Safety cases and siting processes

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Central to any process for building a deep-mined geologic repository for high-activity radioactive waste is the development of a safety case.[1] To date, such cases, in various forms have been elaborated for a variety of concepts for geologic disposal, including in salt, clay, argillite, crystalline rock (granite and gneiss) and volcanic tuff formations. In addition to the technical effort required to develop a safety case, increasingly nations have come to believe that it is also critical to obtain the consent of the region or community[2] where the facility might be located. The purpose of this paper is to explore issues associated with just one aspect of consent-based siting: How can such a process be designed so that *willingness* to accept a site for a repository continues to be meaningful even as new technical knowledge and insights emerge during site characterisation? In short, what is the meaning of "informed consent" in the context of repository development?

The timing of consent

In countries that have selected a site for a deep-mined geologic repository, the timing of consent varies. In France, the village of Bure volunteered to host an underground research laboratory with the understanding that a repository might subsequently be developed nearby (JORF, 1991). In Finland, consent is given when a "decision-in-principle" is taken by government (Finlex, 1987, 1988). That action is based solely on preliminary surface-based investigations. In Sweden, the municipalities must agree to government granting a license to construct the repository (SFS, 1984). Again, permission is given based only on data collected from the surface. The United States is the one nation where consent is sought after site characterisation investigations, including studies at the emplacement horizon, have been completed (USC, 1983).[3] In nations such as Canada and the United Kingdom

1. "An integration of argument and evidence that describe, quantify, and substantiate the safety and the level of confidence in the safety of a geological disposal facility. The safety case draws not only on the results of quantitative modelling but also more directly on site selection and the results of site characterisation and design studies, and also on the research programme and management strategy by which uncertainties and open questions are handled." (OECD/NEA, 2009, p. 15) Safety cases can include probabilistic and non-probabilistic performance assessment but only as one element within a larger set of arguments.
2. Throughout this paper, we use the generic terms "community" and "locality" to refer to some unit of government below the national level. Precisely what type of jurisdiction these terms refer to will vary from country to country.
3. It is important to note that although the Nuclear Waste Policy Act seeks to secure a state's consent, consent was not given in the case of the proposed Yucca Mountain repository. Instead, the US Congress overrode the state of Nevada's veto of the site recommendation. The veto power that a state possesses is therefore much weaker than the veto power a community possesses in either Finland or Sweden.

(except Scotland) that have established siting processes but have not selected a site, communities initially express interest, but they maintain the right to withdraw up to some predetermined point, typically when large investments need to be made to construct underground workings.

The fundamental tension

As site characterisation progresses from literature reviews to surface-based studies to underground investigations at depth, knowledge accumulates. For a community concerned about the possibility of surprise, postponing final consent to as late a stage as possible makes sense. The community can then evaluate how the implementer has resolved outstanding technical questions. At the same time, a community must be sensitive to the possibility that, as the characterisation proceeds, momentum for the project may build to the point where it is difficult to reverse course and withdraw consent, particularly in the face of accumulating sunk costs. In contrast, the implementer wants consent to be exercised early in the process. The implementer worries about investing significant sums to get underground only to discover that the potential host has decided to object even before the regulatory authority has passed judgment.

Safety cases may not be static

By their very nature, safety cases resist fundamental changes. But such shifts are not unknown. The Swedish disposal concept and associated safety case, the KBS-3 method, dates from the mid-1970s. Under prevailing Eh/pH conditions and given the chemical composition of the groundwater found in the granitic formations where the repository would be located, the elemental copper waste canisters are not expected to corrode. Further protection would be gained by placing bentonite clay, which retards the movement of water, around the canisters. Some recent experiments have challenged the corrosion resistance of the canisters and the effectiveness of the bentonite barriers. Although these studies are by no means definitive, they could lead to modifications in the KBS-3 disposal concept (SNCNW, 2009).

The argument in favour of the proposed Yucca Mountain repository, for instance, originally rested upon the belief that water passed slowly from the surface through various layers of volcanic tuff until it reached the emplacement horizon. Once the Exploratory Studies Facility was constructed and access to the horizon gained, experiments seemed to suggest that water moved more rapidly than expected through rock fractures. This finding led directly to a reassessment of a key parameter of the safety case, percolation flux, and prompted a decision to construct an elaborate engineered barrier system, composed of corrosion-resistant waste packages and drip shields (US NWTRB, 2003).

Safety cases differ in terms of their evidentiary support and robustness. Many of these safety cases have been subjected to international peer reviews (OECD/NEA, 2002, 2003, 2004, 2006, 2012). Some of them, such as those that envision a deep-mined geologic repository sited in either clay or salt formations, are closely tied to measurable physical properties of the host rock (Andra, 2005; ONDRAF/NIRAS, 2001; NAGRA, 2002). In contrast, the safety case for a repository located at Yucca Mountain rested upon claims made about complex interactions between the geologic and engineered barriers that would arise under above-boiling operating conditions (US DOE, 2008).

Site characterisation and the potential for surprise

Site characterisation progresses in three stages, each with the potential for major discoveries or surprises. In the first stage, different types of geology may be evaluated according to their generic or assumed properties, such as the sealing characteristics of plastically deforming salt or the slow movement of ground water through indurated clays. In some countries, only one type of geology may be available, and thus surveys of different locations focus on disqualifying characteristics, such as fracture zones that facilitate rapid transport of water. During this initial stage, most of the geologic data will come from detailed surface mapping followed by a variety of remote-sensing (e.g. mapping fractures using sensors at different wavelengths) or geophysical surveys (e.g. magnetic and radiometric surveys from the air or land-based seismic profiling). Based on the results from this first stage, blocks of potentially suitable geology can be identified on a scale of some kilometres.

The second stage heralds a more detailed examination by drilling that provides actual rock core samples at depth and access via down-hole techniques in order to obtain more detailed information on the characteristics of the rock. At this stage, the three-dimensional properties of the site begin to emerge. Pump tests at wells can be used to assess the hydrologic properties of the site, and samples of water can be dated to determine the degree of isolation from the near-surface biosphere. The exact placement of the repository horizon may be adjusted during the second stage in order to avoid faults, fracture zones, or less desirable rock types. The final, or third, stage of investigation requires underground workings that may be the first step in the construction of the repository. It is only at this last stage that a clear picture of the geology of the site at the repository horizon can be obtained.

At each of the three stages, there can be substantial deviations from the originally envisioned safety case. As one revelation piles on the next, one can imagine that a local community may choose to withdraw from the project. However, the issue for the local authorities is to know when a "surprise" becomes an appropriate reason for withdrawing consent. Such decisions are very difficult to make in the context of a total system performance assessment, extending over hundreds of thousands of years, where the role of engineered barriers may be thought to compensate for some lack of performance from the geologic barriers. Any consent-based process has to empower the local community with enough technical expertise that it can arrive at a satisfactory understanding and confidence in the long-term performance of the repository.

Implicit in the formulation of the fundamental tension is the belief that, once surface-based testing has been completed, the likelihood of securing authorisation to construct and then to operate a repository is extremely high. Since none of the four implementers that have selected sites have received regulatory approval, it is difficult to know how valid that belief might be. However, one should note that these three stages of site characterisation are typical of other geoscience activities, such as the exploration for mineral and hydrocarbon deposits. Huge investments in time and money may precede a "dry hole" at the end of an extended exploration campaign. This is, in fact, a typical outcome. Perhaps the lesson is that success is the surprise – and failure must be anticipated and accepted.

Withdrawing consent

In the four countries where a repository siting decision has been made using consent-based arrangements – Finland, France, Sweden and the United States – consent occurs at a single point and, once given, cannot be withdrawn. Siting processes initiated over the last decade in Canada and the United Kingdom incorporate a two-step approach for signalling consent. Communities invite the implementer to undertake preliminary suitability assessments – mostly literature reviews – to determine whether very general selection guidelines can be satisfied. Based on more extensive surface-based testing, communities decide whether to continue their participation in the siting process.

Under the Adaptive Staged Management programme in Canada, for example, communities propose terms and conditions on which they would have the project proceed (NWMO, 2005). They then negotiate with the implementer to produce a formal agreement, from which withdrawal is not permitted. Only after receiving such a binding commitment will the implementer commence characterisation at depth.

The Managing Radioactive Waste Safely (MRWS) programme in the United Kingdom lays out in some detail how a community can exercise its right of withdrawal. As part of the programme's surface-based testing (Stage 5), boreholes would be drilled.[4] It is at this point that the fundamental tension explicitly manifests itself. As the White Paper on MRWS puts it:

> *In order to minimise financial risk and uncertainty,* before *the [implementer] embarks on a borehole survey programme, the circumstances in which a post-borehole right of withdrawal might be exercised should be identified…* [emphasis added]
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> *The requirement to define these circumstances before a borehole programme is likely to be both challenging and beneficial; challenging because it will involve matters of judgement, and beneficial because the definition will focus discussion, enhance understanding and make criteria for a right of withdrawal decision explicit before extensive work has been undertaken.* (DEFRA, 2008, p. 57)

Over a period of slightly more than three years, the West Cumbria MRWS Partnership, composed of local government authorities and a wide range of non-governmental organisations, explored whether to move forward into Stage 4 (let alone Stage 5) of the programme, desk-based studies (West Cumbria, 2012). Ultimately, although the Allerdale and Copeland Borough Councils voted to proceed, a negative vote by the Cumbria County Council blocked further participation. As with many complex decisions, multiple factors led to this outcome. One of the most important, however, was concern that the right of withdrawal could be compromised in the future (West Cumbria, 2012, pp. 60-62).[5]

Institutional requirements for ensuring that consent remains informed

What, then, does "informed consent" mean in the context of a repository development process that is continually generating new, and potentially surprising, information? The MRWS White Paper correctly identified what is challenging and therefore problematic: How can you anticipate the unexpected? How can commitments be made when surprises remain a possibility? One approach, of course, would be to await the final results of in-depth characterisation.[6] More probable, the fundamental tension will be resolved so that the final opportunity to grant consent (or not) will occur before underground investigations begin. Institutionalising several safeguards might make it less likely that a community withdraws from a siting process pre-emptively or prematurely.

1) *The right of withdrawal should be embedded in law.* If the right is simply a matter of policy, it can be modified or reinterpreted. Any legislation would have to address whether the right is conditional or unconditional.

2) *The details of how the right of withdrawal will be implemented in specific cases should be negotiated between the implementer and the community.* Agreements reached ought to be enforceable. Communities should be provided with resources, both legal and technical, so that they can negotiate as equal partners.

4. It is not until Stage 6 that underground construction begins.
5. Those concerns may have been heightened because the MRWS White Paper also stated: "In the event at some point in the future, voluntarism and partnership does not look likely to work, Government reserves the right to explore other approaches." (West Cumbria, 2012, p. 47)
6. This is the approach taken in the United States. But as the Yucca Mountain experience made quite clear, rejection by a state could very well be overridden by Congress.

3) *An independent body should be the final arbiter when differences in interpreting technical information arise.* Well into the siting process in both Sweden and the United States, critical information surfaced that raised fundamental questions about each nation's safety case. That information was subject to differing interpretations. Although such differences in the first instance should be investigated jointly by the implementer and the community, if they remain unresolved the issue should be addressed by an independent disinterested body. That body could be a technical reviewer, such as the National Council for Nuclear Waste in Sweden or the Committee for National Evaluation in France. In any case, the independent body will have to take steps ahead of time to merit the trust and confidence of the community.

4) *At some point, agreed to in advance, a community's option to withdraw can no longer be exercised.* The regulatory authority will need to closely scrutinise the information subsequently developed by the implementer to ensure that "surprises" will not effectively compromise the performance of a proposed repository. As with the independent technical overseer mentioned above, it will be critical that the authority merit the trust and confidence of the locality.

In an ideal world, the fundamental tension would not manifest itself. The implementer and the community would interpret new information identically and would reach a common position about the direction of a repository project. In the real world, however, the implementer may not acknowledge that critical issues have emerged. But even if it does, the implementer has an incentive to "fix" problems as they arise, even if that requires modification of the safety case or interpreting information in the most favourable way. Such adjustments can be entirely appropriate; in fact, they are to be expected in any staged and adaptive siting process. Whether the changes would lead a community to regret the consent it has given at some earlier stage, however, remains an open question.

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