

Yucca Mountain Briefing Book

KHNP Training Program

Module 8: Repository Operation, Design and Closure

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Sandia National Laboratories

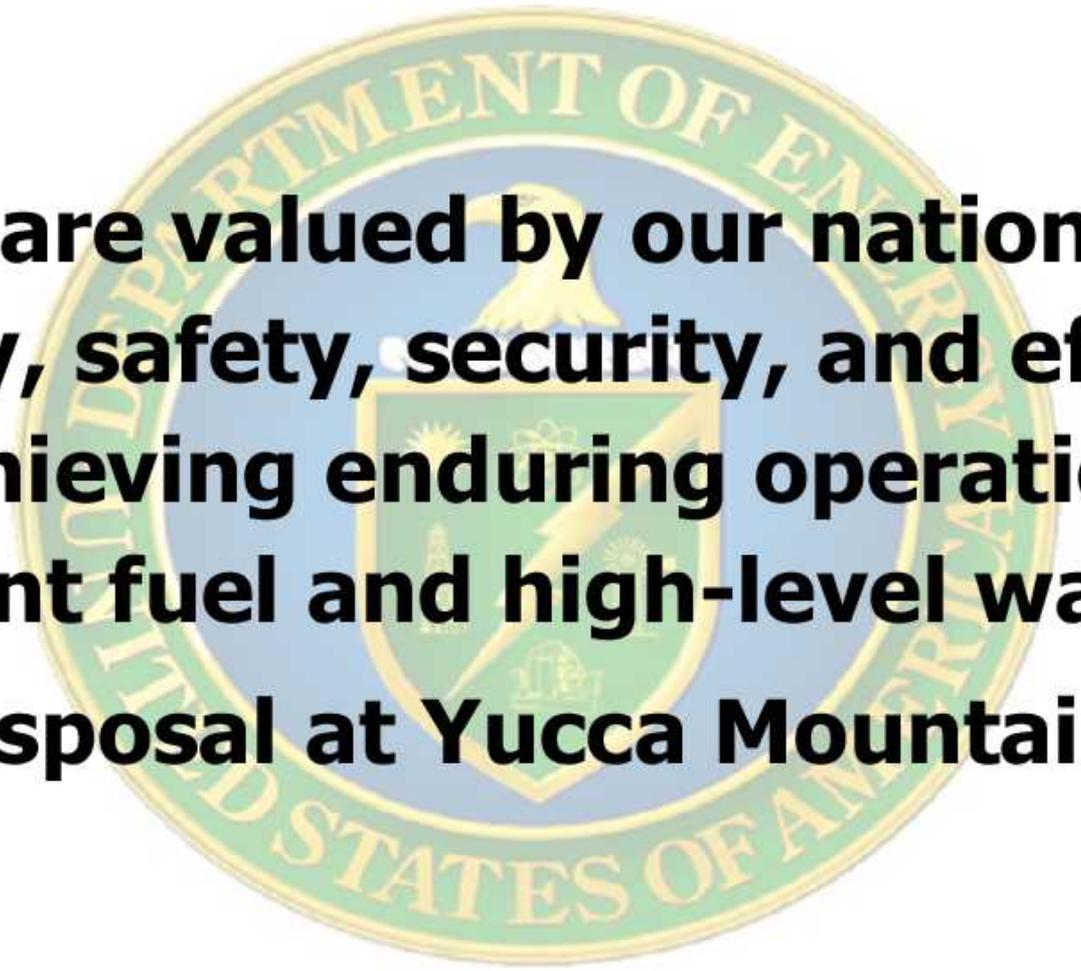
October 31, 2007

SAND 2007-6849P

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Our Vision



We are valued by our nation for integrity, safety, security, and efficiency for achieving enduring operations for spent fuel and high-level waste disposal at Yucca Mountain.

Mission

- **Mission:**

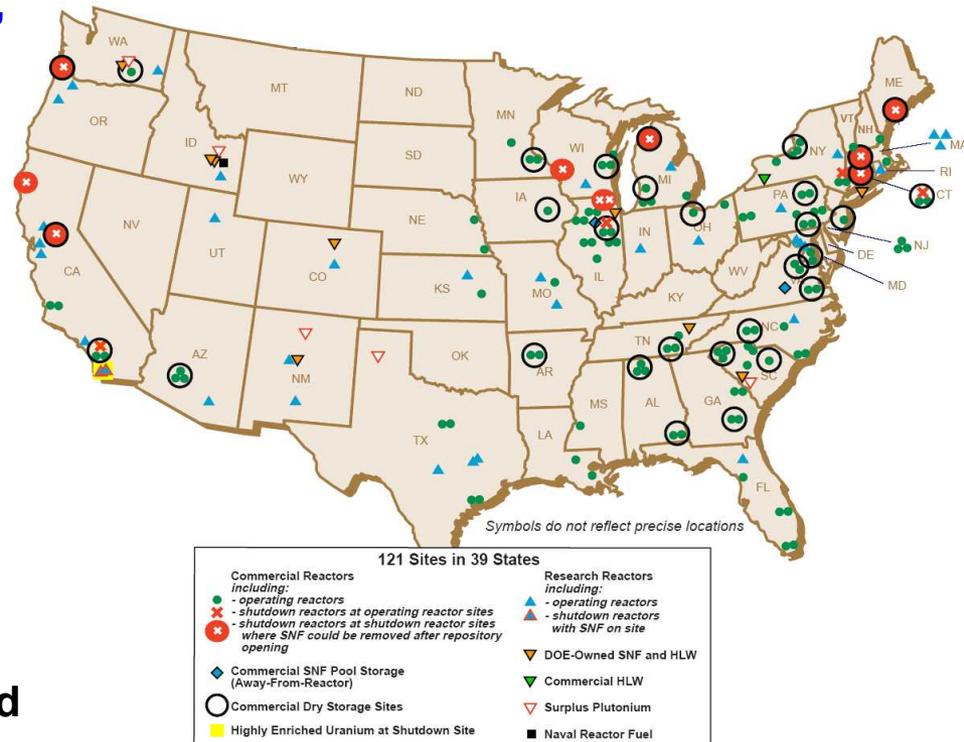
- Our mission is to **manage and dispose** of high-level radioactive waste and spent nuclear fuel in a manner that **protects health, safety, and the environment; enhances national and energy security; and merits public confidence**

- **Priorities:**

- After 20 years of scientific study, Congress **passed a joint resolution** in 2002 to designate the Yucca Mountain site for repository development and enable DOE to move ahead to submit a license application for repository construction authorization
- Protecting public health, safety, and the environment remain our top priorities

Current locations of spent nuclear fuel (SNF) and high-level radioactive waste (HLW) destined for geologic disposal:

121 sites in 39 states



As of February 2002



Why this Program Matters

“Proceeding with the repository program is necessary to protect public safety, health, and the Nation’s security because successful completion of this project would isolate in a geologic repository at a remote location highly radioactive materials now scattered throughout the Nation.”

President G.W. Bush

National Security:
Safely dispose of
waste in one location

Non-proliferation:
Put our priorities
with our policies

Energy Security:
Enable the Expansion
of the Nuclear Option

Protect the Environment:
Facilitate site cleanup

- **Secretarial Performance Goal:** Long-term goal remains for repository operations to address our Nation’s need to isolate, secure and safely dispose of spent nuclear fuel and high-level waste in a repository at Yucca Mountain

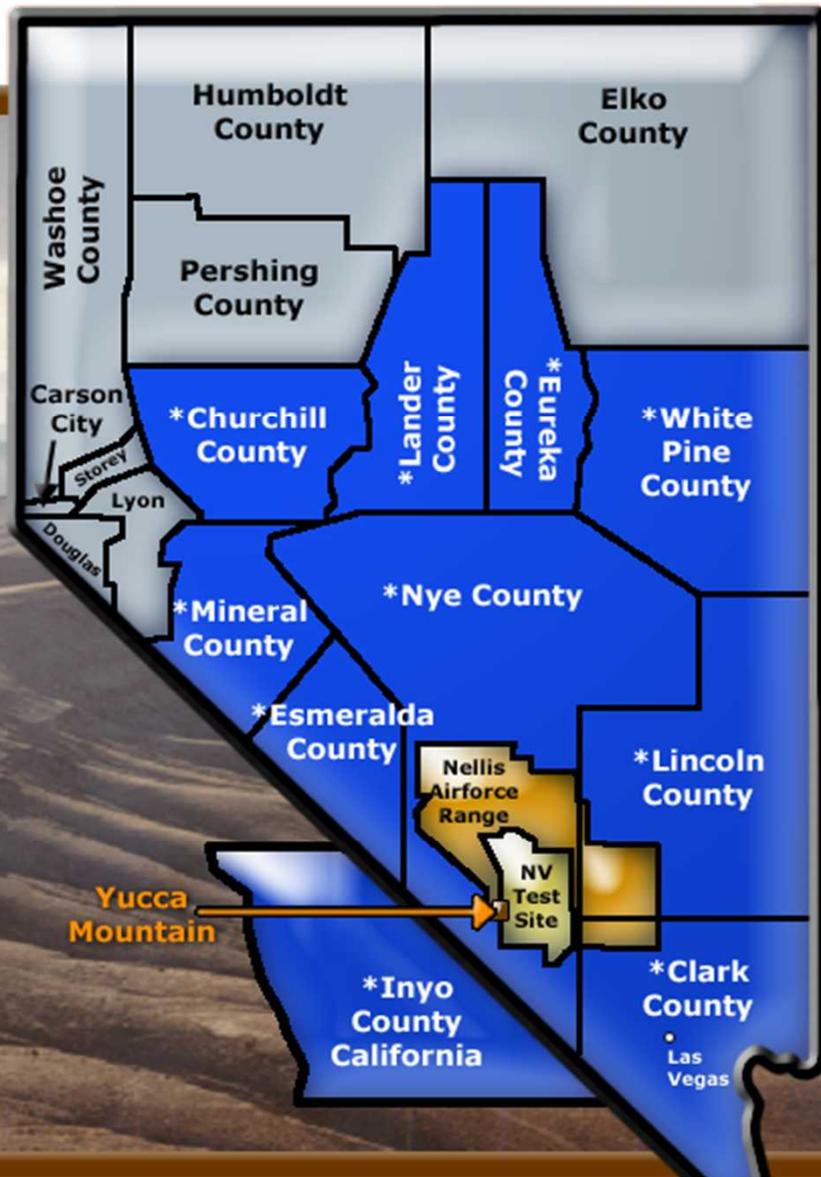


Background

Location of Yucca Mountain, Nevada

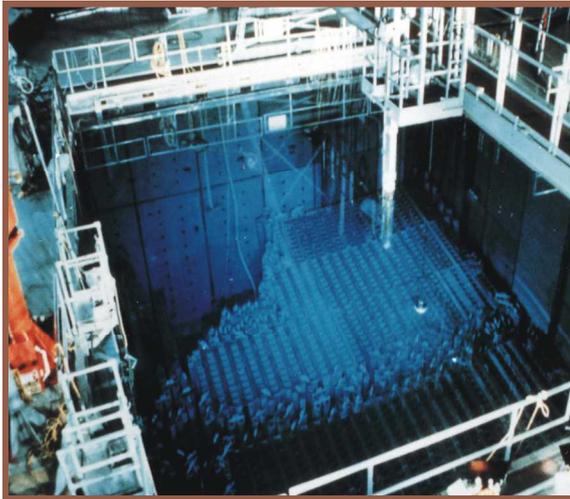
* Counties Designated as Affected Units of Local Government

- 100 miles northwest of Las Vegas in Nye County
- Located on western boundary of the Nevada Test Site, a U. S. Department of Energy (DOE) facility



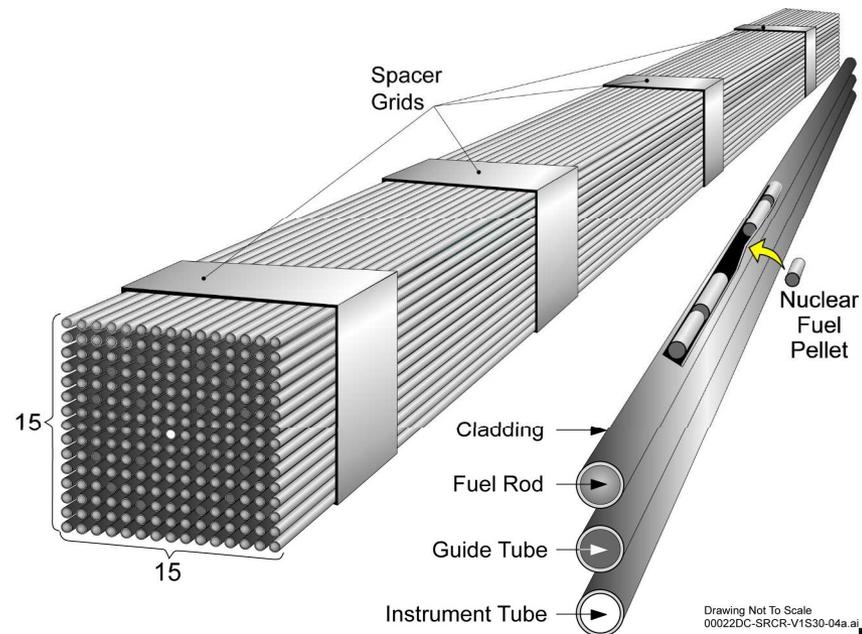
Spent Fuel Statistics

Spent fuel is stored in large pools of water to shield its radioactive properties



Or, spent fuel is stored in above-ground dry casks

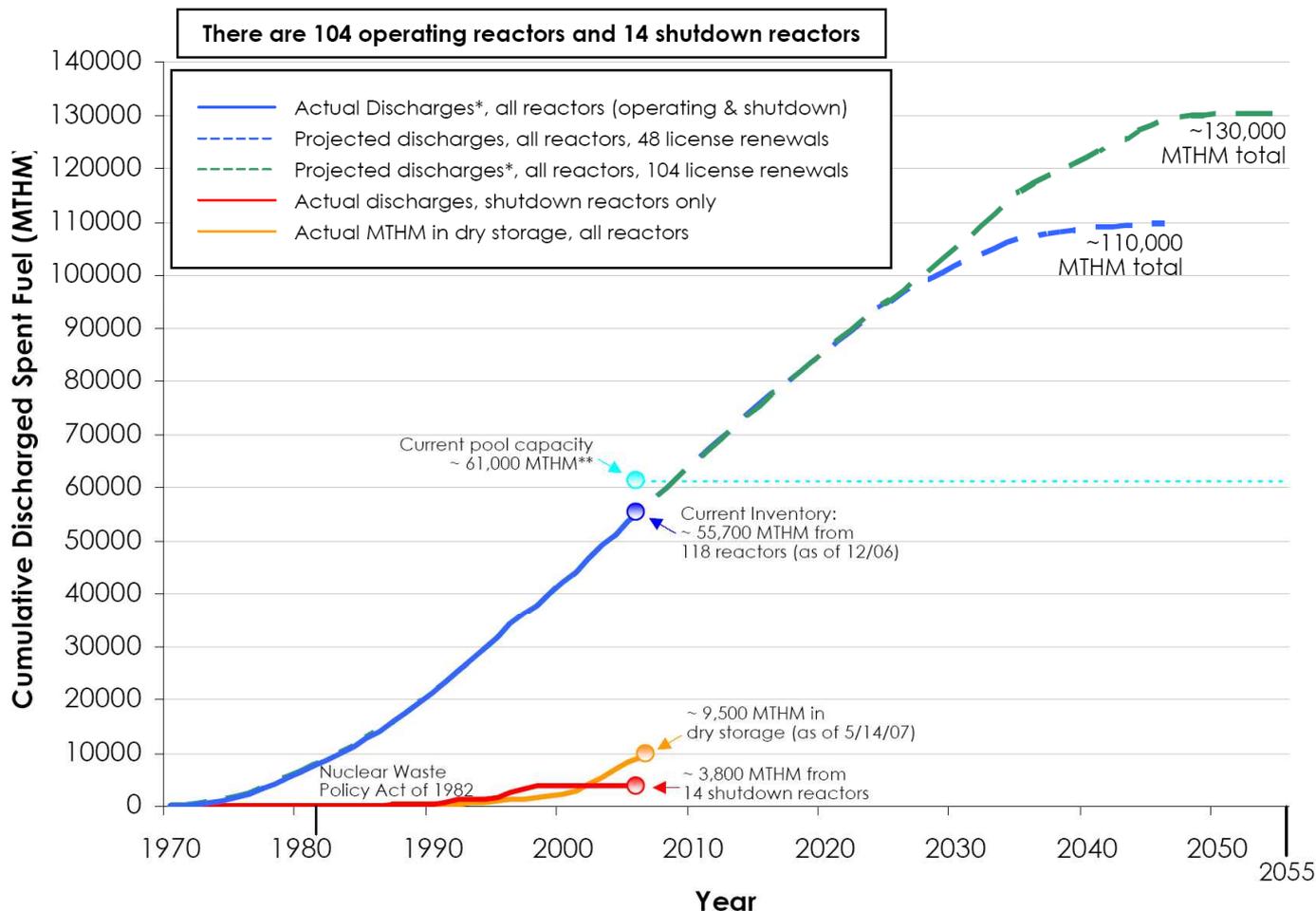
- Nuclear power plants are producing about 20% of the electricity in the U.S.
- 72 plant sites with spent fuel
- Five Department of Energy (DOE) sites with spent fuel
- 39 states with spent fuel
- 55,700 metric tons of spent fuel existed in December 2006
- 119,000 metric tons of spent fuel projected by 2035



Spent Fuel Assembly

Module 8: Repository Operation, Design, and Closure

Historical and Projected Commercial Spent Nuclear Fuel Discharges (as of 05/21/07)

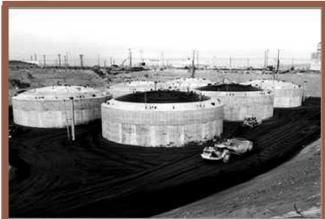


Sources:

* Based on actual discharge data as reported on RW-859's through 12/31/02, and projected discharges, in this case, based on 104 license renewals.

** Represents the aggregate industry pool capacity based on pool capacities provided in 2002 RW-859 (less FCR) and supplemented by utility storage plans. However, the industry is not one big pool and storage situations at individual sites differ based on pool capacities versus discharges into specific pools.

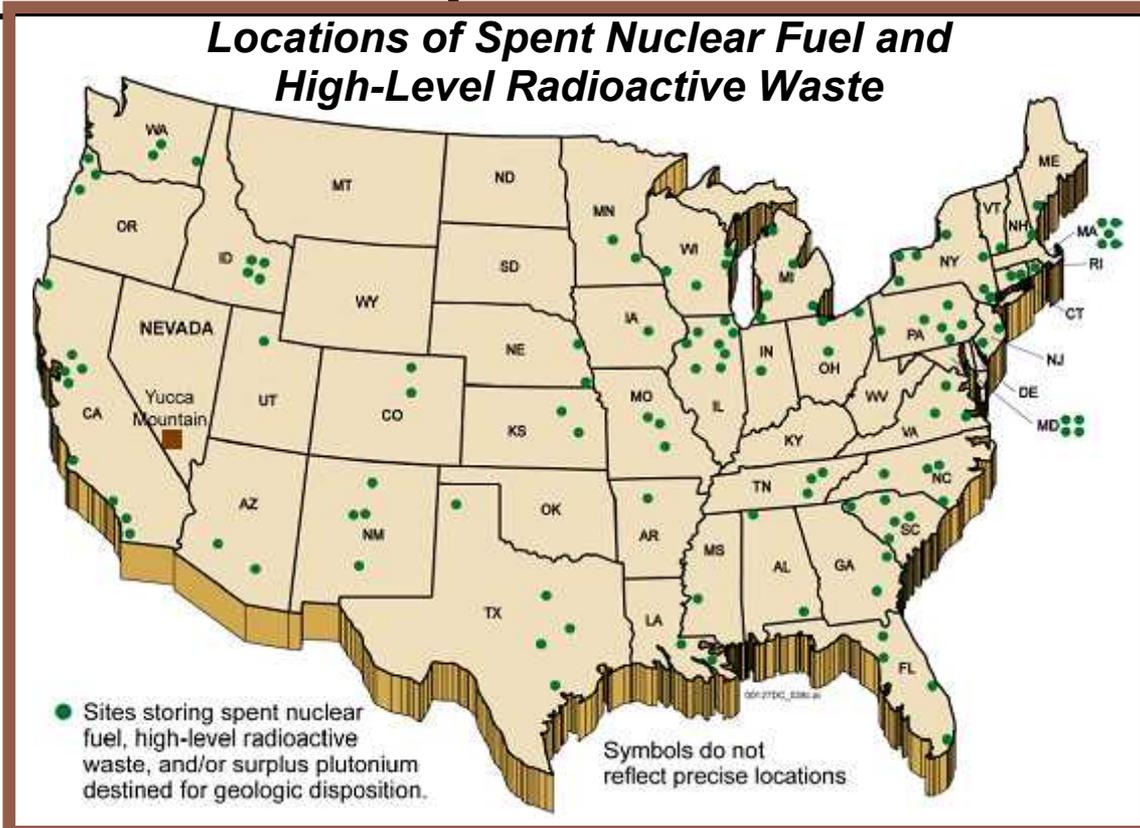
Geologic Disposal Addresses Multiple Missions



Defense Complex Clean-Up



Support of Nonproliferation Initiatives, e.g. Disposal of DOE Foreign Research Reactor Spent Fuel



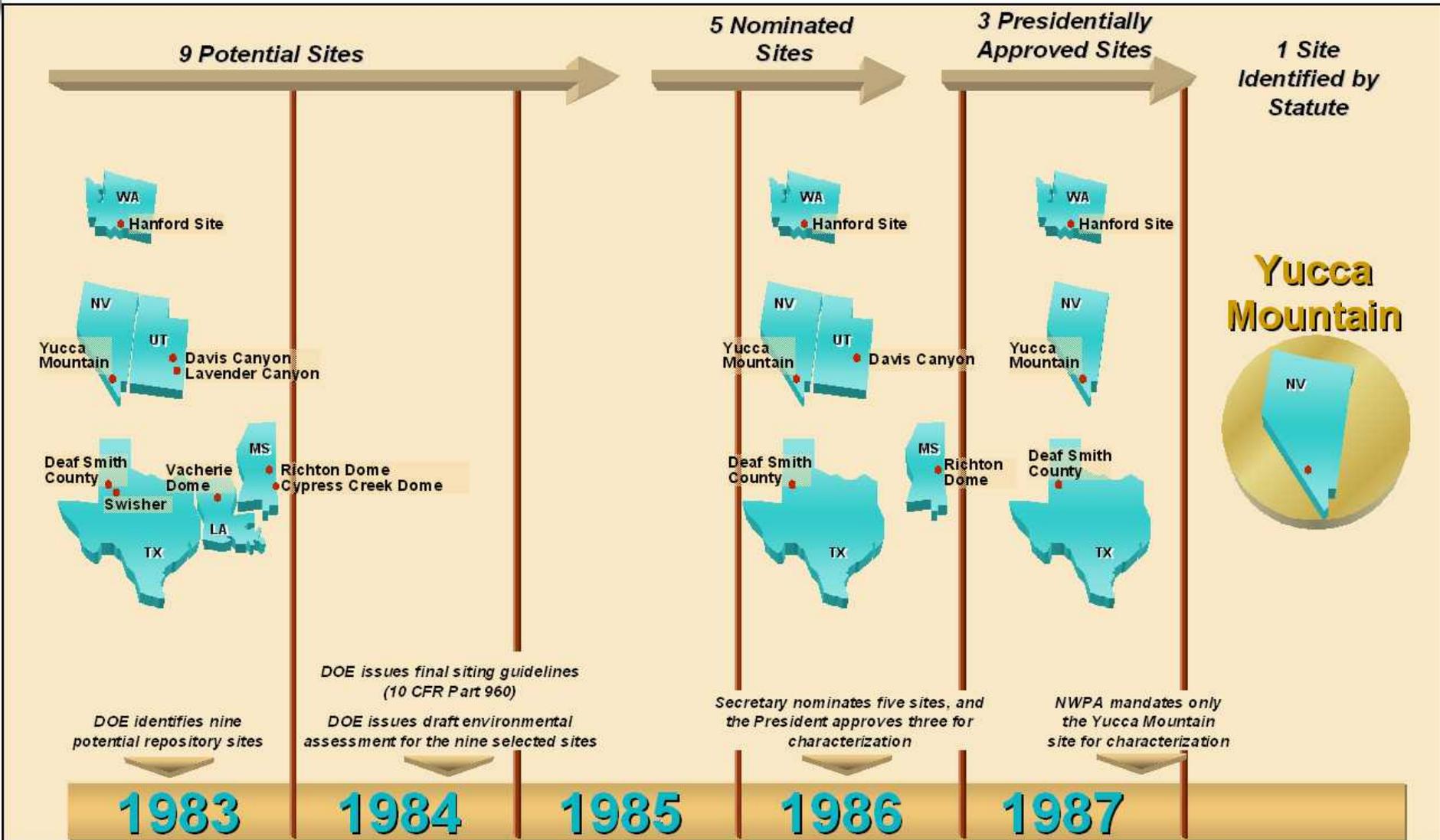
Commercial Spent Nuclear Fuel



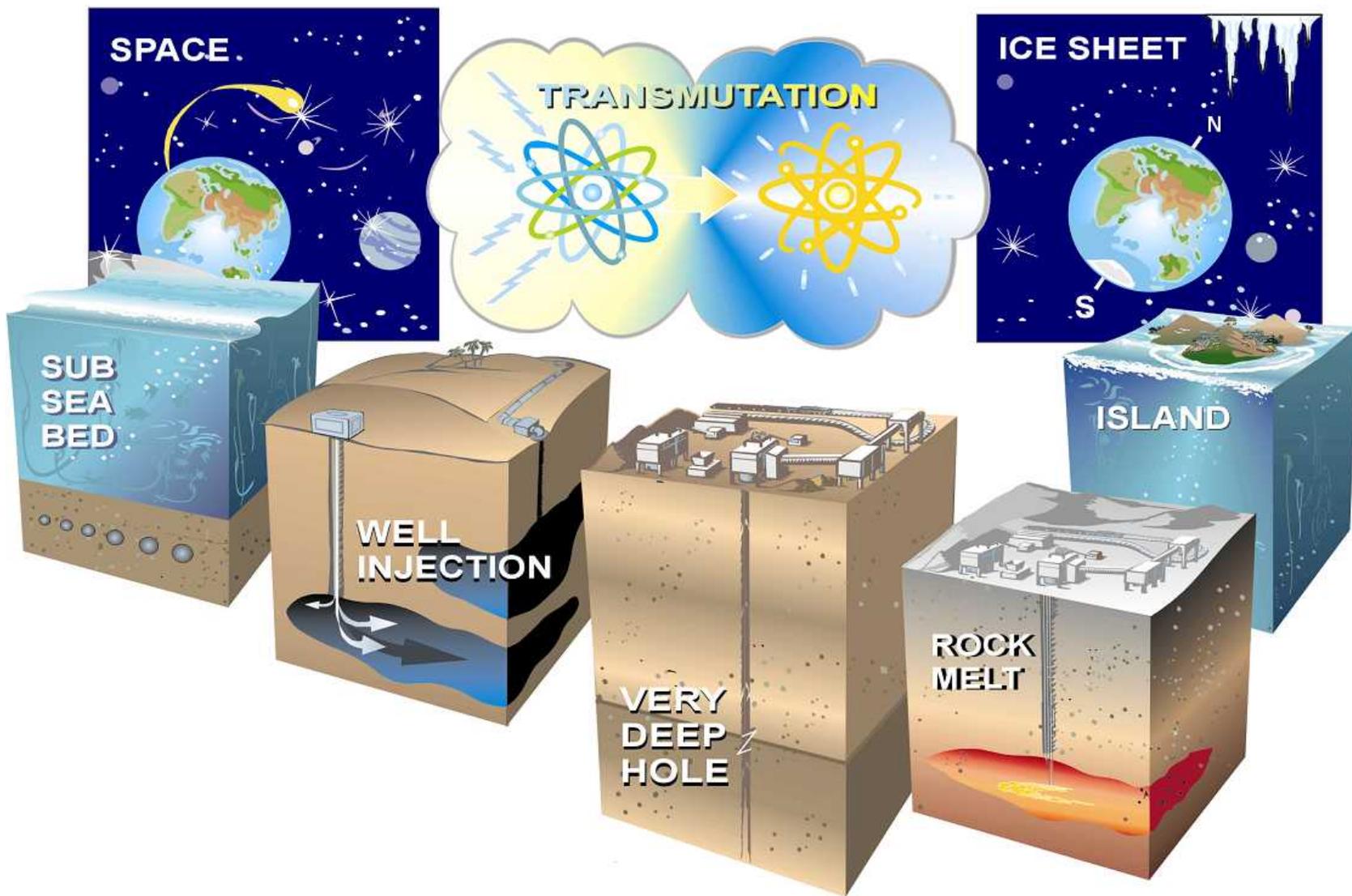
Disposition of Naval Reactor Spent Nuclear Fuel



Site Characterization Studies Selection Five Year Decision Process

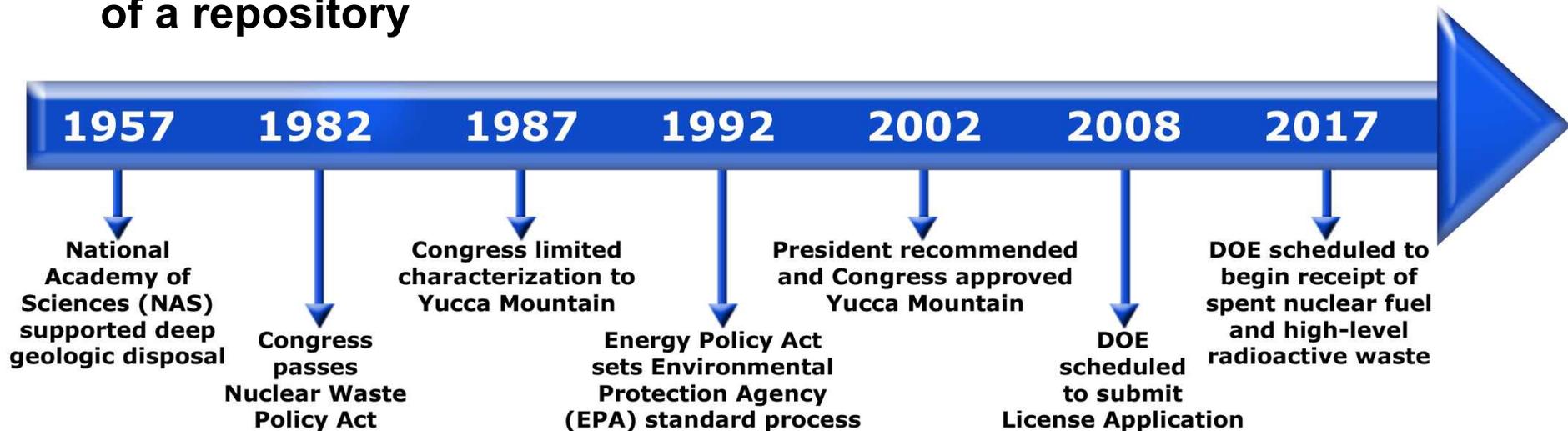


Alternative Concepts for Waste Disposal Were Considered



Congress Created a Legal Obligation to Dispose of Nuclear Waste

- 1982 - Nuclear Waste Policy Act (NWPA) established the national policy for the disposal of commercial spent nuclear fuel and high-level radioactive waste
- 1987 - Congress directed DOE to characterize only the Yucca Mountain site
- 2002 - The Secretary of Energy and the President recommended, and Congress approved, the Yucca Mountain site for development of a repository



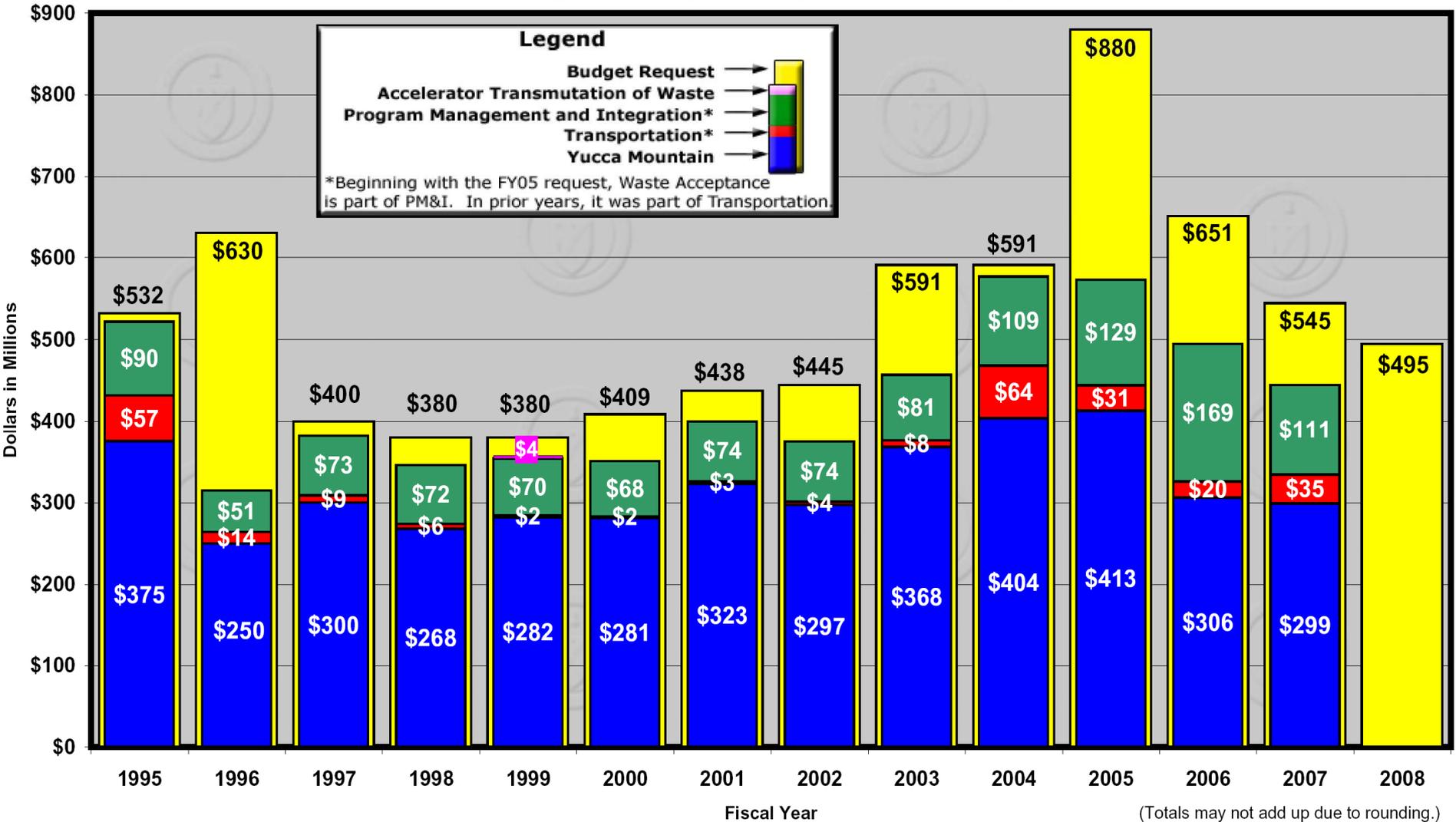


Best-Achievable* Yucca Mountain Repository Schedule

Activity	Date
Begin Nevada Rail construction	Oct. 2009
NRC authorizes construction	Sep. 2011
Submit receive and possess application to NRC	Mar. 2013
Complete initial rail access	Jun. 2014
Complete construction for initial repository operations	Mar. 2016
Begin waste receipt	Mar. 2017

* Schedule dependent on factors outside DOE's Control: i.e., funding, NRC and congressional actions, issuance of authorizations and permits, and potential litigation

Annual Appropriations and Administration's Budget Request (1995-2008)



Cumulative Short Fall: \$1,276B

Project Regulators, Oversight, and Interested Parties

Regulation

- Nuclear Regulatory Commission
- Environmental Protection Agency
- Department of Transportation

Oversight

- Federal Government
 - General Accounting Office
- State/Local Government
- Other Stakeholders
 - Host State and Affected Counties

Review

- National Academy of Sciences
- Nuclear Waste Technical Review Board
- Advisory Committee on Nuclear Waste

Federal Agencies

- Federal Emergency Mgmt. Agency
- Dept. of the Interior
- Dept of Labor
- US Geological Survey

The White House



Congress

Other Interest Groups

- Professional Societies and Organizations
- Environmental Groups
- Public Interest Groups
- States/Regional Organizations

Transportation Industry

- Cask Designers and Manufacturers
- Carriers & Transportation Service Contractors

Public

- Media
- Academic Institutions
- Citizens
- Civic Groups
- Educational Organizations

International

- International Governments
- International Agencies
- International Organizations

Electric Utilities

- Utility Transportation Groups
- Utility Technical & Information Groups

Nation's Ratepayers

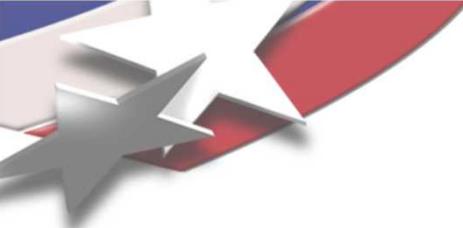
- National Association of Regulatory Utility Commissioners
- Nuclear Waste Strategy Coalition

Funding to Affected Units of Government and Nevada University System

As of 06/19/2007

	Year Initiated	Total to Date (Actual)
Affected Units of Local Government* - Oversight	1989	\$99,801,275
State of Nevada - Oversight	1983	\$87,662,109
Payments Equal to Taxes	1983	\$129,874,737
Nevada System of Higher Education	1984	\$113,654,839
Clark County, NV Transportation Grant	2004	\$2,000,000
Inyo County, CA Death Valley Regional Ground Water Monitoring Program	2002	\$2,839,750
Nye County, NV Science & Verification Program	1996	\$30,416,868
Nye County, NV Transportation Cooperative Agreement	2004	\$430,000
Total Funding to the Affected Units of Government and the Nevada System of Higher Education since 1983	All Years	\$466,679,578

*The Affected Units of Government are the State of Nevada and the ten counties designated "affected" by the Nuclear Waste Policy Act or the Secretary of Energy.



Environmental Impact Statement (EIS)



Environmental Impact Statement

- **A draft EIS for a repository at Yucca Mountain, NV was released to the public on August 13, 1999**
 - **Twenty-one public hearings throughout the U.S. were attended by 2,796 individuals, 716 of whom commented at the hearings**
 - **Ten hearings in Nevada; average attendance 142**
 - **More than 11,000 comments from hearings, U.S. Mail, e-mail, and facsimile were assessed and considered both individually and collectively before being responded to in the Final EIS**
 - **Of 27 categories of comments, the three with the most comments are:**
 - **Transportation of high-level radioactive materials (approx. 3,000)**
 - **the EIS hearing process (approx. 1,900)**
 - **support or opposition for a geologic repository and for alternatives analyzed in the EIS (1,620)**
 - **All commenters can track their comments in the Comments Response Document, which is part of the Final EIS**



Environmental Impact Statement (EIS) (cont.)

- **A supplement to the Draft EIS was released to the public on May 4, 2001**
 - **Three public hearings were attended by 268 individuals, 56 of whom commented at the hearings**
- **The Final EIS accompanied the Site Recommendation to the Secretary of Energy**
- **Copies of the Final EIS were provided in 2002 to federal, state, and local elected and appointed officials and agencies of government; Native American groups; national, state, and local environmental and public interest groups; and other organizations**



Transportation

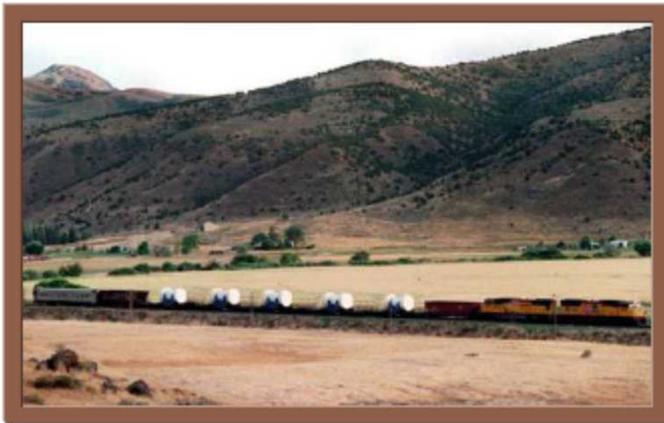


Transportation

- **Spent nuclear fuel shipments in the U.S. carry impressive safety record**
 - **Over 3,000 shipments in the U.S. during the past 30 years**
 - **754 Navy container shipments, traveling over 1 million miles since 1957**
 - **There has never been a release of radioactive material harmful to the public or the environment**
- **Waste Isolation Pilot Plant (WIPP) has completed more than 5,800 shipments**
- **DOE follows DOT and NRC transportation rules**
- **Emergency responders would be trained prior to shipments**
- **More than 70,000 metric tons of spent nuclear fuel have *already* been shipped safely in densely populated Europe; France and Britain average 650 shipments per year**

Transportation (cont.)

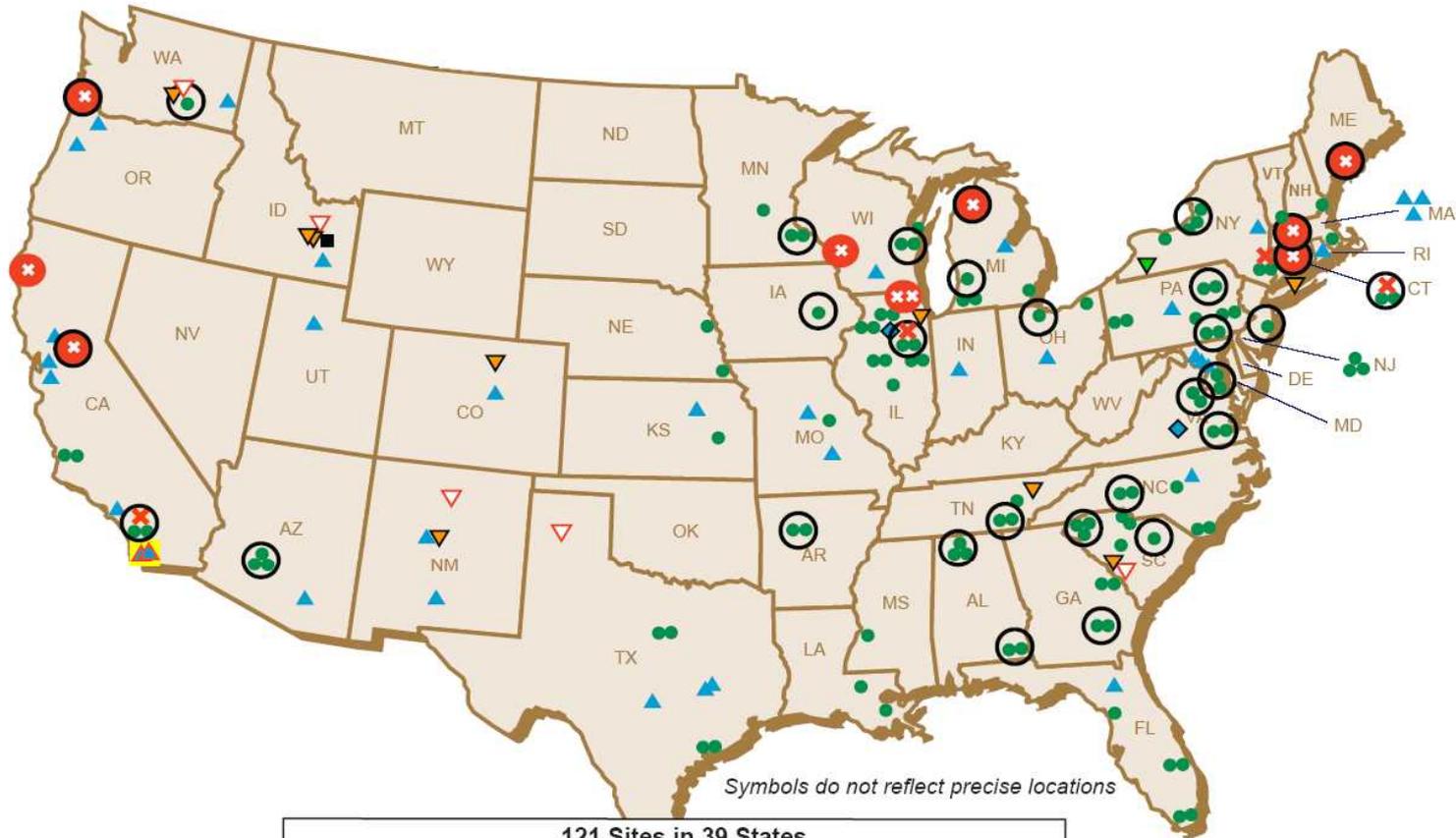
- On April 8, 2004, DOE announced that it had selected the use of rail for the majority of shipments of spent nuclear fuel and high-level waste to a repository at Yucca Mountain
- **Current estimates for shipments:**
 - **175 shipments per year for 24 years**
 - About 130 by rail and 45 by truck each year





National Transportation

Locations of Commercial and DOE Sites



121 Sites in 39 States	
Commercial Reactors including:	Research Reactors including:
● - operating reactors	▲ - operating reactors
✘ - shutdown reactors at operating reactor sites	▲ - shutdown reactors with SNF on site
✘ - shutdown reactors at shutdown reactor sites where SNF could be removed after repository opening	▼ DOE-Owned SNF and HLW
◆ Commercial SNF Pool Storage (Away-From-Reactor)	▼ Commercial HLW
○ Commercial Dry Storage Sites	▽ Surplus Plutonium
■ Highly Enriched Uranium at Shutdown Site	■ Naval Reactor Fuel

As of February 2006

Mostly Rail

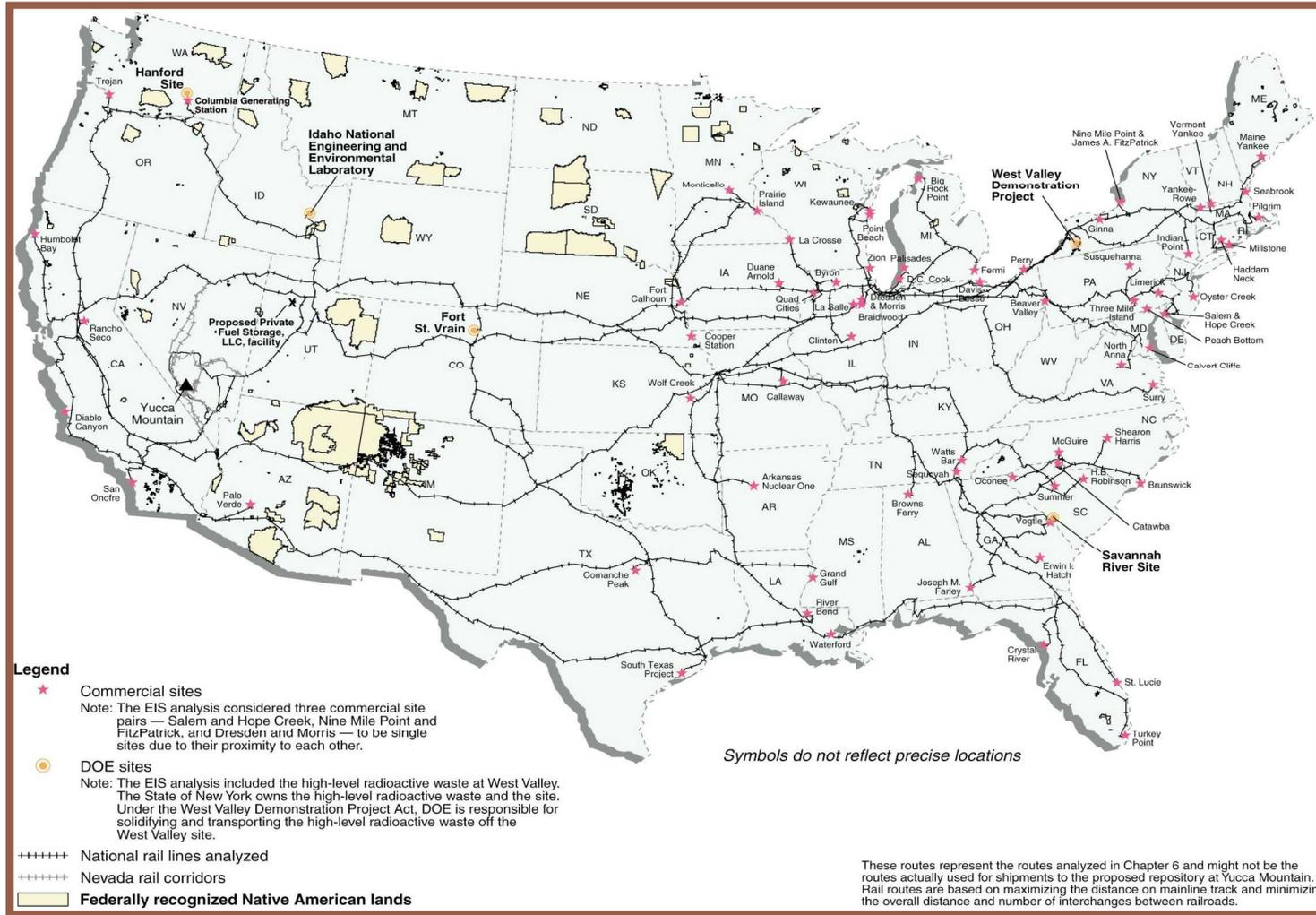
(Preferred Option FEIS)

- On April 8, 2004, DOE announced that it had selected the use of rail for the majority of shipments of spent nuclear fuel and high-level waste to a repository at Yucca Mountain

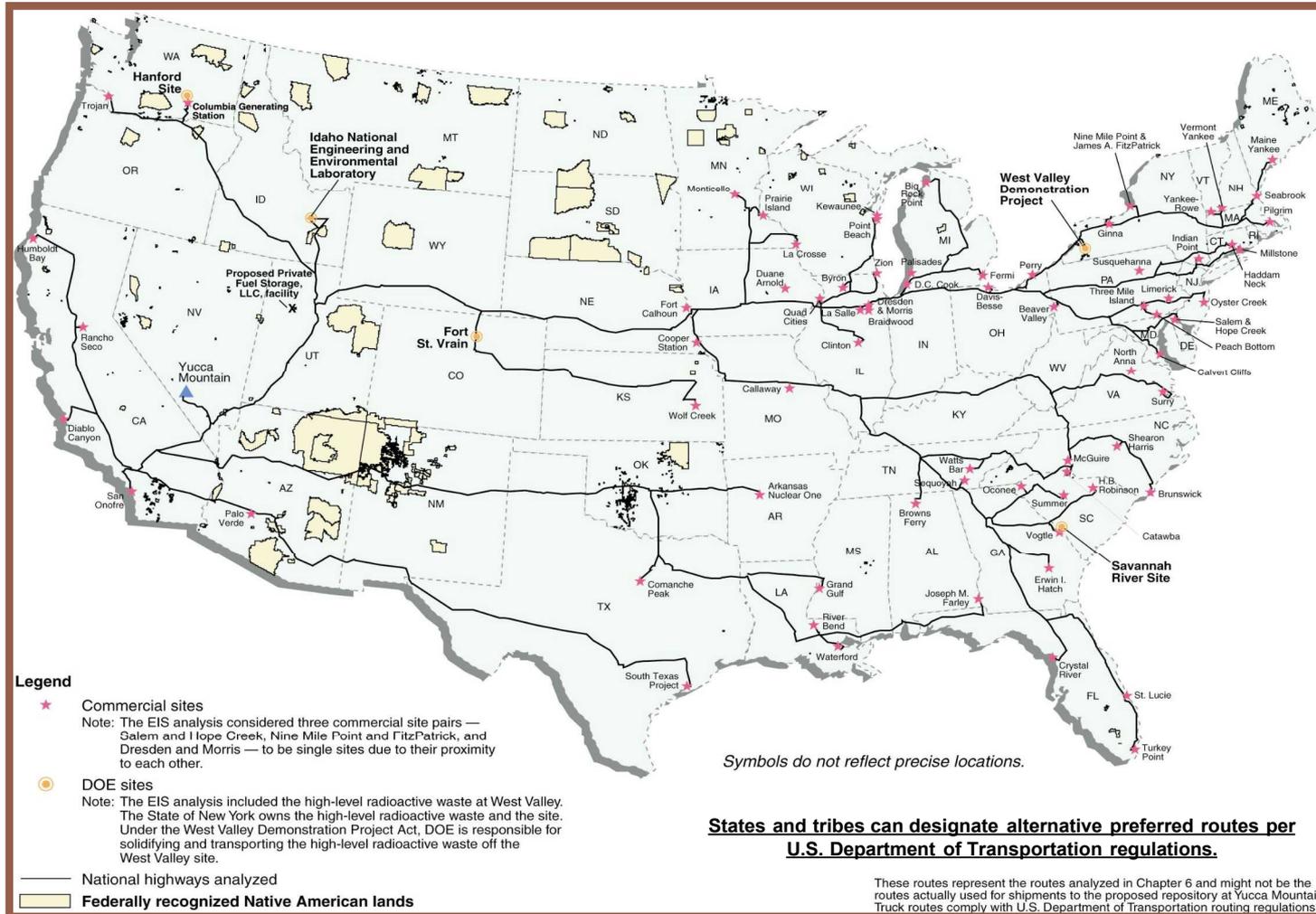


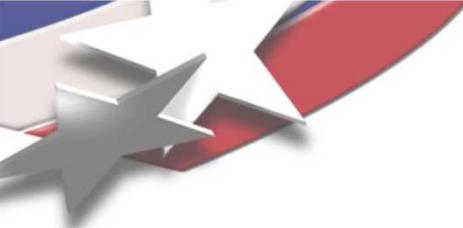
Example of Rail Cask

Rail Routes Analyzed in the Final Environmental Impact Statement



Highway Routes Analyzed in the Final Environmental Impact Statement





Nevada Transportation



Mode and Corridor Record of Decision

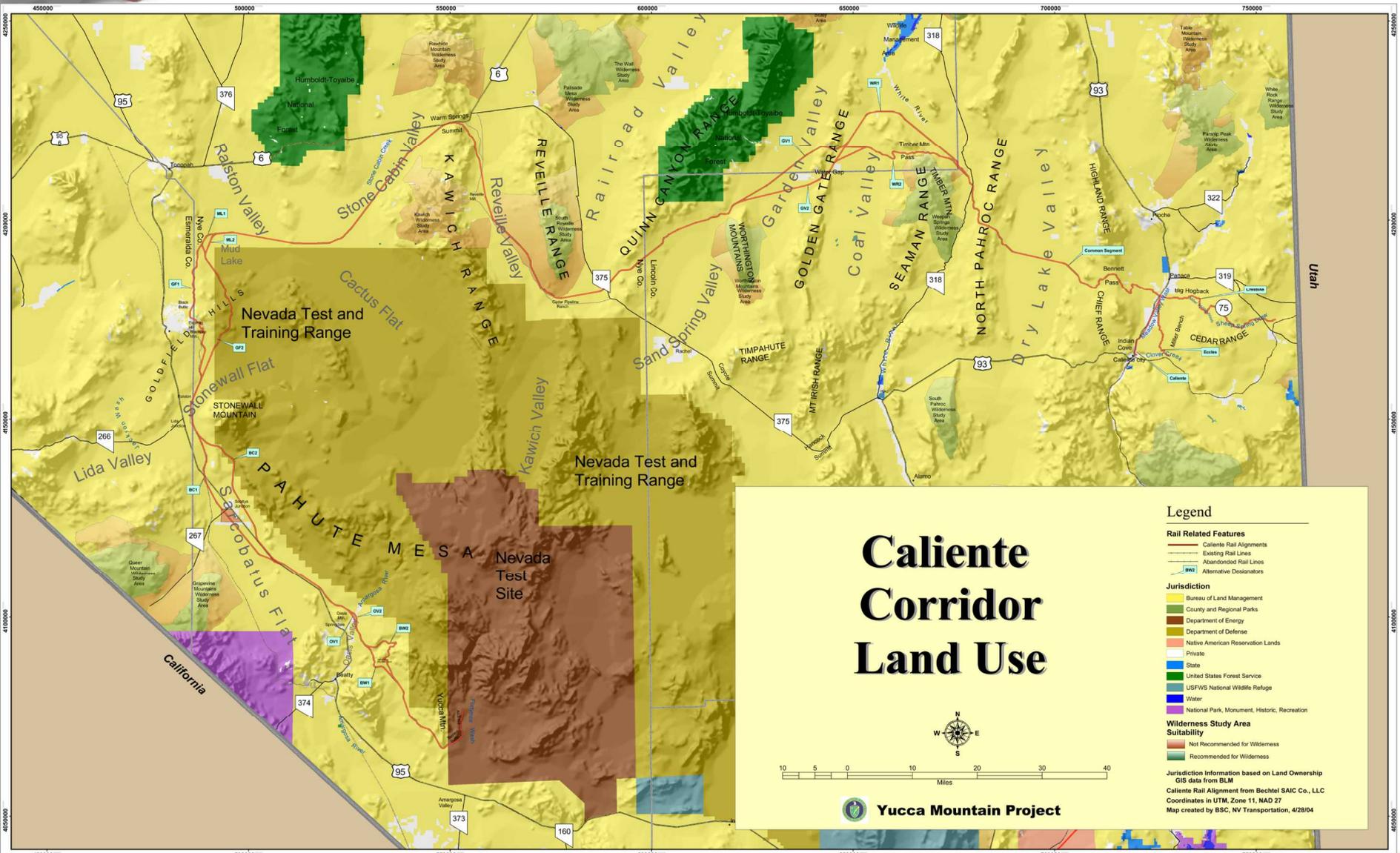
- **On April 8, 2004, the DOE published its selection of mostly rail as the mode of transport, both nationally and in the State of Nevada**
- **The DOE also selected Caliente as the rail corridor in which to determine a rail alignment for the construction and operation of a rail line in Nevada**



Caliente Rail Corridor



Rail Alignment Alternatives



Caliente Corridor Land Use

Yucca Mountain Project

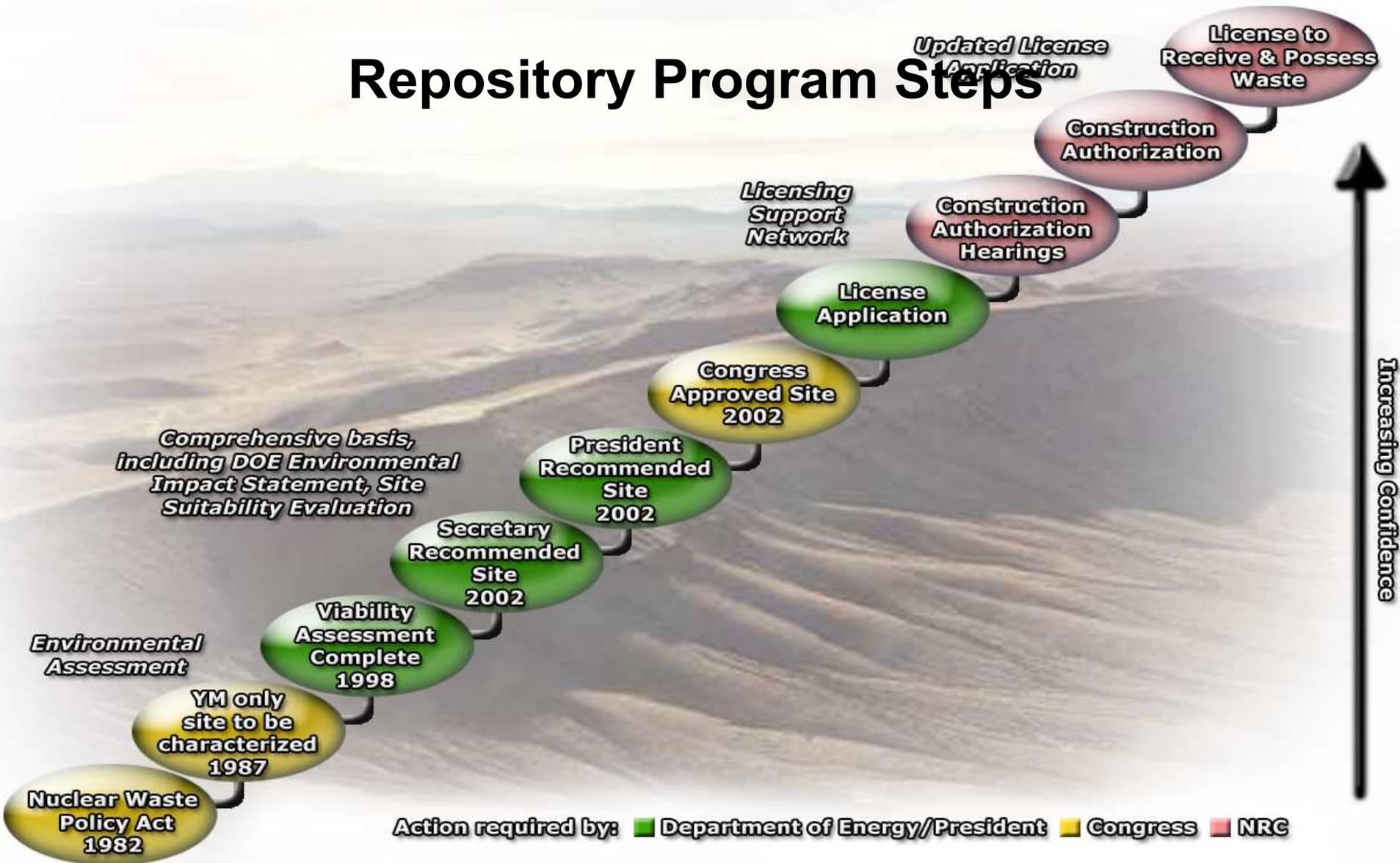
Legend

- Rail Related Features**
 - Caliente Rail Alignments
 - Existing Rail Lines
 - Abandoned Rail Lines
 - Alternative Designations
 - Jurisdiction**
 - Bureau of Land Management
 - County and Regional Parks
 - Department of Energy
 - Department of Defense
 - Native American Reservation Lands
 - Private
 - State
 - United States Forest Service
 - USFWS National Wildlife Refuge
 - Water
 - National Park, Monument, Historic, Recreation
 - Wilderness Study Area Suitability**
 - Not Recommended for Wilderness
 - Recommended for Wilderness
- Jurisdiction Information based on Land Ownership
 GIS data from BLM
 Caliente Rail Alignment from Bechtel SAIC Co., LLC
 Coordinates in UTM, Zone 11, NAD 27
 Map created by BSC, NV Transportation, 4/28/04



Site Recommendation and License Application

Repository Program Steps





2002 Site Recommendation Actions

Jan 10, 2002:

Secretary Abraham notified Governor Guinn of his intent to recommend the Yucca Mountain site to the President



Feb. 14, 2002:

Secretary's recommendation and comprehensive basis for a site recommendation submitted to President Bush and made available to the Public



Feb. 15, 2002:

President Bush approved and submitted recommendation to Congress



April 8, 2002:

Governor Guinn submitted Notice of Disapproval to Congress



May 8, 2002:

U.S. House approved Yucca Mountain joint resolution



July 9, 2002:

U.S. Senate approved Yucca Mountain joint resolution



July 23, 2002:

President Bush signed congressional resolution approving Yucca Mountain, allowing the project to proceed to the next step



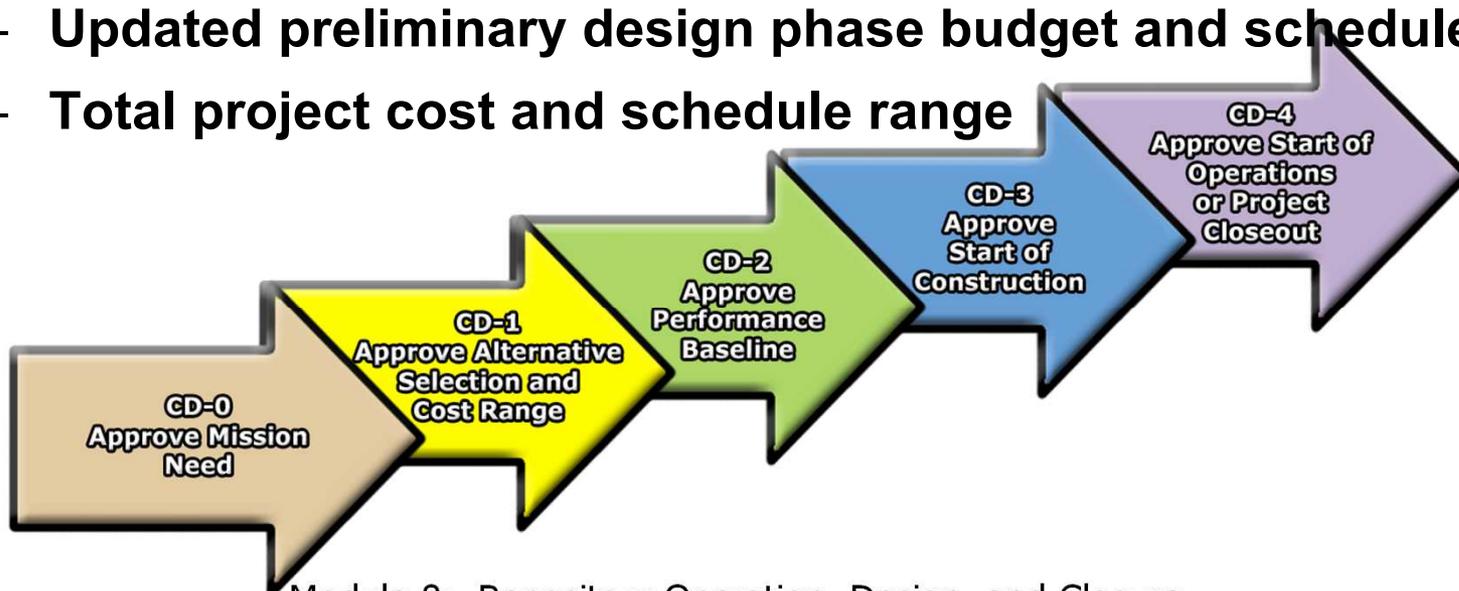


Clean Canistered Approach

- **On October 25, 2005, the DOE announced a new plan that would operate the Civilian Radioactive Waste Management System with a canister based approach that minimizes bare fuel handling**
 - **Spent nuclear fuel (SNF) generally would be sent to the repository in a standardized Transportation, Aging and Disposal (TAD) canister**
 - **Only 5 to 10 percent of fuel received would require bare fuel handling**
 - **SNF would not require repetitive handling prior to disposal**
 - **Canisters would require less handling than individual SNF assemblies**

Critical Decision (CD) - 1

- In October 2005, DOE directed BSC to develop a revised CD-1 package to support a decision to move forward with a canister-based system
 - Conceptual design report
 - Risk assessment
 - Safety hazards analysis
 - Updated preliminary design phase budget and schedule
 - Total project cost and schedule range





Yucca Mountain Repository License Application Schedule*

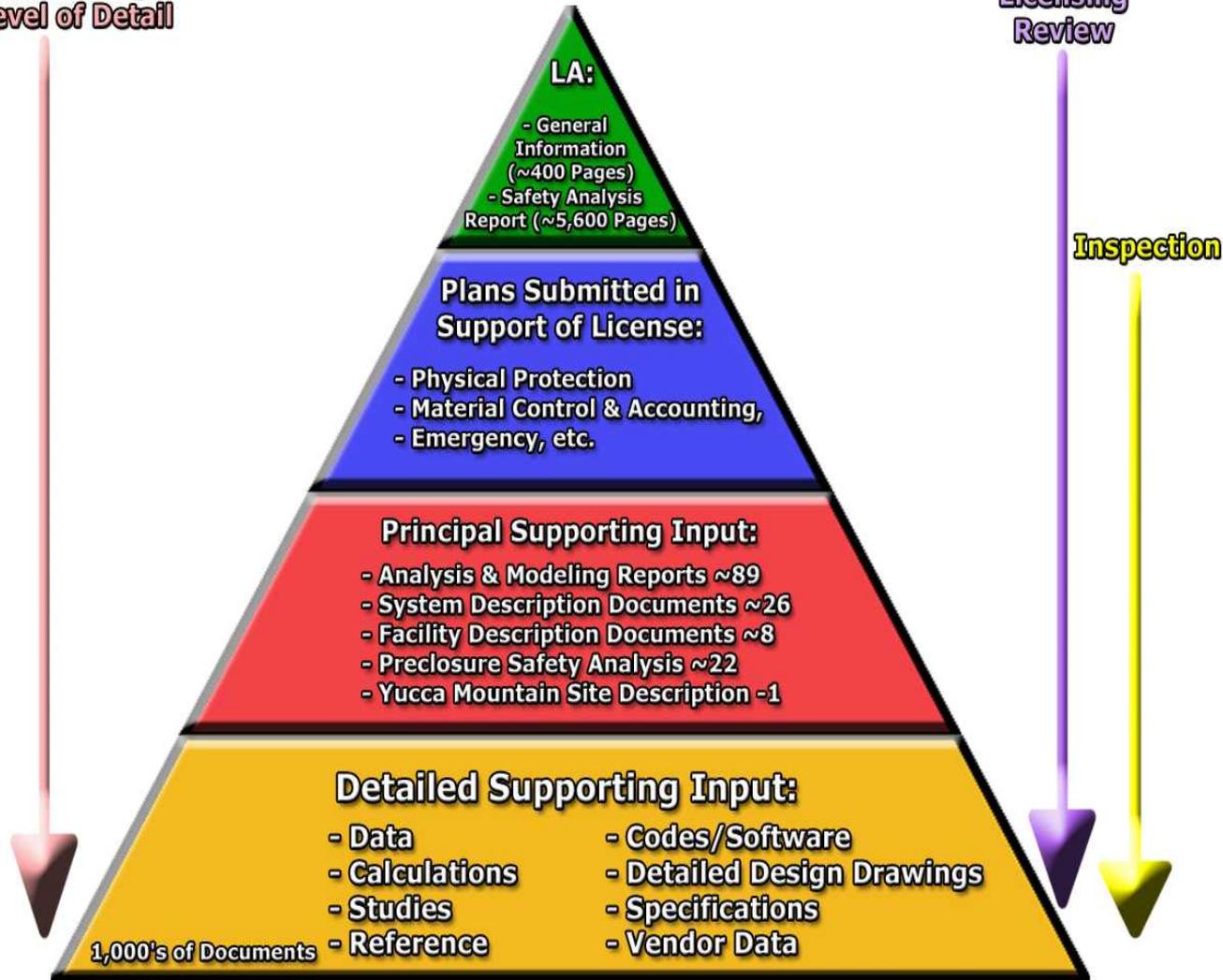
Activity	Date
Complete repository design	Nov. 2007
Certify Licensing Support Network (LSN)	Dec. 2007
Complete repository supplemental environmental impact statement (EIS)	May 2008
Issue final rail alignment EIS	Jun. 2008
Submit license application (LA)	Jun. 2008
Nuclear Regulatory Commission (NRC) dockets LA	Sep. 2008

* Schedule dependent on factors outside DOE's Control: i.e., funding, NRC and congressional actions, issuance of authorizations and permits, and potential litigation

License Application Content and Supporting Documents

- General Information (GI)
 - General Description
 - Proposed Schedules for Construction, Receipt and Emplacement of Waste
 - Physical Protection Plan
 - Material Control and Accounting Program
 - Site Characterization
- Safety Analysis Report (SAR)
 - Repository Safety Before Permanent Closure
 - Repository Safety After Permanent Closure
 - Research and Development Program to Resolve Safety Questions
 - Performance Confirmation Program
 - Administrative and Programmatic Requirements

Increasing
Level of Detail





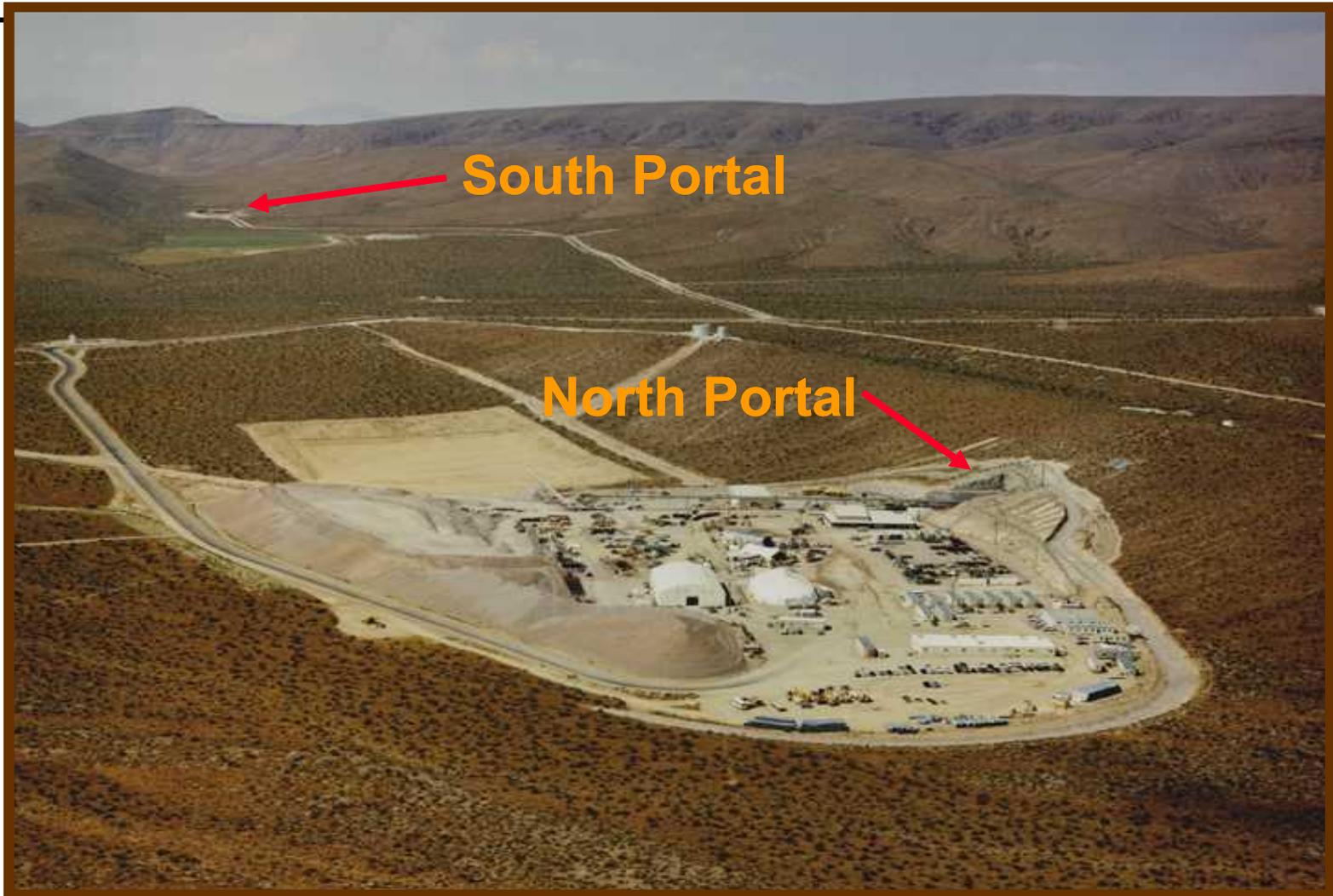
Repository Licensing Overview

- **After determining if the application is suitable for docketing, the NRC will:**
 - **Conduct extensive technical reviews and legal hearings**
 - **The Atomic Safety and Licensing Board, appointed by the NRC, will conduct the hearings**
 - **Hearings will be open to the public**
- **A construction authorization will be granted only if the NRC concludes that the repository would meet reasonable expectations that the safety and health of workers and the public would be protected**

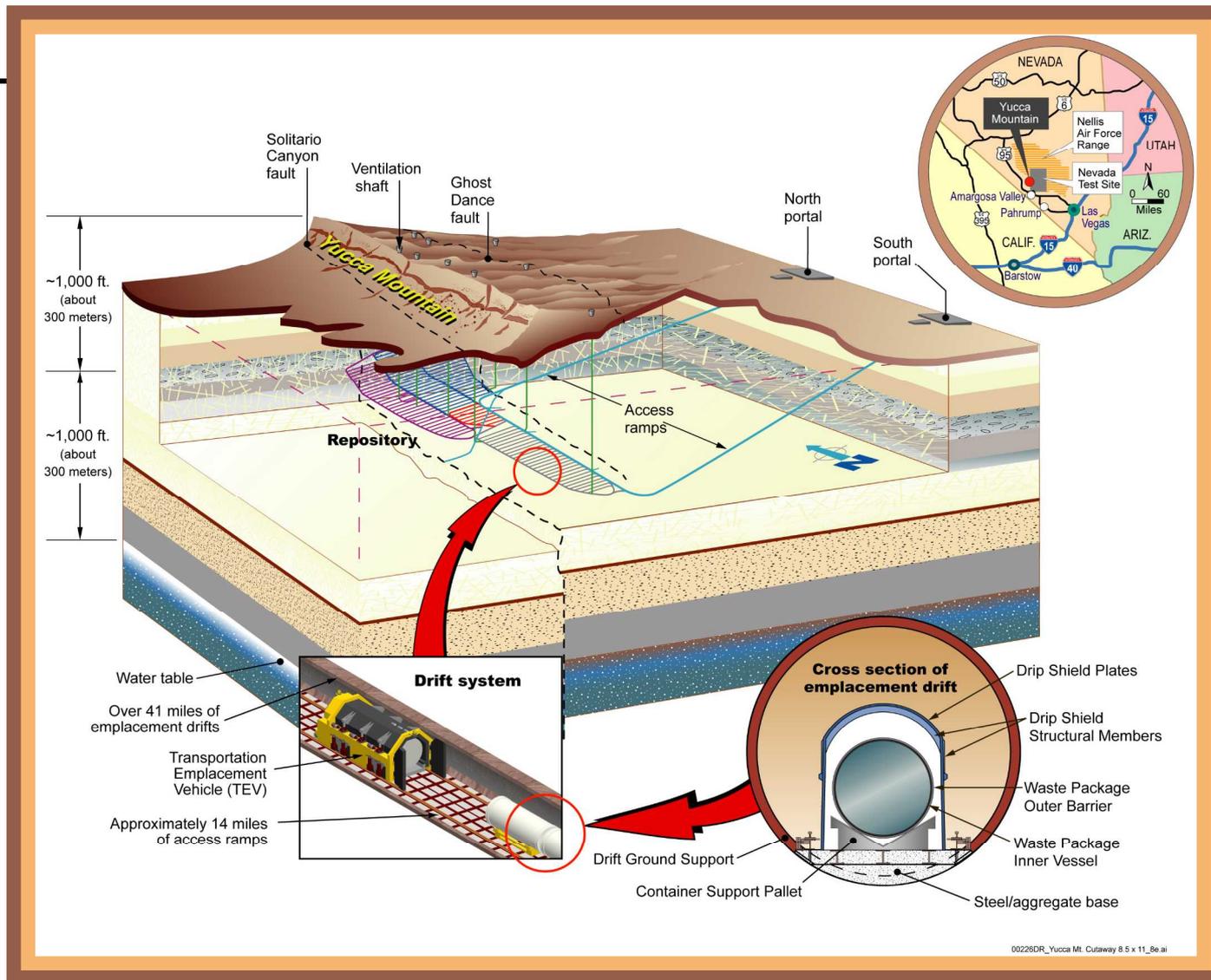


Repository Design

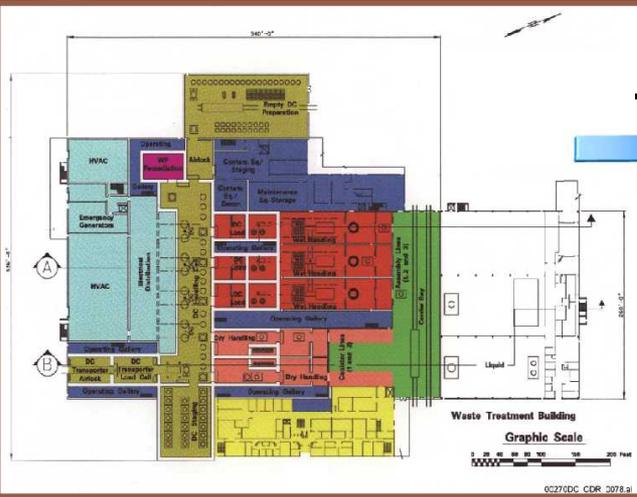
Yucca Mountain Surface at Exploratory Studies Facility Portals



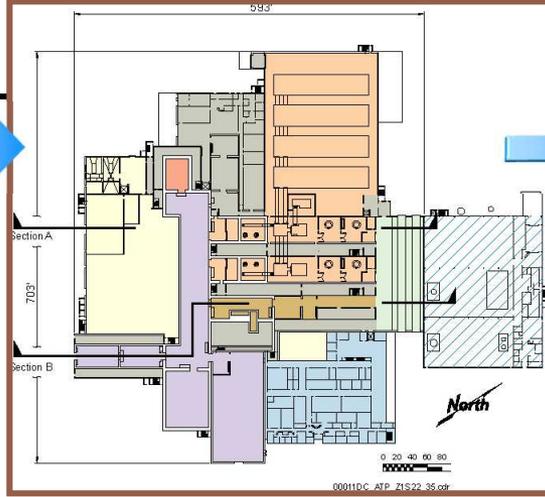
Repository Reference Design Concept



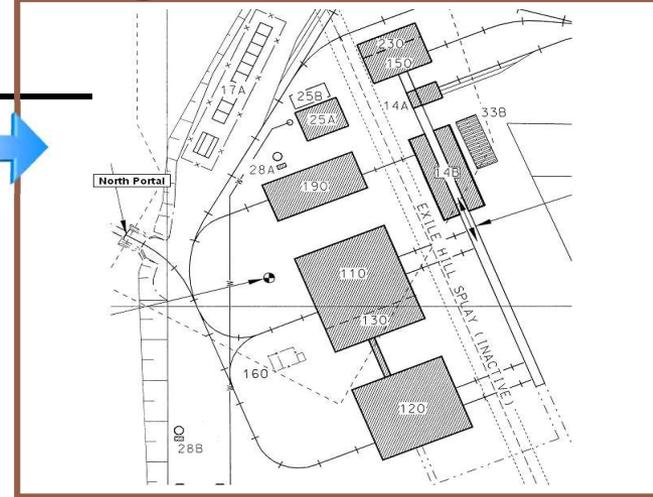
Evolution of Surface Design



VA Design



SR Design



Conceptual Design

- Wet handling for commercial spent nuclear fuel (CSNF)
- Single large building
- 5 transfer lines

- Wet handling for CSNF
- Single large building
- 3 transfer lines
- 5,000 MTHM blending pools (to accommodate thermal blending)

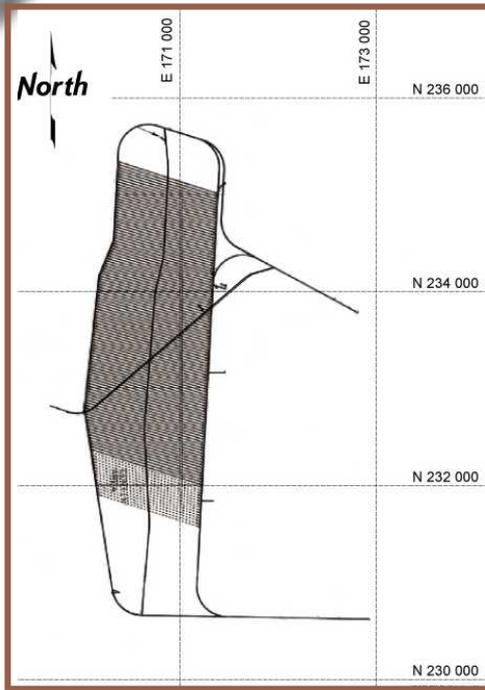
- Dry handling
- Multiple buildings
- Phased construction
- Dry cask aging



Evolution of Surface Design (cont.)

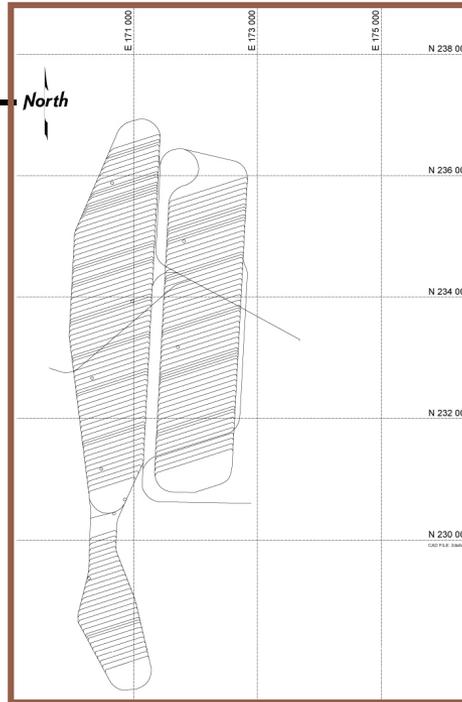
- **The revised surface design provides maximum flexibility in the development of a simple, clean, safe, primarily canister-based repository**
 - **Based on the use of modular waste handling facilities and processes – expansion as needed**
 - **Incorporates commercial waste handling experience**
 - **Can receive by truck and standard rail**
 - **Can accommodate multiple sizes of TADs**
 - **Can handle multiple forms of wastes**

Subsurface Repository Evolution



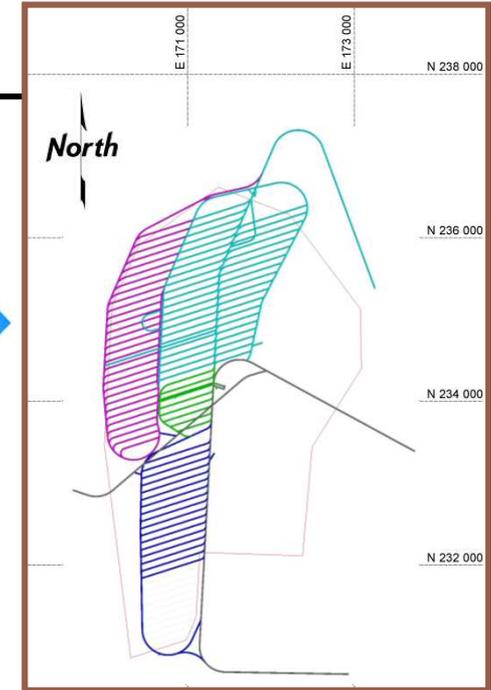
VA Design

- 92 ft Drift Spacing
- Above Boiling Temperature in Rock Pillar
- Single Level
- Minimal Ventilation



SR Design

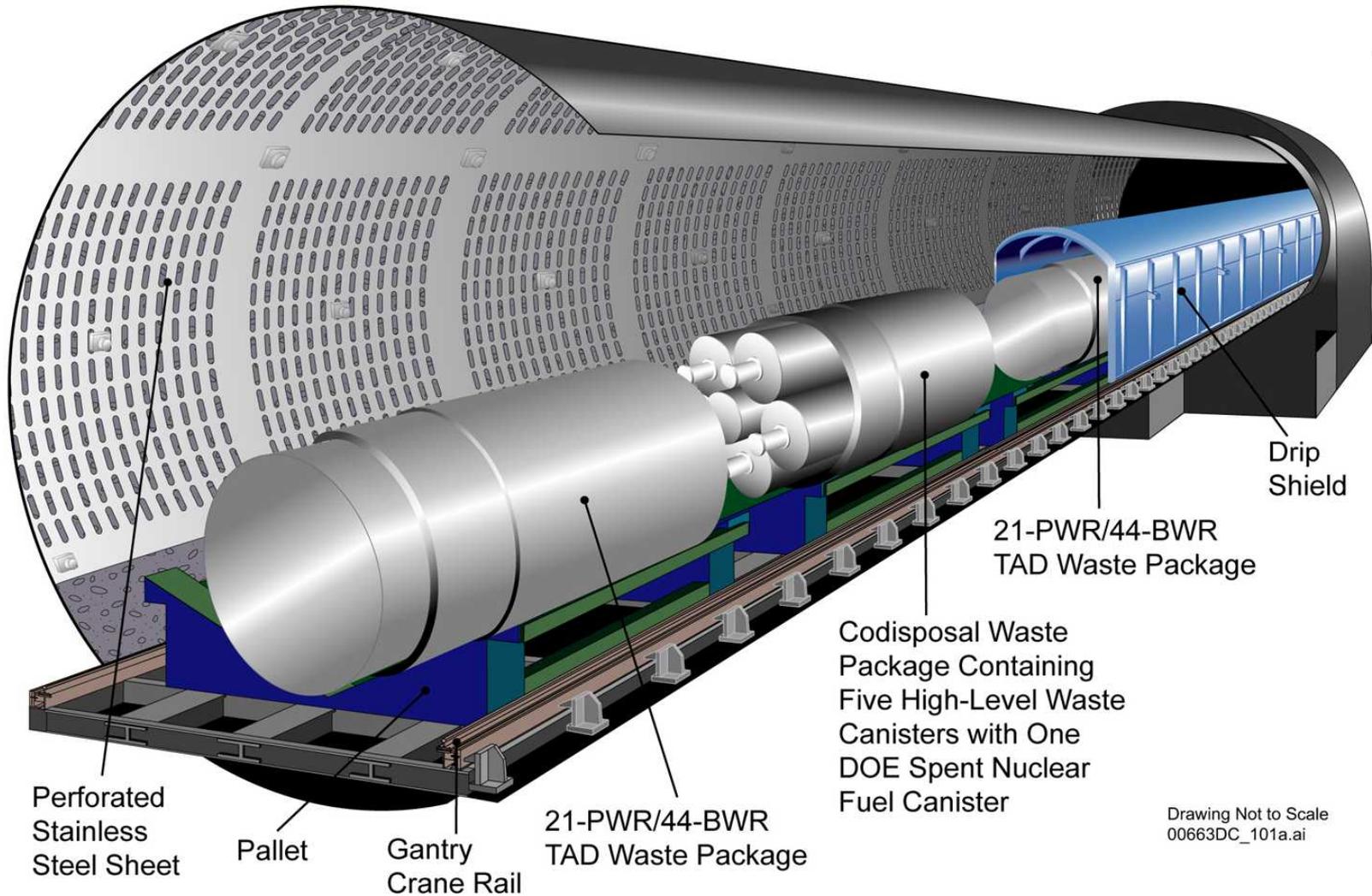
- 266 ft Drift Spacing
- Sub-boiling Temperature in Rock Pillar
- Two Levels
- Robust Ventilation with Allowance for Natural Ventilation

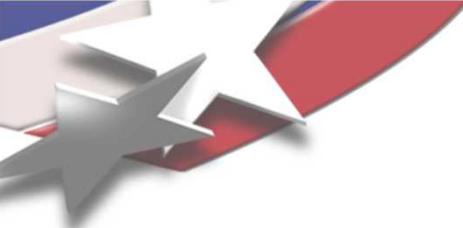


Conceptual Design

- 266 ft Drift Spacing
- Sub-boiling Temperature in Rock Pillar
- 4 Panels – One Level
- Robust Ventilation

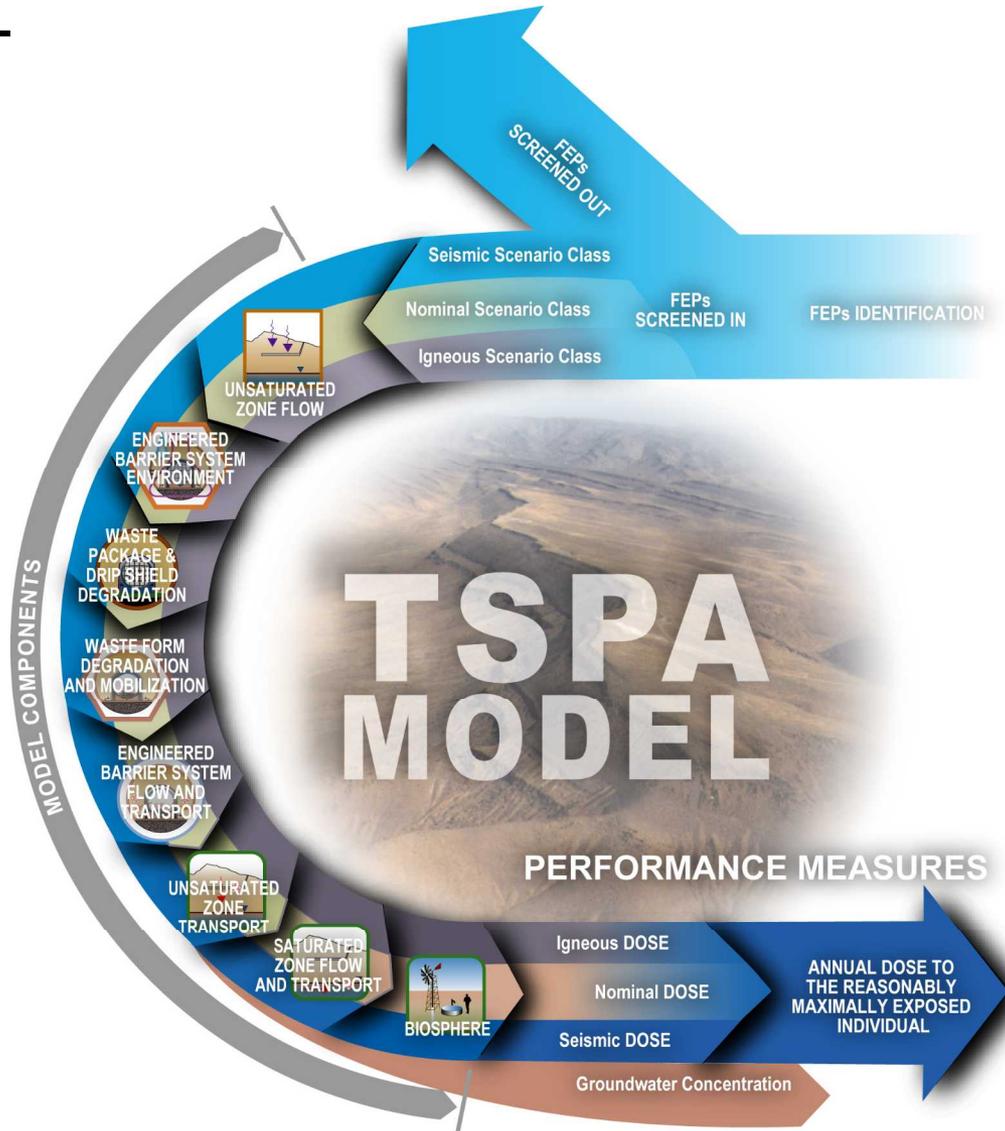
Emplacement Drift





Total System Performance Assessment (TSPA)

Total System Performance Assessment (TSPA) Role in Performance Assessment





TSPA Process

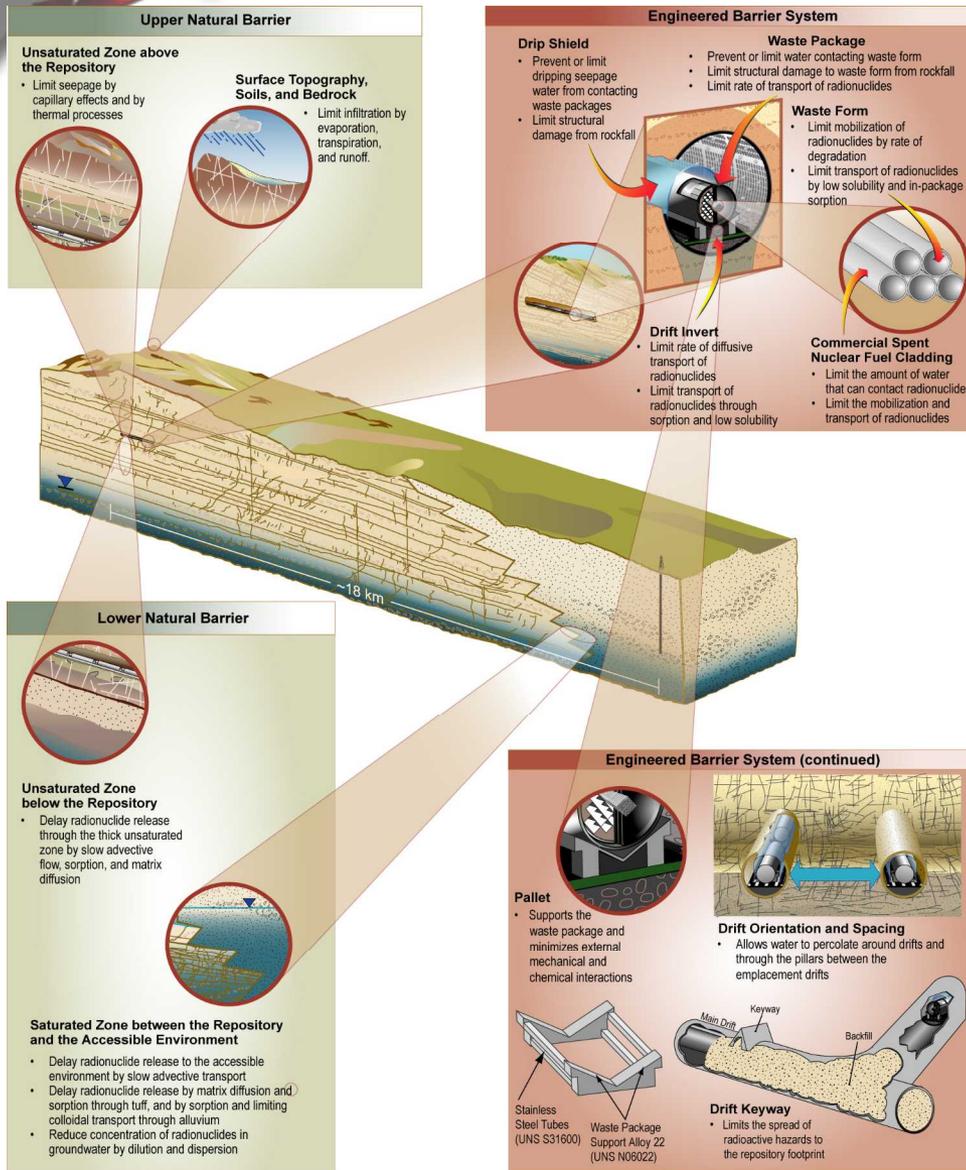
- **Screen features, events, and processes to determine those to be evaluated in performance assessment**
- **Develop models, along with their scientific basis, for each feature, event and process included in TSPA**
- **Evaluate uncertainty in models and parameters**
- **Construct integrated TSPA model using all retained features, events and processes in scenario classes**
 - **Nominal scenario classes contain all features, events, and processes likely to occur (including climate change)**
 - **Disruptive event scenario class contains unlikely events (e.g., igneous and seismic)**
- **Evaluate total-system performance in terms of individual protection and groundwater protection standards; incorporating uncertainty through Monte Carlo simulation**



TSPA Model Architecture

- **TSPA Models consist of three scenario classes**
 - **Nominal Scenario Class**
 - **Igneous Scenario Class**
 - **Seismic Scenario Class**
- **Each scenario class has a separate TSPA model**
- **Each model component has information flow logic diagrams**
- **Each model component has an integrated set of inputs and outputs**
- **Each model abstraction has a conceptual basis**

Barriers, Features, and Components in TSPA



Features and Components

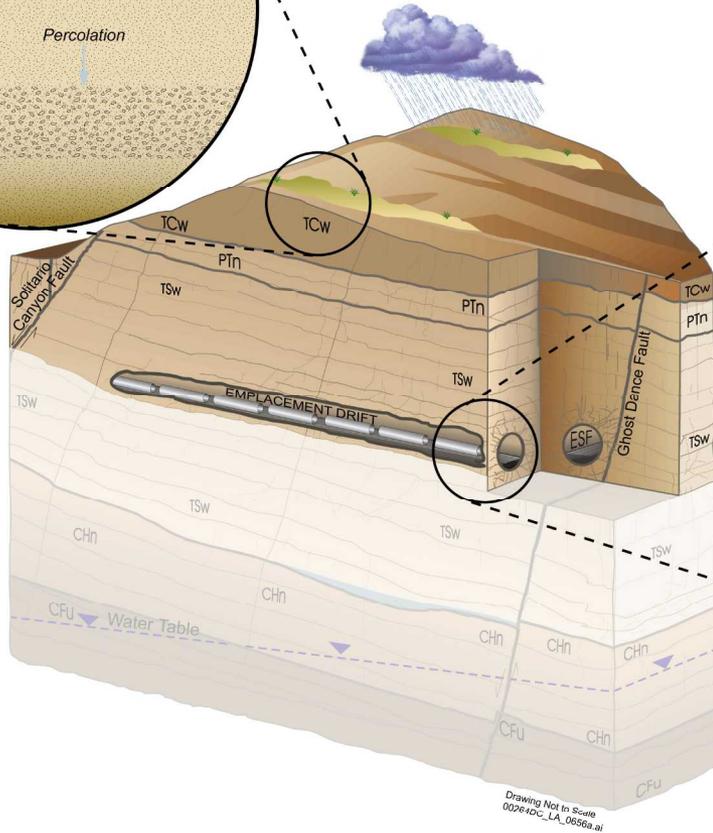
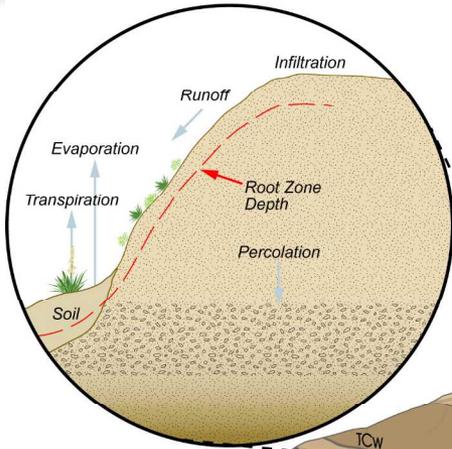
- Surface soils and topography
- Unsaturated zone above the repository
- Drip shield
- Waste package
- Cladding
- Waste form
- Invert
- Unsaturated zone below the repository
- Saturated zone

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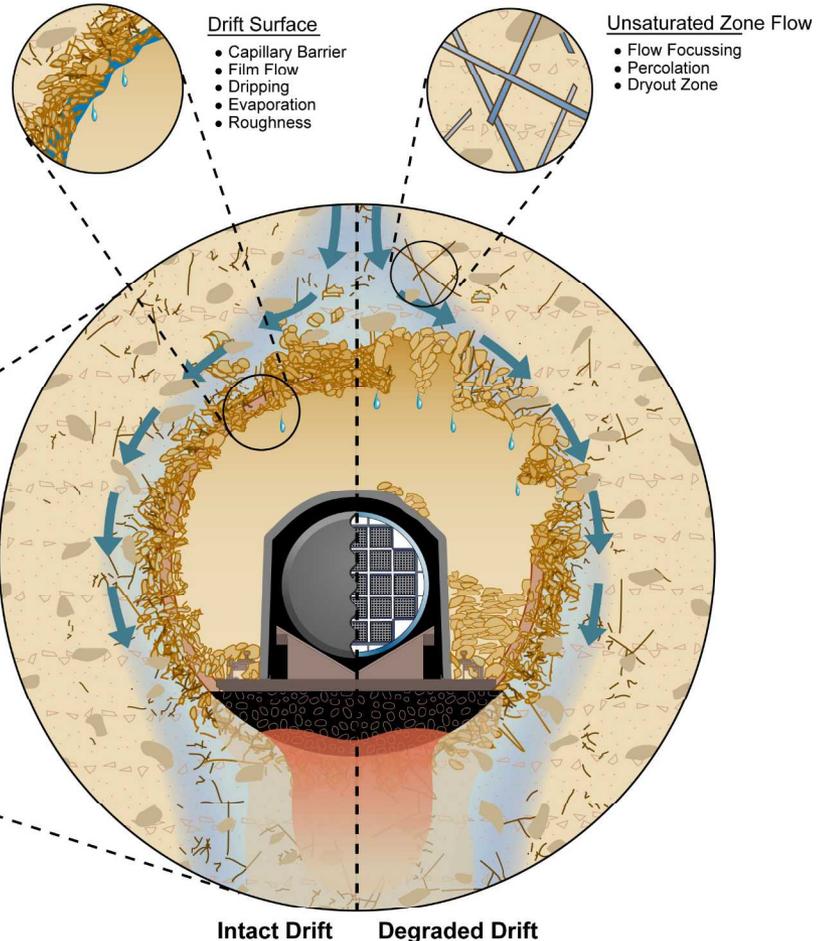
Upper Natural Barrier

Topography and Surficial Soils

- Low precipitation
- Runoff
- Evapotranspiration
- Infiltration



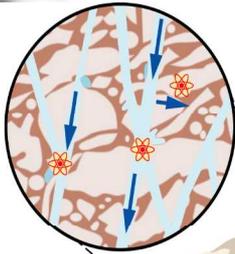
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Unsaturated Zone Above Repository

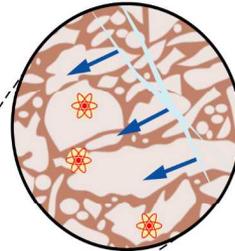
- Percolation
- Capillarity
- Lateral diversion

Lower Natural Barrier



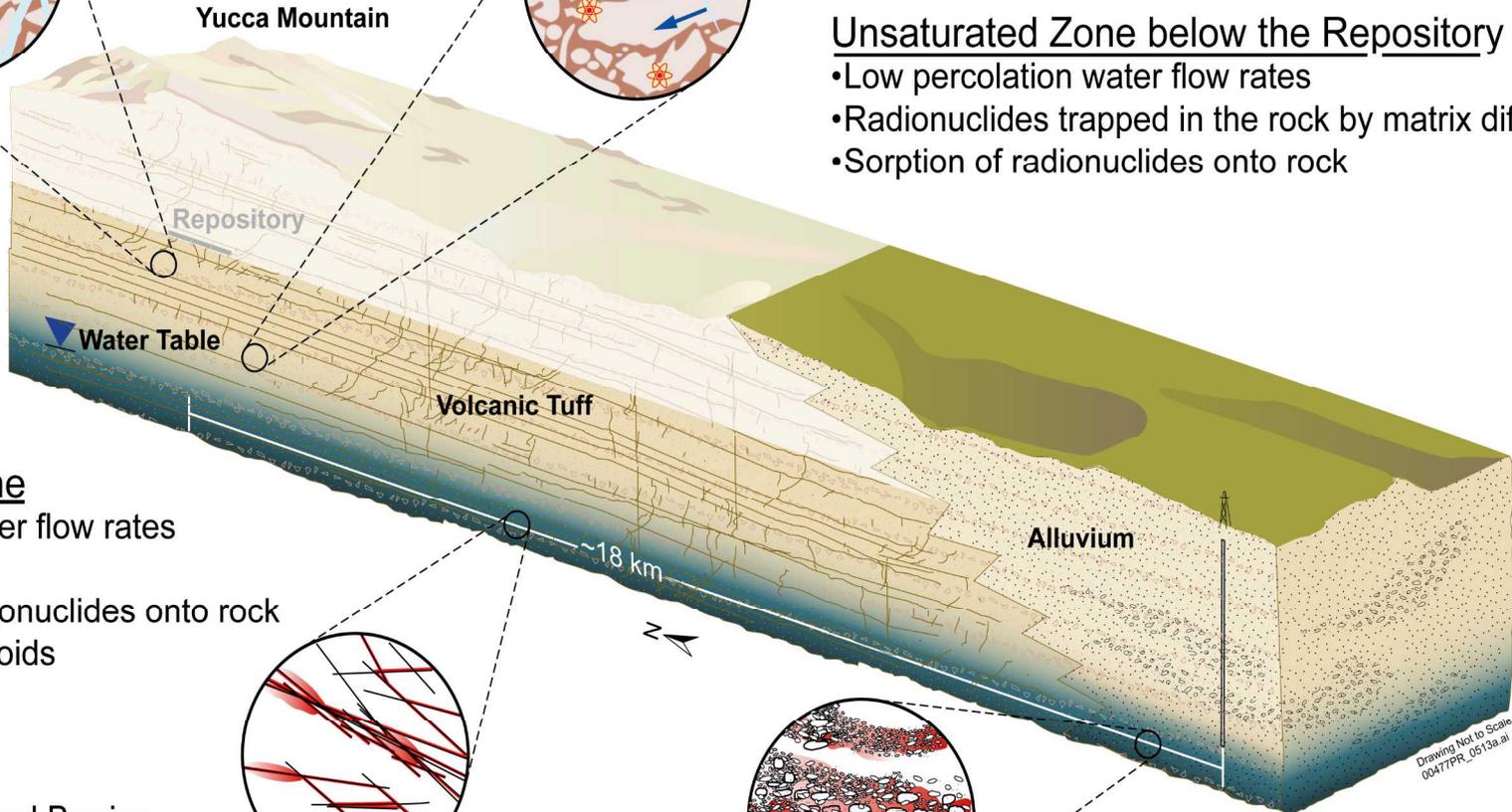
Unsaturated Zone Welded Tuff Units

- Dissolved radionuclides move through fracture flow
- Radionuclides sorb onto colloids that move in fracture flow



Unsaturated Zone Nonwelded Tuff Units

- Dissolved radionuclides diffuse into matrix pore space
- Radionuclides sorbed onto colloids generally filtered out of matrix

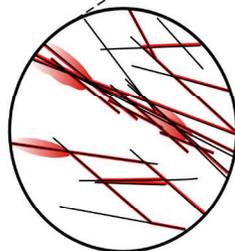


Unsaturated Zone below the Repository

- Low percolation water flow rates
- Radionuclides trapped in the rock by matrix diffusion
- Sorption of radionuclides onto rock

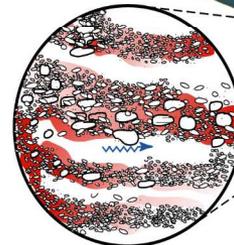
Saturated Zone

- Low groundwater flow rates
- Matrix diffusion
- Sorption of radionuclides onto rock
- Filtration of colloids



Saturated Zone Fractured Volcanic Tuffs

- Diffusion and sorption slow transport of radionuclides



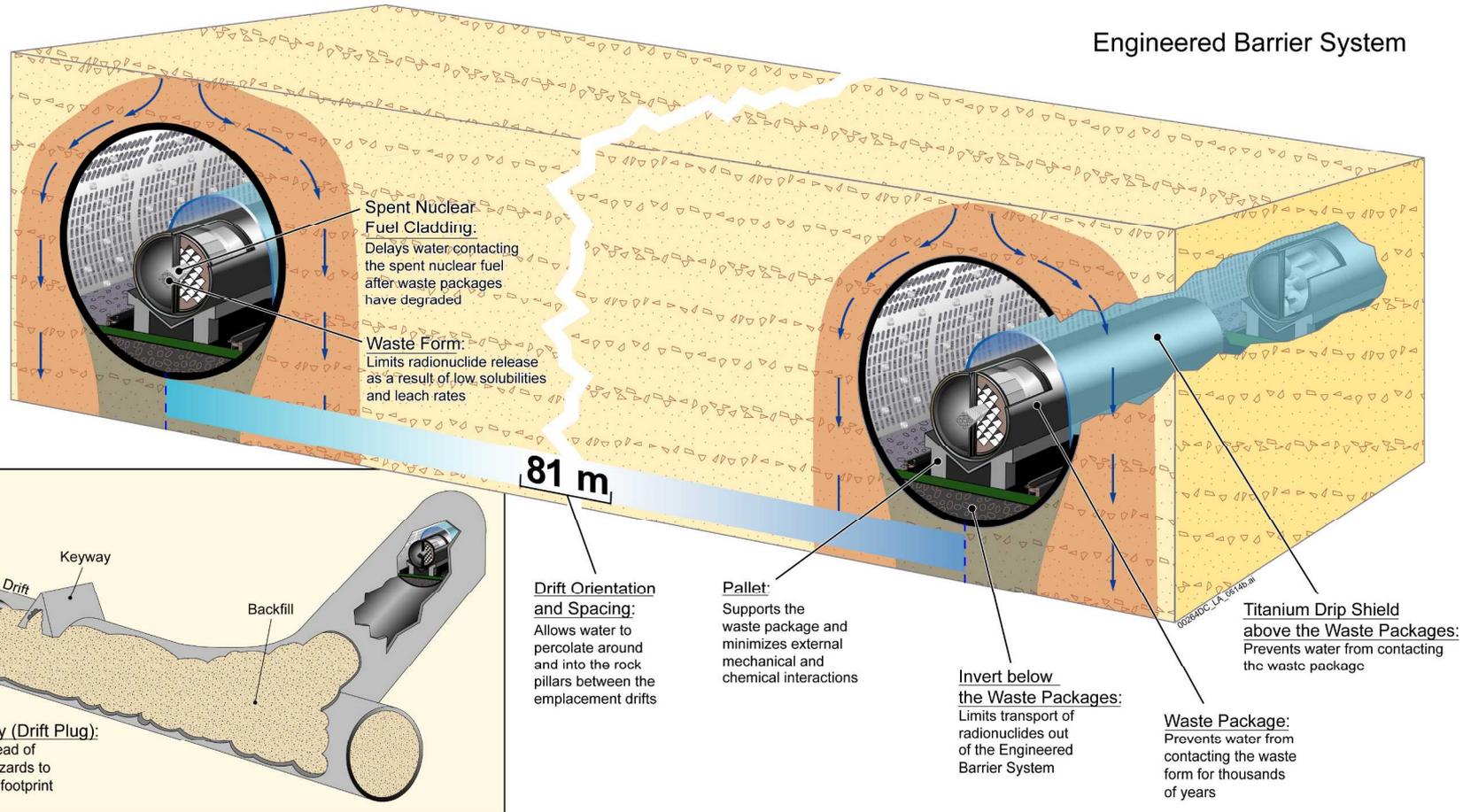
Saturated Zone Alluvium

- Diffusion and sorption slow transport of radionuclides
- Larger effective porosity in alluvium slows water flow, and radionuclides move by diffusion in slow-moving or stagnant water

Lower Natural Barrier

*Drawing Not to Scale
00477PR_0513a.ai*

Engineered Barrier System





Outreach



Outreach Programs Statistics

(FY 2006)

- **Tours:** 154 tours briefing 2,321 visitors plus 1,074 visitors to Public Open House tours
- **Educational Events:** 32 events reaching 3,120 students, teachers, and parents
- **Exhibits:** 23 meetings/conferences/civic events reaching 3,967 people
- **Inquiries:** 139 e-mails and letters
- **Information Centers:** 3 Nevada locations with 4,792 visitors
- **Media Interactions/Communications Support:** The project has dozens of media interactions each year
- **Speakers Bureau:** 34 presentations reaching 1,758 people
- **Toll-free Information Line:** 666 calls were received and processed
- **Website:** The OCRWM Internet website had 1,352,564 user sessions

Information Center in Nye County, Nevada



- **The exhibits, video displays, and interactive computer programs at the Yucca Mountain Information Center are designed to help explain why and how scientists and engineers are studying Yucca Mountain**

User-Friendly Web Site

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CIVILIAN RADIOACTIVE WASTE MANAGEMENT

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Advanced Science Studies
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- Job Opportunities
- Give Us Your Feedback

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- Procurement Opportunities
- Primary Contractors
- Active Contracts


Civilian Radioactive Waste Management

Our mission is to manage and dispose of high-level radioactive waste and spent nuclear fuel in a manner that protects health, safety and the environment; enhances national and energy security; and merits public confidence.

Newsroom
On this page, you'll find the latest news from the Department of Energy about the Office of Civilian Radioactive Waste Management and the Yucca Mountain Project. [Read More >](#)

Current locations of nuclear waste in the United States
Nuclear waste is currently located in more than 120 locations in 39 states. [Read More >](#)

License Application Information
Following more than 20 years of study by the U.S. Department of Energy, Congress approved in July 2002 the President's recommendation of the Yucca Mountain site for development as a repository for the disposal of spent nuclear fuel and high-level radioactive waste. [Read More >](#)

NRC Licensing Support Network

WHAT'S NEW

- OCRWM Director's 2008 Budget Rollout Briefing
- Preliminary Transportation, Aging and Disposal Canister System Performance Specification
- Quarterly Report to Congress-- July 1 - September 30, 2006

VIDEO HIGHLIGHTS


Yucca Mountain: The Making of an Underground Laboratory

- YMP web site - www.ocrwm.doe.gov - reaches global audience