

# Disposal of SNF/HLW in Deep Boreholes

## Drilling Deeper for Safety

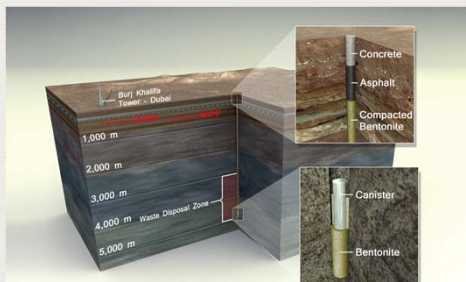
Andrew Orrell

Presented to the Swedish Land and Environmental Court

September 11, 2017

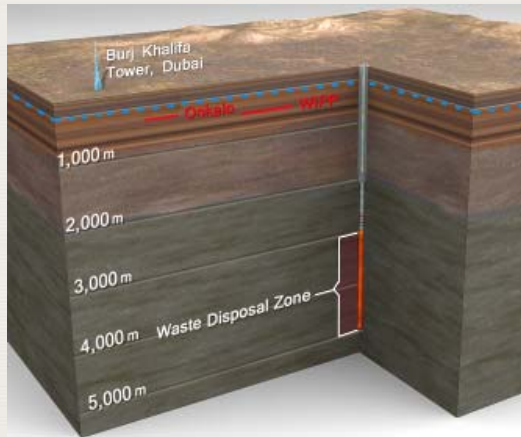
## Introduction

- Disclaimer
- Background
- Objectives

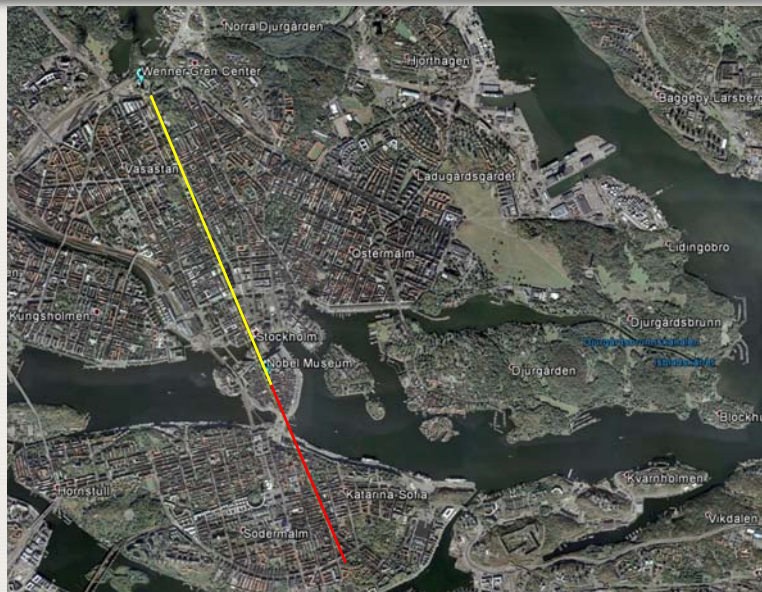


## Deep Borehole Disposal

- 5,000 m deep borehole(s) in crystalline basement rock, well below groundwater resources
  - Waste canisters in bottom 2,000 m
  - Seals in upper 3,000 m
- Bottom hole diameter
  - 17 in. for bulk waste forms or SNF/HLW
  - 8.5 in. for smaller DOE-managed waste forms



## 5 km Paths



## Fundamental Safety Premise

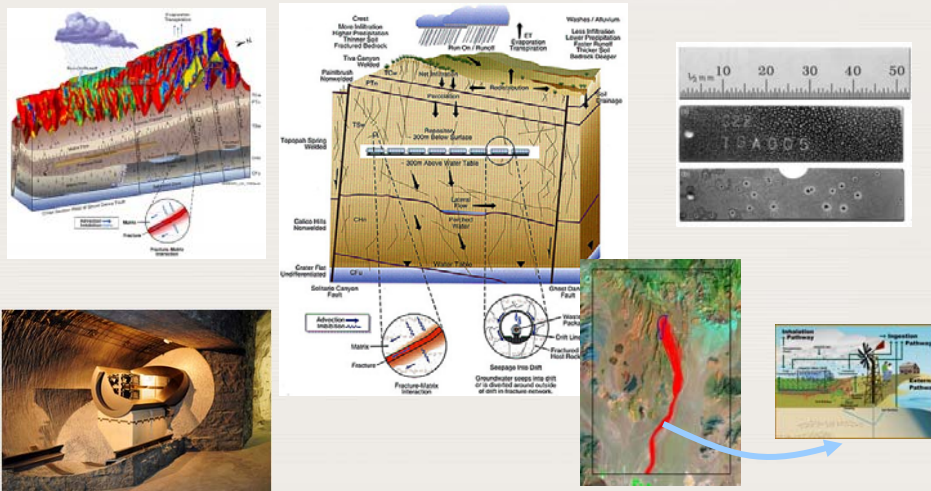
- The fundamental safety objective is to protect people and the environment from the potential for harmful effects of radioactive waste.
- To manage the waste burden through **permanent disposal** in a manner that protects the **accessible biosphere\***
- The strategy to achieve this fundamental safety objective is to **contain and isolate** the waste from the accessible biosphere, to the extent that is necessary to have **reasonable confidence that the uncertainties of e.g. 1Myr timeframes are addressed.**
  - Disposal facilities are to be developed in such a way that people and the environment are protected both now and in the future
  - To leave future risks no greater than one would accept at present.

\*(groundwater and other resources used by or accessed by people).

5

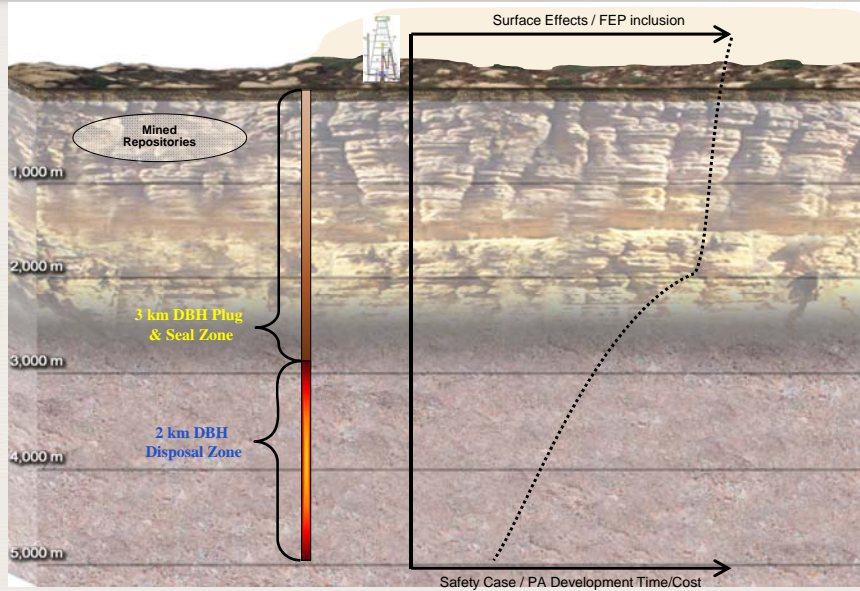
## Perspectives from Mined Repositories

Coupling between the surface and near-field disposal environment



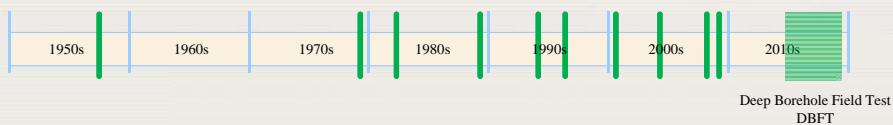
## Deep Borehole Disposal

### Greater confidence in waste isolation



## Deep Borehole Disposal History

- **Hess et al. (1957) NAS Publication 519**  
The Disposal of Radioactive Waste on Land.  
Appendix C: Committee on Deep Disposal
- **O'Brien et al. (1979) LBL-7089**  
The Very Deep Hole Concept: Evaluation of an Alternative for Nuclear Waste disposal
- **Woodward-Clyde (1983) ONWI-226**  
Very Deep Hole Systems Engineering Studies
- **Spent-Fuel Test - Climax (1986):**  
An Evaluation of the Technical Feasibility of Geologic Storage of Spent Nuclear Fuel in Granite
- **Juhlin & Sandstedt (1989) SKB 89-39**  
Storage of Nuclear Waste in Very Deep Boreholes
- **Ferguson (1994) SRNL WSRC-TR-94-0266**  
Excess Plutonium Disposition: The Deep Borehole Option
- **Heiken et al. (1996) LANL LA-13168-MS**  
Disposition of Excess Weapon Plutonium in Deep Borehole: Site Selection Handbook
- **Harrison (2000) SKB-R-00-35**  
Very Deep Borehole – Deutag's Opinion on Boring, Canister Emplacement and Retrieval
- **Nirex (2004) N/108**  
A Review of the Deep Borehole Disposal Concept
- **Beswick (2008)**  
Status of Technology for Deep Borehole Disposal
- **Brady et al. (2009) SNL SAND2009-4401**  
Deep Borehole Disposal of High-Level Radioactive Waste



# Performance Assessment

## August 2009

**SANDIA REPORT**  
SAND2009-4401  
Unlimited Release  
Printed August 2009

### Deep Borehole Disposal of High-Level Radioactive Waste

Patrick V. Brady, Bill W. Arnold, Geoff A. Freeze, Peter N. Swift, Stephen J. Bauer, Joseph L. Kanney, Robert P. Rechar, Joshua S. Stein

Prepared by  
Sandia National Laboratories  
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94NA16000.

Approved for public release; further dissemination unlimited.



## Preliminary analysis suggests excellent long-term performance

- Conservative estimate of deep borehole peak dose to a hypothetical human withdrawing groundwater above the disposal hole is
- $1.4 \times 10^{-10}$  mrem/yr ( $1.4 \times 10^{-12}$  mSv/yr)
- YMP standard is 15 mrem/yr (< 10,000 yrs) and 100 mrem/yr (peak dose to 1M yrs)

Source: Brady, P.V., B.W. Arnold, G.A. Freeze, P.N. Swift, S.J. Bauer, J.L. Kanney, R.P. Rechar, J.S. Stein, 2009, *Deep Borehole Disposal of High-Level Radioactive Waste*, SAND2009-4401, Sandia National Laboratories, Albuquerque, NM

# Raising Visibility (2/2010)

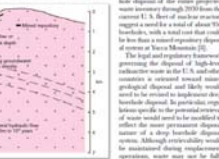
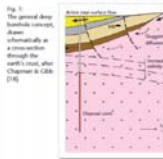


## Into the deep

The lower reaches of a borehole drilled 5km (3mi) into the earth's crust represents an interesting alternative location for high-level radioactive waste compared to mined repositories at much lesser depths. The first deep borehole performance assessment and dose estimate has been carried out. By Bill W. Arnold, Peter N. Swift, Patrick V. Brady, S. Andrew Orrell, and Geoff A. Freeze

The general technical and cost advantages of deep borehole disposal have become more apparent over the past few years. The ability to dispose of high-level waste and spent nuclear fuel in deep boreholes is a potential alternative to mined repositories. Deep borehole disposal offers several advantages over mined repositories. Deep borehole disposal is a more cost-effective method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste. Deep borehole disposal is a more environmentally friendly method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste.

Deep borehole disposal is a more cost-effective method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste. Deep borehole disposal is a more environmentally friendly method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste.



## Looking down the bore

Deep borehole waste disposition research has not progressed to demonstration. Fergus Gibb reviews the steps necessary before drilling can begin.

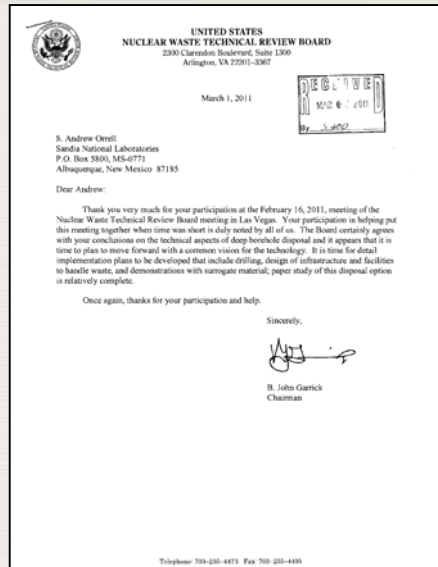
Historically, reluctance to proceed with deep borehole disposal has been based on the fact that, while boreholes a few kilometers in diameter are possible and have been drilled to depths in excess of 10 km, the combination of a hole several tens of cm in diameter to a depth of 5 km has never been attempted. Deep borehole disposal is a more cost-effective method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste.



Deep borehole disposal is a more cost-effective method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste. Deep borehole disposal is a more environmentally friendly method for disposing of high-level waste and spent nuclear fuel. It also offers a more secure and stable environment for the waste.

## Nuclear Waste Technical Review Board Meeting Las Vegas, NV - February 16, 2011

- “The Board certainly agrees with your conclusions on the technical aspects of deep borehole disposal and it appears that it is time to plan to move forward with a common vision for the technology.”
- “It is time for detail implementation plans to be developed that include drilling, design of infrastructure and facilities to handle waste, and demonstrations with surrogate material; **paper study of this disposal option is relatively complete.**”



## October 2011

### Sandia Workshop: Pilot Testing Deep Borehole Disposal of Nuclear Waste

**SANDIA REPORT**  
SAND2011-6749  
Unlimited Release  
Printed October 2011

#### Reference Design and Operations for Deep Borehole Disposal of High-Level Radioactive Waste

Bill W. Arnold, Patrick V. Brady, Stephen J. Bauer, Courtney Herrick, Stephen Pye, and John Finger

Prepared by  
Sandia National Laboratories  
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under Contract DE-AC04-04-OR21400.

Approved for public release; further dissemination unlimited.

 Sandia National Laboratories

In October, 2011 Sandia brought together twenty representatives from the fields of radioactive waste disposal and drilling to:

- review the state of deep borehole science and engineering;
- identify the necessary features of a deep borehole pilot demonstration; and,
- consider organizational approaches to implementing a deep borehole pilot.



**Blue Ribbon Commission on America's Nuclear Future  
Report to the Secretary of Energy, January 2012**

**12. Near Term Actions**

- Disposal
  - DOE should develop an RD&D plan and roadmap for taking the borehole disposal concept to the point of a licensed demonstration (p. 134).
- Regulatory Actions
  - The Administration should identify an agency to take the lead in defining an appropriate process (with opportunity for public input) for developing a generic safety standard for geologic disposal sites. The same lead agency should coordinate the implementation of this standard-setting process with the aim of developing draft regulations for mined repositories and deep borehole facilities (p. 135).

*Blue Ribbon Commission on  
America's Nuclear Future*



U. S. Department of Energy

**Administration Response to BRC  
January 2013**

STRATEGY  
FOR THE MANAGEMENT  
AND DISPOSAL  
OF USED NUCLEAR FUEL AND  
HIGH-LEVEL RADIOACTIVE WASTE



JANUARY 2013

"The ability to retrieve used nuclear fuel and high-level radioactive waste from a geologic repository for safety purposes or future reuse has been a subject of repository design debate for many years. A recently completed technical review by Oak Ridge National Laboratory found that approximately 98 percent of the total current inventory of commercial used nuclear fuel by mass can proceed to permanent disposal without the need to ensure post-closure recovery for reuse based on consideration of the viability of economic recovery of nuclear materials, research and development (R&D) needs, time frames in which recycling might be deployed, the wide diversity of types of used nuclear fuel from past operations, and possible uses to support national security interests. This assessment does not preclude any decision about future fuel cycle options, but does indicate that retrievability it is not necessary for purposes of future reuse."

- this is open recognition of support for direct disposal AND no need for retrievability for reuse

"In FY 2013, the Department is undertaking disposal-related research and development work in the following areas: an evaluation of whether direct disposal of existing storage containers used at utility sites can be accomplished in various geologic media; an evaluation of various types and design features of back-filled engineered barriers systems and materials; evaluating geologic media for their impacts on waste isolation; evaluating thermal management options for various geologic media; establishing cooperative agreements with international programs; and developing a research and development plan for deep borehole disposal, consistent with BRC recommendations."

- explicit recognition of deep borehole development as on the R&D agenda

## October 2014

The screenshot shows the FEDBIZOPPS.GOV website interface. At the top, there is a navigation bar with links for Home, Getting Started, General Info, Opportunities (highlighted), Agencies, and Privacy. Below the navigation bar, there are links for Buyers (Login | Register) and Vendors (Login | Register), along with an Accessibility icon. The main content area features the Department of Energy logo and the title "Request for Information (RFI) - Deep Borehole Field Test". Below the title, the solicitation number (DE-SOL-0007705), agency (Department of Energy), office (Idaho Operations), and location (Idaho Operations Office) are listed. There are buttons for "Notice Details", "Packages", and "Interested Vendors List", along with "Print" and "Link" options. A "Return To Opportunities List" button is also present. The "Original Synopsis" section shows the date and time (Oct 24, 2014, 12:11 pm). The "GENERAL INFORMATION" section lists the Notice Type as "Presolicitation" and the Posted Date as "October 24, 2014".

Request for Information (RFI) - Deep Borehole Field Test  
Solicitation Number: DE-SOL-0007705  
Agency: Department of Energy  
Office: Idaho Operations  
Location: Idaho Operations Office

Original Synopsis  
Oct 24, 2014  
12:11 pm

GENERAL INFORMATION  
Notice Type:  
Presolicitation  
Posted Date:  
October 24, 2014

Other countries have also expressed interest:  
Germany, China, Korea, Ukraine...

## 2015...2016

The collage features the GRS logo on a green background. To the right, there are logos for The University of Sheffield and the Department of Materials Science & Engineering, along with a radiation warning symbol. Below these logos is a photograph of a large industrial site with a crane and heavy machinery. The text "International Meeting on Deep Borehole Disposal of High-Level Radioactive Waste" is overlaid on the photograph. To the left of the photograph, the text "Proceedings of the Workshop 'Final Disposal in Deep Boreholes Using Multiple Geological Barriers: Digging Deeper for safety' Juni 2015, Berlin" is displayed. At the bottom, two URLs are provided: <https://www.grs.de/publikation/grs-405> and <https://www.sheffield.ac.uk/materials/news/deepboreholedisposal-1.586985>.

GRS

Proceedings of the Workshop  
"Final Disposal in Deep Boreholes Using Multiple Geological Barriers: Digging Deeper for safety"  
Juni 2015, Berlin

<https://www.grs.de/publikation/grs-405>

The University of Sheffield  
Department of Materials Science & Engineering

International Meeting on Deep Borehole Disposal of High-Level Radioactive Waste

<https://www.sheffield.ac.uk/materials/news/deepboreholedisposal-1.586985>

## The Deep Borehole Field Test

- December 19, 2016:
  - The Department of Energy (DOE) is announcing the **selection of four companies** to begin exploring the possibility of conducting a deep borehole field test. Ultimately, only one site will be chosen for the field test.
    - AECOM is exploring a site in Texas,
    - ENERCON is exploring a site in New Mexico,
    - TerranearPMC is exploring a site in New Mexico, and
    - RE/SPEC is exploring a site in South Dakota
- May 23, 2017:
  - UPDATE: Due to changes in budget priorities, the Department of Energy does not intend to continue supporting the Deep Borehole Field Test (DBFT) project and has initiated a process to effectively end the project immediately.

## Summary

- Each country has its own unique 'value-engineering' in deciding upon and implementing a disposal strategy, whether by:
  - a mined deep-geologic repository,
  - a deep-borehole disposal system,
  - or both.
- The last decade of research and development by the international community suggests DBH disposal is quite possible.
- There is sufficient international interest that a full-scale demonstration is still possible.

