Public summary on the overall review work completed by the APM-SARG during 2023-2025

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EXECUTIVE SUMMARY

The NWMO has established an Adaptive Phased Management Safety Assessment Review Group (APM-SARG) to provide advice and guidance on the approach, methods, and results of the safety assessment studies and reports produced in support of the impact assessment and initial licence application.

Since its formation in March 2023 the SARG fulfils its role through close interaction with the NWMO Safety Assessment team, reviewing draft documents, participating in regular online meetings and meeting in-person in Canada each year. The SARG provides NWMO with detailed comments on the work it is asked to review and strategic advice on relevant issues. This report provides a summary of the key findings and recommendations.

The SARG considers the approach to post-closure safety assessment to be consistent with international "best practice" for preparing and presenting an assessment for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project. Key elements, such as the use of detailed process modelling to develop an understanding of system performance and associated uncertainties, the definition of safety functions, the use of FEPs and the approach to scenario development, are found in other advanced programmes worldwide.

The SARG has also found that the pre-closure safety assessment methodology is logical and fit-for purpose, and consistent with international "best practice" for preparing and presenting safety assessments for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project and the constraints and prevailing conditions that are specific to the Canadian programme. Furthermore, in applying the methodology, the NWMO has carefully examined potential sources of exposure, and the pre-closure safety scenarios and cases proposed by the NWMO appear comprehensive.

The SARG has also noted a number of areas where measures could be considered to further improve the safety assessments, as well as their integration in the safety case, including, for example, defining key terms such as safety strategy and optimisation, improving specific models, and more fully justifying the selected repository depth. These areas for improvement are recognised by the NWMO and work is ongoing or planned.

Overall, the SARG has been greatly impressed by the open and cooperative atmosphere during its numerous meetings both online and in-person with the NWMO safety assessment team and by the willingness of the team to incorporate the SARG's feedback. Openness of information exchange and cross-discipline discussions with other teams at NWMO is essential to reach a well-founded, optimised repository, EBS design and overall safety case. The SARG has seen evidence of good collaboration with the NWMO design and RD&D teams, and observed that integration with other teams, such as geosciences, is developing and will continue to be enhanced. Likewise, integration with the engineering team responsible for excavation of the underground structures is also developing.

1 INTRODUCTION

The NWMO has established an Adaptive Phased Management Safety Assessment Review Group (APM-SARG) to provide advice and guidance on the approach, methods, and results of the safety assessment studies and reports produced in support of the impact assessment and initial licence application. According to the Terms of Reference provided by the NWMO, each member of the APM-SARG shall review the approach, methods, data and criteria used to conduct the safety assessments and provide comments and recommendations on the adequacy of the preliminary post-closure and pre-closure safety assessments and their key supporting documents.

The APM-SARG members have been asked to address the following questions:

1. Is the Post-closure Safety Assessment consistent with international "best practice" for preparing and presenting an assessment for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project?
2. Are the Pre-closure/Operational Safety Assessments consistent with international "best practice" for preparing and presenting safety assessments for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project?
3. Are there specific areas where the safety assessment (e.g., approach, data, models, analysis and/or presentation) could or should be improved in order to support a licence application for repository construction?

Since its formation in March 2023 the SARG has:

- Reviewed or commented on draft documents authored by NWMO's Safety Assessment team, relating to pre- and post-closure safety.
- Participated in more than 10 on-line meetings with NMWO staff discussing the SARG reviews and sharing suggestions and ideas with the NWMO staff.
- Participated in three yearly in-person meetings with NWMO staff and key consultants at NWMO's offices in Toronto.

Based on these interactions, the SARG has provided detailed technical, as well as more strategic advice to NWMO, both orally during meetings and in written memos.

2 FINDINGS AND RECOMMENDATIONS

Since its formation in March 2023, the SARG has been extensively engaged with the NWMO safety assessment team. Through an open working relationship, the SARG has been afforded deep insights to the team's ways of working, observed the integration across the various disciplines required to produce a safety case and been able to provide advice and guidance on draft documents as the safety case has progressed. The SARG has shared advice, experience and relevant documents from a range of international programmes and the NWMO team has responded well to this advice.

Based on interactions with the NWMO safety assessment team and the documentation reviewed to date, the SARG has the following main observations and recommendations.

The SARG acknowledges the high quality of the documents reviewed. The SARG welcomes the insightful and open discussions with the NWMO safety assessment team, which also demonstrate that the NWMO team has a comprehensive understanding of safety and safety case development. However, the SARG has also identified specific areas where, based on the experience of SARG members with the work of other national programmes and with the work of international bodies such as the IAEA and OECD/NEA, the assessment methodology and documentation would benefit from improvement. These are elaborated in the following sections.

2.1 Inventory

Most of the used fuel to be disposed in the planned repository originates from CANDU reactors. There is generally a very good understanding of the amount, characteristics and radionuclide inventory of this used fuel. However, there are small quantities of used fuel with other origins (e.g., research reactors). NWMO has noted that further characterisation of these fuels is in progress in collaboration with the waste owners. The SARG cannot comment on the assessment until more information is provided.

2.2 Pre-closure safety analysis

The pre-closure safety analysis demonstrates an impressive amount of high-quality work, building on international experience while addressing the Canadian specific issues. It is based on an understanding of the design and operation of both the used fuel packaging plant (UFPP) and the deep geological repository (DGR). The NWMO has carefully examined potential sources of exposure, including fuel bundle failures, e.g. during transportation, even though this is expected to be infrequent.

The pre-closure safety assessment methodology is logical and fit-for purpose, and consistent with international "best practice[1]" for preparing and presenting safety assessments for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project. Furthermore, the pre-closure safety scenarios and cases proposed by the NWMO appear comprehensive, although there may be a need for improved explanation of the logic for inclusion or exclusion of HEPA filter failure with various initiating events. The SARG supports use of empirical models to assist in the identification of relevant pre-closure safety analysis scenarios. This can aid the communication and justification of the safety assessment approach. However, empirical models will need to be benchmarked/calibrated against the detailed models used in the safety analysis.

[1] The most appropriate practice for any national programme will, in general, depend on a range of constraints and other prevailing conditions that can be programme specific. Here, the term "best practice" is used to mean that, based on the experience of SARG members with the work of other national programmes and with the work of international bodies such as the IAEA and OECD/NEA, no alternative practice is available that could be more appropriate for NWMO's purposes.

A specific aspect of pre-closure safety discussed with the SARG has been performance reliability and how to mitigate it. In this regard, the importance of a strong safety culture is widely recognised, as is the need to design job roles for workers that are as meaningful and fulfilling as possible, including considering job rotation for routine tasks that may become boring over time.

Clear and meaningful presentation of the safety assessment results is challenging, and the SARG has made several suggestions in this regard. In particular, the SARG commends the decision to report the details of the methodology separately from the results, and to move certain detailed explanations to report appendices, thus improving considerably the flow and readability of the main text, while still addressing all aspects required by regulations. Nonetheless, although the proposed safety analysis report has a generally clear and logical structure, the SARG has provided further suggestions to the NWMO, such as extending (and possibly renaming) the introduction to incorporate other aspects of analysis context, including safety objectives, design principles and criteria, and adding a conclusions chapter summarising how the stated purpose of the report has been achieved.

2.3 Post-closure safety assessment

The SARG also considers the post-closure safety assessment to be consistent with international “best practice” for preparing and presenting an assessment for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project. The NWMO’s substantial existing experience in this area is apparent from the work presented to the SARG so far.

The SARG has consistently emphasised the key role that performance assessment (i.e., the analysis of the thermal, hydraulic, mechanical and chemical evolution of a repository) plays in post-closure safety assessment and appreciates how this key role is reflected in the NWMO reporting plans and overall safety assessment flowchart. The safety assessment team is currently developing a set of safety functions for the DGR and its geological setting, and substantial feedback has been provided by the SARG, which was greeted positively by the NWMO. Specifically, there needs to be a clear distinction drawn between safety function indicators, safety function indicator criteria and design requirements.

The safety assessment team is currently also revising its selection of post-closure safety assessment scenarios. Regarding the normal evolution scenario, SARG agrees that, due to the high quality and good potential for quality control of the used fuel containers, it is reasonable to assume that there will be no initial container failures in this scenario. SARG also agrees with the NWMO ongoing work to link the extent to which containers, if any, may fail over the post-closure assessment timeframe to scenarios informed by performance assessment. Regarding altered evolution scenarios, a promising initial discussion based around safety functions, with broad participation, took place during an in-person meeting with the SARG in June 2025. The SARG recommends that a systematic presentation of the approach to identifying scenarios, combining a top-down review of the safety functions and what could impact them, cross-checked against a bottom-up consideration of relevant FEPs, is developed in the near future. This presentation should clearly highlight how identified FEPs have been addressed in the safety analysis, including the basis against which any FEPs have been screened out.

Regarding the documentation of FEPs, the SARG considers that the current level of detail and the degree of coupling between FEPs is probably appropriate. It may, however, be worth considering implementing the coupling via the safety functions that each FEP affects. The screening approach has been revised in line with recommendations of the SARG. Caution is, however, advised if FEPs are screened out based on information that may change (e.g., a change in repository depth or design). As part of the wider process of information management, an efficient process is required to check for changes in FEPs screening following

such information changes. A new FEP report is under development and will be reviewed by the SARG in due course.

Several process reports are also under production, early versions of which have been reviewed by the SARG. The SARG welcomes the fact that these reports are being developed in parallel with, and therefore should be consistent with, the safety functions report. Also welcome is:

- The improved connection between the engineered barrier system process report and design requirements.
- The detailed assessment of many key processes and interactions. This includes the analysis of glaciation effects, such as the impact of taliks and other geosphere-biosphere interface (GBI) processes and features, e.g., based on long-term engagement and international collaboration through the IAEA (IAEA, 2016), the possibility of a warm-based glacier, with its associated effects on hydraulic pressure at repository depth, and the identification of the most sensitive parameters related to glaciation in the geosphere process report. The NWMO is encouraged to ensure that it sufficiently references the substantial international research that has been carried out on how glaciation can affect deep repositories.
- The overall nature and level of detail of the interaction matrix for the biosphere process report and the promising approach proposed for handling the GBI, noting that here, in particular, integration between different disciplines will be essential.

A data freeze is planned as part of the preparation for the upcoming safety assessment for the initial licence application. The SARG recommends that conditions for the admissibility of new data following the data freeze should be clarified.

The integrated system model used to assess the release and transport of contaminants and their consequences and the more detailed models that provide input to this have undergone significant evolution. In order to address quickly the differences between the initial site data and initial site model, NWMO has developed a well-structured and balanced integrated workplan for Geoscience and Safety Assessment Hydrogeological and Contaminant Transport Modelling. SARG believes this will result in safety assessment modelling of flow and transport that will be consistent with measured data and overall site understanding, without oversimplifying key elements affecting safety. Evidently the plan includes simplifications that eventually would need to be resolved in later safety assessments, when more detailed data become available, but the current plan is judged appropriate for the current stage.

Concerning the biosphere and the assessment of impacts on humans and non-human biota[2], the SARG believes the engagement with the international community via active participation in the BIOPROTA forum is very useful and should be continued. The basic methodology being developed and applied follows the structure and other recommendations flowing from the updated BIOMASS methodology report recently issued by the IAEA (IAEA, 2025), prepared in cooperation with the BIOPROTA forum. The SARG notes that the application of such international guidance needs to be interpreted in line with Canadian regulatory requirements and needs to take account of the interests of a range of stakeholders, including representatives of Indigenous communities. The SARG also notes that regulations can fall behind the latest scientific understanding, such as those affecting the selection of values of dose coefficients (ICRP, 2024). SARG

[2] Measures of impact are taken to include annual individual radiation doses to humans, dose rates to relevant populations of non-human biota and concentrations of non-radiological contaminants in relevant environmental media, in line with regulatory requirements and guidance.

recognises that the NWMO is fully aware of such challenges and the value of international engagement in determining “best practice”.

2.4 Integration in the safety case

The findings of the pre-closure safety analysis and of the post-closure safety assessment will provide key evidence and arguments in support of the safety case. The NWMO’s plans for the development of the safety case seem both clear and appropriate. However, the interface between the pre-closure and post-closure phases, including possible deviations from the planned state at the time of closure, is an area that would benefit from more detailed consideration during future phases of the programme. In particular, the detailed steps taken in changing from operations to closure need to be clearly elucidated, bearing in mind that some parts of the facility may be closed while others are still operational.

The SARG recommends that, in assembling the team to write the high-level safety case document, the importance of inter-disciplinary interaction is considered, since it is important that evidence and arguments from all relevant disciplines are properly represented and, equally important, that all disciplines can stand behind and fully support the final product.

The reporting structure for the safety case, including pre-closure and post-closure aspects, seems logical, transparent, and includes all aspects one would expect to see in a modern safety case. Representing in a single figure the reporting structure along with the methodological elements that make up the safety case, including the relationships between these elements, without the figure becoming excessively complicated and unclear, is challenging. The SARG recommends that the NWMO considers keeping separate the figures for reporting structure and for safety case methodology but structure these figures such that their relationship to each other is as clear as possible. Examples of such figures exist from other programmes, such as Nagra in Switzerland.

The safety case is the product of a safety strategy. However, the term safety strategy can be understood in different ways. The SARG encourages the NWMO to define clearly what it means by this term, and to use that definition consistently throughout its reports. The same comment applies to the term “optimization”. For example, narrowly, optimization could be taken to mean radiological optimization, but internationally (e.g. by the NEA and IAEA – see (Bailey, 2014)) optimization is now interpreted more broadly, to include optimization over a range of issues and risks, including, for example, the need to progress the project (to move waste to a safer state). Whilst satisfying the regulatory safety requirements will always take precedence over other optimization factors, it is noted that there are few detailed Canadian regulatory requirements regarding the nature of optimization, giving NWMO room for flexibility in how it defines and addresses the process.

The safety case is based on a repository concept that is continuously evolving, and the NWMO is clearly carefully considering the relationship between design development (including repository depth selection), pre-closure safety analysis, post-closure safety assessment and the overall safety case. There is a need to ensure a common basis of understanding regarding the repository concept across all teams, such that they use the same basic assumptions in their work. An approach used in many programmes is to define “reference designs” that should be used by all teams, with changes only being permitted via a managed change control process.

Regarding the specific issue of depth selection, the SARG is of the view that this needs particularly careful thought and justification, since it may depend not only on long-term safety considerations, but also on engineering feasibility and, specifically, on the ability to construct openings that meet both pre- and post-

closure safety requirements. The selection of the proposed depth needs to be clearly justified bearing in mind all these issues and is likely to be an important aspect of the optimization process.

The SARG also encourages the NWMO not to overlook the hydrogeological and other impacts of design features that have no safety functions, such as the concrete floor of the emplacement rooms.

An early version of the claims and arguments that will underpin the safety case has been developed by the NWMO. These were discussed in an excellent and lively discussion with the SARG at the June 2025 face-to-face meeting. Key points arising from this discussion are firstly that, while it is reasonable to organise claims and arguments in a logical hierarchy (in the UK case, for example, NWS has defined three top-level safety claims: isolation, provided by geology, containment, provided by the EBS, and passive safety), there is no single "correct" way in which that must be done. The SARG recommends that, where relevant, aspects which are fixed (waste inventory and site conditions now the site is selected) are represented among the high level claims, while design details provide the safety arguments. For example, a high-level claim could be made that the selected site will provide long-term safety for the disposal of used fuel. The high-level claims may appear trivial or self-evident but are nonetheless useful to include in the overall hierarchy and the SARG urges the NWMO to do this. Experience from SARG members shows that it is the mid-level claims that may be the most challenging to formulate.

Claims should relate not only to the performance of individual barriers, but also to the integrated safety of the system as a whole, where the safety assessment results provide the underpinning evidence in the hierarchy. Claims or arguments about the quality of the safety assessment also have a place, including arguments that all relevant known phenomena have been accounted for, and arguments for the reliability of models and data and for the reliability of their application. Such arguments can include quality assurance, safety culture, etc., as well as evidence from research, model validation processes, robust management systems etc.

One of the lines of arguments under development by the NWMO concerns alternative safety indicators or arguments. The SARG recommends that the NWMO makes a clear distinction between alternative indicators of the overall post-closure safety of the DGR and indicators of satisfactory performance of individual barriers, which, on their own, say little about overall safety. Typical alternative safety indicators include contaminant concentrations and fluxes, which can be compared, for example, with existing concentrations and fluxes of naturally occurring or anthropogenically produced radioisotopes in the environment. Typical alternative indicators or arguments include those obtained from the many natural and anthropogenic analogues of repository materials found in Canada and around the world. These latter types of indicators can form part of the assessment of the barrier safety functions.

Integration with other disciplines will be key to the strength of the safety case. While the SARG has observed evidence that such integration exists and is continually improving in the areas of engineering, design, geoscience and RD&D, NWMO is advised to further promote such integration.

In terms of integration with engineering and design, it is the responsibility of the safety assessment team (pre-closure and post-closure) to specify safety-related requirements, including, for example, the mechanical and thermal loads that must be withstood by the engineered barriers. These requirements form part of the design basis, and the engineering and design team must provide solutions that meet these requirements. Safety analysis will then be used, in turn, as part of the evaluation of these solutions, providing feedback to design. In addition, design changes and developments are often driven by designers moving from hypothetical concepts to practical designs that can be manufactured and quality controlled, with reasonable use of resources. It is also necessary to check that these changes satisfy safety-related requirements. Design development and optimization is thus an iterative process, and the SARG has seen

evidence of this process in operation at the NWMO, e.g., in the feedback provided from the pre-closure safety analysis to the design of the UFPP. Clearly, the repository design basis needs to be consistent between different activities contributing to the safety case, which can be challenging as the design is evolving. To this end, the concept of "reference designs" with managed change control plays an important role.

The design basis will include credible scenarios that the design needs to accommodate, and these may go beyond simply the "expected conditions", such that the design can be said to be robust to reasonably foreseeable perturbations and uncertainty. The NWMO clearly appreciates that the design will be adapted to conditions at repository depth, and especially to the ambient stress field. While specific design issues are outside the scope of the SARG, the safety implication of design features, such as rock reinforcement, shotcrete, tunnel shapes and orientation, etc., must be understood and assessed as part of the safety case. Possible errors and imperfections in implementing the design have also to be considered in safety assessment. For example, defects in one or more of the disposal containers cannot be ruled out and are generally included as part of the normal evolution scenario. However, the growing experience in container fabrication and non-destructive testing (NDT) means that penetrating defects or non-penetrating defects with the potential to affect container lifetime - if deemed credible at all - can be relegated to less likely scenarios.

The SARG recommends a graded approach to optimization, focussing on issues that have a real impact either technically or socially. Minimising discharges and maximising solid waste at the expense of higher doses to workers is no better than minimising solid waste (for future disposal) at the cost of increased near-term doses to the public and environment. In cases where such trade-offs arise, a reasoned argument is needed that demonstrates that the appropriate balance has been achieved. However, efforts to find that balance should be in proportion to the risks or other significant factors involved. Optimization should not be seen as an open-ended process of dose and risk reduction, but rather should follow a pragmatic strategy; as set out in the optimization statement from the Nuclear Energy Agency (NEA, also referenced by the International Atomic Energy Agency (IAEA), "*once safety standards (dose, risk) have been met, further optimisation should focus on progressing the project, which may largely be seen as cost optimisation*" (Bailey 2014). Cost optimisation can be understood in terms of reasonable use of resources, which is considered alongside issues such as reliable, controllable and efficient manufacturing, installation or operation as key drivers of design development, always constrained by the overarching requirement that the design must be safe.

SARG fully appreciates NWMO initiatives to enhance integration between safety assessment and geoscience, including a joint meeting between the SARG and the Geoscience Review Group (GRG) in the summer of 2025, followed by developing an integrated workplan for Geoscience and Safety Assessment Hydrogeological and Contaminant Transport Modelling. Integration with geoscience is essential as many of the key arguments for safety are underpinned by evidence from the geological characterisation of the site, including the already considerable evidence for long-term stability at repository depth. On the other hand, while the geological barrier is a key element of the repository system, the SARG would like to emphasise that defence-in-depth based on a system of multiple engineered and geological barriers remains a cornerstone of post-closure safety and that the complementary roles of all the barriers need to be respected. The NWMO is recommended to consider this further as it develops its hierarchy of safety functions.

Regarding groundwater modelling, the SARG also supports the plan for a unified, i.e. combined, modelling team to be established for both geoscientists and safety assessors. This would ensure shared understanding of the key information about the site, so the geoscientific assessment provides the information needed to assess post-closure safety. This will provide a good basis for developing a common prioritized work plan.

The SARG has already been provided with a good overview of safety-relevant geoscientific information, and, in future, would like to learn more about some specific aspects, including larger scale features that intersect or are "close" to the potential repository volume, the fracture network and its hydrogeological interpretation, e.g. frequency of water-connected features, and key features of individual fractures such as fracture infill, coatings and the connectivity of rock-matrix pores, to satisfy itself that this information is properly incorporated within the safety case.

Finally, in terms of integration with RD&D, the SARG has been impressed with the extensive and important research that has been carried out, which will add to confidence in the safety case. For example, NWMO clearly has comprehensive knowledge of issues surrounding copper corrosion. Other key issues that are critical to the safety case, including the possibility of irregularities in tunnel profile and their potential effects on buffer density, are being addressed.

2.5 Human health and ecological risk assessment

The human health and ecological risk assessment (HHERA) is beyond the scope of SARG. Nonetheless, because it overlaps in some of its aspects with the pre-closure safety analysis and post-closure safety assessment, some brief remarks are made here. The SARG notes that other impacts on the environment, such as noise, and light pollution and changes in groundwater levels, may have a relevant impact on the quality of life of people living in the vicinity. The SARG understands that the NWMO is also looking into these impacts and is encouraged to adopt a graded approach to such overall optimization. The NWMO is also clearly aware of the need for consistency and coherence, at least at a conceptual level, between the pre-closure safety analysis, the post-closure safety assessment and the HHERA. For example, a description of the current biosphere and present-day surface process is needed for all three activities. The SARG recommends avoiding documenting such common features three separate times, since this could lead to difficulties in keeping the text consistent. Rather, all the reporting for all three activities could simply refer to the descriptions provided, for example, in the biosphere process report.

3 CONCLUDING REMARKS

In undertaking its work, the SARG was asked by the NWMO to consider three broad questions, to which we respond below.

1. Is the Post-closure Safety Assessment consistent with international "best practice" for preparing and presenting an assessment for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project?

The SARG considers the approach to post-closure safety assessment to be consistent with international “best practice” for preparing and presenting an assessment for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project. Key elements, such as the use of detailed process modelling to develop an understanding of system performance and associated uncertainties, the definition of safety functions, the use of FEPs and the approach to scenario development, are found in other advanced programmes worldwide.

2. Are the Pre-closure/Operational Safety Assessments consistent with international "best practice" for preparing and presenting safety assessments for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project?

The SARG has also found that the pre-closure safety assessment methodology is logical and fit-for purpose, and consistent with international “best practice” for preparing and presenting safety assessments for a deep geologic repository for used nuclear fuel, considering the current stage of the DGR project and the constraints and prevailing conditions that are specific to the Canadian programme. Furthermore, in applying the methodology, the NWMO has carefully examined potential sources of exposure, and the pre-closure safety scenarios and cases proposed by the NWMO appear comprehensive.

3. Are there specific areas where the safety assessment (e.g., approach, data, models, analysis and/or presentation) could or should be improved in order to support a licence application for repository construction?

The SARG has noted a number of areas where measures could be considered to further improve the safety assessments, and also aid their integration in the safety case, including, for example, defining key terms such as safety strategy and optimisation, improving specific models, and more fully justifying the selected repository depth. These areas for development are recognised by the NWMO and work is ongoing or planned.

Overall, the SARG has been greatly impressed by the open and cooperative atmosphere during its numerous meetings both online and in-person with the NWMO safety assessment team and by the willingness of the team to incorporate the SARG’s feedback. The SARG has been impressed by the team’s willingness to share new materials and with the many productive, lively discussions that have taken place. The strong teamwork that occurs both within the safety assessment team and, increasingly, with other groups and disciplines within NWMO has also been apparent. The safety assessment team includes a good balance of experienced and younger team members, which bodes well for the future success of the project.

The SARG has found the diversity of skills and experiences within the NWMO safety assessment team to be impressive and has seen good evidence of integration of these skills across the team, to the great benefit of the safety case. Openness of information exchange and cross-discipline discussions with other teams at NWMO is also essential to reach a well-founded, optimised repository, EBS design and overall safety case.

The SARG has seen evidence of good collaboration with the NWMO design and RD&D teams, and observed that integration with other teams, such as geosciences, is developing but needs to be enhanced. Integration with the engineering team responsible for excavation of the underground structures is also necessary. The engineering team needs to understand the requirements from safety regarding materials used, e.g., for tunnel support and excavated geometry, and the safety assessment team needs to be aware of what is achievable with current technology. It is also important to provide routes for engagement with those carrying out security assessment at appropriate points in the programme to check and ensure coherence of assumptions and data and completeness of the scenarios being considered, to avoid any potential conflicts between considerations of post-closure safety and security considerations.

As well as reviewing documents at various stages of development, the SARG has appreciated the opportunity to participate actively with the NWMO safety assessment team in discussions of critical areas such as scenario development. These types of brainstorming discussions are highly beneficial and motivating, and the NWMO is encouraged to hold more discussions of this nature in the future, both with and without the SARG, and to consider how best to document them. Such discussions have helped the SARG develop a better understanding of the thinking within the safety assessment team and will enhance the advice that the SARG will be able to provide in the future.

The NWMO's approach to the involvement of communities and incorporation of Indigenous Knowledge is extensive and demonstrates a clear commitment by NWMO in this regard.

4 REFERENCES

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ANNEX A. BRIEF BIOGRAPHIES OF THE SARG MEMBERS

The APM-SARG is composed of four internationally recognized experts from Sweden, Switzerland and the United Kingdom. The members combine extensive multidisciplinary international experience in areas relevant to the safety assessment and safety case development of deep geological repositories in both crystalline rock and sedimentary rock formations.

Dr. Johan Andersson

Dr. Johan Andersson has a MSc in Engineering Physics and a PhD in Hydraulics. He is an independent consultant and senior advisor in projects for the IAEA and Eurad and for the nuclear waste management organisations in e.g. Canada, Czechia, Japan, UK, Finland, and Switzerland. Until June 2019 he was head of the Unit of Analysis, Department of Nuclear Fuel, at the Swedish Nuclear Fuel and Waste Management Co (SKB). In this position he was the responsible client for the technology development related to SKB's planned repository for Spent Nuclear Fuel. He also had a leading role in meetings and interactions with the public in explaining fundamentals of nuclear waste repository safety. Between 1988 and 1995 he worked at the Swedish Nuclear Power Inspectorate (i.e. the nuclear safety regulator in Sweden) managing, among other things, the inspectorate's integrated performance assessment projects and had a leading role in reviewing industry's research programmes. Between 1995 and 2011 he has worked as consultant providing general advice to SKB, as well as to waste management organisations in other countries, on site selection processes and in projects related to development and safety assessment of radioactive waste repositories and other installations with environmental implications.

Prof. Lucy Bailey

Lucy Bailey is a graduate of the University of Cambridge in Natural Sciences and is a Fellow of the Institute of Physics and an Honorary Professor in the Department of Earth and Environmental Sciences at the University of Manchester in the UK. Lucy is currently Chief of Disposal Safety at Nuclear Waste Services (NWS) in the UK, leading the technical guidance and assurance of all safety case work at NWS, including for the planned deep geological repository for higher activity wastes and the existing shallow disposal facility for low level wastes.

Lucy has over 30 years' experience in the safety assessment of radioactive wastes, particularly specialising in the development of sound safety case approaches that aid communication. As well as delivering the UK's generic Disposal System Safety Case, Lucy has been an independent peer reviewer of the Swedish safety case, facilitated safety case discussions with stakeholders in the Swiss disposal programme and participated in IAEA expert missions for Belgium, Ukraine and China. Lucy has a long-standing involvement with the OECD/NEA and was the Chair of the Integration Group for the Safety Case (IGSC) from 2015 - 2021.

In 2020, Lucy launched and led the NWS Research Support Office, working with universities to develop and deliver a needs-driven academic research programme to underpin the UK's geological disposal facility. She has over 50 publications in the field of geological disposal, covering the safety case, research and societal aspects including safety communication.

Prof. Graham Smith

Graham Smith has an honours Physics degree from the Imperial College of Science and Engineering and is an Associate of the Royal College of Science. After graduating in 1975, he was employed at the National Radiological Protection Board (NRPB) and thereafter as a consultant in a wide range of radiation protection

issues. In 2019 he was appointed as an Adjunct Research Professor, Clemson University, S. Carolina. From 2021 to 2023, he was a member of the Scientific Advisory Committee of the Centre for Environmental Radioactivity, based at the Norwegian University of Life Sciences. Since 2021 he has been a member of a UK government advisory body, the Committee on Medical Aspects of Radiation in the Environment. Much of Graham's work is based on making a link between good science and the effective application of radiation protection. Projects have taken him to many parts of the world working within different regulatory frameworks with widely varying cultural perspectives. He has been privileged to work across a wide range of disciplines, as a researcher and research team leader and mentor, while maintaining a feet-on-the-ground perspective on regulating radiological protection. Features include: consultant to the International Atomic Energy Agency, contributing to the development of standards, guidance and technical documents on all aspects of radioactive waste safety and security; long-standing engagement with in international and bilateral programs to support safe management of legacy sites generated as a result of the cold war, and key technical input to and coordination of international programs on radiological assessment, e.g. www.bioprota.org and https://www.andra.fr/mini-sites/bioclim/ . He has contributed to over 30 peer reviewed journal articles and has been recognized by the Institute of Physics as an outstanding reviewer for his work with the Journal of Radiological Protection.

Dr. Paul Smith

Dr. Paul Smith has an MA in Natural Sciences, an MSc in Geophysics and Planetary Physics and a PhD in Computational Fluid Dynamics. He has over 40 years of experience in mathematical modelling, safety assessment and safety case development. This has included 35 years in work related to geological disposal of radioactive waste. Following a period as a post-doctoral research associate at the University of Manchester working in the field of computational fluid dynamics, Dr. Smith moved to Switzerland in 1989 to take up a position as modeller at the Paul Scherrer Institute, supporting Nagra's radioactive waste management programme. He became modelling sub-project leader after 3 years, coordinating modelling work for Nagra's Kristallin-I safety assessment, before transferring to Nagra to complete that project. In 1994, Dr. Smith returned to the UK to work as a senior staff consultant for Quintessa (formerly QuantiSci) and, in 1996, joined Safety Assessment Management, also in the UK. In 2008, Dr. Smith returned to Switzerland to establish Safety Assessment Management (Switzerland) GmbH. During his time as consultant, Dr. Smith has continued to work closely with Nagra on several projects both for the Swiss National programme and for Nagra's international consulting division. He has also participated in a wide range of technical work related to safety assessment for other repository programmes in Europe, North America and Asia, including methodology, model and software development, and execution and review of national assessment studies. He has assisted in the co-ordination of major safety case projects in Switzerland and Finland. He has also participated in several international working groups and projects for the NEA/OECD.