YUCCA MOUNTAIN PROJECT

Studies

Waste Package and Repository Configuration

Presented to:
Nuclear Waste Technical Review Board
Waste Package Workshop
Falls Church, Virginia

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

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- Repository Requirements
- Repository Layout
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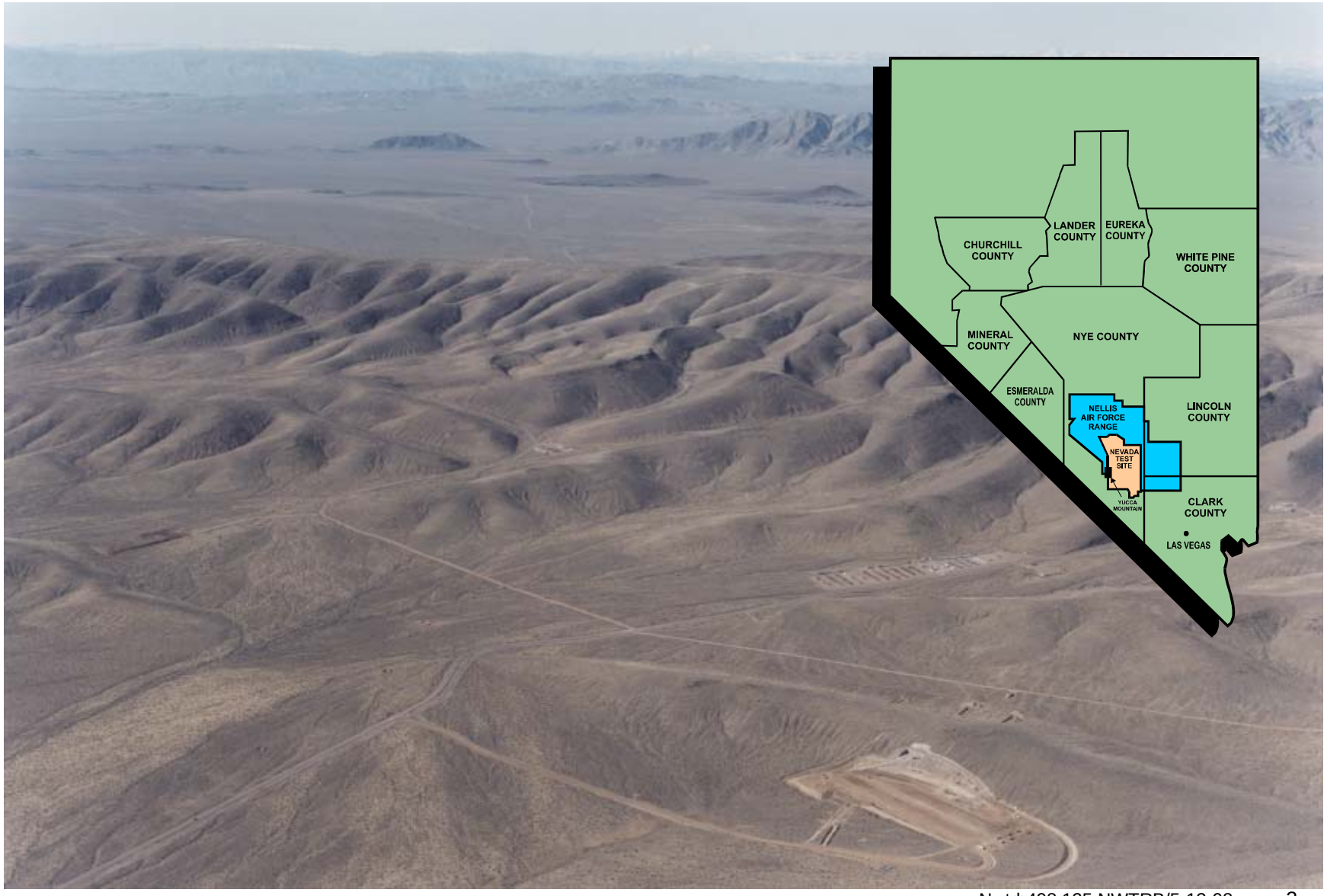
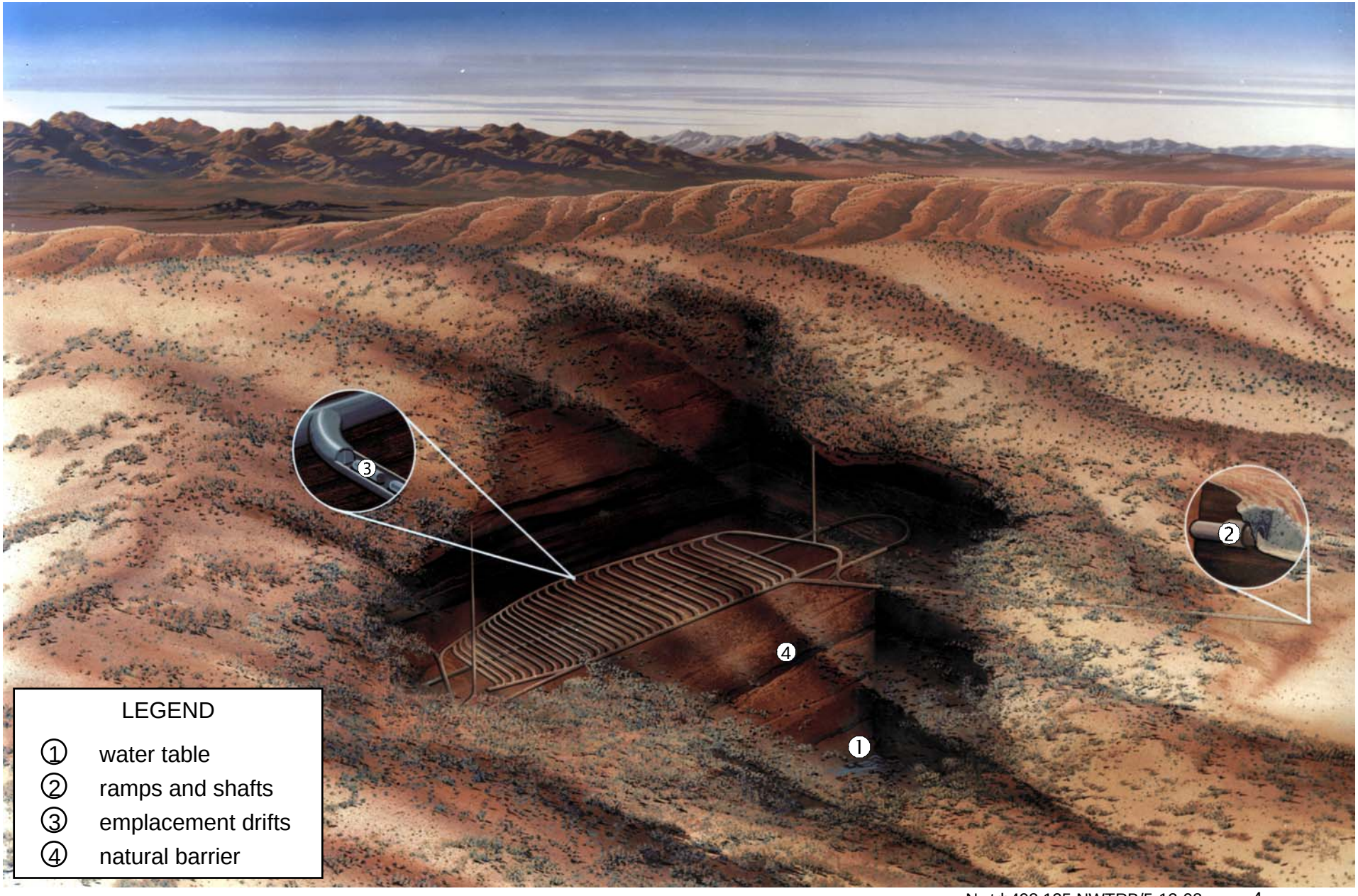
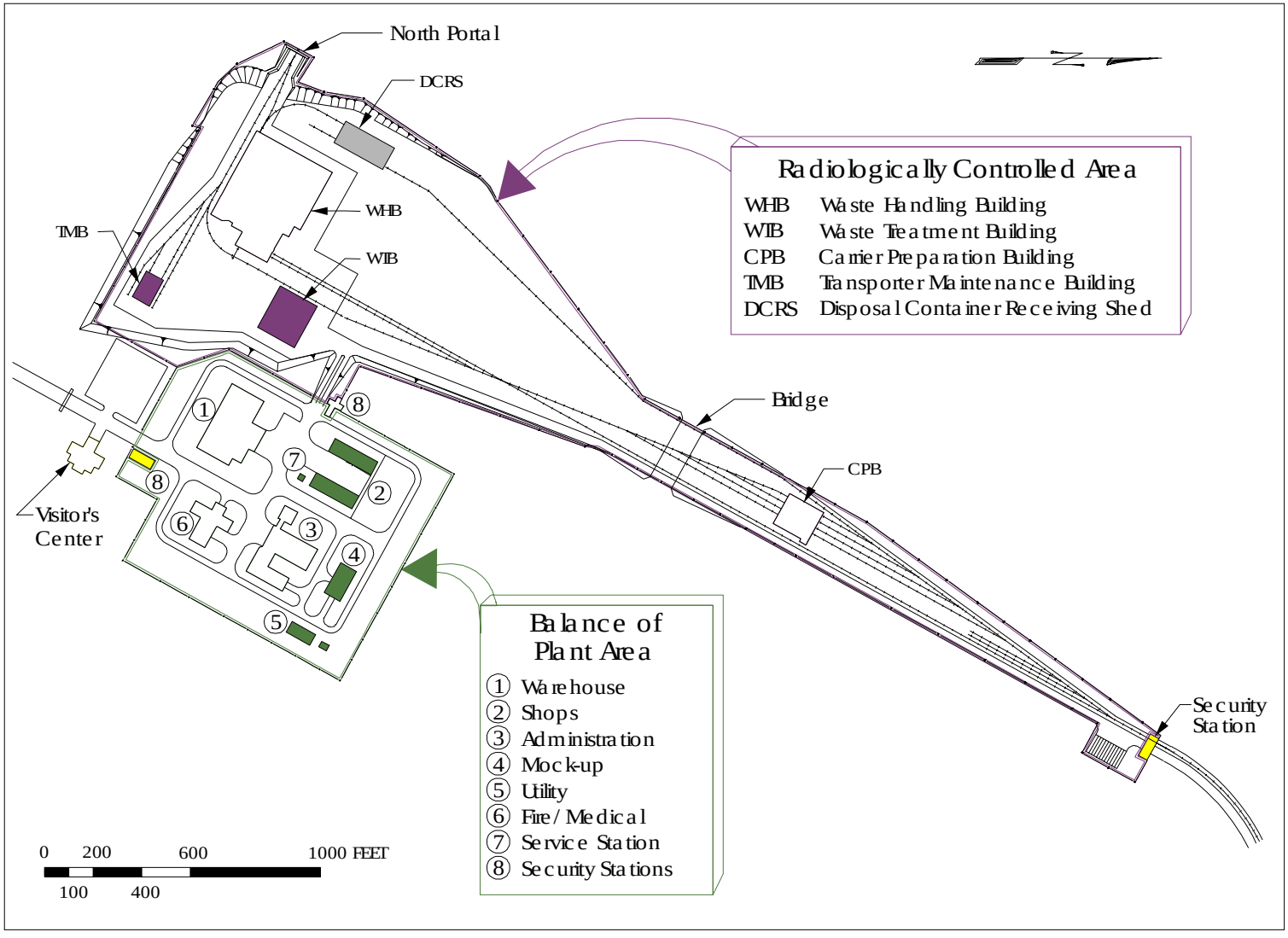
Yucca Mountain



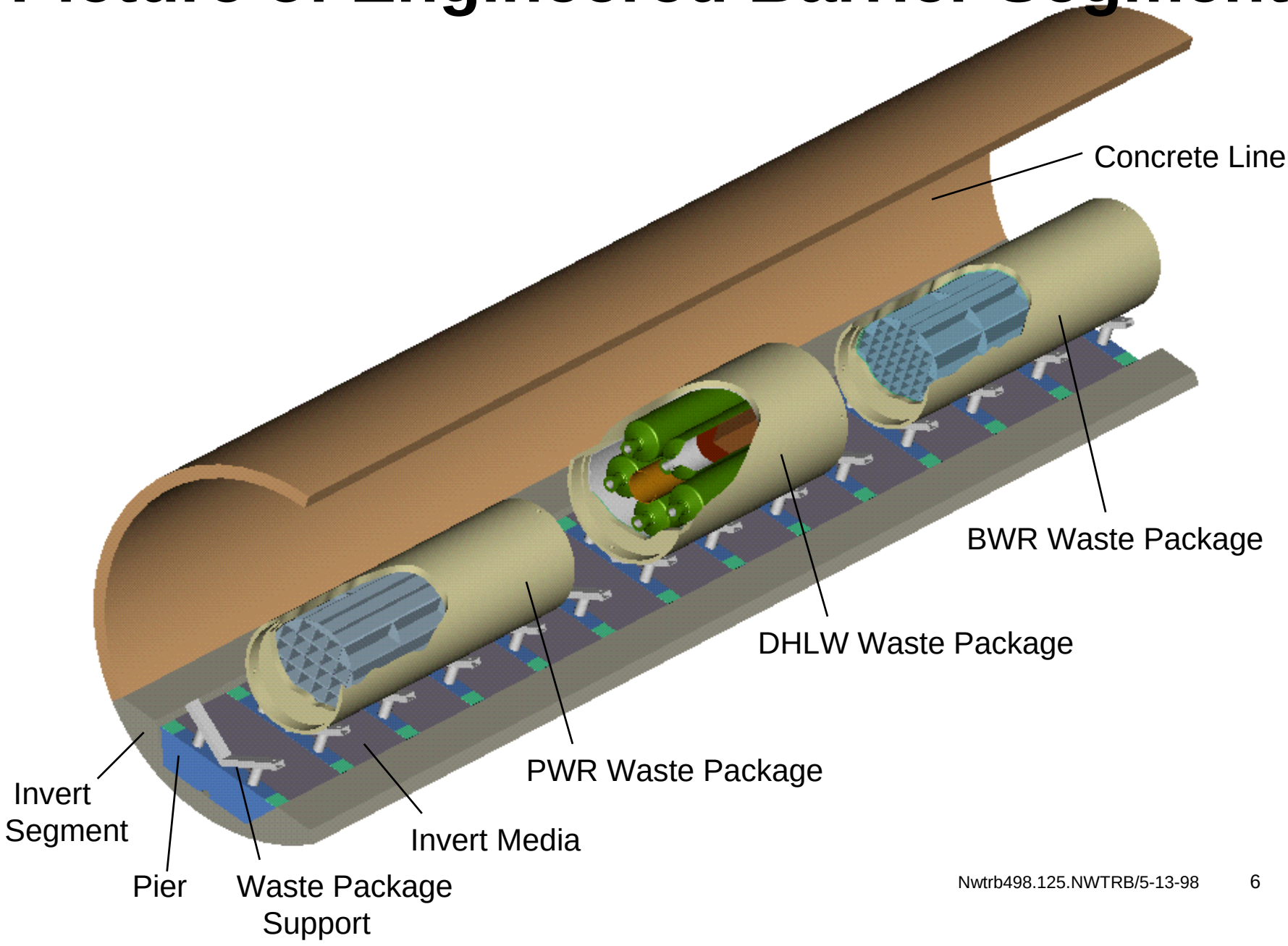
Subsurface Facility



Picture of Surface Facility



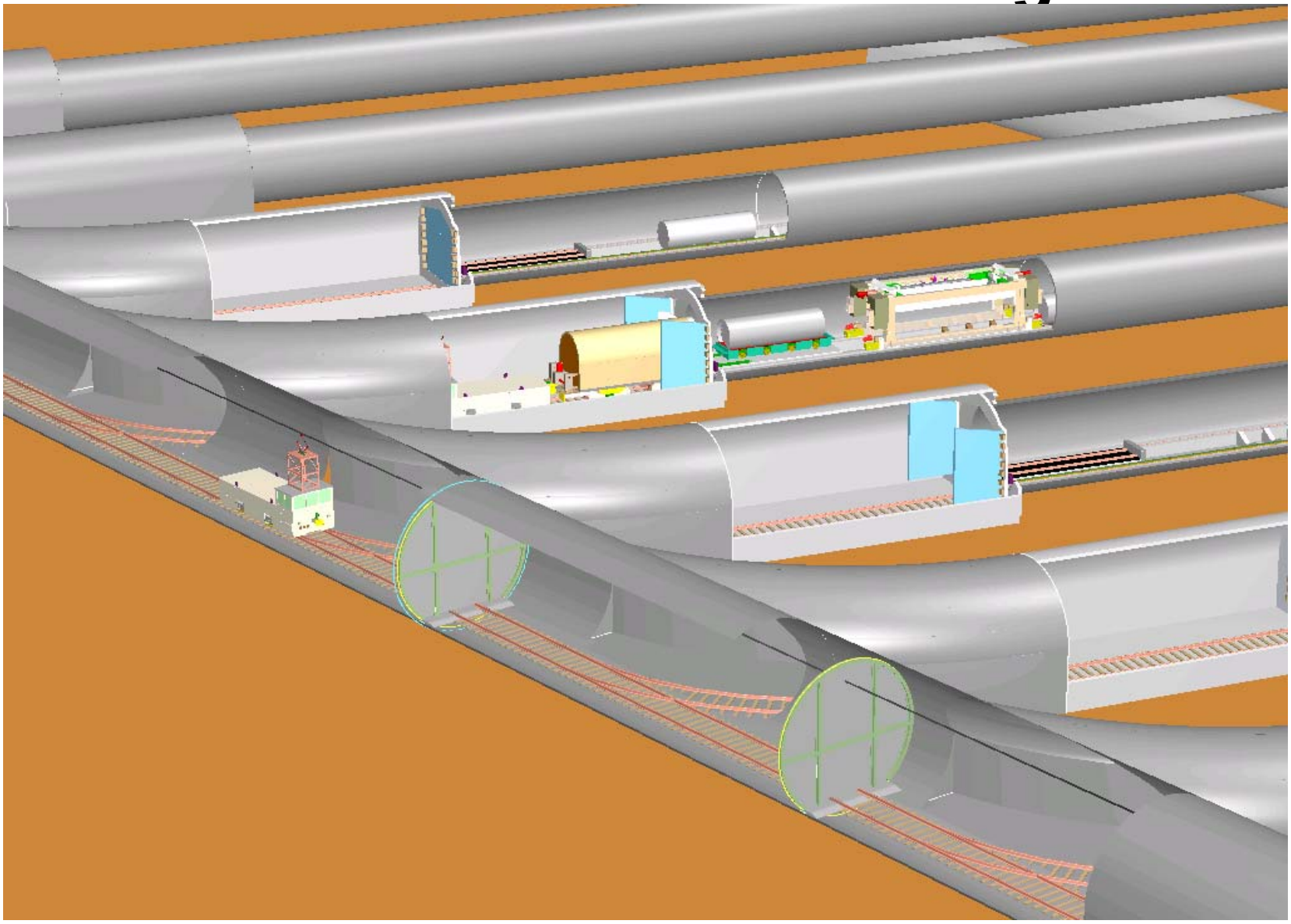
Picture of Engineered Barrier Segment



The Reference VA Design

- **Thermal Load 85 MTU/Acre**
- **Drift spacing 28 m**
- **Commercial and DOE glass-waste waste packages are alternated in drift**
- **Emplacement mode, horizontal in-drift**
- **Zeolite peak temperature of 90 ^{o}C at average 170 m below repository**
- **Drift wall peak temperature below 200 ^{o}C limit, current design 160 -180 ^{o}C**
- **Emplacement drifts ventilated, 5-10 m^3/sec flow during emplacement**
- **An airflow of 0.1 m^3/sec in filled drifts**

Picture of Drift Handling



Major Design Goals

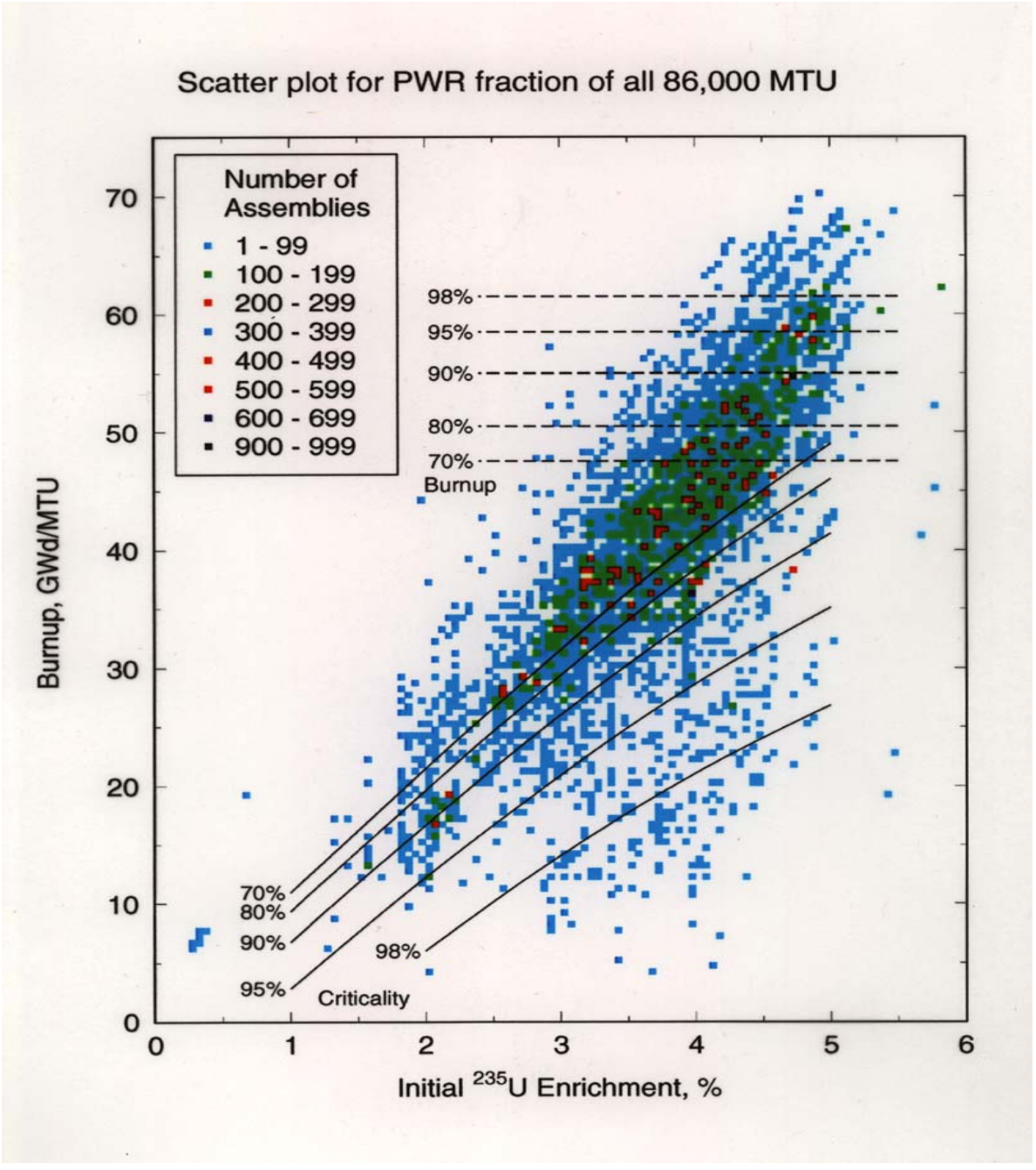
- **Meet future NRC/EPA regulations, with objective evidence**
- **Containment of the waste for at least 3,000 years (program goal, 10 CFR 60 requires 300 to 1,000 years)**
- **Post containment release <1 part in 10^5 per year of inventory of each radionuclide at 1000 years**
- **Protect waste from contact with seeping or dripping water for at least 10,000 years (program goal)**
- **Protect fuel rod cladding (temperature <350^o C)**
- **Waste package containment barrier shielding to protect against radiolytically enhanced corrosion**
- **Criticality control**
  - **Preclosure: prevent criticality during operations**
  - **Postclosure: very low likelihood and insignificant consequences during isolation period**

Waste Forms

- Commercial Spent Nuclear Fuel
  - PWR
  - BWR
- Vitrified Waste
  - Savannah River Site
  - West Valley
  - Hanford
- Other DOE Spent Nuclear Fuel
  - Approximately 250 waste forms compiled into categories
- Navy Fuel
- Plutonium
  - Commercial MOX
  - Immobilized

Design Basis Waste Package Environment

- **High average thermal loading (80 to 100 MTU/Acre)**
  - **Waste container surface temperatures above boiling for thousands of years (about 3,000 years)**
  - **Relative low humidity initially, then as temperatures drop a slow return to initial ambient humidity**
  - **Some containers will see dripping water**
  - **Repository edge and fault avoidance effects will cause localized lower thermal loading**
- **Water in vicinity of waste packages**
  - **Bicarbonate water with pH 4.5 to 10.5**



Scatter Plot of SNF

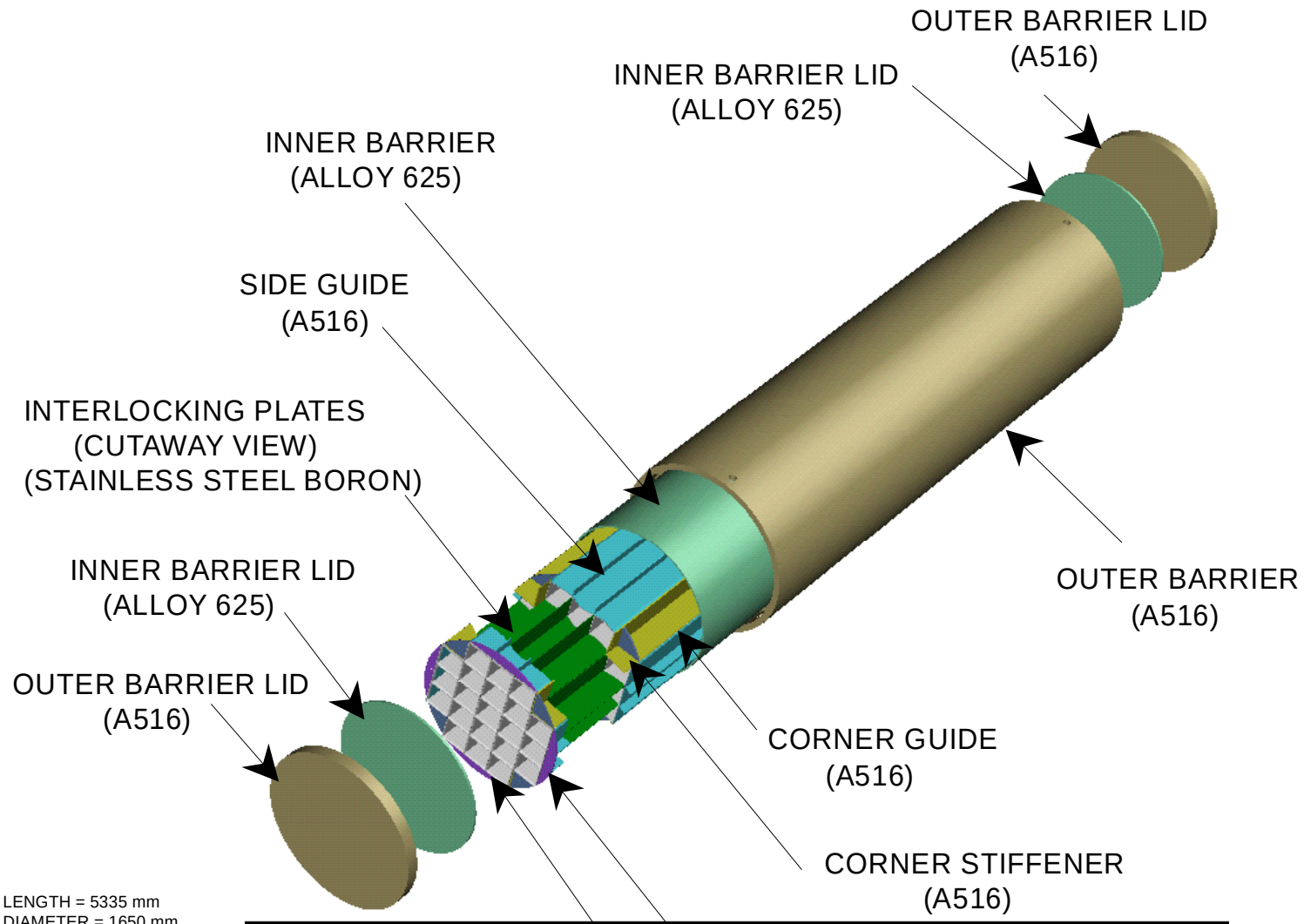
Licensing Considerations

- **Waste package design(s) must have the intended contents specifically defined, similar to cask storage**
  - **SNF size, type, enrichment, burnup, cooling time, etc.**
  - **Bounding SNF defined by the Design Basis Fuel**
- **Each different segment of the waste stream must be addressed in the license, regardless if the same physical WP design was used**
- **Need to demonstrate regulatory compliance**
- **Identification of and compliance with industry consensus codes and standards**

Progression of Design

- **1988: Thin-Walled; Borehole emplacement**
- **1992: Definition of advanced conceptual design options: 7 design options**
- **1992: Robust/Multi-Barrier; Drift emplacement**
- **1993: Multi-Purpose Canister with Robust / Multi-Barrier Waste Package**
- **1996: Advanced Conceptual Design**
- **1998: Viability Assessment Design**
- **2001: License Application Design**

21 PWR UCF Waste Package Assembly



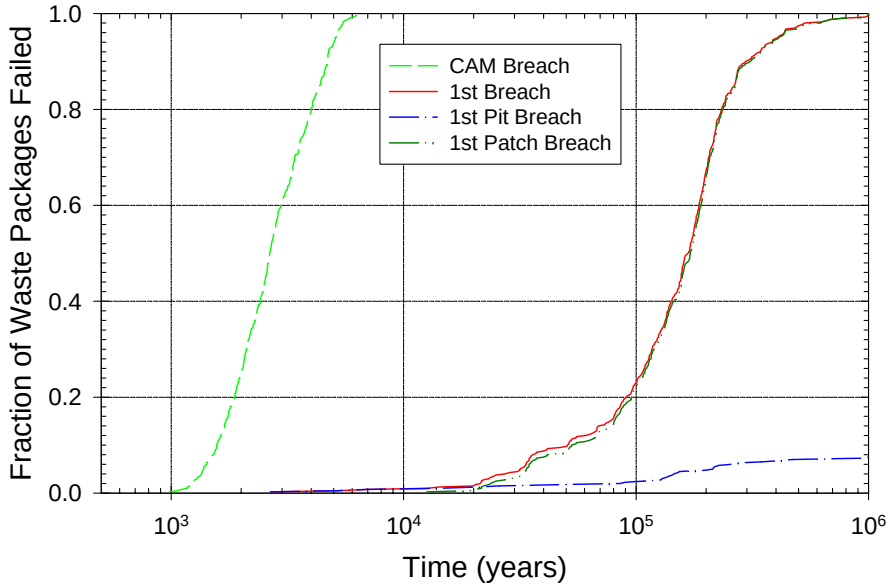
LENGTH = 5335 mm
DIAMETER = 1650 mm
TARE WEIGHT = 34,039 kg
LOADED WEIGHT = 50,423 kg

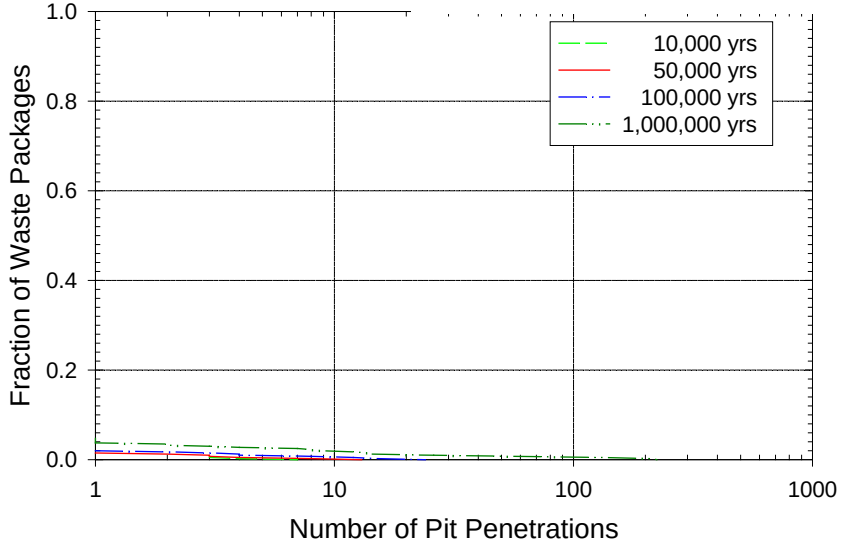
Waste Package Fabrication Process

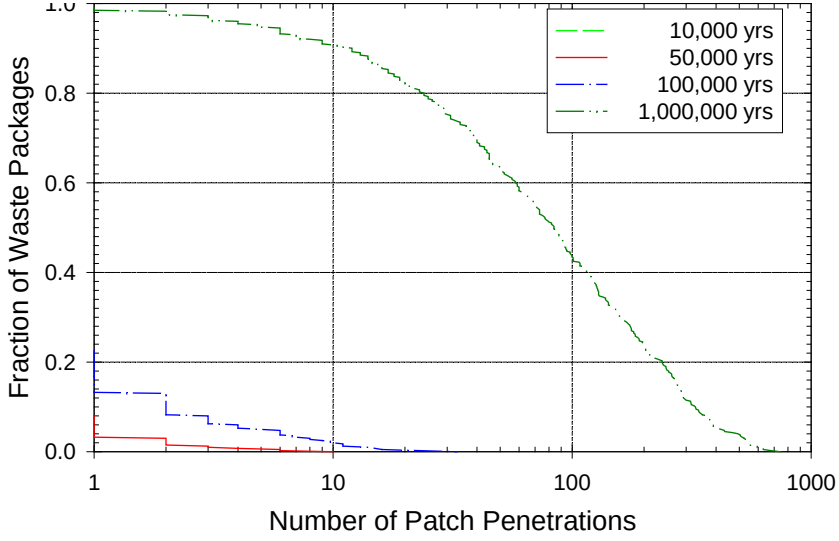
- Barriers are rolled and seam welded
- Inner and outer barriers are assembled using shrink fit process
- Internal basket guides are installed in inner barrier
- Lower end plates are installed and then the assembly is stress relieved
- Basket components are assembled (tubes, stainless-steel boron plates, and thermal shunts) and then inserted into barriers
- After SNF is installed, inner and outer lids are welded using narrow gap process
- All welds and plates are 100% inspected

TSPA-VA Base-Case Waste Package Analysis Results

(NE area; SF WPs; no backfill; always dripping & 100% wetted)





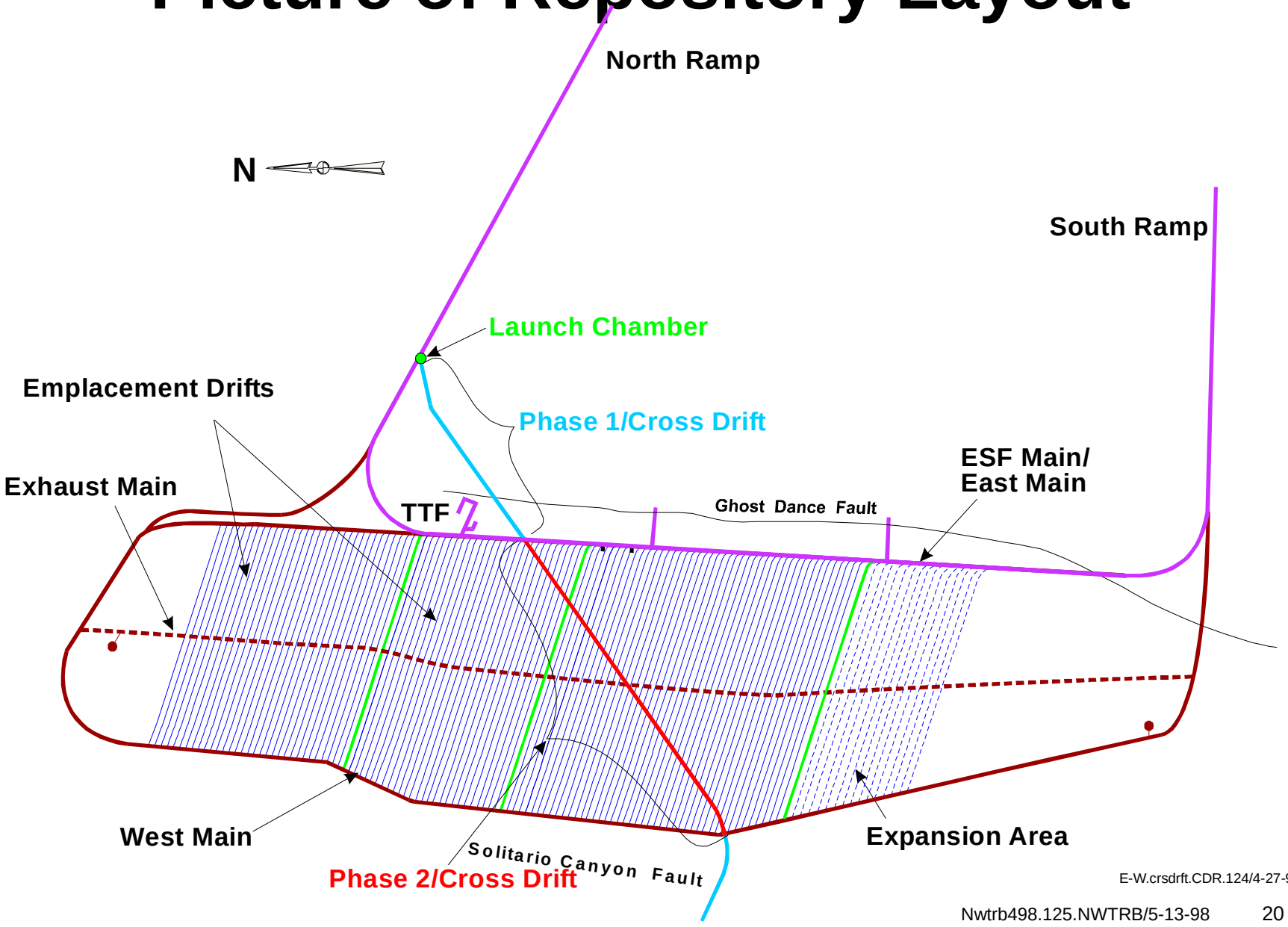


Alternative/Design Options

- **Two CRM design**
  - **Capacity: 21/12 PWR and 44/24 BWR**
  - **Drift emplaced**
- **Shielded waste package**
  - **Shield material: (carbon steel, concrete, DU, composite)**
- **Ceramic coated waste package**
- **VA design with thicker CRM**
  - **Inner barrier: 40 mm of C-22**
  - **Outer barrier: 100 mm of A516**
  - **Capacity: 21/12 PWR and 44/24 BWR**
  - **Drift emplaced**

Backup / Additional Information

Picture of Repository Layout



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Waste Package Transportation Operation

- **Shielded transporter and manually driven locomotive to the mouth of the emplacement drift**
- **A remote controlled gantry picks up the waste package, travels a maximum of 600 m**
- **Emplacement from both ends of emplacement drift**
- **Waste packages are placed from center of the drift towards the entrance of drift. No leap-frogging**

Waste Package Requirements

- **Requirements are stated in the CFRs**
  - **10 CFR 20 Standards for Protection Against Radiation**
  - **10 CFR 60 Disposal of High-Level Radioactive Waste in Geological Repository**
  - **10 CFR 960 General Guidelines for Recommendation of Sites for Nuclear Waste Repositories**
  - **40 CFR 191 (Remanded) Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Waste**
- **Program requirement documents:**
  - **Engineered Barrier Design Requirements Document (EBDRD)**
  - **Control Design Assumptions (CDA)**
  - **System Description Document (SDD) - New requirements documentation, under development**

SCP Concept

- **1988: Thin-Walled, Borehole Design**
  - **Proposed Material: Stainless steel 304L or Inconel 825**
  - **Thickness: 10mm**
  - **Emplacement: Vertical boreholes spaced every 15 feet**
  - **Fixed Thermal Load of 57 kW/Acre, Cladding Temperature Exceeded 350 C (380 C)**
  - **4-PWR and 3-BWR**
  - **No Criticality Control Method Specified**
- **Little or no performance allocated to waste package**

Robust Concepts/Designs

- **1992: Robust/Multi-Barrier, Drift Emplaced**
- **1993: Multi-Purpose Canister/ Robust/Multi-Barrier**
  - **"A Preliminary Evaluation of Using Multi-Purpose Canisters Within the Civilian Radioactive Waste Management System" issued March 1993**
- **1996: Advanced Conceptual Design**
  - **Workable concept**
  - **Handle over 90% Commercial Spent Nuclear Fuel in basic design**
  - **Inner barrier alloy 825; outer barrier carbon steel, high and low thermal load designs**
- **1998: Viability Assessment Design**
  - **Handle 100% of All Specified waste Forms**
  - **Incorporate Scientific Studies, corrosion, site, Performance Assessment**
  - **Inner barrier C-22; outer barrier AS16**

Advanced Conceptual Concepts

- **1992: Definition of Advanced Conceptual Design Options**
  - **Metallic Multi-Barrier, Drift Emplaced**
  - **Metallic Personnel Shielded**
  - **Small Metallic Multi-Barrier**
  - **Non-Metallic Multi-Barrier**
  - **Multi-Purpose Waste Package**
  - **Universal Cask - Waste Package**
  - **SCP-CDR (thin walled container)**
- **Waste package containment/release important to performance**

Waste Stream Considerations

- **Commercial SNF waste stream projections indicate a wide distribution in characteristics**
  - **For example, the heat output of the 90th percentile can be more than twice the average heat output**
- **Projected SNF was sorted by assembly characteristics important to design**
  - **Physical size and weight of assembly**
  - **Heat output at time of emplacement**
  - **Criticality potential (k-infinity)**

Waste Package Designs

- **Uncanistered Spent Nuclear Fuel**
- **Canistered Spent Nuclear Fuel**
- **Defense High Level Waste**
- **DOE-owned Spent Nuclear Fuel**
- **Canistered Navy Fuel**

Waste Package Materials

- **Dual barrier design provides two independent failure mechanisms**
  - **Corrosion-Allowance Barrier**
    - **Subject to general corrosion**
    - **Permits performance prediction; thickness governs time to failure**
    - **Relatively low cost**
    - **Current design 100 mm A516 carbon steel**
  - **Corrosion-Resistant Barrier**
    - **Corrosion resistance in wide range of pH**
    - **Localized corrosion is stifled**
    - **Initiation of corrosion and failure random**
    - **Current design 20 mm high-nickel Alloy C-22**

Waste Package Basket Design/Materials

- **Defense-in-depth**
  - **Basket structure, carbon steel tubes**
    - **Load bearing**
    - **Heat removal**
    - **Long term performance, as it degrades,**
      - **Moderator displacement (reduces probability of criticality)**
      - **Retards radionuclides**
  - **Performance based neutron absorbing material**
    - **Corrosion resistant, Stainless steel-boron**
    - **Non-structural, in compliance with NRC guidance**
  - **Thermal shunt, ensures cladding temperature is met**

Waste Package Thermal Restraints

- **Thermal restraints are governed by temperature limits for:**
  - **Cladding**
  - **Drift wall**
  - **Zeolites**
- **Repository thermal loading 80-100 metric tons uranium per acre**
- **Waste Package maximum thermal output limit is 18kW**

Structural Restraints

- **Preclosure Analyses**
  - **Handling Load**
    - **SNF loading and container closure**
    - **Waste container lifting and moving**
    - **Emplacement/Retrieval**
  - **Design Basis Events**
    - **Drops (vertical, horizontal, oblique)**
    - **Tip-over**
    - **Impacts (missile from failure of pressurized component, rock fall, etc.)**
- **Postclosure Analyses**
  - **Drift Liner Collapse/Rock Fall**
  - **Seismic Event**

Parametric

- **Thicker Corrosion-Resistant Material (CRM) extends waste package life**
- **Worst case: Constant water drip on waste packages**
  - **20mm: ~ 8,000 years to initial breach**
  - **30 mm: ~ 25,000 years to initial breach**
  - **40 mm: ~ 40,000 years to initial breach**

Baseline and Shielded WP Designs

	Baseline WP		Shielded WP		
WP Capacity	Diameter x Length	WP Mass	Diameter x Length		WP Mass
21 PWR	1.7 m x 5.3 m	51,000 kg	A 516	3.8 m x 7.5 m	629,000 kg
			DU	2.9 m x 6.6 m	636,000 kg
			Concrete	2.8 m x 6.5 m	153,000 kg
12 PWR	1.3 m x 5.3 m	34,000 kg	A 516	3.5 m x 7.5 m	531,000 kg
			DU	2.5 mx 6.6 m	519,000 kg
			Concrete	2.5 m x 6.5 m	119,000 kg
5 PWR	1.0 m x 5.3 m	20,000 kg	A 516	3.1 m x 7.4 m	416,000 kg
			DU	2.2 m x 6.5 m	395,000 kg
			Concrete	2.1 m x 6.5 m	84,000 kg

Cost for Options

- **Extended Life with Personnel Shielding**
  - **For 12 PWR size waste package**

	2.5 mrem/hr	100 mrem/hr
– A516	$ 356,000	$ 210,000
– C-22	$3,626,000	$1,688,000
– A516/C-22	$1,992,000	$ 949,000

Comparison Table

Type Package	21 PWR A516/ C-22 Baseline	21 PWR C-22/Ti-7 Extended	21 PWR C-22/Ti-7 Extended with A516 Shield	21 PWR C-22/Ti-7 Extended with C-22 Shield	12 PWR A516/ C22 Baseline	12 PWR C-22/Ti-7 Extended	12 PWR C-22/Ti-7 Extended with A516 Shield	12 PWR C-22/Ti-7 Extended with C-22 Shield
WEIGHT	51 metric tons	40 metric tons	205 metric tons	222 metric tons	34 metric tons	25 metric tons	140 metric tons	152 metric tons
DIA	1663 mm	1573 mm	2609 mm	2609 mm	1320 mm	1230 mm	2163 mm	2163 mm
LENGTH	5335 mm	5230 mm	6276 mm	6276 mm	5335 mm	5230 mm	6164 mm	6164 mm