# 2023 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG)

December 2023

**By NWMO Adaptive Phased Management Geoscientific Review Group**

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## Remarks by GRG Chair

The Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) again follows NWMO's geoscientific initiatives to provide advice, and to undertake a thorough review of technical and scientific documents. This year, the GRG did not undertake field trips but was able to attend an in-person review meeting in Toronto. This greatly helped the GRG to connect with the Geoscience Site Assessment team and to discuss matters in more detail than is possible during virtual meetings. The GRG included an interactive workshop format at the Toronto meeting to stimulate interdisciplinary discussion and debate.

The GRG was established by NWMO in 2012 and now consists of six members. Brief biographies are included at the end of this report. With four members from Sweden and Switzerland, the review team brings scientific and practical experience from countries that have investigated the suitability of repository sites for decades and are in advanced stages of site characterization and selection. These members are also aware of the progress with repository construction in Finland, where an operating license application for a repository was given in late 2021. The remaining two members bring advance knowledge of the geology of the Canadian Shield and Bruce Peninsula, rock mass characterisation of potential host rocks, and experience with underground construction and mining.

The GRG was again informed by high-quality presentations at monthly virtual meetings about the progress at drill sites as well as data processing and interpretation work. This report presents a summary of the GRG's findings and conclusions for 2023. This year, the primary focus of the GRG's review and advisory work concerned the first "Descriptive Geoscientific Site Model (DGSM)" report for the Revell Site and three other geological/geophysical documents. The GRG also reviewed the first 3D geological model for the South Bruce Site with two accompanying geological/geophysical documents. The GRG continues to pay attention to the interface between geoscience and safety assessment and has also reviewed the updated "Confidence in Safety" draft reports for both sites.

Overall, good progress has been achieved this year with high quality work produced by the Geoscience Site Assessment team. Specifically, the GRG is pleased to see good progress in the production of draft data interpretation reports and related modelling of the potential repository sites. The GRG also feels that the interaction between the Geoscience and Safety Assessment teams has been much improved with closer integration between these teams and between different disciplines. The GRG was informed and supports the recent restructuring to integrate the Geoscience R&D group into the Geoscience Site Assessment team but remains concerned about delays in the delivery of material from external consultants. The GRG expressed the opinion that geoscientific information about the site not selected for detailed characterization should be preserved and made available to the public, as it represents a valuable data set.

The GRG shares the opinion of the NWMO, as expressed in the "Confidence in Safety" draft reports, that both the Revell and South Bruce sites would be suitable from a technical perspective to host a repository. These reports are to serve public discussion related to site selection under the understanding that NWMO plans to include ongoing site characterization and engineering design work, to further increase the confidence and to demonstrate the ongoing suitability of a selected site.

On behalf of all GRG members, I wish to express our appreciation for the professional work by the NWMO team and for the diligent response to review feedback provided by the GRG.

Peter K. Kaiser, Ph.D, P.Eng., F.EIC, F.CAE

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# 1 Introduction

The Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) was established by NWMO in 2012. It was formed to provide independent review comments and advice on the geoscientific assessments being conducted as part of NWMO's evaluations to identify a single suitable deep geological repository site for Canada's used nuclear fuel in an informed and willing host community. More specifically, the GRG reviews all site characterization work and provides critical comments on the approach, methods and criteria used, the data interpretation, and reporting of findings. It assesses and advises on the adequacy of proposed preliminary field investigation and drilling programs to advance the understanding of the geology and increase confidence in the potential suitability of the various siting areas being considered by NWMO. Increasingly, the GRG is providing feedback on draft data interpretation reports resulting from this site characterization program and related modelling of the potential repository sites.

This report covers the activities of the GRG during 2023. Previous annual reports are publicly available on NWMO's website (www.nwmo.ca) and are listed in the list of references.

# 2 Geoscience site characterization activities in 2023

The NWMO continues to assess the suitability of the remaining potential sites for a deep geological repository, following a staged approach that includes "Initial Screenings", "Preliminary Assessments" and "Detailed Site Characterization", and considers both technical and community well-being factors (NWMO 2010).

In 2023, the assessment focussed on the potential suitability of siting areas within two regions in Ontario: the Wabigoon Lake Ojibway Nation (WLON)-Ignace area in northwestern Ontario, and the Saugeen Ojibway Nation (SON)-South Bruce area in southern Ontario (Figure 1).

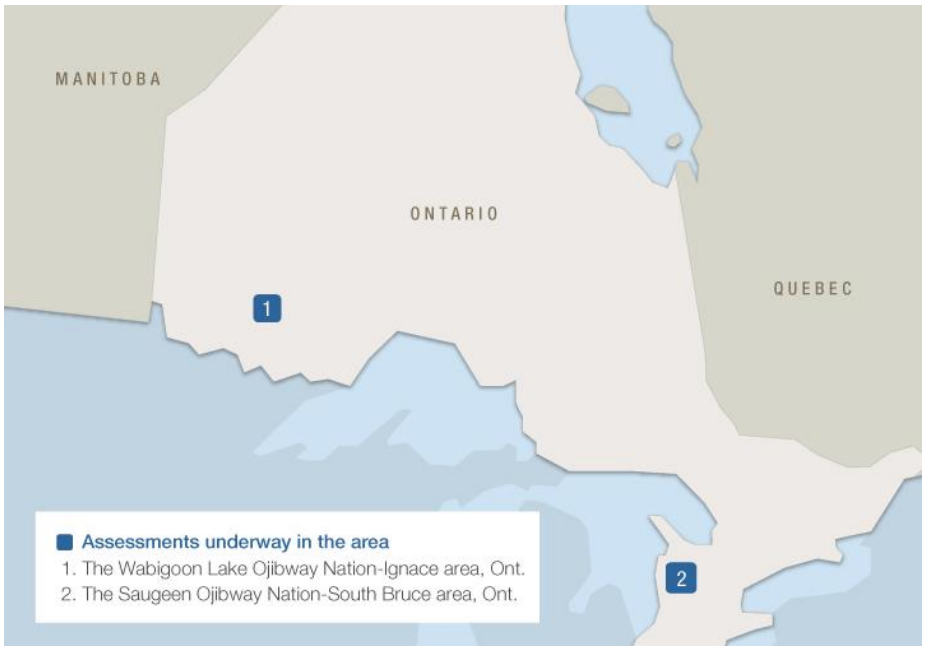


Figure 1: Two areas of ongoing NWMO site suitability assessments

The WLON-Ignace area is underlain by Archean crystalline rocks and, by the end of 2023, the Geoscience Site Assessment team and their contractors had completed the drilling and testing of six deep boreholes in the Revell batholith. The primary geoscientific field activities in this area included ongoing purging, profiling, and sampling of the instrumented deep and shallow

groundwater monitoring wells, as well as maintenance and monitoring of the installed nine-station microseismic monitoring network. Data from fieldwork activities was received, reviewed, and then used to publish a first "Confidence in Safety – Revell Site" report based on the results available in early 2022 (NWMO 2022a). An updated version of the "Confidence in Safety – Revell Site" report, based on the results available up to mid-2023, is currently on track for completion by end of 2023. Both versions of the report indicate that this site, pending further planned investigations, should be suitable, from a technical perspective, for hosting a repository. These reports are intended to support public discussion around site selection. In addition, a partial draft "Descriptive Geoscientific Site Model (DGSM)" has been reviewed by the GRG in 2023. This model constitutes a significant milestone in understanding the Revell Site.

The SON-South Bruce area is underlain by Paleozoic sedimentary rocks and, by the end of 2023, the Geoscience Site Assessment team and their contractors completed the drilling and testing of two deep boreholes at the site. The primary geoscientific activities in this area included completing the installation and initiation of ongoing profiling and sampling of a shallow groundwater well network, as well as maintenance and monitoring of an installed microseismic monitoring network. Data from fieldwork activities is being received, processed, and reviewed, and a draft 3D geological site model has been produced and reviewed by the GRG in 2023. A "Confidence in Safety – South Bruce Site" report was published, summarizing the results as of early 2022 (NWMO 2022b). An updated version of the "Confidence in Safety – South Bruce Site" report, based on the results available up to mid-2023, is currently on track for completion by end of 2023. Both versions of these reports are also intended to support public discussion around site selection and indicate that this site, pending further planned investigations, should be suitable, from a technical perspective, for hosting a repository. In addition, a partial draft "Descriptive Geoscientific Site Model (DGSM)" is under review by the GRG as of late November 2023. This model constitutes a significant milestone in understanding the South Bruce Site.

# 3 GRG review activities in 2023

Review activities this year were conducted by the six GRG members described in brief biographies at the end of this report and shown in Figure 2. The review process followed the same approach as in previous years, involving virtual and in-person meetings, formal reviews of technical documents with completion of disposition tables, and direct correspondence between GRG and the NWMO Geoscience Site Assessment team. The GRG is satisfied with the adopted mode of communication, which allows the GRG to operate effectively.

## *3.1 Meetings between the GRG and the NWMO Geoscience Site Assessment team*

The GRG completed eight virtual meetings in 2023 to discuss specific technical/scientific issues, and to address questions and recommendations emerging from the reviews of technical documents. In addition, a 4-day in-person meeting was held in Toronto in May 2023. The GRG met twice with NWMO's Senior Management, in-person during the meeting in May and during a virtual meeting in November, to inform the GRG of the overall program goals and approaches, and to discuss areas that the GRG considers requiring further attention. In this manner, the GRG continued to fulfill its advisory function on forthcoming work tasks. The schedule and primary focus of the meetings are summarized in Table 1.


Figure 2. APM-GRG members from left to right: Anders Ström, Alexander (Sandy) Cruden and Peter Kaiser (Chairman) all sitting; Sven Follin, Michael Stephens and Andreas Gautschi standing.

Table 1: GRG meeting schedule for 2023

| Meeting | Topic of Focus |
|---|---|
| January 24, 2023 (W)<br>(W for web-meeting) | GRG feedback/comments on the "Descriptive Geoscientific Site Model (DGSM)" of the Revell Site Version 0. South Bruce DGSM Version 1 timeline. |
| February 21, 2023 (W) | Radionuclide transport-related issues and overview of collaboration between Geoscience and Safety Assessment. |
| March 30, 2023 (W) | NWMO responses to GRG feedback on Revell Site DGSM Version 0 and a proposed way forward; hydrogeochemistry update. |
| April 20, 2023 (W) | Revision of agenda for in-person meeting in May. |
| May 7-10, 2023 (IP)<br>(IP for in-person meeting) | In-depth discussions about 3D geological and DFN modelling for Revell Site; detailed site characterization planning for both sites; in-situ stress; rock mechanical and thermal property update at both sites; hydrogeology and hydrogeochemistry for both sites; Geosynthesis; and ongoing work by Safety Assessment. During this in-person meeting, various break-out sessions were held to stimulate discussion and engagement of all involved, and to identify key unresolved issues in each field of investigation. |
| May 9, 2022 (IP) | Meeting with Senior Management to discuss means to support and strengthen the Geoscience Site Assessment team for timely delivery of quality documents required for licensing. |
| June 16, 2023 (W) | Finalizing of structure for DGSMs of both Revell and South Bruce sites; NWMO also addressed the key unresolved issues in each of the sites (as requested by the GRG and identified at the in-person meeting) and a proposed plan to address these issues. |

| | |
|---|---|
| September 22, 2023 (W) | General update of on-going site characterization planning and discussion of key messages on the upcoming revision of the "Confidence in Safety" draft reports (Revell and South Bruce). |
| November 7, 2023 (W) | Overview of strategic aspects concerning the "Geosynthesis" report for Revell and South Bruce sites. NWMO also provided a summary of progress with the South Bruce DGSM Version 0 report. |
| November 14, 2023 (W) | Meeting with Senior Management to hear about key upcoming NWMO milestones and discuss the action taken to address the items raised by the GRG in May. |
| December 6, 2023 (W) | Updated DFN model Version 1 and feedback/discussion on other recently received items for review. |

NWMO shared draft work or test plans and initial findings in technical documents as they became available to solicit review comments. Feedback from the GRG for consideration by the NWMO was shared during and after each meeting, and individual GRG members communicated directly by e-mail or during additional focused virtual meetings. For example, after the January virtual meeting, both A. Ström and Dr. M.B. Stephens contributed further discussion on the structure and content of both the DGSM and DFN Version 0 reports. Furthermore, prior to the GRG-NWMO meeting in early November, Dr A. Gautschi provided feedback on the approach used by the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra) for their "Geosynthesis" report.

These meetings and e-mail exchanges with the Geoscience Site Assessment team served to discuss the GRG's review comments and impressions on progress made. In particular, the in-person meeting in May provided an excellent opportunity to discuss various broader issues identified by the GRG to help enable the team to successfully complete their tasks in the deep geological repository program at NWMO (for details see Section 4). The revised workshop format with break-out sessions facilitated interdisciplinary exchanges and helped to form more comprehensive perspectives to guide interpretation of data and future work.

### *3.2 Specific studies reviewed by the GRG*

In 2023, the GRG systematically reviewed approaches, methods and findings reported in nine technical documents. Two documents received in late 2022, and all documents received and reviewed prior to November 30, 2023, are addressed here. The reviews of three other documents are still in progress and will be addressed in next year's annual report. Several key aspects arising from the review work are summarized below and some are discussed in Section 4.

The GRG appreciates the diligent use of disposition tables linked to the reviewed documents that facilitates tracking and, if necessary, a response to actions planned by or feedback received from the NWMO. These disposition tables and modified final reports were also reviewed by the GRG.

#### 3.2.1 Revell Site in the WLON-Ignace area

The GRG completed reviews of five technical documents (Table 2) addressing various activities close to and around the Revell Site (WLON-Ignace area). A significant milestone report reviewed by the GRG has been the first draft of a "Descriptive Geoscientific Site Model (DGSM)" for the Revell Site. Furthermore, as carried out in 2022 (NWMO 2022a), the GRG reviewed during this year an updated "Confidence in Safety" draft report for the Revell Site

intended to support public discussion around site selection. Even though this report does not contain geoscience details and, in large parts, extended beyond the mandate of the GRG, the GRG did review and discuss the report upon request by the NWMO. The GRG is of the opinion that a tight link between findings in geoscience and repository design, construction and safety is essential for the successful selection of a suitable repository site.

Review work is currently ongoing with two more important reports addressing the first hydrogeological model that makes use, at least in part, of site-specific data from the site, and an updated, site-scale, Discrete Fracture Network (DFN) and subordinate rock model inside the Revell batholith. The results of these two reviews will be summarized in the 2024 Annual Report after completion of the reviews with respective disposition tables.

Table 2: Technical documents reviewed by the GRG from the Revell crystalline rock site in the WLON-Ignace area

| Timing of receipt | Technical document |
|---|---|
| December 2022 | "Descriptive Geoscientific Site Model (DGSM)" Version 0 report. |
| April 2023 | U-Pb zircon geochronology by LA-ICOMS for samples from borehole IG_BH01. |
| April 2023 | Petrographic analysis of samples from IG_BH01 with emphasis on alteration, and secondary mineralization within the rock along and infilled fractures. |
| September 2023 | WP10 – Geological integration report for borehole IG_BH05. |
| October 2023 | "Confidence in Safety" report – 2023 update. |
| November 2023 | Sub-regional scale integrated hydrogeological model for the Revell batholith and surrounding area (review in progress to be reported 2024) |
| November 2023 | Version 1 Discrete Fracture Network (DFN) and subordinate rock model for the Revell Site (review in progress to be reported 2024). |

At the beginning of 2023, the GRG reviewed the first version of the "Descriptive Geoscientific Site Model (DGSM)" report for the Revell Site, after more than five years of focused work by the Geoscience Site Assessment team. The GRG was not satisfied with the internal structure of several chapters, not least Chapter 8 addressing the hydrogeological and hydrogeochemical site models, and radionuclide transport properties. Furthermore, since the in-situ stress state and the 3D geological model are fundamental for an understanding of the thermal, rock mechanical, hydrogeological, hydrogeochemical and radionuclide transport properties of the site, the GRG recommended a broader restructuring of the report. For example, the summary of the geoscientific understanding of the site at the end of the report could be divided accordingly into base models addressing the former two issues, followed by resulting models addressing the other characteristics. The GRG also suggested that a summary of information on in-situ stress on a regional scale be presented with other regional setting information in Chapter 3, while constraints on the in-situ state of stress at the site be handled separately from, and at an early stage within the chapter addressing rock mechanical properties.

As already pointed out in the GRG's 2022 Annual Report, all the information needed for a quantitative assessment of radionuclide transport in the crystalline host rock of the Revell Site should be compiled. An evaluation of the material needed was missing in the bedrock transport properties section of Chapter 8. Such information does not only include transmissivity values and diffusion coefficients, but also information on the internal structure of water-conducting

fractures zones, i.e., the spacing of fracture planes, and the distribution of porosity and mineralogy. This should be visualized in the form of conceptual sketches or models. The workflow should be developed by a collaboration between the Geoscience Site Assessment and Safety Assessment teams. The GRG was also disappointed that uncertainties and possible alternative hypotheses were not handled sufficiently in the DGSM Version 0 report and focused feedback bearing on key aspects of site understanding was not addressed by the Engineering and Safety Assessment teams in the concluding Chapter 10.

The GRG submitted many detailed comments concerning all geoscientific disciplines in their review. NWMO agreed with most of the GRG review comments and confirmed that they will be taken into account in the next version of the DGSM to be presented for review during 2024. The GRG also reviewed and is satisfied with the revised table of contents for this updated version of the DGSM report.

The GRG was pleased to review the report on petrographic analysis of samples from borehole IG_BH01, which presents the findings of a study of thin sections prepared from 14 samples collected along the entire length of borehole IG_BH01 at the Revell Site. Twelve of the samples are of the dominant granodiorite-tonalite rock type and two are of the subsidiary feldspar-phyric dyke and amphibolite units. GRG's feedback on this document was mostly related to issues of terminology and the correctness of some of the microstructural and petrogenesis interpretations presented. The GRG remains concerned about the current level of geological and petrological understanding of the amphibolite subsidiary rock type, including its deformed and undeformed states, given its strong association with high fracture frequency intervals (HFFI's) and water conductive features. The GRG has recommended that this issue be further investigated during detailed site characterization, should the Revell Site be selected.

No significant technical issues were identified by the GRG in their reviews of the report on U-Pb zircon geochronology by LA-ICPMS for borehole IG_BH01, which presents several radiometric age determinations of rock samples from this borehole at the Revell Site, and the integrated geological/geophysical WP10 report for borehole IG_BH05. Only minor technical clarifications and edits were requested by the GRG on the U-Pb geochronology report, and they were pleased to see the release of an important age determination data set relevant to understanding the formation of the Revell batholith. The GRG noted that the IG_BH05 WP10 report confirmed the findings from similar compilations for previous boreholes. However, the GRG has some remaining concerns with the inconsistent use of the structural geological term "brittle-ductile shear zone" by the Geoscience Site Assessment team for intervals within boreholes that record evidence for both brittle and ductile deformation mechanisms. Some clarity around the occurrence of overprinting of ductile strain by brittle fracturing needs to be addressed when describing and interpreting such deformation zones.The GRG also received three reports with the aim of informing the GRG of other activities or studies related the Revell Site (Table 3). Formal review of these reports by the GRG was not requested.

Table 3: Additional technical documents from the Revell crystalline rock site in the WLON-Ignace area sent to the GRG solely for information purposes

| Timing of receipt | Technical document |
|---|---|
| February 2023 | Ignace long-term monitoring 2021. Annual report. |
| April 2023 | Revell Site reference depth memorandum. |
| November 2023 | Future mineral resource potential of the Revell Site. |

### 3.2.2 South Bruce Site in the SON-South Bruce area

The GRG completed reviews of four technical documents (Table 4) addressing various activities close to and around the South Bruce Site (SON-South Bruce area). These reports include an integration of geological and geophysical data from borehole SB_BH02, a milestone report presenting a 3D geological model for the South Bruce Site and surrounding region, and an evaluation of a possible paleochannel at the site using seismic data. The GRG also reviewed this year an updated "Confidence in Safety" draft report for the South Bruce Site with the same purpose as that for the Revell Site. Review work is currently ongoing of the milestone report addressing the first "Descriptive Geoscientific Site Model (DGSM)" for the South Bruce Site, and GRG's findings will be presented in the 2024 Annual Report.

Table 4: Technical documents reviewed by the GRG from the South Bruce sedimentary rock site in the SON-South Bruce area

| Timing of receipt | Technical document |
|---|---|
| November 2022 | 3D Geological Model for South Bruce and surrounding region: Model Version 1.0. |
| May 2023 | WP10 – Geological integration report for borehole SB_BH02. |
| July 2023 | 3D seismic investigation, South Bruce. 2D seismic paleochannel characterization. |
| October 2023 | "Confidence in Safety" report – 2023 update. |
| November 2023 | "Descriptive Geoscientific Site Model (DGSM)" site assessment report (review in progress to be reported 2024). |

The GRG is pleased that the internal structure of the WP10 report for borehole SB_BH02 follows that used in the equivalent WP10 report for borehole SB_BH01 reviewed by the GRG during 2022. The GRG suggested that more care needs to be applied when addressing the structural geological situation at the South Bruce Site, since a vertical drilling programme is not favourable to intersect steeply dipping structures and, for this reason, steeply dipping faults may well have been missed during the drilling.

The 3D geological model for the entire Paleozoic bedrock across southern Ontario (Carter et al. 2021) forms the regional framework that has been followed in the development of the spatially more restricted 3D Geological Model (Version 1) for the South Bruce Site, the latter making use of the results from both SB_BH01 and SB_BH02. The regional framework model predicted the depth at which the proposed host rock for the repository (Cobourg Formation) would be encountered at South Bruce and also suggested that the Cambrian sandstone unit is very thin to non-existent beneath the site. These predictions have been strongly supported by the drilling in the case of depth of the Cobourg Formation, and proven in the case of the geometry of the Cambrian sandstone unit. The geological modelling work demonstrates the predictable lateral extent and thickness of the Ordovician bedrock including the Cobourg Formation, both regionally and at the site. There is now a firm geological basis that can be used for the detailed evaluation of the thermal, rock mechanical, hydrogeological, hydrogeochemical and radionuclide transport properties at South Bruce.

The GRG reviewed the report addressing a 2D seismic, paleochannel characterization at the South Bruce Site, which summarizes the findings of a near-surface geophysical investigation

of a known buried channel within the footprint of the site. Understanding the size and geometry of this Quaternary feature is an important element of site characterization. The GRG found the work in this report to be technically well done but made several recommendations for the document in terms of the presentation of methods and results (improvements to figures and writing), technical clarification and discussion of limitations.

The GRG also received five reports from NWMO with the aim to keep the GRG informed of other activities or studies around the South Bruce Site, in part as preparation for the reviews evaluating the integration of geological and geophysical data from boreholes SB_BH01 (APM-GRG, 2022) and SB_BH02 (Table 5). Formal review of these reports by the GRG was not requested.

Table 5: Additional technical documents from the South Bruce sedimentary rock site in the SON-South Bruce area sent to the GRG solely for information purposes

| Timing of receipt | Technical document |
|---|---|
| February 2023 | Microseismic annual report (2022). |
| April 2023 | WP02 data report – Borehole drilling and coring for SB_BH01. |
| April 2023 | WP02 data report – Borehole drilling and coring for SB_BH02. |
| April 2023 | WP03 data report – Geological and core logging report for SB_BH01. |
| April 2023 | WP03 data report – Geological and core logging report for SB_BH02. |

### 3.2.3 "Confidence in Safety" reports for Revell and South Bruce sites

"Confidence in Safety" reports for each of the candidate sites were published in 2022 and have now been updated with the drafts sent to the GRG for review during October 2023. The latter primarily contain more geoscience results and interpretations, based on available site data mid-2023 and associated site evaluation, and updated engineering information with an updated safety assessment. They relate the results and interpretations at each site to a current site understanding, and to the formal and fundamental suitability criteria developed for the NWMO repository concept. The GRG has at no point in its review process compared the sites in any way. Observations and comments in the reports are presented in the form of briefly summarized text.

The GRG understands that the "Descriptive Geoscientific Site Model (DGSM)" reports for each site include data compilations and interpretations, with the primary aim to provide a condensed description of the geoscientific understanding of the current condition of the site. The GRG has been informed that they are also intended for internal use at this stage. On the other hand, the planned "Geosynthesis" report, with external target groups, will be the ultimate document summarizing the overall site understanding in an integrated form, with the aim to also address the past evolution and likely future natural evolution of the site over the period of interest for safety. This report will not be available in time for site selection but, in due course, for impact assessment and construction license applications for the selected site. Therefore, the "Confidence in Safety" reports are of vital importance for the NWMO's communication about the site selection process, both from internal and external perspectives. These are the official and external reports summarizing site knowledge and understanding in a reasonably condensed format. They are based on more than 50 referenced geoscientific reports and form the background documents supporting, from a technical viewpoint, the expected site selection late in 2024.

The GRG notes that the intended audience for these reports is a "reasonably literate member of the public …". One might expect a much wider interest and set of readers. In their present state, these documents already account for this multitude of readers with different backgrounds. In this regard, the public would benefit from a more condensed and popular science style document. Alternatively, a more literate member of the public would benefit from the addition of an appendix with short explanations of the technical terms used by NWMO in the report.

The GRG has repeatedly stressed the importance of describing the remaining uncertainties of the sites, approaches that will be used to narrow down and eventually eliminate uncertainties, and plans for detailed characterization. Recent reports have been significantly improved in this respect. The GRG also observes that the predictable nature of the South Bruce Site has been utilized effectively in several instances to elaborate on matters of uncertainty. However, more site-specific data needs to be used in the future to further improve confidence in this site.

The GRG pointed out that the following aspects deserve further improvements: (a) inclusion of a discussion on repository-induced effects; (b) better integration of the effect of stress on other geological, rock mass and hydrogeological characteristics; (c) ensure that schematic illustrations of the repository layout respect the orientation of the principal in-situ stresses; and (d) clean-up some terminological issues (e.g., formation, granitoid or granite, undisturbed stress zone, dyke, amphibolite, ductile vs. brittle structures, groundwater velocity, etc.).

# 4 Broader issues identified by the GRG

The GRG is again satisfied with the systematic approach and the methods adopted by the NWMO and is pleased that several key milestone reports have now been delivered to the GRG, and have been or are currently being reviewed. For the Revell Site, these milestone reports address the bedrock geological map at the ground surface, the lineament map and the 3D geophysical model for the Revell batholith and surrounding region, and the one or more versions of the 3D site-scale geological model, the site-scale DFN model, the DGSM and the sub-regional hydrogeological model including site-scale data. For the South Bruce Site, the milestones include the first versions of the 3D geological model for South Bruce and surrounding region, and the DGSM. During the in-person meeting in May, the GRG was pleased to observe good progress in further developments of all Geoscience disciplines, and the GRG looks forward to completing the reviews of the hydrogeological and updated DFN reports for the Revell Site, and the first DGSM report for South Bruce.

As indicated above, the GRG has reviewed much improved updates of the inter-disciplinary "Confidence in Safety" documents for the two sites and agrees with NWMO that the current knowledge and understanding suggest that both sites are suitable for hosting a repository from a technical perspective. The GRG remains interested in the interaction between the Geoscience and Safety Assessment teams but wishes to point out that this interaction has been much improved.

At the in-person meeting in May this year, the GRG inspired the development of break-out sessions with the aim of cross-disciplinary discussion and debate to identify key unresolved issues in each field of investigation. The GRG notes that the Geoscience Site Assessment team has completed this task and presented their findings to the GRG during virtual follow-up sessions. Key issues that were identified and explored include: (a) the role of the in-situ stress on multiple characteristics at both sites, from hydrogeochemistry to groundwater flow; (b) DFN connectivity and hydrogeological fracture characterization at the Revell Site; (c) characterization of the overburden at both sites; and (d) glacial erosion at the South Bruce Site.

During a meeting with Senior Management, the GRG expressed concern about delays in the delivery of results and reports from consultants of, for example, fundamental rock mechanical and hydrogeochemical data, critical for the modelling work at each site. In particular, the GRG notes that only underpinning geological/geophysical information and subsequent geological modelling work at the South Bruce Site has been delivered to the GRG for formal review.

The GRG has also suggested to Senior Management that the organizational division between the Geoscience R&D group and the Geoscience Site Assessment team should be removed. This adjustment has now been made and should serve NWMO well during future site characterization efforts, once a site has been selected. Furthermore, it was pointed out that care needs to be taken to retain competent personnel after site selection.

The GRG enquired about what will happen to all the data and interpretation work from the site that is not selected for detailed site characterization, and expressed the view that it is essential to document and share work completed for the non-selected site. While this is of scientific interest and must be made accessible to the public, the GRG also is of the view that it is essential to quantitatively demonstrate and document that NWMO has identified two suitable sites. Demonstrating that two technically suitable sites with high confidence were found adds to the credibility of NWMO's Geoscience Site Assessment, Safety Assessment, Engineering and Senior Management teams.

At this point in the site characterization process, data integration at various levels of modelling is at a critical stage. At the Geoscience level and in the context of the DGSM reports, linkages between sub-disciplines (e.g., geology, in-situ stress, rock mechanics, thermal properties, hydrogeology, hydrogeochemistry and radionuclide transport properties) need to be further strengthened. As pointed out last year, groundwater flow and transport models are not the ultimate representation of data integration but are rather tools to support and verify linkages between data sub-sets. Coherent data transfer and interpretation between the Geoscience and Safety Assessment teams, and Engineering, must continue to be stringently executed.

# 5 Concluding remarks

This report summarizes the most important findings and conclusions of the GRG in connection with their work during 2023.

Further significant progress was made this year in data processing in the various disciplines, and high-quality reports were obtained and reviewed by the GRG. Most importantly, the Geoscience Site Assessment team presented a much more integrated approach to data interpretation, and we anticipate that this will be reflected in an improved second version of the "Descriptive Geoscientific Site Model (DGSM)" report for the Revell Site (Wabigoon Lake Ojibway Nation (WLON)-Ignace area), the recently received first version of the DGSM report for the South Bruce Site (Saugeen Ojibway Nation (SON)-South Bruce area), and the forthcoming "Geosynthesis" report for the site that will be selected during 2024.

The current understanding of the Revell Site has been well documented and good progress was also made at the South Bruce Site, which further highlights the strong similarities with earlier findings from investigations at the Bruce nuclear site. The geological predictability of the South Bruce Site is a significant feature.

The development of a credible site-scale, Discrete Fracture Network (DFN) model at the Revell Site is extremely important, not least for modelling of the hydrogeological system. The GRG recently received an updated version of the DFN report, which is currently under review.

The GRG noted that the Geoscience Site Assessment team is carefully tracking assumptions, uncertainties, and limitations of the findings from different studies. This is greatly assisting in better assessing the confidence in understanding the two repository sites.

In summary, the GRG was again impressed by the professional work undertaken by the Geoscience Site Assessment team and is looking forward to contributing to a successful resolution of outstanding challenges.

# 6 References

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# 7 Brief biographies of the APM-GRG members

The APM-GRG is composed of six internationally recognized experts from Canada, Australia, Sweden, and Switzerland. They combine extensive multidisciplinary international experience in areas relevant to the siting of deep geological repositories in both crystalline rock and sedimentary rock formations.

**Dr. Peter Kaiser**

Dr. Peter Kaiser, Chairman of the APM-GRG, is Professor Emeritus of Mining Engineering at Laurentian University, former Chair for Rock Engineering and Ground Control, Director of the Rio Tinto Centre for Underground Mine Construction, Founding Director of the Centre for Excellence in Mining Innovation, and geomechanics consultant. His interests lie in geomechanics, underground excavation stability, mine design, mechanized excavation, and the applications of emerging technologies that increase mining safety and productivity. Dr. Kaiser is a Fellow of the Canadian Academy of Engineers and a Fellow of the Engineering Institute of Canada.

**Dr. Sandy (Alexander) Cruden**

Dr. Sandy (Alexander) Cruden is Professor of Tectonics and Geodynamics in the School of Earth, Atmosphere and Environment at Monash University (Australia). Dr. Cruden has more than 30 years of geoscience experience related to structural geology, analysis, and characterization in both crystalline and sedimentary rock settings. Dr. Cruden completed a fault reactivation analysis and structural characterization of southwestern Ontario as part of site characterization activities for Ontario Power Generation's proposed Low- and Intermediate-Level Waste Deep Geologic Repository at the Bruce site.

**Dr. Sven Follin**

Dr. Sven Follin is a retired geoscience consultant who has been actively involved in the Swedish site evaluation process for hosting a deep geological repository, including geoscientific feasibility studies and the detailed site characterization of the Forsmark site, which was selected by SKB (the Swedish Nuclear Fuel and Waste Management Company) as the site for the deep geological repository for spent nuclear fuel in Sweden. Focus has been on hydrogeological aspects using the Discrete Fracture Network (DFN) approach. He was also involved in SKB's subsequent safety assessment. In addition to working with site descriptive hydraulic DFN modelling for SKB, Dr. Follin has been actively involved in the hydraulic investigations and the structural-hydraulic DFN modelling of excavated damage zones (EDZ) around deposition tunnels at the Olkiluoto site, which was selected by Posiva (the Finnish Nuclear Fuel and Waste Management Company) as the site for the deep geological repository for spent nuclear fuel in Finland.

**Dr. Andreas Gautschi**

Dr. Andreas Gautschi was Chief Geoscientific Advisor at the Swiss National Cooperative for the Disposal of Radioactive Waste (Nagra). Since his retirement he works as an international geoscientific consultant and as geoscientific advisor for Nagra. Dr. Gautschi has more than 30 years of geoscience experience related to the planning, co-ordination, and implementation of site evaluation programs for deep geological repositories in both crystalline and sedimentary rocks, in close collaboration with Nagra's safety assessment group. For many years he had lectureships at Tübingen University and ETH Zurich on Deep Geological Disposal of Radioactive Waste.

**Dr. Michael Stephens**

Dr. Michael Stephens is a retired Senior State Geologist with the Geological Survey of Sweden in Uppsala. Dr. Stephens has been actively involved in the Swedish site evaluation process, including country-wide reconnaissance studies conducted in Sweden to identify potentially suitable regions for hosting a deep geological repository, geoscientific feasibility studies, and the detailed site characterization of the Forsmark site, which was selected by SKB as the site for the deep geological repository in Sweden. Focus has been on base geological aspects.

**Mr. Anders Ström**

Mr. Anders Ström is Senior Program Manager of final disposal solutions for spent fuel at SKB (the Swedish Nuclear Fuel and Waste Management Company). Mr. Ström has been actively involved in SKB's siting program since the 1990s, among other things, in charge of the development of requirements on the crystalline rock for the spent fuel repository and criteria for site evaluation. During the site characterization project, he was Chief Project Manager for the multidisciplinary site descriptive modelling conducted for the two candidate sites at Forsmark and Laxemar-Simpevarp (Oskarshamn). He is now international coordinator of SKB and in charge of the close co-operation between SKB and Posiva, in Finland, for implementing robust disposal solutions according to the KBS-3 concept.