

# 2015-2016 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG)

## - Preliminary Geoscientific Assessments -

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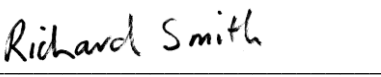
December 2016

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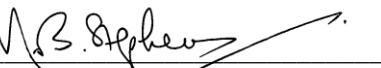
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# 2015-2016 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG) December 2016

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## **Executive summary**

This report provides a summary of the work completed by the Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) in 2015 and 2016. The GRG met five times by teleconference calls; a GRG member participated in a planning meeting for airborne surveys; and in-person presentations summarizing the GRG's activities and findings to the NWMO's Advisory Council and Board of Directors were made by Drs P K Kaiser and M Stephens.

The GRG has systematically reviewed approaches, methods, criteria and findings related to broad geoscientific issues addressed by the NWMO in 2015-2016; findings regarding the location and geoscientific suitability of potential repository areas identified in each candidate area; the adequacy of proposed preliminary field investigation programs to further assess and increase confidence in potential suitability; and the assessments of uncertainties of potential areas. Specific activities included reviews of:

- Findings of initial Phase 2 field studies in Ignace, Creighton and Schreiber;
- A draft Phase 1 geoscientific desktop preliminary assessment report for the Central Huron community.
- Work plans, data, interpretation and reports of Phase 2 high-resolution airborne geophysical surveys in the communities Hornepayne, White River and Manitouwadge.
- Work plans, initial interpretation and reports for Phase 2 lineament interpretations for the same communities.
- Work plans for the conduct of Phase 2 geological mapping.
- Key findings of Phase 2 geological mapping in the Ignace, Hornepayne, White River and Manitouwadge areas; and
- Approach and rationale for identification of potential repository areas and evaluation of uncertainties in the Ignace area.

Other more general GRG reviews during 2015-2016 included:

- Review of draft summary of literature of available information on characteristics of dykes; approach for initial borehole drilling in Ignace and for sedimentary sites; and
- Review of workflow directed towards creating a preliminary illustrative 3D geosphere conceptual model.

As in previous years, the GRG made various contributions to many geoscientific aspects and these are detailed in this report.

The GRG's overall assessment of the progress during 2015 and 2016 is very positive. A systematic assessment approach was adopted and executed by the NWMO and the GRG is impressed with the progress made in geoscientific site assessments. It is evident that the NWMO team and its consultants have undertaken high quality work that has allowed the GRG to carefully assess approaches, interpretations and conclusions. On this basis, the GRG supports the overall outcomes from these studies. The GRG has made many suggestions for process improvements and is pleased to report that the NWMO has responded to all identified issues in a timely, technical high quality, highly transparent and professional manner. As a consequence, NWMO has maintained a high standard of quality and is making steady progress in the site evaluation process. In the GRG members' opinion, the adopted approach follows or exceeds international practices in this early phase of assessment.

Technical and scientific aspects are described in the main body of this report; only a few high level aspects are highlighted here:

### *Geoscientific Review Group Report 2015-2016*

- The GRG agrees that the interpretation of the airborne geophysical surveys for the three North of Superior communities provided a sound basis for lineament interpretations and field geological mapping.
- The GRG provided comments to improve the interpretation of lineaments and to limit subjectivities that are an inherent component in lineament interpretation.
- The GRG was pleased to see that the NWMO engaged a highly experienced field geologist to oversee geological mapping activities and conducted Quality Assurance audits and compliance verification activities in the field. As a consequence, the detailed geological mapping program was well-planned and produced quality and very useful data.
- With respect to the rationale for identification of potential repository areas and associated uncertainties in the Ignace area, the GRG is satisfied with the adopted approach and with the consistent and sound use of geoscientific data collected to date.
- The GRG pointed out that both the use of site-specific data at the surface from geological mapping activities and some documentation of the experience gained at depth from mining activities in Canada should reduce some of the uncertainties around the presence of dykes and their significance for groundwater flow.
- The GRG reviewed the framework for borehole drilling and supports NWMO's proposed approach for drill-site selection for the initial borehole drilling in crystalline and sedimentary rocks as well as for DFN modelling.

## 1 Introduction

The Adaptive Phased Management Geoscientific Review Group (APM-GRG; abbreviated to GRG) was established in 2012 by NWMO to provide independent advice and review comments on the preliminary geoscientific assessments being conducted as part of NWMO's site evaluations to identify a suitable deep geological repository site for Canada's used nuclear fuel in an informed and willing host community. More specifically, the GRG provides comments on the approach, methods and criteria used, the data interpretation, and the adequacy of proposed preliminary field investigation programs to advance the understanding of the geology and increase confidence in potential suitability of the various siting areas being considered by NWMO.

This report covers GRG activities during 2015 and 2016. Previous GRG reports were issued in December 2013 and December 2014 and are publically available on NWMO's website (APM-GRG 2013; 2014). Brief biographies of the five GRG members for the term 2015-2016 are presented as an attachment.

## 2 Objectives of NWMO's geoscientific preliminary assessments

The suitability of communities is assessed using a staged approach including Initial Screenings, Preliminary Assessments and Detailed Site Characterization, considering both technical and community well-being factors (NWMO 2010).

The overall preliminary assessment is conducted through a series of technical, socio-economic and cultural studies conducted in two phases over several years. Technical studies involve geoscience, engineering, transportation, environment and safety. The objective of the geoscientific suitability preliminary assessment is to assess whether candidate areas contain areas that have the potential to meet NWMO's site evaluation factors (geoscientific suitability). It is conducted in two phases:

- **Phase 1 - Desktop Study:** Undertaken for all communities electing to be the focus of a preliminary assessment. This phase involves desktop studies using available geoscientific information, and a set of key geoscientific characteristics and factors that can be realistically assessed at the desktop phase of the preliminary assessment.
- **Phase 2 - Preliminary Field Investigations:** Undertaken to further assess potential suitability of a subset of communities selected by the NWMO. Depending on the geological setting, Phase 2 field investigations can include high resolution airborne surveys, geological mapping and initial borehole drilling.

The subset of communities advanced to Phase 2 preliminary assessment are selected based on the findings from the overall desktop preliminary assessment considering technical, socio-economic and cultural considerations. It is important to note that the mandate of the GRG is entirely focussed on the approach, methods, criteria and findings associated with the geoscientific suitability assessments. The GRG is not involved in or consulted for narrowing down the number of communities.

The status of communities' involvement in NWMO's site selection process as of November 2016 is illustrated in Figure 1. There are currently nine communities remaining in the site selection process, all in Phase 2 of the preliminary assessment (Step 3). These include Ignace, Manitowadge, White River, Hornepayne, Elliott Lake and Blind River on crystalline rock, and Huron-Kinloss, South Bruce and Central Huron on sedimentary rock.

## 3 GRG review activities in 2015-2016

### 3.1 Meetings between GRG and NWMO

In 2015 and 2016, the GRG has been involved in reviewing NWMO's geoscientific activities in one community in Phase 1 and in the remaining communities in Phase 2 of the preliminary assessments. Meetings with NWMO and its consultants included both teleconferences and in-person meetings as follows:

## *Geoscientific Review Group Report 2015-2016*

- Five teleconference calls (February 6, 2015; November 25, 2015; June 8, 2016; November 7<sup>th</sup>, 2016; November 22, 2016);
- Participation of a GRG member in a planning meeting between NWMO and Sanders Geophysics Ltd., the contractors responsible for airborne surveys (March 18, 2015);
- In-person presentations summarizing the GRG's activities and findings to the NWMO's Advisory Council and Board of Directors (December 1 and 2, 2015 by GRG Chair Dr P. K. Kaiser and November 29 and 30, 2016 by GRG member Dr M. Stephens).

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

The GRG has systematically reviewed approaches, methods, criteria and findings related to the following broad geoscientific issues addressed by the NWMO in 2015-2016:

- Findings regarding the location and suitability of potential siting areas identified in each candidate area;
- Adequacy of proposed preliminary field investigation programs to further assess and increase confidence in potential suitability; and
- Assessments of uncertainties of candidate areas.

The more specific activities included the following:

- Review findings of initial Phase 2 field studies in Ignace, Creighton and Schreiber, including high resolution airborne geophysical surveys, lineament interpretations and reconnaissance geological mapping referred to by NWMO as observing general geological features (Section 5.1 below).
- Review of draft Phase 1 geoscientific desktop preliminary assessment report, as well as supporting documents (geophysical interpretation, processing and interpretation of already existing borehole geophysical logs and 2D seismic data, and terrain analysis) for Central Huron (Section 5.2).
- Review of work plans, data, interpretation and reports for Phase 2 high-resolution airborne geophysical surveys in the communities Hornepayne, White River and Manitouwadge (Section 5.3).
- Review of work plans, interpretation and reports for Phase 2 lineament studies in the communities Hornepayne, White River and Manitouwadge (Section 5.4).
- Review of work plans for the conduct of Phase 2 geological mapping (integrated observing general geological features and detailed geological mapping) in the communities Ignace, Hornepayne, White River and Manitouwadge (Section 5.5.1).
- Review of key findings of Phase 2 geological mapping in the Ignace, Hornepayne, White River and Manitouwadge areas (Section 5.5.2).
- Review of approach and rationale for identification of preliminary repository areas in the Ignace area that are candidates for initial borehole drilling and evaluation of uncertainties (Section 5.6).

Other more general GRG reviews during 2015-2016 included:

- Review of draft summary of literature of available information on characteristics of dykes (Section 5.7.1).
- Review of approach for initial borehole drilling in Ignace, including draft framework document

for public discussion (Section 5.7.2).

- Review of approach for initial borehole drilling in sedimentary sites (Huron-Kinloss, South Bruce and Central Huron), including draft framework document for public discussion (Section 5.7.3).
- Review of workflow directed towards creating a preliminary illustrative 3D geosphere conceptual model (Discrete Fracture Network models; Section 5.7.4).

## **4 Review process**

The GRG's review process followed the same systematic approach as in previous years:

- Prior to meetings, NWMO shared with the GRG draft work plans, reports and findings, as they became available;
- Meetings, teleconferences and email exchanges with NWMO and its consultants were held to discuss GRG review comments;
- GRG comments were documented and tracked in disposition tables, which were sent to the GRG to ensure that the approach to address the review comments was appropriate; and
- Draft and or final products were reviewed by the GRG to ensure that review comments were addressed by NWMO and its consultants to the satisfaction of the GRG.

As in previous years, Dr. Richard Smith participated in teleconferences and meetings with consultants dealing with geophysical surveys.

### **4.1 Overall assessment of progress during 2015-2016**

The GRG is satisfied with the systematic assessment approach adopted by the NWMO and is impressed with the progress made in geoscientific site assessments. As during 2013 and 2014, the systematic, iterative process developed and adopted by NWMO allows the GRG to regularly review findings and progress.

It is evident that the NWMO team and its consultants have undertaken high quality work that has allowed the GRG to carefully assess approaches, interpretations and conclusions. On this basis, the GRG supports the overall outcomes from these studies. The GRG has made many suggestions for process improvements and is pleased to report that the NWMO has responded to all identified issues in a timely, highly transparent and professional manner.

As a consequence, NWMO has maintained a high standard of quality and is making steady progress in the site evaluation process. In the GRG members' opinion, the adopted approach follows or exceeds international practices in this early phase of assessment.

Specific contributions of the GRG in 2015 and 2016 include:

- Advice on specific work plans, data interpretations and reports to ensure proper identification of data sources and quality, to improve a characterization approach, to sharpen nomenclature and processes for the consistent interpretation of surficial and geophysical lineaments, and to ensure consistency of desktop assessments and terminology used;
- Systematic review and quality assurance of draft reports to assist in achieving and ensuring high international standards;
- Making recommendations for additional investigations, e.g., during geological mapping (additional investigations) and literature reviews (dykes); and
- Review of the development of Discrete Fracture Network models (MoFrac). In response to an invitation by the developers, Dr Kaiser attended one of the progress meetings.

## **5 GRG review comments**

### ***5.1 Interpretation of Phase 2 Initial Field Studies conducted in Ignace, Schreiber and Creighton (2015)***

In 2015 NWMO completed the interpretation of airborne surveys and observing geological features in Ignace, Schreiber and Creighton. The findings were documented in a series of reports and are available on NWMO website ([www.nwmo.ca](http://www.nwmo.ca)). The GRG reviewed the findings of these Phase 2 initial field studies conducted in each of the communities. Key documents reviewed for each community included draft integrated findings (synthesis) report, draft geophysical interpretation report, draft interpretation of surficial and geophysical lineaments and draft observing general geological features report.

In terms of the overall approach and preliminary findings, the GRG's impression of the field and interpretation work conducted by NWMO for these three communities was that it is of good quality. The GRG was pleased to see that NWMO made appropriate use of its feedback comments on the work plans prior to the beginning of fieldwork. The GRG members agreed with the findings for each community, but made a number of suggestions for improvements in the use and integration of the new Phase 2 data and the final findings report of each community. These recommendations were addressed by NWMO to the satisfaction of the GRG.

Key recommendations included the following:

- The field observation data collected by NWMO during initial field studies in the three communities was useful and GRG recommended ways to improve integration of field observations in the synthesis reports to support the interpretation;
- Request for additional clarity about the objectives and limitations of the forward gravity modelling exercise, and more emphasis on the preliminary nature of the modelling at this early stage of the assessment; and
- Need for improving consistency of reporting geological mapping data (geological features) between reports for each community, and for improving discussion of dykes in the synthesis reports.

In terms of the conclusions with regards to the suitability of Ignace, Schreiber and Creighton areas, the GRG agreed with the findings documented in the synthesis reports, i.e., that:

- Ignace contains large areas that warrant further studies; detailed geological mapping should begin and be followed by borehole drilling;
- Schreiber is a complex site from a lithological and structural perspective offering many more uncertainties; and
- Creighton is also a complex site with limited space available to develop a deep geological repository.

### ***5.2 Phase 1 draft geoscientific desktop preliminary assessment for Central Huron (2015)***

A desktop preliminary assessment was completed for the Central Huron municipality in southern Ontario, within the Paleozoic sedimentary sequence of the Michigan Basin. The desktop assessment relied on information from historic boreholes drilled in the area and the findings of recent site investigations conducted by Ontario Power Generation (OPG) at the Bruce nuclear site for its proposed Low and Intermediate Level Waste Deep Geological Repository.

The GRG reviewed the desktop geoscientific preliminary assessment report for Central Huron, as well as supporting documents (geophysical interpretation, processing and interpretation of borehole geophysical log and 2D seismic data, and terrain analysis). The assessment followed the same approach, methods and criteria previously used for the four other communities in southern Ontario and reflected GRG comments made when reviewing these previous desktop studies.



Overall the desktop geoscientific assessment for Central Huron was found to be comprehensive and well written. The GRG agreed with the findings for the community, in particular that Central Huron has the potential to contain potentially suitable siting areas.

### **5.3 *Airborne Geophysical Surveys in Manitouwadge, White River and Hornepayne***

NWMO completed high resolution airborne geophysical surveys for Hornepayne, White River and Manitouwadge using Sander Geophysics Ltd. The planning, acquisition and interpretation of these new surveys followed the same approach and methods previously reviewed by the GRG for Ignace, Schreiber and Creighton (GRG 2014). The GRG reviewed the community specific work plans for the surveys as well as the interpretation of the acquired magnetic and gravity data including drafts final reports.

#### **5.3.1 Review of community specific airborne survey plans (2015)**

The GRG reviewed survey work plans prior to the acquisition to flying the surveys. Furthermore, a member of the GRG, Dr. Richard Smith, participated in a planning meeting between NWMO and the selected contractor (Sander Geophysics Ltd) to ensure that the approach and goals of these new surveys are consistent with those of the previous surveys flown in other communities. The meeting addressed topics such as equipment to be used, areas to be covered, the required logistics, the flight line characteristics, and the interpretation methods to be applied to the data.

The GRG noted that such detailed discussions between client and contractors at a survey planning stage are not common in the industry and highlight the diligence of the process followed by the NWMO. The NWMO exceeded industry practise by conducting numerous audits both in the field and at the contractor's offices during the acquisition of the surveys.

Due to the planning and diligence of the NWMO and the continuous interaction with the contractor, the newly acquired data is of the highest quality and will serve the needs of the NWMO in assisting with the site evaluation process.

#### **5.3.2 Interpretation of airborne surveys (2016)**

The GRG reviewed a draft final report of the geophysical interpretation reports for the three North of Superior communities. The reports were found to be well-structured, well-written and of high quality. The GRG made a number of comments to improve the clarity of the interpretations.

It is the opinion of the GRG that the interpretation of the airborne geophysical surveys for the three North of Superior communities provided a sound basis for lineament interpretations and field geological mapping, including gaining a better insight into the occurrence of dykes, bedrock heterogeneity and the extent of the need for refining existing geological maps.

### **5.4 *Lineament Interpretations in Manitouwadge, White River and Hornepayne (2016)***

The GRG conducted an initial review of draft interpretation of lineaments in the form of preliminary interpretation figures and key findings, and later reviewed the final draft lineament reports for the three communities Manitouwadge, White River and Hornepayne.

While the GRG found the initial interpretation of good quality, it made a number of comments to improve the interpretation and limit subjectivities that are inherent to lineament interpretations.

Key areas of comments included:

- Treatment and classification of form lines and so-called ductile lineaments, leading to a revision of the approach used prior to completion of the interpretation work;
- Need for the final draft report to highlight uncertainties associated with features that could bias lineament interpretation (e.g. low topographic relief, extensive overburden, high intensity of dykes with magnetic signature, low magnetic intensity of the pre-dyke bedrock);

- Need to take into account flight line direction to ensure that features parallel to flight lines are not missed; and
- Recommendation to compare Phase 2 lineaments interpreted using the geophysical and surficial data sets with previously mapped faults, and the need for field verification of representative lineaments during geological mapping to ensure that significant features are investigated.

The GRG completed the review of the final draft lineament reports and was pleased to see that all review comments made on the initial interpretation were satisfactorily addressed by NWMO. The GRG considers the lineament interpretation conducted by the NWMO for the North of Superior communities to be of very high quality and to have achieved a higher scientific level for lineament interpretation compared to international practices. The approach and style used are consistent across the communities in Phase 2, supporting the decision to use one contractor for the interpretation of lineaments.

### ***5.5 Detailed Geological Mapping in Ignace, Manitouwadge, White River and Hornepayne***

NWMO completed detailed geological mapping activities in four communities (Ignace, Manitouwadge, White River and Hornepayne). Geological mapping in the communities Manitouwadge and White River also included an initial phase of mapping in the form of Observing General Geological Features using existing road and trails to visit rock outcrops similar to what was done for Ignace, Hornepayne, Creighton and Schreiber in 2014.

The objective of the detailed geological mapping program was to advance the understanding of the geology and to ground truth interpretations from airborne geophysical surveys and lineament investigations. Findings from the geological mapping along with geophysical and lineament interpretation were designed to inform the selection of potential repository areas in each community. The approach was to conduct field observations at as many outcrops as possible in the study areas.

The GRG reviewed the community specific work plans for geological mapping activities as well as a summary of interpretations.

#### **5.5.1 Work plans for geological mapping (2015)**

The GRG conducted a review of detailed geological mapping work plans for the community of Ignace and the three communities in North of Superior (Manitouwadge, White River and Hornepayne). These work plans described the extent of areas to be covered by the mapping, the type of lithological and structural observations and a template for reporting field observation. The review also included looking at the remote predictive outcrop mapping using satellite imagery undertaken by NWMO to facilitate planning of field activities.

Overall, the GRG found that detailed geological mapping program was well planned and consistent with the defined objective. The main GRG comments concerned ensuring consistency in the mapping approach and methods used by multiple field geologists within and between the communities. This was an important consideration given the scale of planned mapping activities (i.e. conducting parallel mapping activities using multiple teams in four communities at the same time). The GRG was pleased to see that NWMO planned to hire a highly experienced field geologist (Dr. Greg Stott) to oversee geological mapping activities and ensure consistency in all areas to be mapped. The GRG supported the plan of NWMO staff to conduct their own QA and compliance verification activities in the field.

#### **5.5.2 Key Findings from geological mapping (2015-2016)**

NWMO undertook a large-scale field program involving parallel mapping activities in four communities (Ignace, Manitouwadge, Hornepayne and White River). The interpretation of the mapping data for the Ignace area has reached an advanced stage and initial findings were reviewed by the GRG. The interpretation of mapping data in Manitouwadge, White River and Hornepayne is still ongoing and expected to be reviewed by the GRG in 2017.

The GRG's primary comments were related to ensuring consistency in terminology, the plotting and analysis of structural data, and the character of contacts to dykes. The GRG noted that the field studies confirmed that lineaments inferred from magnetic data are effective for the identification of dykes and, together with surficial data, for the identification of possible fracture zones. GRG was also pleased to see that the NWMO had used a highly experienced field geologist to oversee geological mapping activities and conducted Quality Assurance audits and compliance verification activities in the field. Overall the GRG found that the detailed geological mapping program was well-planned, consistent, and produced quality and very useful data.

### **5.6 Identification of Potential Repository Areas in the Ignace Area (2015)**

The GRG reviewed the approach and rationale for the identification of potential repository areas in the Ignace area, including an assessment of associated uncertainties. Repository areas at this stage of investigation are defined as smaller areas that have the potential to meet NWMO's geoscientific site evaluation criteria and have a sufficient volume of rock to host one or more repository footprints.

GRG members were satisfied with the rationale applied in the identification of preliminary repository areas and the evaluation of associated uncertainties, and are satisfied with the consistent and sound use of geoscientific data collected to date. The GRG encourages the consistent adoption of this approach in the other crystalline bedrock communities. The GRG made some specific comments to improve clarity and requested NWMO to highlight areas with large water bodies, thick overburden and limitations in access when presenting the selected preliminary repository areas to other teams at NWMO. These features potentially provide some limitation in future characterization work. GRG considered that the plan for interplay with other NWMO teams, both technical and social, was also clearly and logically presented.

### **5.7 Additional GRG review components (2015-2016)**

In addition to the above-mentioned reviews, during 2015-2016 the GRG also reviewed additional items, including a literature review on dykes, preliminary approach for borehole drilling in the Ignace area and in Southern Ontario, and the approach to develop Discrete Fracture Network (DFN) models.

#### **5.7.1 Literature review on dykes**

NWMO commissioned a literature review of the role of dykes in the long term performance of a deep geological repository. More specifically, the objectives were to summarize available information in the literature; identify gaps where more data should be collected; and identify key characteristics of dykes that should be included in plans for detailed geological mapping.

From a NWMO perspective, the report achieved most of these objectives and was considered useful for the planning of the detailed geological mapping campaign. It showed that dykes may be a positive or detrimental geological feature depending on the site-specific conditions. The GRG reviewed the draft report of available information in the published literature on characteristics of dykes. However, as highlighted by the GRG during their review, the draft report did not address some essential aspects, and did not critically assess and filter published information. It was pointed out that the report would benefit from including more site-specific data, and the GRG were satisfied that NWMO agreed to revise and complement the literature review using the data from completed geological mapping work (i.e., community-specific dyke data) once these data are interpreted and documented. GRG also recommended that information bearing on the character of groundwater flow along dyke contacts in the sub-surface realm should be acquired using the experience of mining activities in Canada. Both the use of site-specific data at the surface and experience gained from mining activities at depth should help better understand some of the uncertainties around the presence of dykes.

#### **5.7.2 Approach for borehole drilling in the Ignace area- Crystalline rocks**

NWMO's approach for initial borehole drilling in the Ignace areas includes drilling initial boreholes at or near a potential repository site to further advance the understanding of the geology and its

suitability for a deep geological repository. The identification of potential repository areas is based on the interpretation of all geoscientific information collected to date in the Ignace areas (Section 5.6) but borehole drilling is essential to start reducing uncertainties. The NWMO plans to select preferred locations for initial boreholes with the involvement of people and the communities in the area. The GRG reviewed a framework document for borehole drilling and the approach proposed by NWMO and support NWMO's proposed drill site selection process. The GRG plans to conduct a detailed review of the borehole drilling and testing plans when available.

#### 5.7.3 Approach for borehole drilling in southern Ontario- Sedimentary rocks

NWMO's approach for initial borehole drilling in southern Ontario (Huron-Kinloss, South Bruce and Central-Huron) includes the drilling of one borehole in each of the communities on municipal lands to advance and complement the generally available geology across the communities. GRG agrees with NWMO that, in contrast to the crystalline rock communities, drilling rather than other geoscientific studies should be the initial Phase 2 activity. GRG reviewed a framework document for borehole drilling and supports NWMO's proposed approach for drill-site selection. The GRG is expected to conduct a detailed review of the borehole drilling and testing plans when available.

#### 5.7.4 Approach for development of discrete fracture network

The GRG was generally satisfied with the short report on the approach to be used. Some suggestions for additional information were made, e.g. clarify which lineaments are to be included in the input data, clarify which information is to be used to identify orientation sets, clarify what procedure or assumption is to be used to define the depth down to which an individual fracture is modelled as well as depth dependence of fracture frequencies.

## 6 Summary

The GRG is satisfied with the progress made during 2015-2016 and continues to be impressed by the systematic and consistent approach adopted by NWMO to conduct early geoscientific site evaluations. NWMO has developed sound workflows for the various field and interpretation studies to ensure consistency between the many consultants involved and between many communities, which allowed the GRG to carefully assess approaches, interpretations and conclusions. On this basis, the GRG supports the overall outcomes from these studies at this stage of investigation.

The GRG has made many suggestions for process improvements and is pleased to report that the NWMO at all times is responding to all identified issues in a timely, highly transparent, technically sound and professional manner.

Based on the experience of its members, the GRG feels that the adopted approach and the quality of the studies by the NWMO team and its consultants follow or exceed international practices at this early phase of site evaluation.

## 7 References

- NWMO, 2010. Moving Forward Together: Process for Selecting a Site for Canada's Deep Geological Repository for Used Nuclear Fuel, Nuclear Waste Management Organization. Available at [www.nwmo.ca](http://www.nwmo.ca)
- APM-GRG 2013. 2012-2013 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG). Available at [www.nwmo.ca](http://www.nwmo.ca)
- APM-GRG 2014. 2014 Report of the NWMO Adaptive Phased Management Geoscientific Review Group (GRG). Available at [www.nwmo.ca](http://www.nwmo.ca)

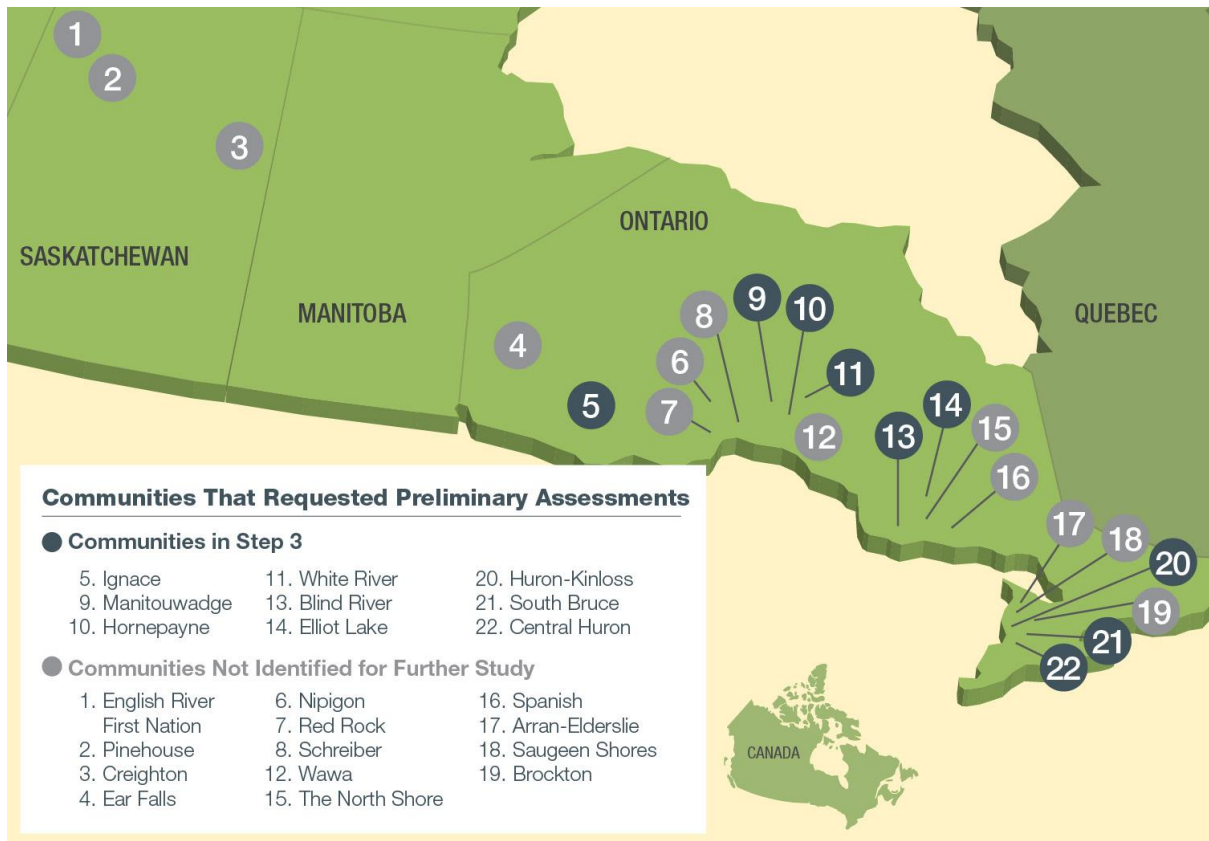


Figure 1 – Status of community interests (as of November 2016)

## 8 Attachment - Brief biographies of the APM-GRG members

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



**Dr. Alexander Cruden** is a Professor and Head of the School of Earth, Atmosphere & Environment at Monash University (Australia). Dr. Cruden has more than 25 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. Andreas Gautschi** is Chief Geoscientific Advisor at the Swiss National Cooperative for the Disposal of Radioactive Waste. 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. He coordinated successful geoscience activities that contributed to the selection of the Opalinus Clay formation as the preferred geologic setting for the long-term management of high-level waste in Switzerland. He also has a lectureship at ETH Zurich.



**Dr. Peter Kaiser** is Chairman of the APM-GRG, Professor Emeritus of Bharti School of Engineering at Laurentian University and former Chair for Rock Engineering and Ground Control, Founding Director of the Center for Excellence in Mining Innovation and Director of the Rio Tinto Centre for Underground Mine Construction. His interests and expertise lie in geomechanics, underground excavation stability, mine design, mechanized excavation and the applications of other 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. He is the author of over 350 technical and scientific publications.



**Dr. Richard Smith** is a Professor in the Department of Earth Sciences at Laurentian University, where he is the Industrial Research Chair of Exploration Geophysics. He has expertise in the application of geophysical methods generally and airborne methods specifically to investigate the geosphere at depth. Dr. Smith brings over 20 years of experience working in the exploration business. In 2015, he was asked by the Geological Society of London and the UK Department of Energy and Climate Change to be a member of the National Geological Screening Independent Review Panel.



**Dr. Michael Stephens** retired in 2015 as Senior State Geologist with the Geological Survey of Sweden. 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 the Swedish Nuclear Fuel and Waste Management Company as the site for that country's deep geological repository for used nuclear fuel.