



# Deep Borehole Disposal of Spent Fuel

Patrick V. Brady, Sandia National Laboratories  
Albuquerque, New Mexico

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"So far not a single permanent repository for nuclear waste has been approved."

In a subterranean vault, the movement of one ceramic plate sliding below another would push the containers down into the earth's mantle at a rate of about ten centimetres a year. America cut off funding for sealed-disposal research in 2006, and only one candidate followed suit. But some people have continued to develop the idea.

Physicist Paul White, based in California, has patented a steel, copper and lead container closely shaped to withstand pressure in a subduction fault. It resembles a bowling pin the size of a car. As it is driven into the subduction fault and the pressure increases, it is closed up vertically by pressure-activated pistons, says designer David Engelbrecht, a former nuclear weapons engineer at General Dynamics. The idea of sealed rock is, however, has failed to catch on, not least because it would require modification of international environmental laws.

Underground burial is regarded as a simpler and more attractive alternative. Salt deposits encrusted into masses beneath the desert near Carlsbad, New Mexico, already hold containers with enough radioactive waste from America's weapons programmes to fill more than 40 Olympic swimming pools. Having spent half a century on the UK's nuclear waste, power stations were promised lots of heat which might, in the long term, destabilise geological formations. No country has yet built a permanent burial site for spent fuel, but the technology for building, monitoring and eventually sealing operations has been worked out, says Charles Brumley of the European Repository Development Organisation, a 14-country working group between Baden, Switzerland.

To find out how a repository carved out of granite, a metamorphic rock, would hold up, French researchers built an underground laboratory and tunnelled down over the carboniferous layers of their. Heat and radioactivity testing show that a repository could be built in about ten years and then safely filled and recognised by at least one hundred metres before being sealed, says Mr Chavanne.

Any permanent repository would be built in a dry geological region. Even so, water must seep in through cracks created by an earthquake, say, or a shifting land mass, allowing radioactive matter to get out. To prevent that, Czech engineers working with a German consultancy called the technology have built a "dry double cage" to keep water out of a future limestone salt mine the Czech town of Jáchymov that holds radioactive waste in

concrete-lined, tin-lined drums. In 2005 they began lining the top, bottom and sides of certain chambers with a five-centimetre layer of gravel, laid in place with new needs every few metres. Each chamber's gravel lining creates "a path of least resistance" to divert any water around it. The project's leader, Mikael Borella of the Radioactive Waste Repository Authority, says it is a work in progress.

Finland and Sweden have also built underground laboratories to test geological formations and packaging technologies. The results look good, says Claus Thoenes, the head of rock, which operates the Swedish facility, the Äspö Hard Rock Laboratory. Repositories built at depths of half a kilometre are more to stable rock levels even in the presence of a future ice age as they remodel Europe's landscape, he says.

Yet so far not a single permanent repository has been approved. Contractors will be expensive, but managing public opinion may pose a bigger problem. As an industry job puts it, the social science has become more difficult than the physical science. Citizens in France and Sweden realise that building projects will be opposed within a few years. But hostile public opinion can derail even advanced plans: more than \$6 billion had been spent on America's Yucca Mountain repository when it was cancelled. People living near the Carlsbad site for weapons-related waste want, in contrast, contained and compensated. Sweden's sea-shore sites for its proposed repository after a long consultation and several referendums.

A leading alternative America's Blue Ribbon Commission concluded that a "basic consent-based approach" was needed. It also called for research into an alternative form of underground burial—packing waste into holes drilled several kilometres deep. Research into borehole disposal, as it is known, is now taking off, says Engelbrecht, a good source at the University of Sheffield in England.

As an extra precaution, borehole containers could be designed so the hot waste melts and solidifies, in as little as a few decades, the rock would form a tight seal. A world-class lab, located at Sandia National Laboratories in Albuquerque, New Mexico, conducted that borehole disposal would be designed, more flexible and easier to implement than repository disposal. But the protection pro-

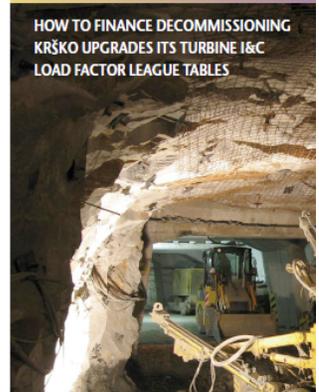
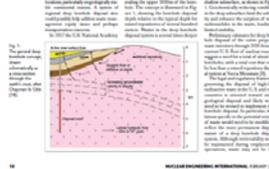
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### Into the deep

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. Swill, Patrick V. Brady, S. Andrew Orrell, and Geoff A. Fozzer

The trouble is that repository operators are now planning, to be clear to state nuclear weapons issues. President Barack Obama's proposal to store spent nuclear fuel in a deep borehole in the United States is a case in point. The idea is to drill a hole 5km (3mi) into the earth's crust, and then to place the waste in a series of containers. The containers are made of a material that is resistant to corrosion and will last for thousands of years. The containers are placed in a series of holes that are drilled into the rock. The holes are sealed with a material that is resistant to corrosion and will last for thousands of years. The containers are placed in a series of holes that are drilled into the rock. The holes are sealed with a material that is resistant to corrosion and will last for thousands of years.



### GOING UNDERGROUND REPOSITORY REIFT • DEEP BOREHOLE REVIEW

tection provided by rock is not perfect. It is not airtight, and it is not immune to seismic activity. The containers are made of a material that is resistant to corrosion and will last for thousands of years. The containers are placed in a series of holes that are drilled into the rock. The holes are sealed with a material that is resistant to corrosion and will last for thousands of years.

### Drilling deep under the US to dispose of nuclear waste

- 06 April 2010 by Phil McKenna
- Magazine issue 2754. Subscribe and get 4 free issues.
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THERE are times when letting go is the best way to move forward. When the US abandoned plans for a nuclear waste repository at Yucca Mountain, Nevada, there was no alternative in sight. Now, less than two months after that decision to walk away from a decades-long, multibillion-dollar boondoggle, a promising solution is coming into view.



What is being proposed is not another Yucca mountain-style set of tunnels in an even more remote location, but hundreds of boreholes that could be drilled where waste would be kilometres down in an approach was discussed by leading experts on deep repositories at a brain organised by geochronologists at Sandia and the Mass

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How to dispose of nuclear waste?  
By Physics Today on April 7, 2010 3:33 PM | Comment | No Trackbacks  
As it is frequently stated in Washington, money talks, and it is now money that is at the heart of the problem surrounding the \$20 billion Yucca Mountain nuclear repository facility. After decades of planning the Obama administration recently announced that Yucca Mountain would no longer be a candidate for storing US nuclear waste (see also Overhauling US nuclear waste policy).



NEI/Used Fuel Management Conference, May 7, 2013  
St. Petersburg, Florida



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-AC04-94AL85000.





BLUE RIBBON COMMISSION ON AMERICA'S NUCLEAR FUTURE



Report to the  
**Secretary of Energy**

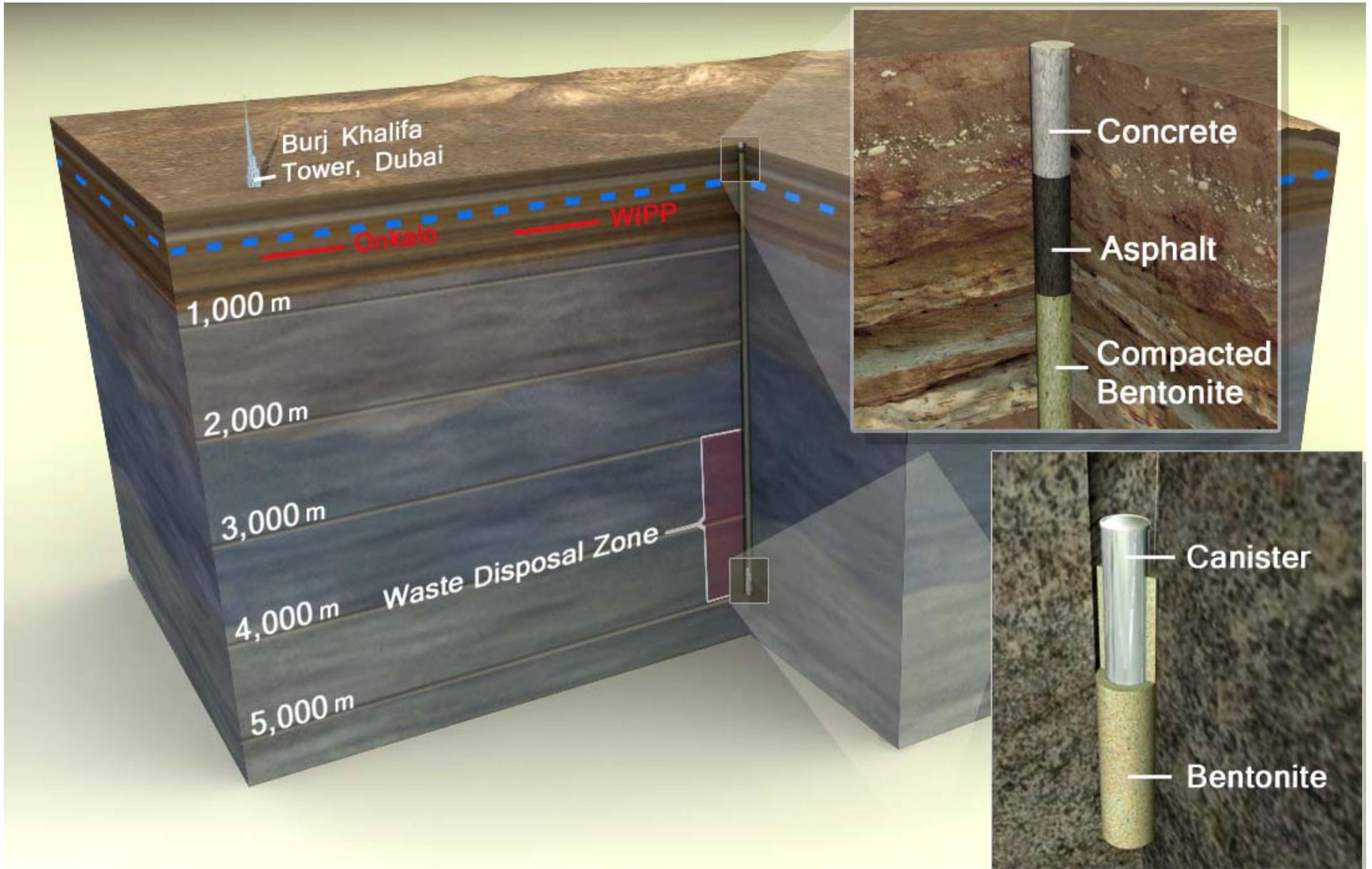
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ON AMERICA'S NUCLEAR FUTURE

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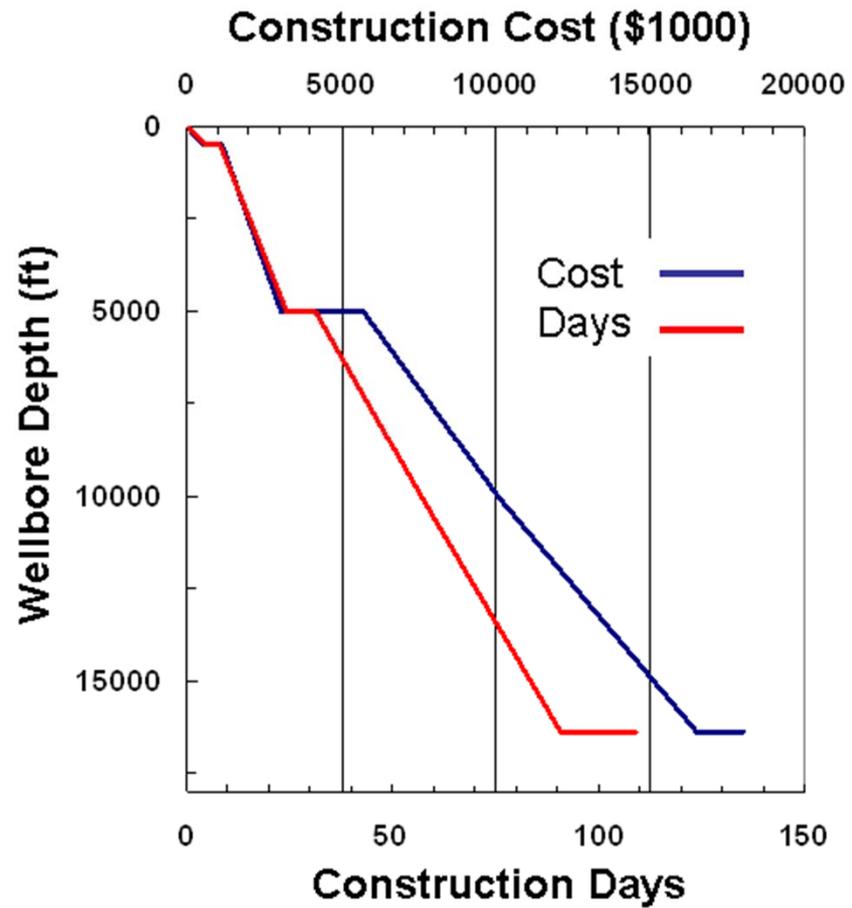
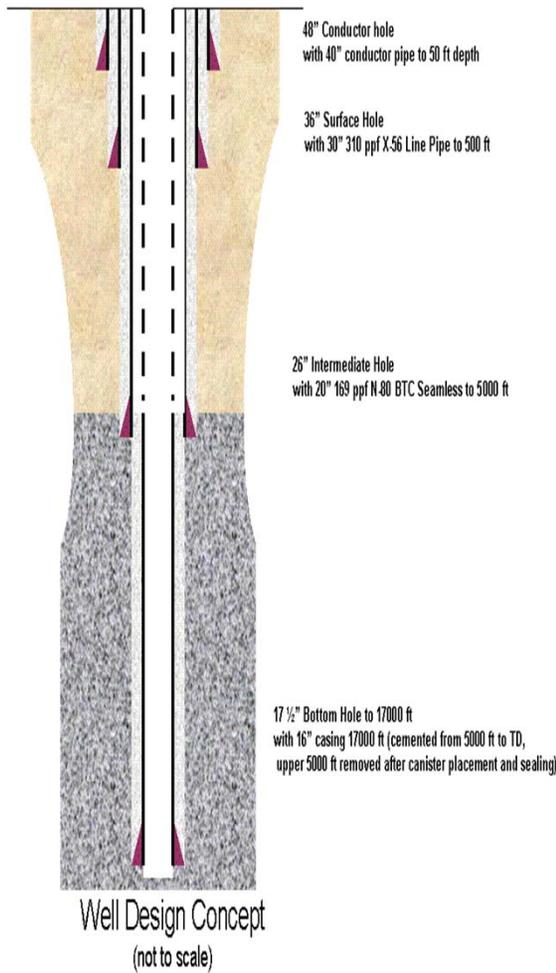
“DOE should develop an RD&D plan and roadmap for taking the borehole disposal concept to the point of a licensed demonstration...

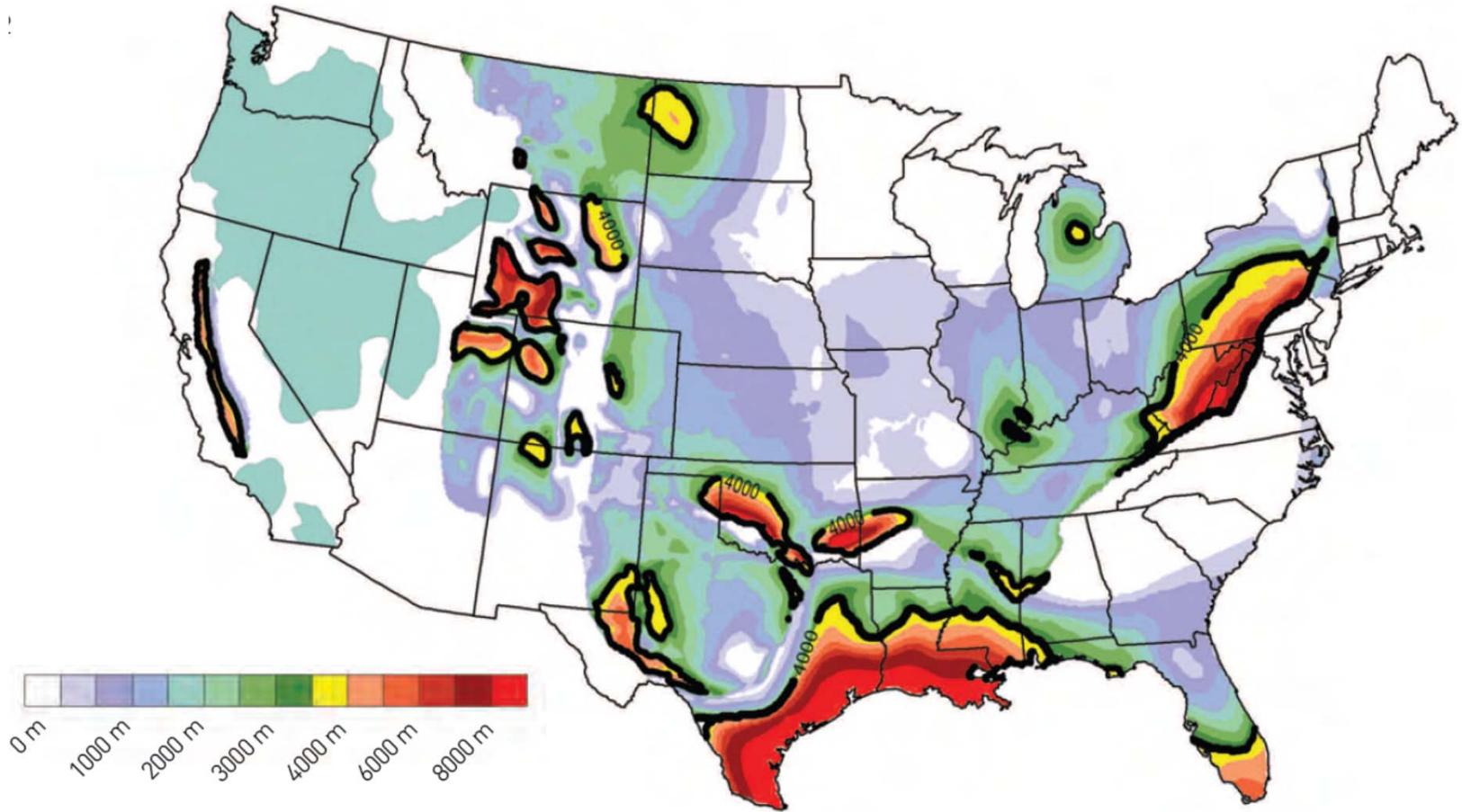
... EPA and NRC ... should be coordinated with the aim of developing draft regulations for mined repositories and deep borehole facilities...”





# Borehole Deployment

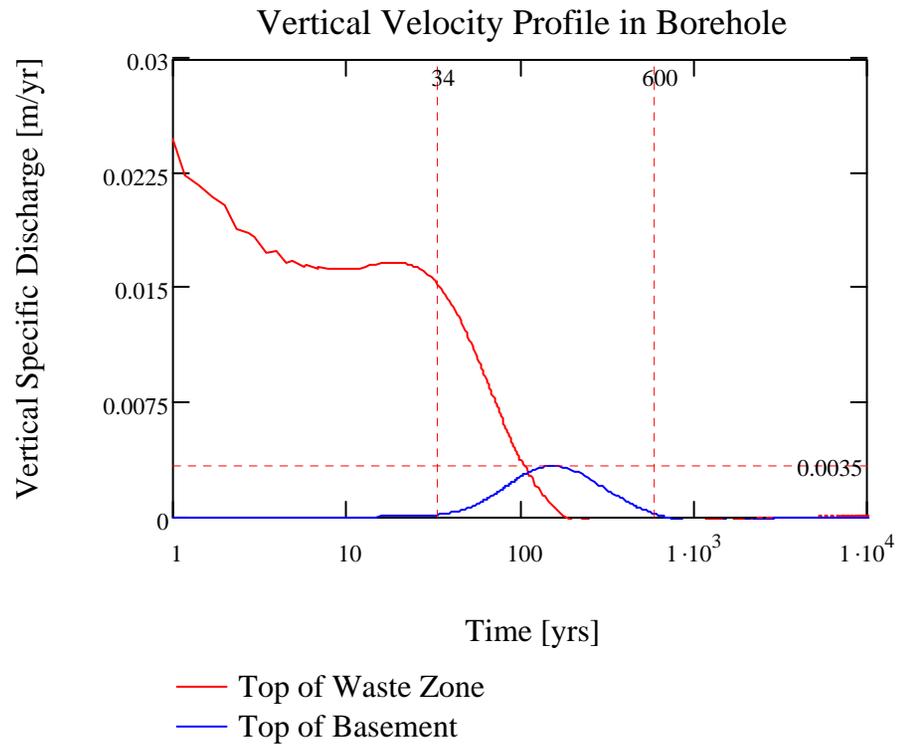
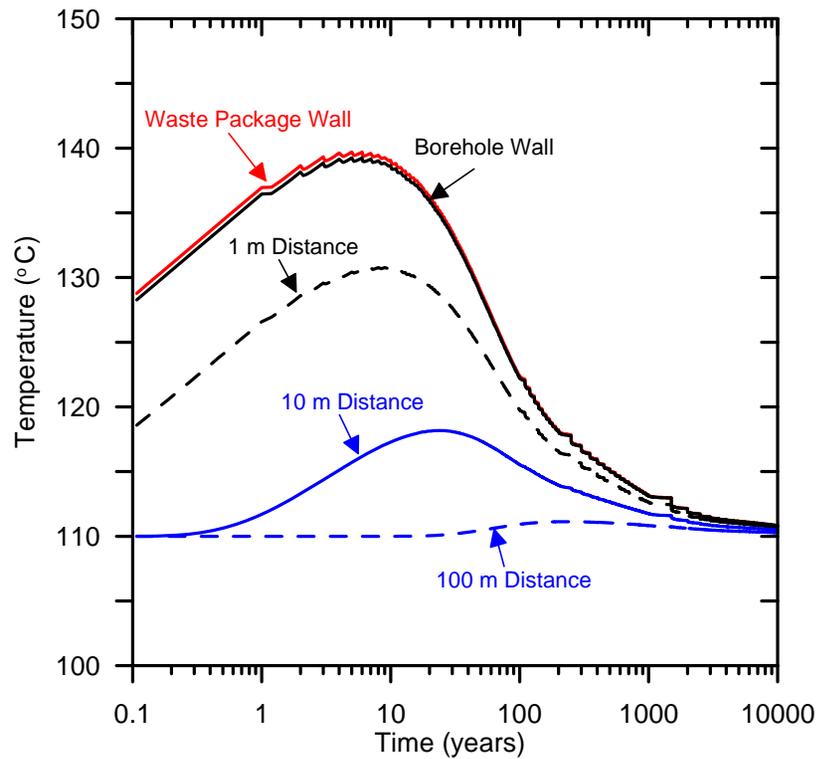




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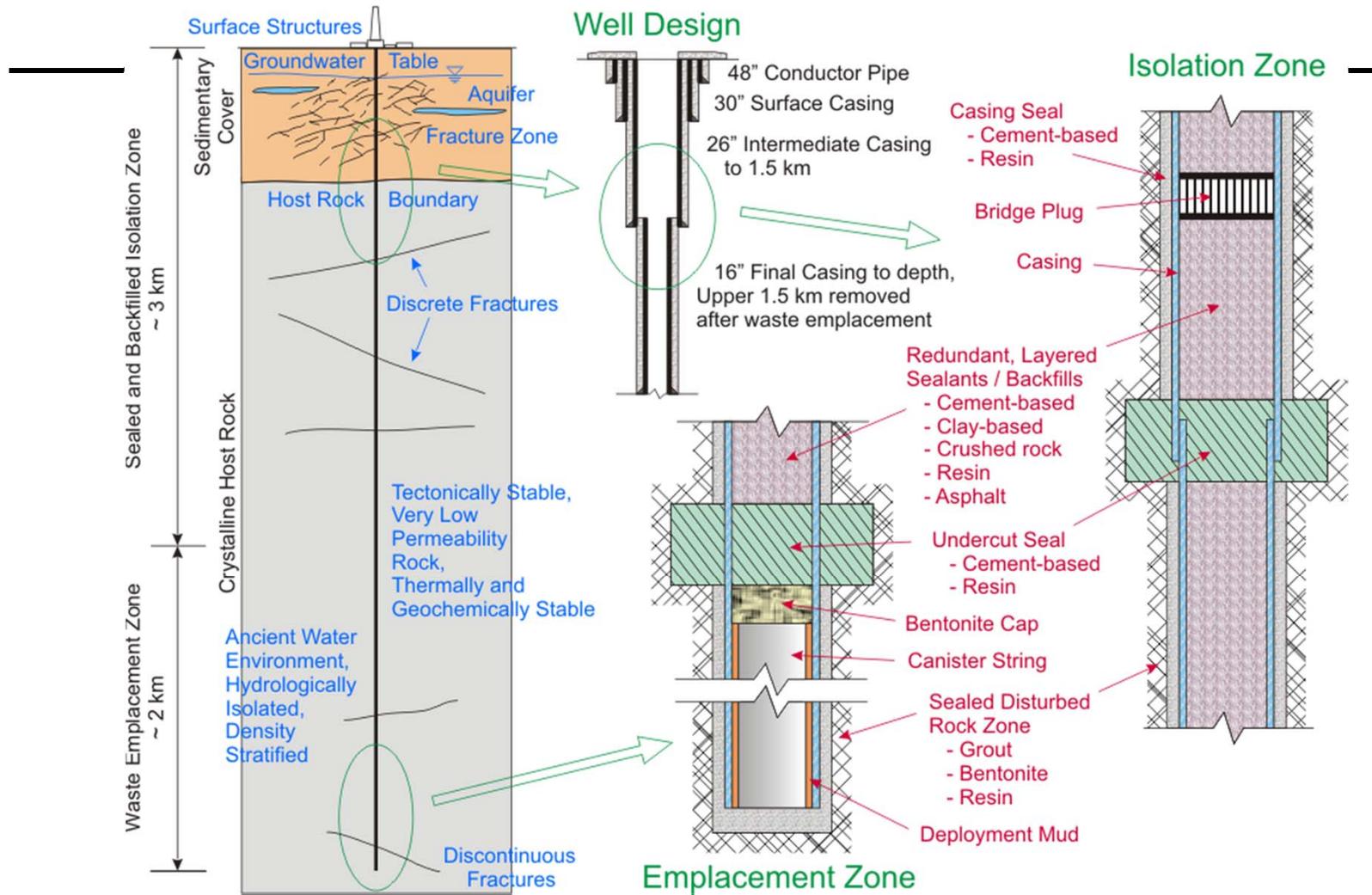


# Temperature and Upward Fluid Flow





# Composite Borehole Sealing





# Borehole Consortium

**MEMORANDUM OF UNDERSTANDING**  
 between  
 Sandia Corporation,  
 URS Energy and Construction, Inc.,  
 AREVA, Inc.,  
 CH2M Hill, Inc.,  
 Fluor Corporation,  
 Olympic Research, Inc.  
 DOSECC Exploration Services, LLC  
 University of Sheffield, UK  
 and  
 Massachusetts Institute of Technology

**SUBJECT:** Enable collaboration between the aforementioned parties to promote the construction and operation of a deep borehole demonstration to evaluate the feasibility of long-term disposal of nuclear waste.

## INTRODUCTION.

Sandia Corporation (Sandia) is a Delaware Corporation that operates Sandia National Laboratories (SNL) pursuant to Contract No. DE-AC04-94AL85000 with the United States Department of Energy (DOE).

Collectively, Sandia, URS, AREVA, CH2M, Fluor, Olympic Research, DOSECC, University of Sheffield and MIT are the Parties; individually, each is the Party.

### (a) Background.

Sandia has a number of missions defined by the National Nuclear Security Administration (NNSA) including nuclear energy research. As part of this mission Sandia has a responsibility to investigate technologies and approaches with the potential to offer significant improvements to the nuclear energy industry.

Disposal of high-level nuclear waste in deep boreholes is a relatively new technology that has not been demonstrated at a large field scale. Moreover, very little expertise in this technology exists. SNL has developed expertise in the deep borehole technology over the past couple of years through a LDRD and DOE-Nuclear Energy (NE) funding. However, the required expertise to implement and operate a deep borehole demonstration is wide ranging and much broader than SNL can provide. Additional expertise is required in many areas of project implementation including project management, construction planning, nuclear material handling and transportation, operations, procurement, safety, quality assurance, and basic science and engineering research. All of the entities below recognize that deep borehole disposal has the

Rev 4/2012

MOU between Sandia Corporation URS, AREVA, CH2M, Fluor, Olympic Research, DOSECC, University of Sheffield, MIT — (April 26, 2013)—page 1

## Consortium Structure

### Executive Group

Responsibilities:

- lead information exchange with outside groups
- establish working groups
- prioritize activities and lead projects
- release non-participating consortium members from the consortium

**Selection Process:** Initially by invitation from Sandia. Maximum of 2 members from each organization in the consortium.

### Consortium Chair

Responsibilities: Prioritizing activities and projects for deployment; establishing working groups; facilitating exchange of information

**Selection Process:** Nominees must be members of the executive group and are selected by majority vote of the executive group.

**Term of Service:** Two years, with possible renewal.

### Working Groups

Working groups have a specific mandate such as completion of a regulatory analysis. These groups include members of the executive group and members outside of the consortium.

### Other Participants

This could include participants such as the Expert Advisory Board.



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Underground burial is regarded as a simpler and more attractive alternative. Salt deposits encrusted into masses beneath the desert near Carlsbad, New Mexico, already hold containers with enough radioactive waste from America's weapons programmes to fill more than 40 Olympic swimming pools. Having spent half a century under the desert, the waste, power and heat were generated in the last few years, but the technology for building, monitoring and eventually sealing operations has been worked out, says Charles Brumley of the Nuclear Repository Development Organisation, a voluntary working group between Berlin, Switzerland.

To find out how a repository carved out of granite, a metamorphic rock, would hold up, French researchers built an underground laboratory and tunnel down over the carboniferous layers of salt. Heat and radioactivity testing show that a repository could be built in about ten years and then safely filled and recognised by at least one hundred metres before being sealed, says Mr Chumley.

Any permanent repository would be built in a dry geological region. Even so, water must seep in through cracks created by an earthquake, say, or a shifting land mass, allowing radioactive matter to get out. To prevent that, Czech engineers working with a German consultancy called the technology have built a "hydrostatic cage" to keep water out of a fissure beneath the salt. The Czech team of Lithovian and Polish scientists were in-

cluded by rock-shifting would have to be abandoned as a core public option, says Dr Gilfo, but that nuclear waste will be buried centuries far enough to melt, says, and some will worry that it might be a victim.

Some say the staff should not even be allowed to see the waste, says Dr Gilfo, but that nuclear waste will be buried centuries far enough to melt, says, and some will worry that it might be a victim.

Finland and Sweden have also built underground laboratories to test geological formations and packaging technologies. The results look good, says Claus Thoenes, the head of one, which operates the Finnish facility, the Äspö Hard Rock Laboratory. Reprocessors built at depths of half a kilometre are more to stable rock levels even over the decades of a future in age as they remodel Europe's landscape, he says.

Yet so far not a single permanent repository has been approved. Contractors will be expensive, but managing public opinion may pose a bigger problem. As an industry job puts it, the social science has become more difficult than the physical science, officials in France and Sweden reckon that building permits will be granted within a few years, but hostile public opinion can delay even advanced plans more than \$6 billion had been spent on America's Yucca Mountain repository when it was cancelled. People living near the Carlsbad site for weapons-related waste, in contrast, consented and compensated, however, and those elements for the proposed repository after a long consultation and several referendums.

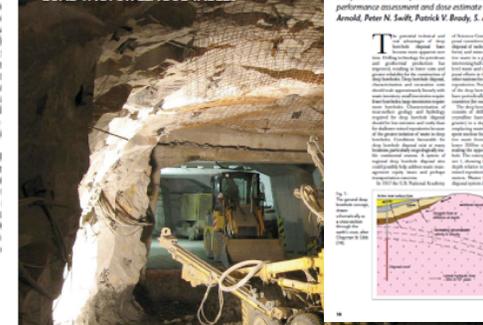
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### GOING UNDERGROUND REPOSITORY REIFT • DEEP BOREHOLE REVIEW

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06 April 2010 by Phil McKenna  
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### How to dispose of nuclear waste?

By Physics Today on April 7, 2010 3:33 PM | Comment | No Trackbacks

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NEI/Used Fuel Management Conference, May 7, 2013  
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