Synthetic Aperture Radar (DInSAR) mapping, using existing knowledge of the ground temperatures, active layer thickness, and ground ice conditions, to create a reference classification where the derived categories are indicative of specific thaw sensitivity and permafrost conditions.

Researchers used available surficial geology, high-resolution topographic data, and multi-spectral satellite imagery features relevant to permafrost (as predictor variables) to predict the thaw sensitivity with an accuracy of 70% compared to the reference classification. When considering only two classes—stable and unstable ground—it was possible to reach 80% accuracy. While this method relies on DInSAR measurements to establish the "reference classification," the same method could be used with expert labelling.

Reference publication:

Oldenborger, G., Short, N., and LeBlanc, A.-M., 2022. Permafrost thaw sensitivity prediction using surficial geology, topography, and remote-sensing imagery: a data-driven neural network approach; Canadian Journal of Earth Sciences v. 59, no. 11, pp. 897–913. https://doi.org/10.1139/cjes-2021-0117.

Improving ground ice modelling and mapping

In 2022, Climate Change Geoscience Program scientists continued to refine and revise national-scale ground ice models to ensure that they are based on the best information available. Version 1.1 of the Ground Ice Map of Canada includes refinements to the relict ice model to correct the maximum limits of inundation following glacial retreat.

The ground ice modelling approach is the foundation for thermokarst mapping and regional ground ice mapping contributing to other GSC geoscience. On a broader scale, the results of this work inform climate change impact assessments and land-use decisions in northern Canada. The results generated by this research are important for developing improved permafrost-climate change models. The results are already being incorporated by government and academia for use in developing climate change models and assessing the impacts of climate change on water resources.

Reference publication:

O'Neill, H. B., Wolfe, S. A., and Duchesne, C., 2022. Ground ice map of Canada; Geological Survey of Canada, Open File 8713, 8 p. https://doi.org/10.4095/330294

Improving the CanCoast database

Climate change is expected to influence all of Canada's marine coasts, but given the diversity of the coasts these changes will not be uniform. This Climate Change Geoscience Program project developed CanCoast, an index that provides a measure of a coastline's sensitivity based on its physical environment and how this is likely to change over the coming decades.

CanCoast consists of a geospatial database of coastal characteristics such as wave-height change, sea-level change, ground ice content, coastal materials, tidal range, and backshore slope. Recent improvements to CanCoast include refining the backshore slope with a higher resolution digital elevation model and using a different statistical method to derive the sensitivity index. CanCoast is used by a number of government agencies to help inform national policy around coastal protection and adaptation.

Reference publications:

Manson, G.K., Couture, N.J., and James, T.S., 2019. CanCoast 2.0: data and indices to describe the sensitivity of Canada's marine coasts to changing climate; Geological Survey of Canada, Open File 8551, 18 p. https://doi.org/10.4095/314669

Hatcher, S.V. and Manson, G. K., 2021. A revised coastal sensitivity index for Canada's marine coasts calculated using nonparametric statistics; Canadian Journal of Earth Sciences, v. 59, no. 11, pp. 803–811. https://doi.org/10.1139/cjes-2021-0010

Reconstructing history through the ARCHIVES project

The ARCHIVES project of the Climate Change Geoscience Program (CCGP) reconstructs the hydro-climatic conditions that have prevailed over the past two centuries in the Quebec upper boreal zone by using natural archives derived from dendrochronology, dendroisotopy, and lake sediment analysis.

CCGP co-edited a new synthesis report on hydro-climatic reconstruction to inform hydroelectric sector decisions in a changing climate. The publication, *Utilisation des archives naturelles pour la reconstitution du passé hydro-climatique*, reports on eight years of work by a multidisciplinary research team that presents the fundamental concepts and methodologies, as well as the results of the retrospective analyses, to facilitate the development of hydrological scenarios for the hydroelectric sector.

Reference publication:

Bégin, C., Nicault, A. and Bégin, Y., 2021. Utilisation des archives naturelles pour la reconstitution du passé hydro-climatique; Commission géologique du Canada, Dossier public 8768, 211 p. https://doi.org/10.4095/328045

Supporting adaptation in coastal regions through sea-level projections

The release of the *Sixth Assessment Report (AR6)* of the Intergovernmental Panel on Climate Change (IPCC) provides an opportunity to update relative sea-level projections for Canada, based on the latest climate information and the vertical land motion model provided by the Canadian Geodetic Survey. This Climate Change Geoscience Program project used the recently released Sixth Assessment Report (AR6) of the IPCC to support—and in some cases, strengthen—the conclusions of *Canada's Changing Climate Report* (CCCR), published in 2019, as provided in *Canada's Changing Climate Report in Light of the Latest Global Science Assessment*, published in 2022.

The CCCR is an authoritative summary of the state of climate science in Canada, detailing projections in temperature, precipitation, the cryosphere, and the oceans, including projections of sea-level change. This report informs a broad range of assessments and planning activities across Canada. In parallel to this scientific update, CCGP is collaborating with several federal departments to develop national guidance on sea-level projections based on the latest science, to provide foundational information for coastal assessments and planning for infrastructure, valued activities, and ecosystems in a changing climate. The sea-level projections are provided through the Canadian Centre for Climate Services, and the guidance will provide information on sea-level projections, including low-probability, high-consequence high-end projections, adaptation approaches, and several case studies.

Reference publication:

Bush, E., Bonsal, B., Derksen, C., Flato, G., Fyfe, J., Gillet, N., Greenan, B. J. W., James, T. S., Kirchmeier-Young, M., Mudryk, L., and Zhang, X., 2022 Canada's changing climate report, in light of the latest global science assessment; Government of Canada, 37 p. https://doi.org/10.4095/329703.

MARINE AND COASTAL

Improving and confirming previous mapping through multidisciplinary field work

In 2022, Marine Geoscience for Marine Spatial Planning (MGMSP) researchers completed a multidisciplinary geoscience expedition to expand the GSC's baseline geoscience data, filling knowledge gaps and ground-truthing targets of interest in the Pacific North Coast Integrated Management Area (PNCIMA) from previous MGMSP mapping projects. This project used bathymetry, sub-bottom profiling, and seabed sampling, and included:

- Assessing the process of baseline shelf site suitability for marine infrastructure to improve the Environmental Assessment (EA) process;
- Assessing Portland Inlet baseline data for an area currently under EA review for liquid natural gas (LNG) development;
- Completing a preliminary assessment of activity at a newly mapped volcano in Milbanke Sound;
- Mapping the multi-use area of Queen Charlotte Strait, an area of particular interest for cumulative effects and rare and sensitive ecosystems (rockfish conservation areas and glass sponge reefs); and,
- Assessing carbon burial around Calvert Island.

Resource assessments of northern Canadian sedimentary basins

In 2021-22, Marine Conservation Targets (MCT) researchers reviewed fifty-one resource assessments spanning the period from 1973 to 2022 and compiled quantitative data from twenty-four of these reports for sedimentary basins in the Canadian Arctic. This report covers twelve distinct areas from the Canada Basin to the Baffin Margin. Hydrocarbon potential was found to be highest in the Beaufort-Mackenzie Delta region and in the Sverdrup Basin in the central Arctic Islands.

This publication provides context and discusses the relevance of historical northern Canada conventional hydrocarbon resource assessments, synthesizes the results, and converts previous assessed resources to a common standarized set of units, namely recoverable barrels of oil equivalent (BOE).

Reference publication:

Dewing, K., Kung, L. E., Lister, C. J., Atkinson, E. A., and King, H. M., 2022. Resource assessment of northern Canadian sedimentary basins, 1973–2022; GSC Open File 8900, 91 p. https://doi.org/10.4095/330301

Assessing qualitative hydrocarbon potential in Nova Scotia

In 2022, Marine Conservation Targets (MCT) researchers updated a qualitative hydrocarbon assessment for the Fundian Channel-Browns Bank Area of Interest, located southwest of Nova Scotia. The area of interest has three domains with distinct geological architectures and resource potential, and project results were shared with LMS Economic Group to support ongoing work on an economic assessment.

Updating our understanding of the surficial geology of the Scotian Shelf Bioregion

The Scotian Shelf surficial geology has been interpreted in the past, notably in 1991 and 2004, but more recent and higher resolution hydroacoustic data have been acquired since the early maps were produced. This Marine Geoscience for Marine Spatial Planning (MGMSP) project updated the existing surficial geology map over the entire Scotian Shelf Bioregion into a contiguous and normalized product using recently available and published maps and updated hydroacoustic datasets.

This project represents the first time that the surficial geology on the shelf and the slope have been combined onto one single map, and where nearshore areas—many of which were previously unmapped—have been included and interpreted. This greater detail allowed MGMSP researchers to identify some geological and geomorphological features, such as bedrock and moraines, not previously identified. Understanding the composition, seabed morphology, stability, and sensitivity of the seafloor is critical information needed for ocean management and evaluating cumulative anthropogenic and natural impacts. This project highlighted the locations where high-resolution data are lacking and where new data need to be acquired to underpin future geoscience.

Investigating how anchoring affects different types of seabeds

As temporary anchorages in the Salish Sea become used more frequently, Marine Geoscience for Marine Spatial Planning (MGMSP) researchers aim to map the disturbances at coastal anchorages in British Columbia as a baseline to detect change over time and better understand how anchoring impacts different types of seabeds. For this project, MGMSP researchers used remote operated vehicle (ROV) camera and video surveys onboard the MV Manyberries and grab samples onboard the CCGS Vector to map the impact to the seabed at commercial anchorages. The resulting grainsize analysis, which provides data to support accurate maps of the area, provided ground-truth data for surficial geology bioregional scale maps, which will lead to a better understanding of cumulative effects and, as a result, better informed selections of anchorage sites.

Discovering sinkholes on the Arctic seafloor from thawing permafrost

Since 2003, GSC scientists have been collecting data through repeat surveys in the remote Beaufort Sea to study how thawing submerged permafrost at the edge of the Arctic Ocean affects the seafloor. High resolution bathymetric data collected from 2010 to 2019 revealed very rapid changes to the seafloor along an area of permafrost that formed between 2,580,000 and 11,700 years ago. Public Safety Geoscience Program (PSGP) researchers found "sinkholes" that developed in less than a decade. They have determined that these are regions of thawing permafrost, the largest sinkhole measuring 28 metres deep, 225 metres long, and 95 metres wide.

The formation of the sinkholes in the Beaufort Sea is attributed to permafrost sediment gradually warming since the last Ice Age, with brackish groundwater flowing across regions of ancient permafrost eventually causing a collapse. These findings have important implications for future offshore infrastructure development in the Beaufort Sea.

Reference publication:

Paull, C.K., Dallimore, S.R., Jin, Y.K., Caress, D.W., Lundsten, E., Gwiazda, R., Anderson, K., Hughes Clarke, J., Youngblut, S., and Melling, H., 2022. Rapid seafloor changes associated with the degradation of Arctic submarine permafrost; Proceedings of the National Academy of Sciences, v. 119, no. 12, p. 1 https://doi.org/10.1073/pnas.2119105119

Interpreting bioregional scale geomorphology

The Newfoundland and Labrador Shelves Bioregion, located on a glaciated continental shelf and adjacent continental slope, is classified into thirteen geomorphic units that reflect its great physiographic diversity. The ten shelf units comprise a bedrock dominant zone, fiord systems, a large inland sea, shelf-crossing troughs, four types of offshore banks, a basin, and glaciotectonic terrain (found nowhere else on Canadian shelves). The three continental slope units are channelized areas, trough-mouth areas, and large sedimentary drifts.

Marine Geoscience for Marine Spatial Planning (MGMSP) researchers incorporated results from sediment transport modelling in order to characterize tide- and wave-generated seafloor disturbance in each of the classified elements.

Monitoring extreme coastal change in the western Canadian Arctic

Past research has shown that erosion of ice-rich coastal permafrost along the Beaufort Sea has increased in the last two decades, affecting infrastructure, communities, and vulnerable Arctic coastal ecosystems. This trend is expected to continue due to increasing temperatures and further reduction of sea ice. In this project, Climate Change Geoscience Program (CCGP) researchers are improving knowledge and understanding of physical conditions in the coastal zone to help understand, mitigate, and reduce the impacts of climate-driven changes.

CCGP researchers have been monitoring the extreme coastal change along the Beaufort Sea coastline for several years. After missing field work in 2020 due to the pandemic, it was critical to service and maintain instruments and collect the data to validate autonomous observations. Researchers conducted several field expeditions in 2021 to ensure continuity of observational time series, ensuring consistent baseline information to support local Indigenous community adaptation to climate change.

Following the field work, CCGP researchers co-developed activities with the Hamlet of Tuktoyaktuk to better understand and communicate these changes, including co-managing coastal community-based monitoring, conducting training to community members, presenting at schools and to the community at large and ensuring that traditional knowledge was incorporated into the project findings.

Reference publication:

Wratten, E. E., Cooley, S. W., Mann, P. J., Whalen, D., Fraser, P., and Lim, M., 2022. Physiographic controls on landfast ice variability from 20 years of maximum extents across the northwest Canadian Arctic; Remote Sensing, v. 14, no. 9, article 2175. https://doi.org/10.3390/rs14092175

"Rescuing" data in the Scotian Shelf Bioregion

As a result of 20 years of collaboration with the University of Maine, Marine Geoscience for Marine Spatial Planning (MGMSP) has received the original paper records of high resolution seismic data from six university expeditions to the Gulf of Maine, covering both American and Canadian waters. All the paper records are being digitized and processed using software developed at the GSC's Atlantic centre with the ultimate objective of placing all this legacy data on line in NRCan's Expedition Database to be universally accessible.

This data will provide valuable insight into previously unmapped areas in the Canadian portion of the Gulf of Maine; for example, the dramatic image of the 50 m-high Georges Tower indicates an ecologically unexplored portion of Georges Basin, the deepest portion of the Gulf of Maine.

Reference publication:

Belknap, D. F., Todd, B. J., Taylor, R., Kostylev, A., and Jarrett, C.A., 2022. Combined expedition report for 88ARGO, 90ARGO, 90CAPE HATTERAS, 91ENDEAVOR, 94EDWIN LINK and 95EDWIN LINK: University of Maine seismic reflection profiles collected in the Gulf of Maine, Maine, USA, and Nova Scotia, Canada; Geological Survey of Canada, Open File 8920, 8 p. https://doi.org/10.4095/330704

Assessing landslide hazards for Baffin communities

In this project, Public Safety Geoscience Program (PSGP) scientists assessed submarine and terrestrial landslide hazards in Pangnirtung Fiord, accompanied by tsunami modelling of a large submarine landslide. Researchers then created data and outreach posters, translated in Inuktitut and shared with the community. This work provides important information for potential mitigation for the hamlet of Pangnirtung and other Baffin Island communities.

Reference Publication:

Bennett, R., Normandeau, A., and Campbell, D.C., 2022. Distribution of slope failures in eastern Baffin Island fiords, Nunavut; Geological Survey of Canada, Open File 8861, 20 p. https://doi.org/10.4095/329603

Examining the petroleum potential of the High Arctic basins, northern Canada

Under the Marine Conservation Targets (MCT) program, researchers presented qualitative and quantitative assessments of the hydrocarbon resource potential for the High Arctic sedimentary basins (HAB) study area underlying a portion of the Arctic Ocean north and west of Ellesmere Island. The researchers developed estimates for each geologic province/assessment area, and reflect the varying chance of success in each area and the limited data. They compared the results to previously published estimates of petroleum resource potential in and around the study area. A qualitative map showing the distribution potential of methane hydrate saturations was also produced and shows that the highest relative methane hydrate saturations are most likely present on the continental shelf and slope of the study area.

Reference publication:

Lister, C. J., Atkinson, E. A., Dewing, K. E., King, H. M., Kung, L. E., and Hadlari, T., 2022. High Arctic basins petroleum potential, northern Canada; GSC Open File 8897, 88 p. https://doi.org/10.4095/330203

Developing a hydrocarbon-potential map of the Canadian Arctic Archipelago and northern offshore areas

This Marine Conservation Targets (MCT) project included creating a generalized hydrocarbon potential map for the Canadian Arctic Archipelago and northern offshore areas. Researchers presented data from sixteen sedimentary basins that have some potential of containing hydrocarbons. Areas underlain by young sediments that have had discoveries or have favourable geological conditions also have the highest potential for oil and gas resources. These include the Beaufort-Mackenzie Basin, the central Sverdrup Basin in the central Arctic Islands, the Saglek Basin off southeastern Baffin Island, Lancaster Sound and the Baffin Fan, the rifted Arctic margin, the Lincoln Sea north of Ellesmere Island, and the Baffin margin between Cumberland and Lancaster sounds.

Reference publication:

Dewing, K. E., Lister, C. J., Kung, L. E., Atkinson, E. A., and King, H. M., 2022. Hydrocarbon-potential map of the Canadian Arctic Archipelago and northern offshore areas; GSC Open File 8884, 5 p. https://doi.org/10.4095/329968

GROUNDWATER AND AQUIFERS

Characterizing the heterogeneity of aquifer systems

After several years of development, Groundwater Geoscience Program (GGP) researchers have created several methods to characterize the heterogeneity of aquifers. Among these advances is the generalization of hydraulic vertical interference tests to model complex geological environments in order to create a regional scale methodology for characterizing contaminated sites in Canada.

This project also developed hydraulic tomography tests using the stresses of unconventional aquifers for the ultra-characterization of locally contaminated sites, as well as an approach for characterizing the hydraulic properties of watersheds through the analysis of natural aquifers stresses. Results of this research also improve the methodology for analyzing nuclear magnetic resonance (NMR) geophysical measurements to estimate hydraulic properties in granular aquifers in Canada.

The results of this research enable stakeholders and decision makers involved in water resource management to identify key hydrogeological parameters more effectively in aquifers in Canada.

Reference publications:

Paradis, D. and Lefebvre, R., 2013. Single-well interference slug tests to assess vertical hydraulic conductivity; Journal of Hydrology, v. 478, pp. 102–118. https://doi.org/10.1016/j.jhydrol.2012.11.047

Paradis, D., Gloaguen, E., Lefebvre, R., and Giroux, B., 2016. A field proof-of-concept of tomographic slug tests in an anisotropic littoral aquifer; Journal of Hydrology, v. 536, pp. 61–73. http://doi.org/10.1016/j.jhydrol.2016.02.041

Crow, H.L., Paradis, D., Grunewald, E., Liang, X.X., and Russell H.A.J., 2022. Hydraulic conductivity from nuclear magnetic resonance logs in sediments with elevated magnetic susceptibilities; Groundwater, v. 60, no. 3, p. 377–392. http://doi.org/10.1111/gwat.13158

Developing methods for non-destructive analysis of sediment in boreholes and cores

To support hydrogeological characterization, the Groundwater Geoscience Program (GGP) is advancing methods to improve aquifer and aquitard characterization in bedrock and surficial sediment settings. Nuclear magnetic resonance (NMR) logging provides in situ, non-destructive, and rapid porosity analysis that expands and is complemented by traditional lithological and geophysical logging tools such as gamma, conductivity, and magnetic susceptibility. This is complemented by core analysis using portable X-ray fluorescence (pXRF) and medical CT scanners for high resolution, non-destructive geochemical and sedimentological analysis.

This research highlights the key role of integrated multidisciplinary analysis to maximize insights into sediment and hydrogeological characterization. To date, work has been completed in Ontario on Champlain Sea muds (Ottawa), sand and gravel aquifers (Toronto), sandstone and limestone-dolostone aquifers (Ottawa, Guelph) and paleokarst aquifers (Bruce County).

Reference publications:

Al-Mufti, O.N., Arnott, R. W. C., Hinton, M. J., Alpay, S., and Russell, H. A. J., 2022. Using computed tomography (CT) to reconstruct depositional processes and products in the subaqueous glaciogenic Champlain Sea basin, Ottawa, Canada; Geomorphology, v. 403, pp. 1–17. https://doi.org/https://doi.org/10.1016/j.geomorph.2022.108165

Crow, H.L., Paradis, D., Grunewald, E., Liang, X.X., and Russell, H.A.J., 2022. Hydraulic conductivity from nuclear magnetic resonance logs in sediments with elevated magnetic susceptibilities; Groundwater, v. 60, no. 3, p. 377–392. https://doi.org/10.1111/gwat.13158

Olson, L. C., Knight, R. D., Crow, H.L., and Russell, H. A. J., 2022. Chemostratigraphic logging of the Lower Ordovician and Precambrian, Bells Corners borehole calibration facility, Ottawa, Ontario; Geological Survey of Canada, Open File 8913, 22 p. https://doi.org/10.4095/330519

Assessing the potential impacts of oil and gas development activities on shallow aquifers

Groundwater Geoscience Program (GGP) and Environmental Geoscience Program (EGP) researchers are part of a collaborative team investigating the cumulative environmental impacts of oil and gas development over the past 50 years in the Fox Creek area in Alberta. This multifaceted project includes creating 2D and 3D hydrogeological models and coupled surface water/groundwater models to study hydrodynamics, estimating the water budgets and water and soil characteristics to better understand the hydrologic cycle in this area, and studying the geochemistry of water resources to determine if they have been affected by industrial activities.

In addition, researchers created a geomechanical model to study the potential impacts of hydraulic fracturing on shallow water resources, assessed the functional recovery of plants in disturbed forest ecosystems, and used satellite imagery and air photos to study landscape change over the last 50 years.

In parallel, EGP and GGP researchers are conducting a general study to improve the current cumulative effects assessment process in environmental assessments (EAs) through interviews and focus groups with various stakeholders including federal government employees, consultants conducting EAs, and Indigenous communities and environmental advisory committees. The objective is to provide concrete and constructive recommendations that will hopefully lead to effective solutions to achieve satisfactory assessments over the long term.

The results of this project will support the characterization of the region's shallow aquifers, as well as the evaluation of the current cumulative environmental effects in this industrial region.

ENERGY RESOURCES

Mitigating the adverse effects of hydrogen sulfide in water

Despite COVID-related challenges, Geoscience for New Energy Supply (GNES) researchers collaborated with Arc Resources and the University of Calgary to collect a full cycle of hydraulic fracturing, flowback, and produced water (FPW) of a Montney well for microbiological and isotope geochemistry analysis. Extracted microbial community DNA identified sulfur-reducing microbes in hydraulic fracturing fluids that generate anthropogenic hydrogen sulphide (H_2S), and the sulfur isotopic composition of produced sulfides further confirms the role of microbial sulfate reduction in H_2S generation. In addition, GNES used bulk and in situ sulfur isotopic analysis of pyrite in geo-genic sources of H_2S to better understand the diagenetic sulfur cycle and its role in H_2S generation. The project also investigated the stratigraphic and structural controls on H_2S distribution. Identifying the origin and formation mechanism(s) of highly toxic and corrosive gas, such as H_2S, improves mitigation of adverse effects on carbon capture, utilization, and storage (CCUS), and other geological storage projects.

Quantifying the effect of oxygen on petroleum spills

In the midst of a global energy crisis, the science surrounding oil spills along major marine shipping routes is of increasing interest to policymakers and regulators. To help inform decision-making, Environmental Geoscience Program (EGP) researchers conducted microcosm experiments that demonstrate the effects of oxygen limitation on the microbial degradation rates of accidentally spilled petroleum products in the Kitimat Fjord System in northern BC.

The results of this study show that microbial communities degrade petroleum products fastest and more completely under oxic conditions, slightly slower under hypoxic conditions, and slowest under anoxic conditions. Specifically, alkanes and several polycyclic aromatic hydrocarbons (PAHs) are depleted early and to the greatest extent under oxic conditions, whereas very little degradation of these bio-available compounds was observed in the anoxic incubations.

Creating detailed CT scan images to unlock the potential of major Canadian unconventional resources

The main goal of this Geoscience for New Energy Supply (GNES) project was to gain insight into the possibility of using the vast unconventional resources in Canada for CO_2 storage and enhanced oil recovery (EOR). Researchers analyzed multiple shale samples from across the Western Canadian Sedimentary Basin (WCSB) for potential CO_2 storage and EOR activities, resulting in two sets of dynamically imaged, detailed CT scan images of shale-CO_2 interaction. Six samples were also thoroughly characterized and extracted using CO_2 for examination of EOR potential in these formations. The results were combined with several characterization tests to analyze and link the field observations with those of CO_2-shale interaction, resulting in multiple scientific papers, conferences, and internal presentations. The results of this project are a significant step toward successful carbon capture, utilization, and storage (CCUS), and other geological storage activities.

Converting abandoned mines into geothermal resources

This Geoscience for New Energy Supply (GNES) project supported work at L'Institut national de la recherche scientifique (INRS) to demonstrate that the abandoned Con Mine in Yellowknife had a heat availability of 29.8 GWh per year, significantly more than the results of previous studies. This project also explored the possibility of developing the Con Mine as a brownfield for thermal energy—an innovative use of, and unique opportunity for, abandoned mines in Canada. Results suggest that the Con Mine site has heating potential for up to 35,770 m^2 of retail space, supporting new economic opportunities for abandoned mine sites, particularly in the North.

Reference publication:

Ngoyo, D., Raymond, J., Comeau, F-A., Grasby, S.E., Terlaky, V., and Grabke, D., 2021. Geothermal potential of closed underground mines: resource assessment study of the Con Mine (Northwest Territories, Canada); Yellowknife Geoscience Forum. https://www.nwtgeoscience.ca/gsforum/geothermal-potential-closed-underground-mines-numerical-study-con-mine-northwest-territories-canada [accessed February 2, 2023]

Increasing the scope of offshore collaboration with Nova Scotia

In March 2022, the GSC and Nova Scotia increased the scope of an existing collaborative agreement to include geohazards research in shallow and surficial geology to address the potential location and infrastructure needs of offshore wind farms, as well as examinations and modelling of existing known reservoirs available for carbon capture and storage potential and capacity. This new agreement includes multiyear scientific planning to establish joint research programs, as well as the recruitment and training of postgraduate researchers to build capacity in the region. Under this enhanced agreement, Geoscience for New Energy Supply (GNES) researchers have already:

- advanced seabed investigations of deepwater seep features located offshore Nova Scotia;
- acquired micro-CT scans on concretions; identified sample slices with micro-XRF mapping prior to micro drilling;
- integrated new geoscience research to advance understanding of the conjugate margin and basin structure in the offshore Atlantic; and,
- completed geochemical analyses (C isotopes and trace elements).

This project will build knowledge and geoscience expertise to inform future decisions and investments in transitional energy and recognize the renewable energy opportunities in offshore Nova Scotia.

GEOSCIENCE TOOLS AND DATA

Developing a new flood risk assessment tool for Canada

CanFlood is an open-source experimental flood risk modelling platform available as a free, open-source QGIS plug-in. Public Safety Geoscience Program (PSGP) researchers contributed to the project over the past year based on Canadian depth damage curves and a flexible modelling framework reflecting the heterogeneity of Canadian assets and values. Launched in May 2021, the innovative application was showcased to over 150 flood risk practitioners from across Canada.

With CanFlood, users assess flood risk using their own data. CanFlood is used to evaluate annualized losses, compare flood scenarios, and perform benefit-cost analysis. To date, the CanFlood application has been used for flood risk assessments in British Columbia, Ontario, and Alberta.

Reference website: CanFlood.

NATIONAL AND INTERNATIONAL SCIENCE POLICY COLLABORATION

Supporting the Laboratories Canada vision with TerraCanada

In 2021-22, NRCan—along with its partners Environment and Climate Change Canada, National Research Council Canada, Health Canada, and the Canada Nuclear Safety Commission—continued contributing to the 25-year vision of Laboratories Canada. To support and promote geoscience capabilities within this vision, GSC scientists:

- Coordinated a workshop on Special Artificial Intelligence and participated in a plenary panel on the evolution of initiatives supporting AI in government;
- Provided DG endorsement of the Functional Program report for the National Capital Region (NCR) facility, with the recognition that there will be opportunities in the future to refine details pertaining to office space;
- Agreed on an approach to operating costs at the proposed Institut national de la recherche scientifique (INRS) facility in Quebec City;
- Provided DG and ADM input to advise on governance structures and processes to enable the timely identification, escalation, and resolution of emerging issues and risks, with three TerraCanada representatives participating in a working group to develop a management action plan and response;
- Co-hosted a DM and ADM tour of 555 and 601 Booth with CanmetMINING, which included a visit to the laboratory facilities and sample collections, as well as discussion on past, present, and potential future infrastructure challenges; and
- Continued to collaborate with CanmetMINING as capability champions, providing input on optimizing science collaborations and common building spaces/services at each proposed TerraCanada location.

Reference websites: Laboratories Canada and TerraCanada.

Annex 1: About the GSC

MISSION

The GSC's mission is to provide authoritative geoscience knowledge to inform the stewardship of Canada's onshore and offshore lands, to sustain responsible resource development for future generations, and to keep Canada safe from natural hazards and related risks.

MANDATE

The GSC has several legislated obligations under various federal acts. The mandate of the GSC includes the following legislated requirements:

- Making a full and scientific examination and survey of the geological structure and mineralogy of Canada (*Resources and Technical Surveys Act*, 1985);
- Enhancing the responsible development and use of Canada's natural resources and the competitiveness of Canada's natural resources products (*Department of Natural Resources Act*, 1994);
- Supporting the sustainable development and management of Canada's natural resources (*Department of Natural Resources Act*, 1994); and,
- Providing expert information to support federal environmental assessments (*Impact Assessment Act, 2019*).

The GSC develops geoscience information products to support government policy, regulatory decision-making, and policy implementation.

THE ROLE OF THE GSC

Like other policy instruments, the uses of science are as varied as the purposes of the policies themselves. Over the years GSC geoscience has been used to

- Support economic development;
- Support regulatory and policy development;
- Demonstrate compliance with international agreements;
- Develop national and international standards;
- Supply public-good products and services;
- Support public health and welfare for civil and national safety, and environmental protection;
- Provide knowledge and technologies to anticipate and respond quickly to national priorities;
- Support domestic and international diplomacy;
- Assert sovereignty at home;
- Support nation building;
- Meet domestic and international obligations;
- Incent behavioural change; and,
- Ensure that international policy is based on scientific principles.

ORGANIZATIONAL STRUCTURE

The GSC is led by a Director General who provides overall leadership on GSC files. Six regional divisions across Canada share program delivery and provincial and territorial liaison responsibilities for the GSC. The GSC also has an office led by a Director dedicated to helping Canada meet its commitments under the United Nations Convention on the Law of the Sea (UNCLOS).

Geological Survey of Canada Management Team (as of March 31, 2022)

Director General: **Daniel Lebel**

GSC Division	Director	Program / Service files	Provincial / Territorial Liaison	International Liaison
Pacific Division 9860 West Saanich Road Sidney, BC V8L 4B2 1500–605 Robson Street Vancouver BC V6B 5J3	Sonia Talwar Sonia.Talwar@nrcan-rncan.gc.ca	Public Safety Geoscience Indigenous Relations Network	British Columbia	Asia, Latin America
Calgary Division 3303 33 Street NW Calgary, Alberta T2L 2A7	Sonya Dehler Sonya.Dehler@nrcan-rncan.gc.ca	Geoscience for New Energy Supply Marine Conservation Targets	Alberta, Saskatchewan	India, Russia

GSC Division	Director	Program / Service files	Provincial / Territorial Liaison	International Liaison
Northern Division 601 Booth Street Ottawa, ON K1A 0E8 1106 Ikaluktuutiak Drive Iqaluit NU X0A 0H0	Linda Richard Linda.Richard@nrcan-rncan.gc.ca	Geo-mapping for Energy and Minerals-GeoNorth Environmental Impact Assessment Service Science Laboratory Network	Nunavut, Northwest Territories, Yukon	Africa
Central Division 601 Booth Street Ottawa ON K1A 0E8	Geneviève Marquis Genevieve.Marquis@nrcan-rncan.gc.ca	Targeted Geoscience Initiative Open Geoscience Network Canada-3D	Ontario, Manitoba	Australia, the United States, China
Quebec Division 490, rue de la Couronne Québec QC G1K 9A9	Réjean Couture Rejean.Couture@nrcan-rncan.gc.ca	Groundwater Geoscience Program Environmental Geoscience Program	Quebec, New Brunswick	Europe
Atlantic Division 1 Challenger Drive Dartmouth, NS B2Y 4A2	Stephen Locke Stephen.Locke@nrcan-rncan.gc.ca	Climate Change Geoscience Marine Geoscience for Marine Spatial Planning	Nova Scotia, Prince Edward Island, Newfoundland and Labrador	Ocean initiatives, United Nations Framework, Convention on Climate Change (UNFCC), Intergovernmental Panel on Climate Change (IPCC)

GSC Division	Director	Program / Service files	Provincial / Territorial Liaison	International Liaison
United Nations Convention on the Law of the Sea 1 Challenger Drive Dartmouth, NS B2Y 4A2	Mary-Lynn Dickson Mary-Lynn.Dickson@nrcan-rncan.gc.ca	United Nations Convention on the Law of the Sea (UNCLOS)		A5 nations: Denmark, Norway, Russia, and the United States; US Great Lakes Bottom Mapping SC; GEBCO-Seabed 2030

FUNDING AND BUDGET EXPENDITURES

Budget expenditures

In 2021-22, the GSC budget expenditures totaled $62.9M.

Geological Survey of Canada 2021-22 Budget Expenditures

GSC 2021-22	A-base ($)	C-base ($)	Total ($)
Vote 1 – Salary	$37,531,003.83	$6,617,093.32	$44,148,097.15
Vote 1 – Operation and Maintenance (O&M)	$2,356,012.13	$12,972,976.21	$15,328,988.34
Vote 5 – Major Capital	-	$2,038,121.55	$2,038,121.55
Vote 10 – Grants	$39,425.50	$1,400,062.00	$1,439,487.50
Total All Votes	$39,926,441.46	$23,028,253.08	$62,954,694.54

Program of Energy Research and Development (PERD) funding

The NRCan Office of Energy Research and Development (OERD) funding is the Government of Canada's coordinator of energy research and development (R&D) activities. Thirteen federal departments and agencies receive funds from OERD under the PERD program to undertake R&D and technology demonstrations. Since the 1970s, the GSC has been collaborating with the OERD to develop science to help ensure a sustainable energy future for Canada in the best interests of both our economy and our environment.

GSC received $776,373 funding for eight projects in 2020-21, under the Federal S&T funding of the OERD.

Other sources of funding

The GSC works closely with collaborators to fund geoscientific research in Canada. The GSC would like to acknowledge the contributions of all its partners, including other Government of Canada departments, provincial and territorial governments, non-governmental organizations, industry, and academia from around the world.

Annex 2: Reporting structure overview

GSC REPORTING STRUCTURE WITHIN THE GOVERNMENT OF CANADA

The Government of Canada's Policy on Results sets out the fundamental requirements for Canadian federal departmental accountability. It highlights the importance of results and ensures open and transparent public reporting.

Under the Policy on Results, each department in the Government of Canada develops a Departmental Results Framework (DRF) identifying core areas of responsibilities. NRCan's three core areas of responsibilities are:

- Natural Resource Science and Risk Mitigation;
- Innovative and Sustainable Natural Resources Development; and,
- Globally Competitive Natural Resource Sectors.

The GSC supports the NRCan priority, "Natural Resource Science and Risk Mitigation."

Departmental Results Reports (DRRs) are individual department and agency accounts of results achieved against planned performance expectations as set out in respective Departmental Plans. Departments must report on Performance Information Profiles (PIPs), outlined in the DRF for each department. Each sector within a department—for example, the Lands and Minerals Sector (LMS), of which GSC is a part—contributes to DRF reporting.

Find more information on results and financial and human resources related to the 2021-22 Departmental Plan here.

The GSC contributes to the following NRCan PIPs:

1. Geological knowledge for Canada's onshore and offshore lands
2. Geoscience for sustainable development of natural resources
3. Geoscience for keeping Canada safe

NATURAL RESOURCES CANADA (NRCAN) DEPARTMENTAL RESULTS FRAMEWORK

NRCan delivers its results through the Departmental Results Framework (DRF) in three core responsibilities (CR): (1) Natural Resource Science and Risk Mitigation; (2) Innovative and Sustainable Natural Resource Development; and, (3) Globally Competitive Natural Resource Sectors.

All GSC work falls under NRCan DRF Core Responsibility 1 (CR-1): *Natural Resource Science and Risk Mitigation.* The objective of CR-1 is to lead foundational science and share expertise for managing Canada's natural resources, reducing the impacts of climate change, and mitigating risks from natural disasters and explosives. The expected results are that Canadians have access to cutting-edge research to inform decisions on the management of natural resources; communities and officials have the tools to safeguard Canadians from natural hazards; and communities and industries are adapting to climate change.

This Core Responsibility supports the advancement of the following Government of Canada Strategic Priorities:

- Protecting Canadians from the impacts of natural and human-induced hazards;
- Accelerating the adoption of clean technology and supporting the transition to a low-carbon future;
- Advancing reconciliation, building relationships, and sharing economic benefits with Indigenous peoples.

The GSC programs within the DRF are:

- Geological knowledge for Canada's onshore and offshore lands (Strategic Priority 1);
- Geoscience for sustainable development of natural resources (Strategic Priority 2); and,
- Geoscience to keep Canada safe (Strategic Priority 3).

See the 2021-22 Departmental Plan for more information.

GSC STRATEGIC PRIORITIES

To fulfil its departmental reporting requirements and guide its programs and services, the GSC develops a Strategic Plan every five years. The most recent Strategic Plan identifies five key priorities for 2018–2023, along with related initiatives to support the implementation of these priorities.

The GSC's strategic priorities for 2018–2023 are:

1. Geological knowledge for Canada's onshore and offshore lands
2. Geoscience for sustainable development of natural resources
3. Geoscience for keeping Canada safe
4. Geoscience for society
5. Our science, our people

Priorities 1–3 outline the key scientific contributions to NRCan's strategic priorities by producing new geoscience knowledge and are aligned with NRCan DRF and LMS PIP priorities. Strategic priorities 4 and 5 describe organizational and business objectives to sustain capacity and foster a healthy work environment that is required to conduct efficient, effective, and relevant work. The following table demonstrates linkages and alignment.

Geological Survey of Canada reporting structure

NRCan DRF Core Responsibility	NRCan DRF Program, LMS PIP, and GSC Strategic Priority (SP)	LMS PIP Projects	GSC Science Programs / Services
Natural resource science and risk mitigation	SP-1: Geological knowledge for Canada's onshore and offshore lands	Geo-mapping for Energy and Minerals Canada's Extended Continental Shelf Program	Geo-Mapping for Energy and Minerals-GeoNorth (GEM-GeoNorth) United Nations Convention on the Law of the Sea (UNCLOS) Canada-3D (C3D)
	SP-2: Geoscience for sustainable development of natural resources	Environmental Studies and Assessment Groundwater Geoscience Targeted Geoscience Initiative Geoscience for New Energy Supply	Environmental Impact Assessment Service (EIAS) Environmental Geoscience Program (EGP) Groundwater Geoscience Program (GGP) Targeted Geoscience Initiative (TGI) Geoscience for New Energy Supply (GNES) Marine Conservation Targets (MCT) Marine Geoscience for Marine Spatial Planning (MGMSP)
	SP-3: Geoscience for keeping Canada safe	Geo-hazards and Public Safety	Public Safety Geoscience Program (PSGP) Climate Change Geoscience Program (CCGP)
	SP-4: Geoscience for society *(not part of DRF or PIPs)		Open Geoscience Network (OGN) Indigenous Relations Network (IRN)
	SP-5: Our people, our science *(not part of DRF or PIPs)		Science Laboratory Network (SLN)

More information about NRCan's DRF can be found online.

PERFORMANCE INFORMATION PROFILES

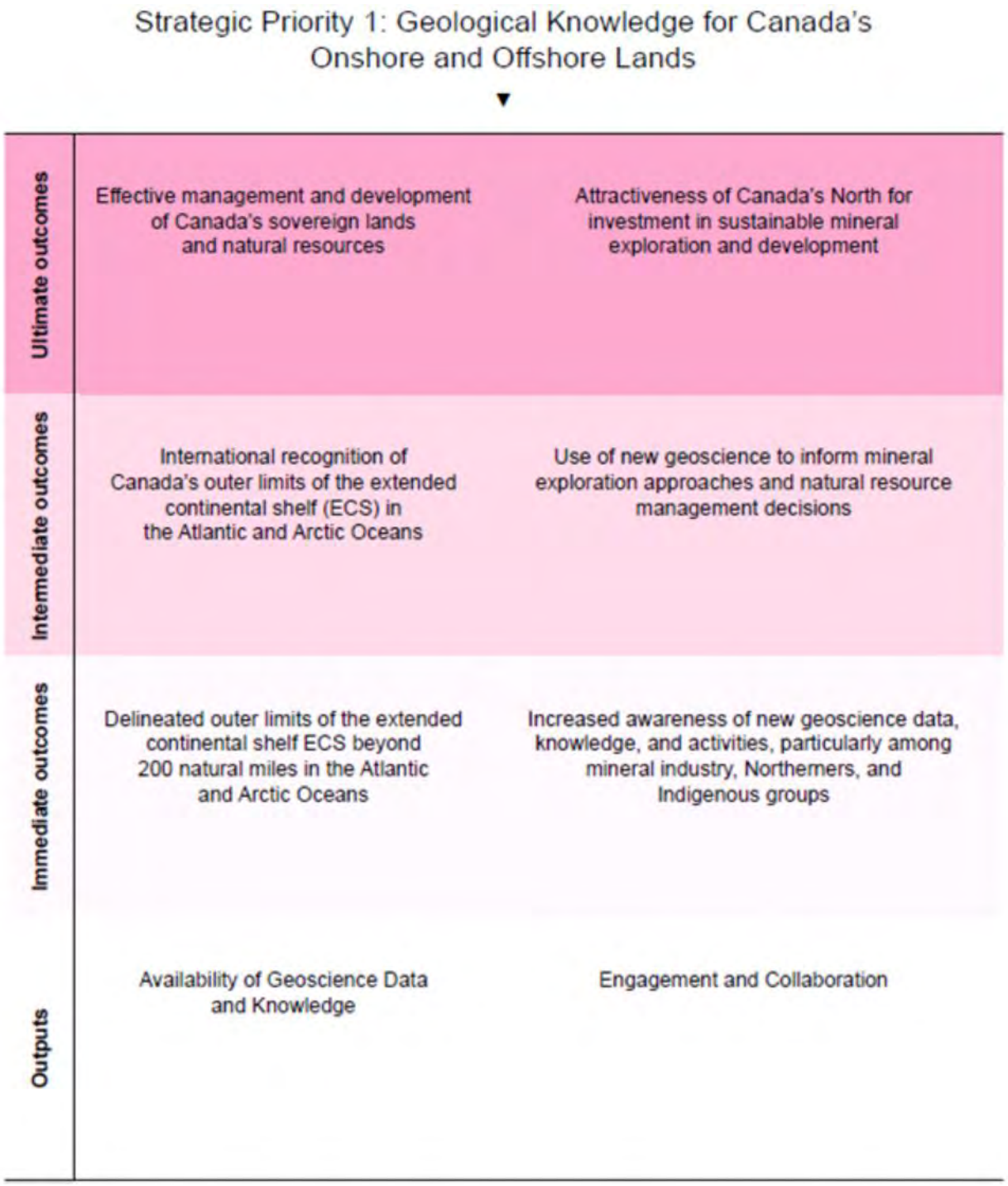
Aligned with the Department Results Framework, NRCan uses Performance Information Profiles (PIPs), a tool to organize, coordinate, and report on performance information relevant to programs. The PIPs enable the collection of data to support monitoring, routine program and policy decision-making, evaluation, reviews, and other activities for programs. The GSC reports annually on the following three PIPs:

1. Geological knowledge for Canada's onshore and offshore lands;
2. Geoscience for sustainable development of natural resources; and,
3. Geoscience for keeping Canada safe.

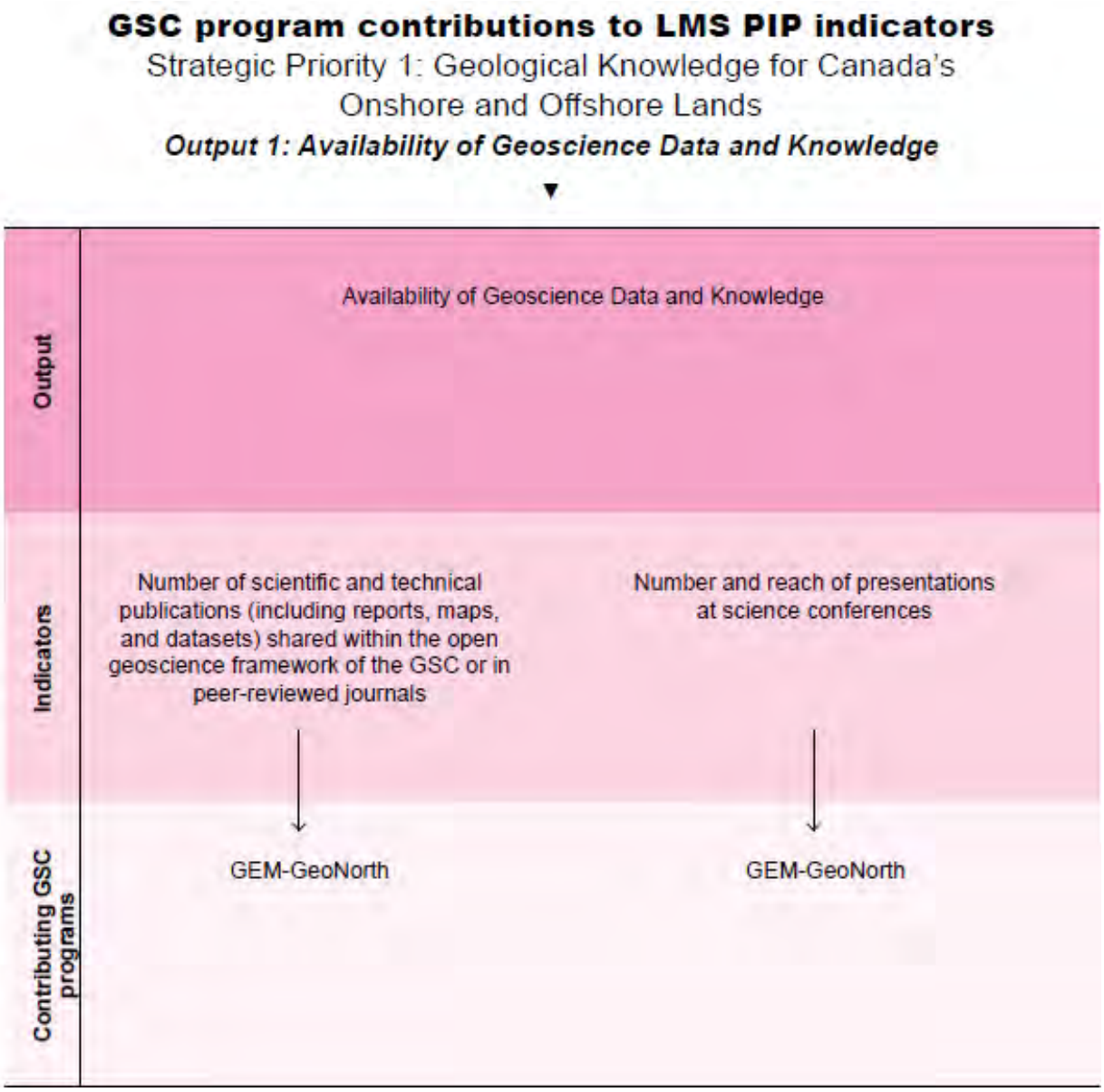
Strategic Priority 1: Geological knowledge for Canada's onshore and offshore lands

Through this PIP, NRCan produces geoscientific data and knowledge to map the regional geological context of Canada's onshore and offshore lands (see following logic model). NRCan provides information on new mineral and hydrocarbon potential to support other sectors and departments with strategic resource assessments, methodologies, and data to make evidence-based decisions. NRCan also increases the availability and use of geoscience data assets and knowledge products by developing value-added analyses and tailoring information to broader audiences.

NRCan acquired and interpreted geophysical data that was the basis of a formal submission defining the outer limits of the extended continental shelf beyond 200 nautical miles in the Atlantic and Arctic oceans as part of Canada's obligation to the United Nations Convention on the Law of the Sea. International recognition of this new offshore territory will give Canada sovereign rights over the natural resources on the seabed and subsoil.



Logic model for Strategic Priority 1: Geological knowledge for Canada's onshore and offshore lands Performance Information Profile



Strategic Priority 1 (Geological knowledge for Canada's onshore and offshore lands), Output 1 (Availability of geoscience data and knowledge)

GSC program contributions to LMS PIP indicators

Strategic Priority 1: Geological Knowledge for Canada's Onshore and Offshore Lands

Output 2: Engagement and Collaboration

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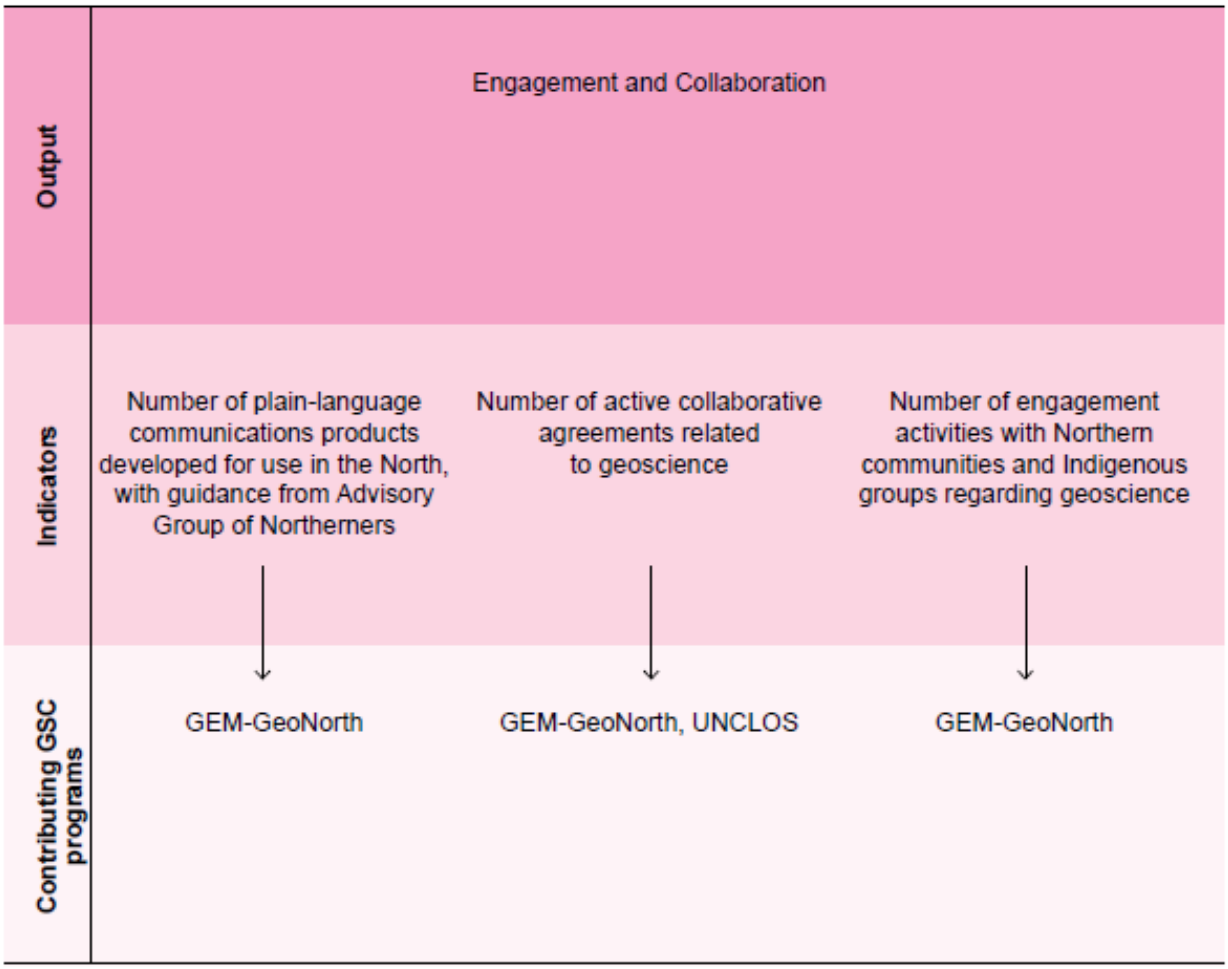


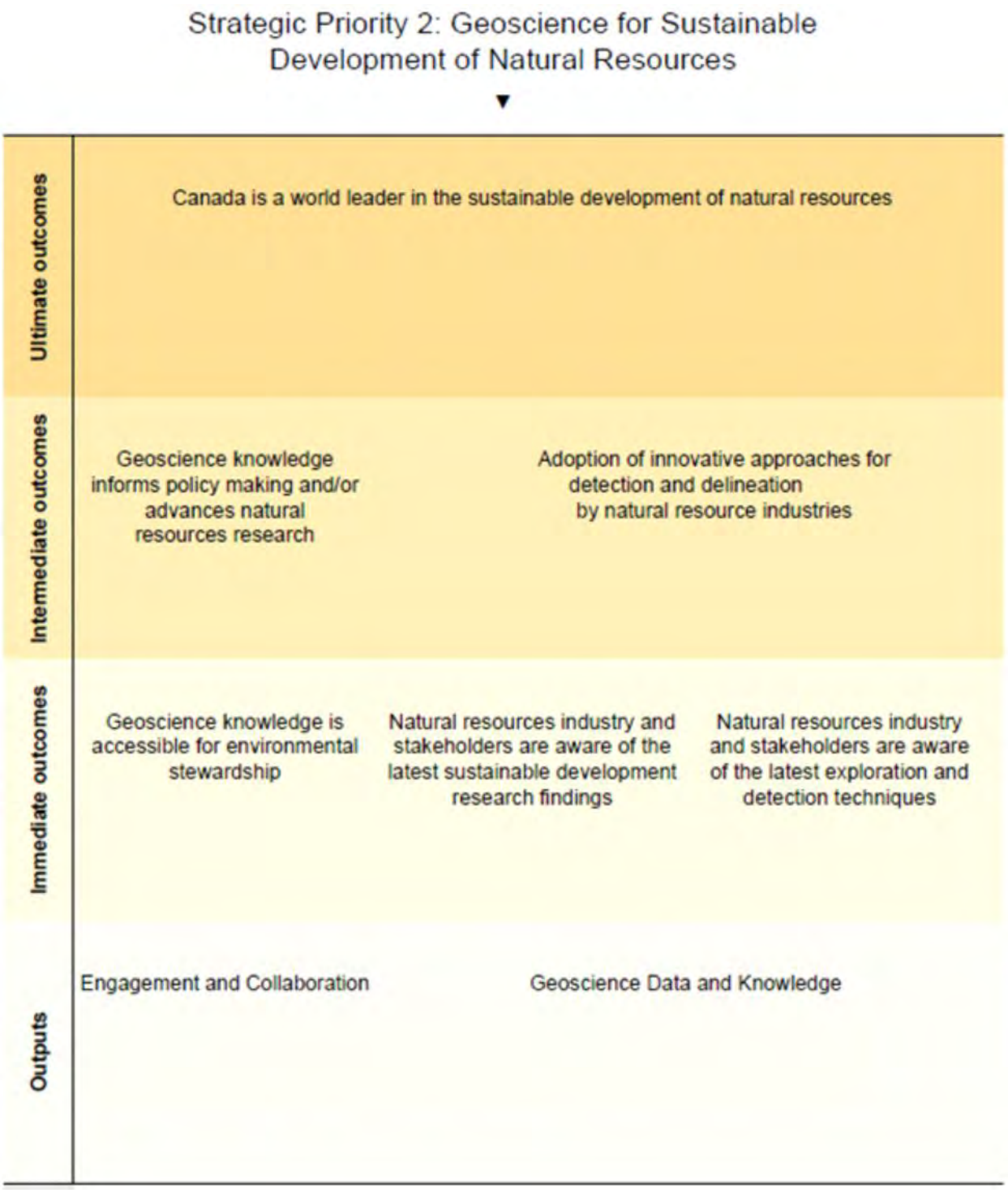
*Program Abbreviations:
GEM-GeoNorth: Geo-Mapping for Energy and Minerals-GeoNorth
UNCLOS: United Nations Convention on the Law of the Sea

Strategic Priority 1 (Geological knowledge for Canada's onshore and offshore lands), Output 2 (Engagement and collaboration)

Strategic Priority 2: Geoscience for sustainable development of natural resources

This PIP creates new geoscience knowledge that supports sustainable development of Canada's land, mineral, energy, and water resources (see the logic model below). Geoscientific knowledge informs land-use decisions such as marine protected areas, pre-exploration geoscience so that companies can efficiently discover new mineral and low-carbon-footprint energy resources, and environmental and groundwater studies so that resource sites can be developed and efficiently remediated post-production. Integrating the results of these studies will increase the efficiency of sustaining mining- and energy-dependent communities, while ensuring that these developments impact the environment and groundwater in the most minimal way.

NRCan/LMS provides expert advice to government departments, regulatory bodies, and industry to inform regulatory policies, industry practices, and environmental assessments that contribute to sustainable land-use decision-making and groundwater management. This ultimately serves to improve Canada's global competitiveness and supports the sustainable development of Canadian mining-dependent communities.



Logic model for Strategic Priority 2: Geoscience for sustainable development of natural resources Performance Information Profile

GSC program contributions to LMS PIP indicators

Strategic Priority 2: Geoscience for Sustainable Development of Natural Resources

Output 1: Engagement and Collaboration

▼

Output	Engagement and Collaboration		
Indicators	Number of stakeholder engagements (e.g. workshops) at which geoscience is discussed including those incorporating Indigenous knowledge	Number of active collaborative agreements related to geoscience	Number of reports and peer-reviewed publications produced annually
Contributing GSC programs	GNES, EGP, GGP, TGI	GNES/MCT, EGP, GGP, TGI	GNES, EGP, GGP, TGI

*Program Abbreviations:
EGP: Environmental Geoscience Program
GGP: Groundwater Geoscience Program
GNES: Geoscience for New Energy Supply
MCT: Marine Conservation Targets
TGI: Targeted Geoscience Initiative

Strategic Priority 2 (Geoscience for sustainable development of natural resources), Output 1 (Engagement and collaboration)

GSC program contributions to LMS PIP indicators

Strategic Priority 2: Geoscience for Sustainable Development of Natural Resources

Output 2: Geoscience Data and Knowledge

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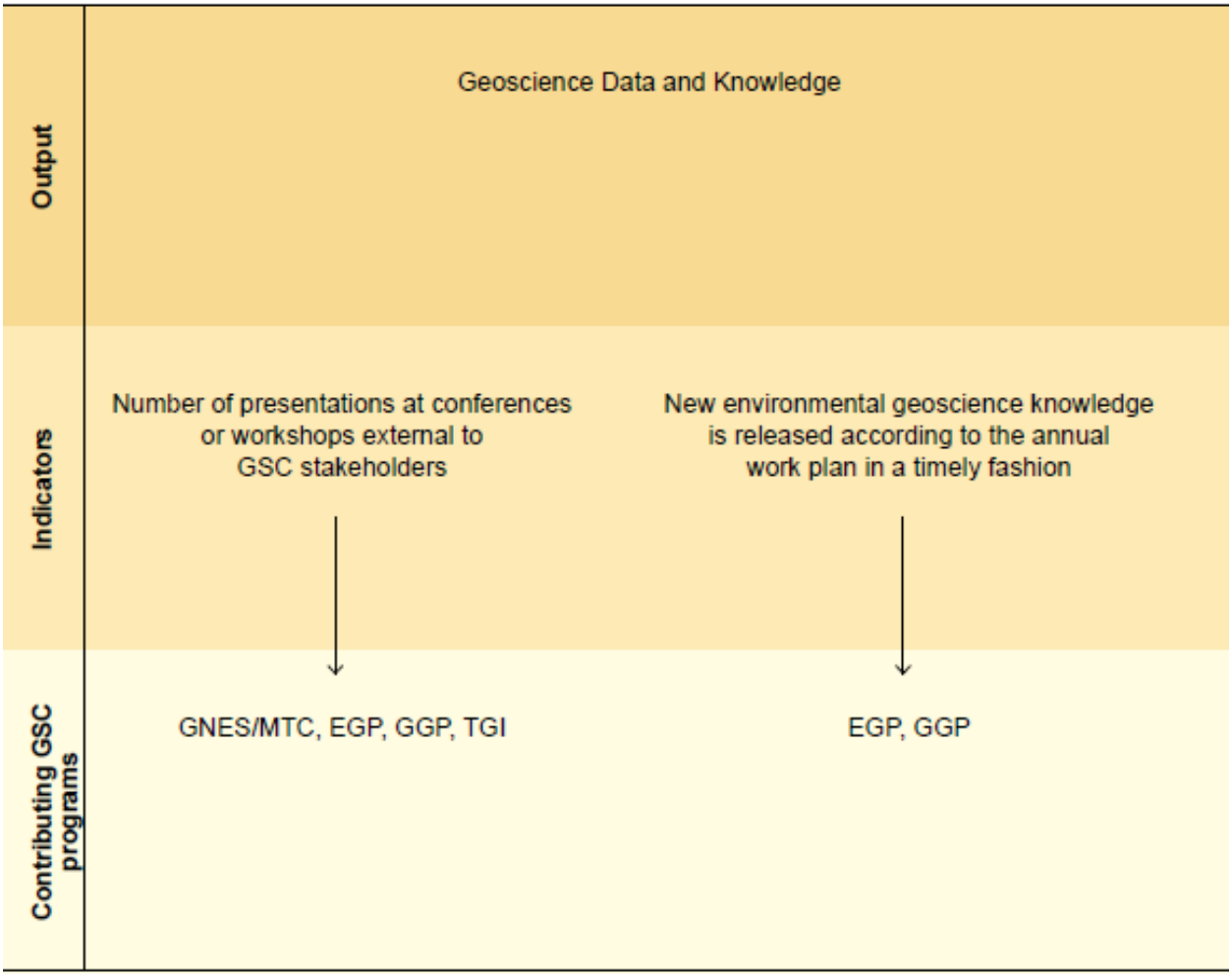


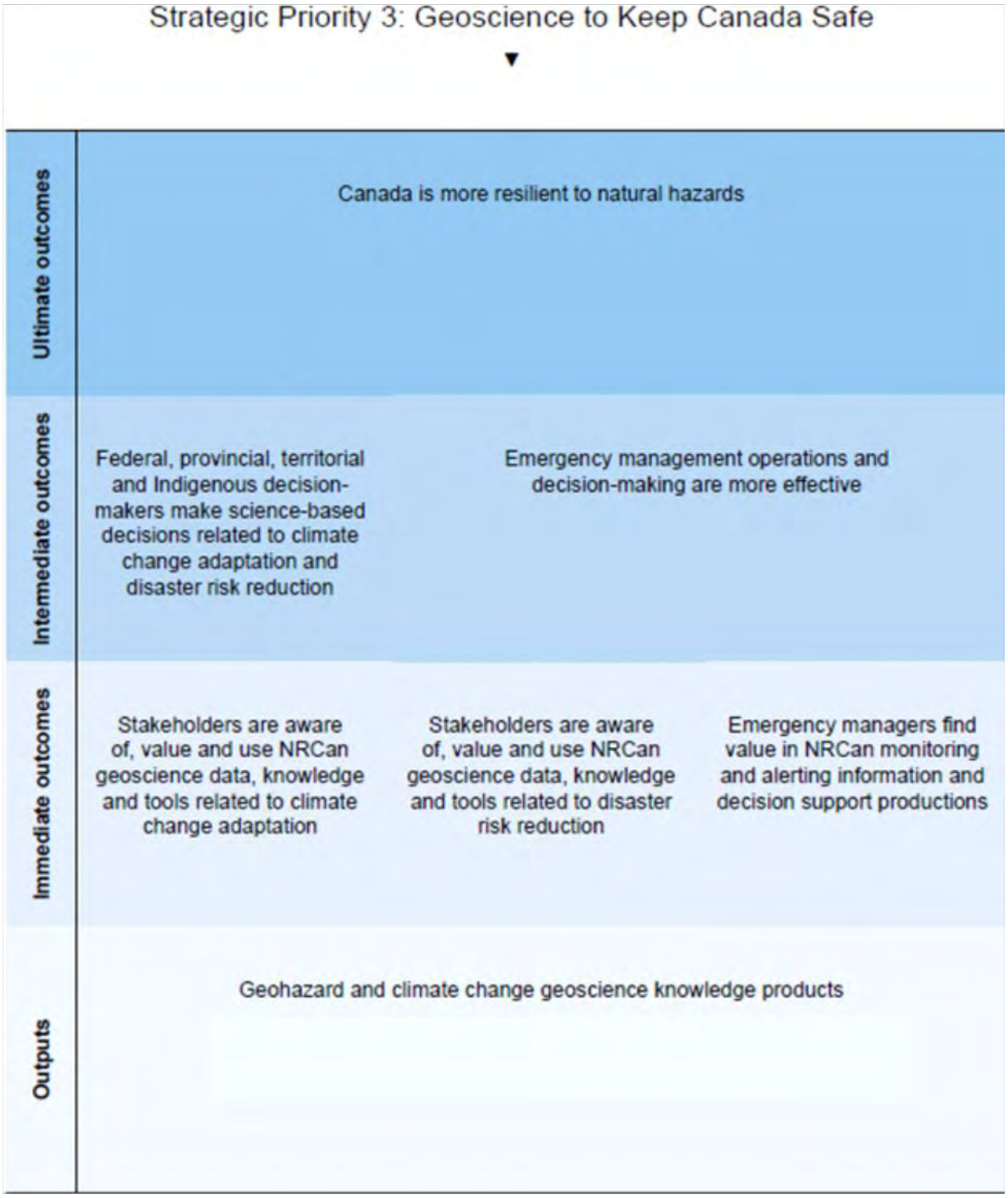
*Program Abbreviations:
EGP: Environmental Geoscience Program
GGP: Groundwater Geoscience Program
GNES: Geoscience for New Energy Supply
MCT: Marine Conservation Targets
TGI: Targeted Geoscience Initiative

Strategic Priority 2 (Geoscience for sustainable development of natural resources), Output 2 (Geoscience data and knowledge)

Strategic Priority 3: Geoscience for keeping Canada safe

This program undertakes the monitoring of, research into, and effective planning against various natural and human-induced hazards including earthquakes, tsunamis, landslides, and impacts related to climate change, geomagnetic storms, and radiological and nuclear incidents (see logic model below).

Through the provision of hazard information, NRCan helps other levels of government, international government bodies, the private sector, and professional organizations, to prevent, mitigate, prepare for, respond to, and recover from natural disasters. Similarly, stakeholders use geoscience information to minimize the risks that climate change poses to communities and infrastructure in vulnerable areas.



Logic model for Strategic Priority 3: Geoscience to keep Canada safe Performance Information Profile

GSC program contributions to LMS PIP indicators

Strategic Priority 3: Geoscience to Keep Canada Safe

Output 1: Geohazard and Climate Change Geoscience Knowledge Products

▼

*Program Abbreviations:
CCGP: Climate Change Geoscience Program
PSGP: Public Safety Geoscience Program

Strategic Priority 3 (Geoscience to keep Canada safe), Output 1 (Geohazard and climate change geoscience knowledge products)

Annex 3: Programs, projects, services, and activities by geoscience focus area

MINERALS

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Ore Systems Kathleen Lauzière	This project aims to enhance understanding of Canadian ore deposits and their critical minerals, and the larger mineral systems that generate them in suitable geological environments, from metal sources to ore deposition. A system-scale understanding of ore deposits and ore-forming processes is critical to sustain discovery of	Hydrothermal Ore Systems Jan Peter	Including a diverse group of deposits where the primary depositional mechanism is related to dissolution, transport, and deposition of metals by aqueous fluids such as seawater, basinal brines, and groundwater. These fluids are commonly rich in metals and salts and precipitate critical and economically important metals such as zinc, copper, gold, lead, tin, antimony, germanium, bismuth, and lithium. This activity focuses on the physical and chemical processes that lead to leaching, transport, and precipitation of economically important elements and minerals from aqueous fluids.	Targeted Geoscience Initiative
		Magmatic Ore Systems Wouter Bleeker	Advancing the geoscience knowledge of magmatic ore deposits and their fundamental mineral systems by integrating data across all scales, from the deposit to the full magmatic system scale. Mafic (Mg-Fe-rich) magmatic systems are the dominant ore system to generate deposits of nickel, copper, cobalt, platinum, chrome, titanium, and vanadium, most of which are considered “critical.”	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	additional ore resources, either at depth or in remote areas, and to reduce risk for companies exploring for ore deposits in Canada. This is essential to secure future supply of critical and other economically important minerals in Canada.		Felsic (silica-rich) or alkaline systems (silica-poor and alkali-rich, including carbonatites) are the dominant host for numerous other minerals and metals ranging from rare metals (Nb, Ta, Zr) and rare earth elements (REE) to battery metals such as lithium. Research will focus on physical and chemical magmatic processes and research outcomes will include improved understanding of how these deposits form, their distribution in space and time across Canada, what localizes them at the system and district scale, and their complete compositional characterization in terms of critical metals.	
		Orogenic Ore Systems Sébastien Castonguay	Contributing to improving the knowledge of mineral deposits that are formed as a result of deformation and metamorphism of Earth's crust during orogenesis, with an emphasis on the relationships in space and time to regional tectonic features and their history. Tectonic processes can generate magmas and/or hydrothermal fluids that can mobilize and transport metals and focus them into broad corridors with specific areas or discrete zones where precious and critical metals (e.g., gold, copper, tellurium, and bismuth) are concentrated to form ore deposits.	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Digital Geoscience and Method Development Jessica Tomkins	This project develops methods for research that is applicable to multiple ore systems and/or original research in support of mineral exploration that is not directly related to an ore system.	Machine Learning/Artificial Intelligence Applications/3D Geological/Geophysical Modelling Gilles Bellefleur	Developing 1) new methods and/or new applications in artificial intelligence (AI) and machine learning (ML) to support exploration for critical and other economically important mineral systems in Canada; and, 2) geophysical and 3D geological modelling methods to obtain subsurface knowledge of ore systems and enhance the effectiveness of deep exploration. Outcomes will include integrated models of the subsurface constrained by geophysical, geological, petrophysical, and geochemical data.	Targeted Geoscience Initiative
		Method Development Dawn Kellett	Developing innovative laboratory analytical and data acquisition methods (geology/geophysics/geochemistry/remote sensing) in support of critical mineral research. Outputs will provide the geoscience community and exploration industry with new methods to improve the efficiency and targeting capability of the entire mineral exploration workflow.	
		Spatial Data Infrastructure Ernst Schetselaar	Creating a program-wide digital infrastructure exploiting spatial data infrastructure designs of other GSC programs to: 1) enhance access to TGI's field and laboratory data and derived scientific interpretations; 2) facilitate in-house and external data-driven analysis (e.g., statistics, machine learning, modelling); and, 3) meet the demands for open public data dissemination via the internet to industrial, governmental, academic TGI stakeholders, and the general public.	Targeted Geoscience Initiative

GEOSCIENCE FOR THE NORTH

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
GEM-GeoNorth Michel Plouffe	GEM-GeoNorth focuses on mineral potential and sustainable land use for economic development in Canada's North, in the context of a changing climate. The program is generating new, public geoscientific data, knowledge, and maps for northern Canada, targeting areas where economic or infrastructure development is likely to benefit northern communities.	Thirty-six one-year transitional/foundational research activities were launched in 2021-22. These were based on the draft priorities settled with provinces and territories and Indigenous governments and organizations. The program finalized the list of research activities for the coming three years based on evaluation from the Science and Technology Advisory Committee. Twenty-eight research activities were approved for 2022-23.	Western Arctic: thematic and systematic studies using multidisciplinary traditional field and laboratory methods, and innovative geological and geophysical approaches to regional 3D modelling. Generation and integration of multidisciplinary datasets will serve a wide range of users including governments, industry, and communities. Central Arctic: combination of traditional methods and innovative approaches. In addition to major compilation and synthesis of robust existing datasets for the Mackenzie Valley itself, models of groundwater and geochemical surveys, and field mapping, new integrative analytical studies combining multiple layers of	GEM-GeoNorth

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			information will serve a wide range of users including governments, industry (developers, explorationists), and educators.	
			Western Hudson Bay: interdisciplinary research approach that combines multiple geological, geophysical, and geochemical methods. Research will have broader implications for the western Hudson Bay region and northern Canada in general.	
			Eastern Arctic: combination of traditional remote sensing and field methods, and innovative modelling and lab approaches. In addition to geophysical and geochemical surveys and field mapping, new integrative analytical studies combining	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			multiple layers of information will serve a wide range of users including governments, industry, and educators. Research currently focuses on the sub-priority regions of Southern Labrador Trough and Hopedale-Nain.	
			Pan-Arctic: thematic studies bridging regional priority areas. They provide perspective on the metallogenic framework that controls mineral deposits, important to enhancing exploration success in the North, as well as landscape factors relevant to development projects.	
Environmental Impacts of Permafrost Thaw in the Arctic Mathieu Duchesne	Since about 50% of the permafrost underlies the Canadian landmass, this project will assess the environmental implications of permafrost degradation and provide a baseline to better appraise	Permafrost Solute Concentrations in an Active Gravel Pit Paul Gammon	The geochemistry resulting from permafrost freeze-thaw processes are poorly understood. This activity aims to refine the current understanding of these processes by investigating the geochemistry of a gravel pit associated	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	the environmental consequences of resource development.		with the building of the Inuvik to Tuktoyaktuk Highway (ITH) in NWT.	

CLIMATE CHANGE

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Reconstructing long-term environmental dynamics to support regional assessment Josué Jautzy	Project split into 2 components of 2 programs: Groundwater Geoscience Program (GGP) and Environmental Geoscience Program (EGP).	Lake Sediments and Tree Rings Geochemical Compilation in Support of Regional Assessments Josué Jautzy	The purpose of this component is to assess the effect of climate variability on the natural level of metal concentrations in lake sediments and tree rings in order to measure impacts of any new mineral resource development. The tools and methods developed will help future regional assessments under IACC lead.	Environmental Geoscience Program
Supporting Adaptation in Permafrost Regions Sharon Smith	Understanding permafrost-climate-infrastructure interactions. Informs adaptation strategies for major existing and proposed transportation routes in the North.	Monitoring permafrost conditions and advancing methodologies for permafrost terrain classification and mapping Sharon Smith, Stephen Wolfe, Peter Morse, Brendan O'Neill, Anne-Marie LeBlanc	Measuring permafrost thermal state and active-layer conditions, analyzing remotely sensed imagery to develop permafrost terrain classification and open talik mapping; mapping landforms associated with ground ice and thermokarst processes; modelling and analysis for assessment of ground ice and thermokarst potentials and terrain sensitivity.	Climate Change Geoscience Program
Supporting Adaptation in Coastal Regions Dustin Whalen	Assessing the sensitivity of Canadian coastal regions to climate change. Informs adaptation	Sea-level Projections for Canada Thomas James	Refining Canada's sea-level change projections and hazard risks (e.g., flooding, infrastructure, and population risk at shorelines).	Climate Change Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	strategies for existing and proposed coastal infrastructure and communities.	Coastal Dynamics Dustin Whalen	Improving the understanding of coastal erosion on land and the nearshore environment in ice-rich permafrost terrain in the Western Arctic (Beaufort Sea).	
		CanCoast Indices: Validation, Refinement, and Application of Coastal Sensitivity Indices Gavin Manson	Developing a national digital database, with scalable models that combine data on different coastal physical features, to generate indices of coastal sensitivity to climate change.	
		Nature-Based Infrastructure for Coastal Resilience and Risk Reduction Gwyn Lintern/Michelle Côté/Gavin Manson	Examining the effectiveness of “soft” coastal infrastructure, such as sediments and vegetation, to attenuate waves and storm surges and provide flood storage.	
Extreme Events: Improving Forecasting for the Hudson Bay Lowlands and Drought Risk Assessment for the Hydro-Power Industry Christian Bégin	Advancing climate adaptation through improved drought indices and flood forecasting.	Advancing Climate Adaptation Through Improved Flood Forecasting for Hudson Bay Lowlands Hazen Russell	Improving understanding of processes necessary to refine flood forecasting for the Hudson Bay Lowlands.	Climate Change Geoscience Program
		Improving Drought Risk Assessment Associated With Climate Change for the Hydro-Power Industry of Central and Eastern Canada	Developing drought indices to provide support for improved hydroelectric water management.	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
		Christian Bégin		
National Glaciology Project David Burgess	Assessing the rate and the causality of glacier changes in Canada's Arctic and alpine environments.	High Arctic David Burgess	Employing *in situ*, remote sensing, and regional climate models to assess synoptic scale glacier change in the Canadian Arctic.	Climate Change Geoscience Program
		Western Cordillera Mark Ednie	Employing *in situ* and remote sensing data to assess synoptic-scale glacier change in western Canada.	

MARINE AND COASTAL

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Scotian Shelf Bioregion Michael Li	Marine geoscience knowledge generation in the Scotian Shelf Bioregion. Includes delivery of maps and data at the bioregional, regional assessment, and targeted study scale.	Geological Constraints for Offshore Wind Energy Development Jordan Eamer	Assessing surficial geology physical properties in the context of offshore wind energy infrastructure.	Marine Geoscience for Marine Spatial Planning
		Regional Bathymetric Data Compilation	Compiling bathymetric data requiring the merging and balancing of various datasets and sources to create a seamless geomorphological base.	
		Marine Surficial Geology Synthesis Geneviève Philibert	Updating previous surficial geology for offshore Nova Scotia and interpreting new data to create a bioregional-scale geology map.	
Newfoundland and Labrador Shelves Bioregion Vladimir Kostylev	Marine geoscience knowledge generation in the Newfoundland and Labrador (NL) Shelves Bioregion. Includes delivery of maps and data at the bioregional, regional	Regional Modelling of Seabed Sheer Stress and Sediment Transport	Calibrating seabed sheer and sediment transport models for offshore NL and NS to support decisions around sediment mobility.	Marine Geoscience for Marine Spatial Planning

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	assessment, and targeted study scale.	Michael Li		
		Marine Surficial Geology Synthesis Gordon Cameron	Synthesizing surficial geology for offshore NL. Consists of updating previous interpretations and interpreting new data to create a bioregional-scale geology map.	
		Nearshore Sedimentary Processes Off Labrador Alex Normandeau	Case studies of nearshore sedimentary processes and geological hazards off Labrador.	
		Slope Stability assessment Laura Broom	Assessing regional slope stability based on extensive legacy and new sediment core samples and geotechnical analysis.	
Pacific North Coast Integrated Management	Marine geoscience knowledge generation in the PNCIMA Bioregion. Includes	Surficial Geology Synthesis	Synthesizing surficial geology for PNCIMA. Consists of updating previous	Marine Geoscience for Marine Spatial Planning

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Area (PNCIMA) Bioregion Cooper Stacey	delivery of maps and data at the bioregional, regional assessment, and targeted study scale.	Cooper Stacey	interpretations and interpreting new data to create a bioregional-scale geology map.	
		Regional Bathymetric Compilation Robert Kung	Bathymetric compilation requires the merging and balancing of various datasets and sources to create a seamless geomorphological base. Covers PNCIMA and Salish Sea bioregions.	
Salish Sea Bioregion Randy Enkin	Marine geoscience knowledge generation in the Salish Sea Bioregion. Includes delivery of maps and data at the bioregional, regional assessment, and targeted study scale.	Anthropogenic Impacts of Anchorage Sites Karen Douglas	Collaborating on a research project with DFO to study effects of ship anchorage on seabed conditions.	Marine Geoscience for Marine Spatial Planning
		Surficial Geology Synthesis Randy Enkin	Synthesizing surficial geology for the Salish Sea Bioregion. Consists of updating previous interpretations and interpretating new data to create a bioregional-scale geology map.	
Autonomous Systems Pilot Project	Project focused on technological development of applications of	Acquisition and Operation of New Autonomous	Developing turnkey operation procedures	Marine Geoscience for Marine Spatial Planning

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Alex Normandeau	autonomous and intelligent marine systems for seabed studies and marine spatial planning.	Seabed Mapping Instrumentation Robbie Bennett	for NRCan autonomous marine systems.	
Data Management IM/IT Sheila Hynes	Ensure coordination of program data and geospatial deliverables for public-facing data platforms (Open Maps, Marine Spatial Data Infrastructure).	Legacy Dataset Release Sheila Hynes	Releasing of geospatially optimized legacy marine geology datasets.	
Marine Conservation Targets Keith Dewing	The Marine Conservation Targets project conducts hydrocarbon and other resource assessments in areas being considered by DFO, ECCC, and Parks Canada Conservation as part of Canada's commitment to conserve 25% of its marine and coastal areas by 2025 through the creation of Marine Protected Areas.	Not applicable	Not applicable	Marine Conservation Targets
Dredge Disposal at Sea Gwyn Lintern	Canada regulates Disposal at Sea (DAS) through a permit system under the *Canadian Environmental Protection Act 1999* (CEPA, 1999) and is required to conduct regular monitoring of DAS sites through *Schedule 6* of *CEPA*. This	Not applicable	Not applicable	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	project assesses sediment dispersion at dredge disposal sites in the Pacific Ocean. These disposal sites will be (and are being) used by major infrastructure proponents, particularly energy export ports. The work comprises adding a day onto several existing LMS cruises to deploy and recover current sensors, and to do calculations and report on the dispersion characteristics of sediment to improve national guidelines.			

HAZARDS AND PUBLIC SAFETY

Project & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Earthquake Geohazards John Cassidy	Research to understand where, at what magnitude, and how often future earthquakes might occur. This includes understanding how the ground will shake, where active faults exist, and what can be expected in terms of aftershocks following an earthquake. The research undertaken in this project fundamentally informs the national seismic hazard model that underpins the seismic provisions in the National Building Code of Canada.	Intraplate Earthquakes Greg Brooks	Improving the understanding of intraplate earthquakes in Quebec, Ontario, and the Eastern Arctic. This includes paleoseismic investigations, seismic site response, and fault mapping.	Public Safety Geoscience Program
		Plate Boundary Earthquakes Andrew Schaeffer	Improving assessments of earthquake hazards in Canada's plate boundary region, from southwestern BC to the Beaufort Sea. This includes developing new models for earthquake hazard and tsunami generation and supporting the development of early warning systems.	
	Research to understand the hazards and risks associated with volcanoes in Canada.	Volcanic Hazard Assessment Melanie Kelman	Volcanic hazard and risk assessment at Canadian volcanoes, including developing outreach materials and models to demonstrate specific hazards at high threat Canadian volcanoes.	
	Assessments of terrestrial and marine slope stability	Baffin Bay and Arctic Channels	Defining nearshore hazards that could affect Baffin	Public Safety Geoscience Program

Project & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Landslides and Marine Geohazards Andrée Blais-Stevens	geohazards, and tsunamis.	Alex Normandeau	communities, including the recurrence of submarine landslides and terrestrial landslides.	
		Beaufort Sea Ned King	Understanding offshore submarine geohazards, including faults and slope instabilities, in the Beaufort Sea, to ensure the safety and security of communities and any future infrastructure.	
		Terrestrial Landslides David Huntley	Innovative assessment and monitoring of slow moving landslides on railway corridors.	
		Submarine Landslides and Tsunami Hazards Gwyn Lintern	Understanding these offshore and coastal hazards and how they might impact people and infrastructure.	
Space Weather Hazards Ljubomir Nikolic	Research to better understand the characteristics of space weather disturbances and the effects they can have in order to support effective mitigation actions.	Ground Effects David Boteler	Understanding geomagnetic effects on ground systems, such as power grids, to support informed decision-making.	Public Safety Geoscience Program
		Ionospheric Effects Robyn Fiori	Investigating ionospheric effects on radio systems and Global Navigation	

Project & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			Satellite System (GNSS) performance.	
		Space Weather Hazard Assessment Lidia Nikitina	Establishing a benchmark for worst-case conditions, which could happen once in a given period of time, or once in several solar cycles, depending on the phenomenon.	
		Forecast Development Ljubomir Nikolic	Improving space weather forecasting.	
National-Scale Geohazard Risk Assessment Nicky Hastings	Development of tools, knowledge, and methodologies to bring together our knowledge of hazards and the people, environment, and infrastructure that are exposed to understand the social, economic, and physical impacts of geohazards.	Coastal Flood Mitigation Nicky Hastings	Advancing an understanding to integrate local and scientific knowledge that informs risk reduction strategies against coastal storm surge and tsunami risks across Canada.	Public Safety Geoscience Program
		CSSP Disaster Risk Reduction Pathways Nicky Hastings	Developing science to transform knowledge about systemic risk into policies that strengthen existing mechanisms for risk governance, mitigation, and resilience in SW BC.	
		Emergency Management Strategy-	Providing a national body of evidence to understand seismic risk	

Project & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
		Earthquake Risk Assessment Malaika Ulmi	and inform mitigation action.	

GROUNDWATER AND AQUIFERS

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Archetypal Aquifers in Canada Hazen Russell	Consolidate GSC knowledge and complete new studies on Canadian Archetypal Aquifer settings	Aquifer Classification and Characterization Hazen Russell	Developing aquifer system nomenclature	Groundwater Geoscience Program
		Archetypal Aquifers Case Studies Hazen Russell	Consolidating literature and complete data collection to support archetypal aquifer descriptions. Southern Ontario hydrostratigraphy, CT Scan work, and modelling	
		South Nation Aquifers Modelling Hazen Russell	Developing physics-based numeric groundwater modelling at the watershed to the regional scale	
		Downhole geophysical applications to hydrogeology (Borehole Calibration Facilities in Bells Corners) Heather Crow	Developing downhole and near-surface geophysics, seismic signal processing, and machine learning	
		eBook Contribution Hazen Russell	Contributing material as co-authors on a series of free books on hydrogeology	
Canada 1 Water Project Hazen Russell	Develop a groundwater-surface water modelling framework for	Groundwater-Surface-Water Model(s) Hazen Russell	Developing physics-based, fully integrated, groundwater-surface-water model(s) coupled with historic climate data and climate change scenario modelling for six	Groundwater Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	continental Canada		major watershed domains, including Canada-US transboundary watersheds	
Groundwater Information Network Boyan Brodaric	Define norms and standards for the purpose of development and distribution of hydrogeological databases	Groundwater Information Network (GIN) portal and database Boyan Brodaric	Improve national groundwater web portal and database for groundwater data (GIN)	Groundwater Geoscience Program
		Permafrost Information Network (PIN) Eric Boisvert	Migrate and maintain a national permafrost information network (PIN), including a web portal and database	
		Standards Development Boyan Brodaric	Maintaining and advancing relevant geoscience data standards	
		Linked Data Boyan Brodaric	Prototyping linked data infrastructure for Canada-US water data	
Water Resources Characterization and Modelling Daniel Paradis	Improve characterization methods and techniques, including remote sensing and 3D numerical modelling to develop better geoscience knowledge of large aquifer	Southern Quebec Groundwater Modelling Daniel Paradis	Developing a platform supporting surface and groundwater allocations, assessing water resources, and forecasting their futures under climate change and anthropogenic stresses	Groundwater Geoscience Program
		Hydrogeophysics Daniel Paradis	Developing hydrogeological characterization approaches, including learning machines, to translate geophysical data in hydraulic properties and	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	systems in Canada and to understand regional groundwater flow dynamics.		high-resolution hydraulic testing for complex aquifers	
		Glaciers and Rockies Regional Groundwater Flow System Daniel Paradis	Quantifying changes in glacial meltwater inputs into the hydrological system, and assessing the related impacts on the different water storage compartments (Canadian Rockies)	
Fox Creek Aquifers System assessment Christine Rivard	Assessing environmental cumulative effects in the Fox Creek area (west-central Alberta).	Characterization of shallow aquifers and their interactions with surface water Christine Rivard	Assessment of aquifer properties and 2D and 3D hydrogeological modelling and coupled surface water/groundwater modelling to study hydrodynamics (MSc and PhD projects)	Groundwater Geoscience Program
		Estimation of water budgets in both vegetated and non-vegetated (disturbed) areas Christine Rivard	Monitoring of soil moisture, interstitial water, rain, and snow to better understand the hydrologic cycle	
		Study of the geomechanical response of the intermediate zone to hydraulic fracturing activities	Development of a 3D geomechanical model to study potential impacts	
		Study of landscape change over the last 50–60 years	Use of recent satellite imagery and old air photos to assess main differences in wetland extent, type of	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			vegetation, forest fragmentation, etc.	
		Geochemical study to assess potential impacts of oil and gas activities over time Omid Haeri Ardakani	Use of groundwater, surface water, and rock samples to determine if water resources have been affected by industrial activities	Groundwater Geoscience Program
		General study to identify existing challenges and barriers in the current cumulative effects assessment process within environmental assessments (EAs) Christine Rivard	Interviews and discussions with First Nations groups, consultants, and federal employees were conducted to identify main obstacles and make recommendations for improving the current process.	
		Environmental study on a post-mining analog context of chromite deposits—Chaudière-Appalaches (Qc) Nicolas Benoit	Developing a preliminary hydrostratigraphic conceptual model using existing data and proposing a Machine Learning workflow to complete the surficial geology mapping Developing a sampling strategy to define the occurrence and mobility of chromium in the post-mining environment Developing field protocols and analytical methodologies	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			to measure representative concentrations of chromium species (Cr+3 and Cr+6)	
Reconstructing long-term environmental dynamics to support regional assessment (Ring of Fire [ROF]) Nicolas Benoit	Improve the understanding of the distribution and mobility of metal(loid)s associated to Cr deposits in the environment	Remote RoF geoscience baseline conditions: regional hydrostratigraphy and surficial geology mapping Environmental study on a post-mining analog context of chromite deposits—Chaudière-Appalaches (Qc) Analytical development of chromium speciation analyses in water: laboratory and field development Nicolas Benoit	Developing a sampling strategy to define the occurrence and mobility of chromium in a post-mining environment	Groundwater Geoscience Program
		Analytical development of chromium speciation analyses in water: laboratory and field development Nicolas Benoit		
		Not applicable	Developing field protocols and analytical methodologies to measure representative	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			concentrations of chromium species (Cr+3 and Cr+6)	
Cumulative Effects of Resource Development on Mining-Impacted Watersheds Alexandre Desbarats	This project will develop geoscience methods for distinguishing the environmental effects of new mining activity from complex existing background conditions in affected watersheds. This information and new data will be synthesized in the first geoenvironmental model for Ag-Ni-Co-As vein-type deposits.	Not applicable	Not applicable	Environmental Geoscience Program
Assessment of potential impacts of oil and gas development activities on shallow aquifers in the Fox Creek area (AB) Christine Rivard	Initially the project scope was to study environmental impacts of hydrocarbon exploration and production activities by studying the potential impacts on shallow groundwater. Now it includes studies on	Not applicable	Not applicable	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	vegetation, forest, snow cover, wetlands, landscape evolution, and woodland caribou habitat, in support of new impact assessment legislation for developing regional cumulative effects evaluation methods.			
Induced Seismicity Research Honn Kao	The exploration and development of shale gas raises questions about potential environmental and public health risks. Geoscience studies provide basic geological context and monitoring data that make it possible to assess potential effects on groundwater and induced seismicity.	Not applicable	Not applicable	Environmental Geoscience Program
Oil Sands Paul Gammon	Open-pit mining in the tar sands region of the lower Athabasca Valley in Alberta continues to raise	Not applicable	Not applicable	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	questions about sources of contaminants and their potential effects on air and water quality, as well as the possible cumulative effects on water and land ecosystems. This project contributes to developing attribution methodologies for the characterization of atmospheric and aqueous contaminants (potentially toxic metals) by using sophisticated isotopic indicators.			
Long-term hydrological dynamics of Canada's largest watershed: The Mackenzie River Basin	The Mackenzie River Basin in NWT is one of the world's largest (4,200 km long) and most important freshwater ecosystems. Climate change is disproportionately affecting high northern		Not applicable	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Jennifer Galloway	latitudes, especially in NW Canada. This project will examine long-term cycles to develop predictive ecohydrological models.			

ENERGY RESOURCES

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
Unconventional Resources Omid Ardakani	This project aims to advance the fundamental geoscience knowledge of Canada's subsurface lands with the intent of improving our environmental performance during the development and production of tight oil and unconventional gas. Such endeavours will ultimately support global steps toward a low-carbon economy. Funded by PERD.	CO_2 Enhanced Oil Recovery Omid Ardakani	Studying the interaction of CO_2 in shales to better understand its role for enhanced oil recovery and CO_2 sequestration and storage.	Geoscience for New Energy Supply
		Montney H_2S Source and Migration Omid Ardakani	Understanding the process by which H2S is formed in the Montney Formation, a major natural gas producing unit in NW Alberta and NE BC.	
Geothermal Resources Steve Grasby	The Geothermal Project supports government goals of reducing CO_2 emissions through a transition to non-emitting energy resources by evaluating regional geothermal resources.	Geothermal St., Lawrence Lowlands Christine Rivard	Characterizing the geothermal energy potential of the Bécancour area of southern Quebec and modelling heat transfer and fluid flow.	Geoscience for New Energy Supply
		Regional Geothermal Steve Grasby	Studying the geothermal energy potential of the WCSB for both electricity and head generation.	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
		Garibaldi Range (Mt. Meager) Geothermal Steve Grasby	Studying the geothermal potential of the Mount Meager region to produce electricity.	
		Hybrid Geothermal Zhuoheng Chen	Investigating the feasibility of co-extraction of tight unconventional gas and heat resources for cogeneration of power through reservoir modelling.	
Laboratory Methods Dennis Jiang	Using renewable and low-carbon energy geoscience research, this project focuses on innovative and novel laboratory methods. This project integrates and applies Augmented Intelligence/Machine Learning to advance Canadian geoscience research and development.	Pore Fluid Implications Zhuoheng Chen	Using modelling to better understand pore fluid interactions in shale gas reservoirs, this project investigates how fluids move in shales at the micro- and nano-scale.	Geoscience for New Energy Supply
		Laboratory Method Development Dennis Jiang	Improving traditional hydrocarbon fingerprinting laboratory methods allows the identification of different but very similar chemical structures and properties. This information improves the identification of source hydrocarbons both from reservoirs	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
			and in surface oil spills.	
		Hydraulic Fracking Flowback Waters Dennis Jiang	Characterizing the chemical composition of flowback waters from hydraulic fracturing and the environmental impacts associated with these waters.	
Nova Scotia Offshore Marine Geoscience Natalie Shea	In collaboration with the province of Nova Scotia, GSC is conducting offshore geoscience research to better understand the depositional environments associated with hydrocarbon deposits. This project is funded by the province of Nova Scotia.	Autonomous Underwater Vehicle (AUV) Surveys of Hydrocarbon Seeps off Nova Scotia Calvin Campbell	Detecting cold seeps from conventional sea surface methods has proven to be a challenge. By using an AUV, superior imaging of cold seeps was possible, improving the quality of data obtained from sites.	Geoscience for New Energy Supply
		Identifying Upper Jurassic Source Rock, Offshore Nova Scotia, Using Geochemical Proxies Nikole Bingham-Koslowski	Using geochemical proxies, this activity will identify and constrain the paleoenvironmental and depositional conditions required to produce source rocks during the Upper Jurassic, offshore Nova Scotia.	
		Play Fairway Biostratigraphic Analysis	Completion of papers based on the biostratigraphy of the Triassic–Early	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
		Rob Fensome	Cretaceous of the Scotian Margin, including the Laurentian channel area, southwestern Nova Scotia, and the Scotian-Moroccan Margin correlation.	
		Carbonate Diagenesis and Clumped Isotopes of the Scotian Slope Hydrocarbon Gas Seeps Josue Jautzy	Using cores collected in 2015 and 2018, clumped isotope analysis of carbonate minerals will improve understanding of the geological history of these sediments.	
Geoscientific Research into Accidentally Spilled Petroleum (GRASP) Jason Ahad	Transporting Canada's energy resources to market is vital to the country's economy. The federal government is committed to ensure the safety of Canadians and their environment, but current uncertainties regarding environmental impacts of accidentally leaked petroleum products limit Canada's capacity to adequately regulate safe transport and	Environmental Impacts of Diluted Bitumen Jason Ahad	Transporting it by pipeline, bitumen is blended with lighter hydrocarbon fractions, yielding a less viscous, diluted bitumen (dilbit). A number of incidents have highlighted the potential environmental risk caused by dilbit pipeline rupture. This project will address the knowledge gap surrounding the transport of dilbit in the environment, particularly shallow groundwater systems.	Environmental Geoscience Program

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC program
	effectively respond to spills in both terrestrial and marine environments. The project involves lab-controlled and field-based experiments, focusing on terrestrial environments analogous to those found along current and proposed pipeline routes, and on the Douglas Channel area (British Columbia's North Coast), which connects the active port of Kitimat to foreign markets.	Baseline of Natural Variability in the Douglas Channel Marine Oil Spill Studies (MOSS) Manuel Bringué	The active port of Kitimat (BC) is a getaway for the export of Canada's energy resources to international markets and an increase of tanker traffic is anticipated. This project will provide a baseline of natural variability in the Douglas Channel and identify the capacity of in situ microbial communities to mitigate accidentally released petroleum products under reduced oxygen and lower pH conditions.	
Geological Carbon Storage Don White	Carbon capture and storage (CCS) is a way to reduce atmospheric emissions of carbon dioxide (CO_2) for a variety of industrial sources. Long-term geological storage of CO_2 involves injecting CO_2 inside deep porous rock formations, such as depleted oil and gas reservoirs or saline aquifers.	Not applicable	Not applicable	Environmental Geoscience Program

GEOSCIENCE TOOLS AND DATA

Projects & Project Leader	Project Description	Activities	Activity Description	GSC program
IT Infrastructure Glen Newton	Put in place and maintain IT systems to securely generate, store, manage, and disseminate GSC data, publications, collections, and knowledge.	• Application Modernization and Workload Migration • Cloud Computing Support • Software Optimization	Updating, transforming, and relocating applications from legacy locations to the cloud or SSC end-state data centres. Supporting activities to acquire cloud space and the transition of research projects. Centralizing software purchases to optimize licensing costs.	Open Geoscience Network
Information Systems and Data Kathleen Lauzière / Kyler Coutts	Create tools, standards, workflows, and governance to manage geoscience data throughout its lifecycle.	• NRCan Datasets Inventory • NRCan Data Strategy • LMS Data Strategy • LMS IM Strategy	Cataloguing datasets provided to the Treasury Board and the public to enhance data findability. Contributing to Data and IM Strategies implemented by NRCan and LMS to improve the management of NRCan data.	Open Geoscience Network
Open Access and Public Engagement Sonya Banal	Make high quality, authoritative geoscience publications timely and freely available to Canadians and communicate with the public about GSC	• S&T Publishing • NRCan Open Science Action Plan • NRCan S&T Publications Guidelines • NRCan Science Communications Guidelines	Managing the business processes and ensuring peer review, editing, layout, and release of GSC S&T information products. Participating in the development of the NRCan Open Science Action Plan, which is required under the GoC Open Science Roadmap. The Roadmap	Open Geoscience Network

Projects & Project Leader	Project Description	Activities	Activity Description	GSC program
	program outputs.	• S&T Publications Official Languages	commits the Government to, among other things, making all publications freely available without embargo by 2022. Participating in the development of various guidelines that provide advice on how to interpret NRCan's Science Integrity Policy with respect to publication and communications.	
Synthesis and Integration Boyan Brodaric/Eric de Kemp	Increase access to new knowledge of the geology on Canada as a whole by integrating various datasets with new and innovative methods, including for dissemination. Increase the capacity for integration of Canadian geoscience knowledge across disciplines and for predictive uses.	• Canada 3D	Developing national framework geology in 2D and 3D that integrates data from various sources and providing access to these via an online portal.	Open Geoscience Network

Projects & Project Leader	Project Description	Activities	Activity Description	GSC program
Canada-3D (C3D) Eric de Kemp	C3D is a collaboration between Canadian federal, provincial, and geological surveys, endorsed by the National Geological Surveys Committee of Canada. It is a national effort to develop national maps and models of the geology of the country, provide an interactive cloud-based portal to access and explore these maps, models, and related information, and conduct research on new methods for geoscience mapping and modelling. C3D supports a commitment to open and accessible data, showcasing the	Advanced research	Current 3D geological modelling research is focused on various Artificial Intelligence methods to make more realistic models from sparse regional data. Using both data and knowledge-based information helps to construct models that make more sense and that are fit for more predictive uses.	Canada-3D
		C3D Web Portal	Experts in geological sciences, data management, and computer science are integrating our legacy 2D and 3D datasets to make new models. Data from federal, provincial, and territorial sources have varying formats, scales, scientific interpretations, and physical boundaries (e.g., overlap, gaps). Harmonizing the data and knowledge pipeline for scientific and technology integration has been our focus for much of our efforts in the last few years.	
		2D & 3D geological compilation	We plan to develop an initial national structural framework including major fault systems, lithospheric anisotropy, and key litho-tectonic boundaries. Building on	

Projects & Project Leader	Project Description	Activities	Activity Description	GSC program
	latest national surficial and geological compilations at various resolutions to ensure a current synthesis of the geology of Canada. C3D is a vision for how Canada's national 2D and 3D geological information will be used to support predictive applications, such as lithospheric mineral systems analysis, carbon storage, and prediction of water resources.		the completed national 3D-layer model (topographic, bedrock, Precambrian, and Moho) will be additional provincial scale 3D models for the Western Canada Sedimentary Basin, Rocky Mountains, and select mining camps.	

LABORATORIES AND COLLECTIONS

Projects & Project Leader	Project Description	Activities / Facilities and Facility Leaders	Activity Description / Facility location(s)	GSC program
Earth Material Collections Rhian Evans	Properly document, preserve and curate GSCs physical collections throughout their lifecycle.	Cross-Branch Collections Management Budget Development	Cross-branch EMC budget that identifies fixed annual operating costs as well as major projects.	Open Geoscience Network
		Collections Infrastructure Management	Performing regular maintenance and upgrading of facilities to ensure sample material integrity, as well as the health and safety of employees.	
		Collections Lifecycle Management	Lifecycle Sample Management activities are supported including the accession, inventory, catalogue, triage and/or deaccession/discard of material on a continual basis, of both new material being added to the collections and legacy material.	
		Collections Supporting Research	Sample material stored in GSC Collections facilities are accessed/loaned/used by internal and external stakeholders to support research activities.	

Projects & Project Leader	Project Description	Activities / Facilities and Facility Leaders	Activity Description / Facility location(s)	GSC program
Inorganic Geochemistry Research Lab Group (IGRL) Paul Gammon	Innovative geochemical research and analysis (isotope systems, metal species) to define geochemical processes in ore-forming bodies and crustal processes, and to identify the movement and impact of elements in the environment.	Environmental and Surficial Geochemistry Lab Facility Paul Gammon	Ottawa, ON	Science Laboratory Network
		Analytical Chemistry Lab Facility Simon Jackson	Ottawa, ON	
		Marine Geochemistry Lab Facility Michael Parsons	Dartmouth, NS	
Paleontology Lab Group Manuel Bringué and Sofie Gouwy	Expertise in paleontology to provide geological age and paleoenvironmental insights from geological records. Supporting basin analyses for hydrocarbon and mineral exploration, geological mapping, and reconstructions of past environmental change over geological time and in modern settings.	Palynology Labs Manuel Bringué and Jennifer Galloway	Calgary, AB Dartmouth, NS Québec, QC	Science Laboratory Network
		Conodont Labs Leanne Komaromi	Calgary, AB Vancouver, BC	
		Macrofossil Lab Facility Jim Haggart	Vancouver, BC	

Projects & Project Leader	Project Description	Activities / Facilities and Facility Leaders	Activity Description / Facility location(s)	GSC program
	Assessing and forecasting the response of ecosystems to cumulative effects of climate and anthropogenic disturbance.			
Mineralogy and Physical Properties Group Randy Enkin	Expertise in mineralogy, quantitative mineralogical analysis, and physical properties of rocks, minerals, and unconsolidated materials in order to resolve geophysical, geotechnical, sedimentological, stratigraphic, and mineralogical research problems.	Marine Core and Sedimentology Lab Facility Alexandre Normandeau	Dartmouth, NS	Science Laboratory Network
		Sedimentology Lab Facility Shauna Madore	Ottawa, ON	
		Mineralogy Lab Facility Lapidary Facility Jeanne Percival	Ottawa, ON	
		Paleomagnetism & Petrophysics Lab Facility Randy Enkin	Sidney, BC	
Isotope Geochemistry and	Developing analytical techniques and applications of	Isotopic Geochemistry & Geochronology Lab Facility	Ottawa, ON	Science Laboratory Network

Projects & Project Leader	Project Description	Activities / Facilities and Facility Leaders	Activity Description / Facility location(s)	GSC program
Geochronology Group (IGGG) Jason Ahad	radiogenic and stable isotope-based studies to date geological events and trace crustal, environmental, and marine processes. Contributing to research in regional geological studies, ore deposit modelling, and environmental stewardship.	Bill Davis,		
		Delta Lab (Stable Isotope) Facility Jason Ahad	Québec, QC	
Organic Geochemistry and Petrology (OGPet) Group Dennis Jiang and Rachel Robinson	Geochemical and petrographic characterization of (1) conventional and unconventional hydrocarbon systems in the subsurface; (2) existing and potential environmental impacts of fossil resource extraction and development on the surface and underground; (3) the origin and fate of organic matter and its interaction with water and sediments.	Organic Geochemistry and Organic Petrology Lab Facilities Rachel Robinson, Omid Haeri Ardakani	Calgary, AB	Science Laboratory Network

ADDITIONAL SERVICES AND PRIORITIES

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC service
Volcanic Mercury Emissions—Research in support of the UNEP 2023 Global Mercury Assessment Peter Outridge	This project will help fill key knowledge gaps when accounting for the natural Hg cycle (volcanic systems emissions), supporting the *Minamata Convention on Mercury, 2017*.	Not applicable	Not applicable	Environmental Geoscience Program
GSC Environmental Impact Assessment Service Danny Wright Aruna Dixit	Coordinate federal environmental assessment reviews that require geoscience expertise, ensuring timely and effective delivery of geoscience information and advice for the northern and southern regimes pursuant to the department's legislated obligations.	All aspects of an EA/IA	Covers all geoscientific aspects of an EA for development projects pursuant to federal EA regimes both north and south of 60° within the GSC's mandate.	Environmental Impact Assessment Service
Science Communication Stephen Locke	Develop, coordinate, support, and promote internal and external communications products and resources for	GSC Communications Committee	Coordinating and supporting science communication initiatives across the GSC by sharing knowledge, forming collaborations on communications products, developing communications training for staff, and	N/A

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC service
	programs, services, and staff across the GSC.	Stephen Locke, Nathalie Jacob and Kelsa Staffa	fostering a culture of broad science communication with staff across programs and divisions.	
		GSC webspace Nathalie Jacob and Kelsa Staffa	Collaborating with programs and divisions across the GSC, as well as LMS and CPS web experts, to ensure that the GSC webspace is continually updated and in compliance with Treasury Board Secretariat (TBS) requirements and best practices.	
		Annual Report on Results and Delivery Nathalie Jacob and Kelsa Staffa	Annually compiling and publishing information on program science highlights, organizational operating context, and projects and activities across the GSC.	
		GSC Twitter Sonya Banal and Alison Weatherston	Coordinating with staff across divisions to highlight and promote geoscience at the GSC and foster knowledge and interest in geoscience across Canada.	Open Geoscience Network
		GSC Connect Sylvia Russ and Dennis Leary	Coordinating with staff across divisions to highlight and promote geoscience activities at the GSC, showcase staff accomplishments, and provide timely tools and information to staff.	N/A

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC service
Indigenous Relations Secretariat Sonia Talwar	Support management in addressing current Indigenous relations issues for the GSC.	GSC Strategic Priority 4 Support Sonia Talwar	Coordinating on behalf of managers.	Indigenous Relations Network
		Indigenous Relations Network (IRN) Sonia Talwar	Creating and managing an Indigenous Relations Network that will promote the development of a community of practice around Indigenous relations at the GSC.	
		Expert advice to management Sonia Talwar	Supporting management to ensure better integration within the Sector, Department, and Government of Canada on Indigenous relations issues.	
Indigenous Relations Network Steering Committee Michelle Côté Mike Ellerbeck	The IRN Steering Committee will build on the GSC's experience to enhance relationships with Indigenous communities and organizations through engagement on geoscience initiatives. It is grounded in the principles of mutual respect and cooperation;	Training Michelle Côté	Recommending and coordinating training for GSC staff to enhance their ability to engage with Indigenous communities effectively and respectfully.	Indigenous Relations Network
		Engagement Tool Box Mike Ellerbeck	Developing organizational tools to help staff establish and maintain respectful and fruitful relations and collaborations with Indigenous communities.	
		Indigenous Engagement Database	Developing internal systems to aid in better coordination	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC service
	recognizes the value of Indigenous worldviews and traditional knowledge; and offers benefits to Indigenous communities, where appropriate.	Guy Buller	and reporting on Indigenous relations across the GSC.	
		IRN Communications Mike Ellerbeck	Evaluating internal and external communications needs for the IRN. Developing communications material for internal (NRCan and Government of Canada) promotion. Identifying other communications needs. Advising the steering committee on communications needs.	
HR Committee Sonya Dehler	Ensuring that the GSC remains modern and efficient through the support and development of staff across the country.	Updating branch and divisional HR plans Sonya Dehler	Incorporating results of the 2020-21 PSES into HR plans at all levels.	N/A
		Career progression of non-research scientist groups Sonya Dehler	Incorporating results of the 2020-21 PSES into clarifying, communicating, and promoting career development strategies at the GSC.	
PSES Working Group Sylvia Russ	Developing and implementing improvements to support and promote the GSC as a workplace of excellence based on the synthesized and analyzed results of the 2020-21 PSES.	Optimizing organizational processes Sylvia Russ	Providing recommendations to senior management for optimizing business processes across functions and regions.	N/A
		Career progression of non-research scientist groups Sylvia Russ	Providing recommendations to senior management for career progression and advancement across non-research occupational groups at all levels.	

Projects & Project Leader	Project Description	Activities & Activity Leader	Activity Description	GSC service
		Communication and engagement Sylvia Russ	Providing recommendations to senior management to involve, engage, and support staff across the GSC.	
Official Languages Réjean Couture	Promoting bilingualism in geoscience research, knowledge, and information.	Reinforcing communications with, and services to, the public Réjean Couture	Providing geoscience knowledge and engagement in both official languages.	N/A
		Supporting a bilingual workplace Réjean Couture	Supporting, strengthening, and promoting use of both official languages in the workplace, and encouraging ongoing language learning.	
		Liaison with Official Language Minorities Communities (OLMCs) Réjean Couture	Liaising with groups of people whose mother tongue or chosen official language is not the majority language in their province or territory.	
Together for Respect Sylvia Russ	Creating healthy relationships through mutual respect and civility, and enabling well-being and mental health in the workplace.	Workplace health and well-being Sylvia Russ	Continuing to implement the TfR eight-point plan to contribute to a culture of respectful relationships across sectors, hierarchies, genders, and nationalities.	N/A

Annex 4: Resources

Canada-3D: https://canada3d.geosciences.ca/

Geological Survey of Canada: https://www.nrcan.gc.ca/science-and-data/research-centres-and-labs/geological-survey-canada/17100

Geological Survey of Canada-Strategic Plan 2018–2023: https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/geological-survey-canada-strategic-plan-2018-2023/15410

GEOSCAN: https://geoscan.nrcan.gc.ca/

Groundwater Information Network: http://gin.gw-info.net/

Laboratories Canada: https://www.science.gc.ca/eic/site/063.nsf/eng/h_97809.html

Minister of Natural Resources Mandate Letter (December 13, 2019): https://pm.gc.ca/en/mandate-letters/2019/12/13/minister-natural-resources-mandate-letter

Minister of Natural Resources Supplementary Mandate Letter (January 15, 2021): https://pm.gc.ca/en/mandate-letters/2021/01/15/minister-natural-resources-supplementary-mandate-letter

Natural Resources Canada: https://www.nrcan.gc.ca/home

Natural Resources Canada Organizational Structure: https://www.nrcan.gc.ca/home/about-us/natural-resources-canada-organizational-structure/23054

NRCan Departmental Plan 2021-22: https://www.nrcan.gc.ca/transparency/reporting-and-accountability/plans-and-performance-reports/departmental-plan-formerly-reports-on-plans-and-priorities/2021-22-departmental-plan/departmental-plan-2021-22/23278

Office of Energy Research and Development: https://www.nrcan.gc.ca/science-and-data/funding-partnerships/funding-opportunities/office-energy-research-development-oerd/

Open Maps: http://open.canada.ca/en/open-maps

Open Science and Data Platform https://osdp-psdo.canada.ca/en/osdp

Permafrost Information Network: https://pin.geosciences.ca/

United Nations Convention on the Law of the Sea: https://www.iucn.org/theme/marine-and-polar/our-work/international-ocean-governance/unclos