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Salt Repository Seal Design and Materials

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Albuquerque, New Mexico

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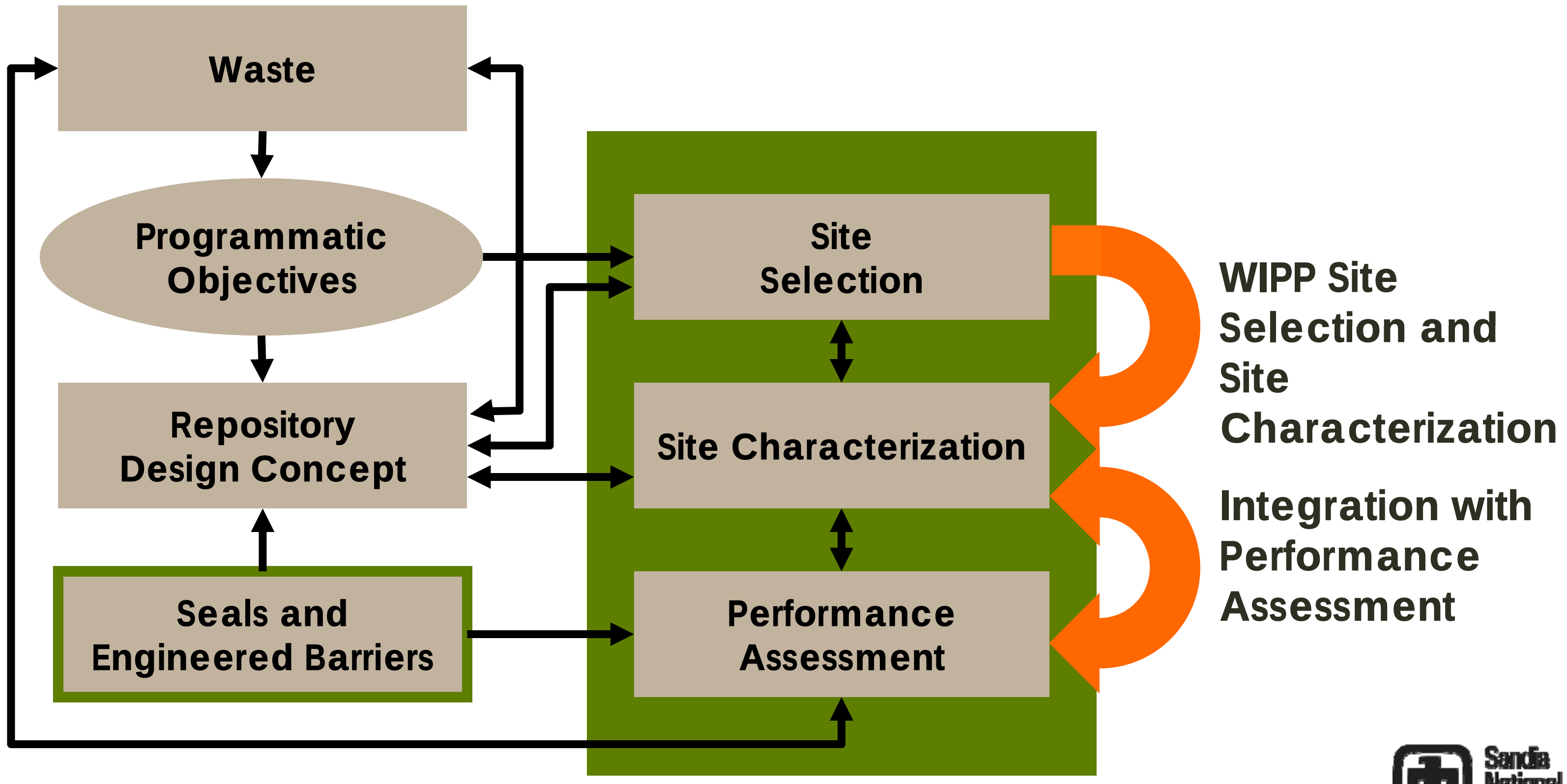
Context for site selection, site characterization, and integration with performance assessment



Waste Isolation Pilot Plant Chronology

1975

1979

2000

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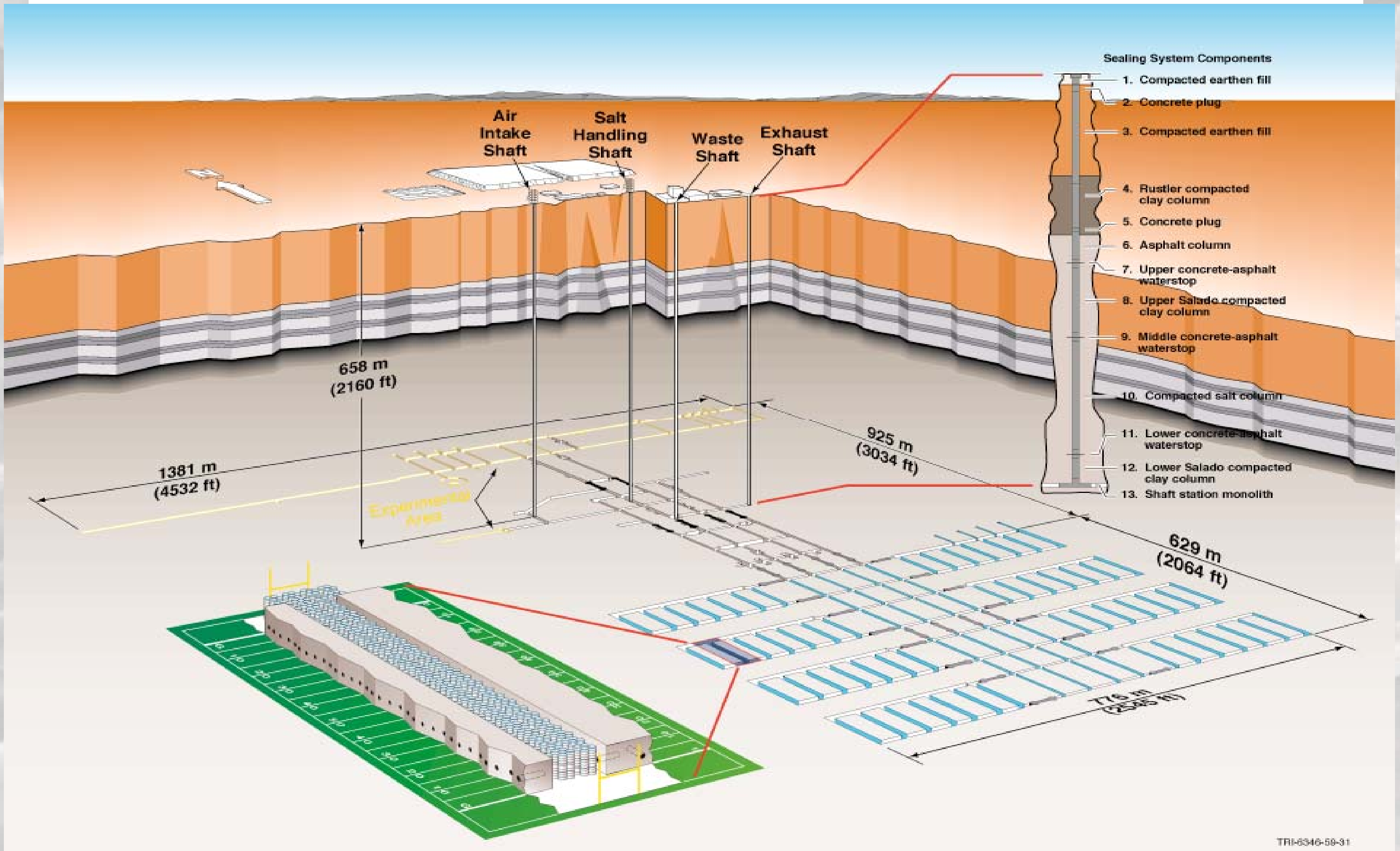
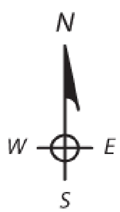
WIPP Facility Layout



WIPP Major Tests

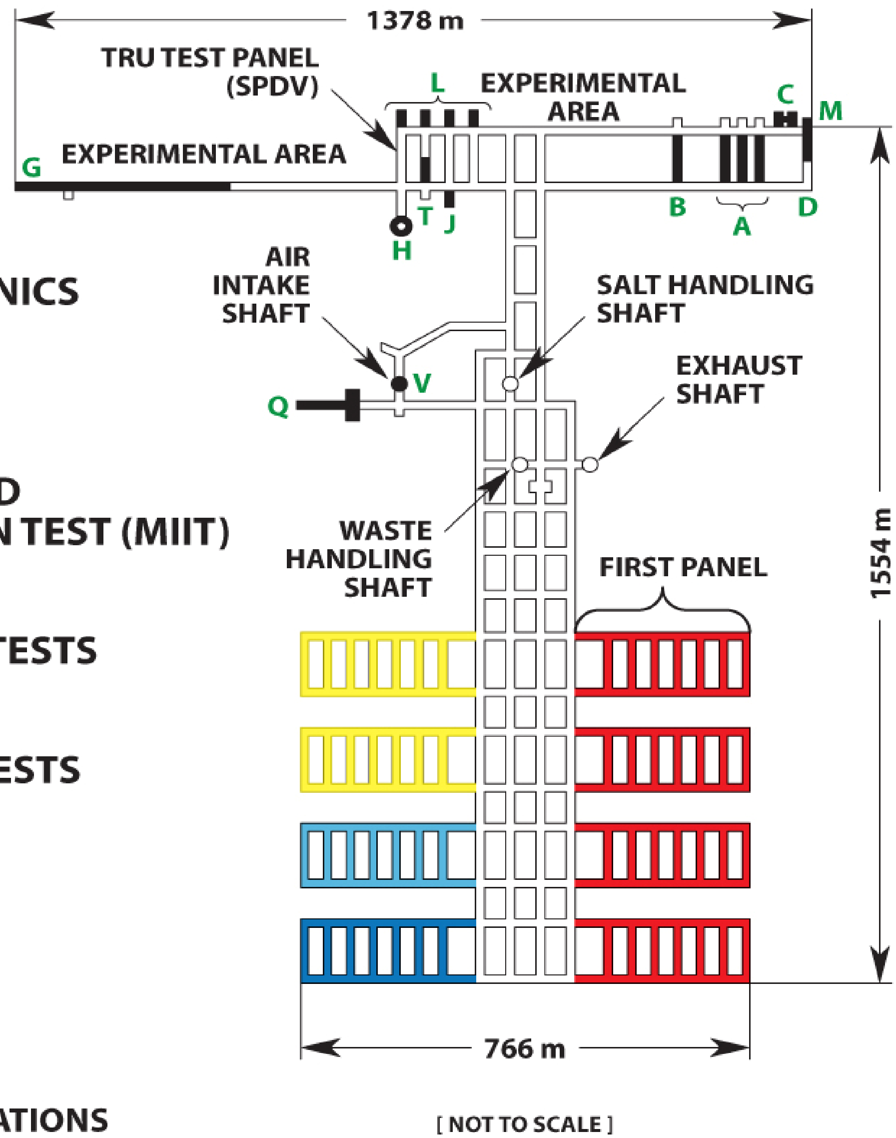
FIELD TESTS:

- **A.** 18 W/m² MOCKUP
- **B.** DHLW OVERTEST
- **C.** INTERMEDIATE SCALE ROCK MECHANICS AND PERMEABILITY TESTS
- **D.** MINING DEVELOPMENT
- **G.** GEOMECHANICAL EVALUATION
- **H.** HEATED PILLAR
- **J.** SIMULATED CH TRU TESTS (WET) AND MATERIALS INTERFACE INTERACTION TEST (MIIT)
- **L.** PLUGGING AND SEALING, WASTE DRUM/BACKFILL TESTS
- **M.** SMALL SCALE SEAL PERFORMANCE TESTS
- **T.** SIMULATED CH AND RH TESTS
- **Q.** CIRCULAR BRINE ROOM TESTS
- **V.** AIR INTAKE SHAFT PERFORMANCE TESTS



- PLANNED MINING
- CURRENTLY BEING MINED
- CURRENTLY BEING FILLED
- FULL

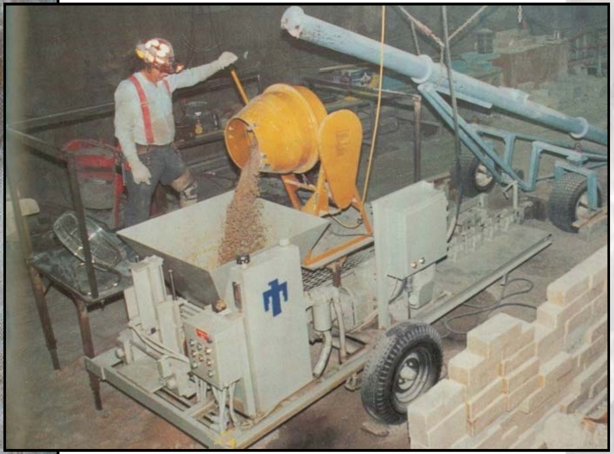
SALT AND INTERBED PERMEABILITY AND BRINE SEEPAGE TESTS AT NUMEROUS LOCATIONS



Underground Test Program

- Large-scale geomechanical and hydrological testing
- Examination characterization of DRZ and seal components
- Coupled natural, excavation- induced, disposal room processes important

Small Scale Seals Performance Testing



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Bedded Salt Attributes

- Salt can be mined easily
- Salt has a relatively high thermal conductivity
- Wide geographic distribution (many potential sites)
- Salt is plastic *
- Salt is essentially impermeable *
- Fractures in salt are self healing *
- Salt has existed underground for millions of years *

* Attributes of Natural Barrier

Assessing Engineered Barriers

Environmental Protection Agency defines barriers as “any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment”

1. Geology – the Most Important Barrier
2. Shaft Sealing System
3. Panel Closure System
4. Magnesium Oxide Engineered Barrier
5. Waste Package
6. Borehole Plugs

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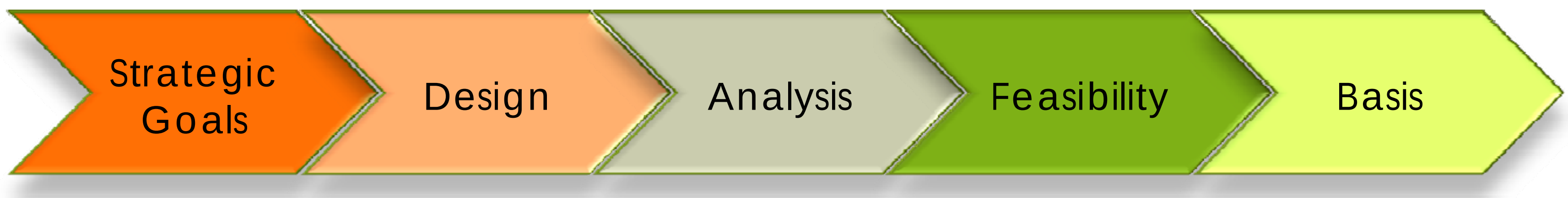
WIPP Case Studies of Seal Systems



Case Study 1
Shaft Seal System

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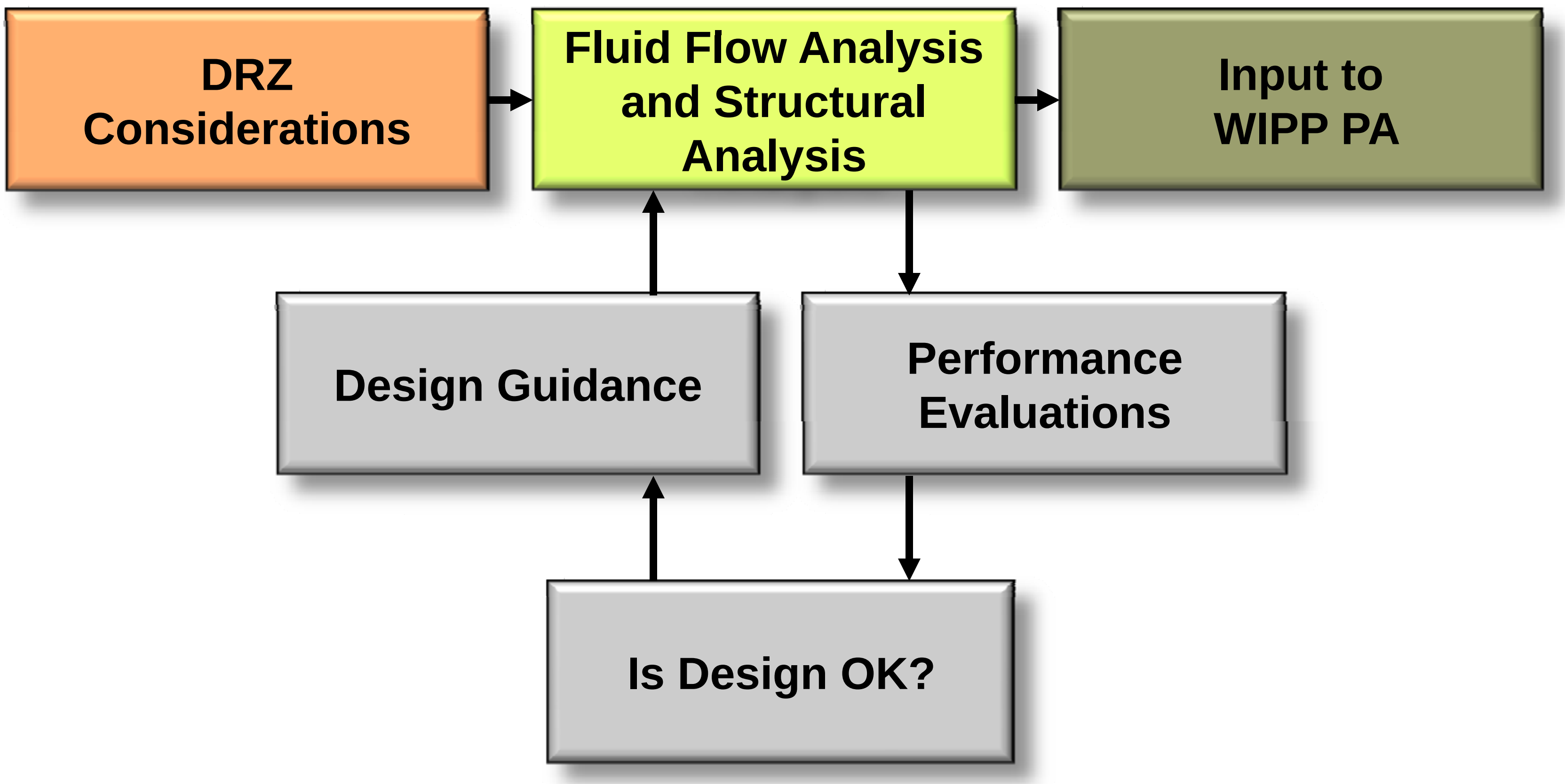
Shaft Seal Systems Analysis Process



Material Specification

- Functions
- Material Characteristics
- Construction
- Performance Requirements
- Verification methods

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Concrete Mixture Proportions

MATERIAL	lb/yd³
Portland cement	278
Class F fly ash	207
Expansive cement	134
Fine aggregate	1292
Coarse aggregate	1592
Sodium chloride	88
Water	225

Kg/m^3 = (lb/yd^3) * (0.59) Water: Cement ratio is weight of water divided by all cementitious materials

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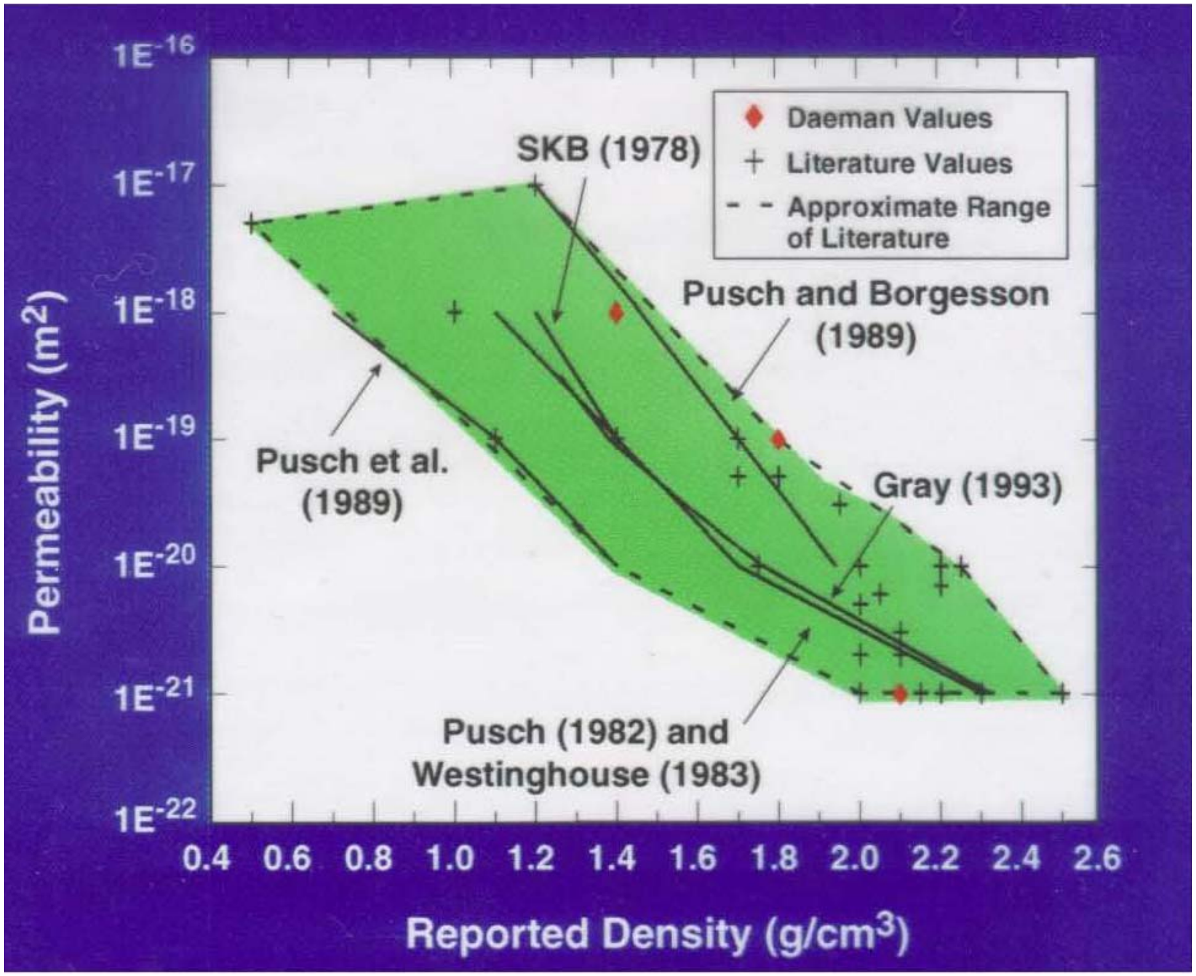
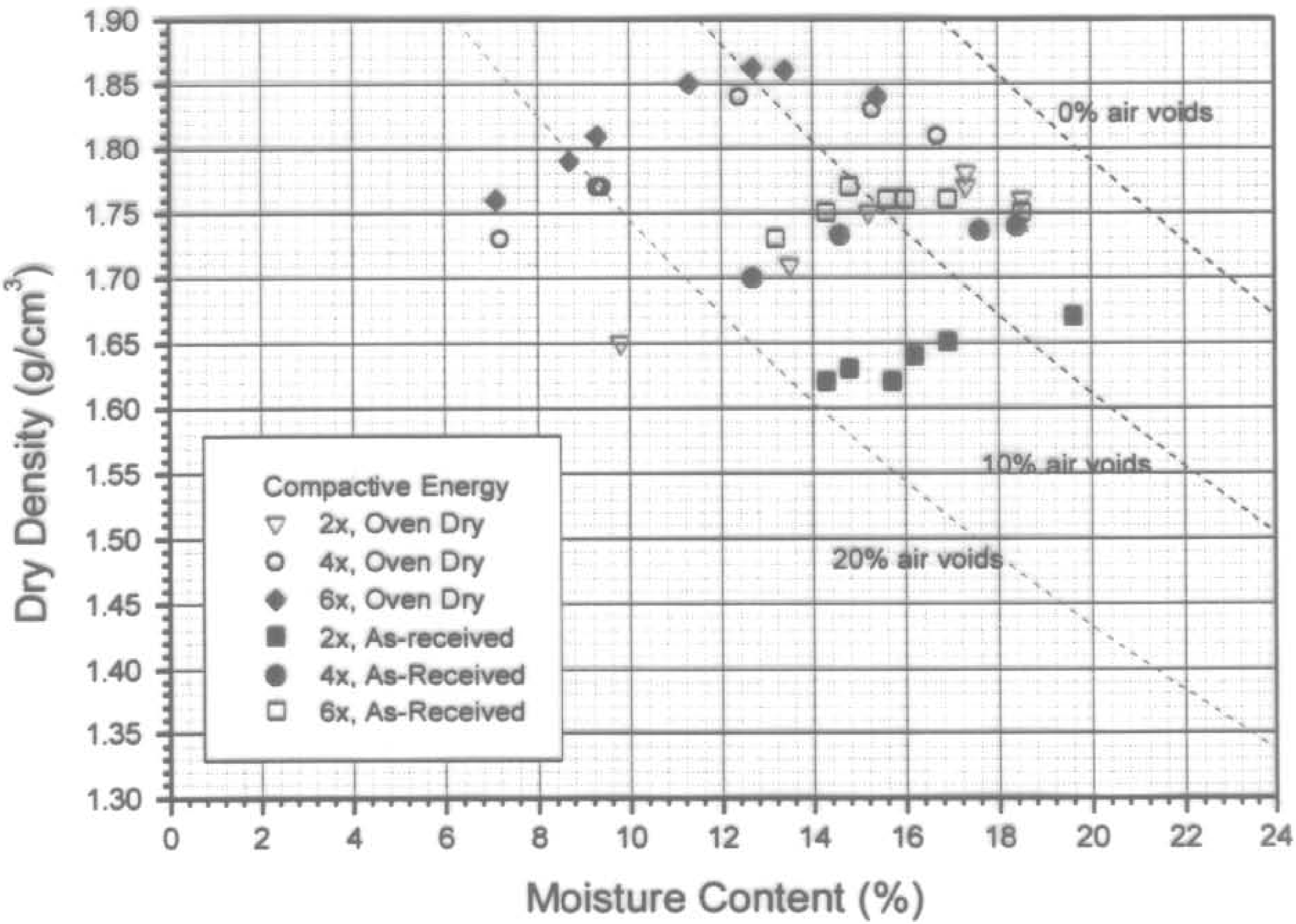
Sodium Bentonite Permeability Versus Density



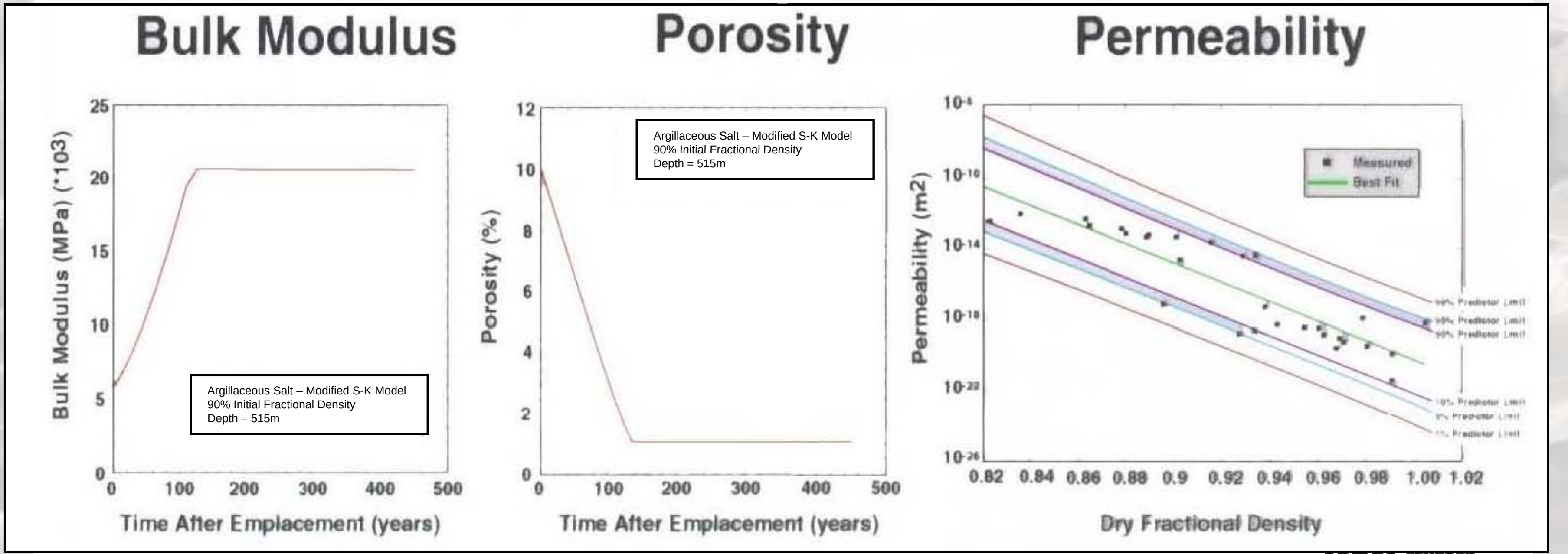
Bentonite Density Versus Moisture



Reconsolidated Salt Properties

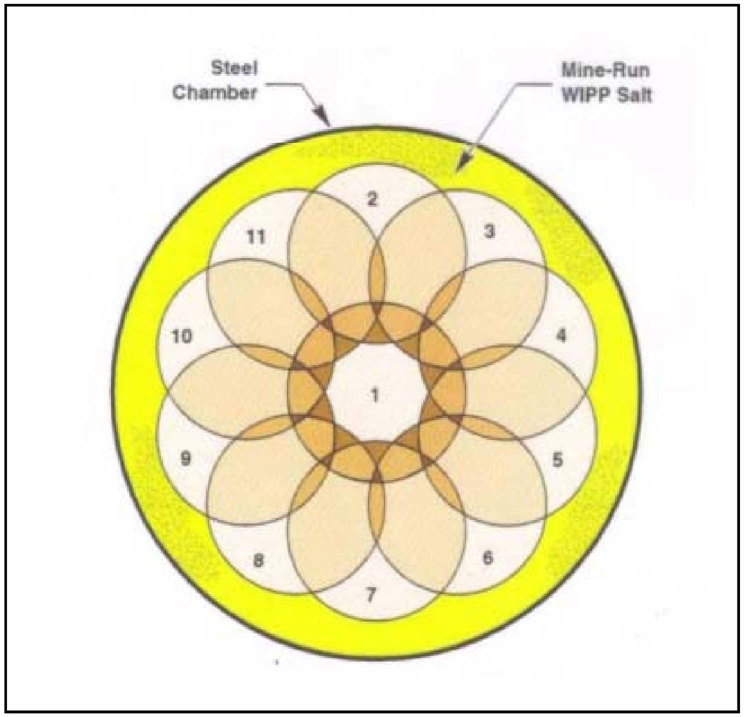
Lab Testing

Crushed Salt

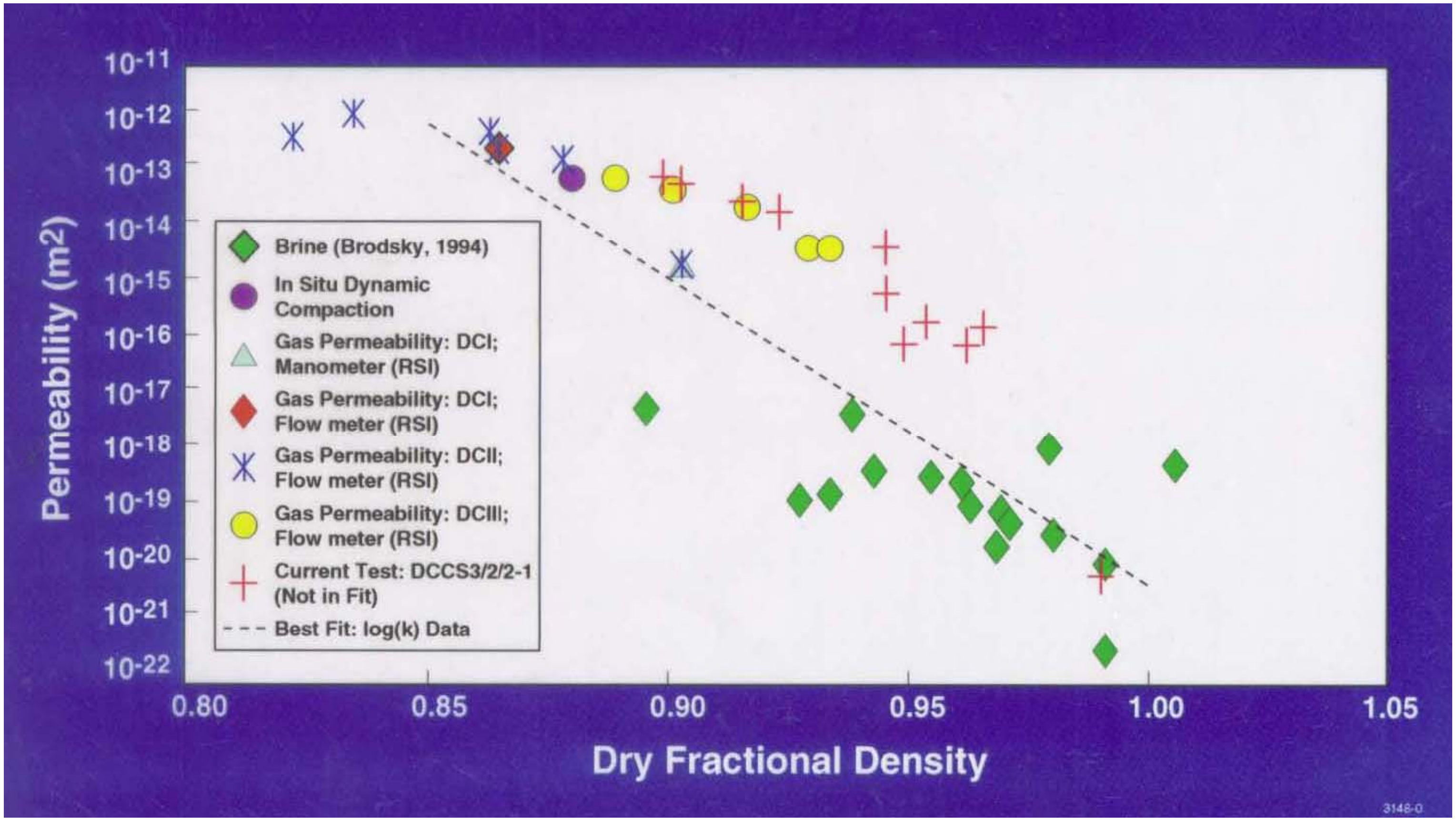


Panorama of the Dynamic Compaction Test Area

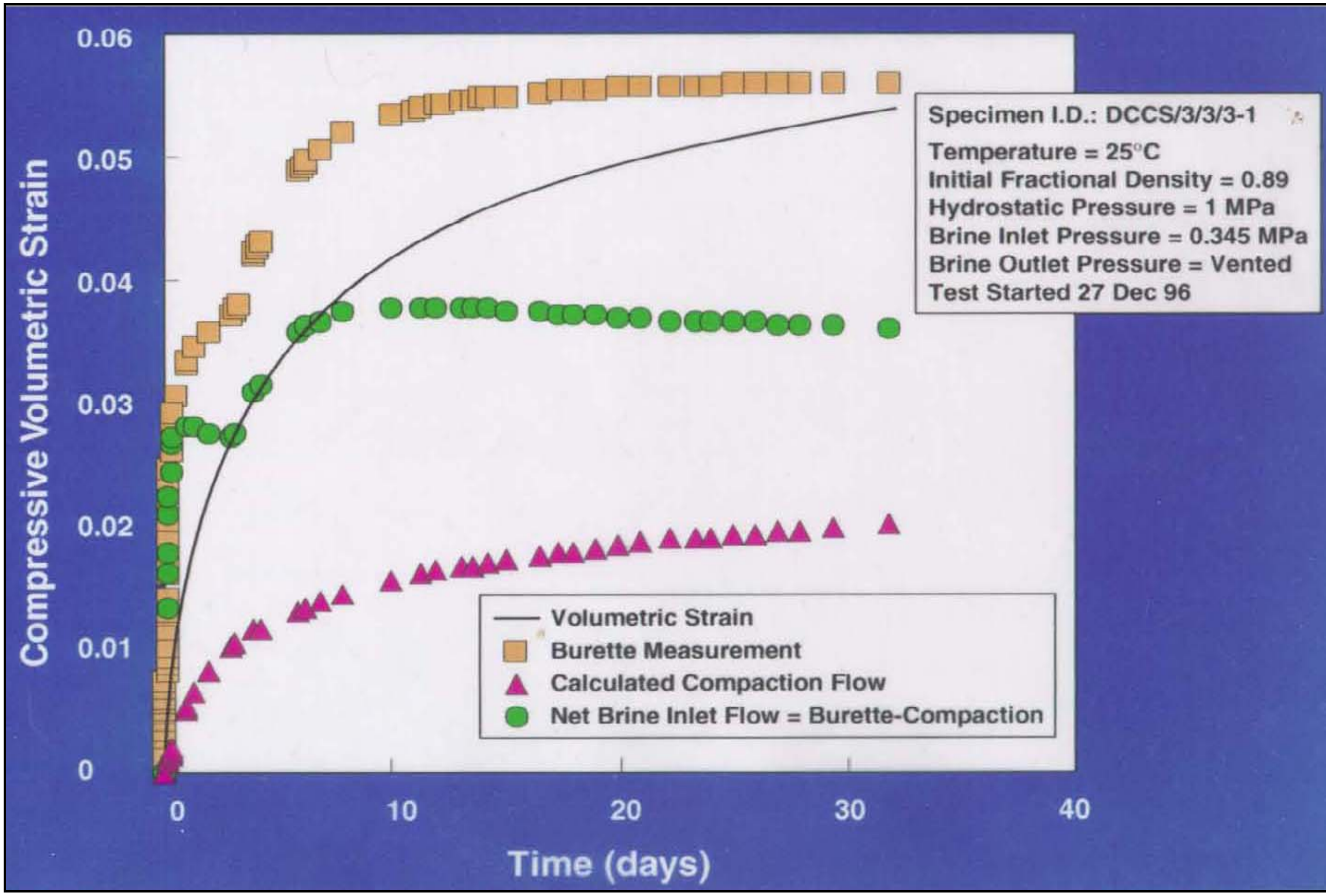
Compaction Pattern



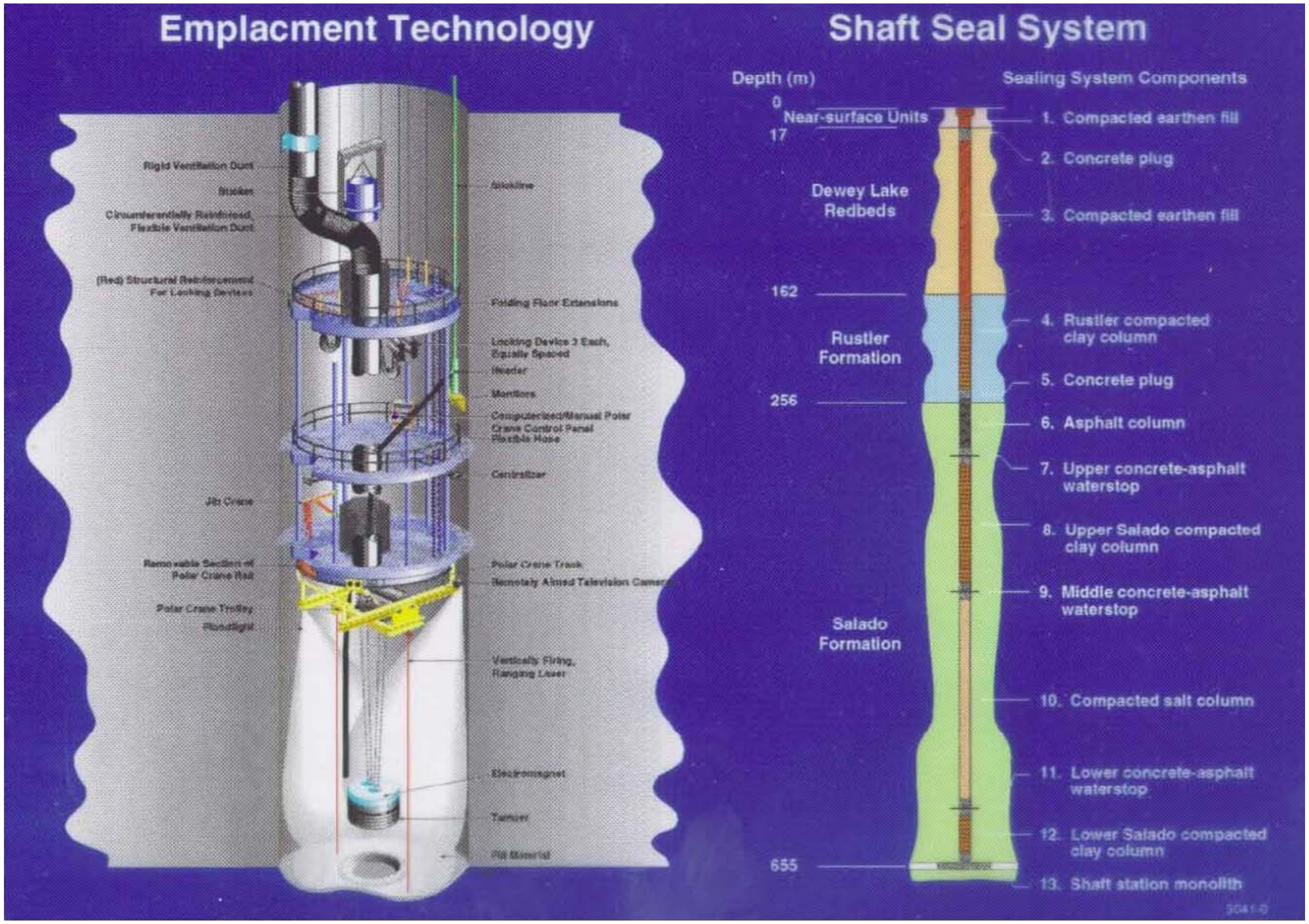
Permeability Versus Fractional Density for WIPP Crushed Salt



Brine Permeability Tests on Specimen DCCS/3/3/3-1



Shaft Seals System Studies



Fluid Flow Analysis of the Waste Isolation Pilot Plant Shaft Seal System

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Model 1 – Brine Flow Down

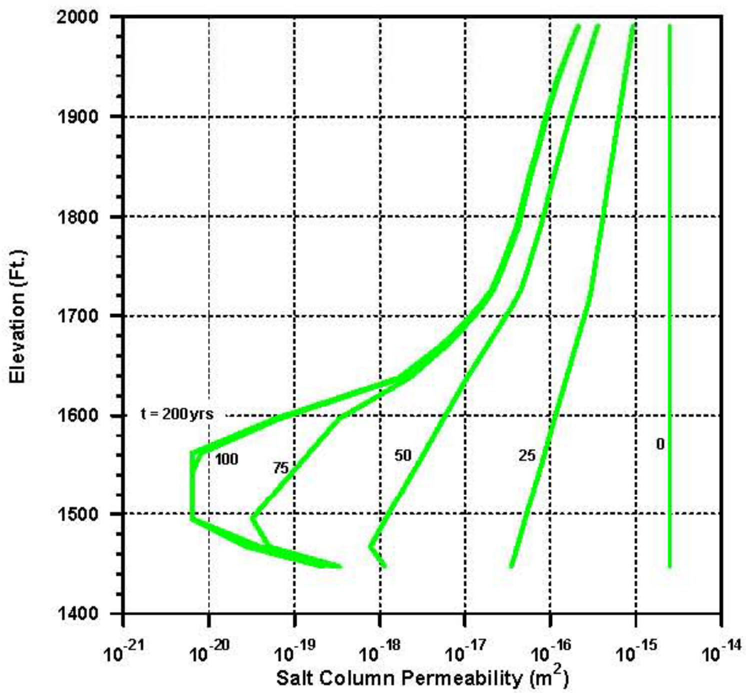
Objectives

- To predict cumulative brine flow through the seal system down to the salt column and the repository
- To demonstrate the effectiveness of the concrete-asphalt

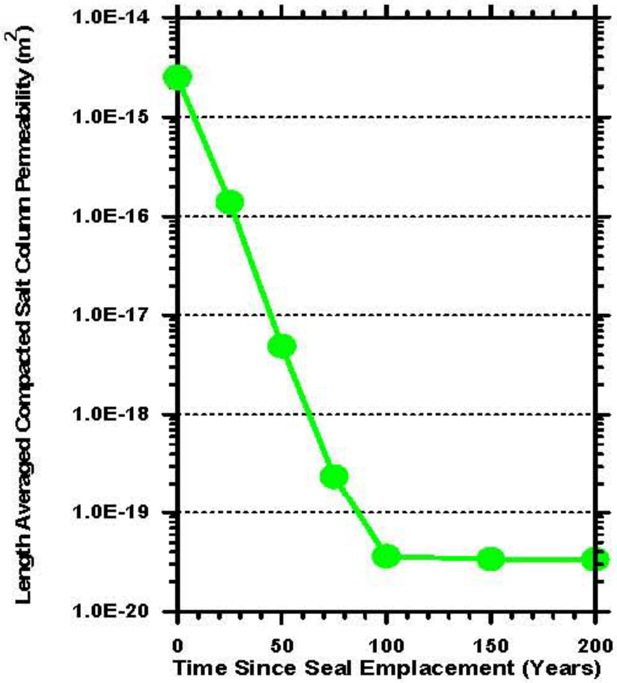
Assumptions

- Single-phase saturated flow
- 50-year, open-shaft period prior to closure
- Far-field BC is hydrostatic consistent with highest undisturbed Rustler head

Results



Salt Column Permeability Vertical Profiles at Several Points in Time



Length Averaged Permeability Versus Time

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Model 2 – Salt Column Performance

Objectives

- Predict the intrinsic permeability of the salt column component of the seal system
- Demonstrate effectiveness of the salt column as a low permeability seal within 200 years after closure
- Estimate gas migration from the repository horizon

Assumptions

- Two-phase flow (brine and hydrogen)
- 50-year, open-shaft period prior to closure
- Hydrostatic outer boundary condition relative to MB-139

Simulation Code

TOUGH28W is a multi-dimensional, multi-phase coupled fluid and heat simulator for porous and fractured media. This Sandia version of the code was developed from the LBL code TOUGH2

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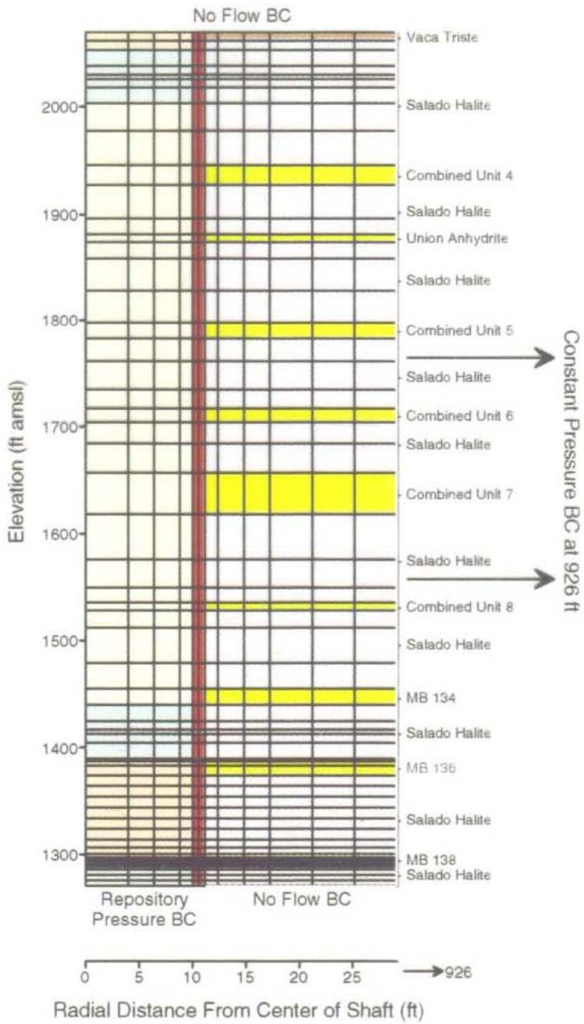
Model 2 – Grid Boundary Conditions



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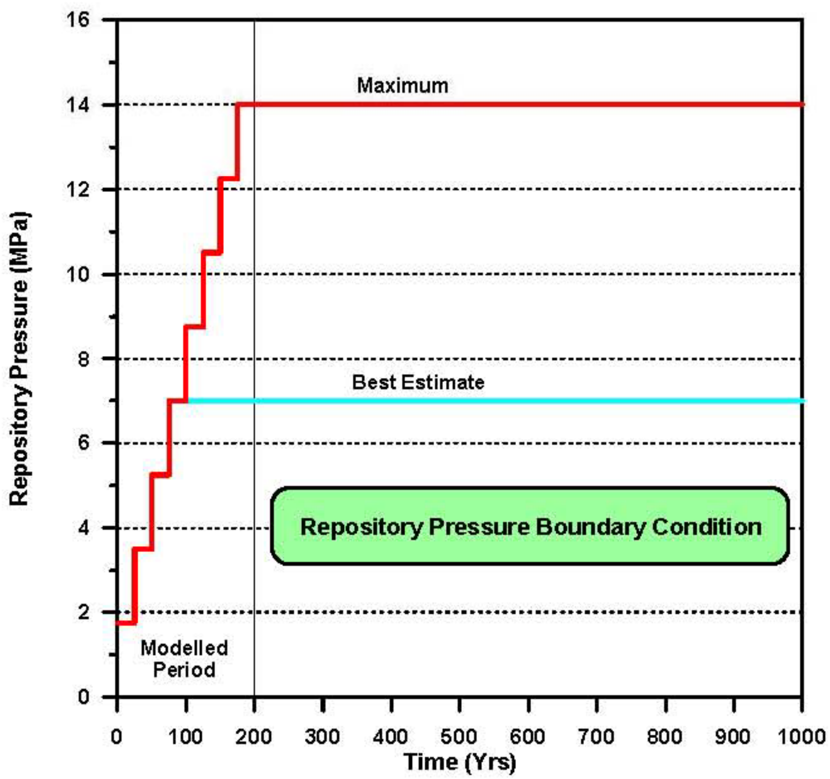
Boundary Conditions



- Pressure boundary is applied at the base of the shaft to simulate repository gas pressure
- Boundary pressure is increased in a stepwise fashion to simulate increasing repository gas pressure
- Two pressure scenarios were simulated representative of best estimate and maximum waste form generated gas pressure from a separate analysis

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Model 3 – Brine Flow Under Ambient Pressure Conditions

Objective

- To predict long-term brine flow through the seal system under ambient vertical pressure conditions

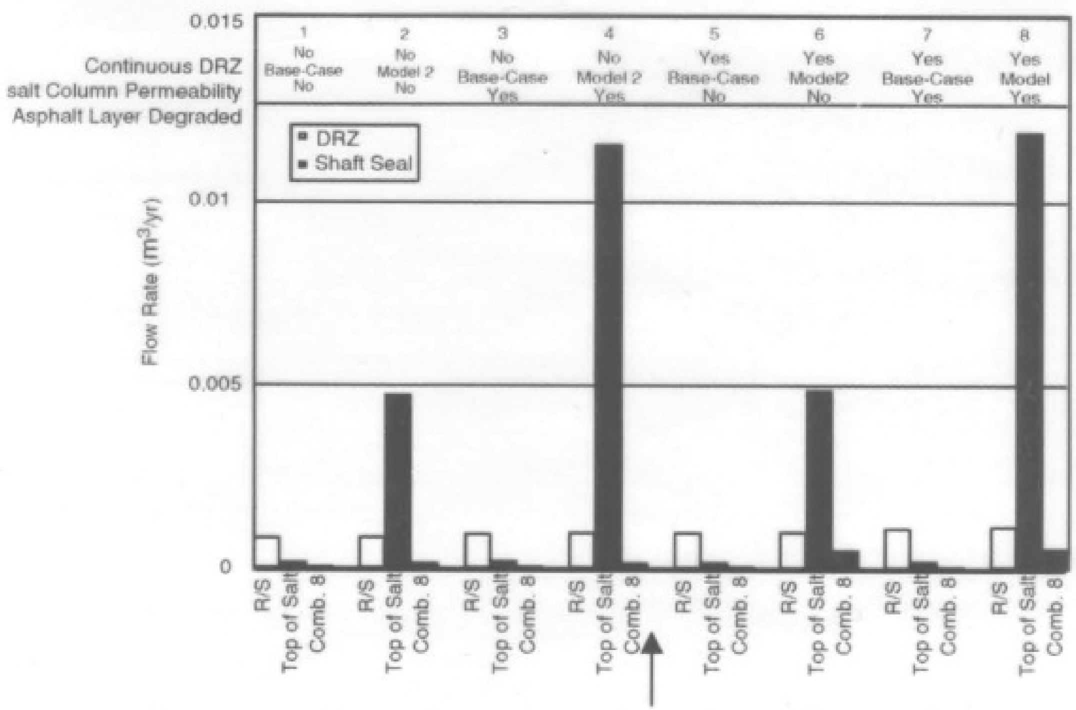
Assumptions

- Single-phase saturated flow
- Calculation representative of times > 400 years closure
- Far-filed BC is non-hydrostatic consistent with undisturbed pressure for the Rustler and Salado
- No-flow boundary at base of shaft

Simulation Code – Models 1 and 3

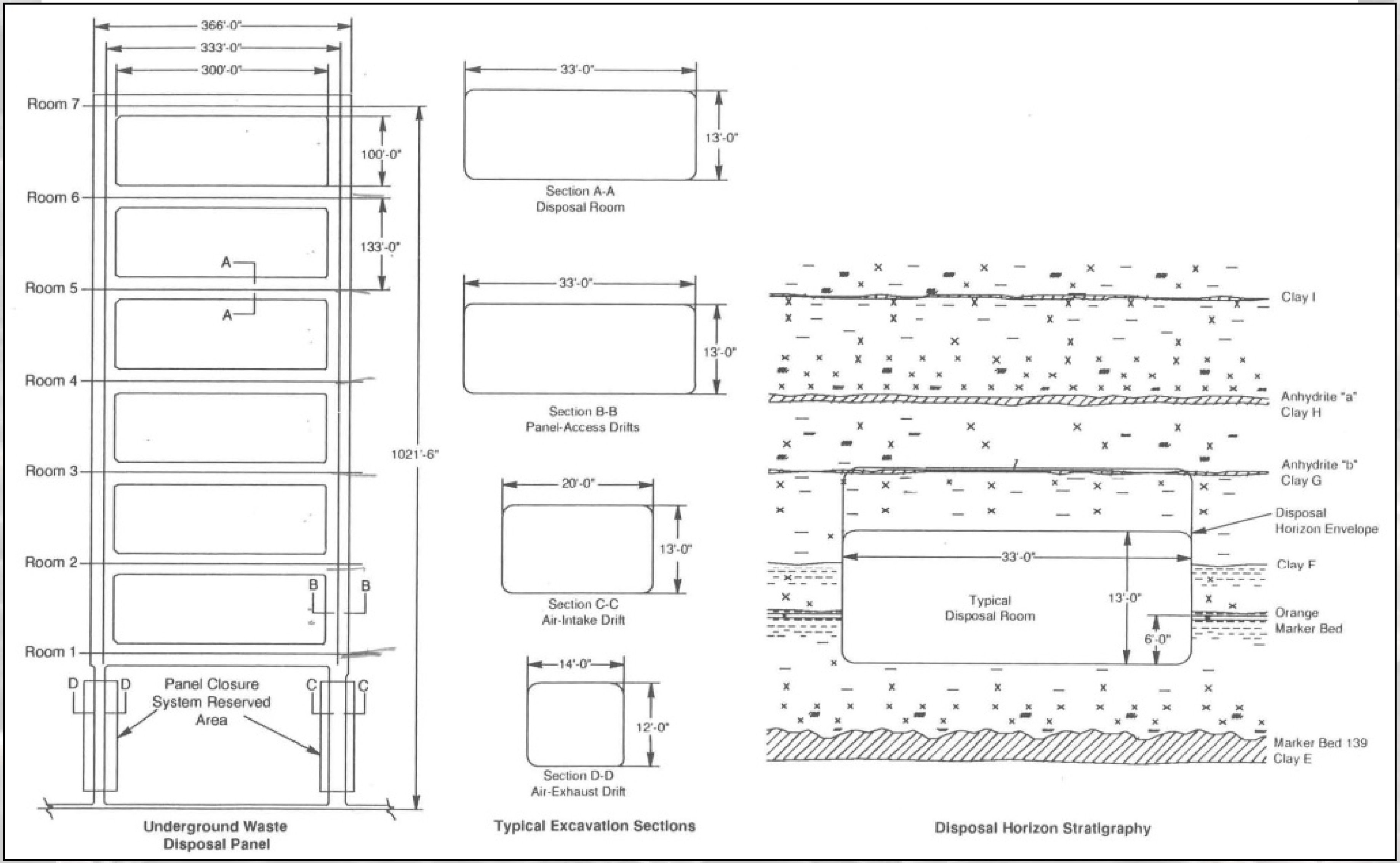
- SWIFT-II is a fully three-dimensional, finite-difference code that solves the coupled equations for variable density flow and transport

Ambient Brine Flow

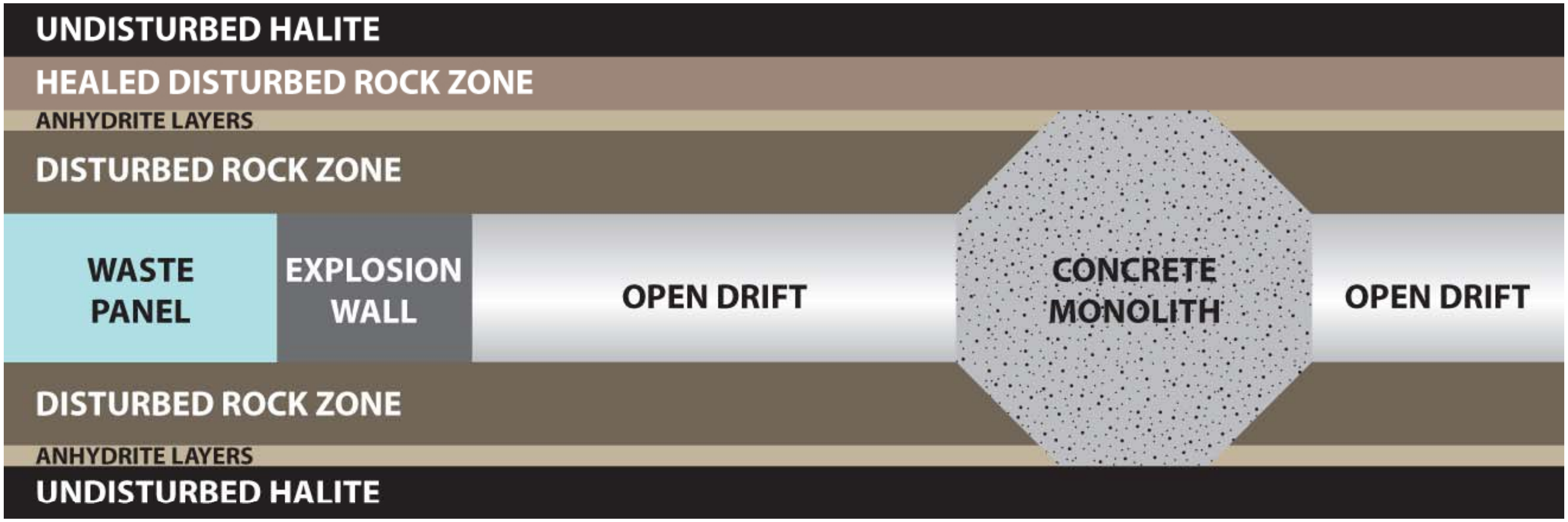


Long-term steady-state brine flow rates measured at the Rustler/Salado contact, the top of the salt column, and the bottom of the salt column (combination unit 8)

Typical Facilities Disposal Panel



Option D Panel Closure System



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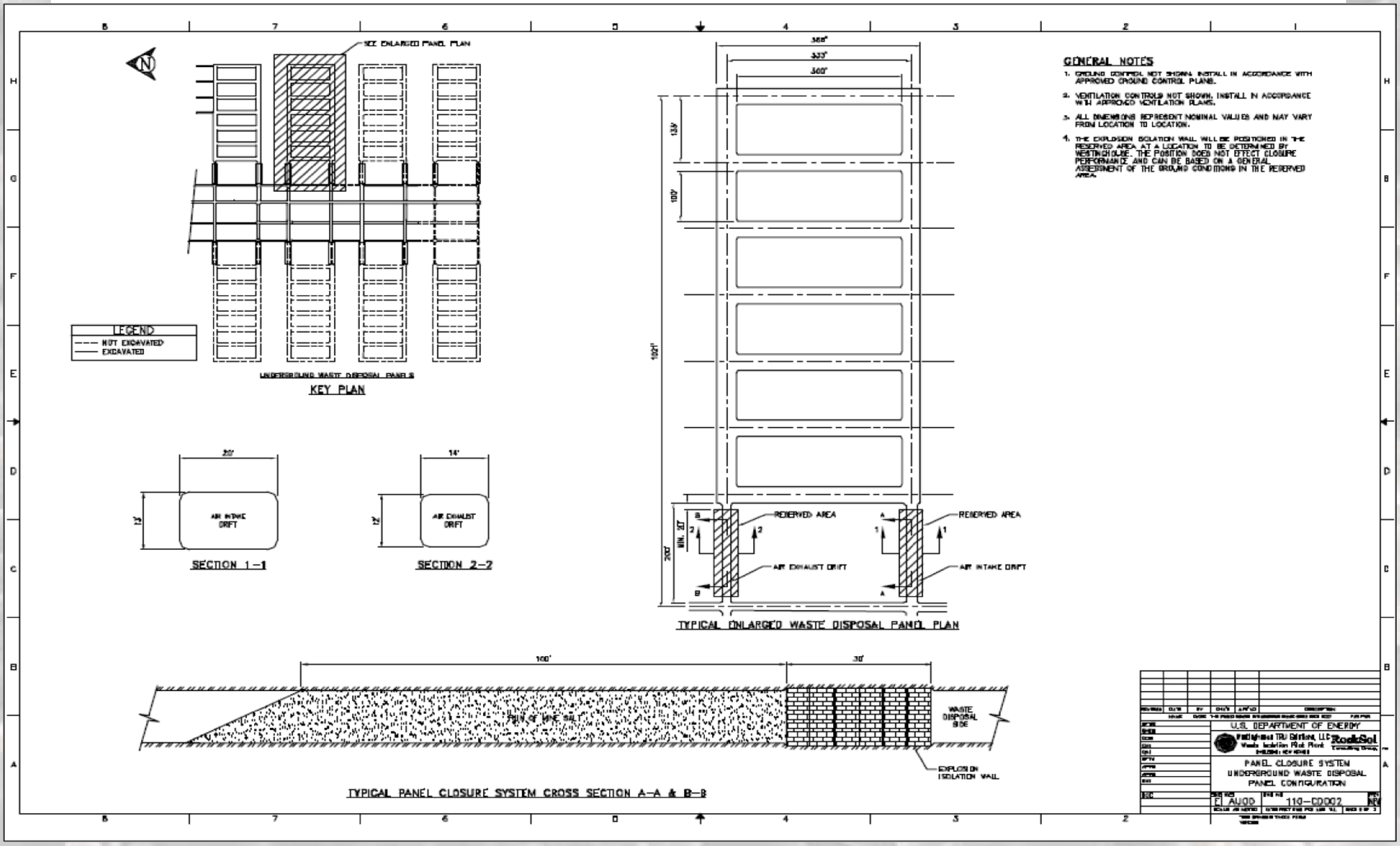
Possible Alternative Panel Closure



Isolation & Containment Strategic Choices for Seals & Backfill

Strategic Goals—Seals or backfill shall provide:

- Limit hazardous constituents reaching regulatory boundaries (**Isolation**)
- Restrict groundwater flow through the sealing system (**Isolation**)
- Use materials possessing mechanical and chemical compatibility (**Feasibility**)
- Protect against structural failure of system components (**Design**)
- Limit subsidence and prevent accidental entry (**Design**)
- Utilize available construction methods and materials (**Feasibility**)

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Isolation & Containment Strategic Choices for Seals & Backfill (concluded)

Design

- Concept of operations dictates size, shape & arrangement
- Barrier capability achieved by independent elements (redundancy)
- Multiple elements
- Differing materials
- Design review
- Quality assurance

Feasibility

- **Materials**
  - Available off-the-shelf no new technology required
  - Demonstrate-proof of principle testing
  - Scalable (lab/field)
  - Suitable properties (density, permeability)
  - Conductivity, durability
  - Analogy, practice, experience
- **Construction**
  - Industry Standard
  - Demonstration
- **Performance**
  - Hydrologic properties
  - Mechanical properties
  - Special accommodations (swelling, desiccation)

Bases

- Results of LTT&M/Science program verify these bases for the safety case
- Modeling
- Continued evaluation via performance confirmation

Shaft Seal System Conclusions

- The WIPP shaft seal system effectively limits fluid flow within the seal system.
- The salt column becomes an effective barrier to gas and brine migration by 100 years after closure.
- Long-term flow rates within the seal system are limited.
- Reference to available reports
- SAND97-1287 Shaft Seal System Parameters Document
- SAND96-1326/1 Shaft Seal Design Report

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Summary

- Several barriers engineered for WIPP
- No performance credit for waste package
- MgO engineered barrier (assurance)
- Panel closure performance implication
- Shaft seal system
- It’s the geology

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