U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD JOINT PANELS ON HYDROGEOLOGY & GEOCHEMISTRY AND STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: THERMAL LOADING SYSTEM STUDY UPDATE

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Presentation Outline

This presentation provides an update of Thermal Loading System Analysis to date being conducted during the FY94-FY95 timeframe

Topics

- Introduction (questions addressed, study objective)
- Waste-stream variability
- Effect of depth variations
- Diffusive gas flux
- Summary of results

Questions Being Addressed

- **Can it be demonstrated that the thermal option will achieve post-closure performance?**
  - Release and containment limits
  - Adequate multiple barriers

- **Will the thermal options meet pre-closure requirements?**
  - Safety
  - Environmental (radiation doses and temperature)
  - Retrieval

- **What analytic models can be used to adequately predict post-closure performance?**
  - Validation/qualified
  - Coupled effects

Questions Being Addressed
(Continued)

- What test data are required to support these efforts and to reduce uncertainty to an adequate level?
- Does sufficient suitable area exist in Yucca Mountain to emplace waste at the thermal option that will eventually be selected?

Objectives of Study (FY94 - FY95)

- **Provide recommendations to design of testing program**
  - Sensitivity analysis to identify parameters important to waste isolation that are influenced by thermal loading
  - Range over which changes in parameters may affect waste isolation

- **Recommendations, if possible, to further narrow range of thermal loading**
  - Fuel variability
  - Impact of MPC on the system
  - Performance-confirmation monitoring
  - Ventilation analysis

Analyses Initiated to Date

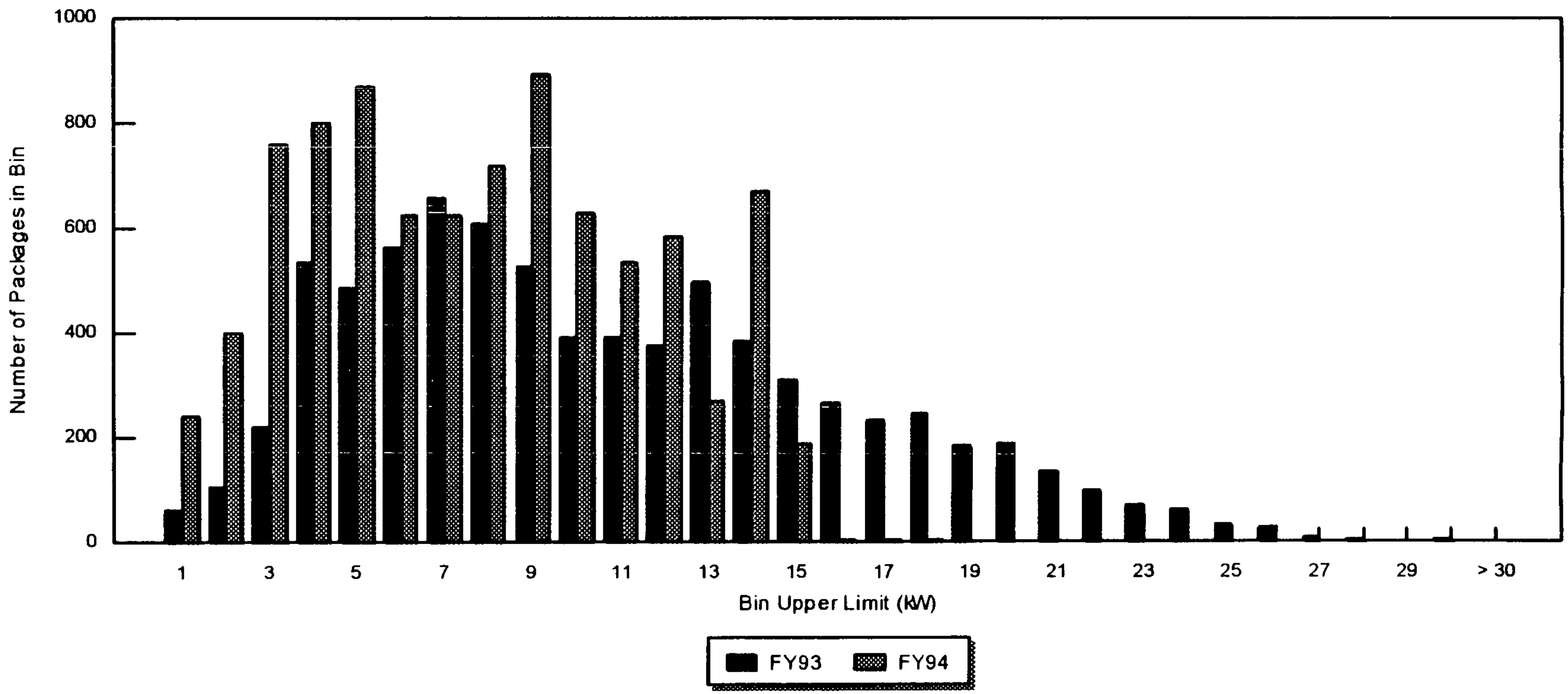
- Bulk permeability variations
- Diffusive gas flux
- Repository depth sensitivity
- Thermomechanical effects
- Waste-stream variability
- Performance-confirmation monitoring

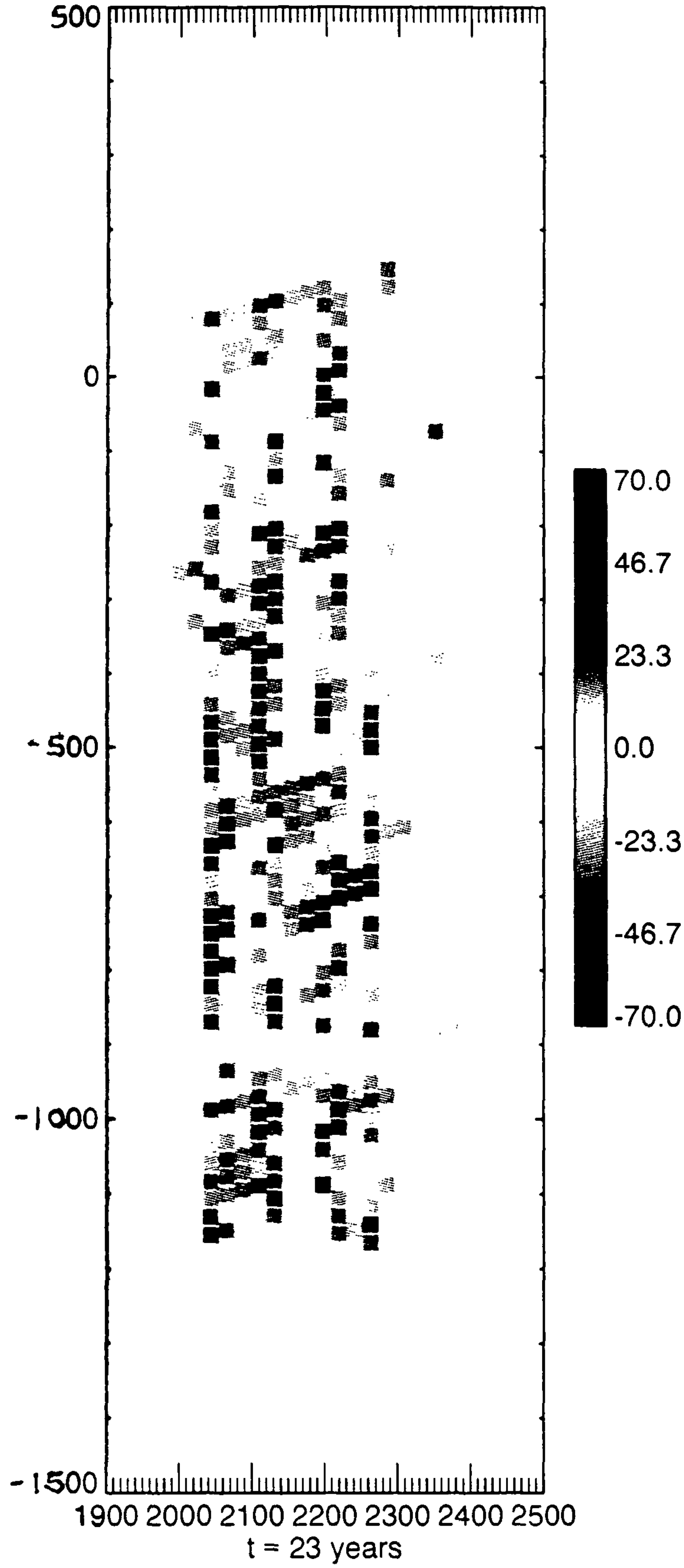
Waste-Stream Variability

- Changes in reference case
  - FY93 study used youngest fuel first (YFF)(10) with an average age and burnup
    - PWR Fuel: 22.7 years, 42.6 GWd/MTU
    - BWR Fuel: 24.0 years, 32.5 GWd/MTU
  - Based on the program approach and analysis conducted reference case changed to oldest fuel first (OFF)
    - PWR Fuel Average: 26.3 years, 39.8 GWd/MTU
    - BWR Fuel Average: 26.0 years, 30.9 GWd/MTU

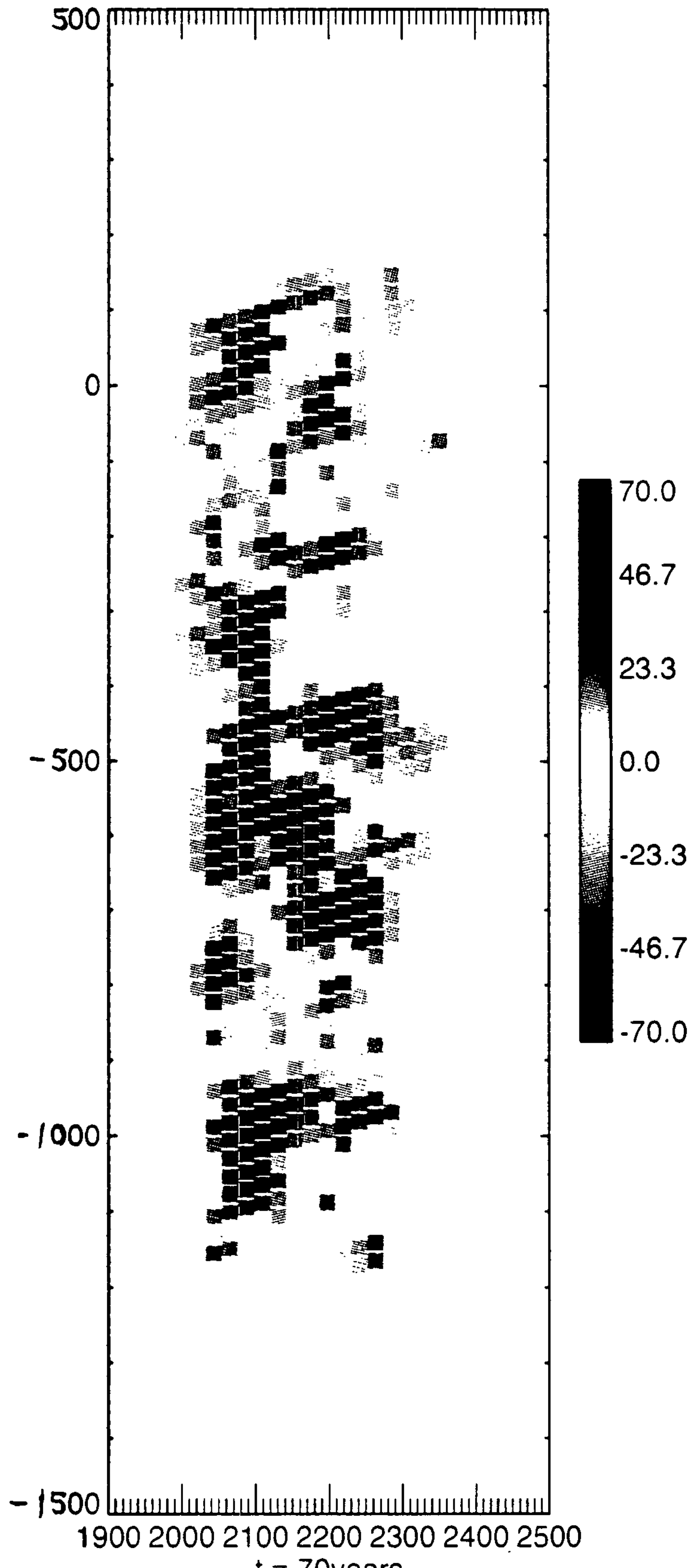
- Fuel variability analysis begun
  - YFF(10) had a few 21 PWR capacity waste packages with heat outputs approaching 30 kW.
  - OFF case had an MGDS disposal limit of 14.2 kw
    - Limit for loading at utilities just over 15 kw
    - About 600 of the large capacity waste packages (15%) would require derating

Comparison of FY93 and FY94 Base Cases' Waste Package Heat at Emplacement Distributions





Temperature Variations for YFF(10) Fuel from Years 2028-2030 Emplaced at About 19.3 KgU/m²(78 MTU/Acre) at 23 Years After Emplacement

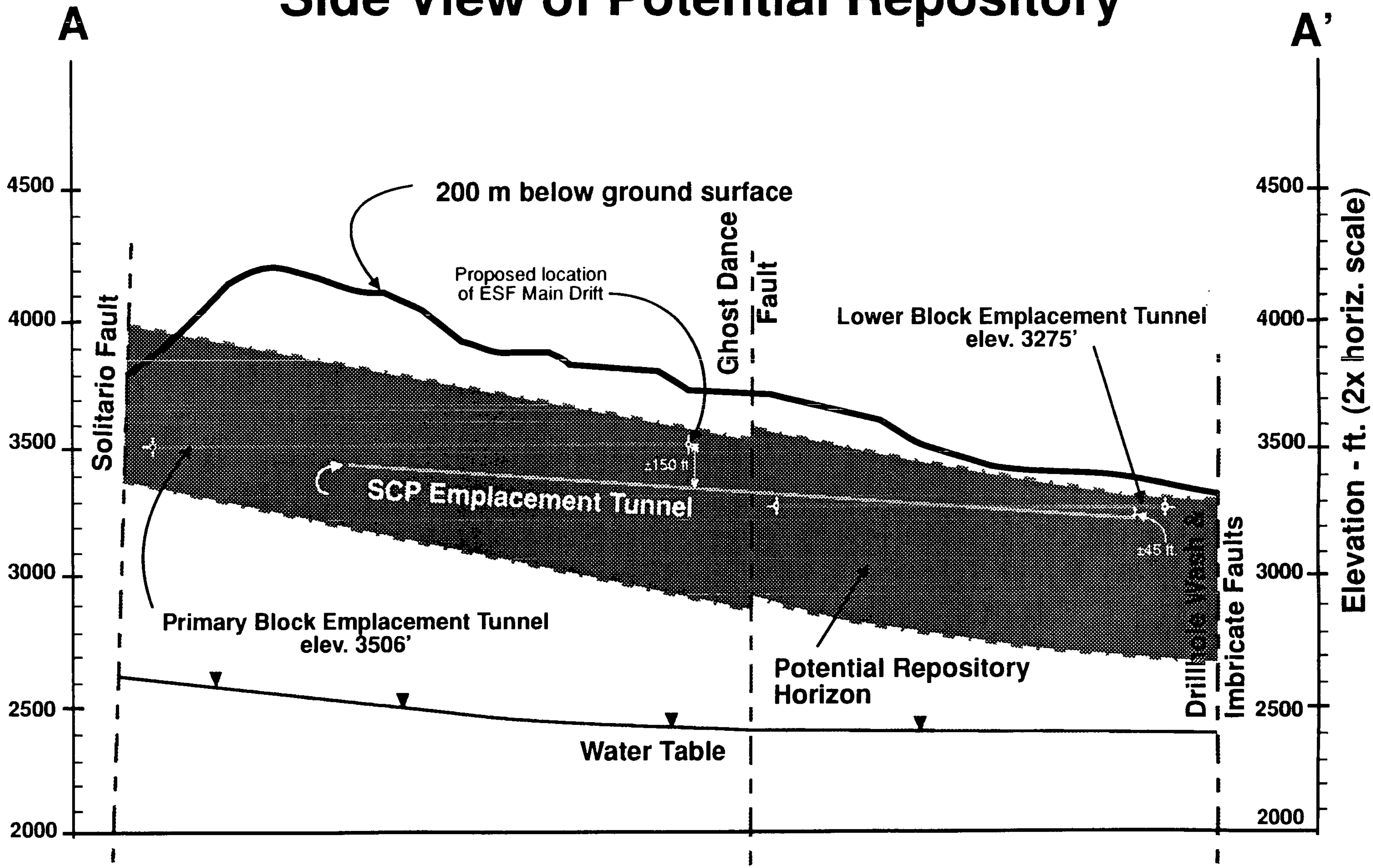


Temperature Variations for YFF(10) Fuel from Years 2028-2030 Emplaced at About 19.3 KgU/m^2(78 MTU/Acre) at 70 Years After Emplacement

Effect of Variations in Depth of Overburden

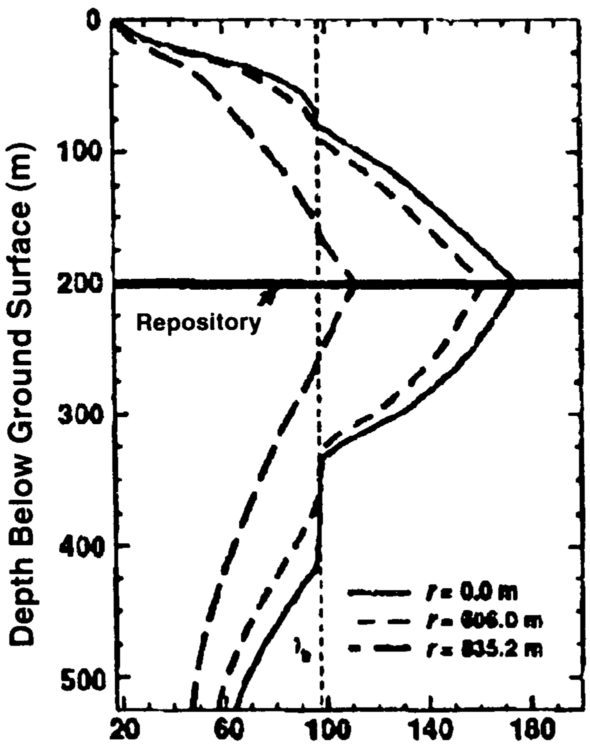
- The potential repository varies in distances to different stratigraphic units
  - Depth of overburden varies from about 200m to 430m
  - Distance to other stratigraphic units, such as water table (110 to 359m), also varies
- Performed far-field hydrothermal calculations
  - Used equivalent continuum model VTOUGH
  - Axi-symmetric uniform heat distribution modeled
  - Assumed that all waste emplaced with a constant overburden distance
  - Used OFF average fuel characteristics

Side View of Potential Repository

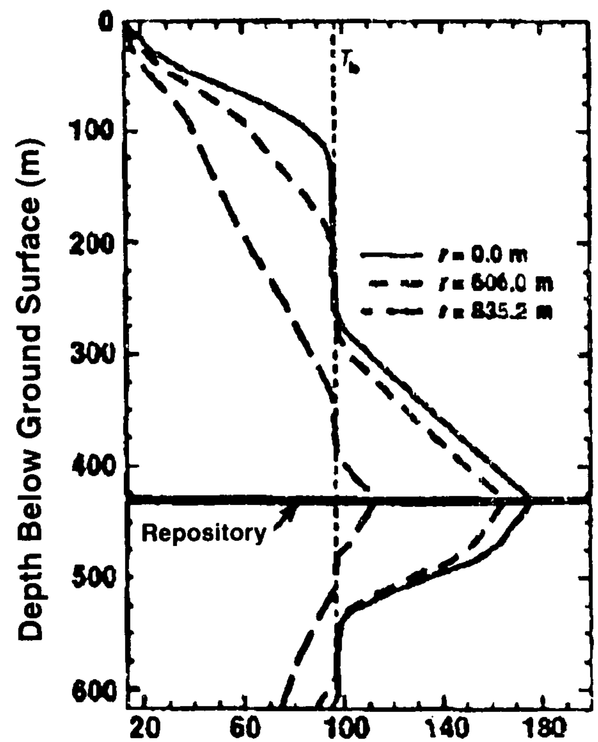


Note: Plane of section cuts through lowest emplacement drift in working concept layout.

Predictions of Temperature at 1000 Years for 27.4 kgU/m²
(110 MTU/Acre)

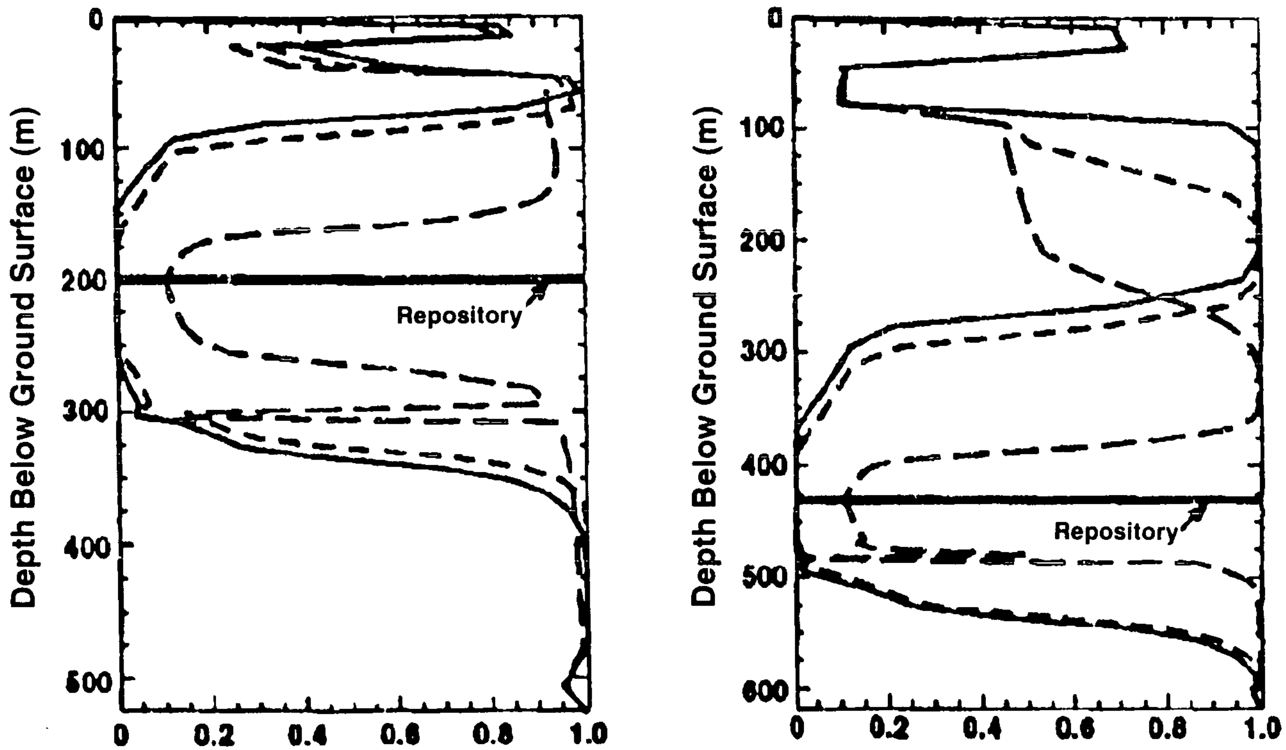


Temperature (c)
a. 200m Overburden



Temperature (c)
b. 430m Overburden

Predictions of Liquid Saturation at 1000 Years for 27.4 kgU/m^2 (110 MTU/Acre)



Liquid Saturation
a. 200m Overburden

Liquid Saturation
b. 430m Overburden

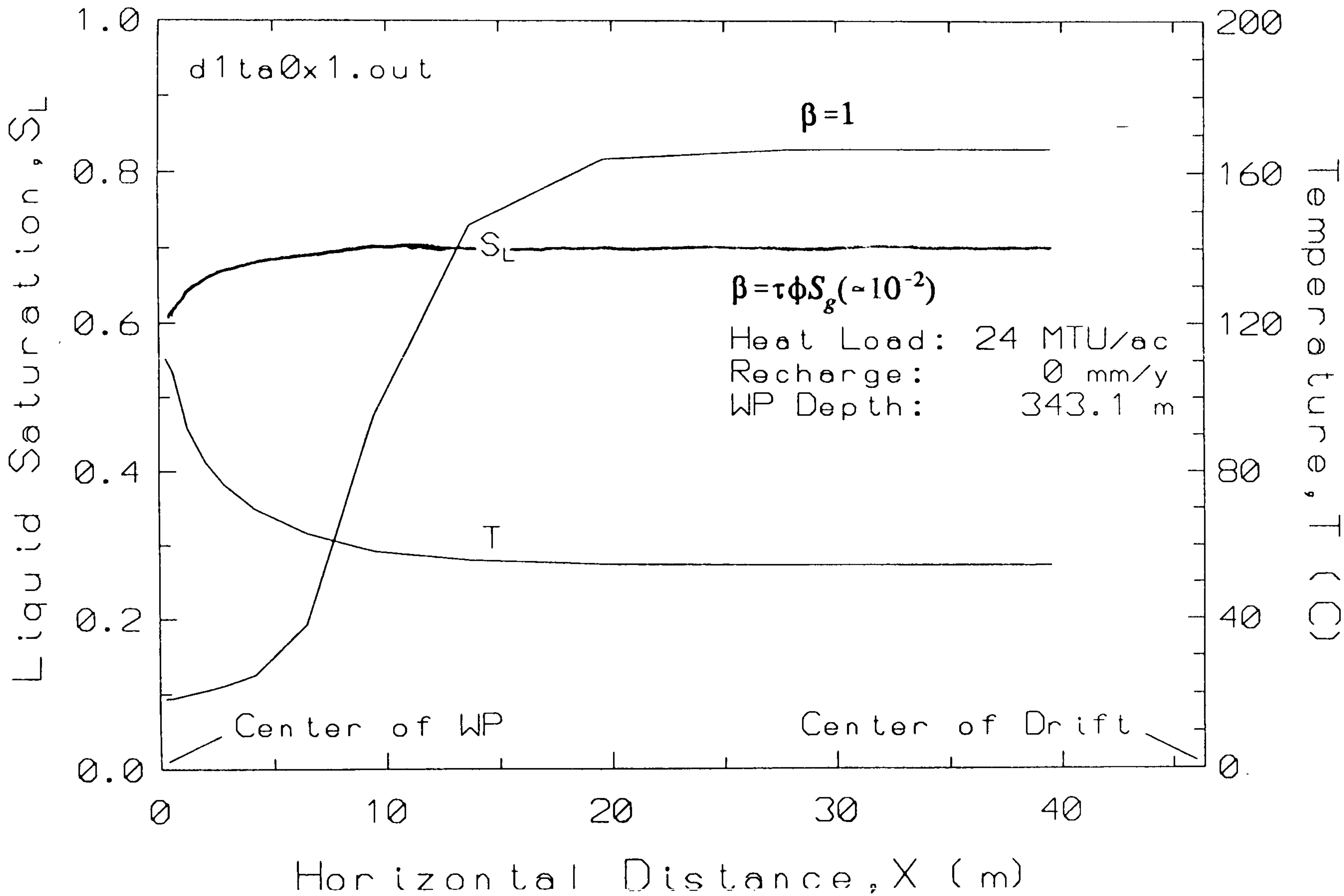
Diffuse Gas Flux Variations

- **Diffusive gas flux influences amount of moisture removed. Diffusion coefficient**

$$D_{va} = \beta\, D^{o}_{va} \left(\frac{P_o}{P}\right) \left(\frac{T}{T_o}\right)^{\theta}$$

- **Varied binary (water vapor and air) diffusion parameter**
  - $\beta = \tau\ \varphi\ S_g$; **for tuff** $\cong 10^{-2}$
  - $\beta = 1$; **for porous media**

Saturations and Temperatures at 50 Years



Results to Date of Parametric Studies

- **Fuel variability examined**
  - Changing to OFF fuel
  - Localized areas in potential repository show ± 50°C excursions for YFF(10)
- **Thermomechanical (drift stability)**
  - Stability criteria exceeded at AMLs ≥ 27.4 kgU/m^2 (111 MTU/acre)
  - Some tunnel support required between 20.5 - 27.4 kgU/m^2 (83 to 111 MTU/acre)
- **Monitoring issue examined**
  - Preliminary assessment of kinds of instruments and locations for making measurements
  - Based on choice of instruments for *in situ* measurement in drift monitoring may be possible to 200°C, but instruments not currently "off the shelf"

Results to Date of Parametric Studies

(Continued)

- **Bulk permeability sensitivity analyses**
  - Current range of uncertainty in TSw2 10^{-13} to 10^{-11} m (0.1 to 10 Darcy)
  - Significant increase in gas-phase convection for permeabilities $\geq 10^{-12}$ m^2 (1 Darcy)
- **Diffusive gas flux sensitivity (depends on connectivity of pores/fractures, porosity, etc.)**
  - Current range of uncertainty about 2 orders to magnitude (Gas Diffusion Coefficient about 10^{-2} to 1)
  - Variations over the range of this parameter can result in a range from minimal drying to significant drying of the rock
- **Repository depth sensitivity**
  - Distance of repository to surface varies over primary area from 200 to 430m
  - Liquid buildup and temperatures were found to depend on the depth
  - Going from an overburden of 200 m to 430 m essentially triples time repository stays above a given temperature

Parametric Studies Planned or Underway

- Complete waste-stream variability thermal calculations

- Drift-scale hydrothermal calculations coupled with ventilation calculations

- Thermal calculations evaluating effects of spatial variations in conductivity

- Complete parametric hydrothermal calculations examining effects of changes in distances to various stratigraphic units

Parametric Studies Planned or Underway

(Continued)

- Complete thermomechanical evaluations
- Evaluation of dual-porosity effects on liquid and gas diffusion
- Develop recommendations for testing based on results of analyses

Thermal Loading System Study
Planned Activities:
Steps to a Decision

The thermal systems study provides the technical framework for making a thermal-loading decision and requires the following activities:

- Scoping calculations initially to narrow the range of thermal loading - Completed
- Parametric analysis to provide recommendations to assist in development of test programs - Initiated
- Further analysis with recommendations to narrow thermal loading range through performance evaluations - Planned
  - Total system performance assessment, thermal goals (re-evaluated), incorporate data, as available