Annex 1. Submission from Bruce McKirdy, NDA

Summary

The geology of West Cumbria is potentially suitable for hosting a geological disposal facility. The British Geological Survey's study[1] of West Cumbria's geology ruled out about 25% of the area as having unsuitable geology, the remaining 75% includes rock types similar to those being investigated in other countries for hosting a geological disposal facility. Therefore, further investigation of the geology of West Cumbria is justified.

The suitability of a particular geological environment for hosting a geological disposal facility is established by the development of a safety case which needs to satisfy the independent nuclear regulators, how the engineered[2] and natural geological barriers work together to isolate and contain radioactivity. Therefore the suitability of a particular geological setting needs to be assessed in the context of a specific waste inventory and engineered barrier design. Safety cases developed internationally demonstrate that a combination of engineered and natural barriers can provide safe geological disposal in a range of different rock types. NDA has reviewed the applicability of these safety cases to the range of UK wastes and geological environments. This review showed that there is a range of repository concepts which could be adapted to enable safe and secure geological disposal of UK wastes in a number of different geological settings.

There is a wide range of techniques available to support development of an understanding of geological environments such as those present in West Cumbria. In particular, there have been a number of significant advances in both characterisation and modelling techniques since the 1990s investigations in the area. Thus we are confident that we could understand a site in West Cumbria in sufficient detail and with enough certainty to be able to assess the effectiveness of its natural isolation and containment characteristics as a contribution to the overall safety of a geological disposal facility.

What types of geology are considered suitable to house a GDF

There is a range of geological environments that are suitable for hosting a GDF. The test of suitability of a particular geological environment for geological disposal is that the safety case demonstrates, to the satisfaction of the independent nuclear regulators, that the engineered barriers will work together and in combination with the natural barrier afforded by the geological environment to prevent radionuclides being released to the surface environment in amounts that could cause harm to life and the environment.

While safety is a national responsibility, the International Atomic Energy Agency sets safety requirements and gives guidance on geological disposal. It sets a requirement for a multi-barrier system in which the various engineered and natural barriers contribute to the two principal objectives with respect to providing safety - the isolation of the wastes and the containment of the radionuclides associated with the wastes.

The guidance explains that multiple safety functions enhance both safety and confidence in safety. The presence of multiple safety functions provides assurance that even if one safety function does not perform fully as expected (e.g. owing to an unforeseen process or an unlikely event), other safety functions will ensure that the overall performance of the disposal system as a whole is not jeopardized. The guidance recognises the role of the geological barrier in contributing to containment by protecting the engineered

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[1] http://mrws.decc.gov.uk/en/mrws/cms/disposal/site_selection/initial_screen/west_cumbria/west_cumbria.aspx

[2] The "engineered barriers" include the fuel or waste material itself, waste encapsulation materials such as glass or cement, the waste container, and protective materials placed around the container within the disposal facility.

barriers and preventing water ingress and also in isolating the radionuclides for the long term. It states that:

> ‘*A promising site should display evidence of favourable natural containment and isolation characteristics for the waste types under consideration and should provide indications that all necessary engineered barriers to prevent or retard the movement of radionuclides from the disposal system to the accessible environment can be implemented. This evidence needs to be tested in subsequent detailed site investigation, characterization and associated safety assessment modelling’.*

It also gives some general characteristics of suitable geological environments. These include mechanical strength suitable for safe construction, operation and closure and stability so that safety is preserved during future evolution. The geological environment should restrict groundwater movement to the facility and result in sufficiently long travel times that reduce their concentration at the surface.

As it is necessary to consider the engineered system and the geological environment together in order to assess safety, an appreciation of the types of geological environment which might be suitable can be obtained from safety cases for geological disposal prepared by overseas agencies. These safety cases consider the pathways by which radioactivity could be released to the surface environment, including transport in groundwater or as gases, and demonstrate that a combination of engineered and natural barriers can provide safe geological disposal in a range of different geological settings.

Sweden and Finland have developed safety cases for disposal of spent fuel in higher strength rocks such as granite. France and Switzerland have developed safety cases for disposal of a range of different radioactive wastes in lower strength sedimentary rocks such as clays or mudstones. The USA is already operating a geological disposal facility for intermediate-level waste in an evaporite environment (salt). The combination of engineered barriers and layout of the facility selected by these countries has been tailored to meet the requirements of the particular geological environment. For example, in Sweden groundwater return times are relatively short and the highly-engineered barrier system for spent nuclear fuel comprising a thick-walled copper canister surrounded by a bentonite buffer makes a strong contribution to the containment of radionuclides. The rock provides protection of these barriers. In France, where the natural groundwater movement through the clay rocks is significantly slower and groundwater return times are far greater, the requirements on the container are less stringent as the natural barrier provides a much greater contribution to the long-term containment of radionuclides. In the safety case developed in the UK in the 1990s[3], the geological barrier provided by the Borrowdale Volcanic group overlain by St Bees sandstone contributed significantly to safety by providing a long travel time somewhere between that expected in Sweden and France.

NDA has reviewed the applicability of these safety cases to the range of UK wastes and geological environments. This review showed that there is a range of geological disposal concepts which could potentially be adapted to enable safe and secure geological disposal of UK wastes in a number of different geological settings. However, a definite answer on suitability of a particular location can only be given once the combination of engineered barriers and the surrounding geological environment have been considered together.

What is known about the geology of West Cumbria and its suitability to house a GDF?

The British Geological Survey’s study of West Cumbria’s geology ruled out about 25% of the area as having unsuitable geology, leaving rock underlying 75% (1,890km^2) as potentially

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[3] Nirex 97: An Assessment of the Post-closure Performance of a Deep Waste Repository at Sellafield (5 Volumes), Nirex Science Report S/97/012, 1997

suitable. We know the main rock types in the remaining area include rock types similar to those being investigated in other countries for hosting a geological disposal facility.

There is a large amount of information available for the area close to the Sellafield site which was studied extensively during investigations in the 1990s. In total, 29 deep boreholes were drilled. The majority of those focussed on the area of about 5 sq km identified for the proposed underground facility. Most lengths of the boreholes were drilled to obtain a core. Additional data were obtained by running wireline geophysical logs, in which devices are lowered down the boreholes to provide a continuous measurement of a variety of physical parameters of the rock. Some devices were used to provide an image of the borehole walls to supplement the information on the fractures in the rock which was obtained from examination of the cores.

Testing was carried out in the boreholes both during and after drilling to determine parameters such as groundwater pressures and hydraulic conductivity which affect the pattern and rate of groundwater flow through the rock. Groundwater samples were taken and analysed to provide data on the age, source and history of the groundwater.

It has been claimed that the Public Inquiry into the Rock Characterisation Facility (RCF) has already ruled out West Cumbria (or even Longlands Farm) on grounds of geology. This is incorrect. The Inquiry does not rule out West Cumbria or even Longlands Farm. The Secretary of State's reasons for refusal of the Nirex Planning application were the conventional environmental impacts of the RCF, such as its impact on visual amenity and protected species. He listed two other areas as areas of concern which would also have justified refusal of the appeal:

- Scientific uncertainties and technical deficiencies in the proposals presented by Nirex - the application was premature;
- The process of the selection of the site and the broader issue of scope and adequacy of the environmental statement – the process was not transparent.

In his report of the Inquiry, the inspector did state that, in his judgement, the site was not suitable; however, he did acknowledge that the assessment did not completely rule it out. Furthermore, he based this conclusion on an early evaluation of the site which used as input data, only information collected up to July 1993, about 25% of the final total, was available for analysis. A further assessment called Nirex 97 which was subjected to external review[4] considered a much more substantial set of field data and research results and also included a number of significant modelling innovations, particularly in the modelling of the hydrogeological regime.

The safety of a GDF needs to be assessed by the appropriate nuclear regulators, rather than a planning inspector, and the current regulatory regime ensures that this vital step would form a key part of planning a geological disposal facility. Since 1997, improvements have been made in the regulatory regime for implementing geological disposal which now requires early engagement with regulators and a permit to be granted before borehole investigations can be undertaken. Even if this region of West Cumbria were to volunteer within the current process, the earlier information would need to be reviewed to consider the current waste inventory and engineered designs

For the rest of the region, insufficient geological information is available to make an informed decision on whether any sub-area is suitable to host a GDF. More work would be needed to gather and assess geological and related information in order to assess potential suitability of different sub-areas.

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[4] Peer Review Report of Nirex 97. QuantiSci March 1998.

3. What further tests could be carried out, and to what extent is further investigation into West Cumbrian geology justified?

There is a wide range of techniques that could be used to increase understanding of the geology of West Cumbria and so demonstrate whether a particular location would be suitable for hosting a geological disposal facility.

Air and land-based non-intrusive techniques; including mapping, satellite imagery, aerial photography and airborne and land-based geophysical surveying, would give general information about the main rock volumes in the area under investigation. This would give new information about the area and would provide valuable input to help target borehole investigations on those regions that were most promising. Drilling of deep boreholes and the subsequent testing of the rock and groundwater from inside the borehole or the testing of samples of rock and groundwater removed from the borehole, would provide detailed information about the local geology and hydrogeology and provide the opportunity to study samples of rock and groundwater from specific sites under consideration.

The footprint of a GDF would be in the region of 5-20 km^2, depending on the particular inventory and design, less than 1% of the 1890 km^2 remaining after the BGS screening.

There have been a number of important advances in techniques for measuring and interpreting geological information since the 1990s[5]. The most relevant advances are:

- Improved 3-dimensional seismic surveying;
- Advances in 3-dimensional computer modelling;
- Improved understanding of the role of geology in containing radionuclides.

These developments would allow a more reliable understanding to be established of the potential for transport of any radionuclides released from the engineered barriers of any disposal facility. Coupled with 3-D information about a site, modern 3-D groundwater flow models can be used to analyse both the present day flow system and the effects of possible future changes in driving forces on important aspects of that system, such as flow rates and the locations of discharges at the surface. They have been used recently to support the investigations of sites in fractured rock in Sweden and Finland. Both these countries have developed site-specific safety cases to support licence applications to construct disposal facilities in their countries.

We recognise that the geology of West Cumbria is relatively complex and therefore it could take longer and cost more to characterise than a site in a simpler geological setting. On the basis of the techniques described above, and the information available from characterisation studies for other industries such as oil and gas exploration, tools and techniques are available that will enable us to achieve the required level of understanding. Thus we are confident that we could understand a site in West Cumbria in sufficient detail and with enough certainty to be able to assess its natural isolation and containment characteristics as a contribution to the overall safety of a facility. We therefore believe that further investigation into the geology of West Cumbria is justified.

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[5] Further Information on Geology for West Cumbria MRWS Partnership, Nuclear Decommissioning Authority Technical Note, 2011

Annex 2: Submission from Professor Bruce Yardley, University of Leeds

Preliminary Observations

Preamble

I am a geologist and geochemist by training and have been Professor of Metamorphic Geochemistry in the University of Leeds since 1995. My research concerns fluids in the Earth's crust in the widest possible terms, and in addition to purely academic work I have published on the formation of ore deposits by fluid flow and on fluids in sedimentary basins. Studies of fluids do not always fit into the classical divisions of geology, and in order to encourage science that crosses traditional boundaries I was one of 3 founding editors of the international journal *Geofluids*, first published by Blackwells in 2001.

My only direct involvement in work on radioactive waste disposal in Cumbria was a small project carried out for BGS about 20 years ago, to investigate the conditions under which late-stage mineral veins formed in a variety of rock types. However as Science Secretary of the Geological Society of London during the CoRWM process, I was responsible for putting together a meeting dealing with geological disposal of radioactive waste, held in January 2006. This meeting was organised in part as a response to the lack of geological expertise in the CoRWM panel and involved members of the panel as well as a wide range of geoscientists. Subsequently I convened a second meeting in October 2008, which aimed to explain how geoscientists are able to make predictions about the nature of the subsurface. Information and contributions from both meetings are available on the web site of the Geological Society of London.

As someone who lives downwind from the Sellafield site, I am dismayed that so few people seem to realise that the Radioactive Waste currently housed in Cumbria has far more potential to release dangerous levels of radioactivity into the environment now than it will have in the future if put into a deep repository, both because it is at the surface, and because radioactivity in waste decays away rapidly.

To illustrate that last point, imagine that a tray containing 640 red ping pong balls is placed on the table at the beginning of a 1 hour meeting. The balls behave like atoms of radioactive isotopes: they can spontaneously turn green, and do so with a half life of 10 minutes. This means that, if all the balls in the tray are red at the outset, then just 10 minutes in, 320 will be green. After 20 minutes have elapsed, just a quarter of the balls are still red, after half an hour there are only 80, and so on, until at the end of the hour only 10 red balls remain. During the first few minutes there is a ball changing colour every second whereas in the final ten minutes the average rate at which the balls change colour is just one every minute. Radioactive waste loses its radioactivity in a similar way, but with an effective half life of a few hundred years. This means that the amount of radioactivity in the waste now is far greater than what will be left in a thousand year's time, let alone in tens of thousands of year's time. We are living in the time period that corresponds to the first few minutes of the hypothetical meeting, but much of our discussion is about the risk posed by the "radioactivity" that is left after the meeting has ended.

Release of Radioactivity from Waste

Very few of the elements of concern have a significant solubility in freshwater under natural conditions. The principal exceptions are isotopes of Caesium and Strontium, but fortunately these have short half lives of around 30 years, so are very unlikely to be present to any appreciable degree by the time the engineered barriers to a repository begin to fail and let in water. Catastrophic exposure of radioactive waste to large quantities of surface water in contact with the atmosphere could result in significant mobility of radionuclides, and this is why it is important to store the wastes in a deep repository. The highest natural dissolved U concentrations known are from remnants of the fluids that formed natural Uranium ore deposits. These contain a few parts per million by weight of Uranium, but these fluids were very unusual, hot, oxidised brines. Even hot surface fluids today contain at most only a few tens of parts per billion of Uranium in solution (seawater has 3 ppb). It is possible to make Uranium more soluble by adding the right cocktail of chemicals to a fluid, but as long as the waste and the engineered barriers do not contain these chemicals, water that has passed through a leaky repository will still only leach Uranium very slowly and ineffectually. It has been claimed by Haszeldine that the groundwaters that will eventually reach the waste will be oxidising, and therefore have a high potential to dissolve Uranium. This claim is not based on any verified evidence of which I am aware, and in my view it is wrong on at least 3 counts.

The suitability of the Geology of Cumbria for hosting a radioactive waste repository:
The design of a radioactive waste repository is intended to prevent leakage of radioactive materials back to the surface. This is most likely to happen if groundwater flows through the waste, dissolves radioactive elements and then returns to the surface. While engineered barriers (notably the use of clay) can reasonably be expected to prevent this happening for a period of many hundreds of years at least, during which much of the radioactivity will decay away, the wider geological setting should also be one that provides little opportunity for groundwater flow. There is wide agreement that the ideal repository site will be in rocks with low permeability (which is a measure of how easily water flows through rock) and in a place with a low hydraulic gradient (which provides the push that causes water to flow). There are a range of ideal types of geology that have been recognised and categorised, but it is important not to lose sight of the purpose of the geological requirements and follow the classification blindly. The existence of nearby mountains means that nowhere in west Cumbria is likely to meet the ideal requirement of a zero hydraulic gradient; deep groundwater will tend to flow away from the mountains. On the other hand, how much flow occurs and how it is focussed must be understood for a specific site before it will be clear whether this is a serious issue. This leads to the other key requirement which is that the repository should be sited in impermeable rocks through which there can be very little water flow, even where a driving force is present. The two main alternatives for this are crystalline (igneous and metamorphic rocks), and clay formations. In general terms, it is clear that there are low permeability crystalline rocks in Cumbria that could host a repository. When you walk through mine tunnels in the types of “basement” rocks present at depth in west Cumbria, it is obvious that water does not flow through them uniformly. There are long stretches where the roof and walls are quite dry, then short stretches where the rocks are fractured and water may flow in quite extensively. A single sample measured in the laboratory will have a very low permeability, but the permeability measured between boreholes over hundreds of metres is a lot higher because it will include some of the fracture zones where the flow is concentrated.

Establishing whether there are large enough blocks of impermeable basement rocks between major fractures to site a repository requires detailed geological investigation, and there has been progress in this for the Sellafield site, but only after the failure of the Nirex appeal.

Considering the importance of understanding fluid flow in the subsurface, it seems remarkable to me that better information was not available at the time of the Nirex appeal. A study by McKeown, Haszeldine and colleagues, funded by Greenpeace, was cited and has since been published in two peer reviewed articles. This was a preliminary study, made using simple software that was designed to investigate large scale flow in oilfields. It is no way comparable to the type of study that would be considered acceptable by industry today. Geological divisions were made at a very general level and the effect of smaller units of contrasting permeability was not considered. The study was perfectly reasonable to make the point that the funders of the project wanted to make, namely that there was a chance that there could be significant issues of groundwater flow through the site, based on the data available, but it was not a definitive study and if more detailed information had been available some of the assumptions made would have had to be changed. In the final stages of the Nirex programme, they completed their own investigation of flow in fractured basement rocks, published in reports and as a peer reviewed paper in 2003. This study provided large amounts of information that was not available to

Haszeldine and confirmed that many of the assumptions made in the earlier work were not reasonable. This study has been selectively quoted by Haszeldine, but contrary to the impression that has been given, it indicates that the flow system is more suitable for the construction of a safe repository than was previously thought. A specific geological concern is the presence of many geological faults in west Cumbria. There will continue to be minor earthquakes in west Cumbria and other parts of the UK, almost exclusively involving very small movements on pre-existing faults. There is no reason to suppose that earthquake faulting would cause damage to the integrity of a repository even if it intersected it, because the waste containers should be surrounded by extensive clay barriers which would flex without breaking or transmitting stresses to the drums themselves. In the past 15 years or so, our understanding of faults and their effect on fluid flow patterns has come on enormously, because of the need to extract hydrocarbons from faulted reservoirs as efficiently as possible. There is now the technology and software available to construct detailed block diagrams of faulted regions of sedimentary basins and predict where fluid will flow across faults and where it will be retarded. Comparable detailed diagrams are prepared for basement rocks as part of major mining operations.

Final Remarks:

The geology of west Cumbria does not correspond exactly to any of the ideal models for radioactive waste repositories. It is likely that better sites from a geological standpoint could be found in the east of England. The immediate risk posed by waste stored at the surface is however so great that geological concerns cannot be the only ones to take into consideration. There is a need for urgency; for example the perceived risks from terrorist attack or from economic collapse are probably greater now than they were at the time of the Nirex appeal. Rejecting the work of the past 10 years leading to the White Paper and MRWS approach should not be an option. Many of the geological arguments against the possibility of a safe repository site in west Cumbria are unsupported by published scientific evidence or detailed explanation and have not been subject to peer review.

There is in my view a good possibility that a suitable repository site will be found in west Cumbria, although this is certainly not guaranteed.

Leeds, January 2nd 2013

Annex 3: Submission from Professor Stuart Haszeldine, University of Edinburgh

Investigations to site a radioactive waste repository in Cumbria: Evidence against proceeding to MRWS Stage 4

1) Buildup to present position: the UK has been generating waste from electrical power production since 1956. Attempts to find a permanent disposal site was started during the 1970s, continued in the 1980s with extensive surveys and 1990's with drilling in West Cumbria, and recommenced in 2010-12 with MRWS (1). The West Cumbria MRWS has attempted to find constructive consensus between all parties. Many important issues have been identified, but none have been fully solved. The total waste volumes are not large, according to NDA these are 477,000 m^3, i.e. 4,100 London buses or five Albert Halls. However the containment of radioactivity into the next 10,000 years, and for a further 1 million years beyond that is a unique challenge of extreme difficulty. In October 2012 a small subgroup of each council were expected to enact their powers as DMB (decision making bodies), in deciding to move forwards into MRWS stage 4. This gives permission to undertake much more detailed desk study, potentially combined with investigations of geology at the surface. That decision has been delayed until 30 January 2013. An increasing number and diversity of objections from the public and from stakeholders have emerged.

2) Need for waste disposal site and MRWS criteria to proceed: the UK was the first adopter of nuclear power for civil purposes. For a variety of historical reasons the UK radioactive waste legacy comprises difficult material which is complex, of mixed origin and chemistry, and is in various stages of containment and packaging. The UK has a long-standing need to identify and construct an adequately performing, cost-effective, and politically feasible option for disposal of radioactive wastes from electricity production. With cost estimates £12-30 Bn, this is clearly a national UK project. Volunteerism is not currently working as anticipated. The present volunteers place all the MRWS eggs in one basket, and are vulnerable to shared-failure from political, social, or technical reasons. The MRWS criterion 2b to proceed is *“Are sufficient areas remaining to make further progress worthwhile?“* The NDA are persistently vague on site identification (2 p6) and have no criteria for failure in identifying sites. The MRWS geologist argues that a number of sites require to be defined in west Cumbria, with selection criteria, before proceeding (3, p14). Because substantial geological information already exists in west Cumbria a lot of this desk-study was undertaken for the Nirex Inquiry (2 p26, 27), and has recently been reviewed (6, 7, 8), failing to find a secure site. In other European countries the search for radioactive waste disposal sites has been led by a national appraisal of geological suitability, followed by many years, even decades, of dialogue and trust building between developers and communities. This has maintained multiple siting options throughout many years, leading to successful repository identification in Finland (spent fuel), Hungary (3) (ILW), France (HLW) and Sweden (spent fuel). The UK must create and maintain multiple diverse options, because Nirex experience in 1995-97 at start MRWS-6, shows that GDF disposal plans could fall apart again in 2028. **Recommendation:** *UK Government could make much, much, greater efforts to use the existing information on national geological suitability, and engage in outline appraisals, of multiple sites around the UK. Several GDF candidates should be investigated.*

3) Timing of decision on a region or a site: even if Cumbria decides to press ahead with MRWS investigations, the time to undertake appraisals, including an underground rock laboratory for in-situ investigations, will mean that the first wastes are not emplaced until at least 2040, potentially 2070. With these timescales, the containment and secure storage of existing waste at or near the surface is much more important than rushing towards choosing a single region for long-term disposal. It is not clear that there is a compelling technical reason for 2013 to be a make or break year, although there are coincidences of timing for bidders on new-build nuclear to

be given assurances on a route to long-term disposal.
Recommendation: *more attention is needed to temporary storage for the next 100 years*

4) Principles of waste disposal: the principles of geological burial for waste disposal have an international consensus. This is that firstly waste should be conditioned and packaged in a surface factory setting, secondly that waste should be emplaced deep below ground within a engineered near field containment system often comprising steel or copper canisters and bentonite clay, thirdly that the surrounding and overlying geology should form an essential failsafe positive contribution to short-term and long-term site performance. All other European nations developing a GDF can make strong evidence-based claims that the geology is positively helpful. In Cumbria some proponents state that engineering can solve all geological problems (i.e. that a GDF could be constructed anywhere below ground) and other proponents state that Cumbria provides minimal assistance with site performance.
Recommendation: *The UK should follow international practice to seek GDF sites where the surrounding geology can make a positive contribution to containment.*

5) Linking of GDF and other nuclear projects: the present debate is complicated by the increased inventory of waste to be disposed of. This includes, for the first time, UK HLW, spent fuel, and plutonium; in addition a successful GDF would be expected to host all waste from future nuclear-power electricity in the UK. The characteristics of these future wastes are unknown in detail because rival bidders (EDF with PWR reactors, or GE Hitachi with Gen IV PRISM reactors) will produce radically different waste streams. In general terms, there is expected to be much less ILW, and the HLW is expected to contain much greater short-term radioactivity and to be much hotter temperature. This hotter temperature is likely to greatly complicate the groundwater circulation in West Cumbria geology (see 7.8 below). Neither EDF nor Hitachi have purchased options to site new nuclear plant adjacent to Sellafield. Therefore there is no direct coupling between a GDF and a local nuclear new build.

As an additional variable, the offer from GEH is for a reactor type which can consume plutonium, and convert this to non-weapons grade. If successful, a modification to the reactor design can be reconfigured to burn plutonium as a fuel, completely eliminating the need for its disposal (4). In principle, this is extremely attractive - but as yet unproven at commercial scale. This factor means that a decision to build a new MOX plant at Sellafield could be premature, as the benefits of using a small percentage of plutonium in EDF reactors would be greatly outweighed by the efficiency of the GEH system. Consequently there is no direct coupling between a GDF and a new MOX plant at Sellafield.
Recommendation: *the proposition for a GDF should be treated separately from additional nuclear facilities, which may well benefit from being sited in West Cumbria.*

6) MRWS process to identify a region into MRWS 4: MRWS has been a very useful process to commence a constructive dialogue between diverse stakeholders. However this has exposed critical deficiencies in the design of the process.
6.1) It is not clear who volunteers, at present this is a small subset of the Councillors, who form a DMB. There is a disconnect between these people and the rest of the Councillors, and between the West Cumbria Parish councils, CALC, and the wider Cumbrian public.
6.2) Councillors on MRWS are frequently the same individuals forming the DMB. This is a fundamental conflict of interest, especially where they have spoken for or against proceeding with MRWS. In normal business, conflicted Councillors are excluded from voting.
6.3) The waste inventory is open-ended, to include future newbuild wastes. That makes it hard to understand what is being requested, for what timescale of emplacement.
6.4) There are no clear metrics of public support. MRWS polling claims public agreement, whereas Parish votes demonstrate the opposite.
6.5) The right to withdraw is highly equivocal. The ramping up of lobbying and pressure from elected representatives, NDA, unions, and government during the past three months of 2012 since the MRWS vote was delayed shows clearly how difficult withdrawal will become as any region goes deeper into MRWS stages.

Recommendation: *The terms and conditions for MRWS need to be made clearer and more robust. A decision to proceed should not be rushed by external pressures.*

7) Geological factors: One item which has surfaced within MRWS, is that of geological suitability of West Cumbria to act as a secure GDF. In European investigations, the criteria to emerge are that GDF site geology should be : as simple as possible, predictable, slow groundwater flow, helpful geochemistry, capable of releasing gas generated during disposal, resilient to future glaciations, earthquakes and human intrusion. As stated by NDA (2, Sect 3.6-3.10) *"hydrogeological characteristics and setting of the geological environment should tend to restrict groundwater flow within the repository".* MRWS was not able to fully understand the importance that prior geological screening has played in other countries. The MRWS also was not able to investigate the uniquely comprehensive investigations made in West Cumbria for radioactive waste disposal by Nirex in the 1990s. The Nirex proposal failed, after 66 days inquisitorial public inquiry, due to substantial geological obstacles. I contend that these geological obstacles are still present, apply to the entire coastal plain of West Cumbria, and form such a tangible threat to the success of a GDF that Cumbria should be abandoned entirely at this stage, to avoid wasting UK attention, time and money. Some issues have been publicly stated (5, 6, 7), these include and are not limited to:

7.1) Nirex comprehensively screened West Cumbria, selecting Longlands Farm as best site
7.2) West Cumbria geology is extremely complex – hence rock type is hard to predict.
7.3) West Cumbria geology is very fractured – that provides pathways for rapid water flow to leach wastes emplaced in a GDF, and flow into potable aquifers, the sea or the surface.
7.4) Borehole investigations by Nirex did not succeed in achieving a predictive understanding of groundwater flow – even between closely spaced boreholes
7.5) The topography of west Cumbria with adjacent mountains, means that groundwater flow will be driven deep, and continually, through any GDF.
7.6) The outflow of water from a deep GDF will, eventually, be into the Irish Sea. That may be internationally not-legal and needs justification by Strategic Environmental Assessment
7.7) The geologically long-term water geochemistry, measured by mineral crystallization, has been oxidizing. The present day water geochemistry measured in boreholes, is also oxidizing. This can dissolve available uranium. All other EU GDF sites have reducing waters of slow flow.
7.8) Simulations of groundwater with added heat from HLW and spent fuel (preliminary, by University of Edinburgh, in process of peer-reviewed publication), show that natural circulation flows are greatly enhanced, so GDF water returns rapidly to the surface within only hundreds of years rather than tens, or hundreds, of thousands of years.
7.9) Simulations of CO2 gas generation within a GDF (by Nirex) show that radioactive 14C waste can return to surface within decades after closure. This fails performance standards.
7.10) The new proposals for a GDF to hold hot HLW and fuel (93% of the radioactivity), will require site specific underground rock laboratory experiments. This construction location, access and timescale does not seem to have been identified by MRWS.

Additionally, in the interaction of surface and subsurface assessments:
7.11) The National Park and environmentally sensitive areas such as SAC, SPA and SSSI are still included in the regional appraisal. This has already led to public concern.
7.12) The "exclusion screening" by BGS in 2010 has not excluded known aquifer zones along the Solway coastal plain, and has not excluded west Cumbria coastal geology which another part of DECC has considered licensing for shale gas exploration in 2011. The resource conflicts have not been fully identified.
7.13) During the MRWS process, dialogue on the geological difficulties of west Cumbria has resulted in two other rock volumes being identified. Desk-based appraisal by Prof David Smythe has shown that Silloth (8) is geologically implausible. Ennerdale (9) lies fully within the National Park, and may also have very substantial difficulties in its geological appraisal (considered to require a closely-spaced seismic reflection survey grid and access for large equipment to drill to 1-2km). Site access to either rock volume during GDF construction could imply extremely

numerous truck movements per hour for several decades. **Recommendation:** *west Cumbria shows no promise for a GDF and should be abandoned.*

8) Geological rationalism or historic accumulation? It is clear that the regional geological position of west Cumbria is not especially favourable. The best that has been said in favour of exploration for a GDF is that “not everything is yet known about west Cumbria”. This is not a good gamble on which to base the UK’s nuclear waste disposal effort. A counter argument made is that “75% of the waste already exists at Sellafield”. Whilst this may be true just now, that does not mean the UK should select a sub-standard permanent site because of the historical accident that waste has accumulated at, and has been sent temporarily to, Sellafield. If nuclear new-build occurs, then much larger amounts of radioactivity are calculated to arise around the UK, and will need to be transported to a disposal site. Surface rail transport is demonstrably safe – the NDA claim 10 million miles of UK rail transport without serious incident since 1962 (10). The present problems are a failure of process, cherry-picking the recommendations of CORWM-1 (12), and also a failure of site choice.

9) Alternative sites. If west Cumbria is a geologically poor GDF, then do other UK locations exist for deep disposal of radioactive waste? During the 1980s, Nirex commissioned the British Geological Survey to appraise the entire UK for radioactive waste disposal. This led to the identification of generically suitable regions (11) which amounted to about 30% of UK land area. Sellafield was not included. This map is still useful as it points to regions which may be investigated further by interpretation of existing seismic reflection records and by scientific deep drilling. Plausible candidates may be the zone between Cambridge and Norwich, regions around Oldbury, Wylfa, Hartlepool, or inland from Dounreay. Although DECC have undoubtedly made approaches to some regions, it is unclear that a multi-year hearts and minds consensual dialogue envisaged by MRWS and by CORWM-1 has actually been seriously attempted. It is a paradox that some of the most suitable areas may not be able to volunteer themselves into MRWS because they have very few human population.

10) Summary. *The MRWS process is promising in a search for plausible GDF regions. However significant flaws have emerged the way it has been challenged. Philosophically, the search for an expensive, unique, and permanent national GDF should be led by the geology, not by local social need. West Cumbria has particular geological adversities and complexities, which fall below international criteria, and resulted in failure of a GDF proposal in 1997. Persisting with Cumbria, and persisting with a single GDF option, courts a very high risk of failure and should be abandoned. Multiple GDF options could be pursued immediately with equal vigour. There is no necessary connection between future development at Sellafield and a GDF. The UK has wasted many decades in fruitless attempts at radioactive waste disposal, and continued serious effort must span several government lifetimes.*

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Annex 4: Submission from Professor David Smythe, University of Glasgow (emeritus)

Why the current MRWS process should not proceed to Stage 4

Where I stand. I am grateful for this opportunity to present written evidence to the *ad hoc* committee. Due to personal circumstances I was unable to accept the invitation to appear in person.

I am a retired academic, whose career spanned firstly, the British Geological Survey (BGS), followed by the University of Glasgow. I believe in the (now outmoded) concept of public service; I have no axe to grind, either over the nuclear industry or West Cumbria; I have no financial or personal interests to declare; I no longer even live in the UK, and am in the process of applying for French nationality; I believe in honest impartial science in the aid of civilised society; I follow current affairs closely, especially from a European perspective.

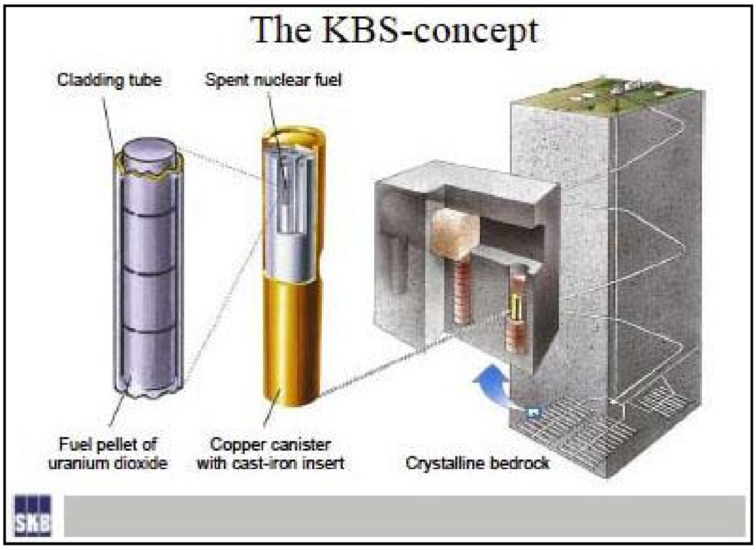
I served on the BNFL Geological Revew Panel, 1990-91. I proposed and carried out the trial 3D seismic reflection survey at Longlands Farm for Nirex in 1994 (a double world first – the first time that an academic research group had used this then novel method, and the first time that a potential radwaste site had been surveyed in this way). But I was so concerned about Nirex's lack of understanding of the highly complex geology there that I felt obliged to appear against Nirex, as an expert witness for FoE, at the Nirex Planning Inquiry in early 1996.

My concerns about radwaste disposal in West Cumbria were revived with the publication of the Defra MRWS White Paper in 2008, to the consultation of which I had submitted a response, pointing out that the 'voluntarist' approach left open a return to consideration of West Cumbria. My fears then have proved to be correct.

This submission summarises my views at Stage 3 of the MRWS process. I have tried to complement rather than duplicate the submission of my former Glasgow colleague Professor Stuart Haszeldine, whose views I largely share, and who is appearing before the committee in my place. It is based on many months of (*pro bono*) full-time study and research. My project folder hosts some 9000 files, of which some 1600 are pdfs of research papers and the like, and some 1700 of which concern BGS

publications, and so on. I have spent over £1K purchasing BGS maps, data, and reports where necessary. Fuller details of my results can be found in my MRWS consultation submission (some 168 pages) and on my website.

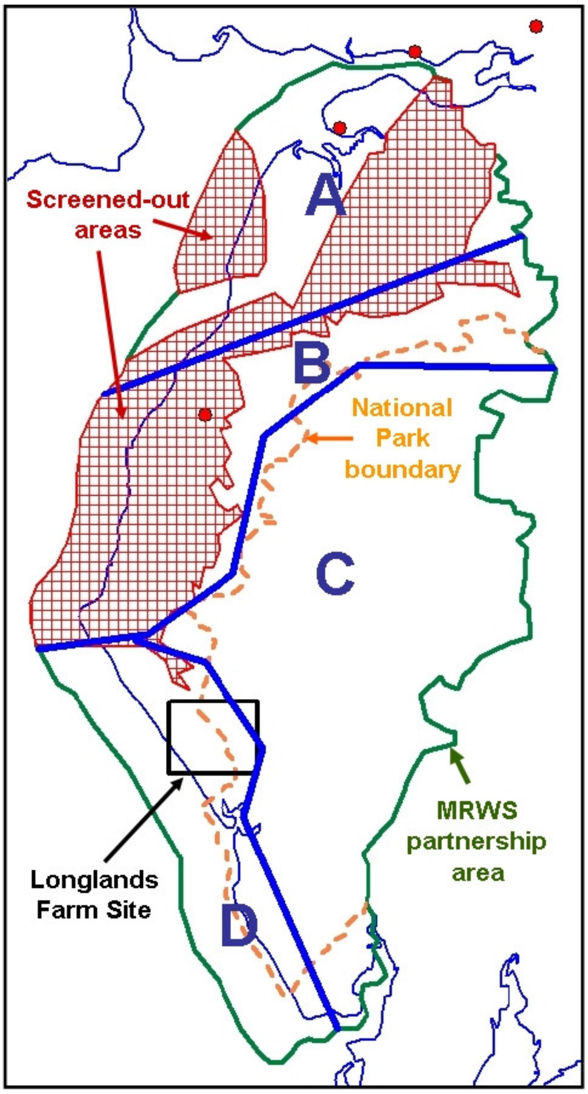
Why the geology is crucial. The final and most important barrier to limit radioactive escape from a repository into the environment is the geology. Engineers may (over-)confidently predict that their 'engineered barrier systems' will succeed, so that the geology of the repository hardly matters, but this is not true. Let us look at the example of the Swedish copper radwaste canisters, the KBS-3 concept. It comprises:



- Fuel placed in isolating copper canisters,
- With a high-strength cast iron insert.
- Canisters are surrounded by bentonite clay,
- In individual holes at 500 m depth,
- In granitic bedrock.

The NDA has adopted this model for the UK. The Swedes developed this concept in the 1970s, and as late as 1999 were still predicting that the canister would be corrosion-resistant (in the right groundwater conditions) for a million years. But the Swedes also fund an independent NGO office to undertake independent critical research (something lacking in the UK); this office funded and published a comprehensive study in 2011 showing that there is a previously unknown leaching mechanism which can eat away all the copper within a 1000-year timescale. The several lessons to be learned here are:

- The UK must fund truly independent critical research.
- The research timescales are decades-long (the Swedish experience above being 35 years).
- Engineers’ predictions simply cannot be trusted when it comes to geological timescales.
- We have to go with Nature, finding the best natural barrier, neither fighting it nor choosing sub-optimum geology.



What is suitable geology? Internationally agreed fundamental criteria for how to search for a potential radwaste site all converge on the same broad principles. These include low hydraulic gradients (so that groundwater flows very slowly), and simple, predictable geology. Most of the Partnership area fails both of these tests immediately.

The whole area is very well known geologically, because the Lake District has been a classic area of geological study for two centuries. Contrary to certain views, the £400M of Nirex studies were not all concentrated within the 50 sq km Site area (see map), but extended well away, from Workington to Barrow, inland for 15-20 km, and west offshore for 50-70 km. Northern Allerdale, not studied by Nirex is, on the other hand, well understood from 40 years of oil exploration.

Area A comprises the Solway plain north of the blue line, but most of it has been screened out by the 2010 BGS exercise for DECC (red hatching), on the basis of coal and coal-bed methane resource potential.

A site at Anthorn Airfield had been considered during the BGS/Nirex national site search in 1988 (the red dots on the map show sites considered at that time), but was then rejected on geological grounds. The rock at the surface in the coastal plain is the Mercia Mudstone Group (MMG), which had been considered and rejected by the BGS in 1986. But Dr Jeremy Dearlove, the MRWS consultant geologist, stated in 2011 “*I understand from brief discussions with the BGS that the Mercia Mudstones within this area would also form part of the BGS*’*s* “*potentially suitable sedimentary formations*”.”.

So the area appears to be back in play on a no more sound basis than a coffee-time chat with anonymous BGS personnel. This is not a rational way to find a repository host rock. My review of the ample available data, published by the BGS, shows that, although the non-excluded area near Silloth has simple geology, and is far enough away from the Cumbrian fells for the hydraulic gradient to be relatively low, the MMG has a hydraulic conductivity from 10,000 to one million times too high for it to be considered as a repository host rock. This is because it is a siltstone, and a brittle fractured shale, not a plastic clay host rock, such as has been found by the Swiss, French and Belgians. Furthermore, the rock volume where the repository would have to be excavated, between the two screened out areas, (a) is very shallow, at around 400 m depth, and (b) is cut through by at least two large faults. The geochemical groundwater environment is oxidising, which is the opposite of what we need. The rock is classed as a 'Secondary B' aquifer, and there are currently active water wells drilled to more than 100 m depth. It should properly have been screened out, leaving nowhere in northern Allerdale for further consideration.

One also has to ask, if waste must be shipped 40 km north from Sellafield to Silloth for burial, why cannot it simply continue on a longer journey to a suitable geological repository somewhere in eastern England?

Area B is a belt of complex limestone and coal geology fringing the northern and western flanks of the National Park. Much of it has been excluded already (iron and coal resource intrusion risk). The part remaining is highly faulted and comprises mainly limestone. Lastly, hydraulic gradients will be high. There is no possibility of finding a suitable host rock environment here, and none has ever been suggested.

Area C comprises the hard crystalline rocks of the National Park. The extreme relief of 800 m is sufficient *a priori* to rule it out of consideration; contrast that with the Swedish and Finnish repository sites, which both comprise coastal hard rock, and where the local ground relief is of the order of 20 m. No other country has considered placing a repository in such steep terrain – except the now-defunct Yucca Mountain site in Nevada, which was selected to be hundreds of metres *above* the water table, in a desert environment. Nevertheless, the Eskdale and Ennerdale granites have both been proposed (informally) as repository host rocks. Both bodies have a *millefeuille* pastry, or lasagne-type structure, in that layers of granite are interleaved with the slates into which they have intruded. This is complex and unpredictable. The granites have also been severely faulted after solidification.

The one area of the granites which appears to be clear of surface faults is the central part of the Ennerdale body, comprising Ennerdale Fell. There has also been mention of direct tunnelling obliquely from Sellafield – or, more probably, from Longlands Farm, which the NDA has inexplicably held on to, 15 years after Nirex lost its planning appeal to site a test repository there.

Firstly, it is unlikely that this portion of the granite is different in structure from the other parts, so the likely complex structure would have to be investigated in detail. There is no question that this would involve extensive heavy engineering investigations. By analogy with Longlands Farm (and hard-rock sites abroad), 20-30 boreholes would be needed for detailed hydrogeological study over a decade or so (the 2010 Entec environmental report for NDA quotes 20 deep boreholes and 50 shallow boreholes). A lightweight drilling rig weighs 30 tonnes or more. This would have to be assembled *in situ* on the top of the Fell by a mobile crane. All this requires HGV-capable roadways to be cut first. The only way to image the subsurface is by a 3D seismic survey, and in this kind of terrain the only possible source would be dynamite. I estimate that around 60,000 holes, each 1 m deep, and charged with 200 g of gelignite and a detonator, would be required to image the 25 sq km of the granite in sufficient detail, together with millions of pounds-worth of sophisticated ground recording gear laid out in grids. Secondly, NDA schematic plans and volumetric calculations show that three permanent vertical shafts are required from the surface (i.e. the summit of Ennerdale Fell) to the repository.

All the above demonstrates that Ennerdale Fell and its surrounds would become an industrial mining zone, closed to the public for security reasons, for many decades; this is clearly incompatible with its status as part of the National Park. The NDA's own planning documents, together with current international practice, show that it would be quite impossible to construct a repository purely by tunnelling obliquely from a surface location like Longlands Farm.

Area D comprises the coastal strip of sediments at the surface, west of the hard rocks of the Lake District. The hard rocks underlie the sediments at a few hundred metres depth. Note that the Partnership area, for the purpose of geological screening by the BGS, extends 5 km offshore.

The 1988 BGS/Nirex national site search did not include Longlands Farm, nor any geologically similar location. The 537 sites selected and sieved (or screened out) at successive stages included only a ‘Sellafield’, where the target was a potential anhydrite (salt) layer dipping offshore. But early drilling proved that the layer was too deep. ‘Sellafield’ then shifted location (twice) and category of rock (once), and was only introduced at a late stage in the national site search. Politics, and not geology, forced this ‘cuckoo’ site onto the shortlist, and it was finally chosen over Dounreay. Longlands Farm was supposed to be in the ‘basement under sedimentary cover’ (BUSC) category, but the Inquiry Inspector perceived that it was not a proper BUSC example. It failed because the geology is far too complex and unpredictable.

In 2005 Nirex tried to claim that a post-Inquiry revision of its modelling (a group of documents known as Nirex 97 and issued in 1997-98) now showed that the Longlands Farm site exceeds the safety threshold. This is wrong. My analysis of the modelling used to predict the water flow shows that the effect of the faults cutting the rocks has been ignored. In fact, the faults will cause contaminated water from a leaking repository situated at 650 m depth in the hard rocks to migrate obliquely upwards along the fault planes, to reach the surface in a short time. My view is supported both by theoretical modelling of fault zones, and by the empirical results of United Utilities, who stated in 2011 that they were drilling the fault zones for drinking water south of Egremont because they gave the best flow. The theoreticians conclude that fault zones on the small scale are inherently unpredictable. The improvement in computing performance since 1997 is irrelevant – the same fundamental errors will simply be recreated, but faster and in more detail. So the only safe way to find a good repository site is to avoid faulted rocks. This is what the French and Swiss are successfully doing – they have selected simple clay geology.

The coastal areas north and south of Longlands Farm are even worse prospects; the site around which £400M was spent could be said to have the ‘least bad’ geology in the area. Offshore west of Sellafield is also unsuitable; it comprises the same MMG as in northern Allerdale, with the same problems. In addition there would be severe political problems with the Irish and Norwegian governments, if any attempt were made to study a potential offshore location.

Summary of areas A-D. No stone has been left unturned, so to speak. There is no possibility that a rock volume exists that conforms even approximately, or in part, to the international guidelines for suitability. The ‘three wise monkeys’ approach adopted by the MRWS process, - that we do not yet know enough to rule out all the geology, because we have not yet done Stage 4 - is false. The evidence is all there in the public domain, mostly the work of the BGS and Nirex. All I have done is review and synthesise it. No-one has seriously challenged, in detail, any of my conclusions, but instead some resort to claiming that ‘only the BGS’ can decide.

The hubris of the engineers, that their engineering can overcome natural obstacles like adverse groundwater flow and chemistry, must not be accepted. We must, in short, go with the flow, and not try to fight Nature.

Comments on the MRWS process to date. The White Paper misleadingly implies that voluntarism has been the successful approach abroad. This is disingenuous. France, Switzerland, Finland and Sweden have all made progress in site selection by doing the geology first, and only then seeking local support or veto. DECC has tried to justify putting the voluntarism cart before the geological horse by claiming that a national screening exercise would be too expensive. This is also untrue, as the overseas examples demonstrate. The assertion wilfully conflates the detailed screening-out of rock volumes with the more general search for potentially suitable geological environments. In fact, a national search by the BGS was done in the 1970s, repeated with new criteria in the 1980s, and evidently nearly finished in revised form in early 2006, when a joint BGS/Nirex statement was issued to say that rather more than 30% of the UK landmass had potential, and that a full report would be published later that year. The report never appeared, allegedly because of a change in government policy (i.e. the birth of the voluntarism approach). The NDA has told me that the maps on which the 30% estimate must have been based do not exist. I find this hard to believe. There is a strong suspicion that the whole process has been predetermined – it is a ‘quick fix’ designed to enable a return to West Cumbria.

What if one or more councils proceed to Stage 4? I no longer have confidence in the impartiality of the BGS as an organisation, although I still trust the integrity of its individual scientists. **Firstly**, comparison of the draft BGS 2010 screening report (which was supplied anonymously to me) with the final published version, together with the published peer reviews, show that severe alterations were made to the draft. Contrary to popular belief, the final BGS screening report has *not* removed aquifer rock volumes from consideration; consideration of this important screening criterion has merely been postponed. Northern Allerdale was also initially screened out in its entirety on hydrocarbon grounds. **Secondly**, the BGS is angling for a lucrative contract to study the Partnership area in detail; this fact means that it is no longer impartial. **Thirdly**, the senior BGS radwaste scientist has stated on public radio that West Cumbria "*offers potential*" for finding a repository site; it will therefore be all-but impossible for the BGS to conclude at some stage in the future, that, sorry, there are in fact no suitable rock volumes worthy of more study. **Fourthly**, I have direct experience as a senior BGS scientist myself, in 1985, of being obliged by BGS management to conform to a Department of Energy instruction to write a confidential paper arguing a case I did not believe in. I believe that this paper was then forwarded as geological 'advice' to the F&CO. It was one of the reasons that persuaded me to quit BGS employment.

Conclusion and recommendations. The MRWS process should not go to Stage 4, as there is ample evidence that public money will be wasted, and time will be lost. Political pressures will mean that a geologically poor site will be chosen, but shored up by nuclear waste civil engineers who will assert that they can solve the insoluble, and that their grouting and filling will be good for 100,000 years.

The urgent problem of Sellafield's current wastes should be taken care of by an interim surface storage solution, to last 100 years. The next 25 years can then be given over to thorough research into waste encapsulation (at Sellafield), together with honest and transparent search for a satisfactory repository site elsewhere.

4 January 2013