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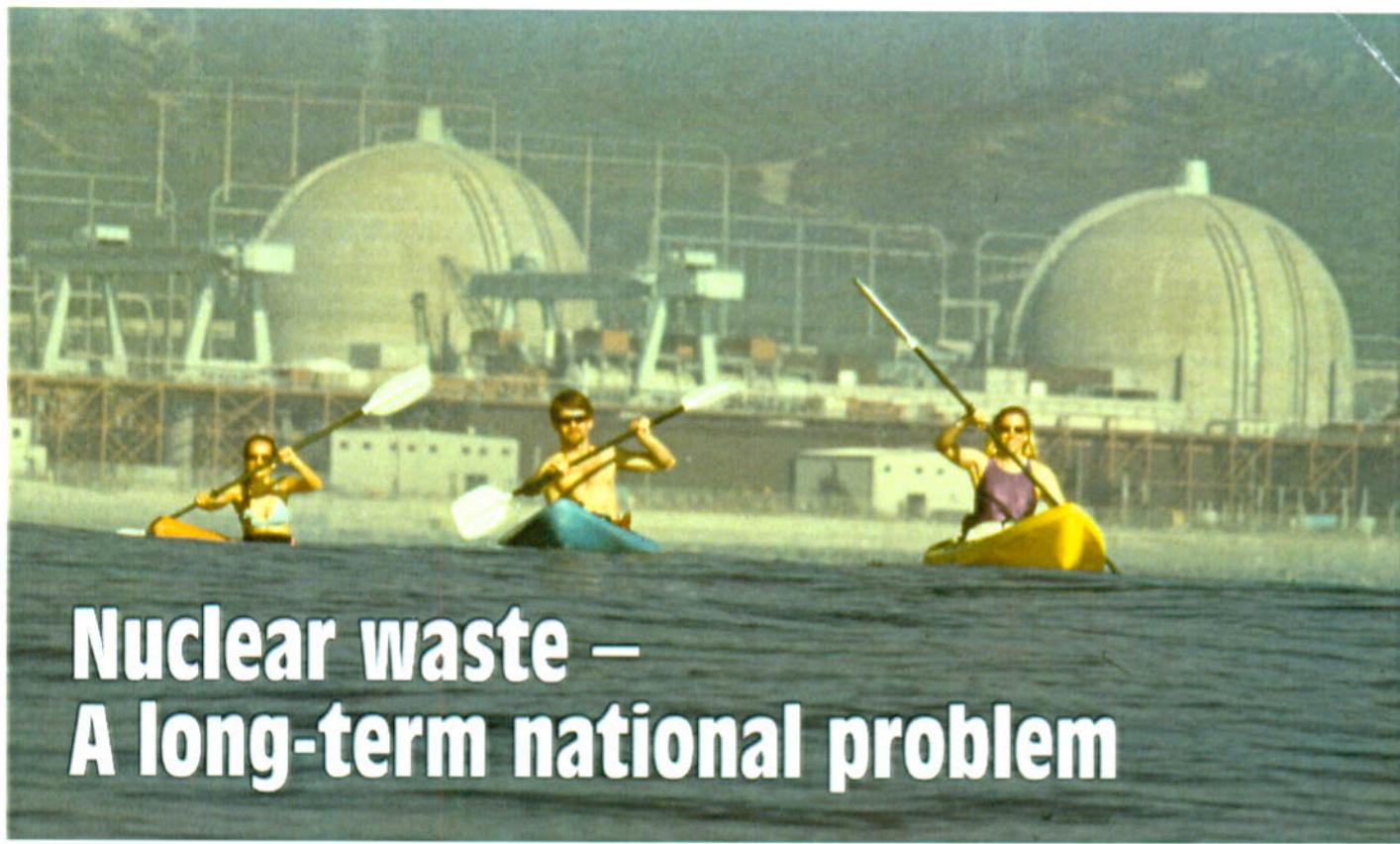
Yucca Mountain Project

— a briefing —



Contents

Nuclear waste – a long-term national problem	1
Spent nuclear fuel	2
High-level radioactive waste	3
Radioactivity and the environment	4
Current storage methods	6
Disposal options	7
U.S. policy on nuclear waste	8
The focus on Yucca Mountain	9
The purpose and scope of the Yucca Mountain Project	10
The approach for permanently disposing of waste	11
The scientific studies at Yucca Mountain	12
The proposed design for a repository at Yucca Mountain	14
Natural and engineered barriers would work together to isolate waste	16
Meticulous science and technology to protect people and the environment	18
Licensing a repository	20
Transporting waste to a permanent repository	21
The Environmental Impact Statement for a repository	22
Current status of the Yucca Mountain Project	23
Further information available on the Internet	24
Glossary	25



Nuclear waste – A long-term national problem

Highly radioactive nuclear waste could pose a risk to the health and safety of future generations if not properly managed. Currently, there are thousands of tons of highly radioactive nuclear waste (high-level radioactive waste and spent nuclear fuel) located in government and commercial storage facilities in 33 states throughout the country.

The total inventory of spent nuclear fuel and high-level radioactive waste in the United States could eventually exceed 100,000 metric tons of heavy

metal (one metric ton equals 2,204.6 pounds). Some elements of this waste are hazardous for only a few years; others are hazardous for centuries.

The safe, permanent disposal of highly radioactive waste is a complex scientific and engineering problem. It is also a difficult social and political issue. The United States is addressing these problems in an effort to isolate highly radioactive wastes until they no longer pose a significant risk to people or the environment. ■

- **Project Fact Sheets:**
Overview: *Yucca Mountain Project* (YMP-0026)

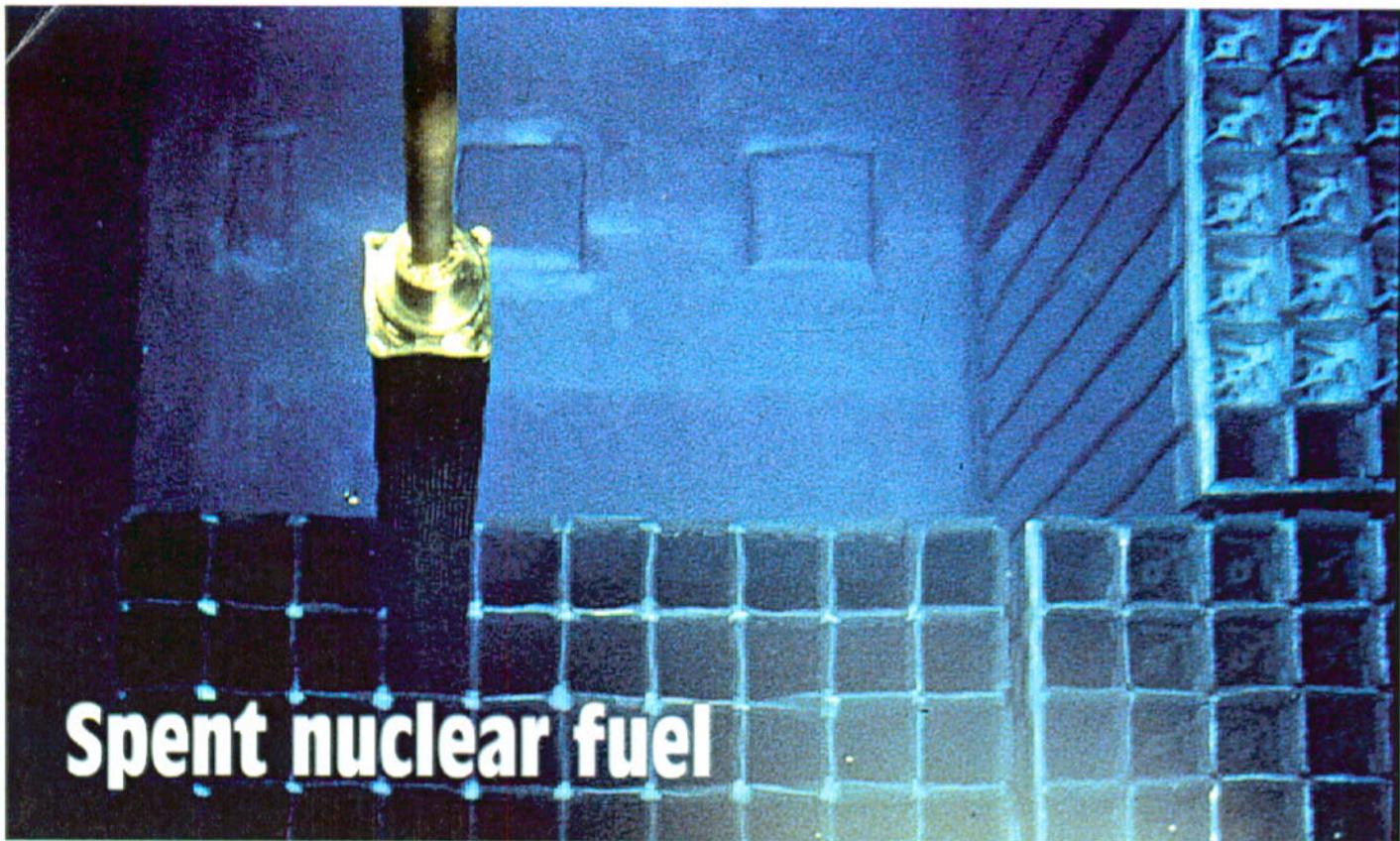
- **Project Documents:**
Viability Assessment of a Repository at Yucca Mountain -Overview: www.domino.ymp.gov/va/va.nsf

Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain: www.ymp.gov/timeline/eis/deis.htm

- **Other Information:**
League of Women Voters Education Fund. *The Nuclear Waste Primer*. Washington, D.C., 1993.

Photo: Kayakers paddle offshore from San Onofre Nuclear Generating Station in San Diego County, California. San Onofre is one of 72 U.S. power plants temporarily storing spent nuclear fuel.

Photo courtesy of Southern California Edison



Spent nuclear fuel

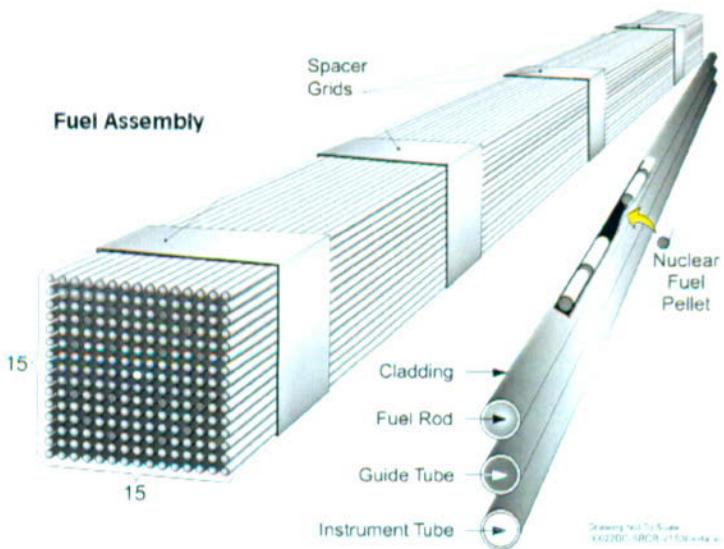
• **Project Fact Sheets:**
What Is nuclear fuel and waste? (YMP-0338)

• **Project Documents:**
Waste Form Characteristics Report: www.ymp.gov/documents/m2gg_a/index.htm

Photo: Spent nuclear fuel is removed from reactors and placed underwater in steel-lined cooling ponds.

Spent nuclear fuel is used fuel from government research reactors, from reactors on nuclear submarines and ships, and from commercial nuclear power utilities. Nuclear reactors use solid, ceramic pellets of enriched uranium for fuel. The pellets are sealed in strong metal tubes, which are bundled together to form a nuclear fuel assembly.

Depending on the type of reactor, fuel assemblies can be as long as 16 feet and weigh up to 1,200 pounds. After three to six years in a reactor, the fuel is no longer efficient for producing electricity and the assembly is removed. After removal, the assembly (now called "spent nuclear fuel") is highly radioactive and, therefore, requires heavy shielding and remote handling. Some elements in spent nuclear fuel remain radioactive for thousands of years. ■



Nuclear power plants produce about 20% of the electricity in the U.S.

- 104 operating reactors
- 14 decommissioned reactors
- 72 plant sites with spent fuel
- 5 DOE sites with spent fuel
- 33 states with spent fuel
- 40,000 metric tons of spent fuel exist in 2000
- 105,000 metric tons of spent fuel projected by 2035



High-level radioactive waste

High-level radioactive waste is a generic term for the radioactive waste that is a result of national defense programs, including clean-up efforts at national laboratories. This waste includes a highly radioactive residue from reprocessing spent nuclear fuel (almost entirely for defense purposes in the United States) and surplus plutonium from dismantled nuclear weapons.

All high-level radioactive waste will be in a solid form before the DOE transports it to a repository. Liquid wastes will be mixed with glass-forming materials and poured into steel canisters where the solution cools into solid glass. Surplus plutonium will be encased in a ceramic material, which immobilizes it and makes it unusable for weapons. ■

• **Project Fact Sheets:**
What is nuclear fuel and waste? (YMP-0338)

• **Project Documents:**
Waste Form Characteristics Report: www.ymp.gov/documents/m2gg_a/index.htm

Photo: A worker in protective clothing holds a ceramic disk that contains immobilized plutonium.

Waste Quantities Projected through 2035

Commercial spent fuel	105,000 metric tons
DOE spent fuel, including:	2,500 metric tons
Naval reactor fuel	65 metric tons
Research fuel loaned	
by U.S. to other countries	16 metric tons
Surplus plutonium	50 metric tons
High-level radioactive waste as glass	22,000 canisters



Radioactivity and the environment

- **Project Fact Sheets:**
Facts about radiation (YMP-0403)

Americans' average radiation exposure (YMP-0337)

- **Internet Links:**
National Institute of Health – What We Need to Know About Radiation: www.nih.gov/health/chip/od/radiation/

University of Michigan
Radiation Information Links: www.umich.edu/~radinfo/introduction/

Idaho State University
Radiation Information Network: www.physics.isu.edu/radinf/index.html

Health Physics Society of America: www.hps.org/

Radiation and radioactivity occur naturally in the physical world. Radiation is a form of energy, while radioactivity is the *spontaneous* emission of energy from certain elements, and from other elements under special conditions, in the form of particles or electromagnetic waves.

More than 80 percent of the radiation we are exposed to comes from such natural sources as sunlight, soil, and certain types of rocks. Cosmic rays filtering down through the atmosphere, and radon gas filtering up through the soil, are sources of natural, or background, radiation. It is present everywhere, all the time and varies greatly depending on our geographical location.

In addition, people are exposed to radiation from man-made sources such as color televisions, smoke detectors,

computer monitors, and X-rays. These sources account for less than one-fifth of our total radiation exposure.

The radiation produced from radioactive atoms is emitted in several forms, most commonly alpha and beta particles, and gamma rays. Alpha particles have the shortest range among these three types of radiation. They can travel only a few inches in the air and can be stopped easily by a sheet of paper or the outer layer of a person's skin. Alpha particles are harmful only if the radioactive source material is swallowed, inhaled, or absorbed into a wound.

Beta particles are more penetrating than alpha particles. They can travel through the air for several feet, but their penetrating power, too, is limited. Although they can pass through a sheet of paper, materials such as a

thin sheet of aluminum foil or glass can stop them. Like alpha particles, they cause their most serious effects if swallowed or inhaled.

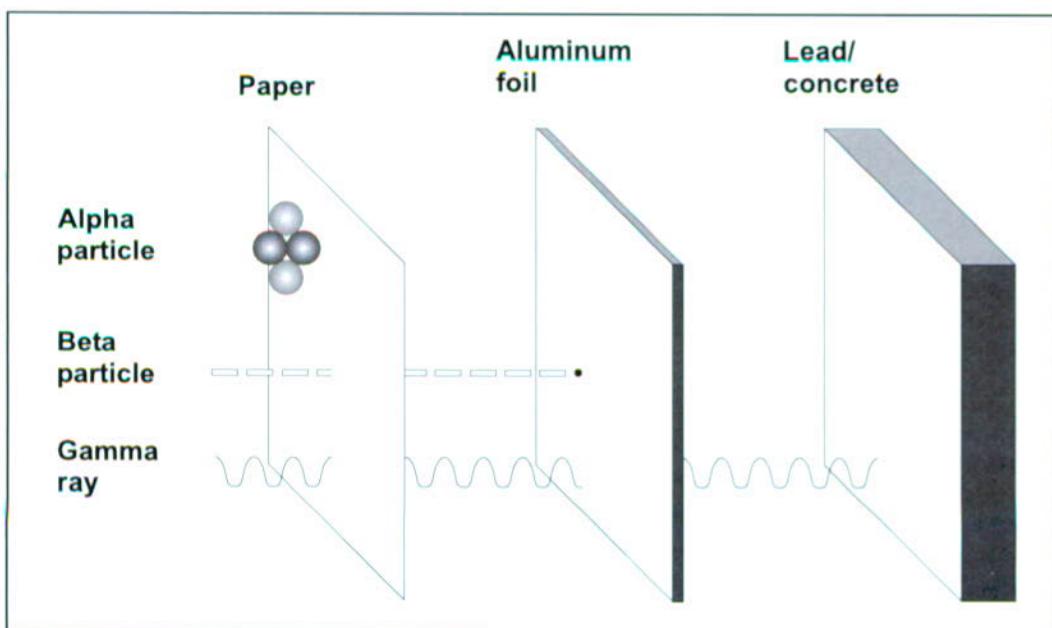
Some radioactive material that emits beta particles could, for example, be attached to dust we might breathe in, or cling to food we might eat. In such cases, some of the material would leave the body through natural elimination processes. Some, however, may be retained in various organs where chemicals in living cells would be ionized and potentially damaged when the beta particles are emitted.

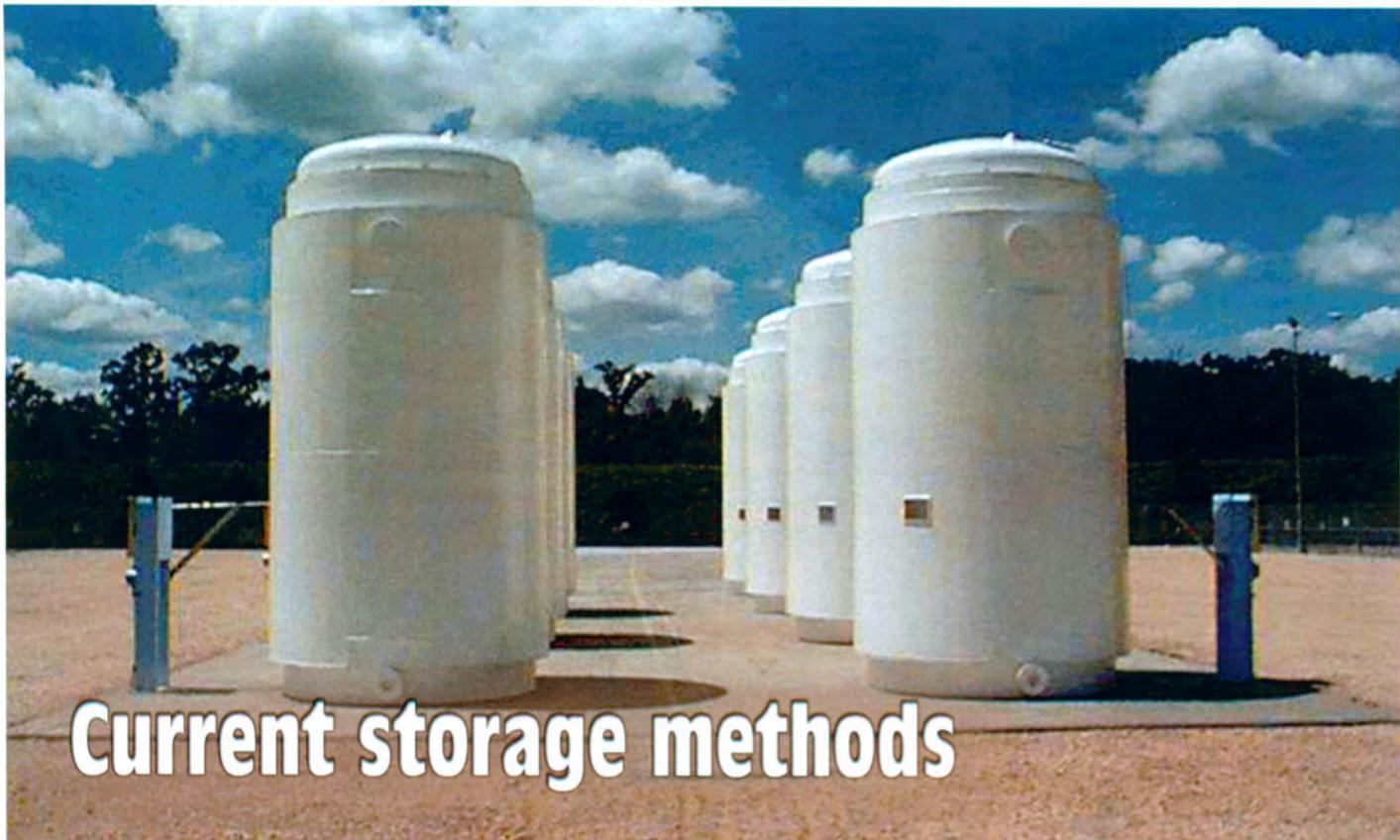
Unlike alpha or beta particles and their relatively short ranges, gamma rays are electromagnetic energy, with much greater penetration power. They are more energetic than X-rays. This type of radiation requires shielding with such materials as concrete, lead,

steel, or water. Water is used to shield workers from neutron radiation emitted by spent nuclear fuel assemblies at nuclear power plants.

In the United States, a person's average exposure to radiation is about 360 millirem per year. A millirem measures the effects of radiation on the human body. Roughly 300 millirem come from natural sources of radiation, and 60 millirem come from man-made sources, primarily medical procedures.

People living in the northwest region of Washington state receive about 240 millirem per year, on average, from natural and man-made sources, whereas residents in the state's northeast region receive doses of about 1,700 millirem per year, most of it from radon that occurs naturally in the rock and soil. ■





Current storage methods

- Project Fact Sheets:
Alternatives to Yucca Mountain (YMP-0017)
- Internet Links:
Nuclear Regulatory Commission High Level Waste Program Web Site: www.nrc.gov/NMSS/DWM/hlw.htm

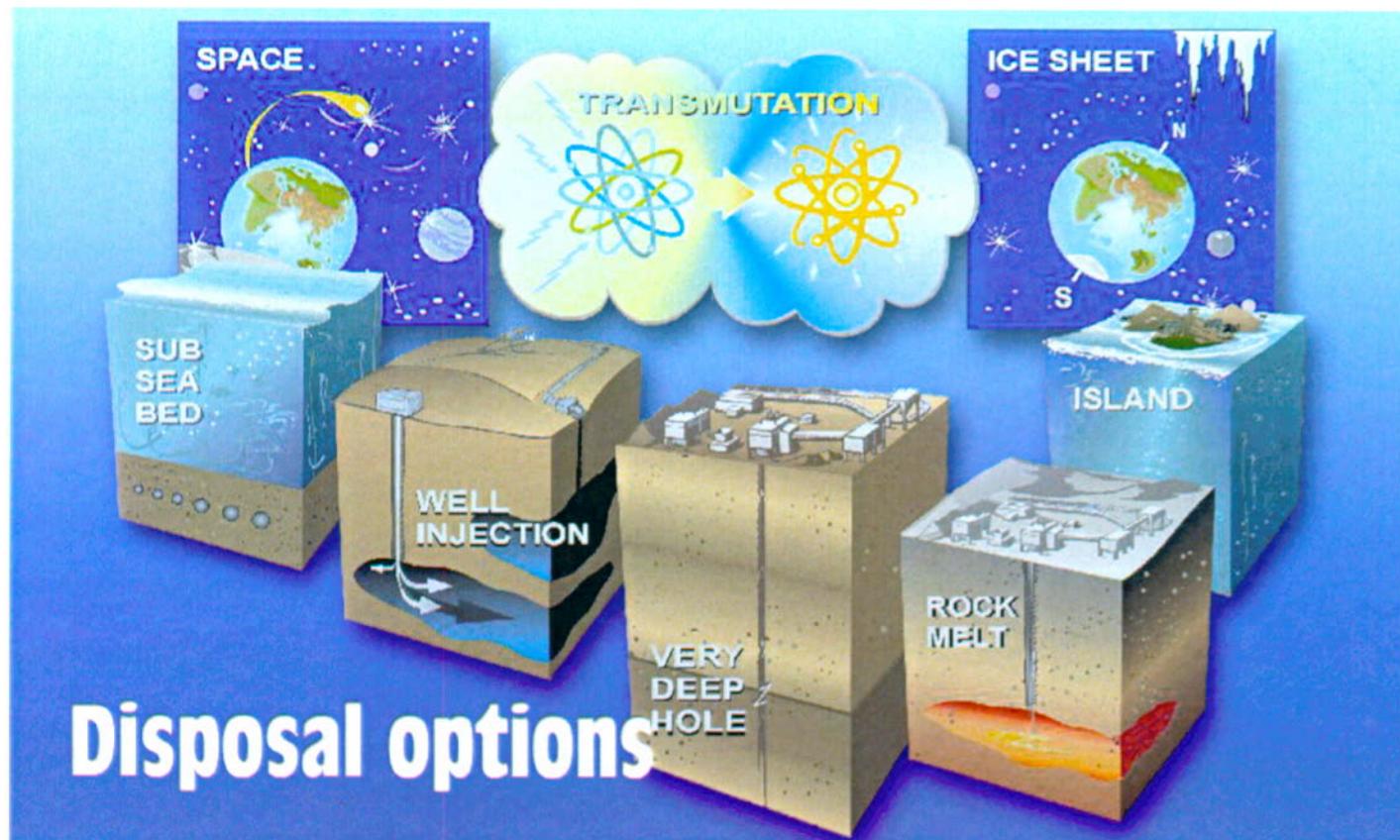
Photo: Above-ground, dry-cask storage containers for temporary isolation of spent nuclear fuel.

Commercial nuclear power plants and DOE facilities can use both wet and dry storage of nuclear waste. After removing spent nuclear fuel from a reactor, operators store it in pools of water contained in steel-lined concrete basins. Besides helping to cool the fuel, the water protects workers and the public from radiation.

After spent nuclear fuel has cooled, it is sometimes moved to a "dry" environment above ground, using heavy containers or casks made of steel and/or concrete. Casks are either placed upright on concrete pads or

stored horizontally in metal canisters in concrete bunkers. DOE facilities store high-level radioactive waste in "wet storage" canisters.

Current storage sites for nuclear waste are located in a mixture of urban, suburban, and rural environments in 33 states; most are located near large bodies of water. Modern storage methods shield any harmful radiation. However, these structures are designed for temporary storage only, and they will not isolate the waste for the thousands of years it will be hazardous. ■



Disposal options

For decades, scientists have studied many options for permanently disposing of nuclear waste, including leaving the material at current storage sites, burying it in the ocean floor, putting it in polar ice sheets, sending it into outer space, and placing it deep underground in a geologic repository. These and studies of other options are documented in the U.S. Department of Energy's 1980 *Final Environmental Impact Statement for the Management of Commercially Generated Radioactive Waste*. The Record of Decision for that environmental impact statement designated deep geologic repositories as the preferred means of disposal.

A 1990 report from the National Academy of Sciences states that there is *"a worldwide scientific consensus that deep geological disposal, the approach being followed by the United States, is the best option for disposing of high-level radioactive waste."* In 1995, an international group of scientists issued a similar opinion that affirmed the consensus for geologic disposal. This report is entitled *The Environmental and Ethical Basis of Geological Disposal of Long-Lived Radioactive Wastes: A Collective Opinion of the Radioactive Waste Management Committee of the OECD Nuclear Energy Agency.* ■

- **Project Fact Sheets:**
Why do scientists think a repository will work? (YMP-0004)

Alternatives to Yucca Mountain (YMP-0017)

Illustration: Various disposal alternatives were considered by the Department of Energy.



U.S. policy on nuclear waste

Internet Links

The Nuclear Waste Policy Act, As Amended, February 1995. www.rw.doe.gov/progdocs/nwpa/nwpa.htm

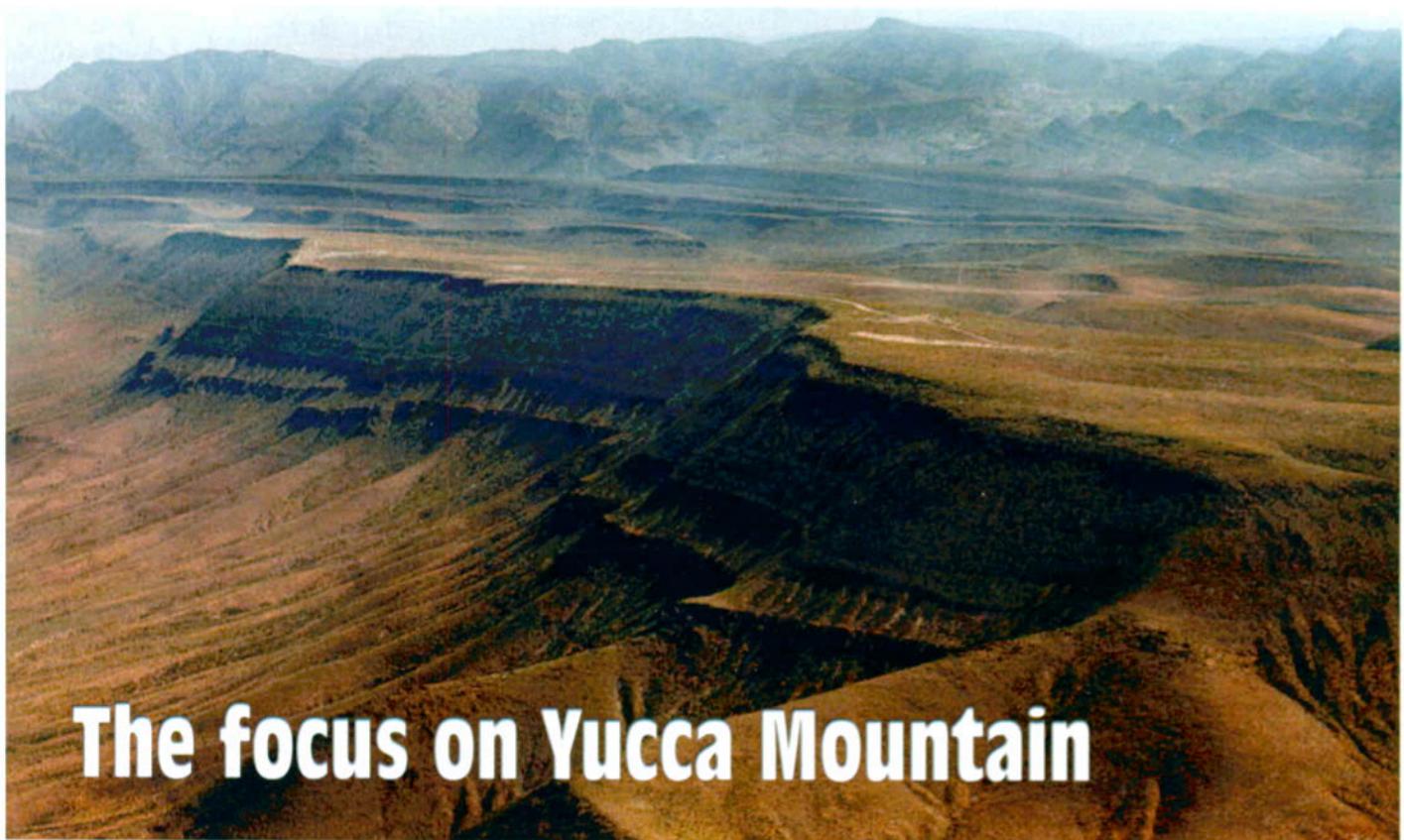
In 1982, Congress enacted a law called the Nuclear Waste Policy Act. The Act established a comprehensive national program for the permanent disposal of highly radioactive wastes from commercial nuclear utilities and national defense programs. It directs the U.S. Department of Energy to site, design, construct, operate, and close a deep geologic repository. This law is based on the principle that the generation benefitting from nuclear materials is responsible for safely disposing of the nuclear wastes we create, rather than leaving a dangerous environmental hazard to future generations. The Act also recognizes that any solution to this problem must include public and state involvement.

In addition, the Act outlines the legal requirements for a site recommendation by the Secretary of Energy, for a

decision by the President, for approval by Congress, and for licensing by the Nuclear Regulatory Commission. The Energy Policy Act of 1992 directs the U.S. Environmental Protection Agency to establish standards for a repository to protect public health and safety and assigns the U.S. Nuclear Regulatory Commission the responsibility to regulate the program to ensure compliance with those health and safety standards. ■

Mission of the Yucca Mountain Site Characterization Office:

"Provide the basis for a national decision regarding the development of a repository for spent nuclear fuel and high-level waste at Yucca Mountain."



The focus on Yucca Mountain

Upon enactment of the 1982 Nuclear Waste Policy Act, the U.S. Department of Energy originally evaluated nine sites in six different states as locations for a potential repository. President Ronald Reagan then approved three of these sites for more detailed study. These sites were Hanford, Washington; Deaf Smith County, Texas; and Yucca Mountain, Nevada.

Yucca Mountain was included in the three sites because scientists have long considered it promising due to the area's arid climate, remoteness from population centers, stable geology, deep water table, and closed water basin. Yucca Mountain is also located on remote federal land, partly within

the secure confines of the Nevada Test Site, which has hosted numerous nuclear-related projects for decades.

Faced with schedule delays and escalating costs for studying three sites, Congress amended the Nuclear Waste Policy Act in 1987 and directed the DOE to study only one site: Yucca Mountain. The State of Nevada disputed this action, and currently opposes the Yucca Mountain Project on the basis that it *"involves fundamental issues of a state's right to determine its economic and environmental future and to consent or object to federal projects within its borders."*¹ ■

* Project Fact Sheets:
Why do scientists think a repository will work? (YMP-0004)

Alternatives to Yucca Mountain (YMP-0017)

* Internet Links:
Office of Civilian Radioactive Waste Management Program:
www.rw.doe.gov/homejava/homejava.htm

Nevada Nuclear Projects Web Site: www.state.nv.us/nucwaste/yucca/state01.htm

Photo: Yucca Mountain, a flat-topped ridge running six miles from north to south, ranges from about 6,000 feet in elevation at the north end to about 4,000 feet at the south end.

¹ Nevada Nuclear Projects Web Site: www.state.nv.us/nucwaste/yucca/state01.htm



The purpose and scope of the Yucca Mountain Project

- **Project Fact Sheets:**
Overview: Yucca Mountain Project (YMP-0026)

The decision process for a repository (YMP-0404)

- **Project Documents:**
Civilian Radioactive Waste Management Program Plan: www.rw.doe.gov/pprev3.pdf
- **Internet Links:**
Office of Civilian Radioactive Waste Management Program: www.rw.doe.gov/homejava/homejava.htm

U. S. Environmental Protection Agency – Yucca Mountain Page: www.epa.gov/rpdweb00/yucca/

U. S. Nuclear Regulatory Commission High Level Waste Program Web Site: www.nrc.gov/NMSS/DWM/hlw.htm

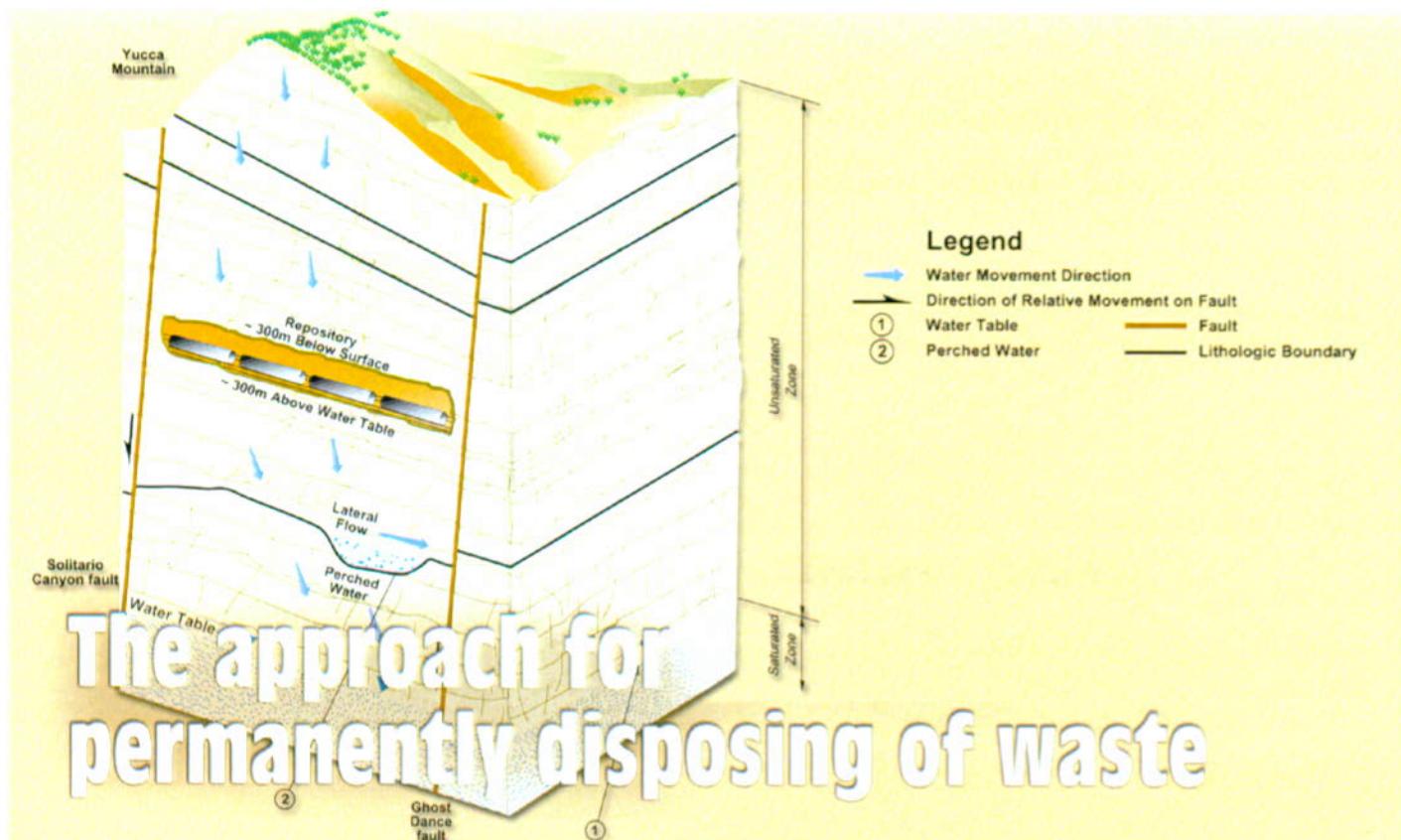
Photo: A view of testing, construction, and maintenance facilities at the North Portal of Yucca Mountain's five-mile long tunnel for exploratory studies.

The purpose of the Yucca Mountain Project is to determine if a potential repository at Yucca Mountain can isolate nuclear waste in a manner sufficient to protect the health and safety of current and future generations. For nearly 20 years, scientists have extensively studied Yucca Mountain's geology, hydrology, chemistry, and climate. Concurrently, experts have designed waste containers and other barriers that would work with the natural environment to isolate the waste in the repository.

Using the information from studies of the area, project scientists have

performed extensive analyses to determine if a potential repository at Yucca Mountain can meet U.S. Nuclear Regulatory Commission regulations and U.S. Environmental Protection Agency radiation exposure standards for 10,000 years.

The U.S. Department of Energy is currently working to provide comprehensive scientific information as a basis for future repository decisions and will provide opportunities for the public and affected units of government to participate in the decision process. ■



The approach for permanently disposing of waste

The United States' approach for permanently disposing of nuclear waste is to place it in a deep geologic repository. All radioactive waste placed in a repository would be solid in form (e.g., metals, ceramics, and glass). Repository workers would seal the waste in extremely durable corrosion-resistant containers before placing it in a repository. Within these containers and deep underground, the radiation emitted from the waste would not harm people or the environment.

Over tens of thousands of years, if enough water came in contact with the waste containers, it could eventually corrode through them. If enough water reached the solid waste itself, it could eventually break down into tiny radioactive particles that could be carried into the groundwater. Therefore, a repository is designed to keep the radioactive materials dry.

Yucca Mountain's environment provides a number of natural barriers and processes that would prevent water from contacting the waste, deteriorating it, and moving it into the human environment. These natural barriers and processes include the dry climate, the unusually thick rock above and below the potential repository, minerals within the rock that attract and hold radioactive particles, a very deep water table, and a closed groundwater basin with geologic boundaries that restrict the groundwater from flowing beyond the basin.

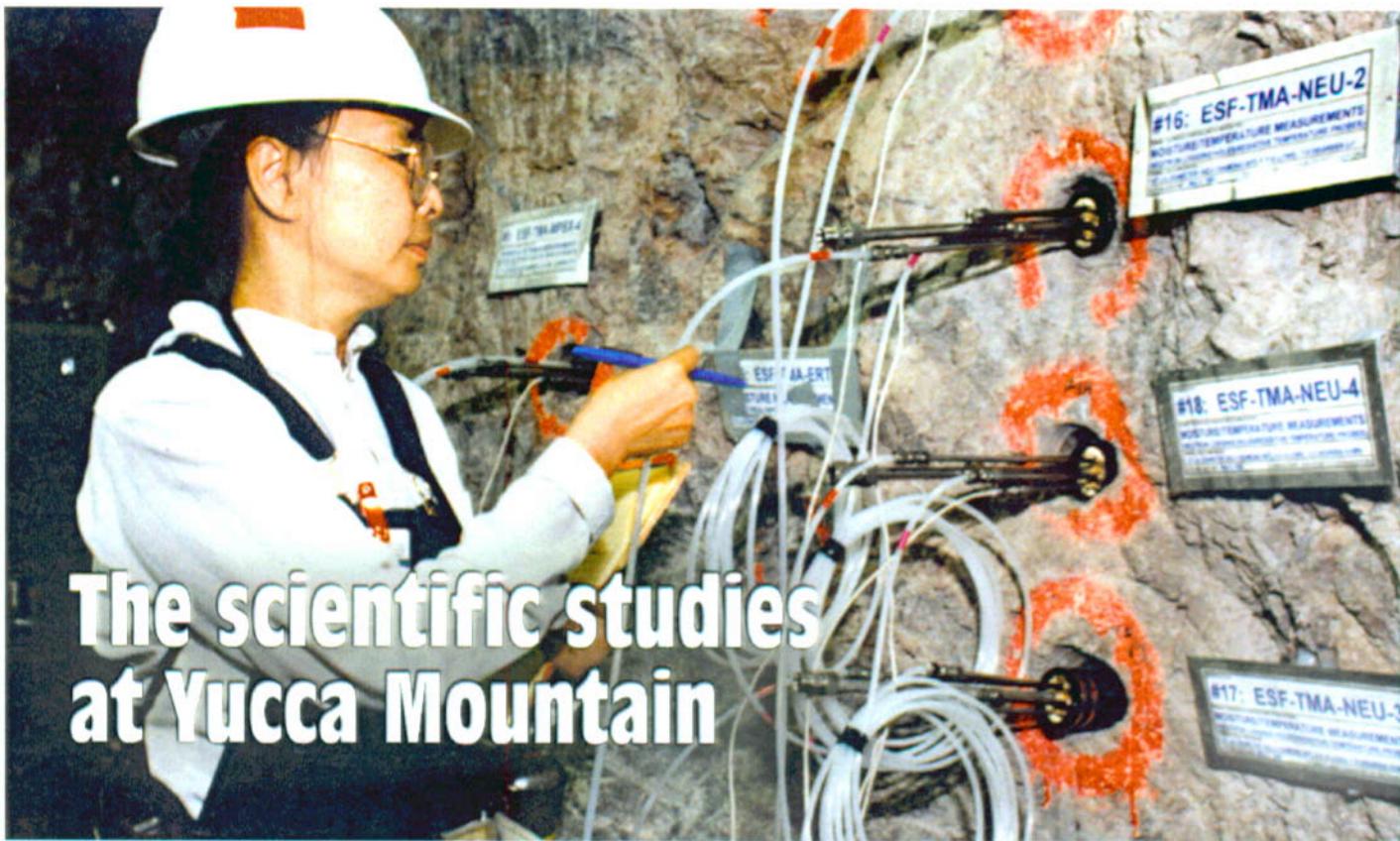
The United States' strategy (called "defense-in-depth") is to engineer a nuclear waste repository based on a system of multiple, independent, and redundant barriers, designed to ensure that failure in any one barrier does not result in failure of the entire system. ■

Project Fact Sheets:
Nature and engineering working together for a safe repository (YMP-0203)

Project Documents:
Yucca Mountain Site Description: www.ymp.gov/documents/ymsdd/index.htm

Viability Assessment Volume 1: Introduction and Site Characteristics: www.domino.ymp.gov/va/vavol1.nsf

Illustration: A cutaway view of the rock layers and a representative emplacement tunnel (drift) deep beneath the mountain's surface



The scientific studies at Yucca Mountain

- **Project Fact Sheets:**

The TBM and its role in creating an underground laboratory (YMP-0001)

The Exploratory Studies Facility (YMP-0395)

Oklo. A natural nuclear reactor (YMP-0010)

A study of how fluid moves through rock (YMP-0006)

Studying the movement of rock and earthquakes (YMP-0344)

Volcanoes and Yucca Mountain (YMP-0341)

Heating tests help scientists predict rock behavior (YMP-0024)

Managing heat in a repository at Yucca Mountain (YMP-0204)

Yucca Mountain Site Characterization environmental field programs (YMP-0399)

Photo: Single-heater test measures transfer of moisture and temperature in volcanic tuff of Alcove 5 of the Exploratory Studies Facility.

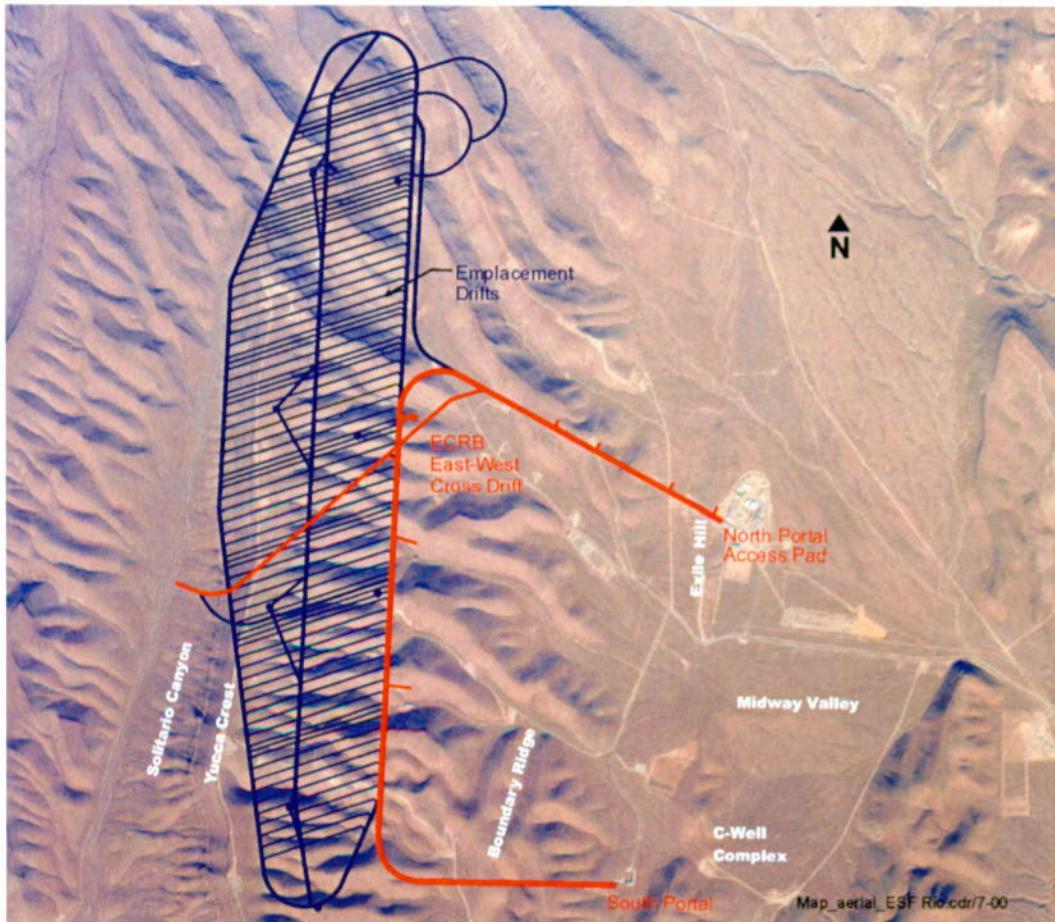
Over the past two decades, hundreds of scientists have performed in-depth studies of Yucca Mountain's geology, hydrology, chemistry, and climate. Using this information, experts have designed repository systems that work within the mountain's specific environment to isolate nuclear waste. Project scientists also use sophisticated computer modeling techniques to understand the various processes and events that could occur in the future and their impact on the safety of the potential repository. These studies and analyses have provided information and increased our understanding of the following:

- The different environmental characteristics of Yucca Mountain

and the surrounding area that could affect the performance of an underground repository (e.g., climate, water flow, seismic activity, volcanism)

- The physical characteristics of the different rock layers (e.g., porosity, dryness, mineral content, fractures), from the surface of the mountain to below the water table
- The processes that affect how water enters and moves through the rock above the water table
- The physical and chemical changes to the rock that would result from excavating emplacement tunnels and from the heat generated by nuclear waste

- The different environmental conditions in the emplacement tunnels and the various processes that could adversely affect the engineered barriers
- The physical properties of spent nuclear fuel and high-level radioactive waste as they decay over time and their deterioration processes if water eventually reached them in a repository
- The groundwater flow system and how radioactive particles could move from the repository to the human environment
- The statistical chances of various disruptive events occurring (e.g., earthquakes, volcanic activity, human intrusion), the effects of these events on repository structures and systems, and the consequences to people and the environment ■



• **Project Documents:**
Biosphere Process Model Report: www.ymp.gov/documents/m2hu_a/index.htm

Disruptive Events Process Model Report: www.ymp.gov/documents/m2hj_a/index.htm

Engineered Barrier System Degradation, Flow, and Transport Process Model Report: www.ymp.gov/documents/m2hn_a/index.htm

Integrated Site Model Process Model Report: www.ymp.gov/documents/m2hk_a/index.htm

Unsaturated Zone Flow and Transport Process Model Report: www.ymp.gov/documents/amr/26346/26346.pdf

Near-Field Environment Process Model Report: www.ymp.gov/documents/m2jc_a/index.htm

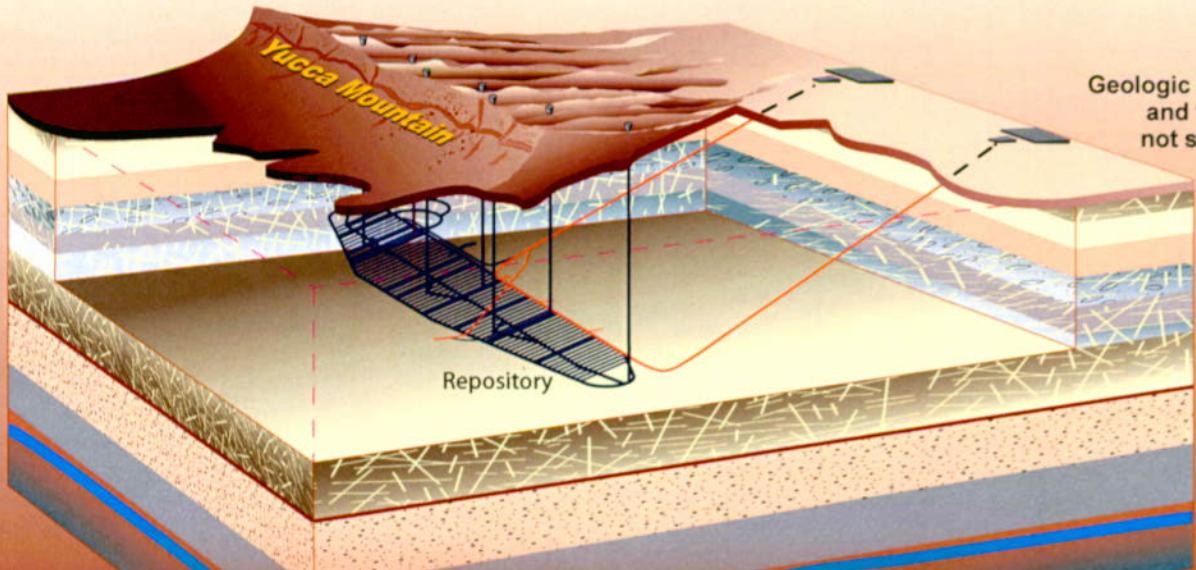
Waste Package Degradation Process Model Report: www.ymp.gov/documents/amr/25927/25927.pdf

Saturated Zone Flow and Transport Process Model Report: www.ymp.gov/documents/m2hd_b/index.htm

Waste Form Degradation Process Model Report: www.ymp.gov/documents/amr/25541/25541.pdf

Total System Performance Assessment—Site Recommendation Methods and Assumptions: www.ymp.gov/documents/m2jh_b/index.htm

Photo/Illustration: Red lines show location of existing study drifts. Dark blue lines show location of emplacement drifts, were a repository to be built.



The proposed design for a repository at Yucca Mountain

- **Project Fact Sheets:**
Nature and engineering working together for a safe repository (YMP-0203)

Managing heat in a repository at Yucca Mountain (YMP-0204)

Heating tests help scientists predict rock's behavior (YMP-0204)

- **Project Documents:**
Reference Design Description for a Geologic Repository: www.ymp.gov/documents/rdd/index.htm

Subsurface Development Design: www.domino.ymp.gov/va/support/subsurfdevdes.nsf/WebFirst?OpenView

Waste Emplacement Design: www.domino.ymp.gov/va/supportwastemplacementdesign.nsf

Illustration: Schematic shows components of the proposed repository design in relation to the geology and geography of Yucca Mountain.

The U.S. Department of Energy has developed a repository design concept that would work with the natural environment of Yucca Mountain to isolate highly radioactive materials for tens of thousands of years. According to the preliminary design, the underground repository would consist of about 60 miles of tunnels carved in solid rock about 660 feet to about 1400 feet beneath the surface of the mountain, and between 570 feet and 1200 feet above the water table.

Because the waste is highly radioactive, and will emit heat for hundreds of years, scientists have performed extensive tests using electric heaters underground in the poten-

tial repository rock to observe how high temperatures affect the rock and moisture movement. Based on these and other tests, the design specifies distances between each repository tunnel and precise waste-package arrangements within the tunnels to obtain an even linear heat distribution for the long-term effectiveness of the repository.

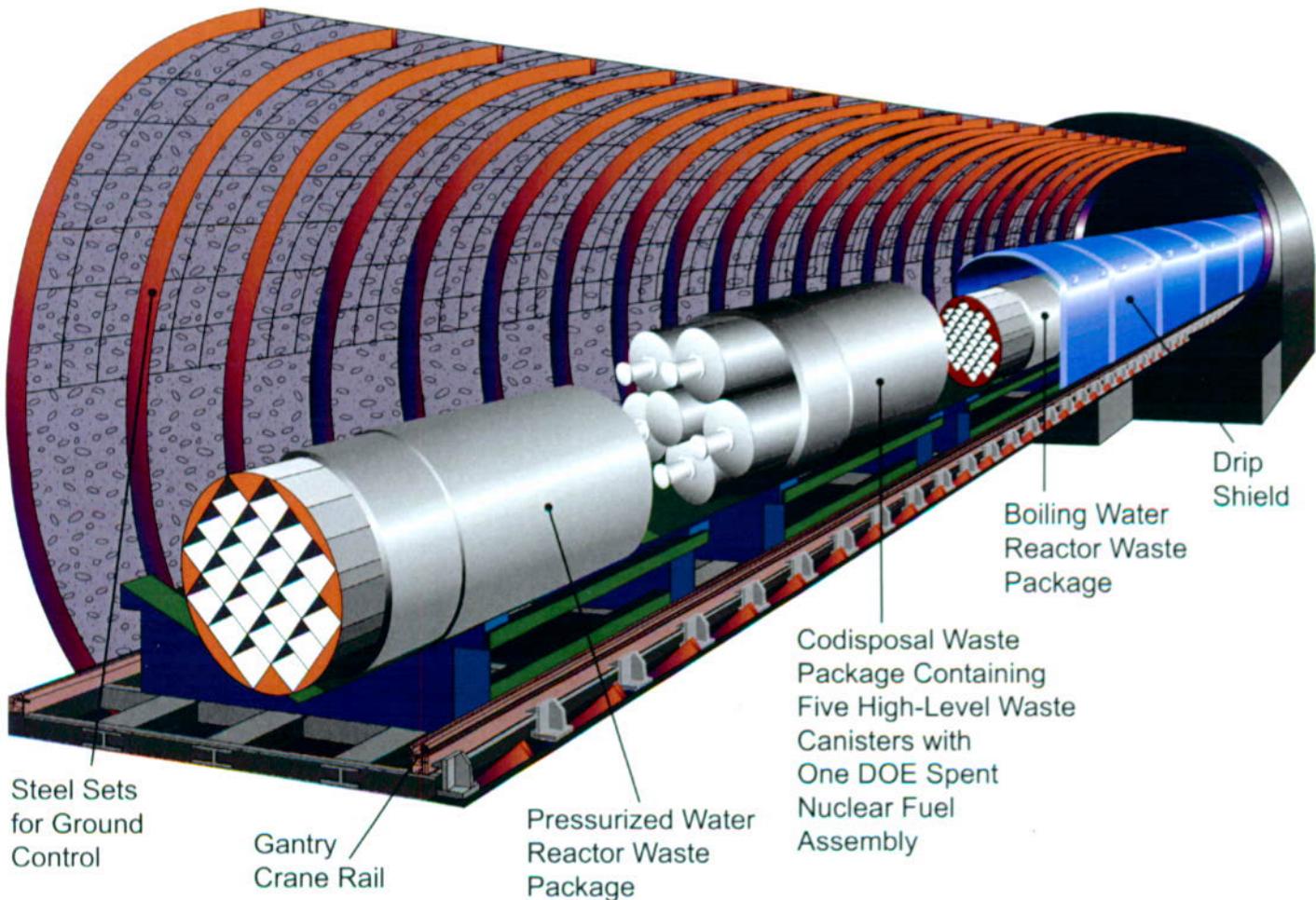
It would take approximately 24 years to transport the 70,000 metric tons of spent nuclear fuel and high-level radioactive waste that Yucca Mountain would contain. Using remote-handling equipment, repository workers would remove the waste from the shipping containers and place it in specially designed storage

containers, called waste packages. The waste packages will be double-shelled, with the outer layer made of a highly corrosion-resistant metal alloy, and a structurally strong inner layer of stainless steel. Protected from radiation by shielding equipment, workers would seal the waste packages and then use rail cars to move them into the underground repository. Robotic equipment would place the waste packages in

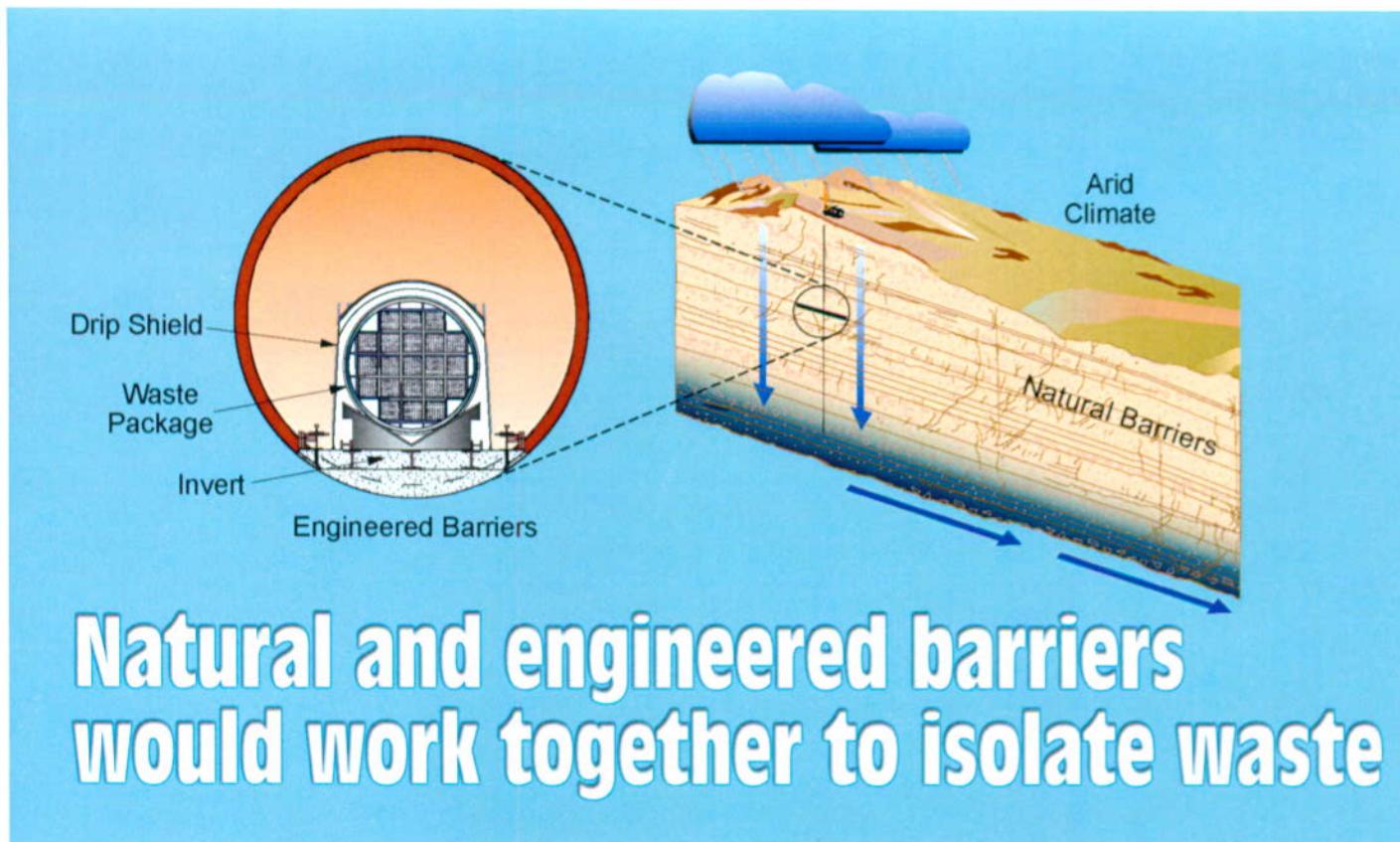
the emplacement tunnels.

The engineered barriers inside the emplacement tunnels would include steel/aggregate inverts in the floors and metal (nickel-based Alloy 22) support pallets to hold the containers off the floor. In addition, drip shields, made of corrosion-resistant titanium, would be placed over the waste packages to divert moisture and protect them from possible falling rock or debris. ■

Illustration: Concept of various waste packages that would be emplaced in a potential repository. Drip shield, shown in blue, would cover each waste package.



Drawing Not to Scale
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Natural and engineered barriers would work together to isolate waste

- **Project Fact Sheets:**
Nature and engineering working together for a safe repository (YMP-0203)

- **Project Documents:**
Engineered Barrier System Degradation, Flow, and Transport Process Model Report: TDR-EBS-MD-000006
REV 00 ICN 01: www.ymp.gov/documents/m2hn_a/index.htm

Reference Design Description for a Geologic Repository:
www.ymp.gov/documents/rdd/index.htm

Map (on facing page): If any radioactive particles were transported out of the repository by water, they would be carried underground toward Death Valley. The trip would take thousands of years.

Water is the primary means by which radioactive elements could be transported from a repository. In the preliminary design for the repository, both the natural and engineered systems work in concert to keep the waste dry and to prevent it from breaking down and moving into the human environment. On average, Yucca Mountain receives about 7.5 inches of combined rain and snow per year; nearly all the precipitation (about 95 percent) runs off, evaporates, or is taken up by plants. The remaining water would seep through hundreds of feet of rock before reaching the potential repository level.

Most of the water moving downward past the repository level travels through fractures in the rock. The heat from the emplacement drifts (tunnels) would force most of the

water away from the drifts and cause it to seep through rock fractures between the drifts. Natural hydrologic processes, such as the tendency of water to flow around tunnel walls, would further limit the amount of water that could encounter the waste.

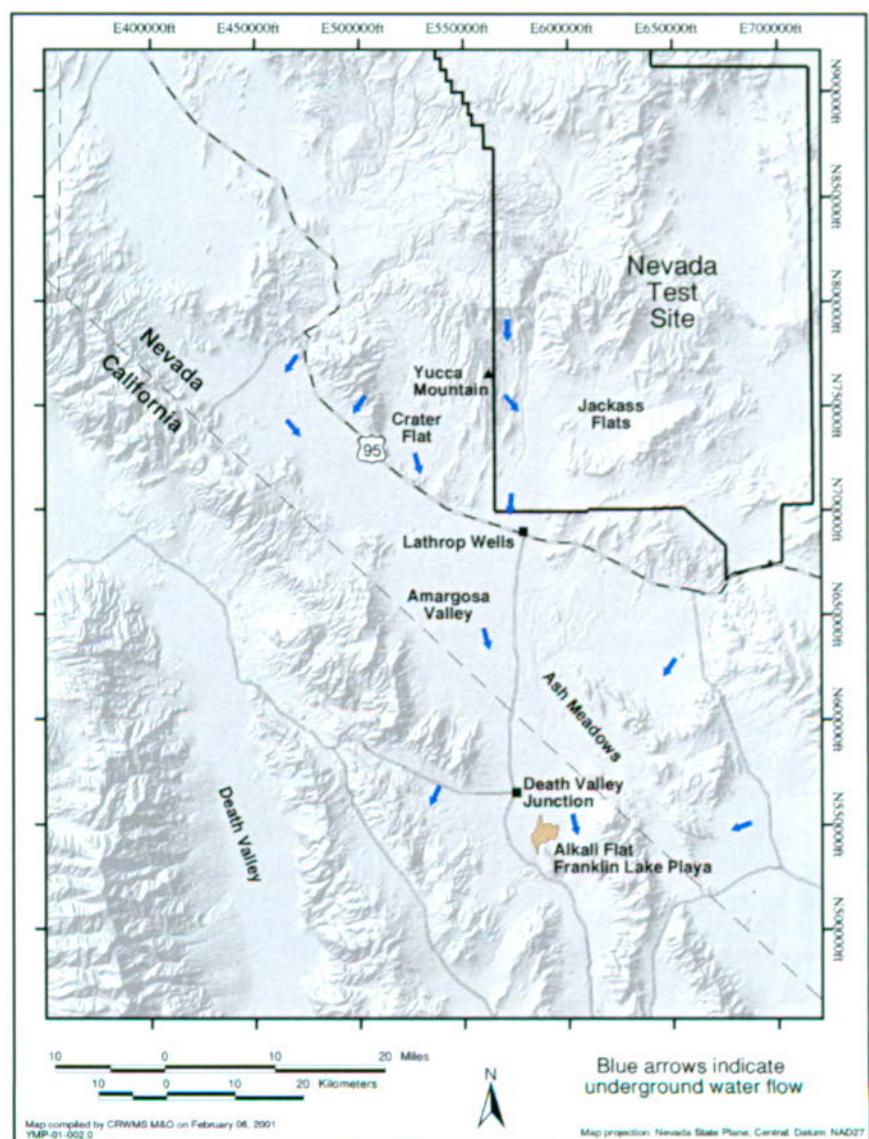
To further limit water from reaching the waste, the preliminary repository design includes highly corrosion-resistant drip shields placed over the waste packages. As long as the drip shields are intact, dripping water will not contact the waste packages. If water were to drip on a shield, it would take thousands of years for it to eventually wear a hole through the shield and reach the waste package beneath it. It would then take thousands more years for water to wear through the double-shelled, corrosion-resistant waste packages.

If water were able to make it through all of these barriers and breach a waste package, it would have to dissolve the solid form of the waste itself. By then, due to radioactive decay, only a few elements in the waste would still be hazardous. Water would also have to seep through the steel/aggregate floor of the emplacement tunnel and carry any remaining radioactive particles from the dissolved waste into the rock below the repository.

At this point, the natural barriers could provide additional protection. It would take hundreds more years for water to carry radioactive particles down through hundreds of feet of rock before they could reach the water table. Moreover, the rock contains minerals called zeolites that would filter many of the radioactive particles from the water. These minerals attract and hold radioactive particles in much the same way as salt in a water softener attracts and holds elements in hard water.

The rock would capture some of them, slow others, and reduce their concentration. Any remaining radioactive particles that reached the water table would move very slowly with the groundwater through numerous geologic units. It would take hundreds more years for any remaining particles to move to an area where people could possibly access the

water through a well. If any radioactive particles did get into the groundwater, they would not migrate any farther than the geologic boundaries of the closed Death Valley Basin. This basin is an area where the hydrologic gradient angles downward from all sides toward the center and the groundwater does not flow beyond the basin. ■



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- **Project Documents**

Description of the Organizations with the Yucca Mountain Project and Their Functions: www.ymp.gov/toc/functional/func.htm

- **Internet Links:**

Clark County, Nevada, Nuclear Waste Division: www.co.clark.nv.us/complan/Nucwaste.htm

Environmental Protection Agency – Yucca Mountain Page: www.epa.gov/rpdweb00/yucca/

Eureka County, Nevada, Nuclear Waste Page: www.yuccamountain.org/

Inyo County, California, Yucca Mountain Repository Assessment Office: www.sdsc.edu/Inyo/yucca-pg.htm

The Yucca Mountain Project involves hundreds of the world's top experts in nuclear waste, the environmental sciences, and engineering from local and federal government, academia, and private industry. The U.S. Geological Survey and the national laboratories—which include Lawrence Berkeley, Sandia, Los Alamos, and Lawrence Livermore—provide expertise and technology to the Project. Bechtel SAIC Company, LLC is the Project's management and operating contractor, providing scientific and technical expertise, support services and administration of the Project's activities. Nye County, Nevada; the University of Nevada Reno; and the University of Nevada

Las Vegas perform many Project-related studies as well.

In addition, the Project is regulated and reviewed by experts in the following organizations:

- **The Nuclear Waste Technical Review Board** – evaluates the technical and scientific validity of site characterization activities and activities relating to the packaging or transportation of high-level radioactive waste or spent nuclear fuel. Congress created this board and directed the National Academy of Sciences to nominate experts who are eminent in the fields of science and engineering to serve as the Board's members. The Presi-

dent subsequently appointed the members. Twice a year, the Board reports its conclusions and recommendations to Congress and the Secretary of Energy.

- **The U.S. Nuclear Regulatory Commission** - holds responsibility to certify and license the components of the waste management system, including the repository and transportation casks
- **The U.S. Environmental Protection Agency** - establishes radiation protection standards for the protection of the public from the activi-

ties associated with the disposal of high-level radioactive waste and spent nuclear fuel

- **The U.S. Department of Transportation** - regulates the routing of highly radioactive materials, including spent nuclear fuel
- **The State of Nevada and Affected Units of Local Government** - provide oversight of Yucca Mountain Project activities
- **The U.S. General Accounting Office** - upon Congressional request, audits and prepares special reports on the U.S. Department of Energy's activities on the Yucca Mountain Project

In addition, the Department of Energy publishes its scientific findings in peer-reviewed scientific journals and presents its findings at conferences and meetings of professional societies and industry organizations. The DOE also solicits judgements from independent experts on specific scientific and technical issues. ■



Nuclear Regulatory Commission High-Level Waste Program Web Site: www.nrc.gov/NMSS/DWM/hlw.htm

Nevada Nuclear Projects Web Site: www.state.nv.us/nucwaste/yucca/state01.htm

Nuclear Waste Technical Review Board: www.nwtrb.gov/

Nye County Nuclear Waste Repository Project Office: www.nyecounty.com/

Office of Civilian Radioactive Waste Management Program: www.rw.doe.gov/homejava/homejava.htm

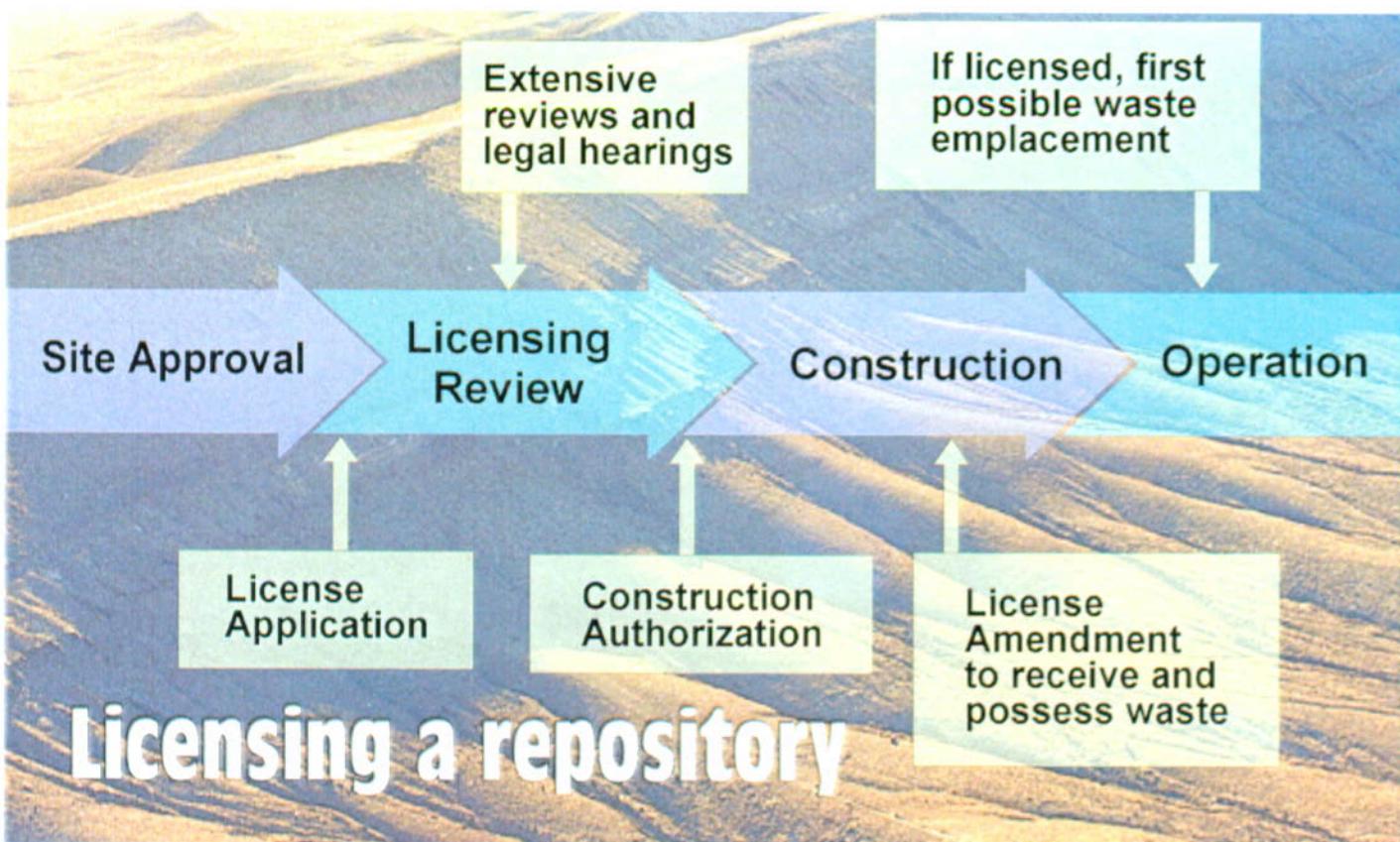
Yucca Mountain Program at Lawrence Berkley National Laboratory: www.esd.lbl.gov/NW/ymp.shtml

Yucca Mountain Program at Lawrence Livermore National Laboratory: www.energy.llnl.gov/Yucca.html

Yucca Mountain Program at Los Alamos National Laboratory: www.lanl.gov/programs/nuclear.shtml

Yucca Mountain Project at Sandia Laboratories: www.nwer.sandia.gov/ymp/ympsnl.html

Photo: Column test used to measure effect of steam on layers of volcanic tuff, Atlas Facility, Las Vegas, Nevada



- Project Fact Sheets:**
The decision process for a repository (YMP-0404)

- Project Documents:**
Civilian Radioactive Waste Management Program Plan: www.rw.doe.gov/pprev3.pdf

Management Plan for the Development of the License Application for a High-Level Waste Repository at Yucca Mountain: www.ymp.gov/documents/ymp9702_a/index.htm

- Internet Links:**
U. S. Environmental Protection Agency – Yucca Mountain Page: www.epa.gov/rpdweb00/yucca/

U. S. Nuclear Regulatory Commission High Level Waste Program Web Site: www.nrc.gov/NMSS/DWM/hlw.htm

Illustration: Sequence of activities required before a repository could start operations

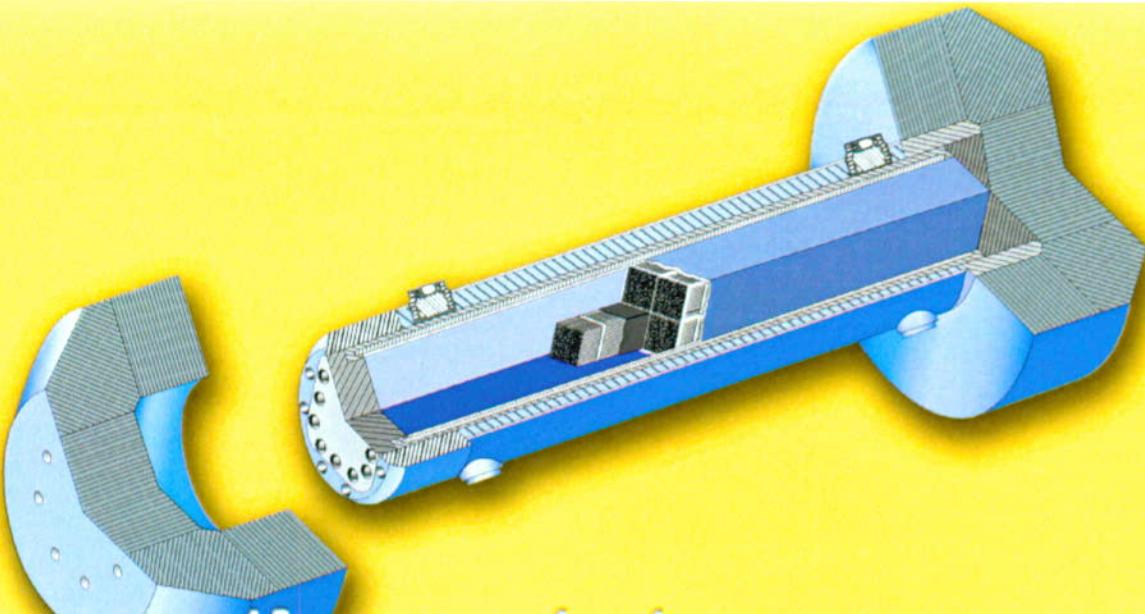
According to the Nuclear Waste Policy Act, if the Secretary of Energy recommends Yucca Mountain to the President as a suitable site for a repository, and if the President considers it suitable, the President would recommend the site to Congress. The Governor and legislature of Nevada would then have 60 days to submit a notice of disapproval to Congress.

If a notice of disapproval is received, in order for the site to be approved, Congress would propose and pass a joint resolution for repository siting approval within the next 90 calendar days of continuous legislative session.

If Congress approves the Yucca Mountain site, the DOE must submit an application to the Nuclear Regulatory Commission to obtain authorization to build a repository. The NRC would then conduct extensive reviews and legal hearings, during which it will

consider all scientific information on the repository, including that of independent scientists, scientific organizations, and governmental entities. The NRC will grant a construction authorization only if it concludes from its investigations that the proposed repository meets all safety and functional requirements specified in applicable federal regulations.

If the DOE receives the construction authorization, it would take approximately five years to build the necessary facilities for receiving initial shipments of waste. When these facilities are near completion, the DOE would apply to the NRC for a license to receive and possess spent nuclear fuel and high-level radioactive waste. If, after another extensive review, the NRC determines that the repository complies with all federal regulations, it would grant a license to allow DOE to begin placing waste in the repository. ■



Transporting waste to a permanent repository

The U.S. Department of Energy would not begin moving radioactive waste from current storage sites to Yucca Mountain unless the site is found suitable for a repository and the Nuclear Regulatory Commission grants the DOE a license to receive waste at the site. Under the current schedule, the earliest this could happen is 2010.

It would take about 24 years to ship 70,000 metric tons of waste to the repository. The waste shipments would originate from 72 nuclear power plants and 5 DOE facilities nationwide. Trucks and trains would transport the waste on the nation's highways and railroads. Barges and large heavy-haul trucks would be used for short-distances from some sites to nearby railroads. Shipments

arriving in Nevada would travel to the Yucca Mountain site by truck or rail. (Currently, there is no rail line in Nevada to Yucca Mountain. However, the DOE has performed preliminary studies to examine the impacts and costs of building one.)

Under current law, the maximum amount of waste the DOE could transport to the repository (if it is found suitable and licensed) is 70,000 metric tons—until a second repository is in operation. If shipments were mostly by rail, larger shipping containers could be used to transport more material at a time. Assuming 3,000 metric tons were transported each year, there would be about 550 shipments by train and 100 shipments by truck per year to the repository, for 24 years. ■

- **Project Fact Sheets:** [Transportation \(YMP-0107\)](http://www.ymp.gov/timeline/eis/dels.htm)

- **Project Documents:** [Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain: www.ymp.gov/timeline/eis/dels.htm](http://www.ymp.gov/timeline/eis/dels.htm)

- **Internet Links:** [U.S. Department of Energy Transportation Program: www.ntp.doe.gov/Index.html](http://www.ntp.doe.gov/Index.html)

U.S. Department of Transportation Office of Hazardous Materials Safety: www.hazmat.dot.gov/

NRC Fact Sheet – Transportation of Spent Fuel: www.nrc.gov/OPA/gmo/tip/fuel.htm

Illustration: Prototype legal-weight truck transportation cask



The Environmental Impact Statement for a repository

- **Project Fact Sheets:**

DOE's DEIS for a geologic repository for the disposal of spent nuclear fuel and high-level radioactive waste (YMP-0106)

- **Project Documents:**

Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain: www.ymp.gov/timeline/eis/deis.htm

- **Internet Links:**

Office of Civilian Radioactive Waste Management Program: www.rw.doe.gov/homejava/homejava.htm

Yucca Mountain EIS Page: www.ymp.gov/timeline/eis/fact/index.htm

Photo: The Draft Environmental Impact Statement Public Hearings elicited many of the more than 11,000 comments DOE received from the public and other Project stakeholders.

The Nuclear Waste Policy Act requires the U.S. Department of Energy to prepare an environmental impact statement to evaluate the impacts to people and the environment if the DOE were to build, operate, monitor, and eventually close a repository at Yucca Mountain. The statement also evaluates the possible impacts of transporting spent nuclear fuel and high-level radioactive waste to Yucca Mountain, as well as the possible impacts of not developing a repository and continuing to store these materials at commercial and DOE sites. This environmental impact statement provides important information for future decisions on whether to recommend the site for development.

In August 1999, the U.S. Department of Energy issued for public comment its *Draft Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain*. The document provides information to help policy-makers and the public understand the potential impacts of the proposed repository on people and the environment. From September 1999 through February 2000, the DOE conducted 21 public hearings throughout the country to provide the public with the opportunity to review and comment on its evaluation of the potential impacts. The DOE is working to respond to the public's comments and publish a final environmental impact statement. ■



Current status of the Yucca Mountain Project

The U.S. Department of Energy continues to compile results from nearly 20 years of scientific study at Yucca Mountain and is preparing other information required by the Nuclear Waste Policy Act to provide a comprehensive statement of the basis for a decision on whether to recommend a repository at Yucca Mountain.

According to the Act, the technical basis must include:

- A repository description including preliminary engineering specifications
- A description of the waste form or packaging
- A discussion of data obtained in site characterization
- A final environmental impact

statement

- Preliminary comments of the Nuclear Regulatory Commission
- Views and comments of state governments and legislatures and Native American tribes
- Other information the Secretary of Energy considers appropriate
- An impact report submitted by the State of Nevada

To date, the DOE has issued a draft environmental impact statement to the public for comment, is wrapping up many of its site characterization studies, and is preparing the required information for the Secretary's decision. ■

- **Project Fact Sheets:**

The decision process for a repository (YMP-0404)

- **Project Documents:**

Civilian Radioactive Waste Management Program Plan: www.rw.doe.gov/pprev3.pdf

Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain: www.ymp.gov/timeline/eis/deis.htm

Management Plan for the Development of the License Application for a High-Level Waste Repository at Yucca Mountain: www.ymp.gov/documents/ymp9702_a/index.htm

Further Information available on the Internet

General:

Draft Environmental Impact Statement for a Geologic Repository at Yucca Mountain: www.ymp.gov/timeline/eis/deis.htm

Environmental Protection Agency – Yucca Mountain Page: www.epa.gov/rpdweb00/yucca/

The National Council for Science and the Environment. Civilian Nuclear Waste Disposal. May 24, 2000 : www.environment.about.com/newsissues/environment/gi/dynamic/offsite.htm?site=http

Nuclear Regulatory Commission Fact Sheet: *Disposal of Radioactive Waste:* www.nrc.gov/OPA/gmo/tip/drwaste.htm

Office of Civilian Radioactive Waste Management Program: www.rw.doe.gov/homejava/homejava.htm

The Nuclear Waste Policy Act, As Amended, February 1995: www.rw.doe.gov/progdocs/nwpa/nwpa.htm
Wastelink [Guide to radioactive waste resources on the Internet] <http://www.radwaste.org/index.html>

What You Need to Know About Radiation, Lauriston S. Taylor: www.umich.edu/~radinfo/introduction/needtoknow/

Viability Assessment of a Repository at Yucca Mountain - Overview: www.domino.ymp.gov/va/va.nsf

Yucca Mountain Project: www.ymp.gov

Other:

Department of Energy: www.energy.gov

Nuclear Regulatory Commission: www.nrc.gov

Office of Civilian Radioactive Waste Management: www.rw.doe.gov

Nuclear Energy Institute: www.nei.org

Citizen Alert: www.igc.org/citizenalert

Greenpeace: www.greenpeace.org

Public Citizen: www.citizen.org

State of Nevada Nuclear Waste Project Office: www.state.nv.us/nucwaste

Yucca Mountain Site Description: www.ymp.gov/documents/ymsdd/index.htm

Yucca Mountain Program at Lawrence Berkley: www.esd.lbl.gov/NW/ymp.html

Yucca Mountain Program at Lawrence Livermore National Laboratory: www.energy.llnl.gov/Yucca.html

Yucca Mountain Program at Los Alamos National Laboratory: www.ees.lanl.gov/

Yucca Mountain Project at Sandia Laboratories: www.nwer.sandia.gov/ymp/ympsnl.html

Glossary

Alpha Radiation: A positively charged particle ejected spontaneously from the nucleus of certain radioactive elements. It has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particles will generally fail to penetrate the dead layers of cells covering the skin and can be easily stopped by a sheet of paper. Alpha particles are hazardous when an alpha-emitting isotope is inside the body.

Beta Radiation: A charged particle emitted from a nucleus during radioactive decay. Beta particles are either electrons or positively charged particles equal in weight to electrons. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Thin sheets of metal or plastic may stop beta particles.

Boreholes: Holes drilled for purposes of collecting site characterization data or for supplying water. Sometimes referred to as drillholes or well bores.

Capillary Pressure: A means by which water will rise through small pores and cracks in rock. Caused by variations in the attractive forces of the liquid's surface to the rock's surface.

Chemistry (Geo-chemistry): The study of the chemicals in natural rock, soil, soil processes such as microbe activity, and gases, especially as they interact with man-made materials from the repository system. In the broad sense, all parts of geology that involve chemical changes.

Climate: Weather conditions, including temperature, wind velocity, precipitation, and other factors, that prevail in a region averaged over some significant period of time.

Closed Water Basin: An area in which the rock strata are inclined downward from all sides toward the center and in which geologic boundaries restrict the groundwater from flowing beyond the basin.

Commercial Nuclear Power Utility: A commercial electrical supplier that uses a nuclear reactor to produce the heat for creating steam to generate electricity.

Computer Modeling: A method for assessing how the total repository system would perform within Yucca Mountain's specific geology and climate for tens of thousands of years. The models include all pertinent data from site characterization studies. To evaluate repository performance, experts use these models to determine changes that could

occur over time and calculate the combined effects on the components of the repository system.

Deep Geologic Repository: A system for disposing of radioactive waste in an excavated area deep underground; includes operational areas on the surface and subsurface, and all adjacent geologic areas and components that would isolate the radioactive waste.

Defense Program: United States military or strategic efforts that are in the interest of national security.

Defense-in-Depth Strategy: A design strategy for a nuclear waste repository based on a system of multiple, independent, and redundant barriers, designed to ensure that failure in any one barrier does not result in failure of the entire system.

Dose: The amount of radioactive energy that is absorbed by living tissues. Dose is measured by the energy produced by the radiation, the absorption capacity of the exposed organism or tissues, the body weight or mass impacted, and the time over which the exposure occurs.

Drip Shield: A corrosion-resistant engineered barrier that would be placed above the waste package in an emplacement tunnel to prevent seepage water from directly contacting the waste package. The drip shield would also protect the waste package from falling rock or debris.

Emplacement Tunnels: The specially designed areas where nuclear waste would be placed in a repository; these nearly horizontal underground passageways would be excavated in solid rock approximately 1000 feet below the surface of Yucca Mountain and 1000 feet above the water table. The tunnels are designed with features to prevent water from contacting the waste and to prevent the waste from migrating from the repository. Sometimes called *Emplacement Drifts* or *Drifts*.

Engineered Barriers: The man-made components of the repository system that are designed to prevent water from contacting the waste and/or to prevent waste from migrating from the repository.

Enriched Uranium: A radioactive metallic element in which the amount of isotope ^{235}U has been increased above 0.71 percent, the amount occurring in nature. Enrichment makes the uranium more efficient in a nuclear reactor.

Environmental Impact Statement: A detailed written statement required by the National Environmental Policy Act (NEPA) for all federal actions affecting the quality of the human environment. Preparation of an environmental impact statement requires a public process that includes public meetings, reviews, and comments, as well as agency responses to the public comments.

Evaporation: The process by which a substance passes from a liquid state to a vapor state in temperatures below the boiling point of the liquid.

Expert Elicitation: A formal process through which expert judgment is obtained.

Fracture: A break in rock caused by mechanical stresses. A fracture along which there has been displacement of the sides relative to one another is called a fault. A fracture along which no appreciable movement has occurred is called a joint. Fractures may act as fast paths for groundwater movement.

Fuel Assembly: A number of fuel rods, each rod containing hundreds of ceramic pellets of enriched uranium. The rods are held together by plates and separated by spacers. Used in a reactor, this assembly is sometimes called a fuel bundle.

Gamma Radiation: Electromagnetic radiation emitted during the radioactive decay process. The gamma ray is a penetrating wave of radiant nuclear energy. It does not contain particles and can be stopped by dense materials such as concrete or lead.

Geology: The study of the geologic features of an area, its history, and its life as recorded in the rocks; such as the geometry of rock formations, weathering and erosion, and faulting.

Ground Water Flow System: The paths in which water moves through underground geologic units.

Heavy Metal: A metal with an atomic mass greater than 230. Examples include thorium, uranium, plutonium, and neptunium. When used in the Civilian Radioactive Waste Management Program, the term usually pertains to heavy metals in spent nuclear fuel.

High-Level Radioactive Waste: (1) The highly radioactive material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing, and any solid material derived from such

liquid waste that contains fission products in sufficient concentrations. (2) Other highly radioactive material that the U.S. Nuclear Regulatory Commission, consistent with existing law, determines by rule requires permanent isolation.

Human Intrusion: The disturbance of a repository by humans that could result in release of radioactive waste.

Hydrology: The study of water characteristics, especially the movement of water involving aspects of geology and meteorology.

Invert: The floor of an emplacement tunnel constructed of materials such as steel and aggregate.

Metal Alloy: A metallic substance that consists of two or more elements. For example, the outer layer of the waste package would be made of Alloy 22, which is nickel based for corrosion resistance.

Metric Ton: A unit of mass equal to 1,000 kilograms (2,205 pounds).

Millirem: A unit of ionizing radiation equal to one one-thousandth of a rem (the term rem is derived from roentgen equivalent man). One rem of ionizing radiation produces the same effects in humans as one roentgen of high-voltage x-rays. The average American receives approximately 360 millirem a year from natural and man-made radiation.

Monitor: To perform the necessary security and maintenance activities that provide the capability to recover radioactive waste after it has been emplaced in a repository.

National Academy of Sciences: A congressionally chartered, private, nonprofit, self-perpetuating organization of scientists devoted to the expansion of science and its use for the general welfare. This organization is mandated to advise the federal government on scientific and technical matters.

Natural Barriers: The physical, mechanical, chemical, and hydrologic characteristics of the geologic environment that individually and collectively act to limit or preclude radionuclide transport.

Neutron Radiation: A type of radiation that involves the release of neutron (or neutrally charged) particles. Most neutron radiation is a result of the fissioning of uranium or plutonium atoms in a nuclear reactor.

Nuclear Chain Reaction: The condition in which nuclear fuel sustains a chain reaction. A process in which some of the neutrons released in one fission cause other fissions to occur.

Nuclear Reactor: A device that contains sufficient amounts of fissionable material (e.g. enriched uranium) arranged in a geometry that enables a controlled, self-sustaining nuclear fission chain reaction. This chain reaction produces heat for generating electricity.

Nuclear Waste Policy Act: The federal statute enacted in 1982 that established the Office of Civilian Radioactive Waste Management and defined its mission to develop a federal system for the management and geologic disposal of commercial spent nuclear fuel and other high-level radioactive wastes. Congress amended the Act in 1987.

Nuclear Waste Technical Review Board: An independent body established within the Executive Office of the President, created by the Nuclear Waste Policy Amendments Act of 1987 to evaluate the technical and scientific validity of site characterization activities and activities relating to the packaging or transportation of high-level radioactive waste and spent nuclear fuel. Members of this Board are appointed by the President from a list composed by the National Academy of Sciences.

Plutonium: A reactive metallic element used as nuclear fuel, to produce radioactive isotopes for research, and as the fissile agent in nuclear weapons.

Porosity: The ratio of openings, or voids, to the total volume of a soil or rock, expressed as a decimal fraction or as a percentage.

Radiation Exposure: Being exposed to ionizing radiation or to radioactive material.

Radioactive Decay: The process in which one radionuclide spontaneously transforms into one or more different radionuclides, which are called daughter radionuclides or daughter products (also called progeny).

Radioactivity: 1. the property of unstable nuclei in certain atoms to spontaneously emit ionizing radiation in the form of alpha or beta particles and sometimes gamma rays during measurably delayed nuclear transitions, the length of delay being measured as the nuclides's half-life. 2. the radiation thus emitted.

Remote Handling: A process for handling hazardous materials using robotic equipment or mechanical equipment run remotely by humans who are protected behind leaded glass and/or other shielding material.

Repository: Any system licensed by the Nuclear Regulatory Commission that is intended to be used for, or may be used for, the permanent deep geologic disposal of high-level radioactive waste and spent nuclear fuel.

Reprocessing: A process that involves the recovery of usable uranium and plutonium from spent nuclear fuel and results in a waste stream of fission products dissolved in nitric acid.

Rock Strata: A layer of rock.

Seismic Activity: Pertaining to, characteristic of, or produced by earthquakes or earth vibration.

Shielding: (1) Reduction of radiation by interposing a shield of absorbing material between any radioactive source and a person, work area, or radiation-sensitive device. (2) Any material that provides radiation protection.

Site Characterization: Activities, whether in the laboratory or in the field, undertaken to establish the geologic conditions and the ranges of the parameters of a candidate site relevant to the location of a repository. These activities include borings, surface excavations, excavations of exploratory shafts, limited subsurface lateral excavations and borings, and in situ testing needed to evaluate the suitability of a candidate site for the location of a repository, but do not include preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken.

Site Recommendation: A possible recommendation by the Secretary of Energy to the President that the Yucca Mountain site be approved for development as the nation's first high-level radioactive waste repository.

Spent Nuclear Fuel: Fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements that have not been separated by reprocessing. Spent fuel that has been burned (irradiated) in a reactor to the extent that it no longer makes an efficient contribution to a nuclear chain reaction. This fuel is more radioactive than it was before irradiation, and it is thermally hot.

Titanium: A corrosion-resistant, structurally strong metallic element. Drip shields for the waste

packages would be made of titanium if a repository were built.

Transpiration: The process in which water enters a plant through its root system, passes through its vascular system, and is released into the atmosphere through openings in its outer covering. It is an important process for removal of water that has infiltrated below the zone where it could be removed by evaporation.

Transportation Cask: A heavily shielded container that meets applicable regulatory requirements. Used to ship spent nuclear fuel or high-level radioactive waste.

Volcanism: The movement of molten rock and its associated gases from the interior into the crust and to the surface of the earth.

Waste Form: A generic term that refers to the different types of radioactive wastes.

Waste Package: The waste form and any containers (i.e., disposal container barriers and other canisters), spacing structures or baskets, shielding integral to the container, packing contained within the container, and other absorbent materials immediately surrounding an individual waste container placed internally to the container or attached to the outer surface of the disposal container. The waste package begins its existence when the outer lid welds are complete and accepted.

Water Table: (1) The upper limit of the portion of the ground wholly saturated with water. (2) The upper surface of a zone of saturation above which the majority of pore spaces and fractures are less than 100 percent saturated with water most of the time (unsaturated zone) and below which the opposite is true (saturated zone).



U.S. Department of Energy
Office of Civilian Radioactive
Waste Management

**YUCCA MOUNTAIN
SITE CHARACTERIZATION
PROJECT**

P.O. Box 30307
North Las Vegas, NV 89036-0307
(702) 794-15555
(800) 225-6972
<http://www.ymp.gov>

Las Vegas Science Center
(702) 295-1312
Address: 4101-B Meadows Lane
(across from the Meadows Mall and
adjacent to the YMCA)

Pahrump Science Center
(775) 727-0896
Address: 1141 S. Hwy. 160 No. 3

Beatty Science Center
(775) 553-2130
Address: 100 North E Ave. &
State Route 374

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