APPENDIX D

KEY PERFORMANCE CONFIRMATION PARAMETERS FOR DESIGN

9701280259 - Part 2

KEY PERFORMANCE CONFIRMATION PARAMETERS FOR DESIGN

This appendix is an extract of the five matrices of Appendix C. It lists the 94 key performance confirmation parameters for design in a single matrix (the actual number is greater because some parameters require several separate measurements).

One or more of the following three major aspects need to be confirmed for the listed parameters:

1. That spatial interpolations and/or extrapolations of point measurements assumed for the License Application are within acceptable bounds of error.

2. That temporal changes in parameter values resulting from repository construction, waste emplacement, and natural events and processes predicted for the License Application are within acceptable bounds of error.

3. That compliance with the regulatory postclosure standards of 10 CFR Part 60 can still be demonstrated in spite of any changes in parameter values, understanding of natural and engineered barrier processes, and mathematical postclosure performance assessment models and computer codes.

The key performance confirmation parameters for design are briefly described in Section 4 and the performance confirmation concepts for their data acquisition are described in Section 5 of the report.

Table D-1. Key Performance Confirmation Parameters for Design

This matrix lists the parameters that have passed all selection screens. None of the saturated zone parameters was selected. A parameter had to pass each screen in order to be considered for the next screen. Only one criterion needed to apply in order for a parameter to move from Screen 1 to Screen 2 and from Screen 2 to Screen 3. At least one criterion had to apply from both Screen 1 and Screen 2, and all three criteria of Screen 3 and the criterion of Screen 4 had to apply in order for a parameter to be selected as a performance confirmation parameter. See the text and flowchart for a more detailed explanation of the selection criteria and process.

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
GENERAL SITE PARAMETERS														
Seismicity														
Location				X			X	X	X	X	X	X	X	Continuous monitoring at existing surface-based & new underground seismic stations
Magnitude				X			X	X	X	X	X	X	X	
Acceleration/ground motion				X			X	X	X	X	X	X	X	
Hydrocarbon (Coal, Oil and Gas) and Mineral Resource Exploration and Extraction														
Location	X				X			X	X	X	X	X	X	Geologic mapping during underground excavation & off-site lab analysis
Quantity	X				X			X	X	X	X	X	X	
UNSATURATED ZONE PARAMETERS														
Stratigraphy of the Alluvium/colluvium and Rock Matrix														
Rock types	X	X	X	X	X			X	X	X	X	X	X	Geologic mapping during underground excavation
Mineralogy	X	X	X	X	X		X	X	X	X	X	X	X	
Hydraulic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Saturated hydraulic conductivity/permeability	X	X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Effective porosity	X	X	X	X	X	X		X	X	X	X	X	X	

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con-fine & Isolate Waste Funct.	Con-tain. & Isol. Stra-tegy	TSPA & PA process models	Sub-surface condi-tions	Affec-ted by const./ empla-cement	Time depen-dent vari-able	Can be mea-sured or derived	Can be pre-dicted or esti-mated	Impor-tant to per-form-ance	Reduce uncer-tainty	All perf. conf. para-meters	Key para-meters for design	
Dispersivity/dispersion coefficient	X	X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Hydraulic potential - moisture content relationship	X	X	X	X	X	X		X	X	X	X	X	X	
Moisture content - hydraulic conductivity relationship	X	X	X	X	X	X		X	X	X	X	X	X	
Pneumatic Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Air permeability	X	X		X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Mechanical Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
In-situ stress	X	X		X	X	X	X	X	X	X	X	X	X	Continuous underground monitoring
Strain	X			X	X	X	X	X	X	X	X	X	X	
Rock deformation & displacement	X	X		X		X	X	X	X	X	X	X	X	
Thermal Characteristics of Alluvium/Colluvium and Rock Matrix of Altered Zone														
Soil & rock temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Geometry, Including Future Displacements of Rock Fracture Zones (Including Faults)														
Location	X	X	X	X	X		X	X	X	X	X	X	X	Geologic mapping during underground excavation
Width	X	X	X	X	X		X	X	X	X	X	X	X	
Length	X	X	X	X	X		X	X	X	X	X	X	X	
Orientation	X	X	X	X	X		X	X	X	X	X	X	X	

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Displacement				X			X	X	X	X	X	X	X	Geologic mapping during underground excavation
Fracture aperture	X	X	X	X	X		X	X	X	X	X	X	X	
Fracture density	X			X	X		X	X	X	X	X	X	X	
Biological Characteristics of Rock Fracture Zones (Including Faults)														
List of microbes	X	X	X	X	X	X	X	X	X	X	X	X	X	Underground sampling & off-site lab analysis
Microbial activity	X	X	X	X	X	X	X	X	X	X	X	X	X	
Chemical/Mineralogical Characteristics of Infillings of Rock Fracture Zones (Including Faults)														
Apparent age of minerals	X	X		X	X	X	X	X	X	X	X	X	X	Underground sampling & off-site lab analysis
Hydraulic Characteristics of Rock Fracture Zones (Including Faults)														
Saturated hydraulic conductivity/permeability		X	X	X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis if untested fracture zones encountered during excavations
Effective porosity		X	X	X	X	X		X	X	X	X	X	X	
Dispersivity/dispersion coefficient		X	X	X	X	X		X	X	X	X	X	X	
Hydraulic potential - moisture content relationship		X	X	X	X	X		X	X	X	X	X	X	
Moisture content - hydraulic conductivity relationship		X	X	X	X	X		X	X	X	X	X	X	
Pneumatic Characteristics of Rock Fracture Zones (Including Faults) of Altered Zone														
Air permeability	X	X		X	X	X		X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria: Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4	Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Gaseous dispersion coefficient	X	X		X	X			X	X	X	X	X	X	Underground testing/sampling & off-site lab analysis
Thermal Characteristics of Rock Fracture Zones (Including Faults) of Altered Zone														
Rock temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Chemical Characteristics of Ground Water (in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
Altered zone chemical composition, Eh & pH	X	X	X	X	X	X	X	X	X	X	X	X	X	Surface-based & underground sampling & off-site lab analysis
Age (H-3, C-14, Cl-36)				X			X	X	X	X	X	X	X	
Hydraulic Characteristics of Ground Water (in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
In-situ fluid potential	X	X	X	X		X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Altered zone moisture content	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous underground monitoring
Altered zone water vapor content/humidity	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Thermal Characteristics of Ground Water (in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities) of Altered Zone														
Fluid temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring
Pneumatic Characteristics of Subsurface Air and Gases (in Rock Matrix, Fractures, Fault Zones, and Other Discontinuities)														
Air pressure	X			X	X	X	X	X	X	X	X	X	X	Continuous surface-based & underground monitoring

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
REPOSITORY EXCAVATION AND BOREHOLE PARAMETERS														
Geometry of Waste Emplacement Drifts														
Deformation/ convergence	X	X		X	X	X	X	X	X	X	X	X	X	Continuous monitoring at selected underground locations
Rock fall/collapse size	X	X		X	X	X	X	X	X	X	X	X	X	Periodic underground inspection
Physical Characteristics of Excavation Environment (Ramps, Shafts, Alcoves, and Emplacement Drifts)														
Dry bulb air temperature		X		X		X	X	X	X	X	X	X	X	Continuous monitoring at portals & selected underground locations
Relative humidity		X	X	X		X	X	X	X	X	X	X	X	
Ground-water inflow rate into excavation	X	X	X	X	X	X	X	X	X	X	X	X	X	According to perched water procedure
Ground-water inflow temperature	X	X		X	X	X	X	X	X	X	X	X	X	According to perched water procedure
Chemical Characteristics of Excavation Environment (Ramps, Shafts, Alcoves, and Emplacement Drifts)														
Chemical composition, Eh & pH of ground-water inflow	X	X		X	X	X	X	X	X	X	X	X	X	According to perched water procedure
Construction and Fire Water, Including Accidental Spills Remaining after Repository Closure														
Quantity remaining in rock		X		X		X	X	X	X	X	X	X	X	Periodic rock sampling at selected underground locations & off-site lab analyses
Chemical composition, incl. Eh & pH		X		X		X	X	X	X	X	X	X	X	

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Hydrocarbons, Including Accidental Spills Remaining after Repository Closure (each type that may affect postclosure performance)														
Quantity remaining in rock		X		X		X	X	X	X	X	X	X	X	Periodic rock sampling at selected underground locations & off-site lab analyses
Chemical composition, incl. Eh & pH		X		X		X	X	X	X	X	X	X	X	
Concrete Remaining after Repository Closure														
Chemical composition/ alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of samples
Steel Remaining after Repository Closure														
Chemical composition/ alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of samples
Ground Support Remaining after Repository Closure														
Chemical composition/ alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens
Railcars Remaining after Repository Closure														
Chemical composition/ alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens
Other Fluids and Materials Remaining in Repository after Closure (each type that may affect postclosure performance)														
Chemical composition/ alteration		X		X		X	X	X	X	X	X	X	X	Periodic inspection & off-site lab analysis of specimens or rock samples, as applicable

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria										Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Sub-part F	Con-fine & Isolate Waste Funct.	Con-tain. & Isol. Stra-tegy	TSPA & PA process models	Sub-surface condi-tions	Affec-ted by const./ empla-cement	Time depen-dent vari-able	Can be mea-sured or derived	Can be pre-dicted or esti-mated	Impor-tant to per-form-ance	Reduce uncer-tainty	All perf. conf. para-meters	Key para-meters for design	
WASTE PACKAGE PARAMETERS														
Waste Form Characteristics (E.g., of Spent Fuel and Glass Defense High-Level Waste)														
Geometry/dimensions of waste form	X	X	X	X			X	X	X	X	X	X	X	On-site lab analyses of failed waste packages, if any, and of waste not emplaced
Geometry/dimensions of waste pellets/particles	X	X	X	X			X	X	X	X	X	X	X	
Surface area of waste pellets or particles	X	X	X	X			X	X	X	X	X	X	X	
Weight & activity of each radionuclide		X	X	X			X	X	X	X	X	X	X	
Gas composition inside fuel element		X	X	X			X	X	X	X	X	X	X	
Geometry of Waste Package (Excluding Backfill)														
Corrosion effects on barrier thickness & shape		X	X	X		X	X	X	X	X	X	X	X	Periodic visual inspection, on-site lab analyses of pulled specimens & non-waste packages
Mechanical effects on barrier thickness & shape		X		X		X	X	X	X	X	X	X	X	Periodic visual inspection
Location & geometry of criticality control materials		X		X			X	X	X	X	X	X	X	Non-waste package off-site & pulled dummy waste package on-site lab analysis
Corrosion and Other Degradation Characteristics of Each Waste Package Barrier (Excluding Backfill)														
Threshold humidity for humid-air corrosion			X	X			X	X	X	X	X	X	X	On-site lab analysis of pulled specimens & dummy waste packages

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Dry oxidation corrosion rate		X	X	X		X		X	X	X	X	X	X	On-site lab analysis of pulled specimens & dummy waste packages
Humid-air general corrosion rate		X	X	X		X		X	X	X	X	X	X	
Aqueous general corrosion rate		X	X	X		X		X	X	X	X	X	X	
Humid-air pit corrosion rate		X	X	X		X		X	X	X	X	X	X	
Aqueous pit corrosion rate		X	X	X		X		X	X	X	X	X	X	
Microbial corrosion rate				X		X		X	X	X	X	X	X	
Cladding failure rate[1]		X		X		X		X	X	X	X	X	X	On-site lab analysis of pulled waste packages
Chemistry of Each Waste Package Barrier (Including Degradation Products but Excluding Backfill)														
Gas composition inside waste container		X	X	X			X	X	X	X	X	X	X	On-site lab analyses of failed waste packages, if any, and of waste not emplaced
Chemical composition of criticality control materials		X		X			X	X	X	X	X	X	X	Non-waste package off-site & pulled dummy waste package on-site lab analysis
Oxidation product composition			X	X			X	X	X	X	X	X	X	
Aqueous corrosion product composition			X	X			X	X	X	X	X	X	X	

1 Needed only if (a) credit will be taken for cladding performance or (b) its performance will adversely affect the performance of other engineered barrier system components.

Table D-1. Key Performance Confirmation Parameters for Design

Parameters	Selection Criteria											Performance Confirmation Parameters		Preliminary Performance Confirmation Concepts
	Screen 1 (one must apply)				Screen 2 (one must apply)			Screen 3 (all must apply)			Screen 4			
	10 CFR 60 Subpart F	Confine & Isolate Waste Funct.	Contain. & Isol. Strategy	TSPA & PA process models	Subsurface conditions	Affected by const./emplacement	Time dependent variable	Can be measured or derived	Can be predicted or estimated	Important to performance	Reduce uncertainty	All perf. conf. parameters	Key parameters for design	
Physical/chemical degree of embrittlement				X		X	X	X	X	X	X	X	X	Non-waste package off-site & pulled dummy waste package on-site lab analysis
Physical/chemical weld integrity	X			X		X	X	X	X	X	X	X	X	
Mechanical Characteristics of Each Waste Package Barrier (Excluding Backfill)														
In-situ stress		X		X		X	X	X	X	X	X	X	X	Non-waste package off-site & pulled dummy waste package on-site lab analysis
Strain				X		X	X	X	X	X	X	X	X	
Thermal Characteristics of Each Waste Package Barrier (Excluding Backfill)														
Barrier wall temperature		X	X	X		X	X	X	X	X	X	X	X	In-situ monitoring of selected waste packages in emplacement drifts & at underground test location
Waste Package Radionuclide Containment and Release for Each Waste Form, Package Design, and Important Radionuclide (see TSPA-1995 list at end of table)														
Waste package life or time of initial radionuclide release	X	X	X	X		X	X	X	X	X	X	X	X	Continuous radiation monitoring of excavation air
Radionuclide release rate from waste form	X	X	X	X		X	X	X	X	X	X	X	X	Remedial action if needed
Radionuclide release rate from waste package	X	X	X	X		X	X	X	X	X	X	X	X	

Abbreviations:
CFR = Code of Federal Regulations, ESF = Exploratory Studies Facility, PA = performance assessment, TSPA = total system performance assessment, WP = waste package.

TSPA-1995 Radionuclide List (for spent-fuel inventory):
Ac-227, Am-241, Am-242M, Am-243, C-14 (gaseous), Cl-36 (gaseous), Cm-244, Cm-245, Cm-246, Cs-135, I-129 (gaseous), Nb-93M, Nb-94, Ni-59, Ni-63, Np-237, Pa-231, Pb-210, Pd-107, Pu-238, Pu-239, Pu-240, Pu-241, Pu-242, Ra-226, Ra-228, Se-79, Sm-151, Sn-126, Tc-99, Th-229, Th-230, Th-232, U-233, U-234, U-235, U-236, U-238, Zr-93.

APPENDIX E

SURVEY OF FOREIGN GEOLOGIC REPOSITORY PERFORMANCE CONFIRMATION PROGRAMS

SURVEY OF FOREIGN GEOLOGIC REPOSITORY
PERFORMANCE CONFIRMATION PROGRAMS

E.1 INTRODUCTION

An attempt was made, using readily available literature, to determine if the approach of other countries involved in geologic disposal would be of use in the planning of performance confirmation concepts for Yucca Mountain. Appendix E contains a comparison of eight countries involved in geologic disposal of nuclear waste, and contains tables that contain expected date of repository operations, status of activities, and the test/monitoring concepts identified.

In an effort to take advantage of previous work and to minimize any unnecessary work, eight countries with geological repository programs were identified. A literature search was conducted to determine what requirements and concepts for a performance confirmation program during the preclosure period have been identified by foreign countries. The intent was to determine if anything in the Yucca Mountain Performance Confirmation Program had been overlooked that could possibly be more cost effective or time conservative. A detailed analysis of the findings is presented below.

Objective: To determine the requirements and concepts for performance confirmation that have been considered in the disposal of high-level waste in foreign geologic repository programs, and assess their applicability to the U.S. program.

Purpose: To determine what, if anything, could be learned from foreign geological repository program approaches to performance confirmation and apply findings to minimize unnecessary work on the U.S. program.

Methodology: A survey was conducted from readily assessable sources. Subject matter experts were interviewed for research task prioritization advice. A literature search was conducted which included various technical reports, environmental impact statements, and regulatory documents. A briefing by the Canadian Waste Management director was also attended to gain first hand knowledge on the Canadian repository program. The Canadian, Swedish, and Swiss repository programs were given priority in this survey.

E.2 FINDINGS

Currently France, Japan, and Belgium are reprocessing and practicing long term storage of the resulting high-level waste. They seem to be far enough from their target dates for having a geologic repository that they have not yet made provisions for a performance confirmation program. The United Kingdom has a relatively low volume of high-level waste and therefore will not address high-level waste disposal until 2040. Germany is currently constructing an underground test facility and has set its repository operation date for 2008; however, no applicable information was obtained. No applicable information was found on a performance confirmation program for the Swiss repository program. Of the eight countries surveyed, only Canada and Sweden were found to address performance confirmation through monitoring programs.

The Canadians have assessed that monitoring for performance confirmation would be initiated early in the siting stage. The parameters to be monitored would include seismic activity and geosphere, biosphere, and vault conditions. Potentially affected communities will also be monitored for socioeconomic impacts.

For the seismic activity monitoring program a local seismic network would be established to expand the present earthquake data base to earthquakes of smaller magnitude. Seismographs would be located in various locations within Canada, and additional monitoring instruments would be installed in boreholes at candidate sites to determine the relationship between depth and seismic ground motion. At the preferred site acoustic-emission/micro-seismic instruments would be installed underground to record extremely small seismic events. Geosphere monitoring would include observation of groundwater chemistry, hydraulic activities, borehole temperature, and rock stress. Measuring instruments would be installed in exploratory excavations and boreholes.

Biosphere monitoring, lasting from site evaluation to as long as deemed necessary by society, would include operational, effluent, and environmental monitoring. Measuring instruments would be placed near the source of contaminants. Nearby and drinking water would be tested to determine pH and possible contamination.

Due to limitations on testing the actual disposal room, component testing would be the preferred choice for vault monitoring. The program would monitor the temperature of containers, vault seals, and rock; pore-water pressures and swelling pressures in the buffer and backfill; transport of non-radioactive tracers through the vault seals; and hydraulic conductivity of the buffer and backfill.

Human health monitoring would consist of surveying levels of radiation found in natural resources. On a volunteer basis, dosimeters could be placed on humans or in homes (AECL 1994 pp 173-182).

The Swedish monitoring program is currently being developed. The methodology will be based on experience gained from experiments at their Underground Laboratory (Aspo Hard Rock Laboratory); however, they have identified that for several decades they will monitor parameters of the canisters such as pressure, temperature, moisture content and radiation level (SKB 1995, p 111).

Table E-1. Status of Foreign Geological Repository Programs

Country	**Expected Date of Repository Operation**	**Status**
Germany	2008	Constructing underground test facility
Sweden	2020	Searching for suitable site
Switzerland	2020 or later	Searching for suitable site
France	2020 or later	Developing repository concept
Canada	2025 or later	Reviewing repository concept
Japan	2030	
Belgium	2030	
United Kingdom	after 2040	

Table E-2. Foreign Geologic Repository Programs

COUNTRY	EXPECTED DATE OF REPOSITORY OPERATIONS	STATUS OF ACTIVITIES	TESTS AND MONITORING CONCEPTS IDENTIFIED
CANADA	2025 or later	■ in 1978 Nuclear Fuel Waste Management Program (NFWMP) was established for research and development ■ completed Environmental Impact Statement in 1994	■ documentation is stressed and must follow quality assurance procedures ■ seismic activity, biosphere, geosphere, and vault monitoring ■ instruments installed in boreholes at candidate sites to determine the relationship between depth the seismic ground motion ■ at preferred site acoustic-emission /micro-seismic instruments would be installed underground to collect data for calculating possible hazards following closure ■ biosphere monitoring would include operational, effluent, and environmental monitoring ■ geosphere monitoring would provide data (such as hydraulic head, groundwater chemistry, and temperature in isolated monitoring intervals in boreholes) to establish baseline conditions, determine reliability of models, and obtain approvals such as licenses. It would keep records of hydraulic conductivities, in situ stresses, and temperature near the excavation ■ component testing is preferred for vault monitoring ■ socio-economic monitoring (AECL 1994, p 173-182)

Table E-2. Foreign Geologic Repository Programs

COUNTRY	EXPECTED DATE OF REPOSITORY OPERATIONS	STATUS OF ACTIVITIES	TESTS AND MONITORING CONCEPTS IDENTIFIED
SWEDEN	2020	■ in 1984 the Swedish Nuclear Fuel and Waste Management Company was commissioned to develop a disposal concept (Schneider et al. 1990, p 7.3) ■ since 1985 Central Facility for Interim Storage of Spent Nuclear Fuel (CLAB) has been operational ■ spent fuel will be stored in CLAB for approximately 40 years before final geologic disposal *(SKB 1994, p 3)* ■ in 1995 they constructed an underground laboratory (the Aspo Hard Rock Laboratory) *(SKB 1995, p 165)*	■ instrumentation to measure canister parameters such as pressure, temperature, moisture content and radiation level will be emplaced for several decades **Monitoring Program is currently being developed. Methodology will be formed based on experiments at their Underground Laboratory** (SKB 1995, p 111)

Table E-2. Foreign Geologic Repository Programs

COUNTRY	EXPECTED DATE OF REPOSITORY OPERATIONS	STATUS OF ACTIVITIES	TESTS AND MONITORING CONCEPTS IDENTIFIED
SWITZERLAND	2020 or later	■ in 1972 the Utility company and the Federal government set up the National Cooperative for the Disposal of radioactive Waste (Nagra) for research and development of the waste disposal program ■ identified crystalline formation and sediments as potential host rocks in 1978 ■ Project Gewahr 1985 to demonstrate the capability of having a safe repository ■ in 1994 the Kristallin-I project completed evaluation of data obtained in Project Gewahr 1985 and assessed the suitability of crystalline basement as a host rock for a repository (Curti, et al. 1994, p 1-1 to 7; 2-3) ■ plan to propose a repository site and have an interim storage facility in operation before 2000 (U.S. General Accounting Office 1994, p 51)	No information found
FRANCE	2020 or later	■ National Radioactive Waste Management Agency (ANDRA) given responsibility for waste management in 1979 (Schneider et al. 1990, p 4.2) ■ currently reprocessing spent nuclear fuel ■ 1991 legislation requires research to be conducted until 2007 (U.S. General Accounting Office 1994, p 27-28)	■ determined that monitoring will not be required for more than 300 yrs. (Schneider et al. 1990, p 4.12) No other information was available

Table E-2. Foreign Geologic Repository Programs

COUNTRY	EXPECTED DATE OF REPOSITORY OPERATIONS	STATUS OF ACTIVITIES	TESTS AND MONITORING CONCEPTS IDENTIFIED
GERMANY	2008	■ responsibility for construction and operation of disposal facility allocated to Federal Institute of Physics and Metrology (PTB) (powers were scheduled to transfer to the Federal Office for Radiation Protection [BFS] in 1989) (OECD/NEA 1989) ■ conducted a five-year study (1980 to 1984) to compare safety aspects for direct disposal of spent fuel versus reprocessing and disposal of high-level waste ■ conducted preliminary investigations at Konrad mine in 1975 (OECD/NEA 1989) ■ began site investigation at Gorleben in 1979 ■ began drilling in the 1980s ■ plan to conduct tests up until the late 1990 to determine if Gorleben is suitable to start accepting high-level waste in 2008 (U.S. General Accounting Office 1994, p 35)	No information found

Table E-2. Foreign Geologic Repository Programs

COUNTRY	EXPECTED DATE OF REPOSITORY OPERATIONS	STATUS OF ACTIVITIES	TESTS AND MONITORING CONCEPTS IDENTIFIED
JAPAN	2030	■ by the year 2000, they plan to have reprocessing facility operational (U.S. General Accounting Office 1994, p 38) ■ in 1992 Atomic Energy Commission enacted a new high-level waste policy under which the Power Reactor and Nuclear Fuel Development Corporation (PNC) is responsible for research and development of disposal concept ■ plan to store high-level waste in vault for 30-50 yrs. before final disposal (NWTRB 1995 Appendix I)	No information found
BELGIUM	2030	■ reprocessing spent fuel in France and the United Kingdom ■ developing a geologic repository at the Mol. Site ■ plan to have engineered storage facilities for long-term storage (Schneider et al. 1990, pp 2.2 and 2.7)	No information found
UNITED KINGDOM	After 2040	■ volume of high-level waste is relatively low and can be stored easily, therefore the decision of whether or not to construct a high-level waste repository will be delayed until around 2040 ■ plan to have a lower-level radioactive waste repository operational by 2007 (U.S. General Accounting Office 1994, p 53-55)	No information found

E.3 DISCUSSION

From the foregoing survey it may be seen that most national geologic disposal programs are in the site-selection for characterization phase, or even in a proof-of-concept phase. Confirmatory studies, whether through aggressive additional characterization or through more passive monitoring of key components of the disposal system and its environment, have not been contemplated in most national programs.

Two exceptions are the Canadian program, which is still in the pre-site-selection phase, and the Swedish program, which is actively attempting to select for characterization. In both these programs, pre- and postclosure monitoring has been discussed in general terms. The geologic medium and disposal concept to be used in these two programs focuses their confirmatory monitoring on system components that are not directly applicable to the system components contemplated for the Yucca Mountain site disposal system.

E.4 CONCLUSION AND RECOMMENDATION

The foregoing observations lead to the conclusion that although it would be useful to stay aware of progress made in defining aspects of the system to be monitored and the techniques developed to perform that monitoring, the likelihood that there could be technology transfer from these projects to Yucca Mountain is not high. It is recommended, however, that the Yucca Mountain Project share its monitoring plans and experience internationally, and that it stay abreast of international developments in monitoring technology and planning so as to be in a position to take advantage of technology transfer and exchange opportunities as they may rise.

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APPENDIX F

COST DETAILS

COST DETAILS

Additional detail on the cost estimates for the Performance Confirmation Concepts are presented in this appendix. Each major concept that was estimated will have a section in this appendix. In each section, a brief list of what was used in the cost estimate is provided. Typically this consists of an initial cost and a yearly cost that concept and the assumed time frame over which it occurs.

F.1 Performance Confirmation Monitoring and Testing Concepts

Additional cost estimating detail will be provided for three areas Site, Repository, and Waste Package Monitoring and Testing Concepts.

F.1.1 Site Performance Confirmation Monitoring and Testing Concepts

Additional cost estimating detail will be provided for four testing packages: Subsurface Geologic Mapping Package, Surface-Based Unsaturated Zone Hydrology Package, Underground Fault Zone Hydrology Package, Thermal Testing Package.

F.1.1.1 Subsurface Geologic Mapping Package

This package was assumed to begin in the year 2004 and extend for 30 years following the initial construction effort and the development of the emplacement drifts. The costs for the nominal and enhanced cases are documented in the following pages.

PRELIMINARY COST ESTIMATE FOR TEST PACKAGE #1: UNDERGROUND MAPPING, SAMPLING, & LAB TESTING

The estimated cost of the underground mapping, sampling, and lab testing program is approximately $18 million for the lowest cost program, and $89 million for the highest cost program (FY96 dollars). Each estimate is organized as follows:

- Summary
- Part 1A Drilling for Core Samples
- Part 1B Construction Support for Mapping
- Part 1C Tunnel Mapping & Sampling
- Part 1D Lab Testing

Key estimating assumptions used as a basis for the cost estimates include the following:

- The number of core samples is estimated as 200 and 1000, corresponding to the lowest and highest cost sampling programs.

- For the lowest cost mapping program, the estimated progress rate for tunnel mapping, including geologic structure and rock mass classification, is 100 m/shift; the estimated crew size for mapping and sampling is 7 full time geologists, 3 full time clerks, and 1 part time M&O senior geological engineer per shift. In the lowest cost mapping program, the tunnel mapping is assumed to occur independently of TBM operations, or lagging behind the heading(s).

- For the highest cost mapping program, the estimated progress rate for tunnel mapping, including geologic structure and rock mass classification, is 20 m/shift; the estimated crew size for mapping and sampling is 5 full time geologists, 2 full time clerks, and 1 part time consultant per shift. In the highest cost mapping program, the tunnel mapping is assumed to occur immediately behind the TBM.

- Estimated labor rates are based on FY96 rates for USGS/USBR geologists and for Kiewit construction personnel.

- The construction support includes cleaning tunnel perimeter to facilitate mapping, and core drilling short holes for samples.

- Laboratory testing will be performed by an off-site subcontractor, and is assumed to be limited to permeability testing and moisture content measurement of core samples.

- Project management is assumed to be performed by an M&O Contractor, with cost and markup roughly estimated as percentages of the total costs of other activities. (Refer to attached estimates for details.)

SUMMARY OF PRELIMINARY COST ESTIMATE FOR REPOSITORY PERFORMANCE CONFIRMATION TESTING

7/24/96
TRS

TEST PKG #1.TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT--LOWEST COST

PART 1A(1) DRILLING FOR CORE SAMPLES (200 samples)

LABOR	163620	
EQUIPMENT	134550	
MATERIALS	14400	
TOTAL COST		312570

PART 1B(1) CONSTRUCTION SUPPORT FOR MAPPING (mapping indep of TBM)

LABOR	994954	
EQUIPMENT	1340352	
MATERIALS	7200	
TOTAL COST		2342506

PART 1C(1) TUNNEL MAPPING & SAMPLING (200 samples, mapping indep of TBM)

LABOR	7862240	
EQUIPMENT	585600	
MATERIALS	62000	
TOTAL COST		8509840

PART 1D(1) LAB TESTING (200 samples)

LABOR	0		
EQUIPMENT	0		
MATERIALS	0		
SUBCONTRACTS	878400		
SUBCONTRACT ADMIN	87840		
SUBTOTAL		966240	
CONTINGENCY @ 20%		193248	
TOTAL COST			1159488

SUBTOTAL	12324404
M&O CONTRACTOR MGMT/ADMIN @ 30%	3697321
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN	2403259
TOTAL COST, FY96 DOLLARS	18424983
	18 MILLION

PRELIMINARY COST ESTIMATE: 7/24/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1A(1) DRILLING FOR CORE SAMPLES

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of 10" to 15" Dia. Samples:	50	
Est No. of 2" to 3" Dia. Samples:	150	
Set up & Move drill, Prep Work Area, Demob & Cleanup		800 hr
Core drill 10" to 15" dia., 2 to 5 ft holes		200 hr
Core drill 2" to 3" dia., 2 to 5 ft holes		150 hr
TOTAL DURATION		1150 hr

ESTIMATED CREW SIZE
Full time: 1 driller, 1 driller's helper
Part time: 1 miner, 1 labor, 1 electrician

LABOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Drillers	1150	23		26450 Rates from Kiewitt		
Drllr Helper	1150	23		26450		
Miner	800	18		14400		
Labor	800	17		13600		
Electrician	400	25		10000		
Subtotal Labor					90900	
Fringes, Taxes, & Ins @ 50% of Base Labor					45450	
G&A + Profit @ 20% of Burdened Labor					27270	
TOTAL LABOR						163620

EQUIPMENT	Hours	Rate	Amount	
Drill	1150	60	69000	
Scissor/Fork Lift	1150	30	34500	
Subtotal Equipment			103500	
Utilities, G&A, + Profit @ 30%			31050	
TOTAL EQUIPMENT				134550

MATERIALS	Qty. Unit	Unit Cost	Amount		
Core Bits/Barrels	L.S.	L.S.	10000		
Misc Tools	L.S.	L.S.	1000		
Air Hose	200 LF	5	1000		
Subtotal Materials				12000	
G&A + Profit @ 20%				2400	
TOTAL MATERIALS					14400

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 312570

PRELIMINARY COST ESTIMATE: 7/24/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1B(1) CONSTRUCTION SUPPORT FOR MAPPING

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est Total Tunnel Length:	179000 m				
Est Avg Mapping Rate:	100 m/sh				
Clean Tunnel Prior to Mapping:		1790	shifts =	14320	hr
Provide Access to Crown:		358	shifts =	2864	hr
TOTAL EST. DURATION:		2148	shifts =	17184	hr

ESTIMATED CREW SIZE
Full time: 1 miner, 1 labor (bull gang)
Part time: 1 labor (bull gang)

LABOR

	Manhours	Base Rate	Burdened Rate	Base Amount		
Miner	17184	18		309312		
Labor	14320	17		243440		
Subtotal Labor					552752	
Taxes & Ins @ 50% of Base Labor					276376	
G&A + Profit @ 20% of Burdened Labor					165826	
TOTAL LABOR						994954

EQUIPMENT

	Hours	Rate	Amount	
Scissor/Fork Lift	17184	30	515520	
Compressor	17184	30	515520	
Subtotal Equipment			1031040	
Utilities, G&A, + Profit @ 30%			309312	
TOTAL EQUIPMENT				1340352

MATERIALS

	Qty.	Unit	Unit Cost	Amount	
Air Hose	1000	LF	5	5000	
Misc Tools & Parts	L.S.		L.S.	1000	
Subtotal Materials				6000	
G&A + Profit @ 20%				1200	
TOTAL MATERIALS					7200

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 2342506

PRELIMINARY COST ESTIMATE: 7/24/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1C(1) TUNNEL MAPPING & SAMPLING
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est Total Tunnel Length:	179000 m				
Est Avg Mapping Rate:	100 m/sh				
Est No. of Core Samples:	200				
Tunnel Mapping:		1790	shifts =	14320	hr
Collect, Tag, Store Intact Samples		40	shifts =	320	hr
TOTAL EST. DURATION:		1830	shifts =	14640	hr
Review Mapping, Attend Meetings with Designers				7160	hr

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol, 3 Project Geol, 3 Staff Geol, 3 Clerks
Part time: 1 Sr Geol/Engr

LABOR--TUNNEL MAI	Manhours	Base Rate	Burdened Rate	Base Amount		
Sup Geol	14640		74	1083360	Rates from RCQ FY97 BOE	
Proj Geol	43920		61	2679120	(USGS/USBR)	
Staff Geol	43920		49	2152080		
Clerk	43920		30	1317600		
SUBTOTAL LABOR					7232160	

LABOR: TECH OVERSIGHT FOR TUNNEL MAPPING

	Manhours	Base Rate	Burdened Rate	Amount		
Sr G/E	7160		80	572800		
Subtotal Labor				572800		
G&A + Profit @ 10%				57280		
SUBTOTAL LABOR					630080	
TOTAL LABOR						7862240

EQUIPMENT	Hours	Rate	Amount	
Site vehicles (4)	14640	40	585600	
Subtotal Equipment			585600	
TOTAL EQUIPMENT				585600

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Office Equip	L.S.		L.S.	50000	
Office Supplies	L.S.		L.S.	2000	
Field Gear	L.S.		L.S.	10000	
TOTAL MATERIALS					62000

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 8509840

PRELIMINARY COST ESTIMATE: 7/20/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1D(1) LAB TESTING

SUBCONTRACTS

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS

Est No of 10" to 15" Core Samples:	50	
Est No of 2" to 3" Dia. Core Samples:	150	
Total No. Samples	200	
Prep Samples (cutting, capping, etc)		400 hr
Testing (permeability, ~~water potl,~~ moisture content)		1600 hr
Prep Reports		400 hr
TOTAL EST. DURATION:		2400 hr

ESTIMATED CREW SIZE
1 Sr Lab Geol/Engr, 1 Lab Geol, 1 Lab Tech, 1 Clerk

SUBCONTRACT LABOR

	Manhours	Base Rate	Burdened Rate	Amount		
Sr Lab G/E	2400		100	240000		
Lab Geol	2400		80	192000		
Lab Tech	2400		60	144000		
Clerk	2400		40	96000		
Subtotal Labor					672000	
G&A + Profit @ 20%					134400	
TOTAL SUB LABOR						806400

SUBCONTRACT MATERIALS

	Qty.	Unit	Unit Cost	Amount	
Lab Equip	L.S.		L.S.	50000	
Office Equip	L.S.		L.S.	10000	
Subtotal Materials				60000	
G&A + Profit @ 20%				12000	
TOTAL SUB MATERIALS					72000

TOTAL SUBCONTRACT (LABOR, EQUIP, MATLS)	878400
SUBCONTRACT ADMIN	87840
TOTAL COST (LABOR, EQUIPMENT, MATERIALS, SUBCONTRACT & ADMIN)	966240

SUMMARY OF PRELIMINARY COST ESTIMATE FOR REPOSITORY PERFORMANCE CONFIRMATION TESTING

7/24/96
TRS

TEST PKG #1.TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT--HIGHEST COST

PART 1A(2) DRILLING FOR CORE SAMPLES (1000 samples)			
LABOR	805680		
EQUIPMENT	655200		
MATERIALS	14400		
TOTAL COST			1475280
PART 1B(2) CONSTRUCTION SUPPORT FOR MAPPING (mapping behind TBM)			
LABOR	4510800		
EQUIPMENT	7446400		
MATERIALS	7200		
TOTAL COST			11964400
PART 1C(2) TUNNEL MAPPING & SAMPLING (1000 samples, mapping behind TBM)			
LABOR	38678880		
EQUIPMENT	2157600		
MATERIALS	62000		
TOTAL COST			40898480
PART 1D(2) LAB TESTING (1000 samples)			
LABOR	0		
EQUIPMENT	0		
MATERIALS	0		
SUBCONTRACTS	4104000		
SUBCONTRACT ADMIN	410400		
SUBTOTAL		4514400	
CONTINGENCY @ 20%		902880	
TOTAL COST			5417280
SUBTOTAL			59755440
M&O CONTRACTOR MGMT/ADMIN @ 30%			17926632
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			11652311
TOTAL COST, FY96 DOLLARS			89334383
			89 MILLION

PRELIMINARY COST ESTIMATE:
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT

7/20/96
TRS

PART 1A(2) DRILLING FOR CORE SAMPLES

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of 10" to 15" Dia. Samples:	200	
Est No. of 2" to 3" Dia. Samples:	800	
Set up & Move drill, Prep Work Area, Demob & Cleanup		4000 hr
Core drill 10" to 15" dia., 2 to 5 ft holes		800 hr
Core drill 2" to 3" dia., 2 to 5 ft holes		800 hr
TOTAL DURATION		5600 hr

ESTIMATED CREW SIZE
Full time: 1 driller, 1 driller's helper
Part time: 1 miner, 1 labor, 1 electrician

LABOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Drillers	5600	23		128800	Rates from Kiewitt	
Drllr Helper	5600	23		128800		
Miner	4000	18		72000		
Labor	4000	17		68000		
Electrician	2000	25		50000		
Subtotal Labor					447600	
Fringes, Taxes, & Ins @ 50% of Base Labor					223800	
G&A + Profit @ 20% of Burdened Labor					134280	
TOTAL LABOR						805680

EQUIPMENT	Hours	Rate	Amount	
Drill	5600	60	336000	
Scissor/Fork Lift	5600	30	168000	
Subtotal Equipment			504000	
Utilities, G&A, + Profit @ 30%			151200	
TOTAL EQUIPMENT				655200

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Core Bits/Barrels	L.S.		L.S.	10000	
Misc Tools	L.S.		L.S.	1000	
Air Hose	200	LF	5	1000	
Subtotal Materials				12000	
G&A + Profit @ 20%				2400	
TOTAL MATERIALS					14400

TOTAL COST (LABOR, EQUIP, MATLS) 1475280

PRELIMINARY COST ESTIMATE: 7/24/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1B(2) CONSTRUCTION SUPPORT FOR MAPPING

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est Total Tunnel Length:	179000 m			
Est Avg TBM Adv Rate:	20 m/sh			
Clean Tunnel Prior to Mapping		8950	shifts =	71600 hr
TOTAL EST. DURATION:		8950	shifts =	71600 hr

ESTIMATED CREW SIZE
1 miner, 1 labor (bull gang)

LABOR

	Manhours	Base Rate	Burdened Rate	Base Amount		
Miner	71600	18		1288800		
Labor	71600	17		1217200		
Subtotal Labor					2506000	
Taxes & Ins @ 50% of Base Labor					1253000	
G&A + Profit @ 20% of Burdened Labor					751800	
TOTAL LABOR						4510800

EQUIPMENT

	Hours	Rate	Amount	
Mapping gantry	71600	50	3580000	
Compressor	71600	30	2148000	
Subtotal Equipment			5728000	
Utilities, G&A, + Profit @ 30%			1718400	
TOTAL EQUIPMENT				7446400

MATERIALS

	Qty.	Unit	Unit Cost	Amount	
Air Hose	1000	LF	5	5000	
Misc Tools & Parts	L.S.		L.S.	1000	
Subtotal Materials				6000	
G&A + Profit @ 20%				1200	
TOTAL MATERIALS					7200

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 11964400

PRELIMINARY COST ESTIMATE: 7/24/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1C(2) TUNNEL MAPPING & SAMPLING
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est Total Tunnel Length:	179000 m			
Est Avg Mapping Rate (TBM Adv):	20 m/sh			
Est No. of Core Samples:	200			
Tunnel Mapping:		8950 shifts =	71600	hr
Collect, Tag, Store Intact Samples		40 shifts =	320	hr
TOTAL EST. DURATION:		8990 shifts =	71920	hr
Review Mapping, Attend Meetings with Designers			35800	hr

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol, 3 Project Geol, 3 Staff Geol, 3 Clerks
Part time: 1 Sr Geol/Engr

LABOR--TUNNEL MAI	Manhours	Base Rate	Burdened Rate	Base Amount		
Sup Geol	71920		74	5322080	Rates from RCQ FY97 BOE	
Proj Geol	215760		61	13161360	(USGS/USBR)	
Staff Geol	215760		49	10572240		
Clerk	215760		30	6472800		
SUBTOTAL LABOR					35528480	

LABOR: TECH OVERSIGHT FOR TUNNEL MAPPING

	Manhours	Base Rate	Burdened Rate	Amount		
Sr G/E	35800		80	2864000		
Subtotal Labor				2864000		
G&A + Profit @ 10%				286400		
SUBTOTAL LABOR					3150400	
TOTAL LABOR						38678880

EQUIPMENT	Hours	Rate	Amount	
Site vehicles (3)	71920	30	2157600	
Subtotal Equipment			2157600	
TOTAL EQUIPMENT				2157600

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Office Equip	L.S.		L.S.	50000	
Office Supplies	L.S.		L.S.	2000	
Field Gear	L.S.		L.S.	10000	
TOTAL MATERIALS					62000

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 40898480

PRELIMINARY COST ESTIMATE: 7/20/96
TUNNEL MAPPING, SAMPLING, & CONSTRUCTION SUPPORT TRS

PART 1D(2) LAB TESTING

SUBCONTRACTS

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS

Est No of Large Dia. 10" to 15" Core Samples:	200	
Est No of 2" to 3" Dia. Core Samples:	800	
Total No. Samples	1000	
Prep Samples (cutting, capping, etc)		2000 hr
Testing (permeability, ~~water path~~, moisture content)		8000 hr
Prep Reports		2000 hr
TOTAL EST. DURATION:		12000 hr

ESTIMATED CREW SIZE
1 Sr Lab Geol/Engr, 1 Lab Geol, 1 Lab Tech, 1 Clerk

SUBCONTRACT LABOR

	Manhours	Base Rate	Burdened Rate	Base Amount		
Sr Lab G/E	12000		100	1200000		
Lab Geol	12000		80	960000		
Lab Tech	12000		60	720000		
Clerk	12000		40	480000		
Subtotal Labor					3360000	
G&A + Profit @ 20%					672000	
TOTAL SUB LABOR						4032000

SUBCONTRACT MATERIALS

	Qty.	Unit	Unit Cost	Amount		
Lab Equip	L.S.		L.S.	50000		
Office Equip	L.S.		L.S.	10000		
Subtotal Materials				60000		
G&A + Profit @ 20%				12000		
TOTAL SUB MATERIALS					72000	
TOTAL SUBCONTRACT (LABOR, EQUIP, MATLS)						4104000
SUBCONTRACT ADMIN						410400
TOTAL COST (LABOR, EQUIPMENT, MATERIALS, SUBCONTRACT & ADMIN)						4514400

F.1.1.2 Surface-Based Unsaturated Zone Hydrology Package

This package was assumed to begin in the year 2004 with the construction of the boreholes. It would extend for 117 years until the year 2121. The costs for the nominal and enhanced cases are documented in the following pages.

PRELIMINARY COST ESTIMATE FOR TEST PACKAGE #2: SURFACE BASED UNSATURATED ZONE HYDROLOGY

The estimated cost of the assumed surface based borehole instrumentation program is approximately $4 million for the lowest cost program, and $11 million for the highest cost program, plus an annual operation and maintenance cost of approximately $0.5 million for the lowest cost program, and $1.6 million for the highest cost program (FY96 dollars). Each estimate is organized as follows:

- Summary
- Part 2A Planning
- Part 2B Drilling
- Part 2C Geophysical Logging
- Part 2D Drilling & Logging Inspection & Sampling
- Part 2E Installation of Borehole Instrumentation
- Part 2F Operation & Maintenance of Instrumentation & Data Acquisition System

Key estimating assumptions used as a basis for the cost estimates include the following:

- The number of instrumented boreholes is 5 and 15, corresponding to the lowest and highest cost drilling and instrumentation programs.

- Sampling of boreholes is limited to collection of drill cuttings. No core sampling is considered necessary due to assumed use of nearby existing boreholes and geophysical logging for geologic control.

- The absence of coring requirements allows an estimated drilling rate of 70 ft/shift.

- The drilling operation uses 6 men full time, plus two men half time, based on a typical estimated crew size by DMO and Kiewit. A smaller crew size would probably be used if the drilling contract is to be competitively bid.

- The drilling operation uses a drill rig with dual wall reverse air circulation, similar to the LM-300 used in drilling operations prior to recent budget reductions of the past fiscal year. The equipment cost for this rig ($150/hr) is a significant cost driver, and was obtained from DMO and Kiewit. A lower equipment cost could probably be used if the drilling contract is to be competitively bid.

- The estimated crew size for drilling inspection and sampling is 3 full time geologists/engineers.

- For the lowest cost testing program, the estimated total duration of annual monitoring, operation, and maintenance activities is approximately 280 shifts. The estimated crew size is 2 full time geologists.

- Existing boreholes must be adequately sealed, or new boreholes must be located far enough from new boreholes so that instrumentation measurements are not affected by the presence of the existing boreholes.

- All necessary geophysical logging data, plus downhole video, can be obtained in a single run.

- No laboratory testing costs are included.

- Estimated labor rates are based on FY96 rates for M&O technical personnel, USGS/USBR geologists, and for Kiewit drilling personnel.

- Existing access roads and drill pads can be used with negligible or no improvement. No associated earthwork costs are included.

- Project management is assumed to be performed by an M&O Contractor, with cost and markup roughly estimated as percentages of the total costs of other activities. (Refer to attached estimates for details.)

8/22/96
TRS

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING
TEST PKG #2. SURFACE BASED TESTING PACKAGE--LOWEST COST

PART 2A(1) PLANNING (5 Holes)			
LABOR	48400		
EQUIPMENT	1100		
MATERIALS	24200		
TOTAL COST		73700	
PART 2B(1) DRILLING; NO CORE SAMPLES (5 Holes)			
LABOR	492531		
EQUIPMENT	696707		
MATERIALS	129600		
TOTAL COST		1318839	
PART 2C(1) GEOPHYSICAL LOGGING (5 Holes)			
LABOR	96096		
EQUIPMENT	3432		
MATERIALS	57200		
SUBCONTRACTS	281860		
SUBCONTRACT ADMIN	28186		
TOTAL COST		466774	
PART 2D(1) DRILLING & LOGGING INSPECTION & SAMPLING (5 Holes)			
LABOR	415863		
EQUIPMENT	51983		
MATERIALS	32000		
TOTAL COST		499846	
PART 2E(1) INSTALL SEAMIST INSTRUMENTATION (5 Holes)			
LABOR	66000		
EQUIPMENT	19200		
MATERIALS	171000		
TOTAL COST		256200	
SUBTOTAL			2541658
M&O CONTRACTOR MGMT/ADMIN @ 30%			762497
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			495623
TOTAL COST, FY96 DOLLARS			3799779

PART 2F(1) MONITOR, OPERATE & MAINT INSTRUM & DAS (Annual, 5 Holes)		
LABOR	302400	
EQUIPMENT	44800	
MATERIALS	10000	
SUBTOTAL		357200
M&O CONTRACTOR MGMT/ADMIN @ 30%		107160
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN		69654
TOTAL ANNUAL COST, FY96 DOLLARS		534014

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2A(1) PLANNING (5 Holes)
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Boreholes:	5		
Planning for Drilling:		20 shifts	
prep contracts			
state permits			
FWP, DIE assistance, Work Program			
coordination			
Planning for Geophys Logging:		15 shifts	based partly on
prep contracts			M&O Geophys Logging
state permits			cost est 1/25/96
NTS access arrangements			
QA planning			
Planning for Instrumentation:		15 shifts	
FWP, DIE ~~support~~ assistance, Work Program			
TOTAL EST. DURATION:		50 shifts =	400 hr

ESTIMATED CREW SIZE
Full time: 1 Project Geol/Engr, 1 Staff Geol/Engr, 1 Clerk
Part time: 1 Supervising Geol/Engr

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup G/E	200		100	20000		
Proj G/E	400		60	24000		
Staff G/E	400		40	16000		
Clerk	400		30	12000		
Subtotal Labor					44000	
G&A + Profit @ 10%					4400	
TOTAL LABOR						48400

EQUIPMENT	Hours	Rate	Amount	
Site vehicle	100	10	1000	
Subtotal Equipment			1000	
G&A + Profit @ 10%			100	
TOTAL EQUIPMENT				1100

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Office Equip	L.S.		L.S.	20000	
Office Supplies	L.S.		L.S.	2000	
Subtotal Materials				22000	
G&A + Profit @ 10%				2200	
TOTAL MATERIALS					24200

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 73700

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2B(1) DRILLING; NO CORE SAMPLES (5 Holes)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Boreholes:	5	
Est Avg Depth of Boreholes:	2000	ft
Est Avg Drilling Rate:	70	ft/sh

Mob, Set up & Move drill, Prep Work Area	30	sh		
Drill & Set sfc casings to 50 ft depth	30	sh		
Drill 9" to 12" dia. holes	143	sh		
Demob & Cleanup	15	sh		
TOTAL DURATION	218	sh =	1743	hr

ESTIMATED CREW SIZE
Full time: 1 supt, 1 driller, 1 driller's helper, 1 derrickman, 1 motorman, 1 labor
Part time: 1 mechanic, 1 electrician

LABOR	Manhours	Base Rate	Burdened Rate	Base Amount	
Supt	1743	28		48800	Rates from Kiewitt
Drillers	1743	23		40086	(DMO cost est 1/23/96)
Drllr Helper	1743	21		36600	
Derrickman	1743	22		38343	
Motorman	1743	21		36600	
Labor	1743	17		29629	
Mech	871	25		21786	
Electrician	871	25		21786	

Subtotal Labor	273629	
Fringes, Taxes, & Ins @ 50% of Base Labor	136814	
G&A + Profit @ 20% of Burdened Labor	82089	
TOTAL LABOR		492531

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2B(1) DRILLING; NO CORE SAMPLES (5 Holes) (cont)

EQUIPMENT

	Hours	Rate	Amount		
Drill, dual wall rev air	1743	150	261429	Rates from	
Compressor, 1200 cfm	1743	60	104571	DMO cost est 1/23/96	
Baghouse	1743	15	26143		
Generator, 40 kw	1743	15	26143		
Fork lift, 15 ton	1743	20	34857		
Light plant	1743	5	8714		
Portable toilet	1743	5	8714		
Pickup trks (3)	1743	30	52286		
Tool trk	871	15	13071		
Subtotal Equipment			535929		
G&A + Profit @ 20%			160779		
TOTAL EQUIPMENT					696707

MATERIALS

	Qty.	Unit	Unit Cost	Amount	
Drill Bits	10	ea	5000	50000	
Drill pipe	2200	LF	20	44000	
Casing	250	LF	20	5000	
Grout matls	L.S.		L.S.	5000	
Misc Tools	L.S.		L.S.	2000	
Air Hose	200	LF	10	2000	
Subtotal Materials				108000	
G&A + Profit @ 20%				21600	
TOTAL MATERIALS					129600

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 1318839

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2C(1) GEOPHYSICAL LOGGING (5 Holes)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS--LOGGING SUBCONTRACTOR

No. of Boreholes:	5		
Mob, Demob	10 shifts		
Logging in single run:	5 shifts		
Resistivity log			
Density log			
Neutron log			
Oriented caliper log			
Specific gravity log			
Borehole video			
Other logs (?)			
SUBTOTAL EST. DURATION:	15 shifts =	120	hr

PARTIAL COST: M&O Geophys Logging cost est 1/25/96
SUBCONTRACT LABOR, EQUIP, & MATLS COST PER BOREHOLE 54500
SUBTOTAL COST FOR ALL BOREHOLES (LABOR, EQUIPMENT, MATERIALS) 272500

SUBCONTRACT EQUIPMENT

	Hours	Rate	Amount		
Logging tools	(incl in Partial Cost above)			Rates from	
Crane	120	60	7200	M&O Geophys Logging	
Subtotal Equipment			7200	cost est 1/25/96	
G&A + Profit @ 30%			2160		
SUBTOTAL EQUIPMENT					9360

SUBCONTRACT MATL: (incl in Partial Cost above)

TOTAL SUBCONTRACT	281860
SUBCONTRACT ADMIN @ 10%	28186

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2C(1) GEOPHYSICAL LOGGING (5 Holes)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS--LOGGING SUBCONTRACTOR

No. of Boreholes:	5		
Mob, Demob		8 shifts	
Logging in single run:		5 shifts	
Resistivity log			
Density log			
Neutron log			
Oriented caliper log			
Specific gravity log			
Borehole video			
Other logs (?)			
SUBTOTAL EST. DURATION:		13 shifts =	100 hr

PARTIAL COST: M&O Geophys Logging cost est 1/25/96

SUBCONTRACT LABOR, EQUIP, & MATLS COST PER BOREHOLE	54500	
SUBTOTAL COST FOR ALL BOREHOLES (LABOR, EQUIPMENT, MATERIALS)		272500

SUBCONTRACT EQUIPMENT

	Hours	Rate	Amount		
Logging tools	(incl in Partial Cost above)			Rates from	
Crane	100	60	6000	M&O Geophys Logging	
Subtotal Equipment			6000	cost est 1/25/96	
G&A + Profit @ 30%			1800		
SUBTOTAL EQUIPMENT					7800

SUBCONTRACT MATLS (incl in Partial Cost above)

TOTAL SUBCONTRACT	280300
SUBCONTRACT ADMIN @ 10%	28030

PRELIMINARY COST ESTIMATE:
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION

7/25/96
TRS

PART 2C(1) GEOPHYSICAL LOGGING (5 Holes) (cont)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS--M&O GEOPHYS LOGGING

based partly on M&O Geophys Logging cost est 1/25/96

Log analysis:		
verify digits	12	shifts
forensic eval & rept	17	shifts
log analyis & rept	20	shifts
QA review support	4	shifts
update database	10	shifts
misc	15	shifts

SUBTOTAL EST. DURATION: 78 shifts = 624 hr

ESTIMATED CREW SIZE
1 Sr Geol, 1 Project Geol, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sr Geol	624		80	49920		
Proj Geol	624		60	37440		
Staff Geol	0		40	0		
Clerk	624		30	18720		
Subtotal Labor					87360	
G&A + Profit @ 10%					8736	
TOTAL LABOR						96096

EQUIPMENT	Hours	Rate	Amount	
Site vehicle	156	20	3120	
Subtotal Equipment			3120	
G&A + Profit @ 10%			312	
TOTAL EQUIPMENT				3432

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Office Equip	L.S.		L.S.	50000	
Office Supplies	L.S.		L.S.	2000	
Subtotal Materials				52000	
G&A + Profit @ 10%				5200	
TOTAL MATERIALS					57200

TOTAL COST (LABOR, EQUIP, MATLS, SUBCONTRACTS) ~~675709~~ ~~[illegible]~~ 466,774

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2D(1) DRILLING INSPECTION & SAMPLING (5 Holes)
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Boreholes:	5			
Est No. of Samples per Borehole:	100			
Drilling & Logging Inspection, incl Collect, Tag, & Haul Cutting Samples		221	shifts	drilling & logging duration
Store Cutting Samples		63	shifts	est based on SMF cost est 1/22/96
TOTAL EST. DURATION:		283	shifts =	2267 hr

ESTIMATED CREW SIZE
1 Supervising Geol/Engr, 1 Project Geol/Engr, 1 Staff Geol/Engr, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup G/E	2267		100	226686		
Proj G/E	2267		60	136011		
Staff G/E	2267		40	90674		
Clerk	2267		30	68006		
Subtotal Labor					362697	
G&A + Profit @ 10%					36270	
TOTAL LABOR						398967

EQUIPMENT	Hours	Rate	Amount	
Site vehicles (2)	2267	20	45337	
Subtotal Equipment			45337	
G&A + Profit @ 10%			4534	
TOTAL EQUIPMENT				49871

MATERIALS	Qty.	Unit	Unit Cost	Amount	
Office Equip	L.S.		L.S.	20000	
Office Supplies	L.S.		L.S.	2000	
Field Gear	L.S.		L.S.	10000	
TOTAL MATERIALS					32000

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 480838

PRELIMINARY COST ESTIMATE:
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION

7/25/96
TRS

PART 2E(1) INSTALL SEAMIST INSTRUMENTATION (5 Holes)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Boreholes:	5		
Mob, Demob		10 shifts	
Install SEAMIST		10 shifts	
Set up DAS (solar panel, pump, PC, trailer)		10 shifts	
TOTAL EST. DURATION:		30 shifts =	240 hr

ESTIMATED CREW SIZE
1 Supervising Geol, 1 Project Geol, 2 Consult (SEAMIST)

LABOR

	Manhours	Base Rate	Burdened Rate	Base Amount		
Sup Geol	240		74	17760	Rates from RCQ FY97 BOE	
Proj Geol	240		61	14640	(USGS/USBR)	
Consult	480		70	33600		
Subtotal Labor					66000	
TOTAL LABOR						66000

PRELIMINARY COST ESTIMATE: 7/25/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2E(1) INSTALL SEAMIST INSTRUMENTATION (~~5 Holes~~)(cont)

EQUIPMENT

	Hours	Rate	Amount	
Pickup trks (2)	240	20	4800	
Generator, 10 kw	240	10	2400	
Gas canister	240	50	12000	
Subtotal Equipment			19200	
TOTAL EQUIPMENT				19200

MATERIALS

	Qty.	Unit	Unit Cost	Amount		
Borehole liner & gas pressure instrum	5	ea	23000	115000	SEAMIST quote 7/16/96	
Moisture cont instrum	5	ea	500	2500		
Wtr potl instrum	5	ea	500	2500		
Fabric balloons for temp	5	ea	1000	5000		
Solar panel & pump	5	ea	2200	11000		
Datalogger	5	ea	1000	5000		
Trailer	5	ea	5000	25000		
Misc tools	5	ea	1000	5000		
TOTAL MATERIALS						171000

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 256200

PRELIMINARY COST ESTIMATE: 8/22/96
SURFACE BASED DRILLING, LOGGING, & INSTRUMENTATION TRS

PART 2F(1) MONITOR, OPERATE & MAINT INSTRUM & DAS (Annual, 5 Holes)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS (ANNUAL)

Est No. of Boreholes:	5		
Ck & maint DAS, ck & calibrate instrum:		120 shifts	
Download data:		60 shifts	
Review & analyze data, prep qrtly repts:		100 shifts	
TOTAL EST. DURATION:		280 shifts =	2240 hr

ESTIMATED CREW SIZE
1 Supervising Geol, 1 Project Geol

LABOR

	Manhours	Base Rate	Burdened Rate	Base Amount		
Sup Geol	2240		74	165760 Rates from RCQ FY97 BOE		
Proj Geol	2240		61	136640 (USGS/USBR)		
Subtotal Labor					302400	
TOTAL LABOR						302400

EQUIPMENT

	Hours	Rate	Amount		
Site vehicle	2240	10	22400		
Generator, 10 kw	2240	10	22400		
Subtotal Equipment				44800	
TOTAL EQUIPMENT					44800

MATERIALS	Qty. Unit	Unit Cost	Amount	
Misc parts	L.S.	L.S.	10000	
TOTAL MATERIALS				10000

TOTAL ANNUAL OP & MAINT COST	347200

8/22/96
TRS

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING
TEST PKG #2. SURFACE BASED TESTING PACKAGE--HIGHEST COST

PART 2A(2) PLANNING (15 Holes)		
LABOR	145200	
EQUIPMENT	3300	
MATERIALS	72600	
TOTAL COST		221100
PART 2B(2) DRILLING; NO CORE SAMPLES (15 Holes)		
LABOR	1477594	
EQUIPMENT	2090121	
MATERIALS	388800	
TOTAL COST		3956516
PART 2C(2) GEOPHYSICAL LOGGING (15 Holes)		
LABOR	288288	
EQUIPMENT	10296	
MATERIALS	171600	
SUBCONTRACTS	845580	
SUBCONTRACT ADMIN	84558	
TOTAL COST		1400322
PART 2D(2) DRILLING & LOGGING INSPECTION & SAMPLING (15 Holes)		
LABOR	1247589	
EQUIPMENT	155949	
MATERIALS	96000	
TOTAL COST		1499537
PART 2C(2) INSTALL SEAMIST INSTRUMENTATION (15 Holes)		
LABOR	198000	
EQUIPMENT	57600	
MATERIALS	513000	
TOTAL COST		768600

SUBTOTAL	7624975
M&O CONTRACTOR MGMT/ADMIN @ 30%	2287492
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN	1486870
TOTAL COST, FY96 DOLLARS	11399337

PART 2F(2) MONITOR, OPERATE & MAINT INSTRUM & DAS (Annual, 15 Holes)		
LABOR	907200	
EQUIPMENT	134400	
MATERIALS	30000	
SUBTOTAL		1071600
M&O CONTRACTOR MGMT/ADMIN @ 30%		321480
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN		208962
TOTAL ANNUAL COST, FY96 DOLLARS		1602042

F.1.1.3 Underground Fault Zone Hydrology Package

This package was assumed to begin in the year 1998 with the start of the performance confirmation program following the viability assessment. It would extend for 111 years until the year 2109. The costs for the nominal and enhanced cases are documented in the following pages.

PRELIMINARY COST ESTIMATE FOR TEST PACKAGE #3: UNDERGROUND FAULT ZONE HYDROLOGIC INSTRUMENTATION & TESTING

The estimated cost of the assumed underground borehole instrumentation and testing program is approximately $7 million for the lowest cost program, and approximately $28 million for the highest cost program, plus an annual monitoring, repeat testing, and maintenance cost of approximately $0.3 million for the lowest cost program, and approximately $1.4 million for the highest cost program (FY96 dollars). Each estimate is organized as follows:

- Summary
- Part 3A Planning
- Part 3B Drilling for Core Samples & Test Holes
- Part 3C Drilling Inspection & Core Sampling
- Part 3D Instrumentation & Initial Testing
- Part 3E Monitoring, Maintenance, & Repeat Testing

Key estimating assumptions used as a basis for the cost estimates include the following:

- The number of underground fault zone testing sites ranges from one to four, corresponding to the lowest and highest cost instrumentation and testing programs.

- Each testing site has one 100 ft "geothermal" borehole and seven 50 ft boreholes. No existing boreholes will be used.*

- Each testing site has the same drilling and testing plan, assumed as follows*:

  - Drill the 100 ft borehole ahead of alcove excavation.
  - Complete initial testing in the 100 ft borehole.
  - Drill the 50 ft boreholes.
  - Complete initial testing in the 50 ft boreholes.
  - Repeat testing in the 50 ft boreholes at a frequency of one time per 5 years.

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* Note that the cost estimate may be decreased as follows for incorporation into the main body of the report:

- Subtract subtotals for Parts 3B through 3D for the lowest cost program, due to the fact that the existing S Ghost Dance Fault alcove may be used.

- Subtract one half of the subtotals for Parts 3B through 3D for the highest cost program, due to the fact that the N and S Ghost Dance Fault alcoves may be used.

- For the lowest cost instrumentation and testing program, the estimated total duration of instrumentation and initial testing is 1350 shifts. The estimated crew size for instrumentation and initial testing is 2 full time geologists, 2 full time technicians, 1 part time instrumentation consultant, and 2 part time construction personnel per shift.

- The estimated duration for data analysis and report preparation is approximately 160 shifts for initial testing and approximately 60 shifts for repeat testing.

- Estimated labor rates are based on FY96 rates for M&O geologists and for Kiewit construction personnel.

- Alcove construction costs are not included.

- Project management is assumed to be performed by an M&O Contractor, with cost and markup roughly estimated as percentages of the total costs of other activities. (Refer to attached estimates for details.)

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING

8/2/96
TRS

TEST PKG #3. UNDERGROUND FAULT ZONE HYDROLOGY--LOWEST COST

PART 3A(1) PLANNING (1 Fault Zone Site)			
LABOR			
EQUIPMENT	63360		
MATERIALS	990		
TOTAL COST	24200		
			88550
PART 3B(1) DRILLING FOR CORE SAMPLES & TEST HOLES (1 Fault Zone Site)			
LABOR			
EQUIPMENT	32159		
MATERIALS	24180		
TOTAL COST	14400		
			70739
PART 3C(1) DRILLING INSPECTION & CORE SAMPLING (1 Fault Zone Site)			
LABOR			
EQUIPMENT	43648		
MATERIALS	5456		
TOTAL COST	29700		
			78804
PART 3D(1) INSTRUMENTATION & INITIAL TESTING (1 Fault Zone Site)			
LABOR--TECHNICAL			
LABOR--CONSTRUCTION SUPPORT	3056351		
EQUIPMENT	123616		
MATERIALS	356190		
SUBTOTAL	195415		
CONTINGENCY @ 20%		3731572	
TOTAL COST, FY96 DOLLARS		746314	
			4477887
SUBTOTAL			
M&O CONTRACTOR MGMT/ADMIN @ 30%			4715980
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			1414794
TOTAL COST, FY96 DOLLARS			919616
			7050390 (7 M)

PART 3E(1) MONITORING, MAINT, & ANNUAL REPEAT TESTING (1 Fault Zone Site)			
LABOR--TECHNICAL			
LABOR--CONSTRUCTION SUPPORT	255552		
EQUIPMENT	0		
MATERIALS	21296		
SUBTOTAL	11000		
CONTINGENCY @ 20%			287848
M&O CONTRACTOR MGMT/ADMIN @ 30%			57570
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			86354
TOTAL ANNUAL COST, FY96 DOLLARS			56130
			345418 (0.3 M)

PRELIMINARY COST ESTIMATE: 7/26/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3A(1) PLANNING (1 Fault Zone Site)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Testing Sites:	1			
Planning for Drilling & Testing:		30 shifts		
state permits FWP, DIE assistance, Work Program coord & scheduling for underground work				
Planning for Instrumentation:		15 shifts		
FWP, DIE assistance, Work Program coordination				
TOTAL EST. DURATION:		45 shifts =	360	hr

ESTIMATED CREW SIZE
1 Supervising Geol/Engr, 1 Project Geol/Engr, 1 Staff Geol/Engr, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	360		100	36000		
Proj Geol	360		60	21600		
Staff Geol	360		40	14400		
Clerk	360		30	10800		
Subtotal Labor					57600	
G&A + Profit @ 10%					5760	
TOTAL LABOR						63360

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (1)	90	10	900		
Subtotal Equipment				900	
G&A + Profit @ 10%				90	
TOTAL EQUIPMENT					990

MATERIALS	Qty.	Unit	Unit Cost	Amount		
Office Equip	L.S.		L.S.	20000		
Office Supplies	L.S.		L.S.	2000		
Subtotal Materials					22000	
G&A + Profit @ 10%					2200	
TOTAL MATERIALS						24200

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 88550

PRELIMINARY COST ESTIMATE: 7/26/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3B(1) DRILLING FOR CORE SAMPLES & TEST HOLES (1 Fault Zone Site)
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Testing Sites:			1						
Est No. & Depth of Boreholes per Site:									
	1	hole @	100	ft =			100	ft	
	7	holes @	50	ft =			350	ft	
Totals	8	holes @	150	ft =			450	ft	
Mob Drilling Equip, Prep Work Area					5	shifts			
Move & Set Up Drill betw Holes					8	shifts			
Core Drilling	30	ft/sh			15	shifts			actual avg. drilling rate
Demob & Cleanup					3	shifts			
TOTAL DURATION					31	shifts =	248	hr	

ESTIMATED CREW SIZE
Full time: 1 driller, 1 driller's helper
Part time: 1 mech/op, 1 electrician

LABOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Driller	248	23		5704		
Drlr Helper	248	20		4960		
Mech/Op	124	22		2728		
Electrician	124	25		3100		
Subtotal Labor					16492	
Fringes, Taxes, & Ins @ 50% of Base Labor					8246	
G&A + Profit @ 30% of Burdened Labor					7421	
TOTAL LABOR						32159

EQUIPMENT	Hours	Rate	Amount		
Drill & specialized equip	248	60	14880		
Loader/Fork Lift	124	30	3720		
Subtotal Equipment				18600	
Utilities, G&A, + Profit @ 30%				5580	
TOTAL EQUIPMENT					24180

MATERIALS	Qty	Unit	Unit Cost	Amount		
Drill bits	2	ea	2000	4000		
Drill pipe	100	LF	20	2000		
Air Hose	1000	LF	5	5000		
Misc Tools & Parts	L.S.		L.S.	1000		
Subtotal Materials					12000	
G&A + Profit @ 20%					2400	
TOTAL MATERIALS						14400

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 70739

PRELIMINARY COST ESTIMATE: 7/26/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3C(1) DRILLING INSPECTION & CORE SAMPLING (1 Fault Zone Site)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Testing Sites: 1

Drilling & Logging Inspection, incl Repts, Collect, Seal, Tag, Haul, & Store Core Samples	31	shifts	drilling duration	
TOTAL EST DURATION:	31	shifts =	248	hr

ESTIMATED CREW SIZE

1 Supervising Geol/Engr, 1 Project Geol/Engr, 1 Staff Geol/Engr, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	248		100	24800		
Proj Geol	248		60	14880		
Staff Geol	248		40	9920		
Clerk	248		30	7440		
Subtotal Labor					39680	
G&A + Profit @ 10%					3968	
TOTAL LABOR						43648

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	248	20	4960		
Subtotal Equipment				4960	
G&A + Profit @ 10%				496	
TOTAL EQUIPMENT					5456

MATERIALS	Qty.	Unit	Unit Cost	Amount		
Office Equip	L.S.		L.S.	20000		
Office Supplies	L.S.		L.S.	2000		
Core sealing matls	L.S.		L.S.	5000		
Subtotal Materials					27000	
G&A + Profit @ 10%					2700	
TOTAL MATERIALS						29700

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 78804

7/26/96
TRS

PRELIMINARY COST ESTIMATE:
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION

ART 3D(1) INSTRUMENTATION & INITIAL TESTING (1 Existing Fault Zone Site)
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Testing Sites:		1	
Est. No. of Boreholes per Site:		8	
Total depth of boreholes		450 ft	
Est dist from Alcove #6 to PC at N Portal:	5000 m =	16393 ft	

Unpack & inventory instrum & testing equip	16 shifts	
Mob (move instrum & equip to site), Demob	10 shifts	
Install SEAMISTs & cable to multiplexers	24 shifts	
Install multiplexers, datalogger, & accessories	10 shifts	
Lay cable, datalogger to PC at N Portal	33 shifts	500 ft/sh
Set up & program PC		
Test & debug instrum & DAS	16 shifts	
Testing in 100 ft borehole:		
Temp logging	45 shifts	Ltr Statton to Williams
Geophys logging	45 shifts	2/22/96; assume
Pressure monitoring	60 shifts	3 sh/day
Gas sampling	30 shifts	
Air-k testing	60 shifts	
esting in 7 x 50 ft boreholes:		
Temp logging	158 shifts	Assume test durations
Geophys logging	158 shifts	proportional to
Pressure monitoring	210 shifts	borehole depth
Gas sampling	105 shifts	
Air-k testing	210 shifts	
Data anlysis & report	160 shifts	
TOTAL EST DURATION:	1349 shifts =	10790

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol/Engr, 1 Project Geol/Engr, 2 Techs
Part time: 1 Consult (SEAMIST), 1 mech/op, 1 electrician

LABOR--TECHNICAL	Manhours	Base Rate	Burdened Rate	Amount	
Sup Geol	10790		100	1079030	
Proj Geol	10790		60	647418	
Tech	21581		40	863224	
Consult	2698		70	188830	
Subtotal Labor					2778501
G&A + Profit @ 10%					277850
TOTAL LABOR--TECHNICAL					

PRELIMINARY COST ESTIMATE: 7/29/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3D(1) INSTRUMENTATION & INITIAL TESTING (1 Existing Fault Zone Site)(cont)

LABOR--CONSTRUCTION SUPPOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Mech/Op	1349	22		29673		
Electrician	1349	25		33720		
Subtotal Labor					63393	
Fringes, Taxes, & Ins @ 50% of Base Labor					31696	
G&A + Profit @ 30% of Burdened Labor					28527	
TOTAL LABOR--CONSTRUCTION SUPPORT						123616

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	10790	20	215806		
Loco & mancars	1349	50	67439		
Fork lift/loader	1349	30	40464		
Subtotal Equipment				323809	
G&A + Profit @ 10%				32381	
TOTAL EQUIPMENT					356190

MATERIALS	Qty	Unit	Unit Cost	Amount			
Gas pressure instrum	8	ea	10000	80000	Est		
Gas sampling equip	L.S.		L.S.	2000	Est		
Moisture cont instrum	8	ea	500	4000	Est		
Thermocouple psychrom(	40	ea	80	3200	Purchase requisitions		
Borehole liner system	8	ea	8300	66400	Purchase requisitions		
Air mass flow controller	1	ea	1500	1500	Purchase requisitions		
Datalogger & software	1	ea	1500	1500	Campbell Sci quote		
Datalogger accessories	L.S.		L.S.	1000	Campbell Sci quote		
Enclosure	1	ea	3000	3000	Campbell Sci quote		
Power supply(incl backu}	2	ea	300	600	Campbell Sci quote		
Multiplexers	16	ea	500	8000	Campbell Sci quote		
Cable, datalogger to PC at N Portal	450	ft	1	450	Est		
Cable, instrum to multiplexers	1000	ft	1	1000	Est		
Misc tools	L.S.		L.S.	5000	Est		
Subtotal Materials						177650	
G&A + Profit @ 10%						17765	
TOTAL MATERIALS							195415

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 3731572

PRELIMINARY COST ESTIMATE: 8/2/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3E(1) MONITORING, MAINT, & REPEAT TESTING (1 Fault Zone Site)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Testing Sites:	1	
Est. No. of Boreholes per Site:	8	
Long Term Monitoring (durations per yr):		
Ck, calibrate, & maint instrum & DAS (power supply, datalogger, shelter, cable)	48 shifts	Est 0.5 sh/hole, monthly
Download long term data (monthly)	12 shifts	Est 1 sh/mo
Repeat Testing in 7 x 50 ft boreholes (durations per yr):		
Geophys logging	9 shifts	Assume same durations
Air-k testing	12 shifts	as initial testing, every 5 yr
Review & analyze data; quarterly reports	40 shifts	Est 10 sh per rept, quarterly
TOTAL EST DURATION:	121 shifts =	968 hr

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol/Engr, 1 Project Geol/Engr, 2 Techs

LABOR--TECHNICAL	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	968		100	96800		
Proj Geol	968		60	58080		
Tech	1936		40	77440		
Subtotal Labor					232320	
G&A + Profit @ 10%					23232	
TOTAL LABOR--TECHNICAL						255552

PRELIMINARY COST ESTIMATE: 7/26/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 3E(1) MONITORING, MAINT, & REPEAT TESTING (1 Fault Zone Site)(cont)

LABOR--CONSTRUCTION SUPPOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Mech/Op	0	22		0		
Electrician	0	25		0		
Subtotal Labor					0	
Fringes, Taxes, & Ins @ 50% of Base Labor					0	
G&A + Profit @ 30% of Burdened Labor					0	
TOTAL LABOR--CONSTRUCTION SUPPORT						0

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	7680	20	153600		
Loco & mancars	960	50	48000		
Fork lift/loader	960	30	28800		
Subtotal Equipment				153600	
G&A + Profit @ 10%				15360	
TOTAL EQUIPMENT					168960

MATERIALS	Qty	Unit	Unit Cost	Amount			
Misc tools & parts	L.S.		L.S.	10000	Est		
Subtotal Materials						10000	
G&A + Profit @ 10%						1000	
TOTAL MATERIALS							11000

TOTAL ANNUAL COST (LABOR, EQUIPMENT, MATERIALS) 2207480

8/22/96

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING

TEST PKG #3. UNDERGROUND FAULT ZONE HYDROLOGY--HIGHEST COST

PART 3A(2) PLANNING (4 Fault Zone Sites)

LABOR	253440		
EQUIPMENT	3960		
MATERIALS	96800		
TOTAL COST			354200

PART 3B(2) DRILLING FOR CORE SAMPLES & TEST HOLES (4 Fault Zone Sites)

LABOR	128638		
EQUIPMENT	96720		
MATERIALS	57600		
TOTAL COST			282958

PART 3C(2) DRILLING INSPECTION & CORE SAMPLING (4 Fault Zone Sites)

LABOR	174592		
EQUIPMENT	21824		
MATERIALS	118800		
TOTAL COST			315216

PART 3D(2) INSTRUMENTATION & INITIAL TESTING (4 Fault Zone Sites)

LABOR--TECHNICAL	12225404		
LABOR--CONSTRUCTION SUPPORT	494465		
EQUIPMENT	1424759		
MATERIALS	781660		
SUBTOTAL		14926289	
CONTINGENCY @ 20%		2985258	
TOTAL COST			17911546

SUBTOTAL	18863920
M&O CONTRACTOR MGMT/ADMIN @ 30%	5659176
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN	3678464
TOTAL COST, FY96 DOLLARS	28201560

PART 3E(2) MONITORING, MAINT, & ANNUAL REPEAT TESTING (4 Fault Zone Sites)

LABOR--TECHNICAL	1022208	
LABOR--CONSTRUCTION SUPPORT	0	
EQUIPMENT	85184	
MATERIALS	44000	
SUBTOTAL		1151392
CONTINGENCY @ 20%		230278
M&O CONTRACTOR MGMT/ADMIN @ 30%		345418
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN		224521
TOTAL ANNUAL COST, FY96 DOLLARS		1381670

F.1.1.4 Thermal Testing Package

This package was assumed to begin in the year 2009 with the construction of the first observation drift. It would extend for 100 years until the year 2109. The costs for the nominal and enhanced cases are documented in the following pages.

PRELIMINARY COST ESTIMATE FOR TEST PACKAGE #4A: THERMAL INSTRUMENTATION & TESTING WITH BOREHOLES IN OBSERVATION DRIFTS ABOVE WASTE EMPLACEMENT DRIFTS

The estimated cost of the assumed underground borehole instrumentation and testing program is approximately $9 million for the lowest cost program, and approximately $88 million for the highest cost program, plus an annual monitoring, repeat testing, and maintenance cost of approximately $1 million for the lowest cost program, and approximately $7 million for the highest cost program (FY96 dollars). Each estimate is organized as follows:

- Summary
- Part 4A Planning
- Part 4B Drilling for Core Samples & Test Holes
- Part 4C Drilling Inspection & Core Sampling
- Part 4D Instrumentation & Initial Testing
- Part 4E Monitoring, Maintenance, & Repeat Testing

Key estimating assumptions used as a basis for the cost estimates include the following:

- All borehole instrumentation is required to be retrievable and physically accessible by repository personnel. (It is assumed that no instrumentation within waste emplacement drifts is allowed.) Therefore, all drilling and borehole instrumentation is implemented within observation drifts located approximately 17 m (vertical distance between centerlines) above the waste emplacement drifts.

- The number of observation drifts ranges from one to six, corresponding to the lowest and highest cost instrumentation and testing programs.

- The number of instrumented waste emplacement drifts ranges from three to eighteen, corresponding to the lowest and highest cost instrumentation and testing programs.

- The number of instrumentation stations within each observation drift ranges from ten to seventeen, corresponding to the lowest and highest cost instrumentation and testing programs.

- The number of boreholes at each station along the observation drift(s) is 11.

- The number of each type of instrumentation borehole within each observation drift is based roughly on the current design of the Drift Scale Thermal Test, planned for FY97. (Refer to CRWMS M&O, 1996, Test Design, Plans, and Layout for the First ESF Thermal Test, Rev. 1, June 1996.)

- Each observation drift has the same drilling, instrumentation, and testing plan, assumed as follows:

  - Complete drilling after completion of observation drift and emplacement drift excavation.

  - Complete initial testing in selected boreholes.

  - Complete installation of instruments in all boreholes.

  - Repeat testing and water sampling at a frequency of one time per 5 years.

- For the lowest cost testing program, the estimated total duration of initial testing is 138 shifts, and the estimated total duration of repeat testing is 10 shifts at 5 year intervals. The estimated crew size for instrumentation and initial testing is 2 full time geologists/engineers, 2 full time technicians, 1 part time instrumentation consultant, and 2 part time construction personnel per shift. The estimated crew size for monitoring and repeat testing is 2 full time geologists/engineers and 2 full time technicians per shift.

- For the lowest cost testing program, the estimated duration for data analysis and report preparation is 138 shifts for initial testing and 44 shifts per year for repeat testing.

- Estimated labor rates are based on FY96 rates for M&O geologists and for Kiewit construction personnel.

- Alcove construction costs are not included.

- Cable tray installation cost are not included.

- Laboratory testing costs are not included.

- Project management is assumed to be performed by an M&O Contractor, with cost and markup roughly estimated as percentages of the total costs of other activities. (Refer to attached estimates for details.)

SUMMARY OF PRELIMINARY COST ESTIMATE FOR REPOSITORY PERFORMANCE CONFIRMATION TESTING

~~7/31/96~~
TRS

TEST PKG #4A. IN SITU THERMAL TESTING--LOWEST COST

PART 4A(1) PLANNING (1 Obs Drift, 3 Waste Drifts)			
LABOR	119680		
EQUIPMENT	1760		
MATERIALS	24200		
TOTAL COST			145640
PART 4B(1) DRILLING FOR CORE SAMPLES & TEST HOLES (1 Obs Drift, 3 Waste Drifts)			
LABOR	347529		
EQUIPMENT	261300		
MATERIALS	36000		
TOTAL COST			644829
PART 4C(1) DRILLING INSPECTION & CORE SAMPLING (1 Obs Drift, 3 Waste Drifts)			
LABOR	471680		
EQUIPMENT	58960		
MATERIALS	29700		
TOTAL COST			560340
PART 4D(1) INSTRUMENTATION & INITIAL TESTING (1 Obs Drift, 3 Waste Drifts)			
LABOR--TECHNICAL	2038032		
LABOR--CONSTRUCTION SUPPORT	77184		
EQUIPMENT	222441		
MATERIALS	1448541		
SUBTOTAL		3786197	
CONTINGENCY @ 20%		757239	
TOTAL COST, FY96 DOLLARS			4543437
SUBTOTAL			5894246
M&O CONTRACTOR MGMT/ADMIN @ 30%			1768274
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			1149378
TOTAL COST, FY96 DOLLARS			8811897 (9 M)
PART 4E(1) MONITORING, MAINT, & ANNUAL REPEAT TESTING (1 Obs Drift, 3 Waste Drifts)			
LABOR--TECHNICAL	425990		
LABOR--CONSTRUCTION SUPPORT	0		
EQUIPMENT	35499		
MATERIALS	110000		
SUBTOTAL			571490
CONTINGENCY @ 20%			114298
M&O CONTRACTOR MGMT/ADMIN @ 30%			171447
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN			111440
TOTAL ANNUAL COST, FY96 DOLLARS			685788 (1 M)

PRELIMINARY COST ESTIMATE:
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION

7/31/96
TRS

DRILLING QUANTITIES (1 Obs Drift, 3 Waste Drifts)

Est No. of Obs Drifts:	1	
Est Total No. Stations:	10	
Est Total Hole Depth per Sta:	930	ft
Est Total Hole Depth:	9300	ft
Est Total No. Holes:	110	

EST BREAKDOWN OF BOREHOLE INSTRUM QUANTITIES:

Sta Type	Hole Type	Holes per Sta	No. Stations	No. of Each Hole Type per Obs Drift	Total No. of Each Hole Type
A	MPBX	5	3	15	15
	Temp	6		18	18
B	RH/Press	4	3	12	12
	Temp	2		6	6
	MPBX	3		9	9
	Open (Neutron Log/Air-k Borehole Camera)	2		6	6
C	ERT	7	3	21	21
	Temp	4		12	12
D	Chem	11	1	11	11
TOTALS			10	110	110
			Total MPBX Holes:	24	24
			Total Temp Holes:	36	36

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 4A(1) PLANNING (1 Obs Drift, 3 Waste Drifts)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Obs Drifts:	1			
Planning for Drilling & Testing:		50 shifts		
state permits				
FWP, DIE assistance, Work Program				
coord & scheduling for underground work				
Planning for Instrumentation:		30 shifts		
FWP, DIE assistance, Work Program				
coordination				
TOTAL EST. DURATION:		80 shifts =	640	hr

ESTIMATED CREW SIZE
1 Supervising Engr, 1 Project Engr, 1 Staff Engr, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup Engr	640		100	64000		
Proj Engr	640		70	44800		
Staff Engr	640		45	28800		
Clerk	640		30	19200		
Subtotal Labor					108800	
G&A + Profit @ 10%					10880	
TOTAL LABOR						119680

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (1)	160	10	1600		
Subtotal Equipment				1600	
G&A + Profit @ 10%				160	
TOTAL EQUIPMENT					1760

MATERIALS	Qty.	Unit	Unit Cost	Amount		
Office Equip	L.S.		L.S.	20000		
Office Supplies	L.S.		L.S.	2000		
Subtotal Materials					22000	
G&A + Profit @ 10%					2200	
TOTAL MATERIALS						24200

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 145640

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 4B(1) DRILLING FOR CORE SAMPLES & TEST HOLES (1 Obs Drift, 3 Waste Drifts)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Mob Drilling Equip, Prep Work Area			10	shifts		
Move & Set Up Drill betw Stations			10	shifts		
Core Drilling	30	ft/sh	310	shifts	Actual avg drilling rate	
Demob & Cleanup			5	shifts		
TOTAL DURATION			335	shifts =	2680	hr

ESTIMATED CREW SIZE
Full time: 1 driller, 1 driller's helper
Part time: 1 mech/op, 1 electrician

LABOR	Manhours	Base Rate	Burdened Rate	Base Amount		
Driller	2680	23		61640		
Drlr Helper	2680	20		53600		
Mech/Op	1340	22		29480		
Electrician	1340	25		33500		
Subtotal Labor					178220	
Fringes, Taxes, & Ins @ 50% of Base Labor					89110	
G&A + Profit @ 30% of Burdened Labor					80199	
TOTAL LABOR						347529

EQUIPMENT	Hours	Rate	Amount		
Drill & specialized equip	2680	60	160800		
Loader/Fork Lift	1340	30	40200		
Subtotal Equipment				201000	
Utilities, G&A, + Profit @ 30%				60300	
TOTAL EQUIPMENT					261300

MATERIALS	Qty	Unit	Unit Cost	Amount		
Drill bits	10	ea	2000	20000		
Drill pipe	200	LF	20	4000		
Air Hose	1000	LF	5	5000		
Misc Tools & Parts	L.S.		L.S.	1000		
Subtotal Materials					30000	
G&A + Profit @ 20%					6000	
TOTAL MATERIALS						36000

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 644829

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 4C(1) DRILLING INSPECTION & CORE SAMPLING (1 Obs Drift, 3 Waste Drifts)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Drilling & Logging Inspection, incl Repts,	335 shifts	drilling duration	
Collect, Seal, Tag, Haul, & Store Core Samples			
TOTAL EST DURATION:	335 shifts =	2680	hr

ESTIMATED CREW SIZE
1 Supervising Geol/Engr, 1 Project Geol/Engr, 1 Staff Geol/Engr, 1 Clerk

LABOR	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	2680		100	268000		
Proj Geol	2680		60	160800		
Staff Geol	2680		40	107200		
Clerk	2680		30	80400		
Subtotal Labor					428800	
G&A + Profit @ 10%					42880	
TOTAL LABOR						471680

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	2680	20	53600		
Subtotal Equipment				53600	
G&A + Profit @ 10%				5360	
TOTAL EQUIPMENT					58960

MATERIALS	Qty.	Unit	Unit Cost	Amount		
Office Equip	L.S.		L.S.	20000		
Office Supplies	L.S.		L.S.	2000		
Core sealing matls	L.S.		L.S.	5000		
Subtotal Materials					27000	
G&A + Profit @ 10%					2700	
TOTAL MATERIALS						29700

TOTAL COST (LABOR, EQUIPMENT, MATERIALS) 560340

PART 4D(1) INSTRUMENTATION & INITIAL TESTING (1 Obs Drift, 3 Waste Drifts)
SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Obs Drifts:		1	
Est No. of Holes per Obs Drift:		110	
Est No. MPBXs (10 channels ea):		24	240 channels
Est No. Other Instrum:		1720	3440 channels
(2 channels ea, 20 instrum/hole)			
Est. No. of Multiplexers:		115	3680 channels
Est. No. of Dataloggers:		29	
Est dist from Obs Drift			
to PC at N Portal:	5000 m =	16393 ft	

Unpack & inventory instrum, prep wiring sketch	60 shifts	Est 0.5 sh/hole + 5 sh	
Mob (move instrum & equip to site), Demob	10 shifts		
Install instrum & cable to multiplexers	220 shifts	Est 2sh/hole	
Install cable betw dataloggers	14 shifts	Est 0.5 sh/unit	
Install dataloggers, multiplexers, & accessories	58 shifts	Est 2 sh/unit	
Install cable, datalogger to PC at N Portal	33 shifts	Est 500 ft/sh	
Set up & program dataloggers & PC	63 shifts	Est 2 sh/unit + 5 sh	
Test & debug instrum & DAS	110 shifts	Est 1sh/hole	
Testing:	138 shifts	Assume testing 25% of total holes; est 5 sh/hole	
Temp logging			
Geophys logging			
Pressure monitoring			
Gas sampling			
Air-k testing			
Data analysis & report	138 shifts		
TOTAL EST DURATION:	842 shifts =		6737 hr

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol/Engr, 1 Project Geol/Engr, 2 Techs
Part time: 1 Consult (instrum mfr), 1 mech/op, 1 electrician

LABOR--TECHNICAL	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	6737		100	673730		
Proj Geol	6737		60	404238		
Tech	13475		40	538984		
Consult	3369		70	235805		
Subtotal Labor					1852756	
G&A + Profit @ 10%					185276	
TOTAL LABOR--TECHNICAL						2038032

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 4D(1) INSTRUMENTATION & INITIAL TESTING (1 Obs Drift, 3 Waste Drifts)

LABOR--CONSTRUCTION SUPPORT	Manhours	Base Rate	Burdened Rate	Base Amount		
Mech/Op	842	22		18528		
Electrician	842	25		21054		
Subtotal Labor					39582	
Fringes, Taxes, & Ins @ 50% of Base Labor					19791	
G&A + Profit @ 30% of Burdened Labor					17812	
TOTAL LABOR--CONSTRUCTION SUPPORT						77184

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	6737	20	134746		
Loco & mancars	842	50	42103		
Fork lift/loader	842	30	25265		
Subtotal Equipment				202219	
G&A + Profit @ 10%				20222	
TOTAL EQUIPMENT					222441

MATERIALS	Qty Unit	Unit Cost	Amount			
MPBXs, 30m, LVDT	24 ea	25000	600000			
Thermocouple probes	36 ea	6000	216000	Purchase requisitions		
Gas pressure transducer	12 ea	1000	12000	Purchase requisitions		
Gas sampling equip	L.S.	L.S.	2000	Est		
Thermocouple psychromet	11 ea	80	880	Purchase requisitions		
Humicaps	11 ea	1600	17600	Purchase requisitions		
Humidity probe	11 ea	800	8800	Purchase requisitions		
Borehole liner system	11 ea	8300	91300	Purchase requisitions		
Air mass flow controller	3 ea	1500	4500	Purchase requisitions		
Datalogger & software	29 ea	1500	43125	Campbell Sci quote		
Datalogger accessories	29 ea	1000	28750	Campbell Sci quote		
Enclosure	29 ea	3000	86250	Campbell Sci quote		
Power supply(incl backup)	35 ea	300	10350	Campbell Sci quote		
Multiplexers	115 ea	500	57500	Campbell Sci quote		
Cable, datalogger to PC at N Portal	5000 m	1	5000	Est		
Cable, instrum to multiplexers	22000 ft	1	22000	Est; incl downhole cable		
Cable betw dataloggers	800 m	1	800	Est		
Neutron probe	2 ea	5000	10000			
Misc tools & matls	L.S.	L.S.	100000	Est		
Subtotal Materials					1316855	
G&A + Profit @ 10%					131686	
TOTAL MATERIALS						1448541

TOTAL COST (LABOR, EQUIPMENT, MATERIALS)	3786197

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

PART 4E(1) MONITORING, MAINT, & ANNUAL REPEAT TESTING (1 Obs Drift, 3 Waste Drifts)

SUMMARY OF WORK SCOPE & ESTIMATED DURATIONS:

Est No. of Obs Drifts:	1		
Est No. of Holes per Obs Drift:	110		
Long Term Monitoring (durations per yr):			
Ck, calibrate, & maint instrum & DAS (power supply, datalogger, shelter, cable)		88 shifts	Est 0.2 sh/hole, quarterly
Download long term data (monthly)		44 shifts	Est 0.1 sh/hole, quarterly
Repeat Testing (durations per yr):			
Moisture content (neutron log), water sampling		2 shifts	Est 0.5 sh/hole, 5 yr interval
Air-k testing		24 shifts	20 sh/open hole, 5 yr interval
Review & analyze data; quarterly reports		44 shifts	Est 0.1sh/hole, quarterly
TOTAL EST DURATION:		202 shifts =	1614 hr

ESTIMATED CREW SIZE
Full time: 1 Supervising Geol/Engr, 1 Project Geol/Engr, 2 Techs

LABOR--TECHNICAL	Manhours	Base Rate	Burdened Rate	Amount		
Sup Geol	1614		100	161360		
Proj Geol	1614		60	96816		
Tech	3227		40	129088		
Subtotal Labor					387264	
G&A + Profit @ 10%					38726	
TOTAL LABOR--TECHNICAL						425990

8/2/96
~~7/31/96~~
TRS

PRELIMINARY COST ESTIMATE:
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION

PART 3E(1) MONITORING, MAINT, & REPEAT TESTING (1Obs Drift, 3 Waste Drifts)(cont)

LABOR--CONSTRUCTION SUPPORT	Manhours	Base Rate	Burdened Rate	Base Amount		
Mech/Op	0	22		0		
Electrician	0	25		0		
Subtotal Labor					0	
Fringes, Taxes, & Ins @ 50% of Base Labor					0	
G&A + Profit @ 30% of Burdened Labor					0	
TOTAL LABOR--CONSTRUCTION SUPPORT						0

EQUIPMENT	Hours	Rate	Amount		
Site vehicles (2)	5595	20	111904		
Loco & mancars	0	50	0		
Fork lift/loader	0	30	0		
Subtotal Equipment				111904	
G&A + Profit @ 10%				11190	
TOTAL EQUIPMENT					123094

MATERIALS	Qty Unit	Unit Cost	Amount		
Misc tools & parts	L.S.	L.S.	100000 Est		
ubtotal Materials				100000	
G&A + Profit @ 10%				10000	
TOTAL MATERIALS					110000

8/2/96
~~7/31/96~~
TRS

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING

TEST PKG #4A. IN SITU THERMAL TESTING--HIGHEST COST

PART 4A(2) PLANNING (6 Obs Drifts, 18 Waste Drifts)			
LABOR	1196800		
EQUIPMENT	17600		
MATERIALS	242000		
TOTAL COST			1456400
PART 4B(2) DRILLING FOR CORE SAMPLES & TEST HOLES (6 Obs Drift, 18 Waste Drifts)			
LABOR	3475290		
EQUIPMENT	2613000		
MATERIALS	360000		
TOTAL COST			6448290
PART 4C(2) DRILLING INSPECTION & CORE SAMPLING (6 Obs Drift, 18 Waste Drifts)			
LABOR	4716800		
EQUIPMENT	589600		
MATERIALS	297000		
TOTAL COST			5603400
PART 4D(2) INSTRUMENTATION & INITIAL TESTING (6 Obs Drift, 18 Waste Drifts)			
LABOR--TECHNICAL	20380318		
LABOR--CONSTRUCTION SUPPORT	771841		
EQUIPMENT	2224407		
MATERIALS	14485405		
SUBTOTAL		37861971	
CONTINGENCY @ 20%		7572394	
TOTAL COST			45434366

SUBTOTAL	58942456	
M&O CONTRACTOR MGMT/ADMIN @ 30%	17682737	
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN	11493779	
TOTAL COST, FY96 DOLLARS	88118971	(88 M)

PART 4E(2) MONITORING, MAINT, & ANNUAL REPEAT TESTING (6 Obs Drift, 18 Waste Drifts)			
LABOR--TECHNICAL	4259904		
LABOR--CONSTRUCTION SUPPORT	0		
EQUIPMENT	354992		
MATERIALS	1100000		
SUBTOTAL		5714896	
CONTINGENCY @ 20%		1142979	
M&O CONTRACTOR MGMT/ADMIN @ 30%		1714469	
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN		1114405	
TOTAL ANNUAL COST, FY96 DOLLARS		6857875	(7 M)

PRELIMINARY COST ESTIMATE: 7/31/96
UNDERGROUND DRILLING, TESTING, & INSTRUMENTATION TRS

DRILLING QUANTITIES (6 Obs Drifts, 18 Waste Drifts)

Est No. of Obs Drifts:	6	
Est Total No. Stations:	102	
Est Total Hole Depth per Sta:	930	ft
Est Total Hole Depth:	94860	ft
Est Total No. Holes:	1122	

Multiplication factor for increased cost, to be applied to lowest cost estimate:
10

EST BREAKDOWN OF BOREHOLE INSTRUM QUANTITIES:

Sta Type	Hole Type	Holes per Sta	No. Stations	No. of Each Hole Type per Obs Drift	Total No. of Each Hole Type
A	MPBX	5	5	25	150
	Temp	6		30	180
B	RH/Press	4	5	20	120
	Temp	2		10	60
	MPBX	3		15	90
	Open (Neutron Log/Air-k Borehole Camera)	2		10	60
C	ERT	7	5	35	210
	Temp	4		20	120
D	Chem	11	2	22	132
TOTALS			17	187	1122
	Total MPBXs		Total MPBX Holes:	40	240
	Total Temp		Total Temp Holes:	60	360

F.1.2 Repository Performance Confirmation Monitoring and Testing Concepts

Additional cost estimating detail will be provided for repository testing packages: Follow-on Drift Heater Testing, Seismic Monitoring, Remote Observation and Inspection of Emplacement Drifts. No cost estimates were developed for either the backfill or seals testing.

F.1.2.1 Follow-on Drift Heater Test

This package was assumed to begin in the year 2004 with the construction of the boreholes. It would extend for 105 years until the year 2109. The costs for the nominal and enhanced cases are documented in the following pages.

PRELIMINARY COST ESTIMATE FOR TEST PACKAGE #4B: THERMAL INSTRUMENTATION & TESTING WITH BOREHOLES IN TEST ALCOVE

The estimated cost of the assumed underground borehole instrumentation and testing program is approximately $17 million plus an annual monitoring, repeat testing, and maintenance cost of approximately $2 million (FY96 dollars). Each estimate is organized as follows:

- Summary
- Part 4A Planning
- Part 4B Drilling for Core Samples & Test Holes
- Part 4C Drilling Inspection & Core Sampling
- Part 4D Instrumentation & Initial Testing
- Part 4E Monitoring, Maintenance, & Repeat Testing

Note that a detailed cost breakdown was not prepared for this testing package. A detailed estimate for the Drift Scale Heater Test, planned for FY97, will be available in the near future.

Key estimating assumptions used as a basis for the cost estimates include the following:

- The number of test alcoves is one.

- The scope, extent, and cost of drilling and instrumentation in the test alcove(s) is similar to that planned for the Drift Scale Heater Test. (Refer to CRWMS M&O, 1996, Test Design, Plans, and Layout for the First ESF Thermal Test, Rev. 1, June 1996.)

- Each test alcove has the same drilling, instrumentation, and testing plan, assumed as follows:

  - Complete drilling after completion of alcove excavation.
  - Complete initial testing in selected boreholes.
  - Complete installation of instruments in all boreholes.
  - Repeat testing and water sampling at a frequency of four times per year.

- All boreholes are assumed to be core drilled.

- The construction support cost includes equipment rental or depreciation and operation and maintenance costs.

- Alcove construction costs are not included.
- Laboratory testing costs are not included.
- Project management is assumed to be performed by an M&O Contractor, with cost and markup roughly estimated as percentages of the total costs of other activities. (Refer to attached estimate for details.)

TRS

SUMMARY OF PRELIMINARY COST ESTIMATE FOR
REPOSITORY PERFORMANCE CONFIRMATION TESTING

TEST PKG #4B. IN SITU THERMAL TESTING--LOWEST COST

PART 4B-A(1) PLANNING (1Test Alcove)				
LABOR	100000			
EQUIPMENT	2000			
MATERIALS	20000			
TOTAL COST			122000	
PART 4B-B(1) DRILLING FOR CORE SAMPLES & TEST HOLES (1Test Alcove)				
LABOR	690000		Draft FY97 BOE	
EQUIPMENT	300000			
MATERIALS	300000			
TOTAL COST			1290000	
PART 4B-C(1) DRILLING INSPECTION & CORE SAMPLING (1 Test Alcove)			Rough est	
LABOR	400000			
EQUIPMENT	100000			
MATERIALS	50000			
TOTAL COST			550000	
PART 4B-D(1) INSTRUMENTATION & INITIAL TESTING (1 Test Alcove)			Draft FY97 BOE	
LABOR--TECHNICAL	2200000			
LABOR--CONSTRUCTION SUPPORT	100000			
EQUIPMENT	250000			
MATERIALS	5500000			
SUBTOTAL		8050000		
CONTINGENCY @ 20%		1610000		
TOTAL COST, FY96 DOLLARS			9660000	

SUBTOTAL	11622000	
M&O CONTRACTOR MGMT/ADMIN @ 30%	3486600	
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN	2266290	
TOTAL COST, FY96 DOLLARS	17374890	(17 M)

PART 4B-E(1) MONITORING, MAINT, & ANNUAL REPEAT TESTING (1 Test Alcove)			
LABOR--TECHNICAL	1200000	Rough est	
LABOR--CONSTRUCTION SUPPORT	0		
EQUIPMENT	100000		
MATERIALS	100000		
SUBTOTAL		1400000	
CONTINGENCY @ 20%		280000	
M&O CONTRACTOR MGMT/ADMIN @ 30%		420000	
M&O CONTRACTOR MARKUP @ 15% OF SUBTOTAL + MGMT/ADMIN		273000	
TOTAL ANNUAL COST, FY96 DOLLARS		1680000	(1.7 M)

F.1.2.2 Seismic Monitoring

The subsurface strong ground motion instrument will be used to confirm our assumptions concerning attenuation of ground motion with depth (in addition to preclosure safety needs), if an event actually occurs during the preclosure period. The instrument will be tied to the surface network. The cost for the instrument will be minimal, and maintaining the instrument in the subsurface will also be minimal since the instrument is event-triggered and can be combined with maintenance of the surface network. If an event occurs, the data could be downloaded remotely or by subsurface access.

F.1.2.3 Remote Observation and Inspection of Emplacement Drifts

Preliminary cost estimates are provide for the following systems: visual inspection, IR thermal imaging inspection, radiological inspection, geologic inspection, and telerobotic manipulation.

PLATFORM-MOUNTED SYSTEMS:

Visual Inspection System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 1 M
Phase II (Detailed Design & Specification):	$ 1 M
• Acquisition Costs	
System Fabrication:	$ 0.5 M
System Installation, Integration & Testing:	$ 0.5 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (.5 personnel x $100K/yr x 100 yr):	$ 5 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $10K/yr x 100 yr):	$ 1 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 9 M**

F.1.2.2 Seismic Monitoring

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PLATFORM-MOUNTED SYSTEMS:

Visual Inspection System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 1 M
Phase II (Detailed Design & Specification):	$ 1 M
• Acquisition Costs	
System Fabrication:	$ 0.5 M
System Installation, Integration & Testing:	$ 0.5 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (.5 personnel x $100K/yr x 100 yr):	$ 5 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $10K/yr x 100 yr):	$ 1 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 9 M**

IR Thermal Imaging Inspection System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 3 M
Phase II (Detailed Design & Specification):	$ 2 M
• Acquisition Costs	
System Fabrication:	$ 1.5 M
System Installation, Integration & Testing:	$ 1.5 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (.5 personnel x $100K/yr x 100 yr):	$ 5 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $20K/yr x 100 yr):	$ 2 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 15 M**

Radiological Inspection System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 1 M
Phase II (Detailed Design & Specification):	$ 1 M
• Acquisition Costs	
System Fabrication:	$ 0.5 M
System Installation, Integration & Testing:	$ 0.5 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (.5 personnel x $100K/yr x 100 yr):	$ 5 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $10K/yr x 100 yr):	$ 1 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 9 M**

Geologic Inspection System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 5 M
Phase II (Detailed Design & Specification):	$ 3 M
• Acquisition Costs	
System Fabrication:	$ 2 M
System Installation, Integration & Testing:	$ 2 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (1 personnel x $100K/yr x 100 yr):	$ 10 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $ 30K/yr x 100 yr):	$ 3 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 25 M**

Telerobotic Manipulation System

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 10 M
Phase II (Detailed Design & Specification):	$ 4 M
• Acquisition Costs	
System Fabrication:	$ 3 M
System Installation, Integration & Testing:	$ 3 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (1 person x $120K/yr x 100 yr):	$ 12 M
Consumables (power, etc.)	$ -----
Repairs (preventative maintenance, component replacement; $100K/yr x 100 yr):	$ 10 M
• Close-out Costs:	$ -----
Total Life-Cycle Cost Estimate:	**$ 42 M**

F.1.3 Waste Package Performance Confirmation Monitoring and Testing Concepts

Additional cost estimating detail will be provided for four testing concepts: Laboratory Measurements Performed "Off-Site", In Situ Monitoring, Pull Radioactive Waste Package -- Perform Measurements On-Site or Off-Site, Pull Specimens -- Perform Measurements On-Site or Off-Site.

F.1.3.1 Laboratory Measurements Performed "Off-Site"

This package was assumed to begin in the year 1998 with the start of the performance confirmation program following the viability assessment. It would extend for 112 years until the year 2109. The costs support the nominal and enhanced cases are documented in the following paragraphs.

Container materials, basket materials testing

It is estimated that the steady-state rate of maintaining a corrosion/oxidation test facility for the container materials and basket materials, and to perform periodic characterization of the specimens and report results would require a 2 man-year effort (0.5 effort of an engineer, 1.0 for a technician, and 0.5 for analysts). Note, a rate $200K/man-year is assumed throughout the waste package testing concepts. Specimens and equipment would already have been purchased, so the major expense would be in the operation, surveillance and maintenance of the test facility. Again, much of this estimate depends a lot on the level of activity one would require. It was assumed a high one for the enhanced case. Scale this back somewhat, but not too much, for the nominal case. One man-year is estimated for nominal case.

Waste form testing

Since nearly all waste form testing must be performed in hot cells and there are very few such facilities operating in the USA, the facility costs are significantly more expensive than those for the container material testing. It is assumed that this can be estimated by figuring the operating expenses for radiation facilities as extra people, so it is estimated as 4 man-years (enhanced), and 2 man-year (low). However, since we are only sampling radioactive waste packages as a contingency and repository in situ testing is not applicable, the laboratory effort is the only way we have of increasing our knowledge base on the long term performance of the waste form.

F.1.3.2 In Situ Monitoring

This package was assumed to begin in the year 2010 with the start of the emplacement operations. It would extend for 100 years until the year 2109. The costs support the nominal and enhanced cases are documented in the following paragraphs.

This would involve mostly labor at the repository with some initial outlay for the various sensor packages, infrared cameras, etc., plus an "infrastructure" to power and support these items. Most measurements would be performed on site, with perhaps an occasional specialty analysis performed at an off-site location. To operate and maintain it, it is estimated it would be a minimum 2 man-years (nominal level) and 4 (enhanced level), since one would have more locations to monitor to achieve the enhanced case.

F.1.3.3 Pull Radioactive Waste Package -- Perform Measurements On-Site or Off-Site

Since this concept is viewed as a contingency and not a "steady state" effort, there is no cost.

F.1.3.4 Pull Dummy Waste Package -- Perform Measurements On-Site or Off-Site

This concept was assumed to begin in the year 2005 soon after the start of construction. It would extend for 105 years until the year 2109. The costs support the nominal and enhanced cases are documented in the following paragraphs.

Cost of the "dummy" waste package specimen is estimated at $95,000. The basis for this is as follows: an estimate was received of about $20K to build a full-scale hollow container out of carbon steel for an underground test that has been contemplated. To build a multiple-barrier container like that envisioned for the disposal container design, it is estimated that the inner barrier of a high-performance alloy would cost roughly $60K, so that the composite would be $80K. It is estimated that the heaters and pro-rata share of the electrical infrastructure to power the heaters would add another $15K to the cost, hence $95K.

It is evident that the cost of the dummy waste packages will be a main driver. Since there will be something like 10,000 waste packages in the repository at completion, approximately 300 "dummy" waste packages is not unreasonable for the enhanced case.

Assuming 30 dummy containers for a nominal level and 300 for a enhanced level, with respective withdrawals of 3/10 yr. (nominal) and 3 per year (enhanced), then it is estimated that the cost for people to perform the measurements, analyses, and report the results would be on the order of 0.2 man-year (nominal) and 2.0 man-year (enhanced). Compared to the pull specimen approach, there would be more analyses and more specimen area to examine, hence the higher labor estimate. Compared to the pull specimens, these dummy container would cost more to withdraw, handle and transport to an off-site facility where most of the analyses would be performed (those dealing with corrosion and oxidation characterization). Those analyses dealing with stress measurements could be performed on site and those dealing with weld integrity might be performed on site, particularly if the surface facility is well equipped.

It is important to point out that, although a number of parameters are listed in the Key Waste Package Performance Confirmation Parameters tables, most of these are measured on the *same* dummy packages or pull specimens.

F.1.3.5 Pull Specimens -- Perform Measurements On-Site or Off-Site

This concept was assumed to begin in the year 2005 soon after the start of construction. It would extend for 105 years until the year 2109. The costs support the nominal and enhanced cases are documented in the following paragraphs.

Cost of test specimens is estimated at between $2 (simple carbon steel coupon) per specimen to perhaps $200 (large panel-size welded section of the two barriers). Since a mixture of different types would be used, an average specimen cost of $50 is assumed. There would be perhaps 300 specimens to achieve the nominal case and 3000 specimens for the enhanced case. Specimens placed throughout the repository, some in the emplacement drift, others in heated and unheated alcoves, and scattered around so that their placement would be associated with various geological features. Specimens would be withdrawn at a rate of 3/yr (nominal case) and 10/yr (enhanced case). It is assumed that these specimens would be withdrawn rather easily and transported to an off-site laboratory for characterizations.

Cost of doing characterization and reporting it: nominal case, perhaps 0.2 man-year and for the enhanced case 1.0 man-year. Many of the analyses would be similar to those performed in the off-site laboratory testing concept so one could likely make the argument that the people and laboratory instrumentation could be shared. As in the Pull Dummy Waste Package concept, it is important to point out that multiple measurements are made on the *same* pull specimen to provide information for several key parameters.

F.2 Performance Confirmation Test Facilities and Support Concepts

Additional cost estimating detail will be provided for the Subsurface and Surface concepts.

F.2.1 Repository Subsurface Performance Confirmation Test Facilities and Support Concepts

Additional cost estimating detail will be provided for five concepts: Permanent Observation Drifts, Emplacement Drift Ventilation Monitoring, Recovery of Waste Packages for Performance Confirmation, Alcove Concepts for Performance Confirmation Program Testing in Non-Emplacement Areas, and Remotely Operated Systems for Temporary In-Drift Monitoring.

F.2.1.1 Permanent Observation Drifts

Cost is for excavation/maintenance of a single observation drift of a length of 1,580 meters. The unit cost per meter is estimated at: $8,419/meter. Therefore, one observation drift cost is $8,418/meter x 1580 meters = **$ 13.3 M.** For monitoring from operational (unemplaced) drifts, there is no added cost because the drifts are planned as part of the operation. (Three are planned.)

F.2.1.2 Emplacement Drift Ventilation Monitoring

Emplacement Drift Ventilation for Monitoring

It is estimated that there is no added cost for the ventilation. Even if no ventilation of emplacement drifts is planned, unavoidable leakage will occur. This leakage will have the effect of heating the exhaust main exactly as the monitoring flow would. Therefore, a cooling/dilution flow will be required in the emplacement system regardless.

Exhaust Drift Monitoring

Assume:

Radiation Monitoring units @ $10,000 ea.
Air temp & Humidity monitoring units at $750 ea.
Data collection system consisting of coaxial cables, PLC local collection units, main coaxial trunkline, data acquisition computer and software. Cables routed along north ramp and central exhaust main. (Perimeter exhaust in lower block)

Total for Data system = $500,000

1 set of monitoring units (1 Rad, 1 Temp) at the bottom of each raise.

Data collection computer, first 4500 meters of network, and 13 sets of monitoring units installed during pre-emplacement development. Balance distributed evenly over the emplacement period.

2009:	Units:	140,000
	Data Collection:	78,000
	Total Parts	218,000

Labor: 2 FTE for installation, calibration @ 120K/year = 240,000

Total parts & Labor = $458,000

Say, $500,000

2010 thru 2032:

System Additions	101,000/year
Replacement parts	50,000/year

Labor: 2 FTE for maintenance and installation: @ 120K/year = 240,000

Total yearly cost = $391,000, Say $400,000/year

2033 thru 2110:

Replacement Parts	50,000/year
Labor 2 FTE @ 120K	240,000/year
	290,000/year

Say, $300,000/yr.

F.2.1.3 Recovery of Waste Packages for Performance Confirmation

No cost is estimated since this is a contingency.

F.2.1.4 Alcove Concepts for Performance Confirmation Program Testing in Non-Emplacement Areas

Assume they are all built during a two year period of pre-emplacement development:

Backfill Test Alcove:

Using the same unit drifting cost as for the Observation Drifts, the estimated cost is:

130 meters x $8,419 = **$1.1 M**

Seal Tests Alcove:

Three test areas are assumed. The number and required length of drifting are assumed, based on the ESF testing description called out in the body of the report.

Each Test Area:

300 meters x $8,419/m = **$2.5 M**

For Three test areas: 3 x 2.5 = **$7.5 M**

Seismic Monitoring Alcove:

One alcove assumed, 30 meters in length:

30 x $8,419 = **$250 K**

Follow-on Heater Test Alcove:

It is assumed that 600 m of drifting will be adequate to develop a heated drift test with sufficient observation area.

600 x $8419 = **$5.1 M**

Underground Fault Zone Hydrology Test Alcove:

It is assumed that 100 m of drifting will be adequate.

100 x $8419 = **$0.8 M**

F.2.1.5 Remotely Operated Systems for Temporary In-Drift Monitoring

PLATFORMS:

Gantry ROV

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 12 M
Phase II (Detailed Design & Specification):	$ 6 M
• Acquisition Costs	
System Fabrication:	$ 4 M
System Installation, Integration & Testing:	$ 6 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (3 personnel x $120K/yr x 100 yr):	$ 36 M
Consumables (power, etc.)	$ 1 M
Repairs (preventative maintenance, component replacement; $100K/yr x 100 yr):	$ 10 M
• Close-out Costs	$ 1 M
Total Life-Cycle Cost Estimate:	**$76 M**

Mini-Rover ROV

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 22 M
Phase II (Detailed Design & Specification):	$ 8 M
• Acquisition Costs	
System Fabrication:	$ 2 M
System Installation, Integration & Testing:	$ 2 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (2 personnel x $120K/yr x 100 yr):	$ 24 M
Consumables (power, etc.)	$ 1 M
Repairs (preventative maintenance, component replacement; $100K/yr x 100 yr):	$ 10 M
• Close-out Costs:	$ 1 M
Total Life-Cycle Cost Estimate:	**$ 70 M**

Mono-Rail ROV

• Design & Development Costs	
Phase I (R&D, Prototypes & Testing):	$ 6 M
Phase II (Detailed Design & Specification):	$ 4 M
• Acquisition Costs	
System Fabrication:	$ 5 M
System Installation, Integration & Testing:	$ 10 M
• Maintenance & Operation Costs Over 100 Year-Life	
Staffing (3 personnel x $120K/yr x 100 yr):	$ 36 M
Consumables (power, etc.)	$ 1 M
Repairs (preventative maintenance, component replacement; $200K/yr x 100 yr):	$ 20 M
• Close-out Costs:	$ 1 M
Total Life-Cycle Cost Estimate:	**$83 M**

F.2.2 Repository Surface Performance Confirmation Test Facilities and Support Concepts

A number of spreadsheets are include which show the delta costs from the reference ACD case.

Revised ACD

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	97,045,000	736,278,000	347,084,000	13,212,000	1,193,619,000
22010	Health/Medical Facilities	2,246,000	12,456,000	5,489,000	296,000	20,487,000
22020	Fire Protection Facilities	6,712,000	43,824,000	9,813,000	926,000	61,275,000
22030	Security Facilities	16,445,000	115,157,000	139,970,000	2,063,000	273,635,000
22040	Maintenance Facilities	11,110,000	137,766,000	61,549,000	1,410,000	211,835,000
22050	Administration/Personnel Fac.	10,476,000	167,410,000	80,014,000	1,380,000	259,280,000
22060	Training/Mockup Facility	4,209,000	27,874,000	7,550,000	580,000	40,213,000
22070	Warehouse and Receiving	1,841,000	35,665,000	14,452,000	231,000	52,189,000
22080	Visitors Center Facility	5,445,000	27,729,000	501,000	717,000	34,392,000
22090	Backup Power Generation Facility					
22100	Change Room Facility	312,000	175,000	29,000	41,000	557,000
22110	Performance Confirmation Support Building					
22120	Compressed Air and Steam Facility	1,707,000	68,276,000	13,906,000	246,000	84,135,000
22131	Cooling Tower	1,394,000	7,050,000	259,000	183,000	8,886,000
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility	4,373,000	12,361,000	2,478,000	577,000	19,789,000
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility	306,000	173,000	29,000	38,000	546,000
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities	30,469,000	80,362,000	11,045,000	4,524,000	126,400,000
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**	66,126,000			15,402,000	81,528,000
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*	66,126,000			15,402,000	81,528,000
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	452,682,000	1,904,785,000	507,486,000	124,714,000	2,989,667,000
	TOTAL	686,355,000	1,986,432,000	540,231,000	131,535,000	3,344,553,000

Note: This estimate is the same Life Cycle Cost as the ACD report.
The Security staffing and electrical utilities were redistributed to correct discrepencies which developed when we changed the schedule for the purposes of this study.
You will notice swapping of funds between Emplacement and Caretaker periods. {$10,696,000}

-- Base Case (ACD) --

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**	38,035,000				38,035,00(
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER	88,749,000				88,749,000
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT	49,287,000				49,287,000
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**	176,071,000				176,071,000
11000	EMPLOYEE TRANSPORTATION	4,137,000	42,638,000	28,437,000	983,000	76,195,000
12000	ON-SITE	53,465,000	38,592,000	4,580,000	5,838,000	102,475,000
12010	Roads	6,463,000			784,000	7,247,000
12020	Rail	6,048,000			731,000	6,779,000
12030	Communications	1,745,000	3,066,000	396,000	242,000	5,449,000
12040	Clearing					
12050	Grading	8,400,000				8,400,000
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities	30,809,000	35,526,000	4,184,000	4,081,000	74,600,000
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**	57,602,000	81,230,000	33,017,000	6,821,000	178,670,000
21000	**WASTE HANDLING FACILITY**	289,511,000	1,168,485,000	160,402,000	96,100,000	1,714,498,000
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2	234,844,000	690,256,000	111,913,000	74,690,000	1,111,703,000
21202	Building/Structures	120,618,000			41,656,000	162,274,000
21203	Hot Cell	11,941,000	138,468,000	22,472,000	4,986,000	177,867,000
21204	Utilities	23,302,000	52,169,000	4,156,000	9,437,000	89,064,000
21205	HVAC	9,298,000	28,597,000	1,645,000	3,887,000	43,427,000
21206	Handling/Packaging Equip.	17,341,000	153,896,000	16,980,000	6,899,000	195,116,000
21207	Support Facilities	52,344,000	317,126,000	66,660,000	7,825,000	443,955,000
21300	Cask Maintenance Facility	41,086,000	340,833,000		15,960,000	397,879,000
21500	Other Facilities	13,581,000	137,396,000	48,489,000	5,450,000	204,916,000
21501	Site-Generated Radwaste Treat. Fac.	13,581,000	137,396,000	48,489,000	5,450,000	204,916,000

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	97,045,000	726,021,000	357,508,000	13,212,000	1,193,786,000
22010	Health/Medical Facilities	2,246,000	12,456,000	5,489,000	296,000	20,487,000
22020	Fire Protection Facilities	6,712,000	43,823,000	9,813,000	926,000	61,274,000
22030	Security Facilities	16,445,000	104,907,000	150,396,000	2,063,000	273,811,000
22040	Maintenance Facilities	11,110,000	137,765,000	61,549,000	1,410,000	211,834,000
22050	Administration/Personnel Fac.	10,476,000	167,410,000	80,014,000	1,380,000	259,280,000
22060	Training/Mockup Facility	4,209,000	27,874,000	7,549,000	580,000	40,212,000
22070	Warehouse and Receiving	1,841,000	35,665,000	14,452,000	231,000	52,189,000
22080	Visitors Center Facility	5,445,000	27,729,000	501,000	717,000	34,392,000
22090	Backup Power Generation Facility					
22100	Change Room Facility	312,000	175,000	29,000	41,000	557,000
22110	Performance Confirmation Support Building					
22120	Compressed Air and Steam Facility	1,707,000	68,273,000	13,906,000	246,000	84,132,000
22131	Cooling Tower	1,394,000	7,049,000	259,000	183,000	8,885,000
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility	4,373,000	12,361,000	2,477,000	577,000	19,788,000
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility	306,000	173,000	29,000	38,000	546,000
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities	30,469,000	80,361,000	11,045,000	4,524,000	126,399,000
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**	66,126,000			15,402,000	81,528,000
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*	66,126,000			15,402,000	81,528,000
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	452,682,000	1,894,506,000	517,910,000	124,714,000	2,989,812,000
	TOTAL	686,355,000	1,975,736,000	550,927,000	131,535,000	3,344,553,000

Note: This is the unmodified ACD report

-- Base Case (ACD) --

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**					
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER					
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT					
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**					
11000	EMPLOYEE TRANSPORTATION		413,000	(273,000)		140,000
12000	ON-SITE		4,000	1,000		5,000
12010	Roads					
12020	Rail					
12030	Communications		1,000			1,000
12040	Clearing					
12050	Grading					
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities		3,000	1,000		4,000
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**		417,000	(272,000)		145,000
21000	**WASTE HANDLING FACILITY**		22,000			22,000
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2		12,000			12,000
21202	Building/Structures					
21203	Hot Cell		1,000			1,000
21204	Utilities		3,000			3,000
21205	HVAC		2,000			2,000
21206	Handling/Packaging Equip.		3,000			3,000
21207	Support Facilities		3,000			3,000
21300	Cask Maintenance Facility		7,000			7,000
21500	Other Facilities		3,000			3,000
21501	Site-Generated Radwaste Treat. Fac.		3,000			3,000

-- Base Case (ACD) --

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**		10,257,000	(10,424,000)		(167,000)
22010	Health/Medical Facilities					
22020	Fire Protection Facilities		1,000			1,000
22030	Security Facilities		10,250,000	(10,426,000)		(176,000)
22040	Maintenance Facilities		1,000			1,000
22050	Administration/Personnel Fac.					
22060	Training/Mockup Facility			1,000		1,000
22070	Warehouse and Receiving					
22080	Visitors Center Facility					
22090	Backup Power Generation Facility					
22100	Change Room Facility					
22110	Performance Confirmation Support Building					
22120	Compressed Air and Steam Facility		3,000			3,000
22131	Cooling Tower		1,000			1,000
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility			1,000		1,000
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility					
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities		1,000			1,000
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**					
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*					
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**		10,279,000	(10,424,000)		(145,000)
	TOTAL		10,696,000	(10,696,000)		

Note: This report shows the result of the Security staffing and Electrical utility cost adjustments. {Revised ACD Report minus Original ACD report}

--Enhanced ACD--

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**	38,300,000				38,300,000
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER	89,367,000				89,367,000
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT	49,699,000				49,699,000
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**	177,366,000				177,366,000
11000	EMPLOYEE TRANSPORTATION	4,181,000	44,198,000	29,874,000	993,000	79,246,000
12000	ON-SITE	53,465,000	38,596,000	4,581,000	5,838,000	102,480,000
12010	Roads	6,463,000			784,000	7,247,000
12020	Rail	6,048,000			731,000	6,779,000
12030	Communications	1,745,000	3,067,000	396,000	242,000	5,450,000
12040	Clearing					
12050	Grading	8,400,000				8,400,000
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities	30,809,000	35,529,000	4,185,000	4,081,000	74,604,000
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**	57,646,000	82,794,000	34,455,000	6,831,000	181,726,000
21000	**WASTE HANDLING FACILITY**	291,187,000	1,168,542,000	160,403,000	96,798,000	1,716,930,000
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2	236,520,000	690,303,000	111,914,000	75,388,000	1,114,125,000
21202	Building/Structures	122,272,000			42,344,000	164,616,000
21203	Hot Cell	11,941,000	138,469,000	22,472,000	4,986,000	177,868,000
21204	Utilities	23,314,000	52,191,000	4,157,000	9,442,000	89,104,000
21205	HVAC	9,304,000	28,609,000	1,645,000	3,890,000	43,448,000
21206	Handling/Packaging Equip.	17,341,000	153,899,000	16,980,000	6,899,000	195,119,000
21207	Support Facilities	52,348,000	317,135,000	66,660,000	7,827,000	443,970,000
21300	Cask Maintenance Facility	41,086,000	340,840,000		15,960,000	397,886,000
21500	Other Facilities	13,581,000	137,399,000	48,489,000	5,450,000	204,919,000
21501	Site-Generated Radwaste Treat. Fac.	13,581,000	137,399,000	48,489,000	5,450,000	204,919,000

--Enhanced ACD--

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	99,589,000	783,776,000	414,230,000	13,547,000	1,311,142,000
22010	Health/Medical Facilities	2,246,000	12,456,000	5,489,000	296,000	20,487,000
22020	Fire Protection Facilities	6,712,000	43,824,000	9,813,000	926,000	61,275,000
22030	Security Facilities	16,445,000	115,157,000	139,970,000	2,063,000	273,635,000
22040	Maintenance Facilities	11,110,000	137,766,000	61,549,000	1,410,000	211,835,000
22050	Administration/Personnel Fac.	10,476,000	167,410,000	80,014,000	1,380,000	259,280,000
22060	Training/Mockup Facility	4,209,000	27,874,000	7,550,000	580,000	40,213,000
22070	Warehouse and Receiving	1,841,000	35,665,000	14,452,000	231,000	52,189,000
22080	Visitors Center Facility	5,445,000	27,729,000	501,000	717,000	34,392,000
22090	Backup Power Generation Facility					
22100	Change Room Facility	312,000	175,000	29,000	41,000	557,000
22110	Performance Confirmation Support Building	2,544,000	47,498,000	67,146,000	335,000	117,523,000
22120	Compressed Air and Steam Facility	1,707,000	68,276,000	13,906,000	246,000	84,135,000
22131	Cooling Tower	1,394,000	7,050,000	259,000	183,000	8,886,000
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility	4,373,000	12,361,000	2,478,000	577,000	19,789,000
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility	306,000	173,000	29,000	38,000	546,000
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities	30,469,000	80,362,000	11,045,000	4,524,000	126,400,000
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**	66,126,000			15,402,000	81,528,000
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*	66,126,000			15,402,000	81,528,000
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	456,902,000	1,952,318,000	574,633,000	125,747,000	3,109,600,000
	TOTAL	691,914,000	2,035,112,000	609,088,000	132,578,000	3,468,692,000

Note: This estimate is made up of the Revised ACD report plus the Performance Confirmation Support Building and the Cell Revisions to the Waste Handling Building.
This estimate assumes the same schedule as the original ACD Report.

--Enhanced ACD--

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**	265,000				265,000
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER	618,000				618,000
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT	412,000				412,000
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**	1,295,000				1,295,000
11000	EMPLOYEE TRANSPORTATION	44,000	1,147,000	1,710,000	10,000	2,911,000
12000	ON-SITE					
12010	Roads					
12020	Rail					
12030	Communications					
12040	Clearing					
12050	Grading					
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities					
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**	44,000	1,147,000	1,710,000	10,000	2,911,000
21000	**WASTE HANDLING FACILITY**	1,676,000	35,000	1,000	698,000	2,410,000
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2	1,676,000	35,000	1,000	698,000	2,410,000
21202	Building/Structures	1,654,000			688,000	2,342,000
21203	Hot Cell					
21204	Utilities	12,000	19,000	1,000	5,000	37,000
21205	HVAC	6,000	10,000		3,000	19,000
21206	Handling/Packaging Equip.					
21207	Support Facilities	4,000	6,000		2,000	12,000
21300	Cask Maintenance Facility					
21500	Other Facilities					
21501	Site-Generated Radwaste Treat. Fac.					

--Enhanced ACD--

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	2,544,000	47,498,000	67,146,000	335,000	117,523,000
22010	Health/Medical Facilities					
22020	Fire Protection Facilities					
22030	Security Facilities					
22040	Maintenance Facilities					
22050	Administration/Personnel Fac.					
22060	Training/Mockup Facility					
22070	Warehouse and Receiving					
22080	Visitors Center Facility					
22090	Backup Power Generation Facility					
22100	Change Room Facility					
22110	Performance Confirmation Support Building	2,544,000	47,498,000	67,146,000	335,000	117,523,000
22120	Compressed Air and Steam Facility					
22131	Cooling Tower					
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility					
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility					
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities					
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**					
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*					
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	4,220,000	47,533,000	67,147,000	1,033,000	119,933,000
	TOTAL	5,559,000	48,680,000	68,857,000	1,043,000	124,139,000

Note: This report shows the resulting delta cost with Performance Confirmation Cost Changes and no Scheduling Changes
{Enhance ACD Report minus Revised ACD Report}

Performance Confirmation

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**	38,300,000				38,300,000
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER	89,367,000				89,367,000
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT	49,699,000				49,699,000
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**	177,366,000				177,366,000
11000	EMPLOYEE TRANSPORTATION	4,181,000	44,198,000	19,994,000	993,000	69,366,000
12000	ON-SITE	53,465,000	38,596,000	1,531,000	5,838,000	99,430,000
12010	Roads	6,463,000			784,000	7,247,000
12020	Rail	6,048,000			731,000	6,779,000
12030	Communications	1,745,000	3,067,000	229,000	242,000	5,283,000
12040	Clearing					
12050	Grading	8,400,000				8,400,000
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities	30,809,000	35,529,000	1,302,000	4,081,000	71,721,000
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**	57,646,000	82,794,000	21,525,000	6,831,000	168,796,000
21000	**WASTE HANDLING FACILITY**	291,187,000	1,168,542,000	21,374,000	96,798,000	1,577,901,000
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2	236,520,000	690,303,000	19,619,000	75,388,000	1,021,830,000
21202	Building/Structures	122,272,000			42,344,000	164,616,000
21203	Hot Cell	11,941,000	138,469,000	518,000	4,986,000	155,914,000
21204	Utilities	23,314,000	52,191,000	471,000	9,442,000	85,418,000
21205	HVAC	9,304,000	28,609,000	144,000	3,890,000	41,947,000
21206	Handling/Packaging Equip.	17,341,000	153,899,000		6,899,000	178,139,000
21207	Support Facilities	52,348,000	317,135,000	18,486,000	7,827,000	395,796,000
21300	Cask Maintenance Facility	41,086,000	340,840,000		15,960,000	397,886,000
21500	Other Facilities	13,581,000	137,399,000	1,755,000	5,450,000	158,185,000
21501	Site-Generated Radwaste Treat. Fac.	13,581,000	137,399,000	1,755,000	5,450,000	158,185,000

Performance Confirmation

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	99,589,000	783,776,000	213,646,000	13,547,000	1,110,558,000
22010	Health/Medical Facilities	2,246,000	12,456,000	245,000	296,000	15,243,000
22020	Fire Protection Facilities	6,712,000	43,824,000	758,000	926,000	52,220,000
22030	Security Facilities	16,445,000	115,157,000	134,293,000	2,063,000	267,958,000
22040	Maintenance Facilities	11,110,000	137,766,000	7,664,000	1,410,000	157,950,000
22050	Administration/Personnel Fac.	10,476,000	167,410,000	3,052,000	1,380,000	182,318,000
22060	Training/Mockup Facility	4,209,000	27,874,000	237,000	580,000	32,900,000
22070	Warehouse and Receiving	1,841,000	35,665,000	1,044,000	231,000	38,781,000
22080	Visitors Center Facility	5,445,000	27,729,000	13,000	717,000	33,904,000
22090	Backup Power Generation Facility					
22100	Change Room Facility	312,000	175,000	1,000	41,000	529,000
22110	Performance Confirmation Support Building	2,544,000	47,498,000	64,887,000	335,000	115,264,000
22120	Compressed Air and Steam Facility	1,707,000	68,276,000	685,000	246,000	70,914,000
22131	Cooling Tower	1,394,000	7,050,000	3,000	183,000	8,630,000
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility	4,373,000	12,361,000	318,000	577,000	17,629,000
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility	306,000	173,000	1,000	38,000	518,000
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities	30,469,000	80,362,000	445,000	4,524,000	115,800,000
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**	66,126,000			15,402,000	81,528,000
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*	66,126,000			15,402,000	81,528,000
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	456,902,000	1,952,318,000	235,020,000	125,747,000	2,769,987,000
	TOTAL	691,914,000	2,035,112,000	256,545,000	132,578,000	3,116,149,000

Note: This estimate conforms with the Performance Confirmation Concepts Study.
It includes New facilities required, additional staffing, and revised schedule eliminating Caretaker Decon (Except for 1 year at the end of Emplacement) and all Caretaker Restart.
Caretaker standby staffing is used for total Caretaker period.

Performance Confirmation

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
01000	**SUPPORT CONTRACTOR**	265,000				265,000
01010	License Application, Support Contractor					
01020	Other					
02000	ARCHITECT ENGINEER	618,000				618,000
02010	License Application, A/E					
02020	Final Procurement and Construction					
02030	Title III					
03000	CONSTRUCTION MANAGEMENT	412,000				412,000
04000	CONSULTANTS					
05000	PERFORMANCE CONFIRMATION PROG.					
07000	REPOSITORY LAND ACQUISITION					
00000	**MANAGEMENT AND INTEGRATION**	1,295,000				1,295,000
11000	EMPLOYEE TRANSPORTATION	44,000	1,147,000	(8,170,000)	10,000	(6,969,000)
12000	ON-SITE			(3,050,000)		(3,050,000)
12010	Roads					
12020	Rail					
12030	Communications			(167,000)		(167,000)
12040	Clearing					
12050	Grading					
12060	Landscaping					
12070	Drainage Control					
12080	Fencing					
12090	Utilities			(2,883,000)		(2,883,000)
12100	Other (Heliport)					
13000	OFF-SITE					
13010	Roads					
13020	Rail					
13030	Communications					
13040	Drainage					
13050	Utilities					
13060	Other Offsite Improvements					
14000	MONUMENTS					
10000	**SITE PREPARATION**	44,000	1,147,000	(11,220,000)	10,000	(10,019,000)
21000	**WASTE HANDLING FACILITY**	1,676,000	35,000	(139,028,000)	698,000	(136,619,000)
21100	Waste Handling Building 1					
21102	Building/Structures					
21103	Hot Cell					
21104	Utilities					
21105	HVAC					
21106	Handling/Packaging Equip.					
21107	Support Facilities					
21200	Waste Handling Building 2	1,676,000	35,000	(92,294,000)	698,000	(89,885,000)
21202	Building/Structures	1,654,000			688,000	2,342,000
21203	Hot Cell			(21,954,000)		(21,954,000)
21204	Utilities	12,000	19,000	(3,685,000)	5,000	(3,649,000)
21205	HVAC	6,000	10,000	(1,501,000)	3,000	(1,482,000)
21206	Handling/Packaging Equip.			(16,980,000)		(16,980,000)
21207	Support Facilities	4,000	6,000	(48,174,000)	2,000	(48,162,000)
21300	Cask Maintenance Facility					
21500	Other Facilities			(46,734,000)		(46,734,000)
21501	Site-Generated Radwaste Treat. Fac.			(46,734,000)		(46,734,000)

Performance Confirmation

Delta Only

Account	DESCRIPTION	ENGG CONSTR	SU_EMP OPS	CARE OPS	CLOSE DECOM	TOTAL
21502	Vehicle Wash Facility					
21503	Decontamination Building					
21504	Performance Confirmation Bldg					
21505	Radwaste Storage					
21506	Transfer Corridors					
21507	Turntable					
21508	Waste Shaft Staging Facility					
22000	**BALANCE OF PLANT**	2,544,000	47,498,000	(133,438,000)	335,000	(83,061,000)
22010	Health/Medical Facilities			(5,244,000)		(5,244,000)
22020	Fire Protection Facilities			(9,055,000)		(9,055,000)
22030	Security Facilities			(5,677,000)		(5,677,000)
22040	Maintenance Facilities			(53,885,000)		(53,885,000)
22050	Administration/Personnel Fac.			(76,962,000)		(76,962,000)
22060	Training/Mockup Facility			(7,313,000)		(7,313,000)
22070	Warehouse and Receiving			(13,408,000)		(13,408,000)
22080	Visitors Center Facility			(488,000)		(488,000)
22090	Backup Power Generation Facility					
22100	Change Room Facility			(28,000)		(28,000)
22110	Performance Confirmation Support Building	2,544,000	47,498,000	64,887,000	335,000	115,264,000
22120	Compressed Air and Steam Facility			(13,221,000)		(13,221,000)
22131	Cooling Tower			(256,000)		(256,000)
22140	*Exc. Material Storage and Handling*					
22141	Surface Exc. Mat. Storage and Hand.					
22142	Offsite Excavated Material Disposal					
22150	Fuel Storage Facility			(2,160,000)		(2,160,000)
22160	Chemical Storage Facility					
22170	Lab and Testing Facilities					
22180	Potable Water Facility					
22190	Sewage Treatment Facility			(28,000)		(28,000)
22200	Backfill Facility					
22210	Packing Facility					
22220	Control and Monitoring Facilities			(10,600,000)		(10,600,000)
22230	Standard Equipment					
22240	Other (Conventional Waste System)					
23000	**SURFACE SHAFT FACILITIES**					
23010	Men and Materials Facility*					
23020	Waste Facility					
23030	Excavated Material Handling Fac.					
23040	Development Intake Facility					
23050	Confinement Intake Facilities					
23070	Development Exhaust Facility					
23080	Confinement Exhaust Facilities*					
23100	Exploratory Shaft Facility - 1					
23110	Exploratory Shaft Facility - 2					
23120	Other					
20000	**SURFACE FACILITIES**	4,220,000	47,533,000	(272,466,000)	1,033,000	(219,680,000)
	TOTAL	5,559,000	48,680,000	(283,686,000)	1,043,000	(228,404,000)

Note: This report shows the resulting delta cost with Performance Confirmation Cost Changes and all Scheduling Changes
{Performance Confirmation Case minus Revised ACD Report}

F.2.3 Performance Confirmation Evaluation and Reporting Concept

ESTIMATED SCHEDULE AND LEVEL OF EFFORT

Following are estimated schedules, durations, and levels of effort for the analyses and reporting planned for the performance confirmation evaluations. The estimates are very rough because there is no direct precedence for this work. The reasons for the estimates are described in the following sections. Table F-1 provides a summary of the estimates.

Pre-License Application Predictions

Pre-license application predictions should be performed twice: first, as soon as funding permits in order to provide more definitive guidance to the performance confirmation planning than is possible without these analyses, and second, in the year before the submittal of the license application to establish the baseline for the post-license application performance confirmation program. The first set of predictions is estimated to require at least a similar duration and level of effort as a TSPA. Its level of effort and duration may even exceed a TSPA because of complications in the analyses arising from the need to consider repository layout and waste emplacement as a function of time (rather than assuming a constant initial condition at the time of repository closure as has been the practice with TSPA). The second set of pre-license application predictions is expected to require the same duration as the first because of the staffing competition with the license application TSPA at the same time, but a smaller level of effort because of the experience gained in the first iteration.

A duration of one year and a level of effort of 6 FTEs is estimated for the first set of predictions. The same duration and a level of effort of 4 FTEs is estimated for the second set of predictions.

Performance Confirmation Data Analyses

It is assumed that performance confirmation data reductions are performed on a continuous basis similar to the current site characterization practices. Consequently, the required duration and level of effort is considered to be part of the data collection rather than the data evaluation. Consequently, the duration and level of effort estimated here is only for the comparison of the performance confirmation data with the baseline data.

It is assumed that the comparisons will be performed annually from now until the end of the first year following the start of subsurface repository construction. After that, the first evaluation is assumed to be needed two years later, then 5 years after that, and then at 10 year-intervals until repository closure. This is a very rough assumption that may have to be revised depending on differences between the "as-built" repository conditions and the license application design and between actually measured data from expected values after the begin of subsurface construction. If the differences are significant, then the evaluations may have to be at shorter intervals. On the other hand, if everything turns out as planned and expected, or close to it, the time intervals between the evaluations may be stretched.

A duration of 3 months and a level of effort of 2 FTEs is estimated each time this activity is performed.

F.2.3 Performance Confirmation Evaluation and Reporting Concept

ESTIMATED SCHEDULE AND LEVEL OF EFFORT

Following are estimated schedules, durations, and levels of effort for the analyses and reporting planned for the performance confirmation evaluations. The estimates are very rough because there is no direct precedence for this work. The reasons for the estimates are described in the following sections. Table F-1 provides a summary of the estimates.

Pre-License Application Predictions

Pre-license application predictions should be performed twice: first, as soon as funding permits in order to provide more definitive guidance to the performance confirmation planning than is possible without these analyses, and second, in the year before the submittal of the license application to establish the baseline for the post-license application performance confirmation program. The first set of predictions is estimated to require at least a similar duration and level of effort as a TSPA. Its level of effort and duration may even exceed a TSPA because of complications in the analyses arising from the need to consider repository layout and waste emplacement as a function of time (rather than assuming a constant initial condition at the time of repository closure as has been the practice with TSPA). The second set of pre-license application predictions is expected to require the same duration as the first because of the staffing competition with the license application TSPA at the same time, but a smaller level of effort because of the experience gained in the first iteration.

A duration of one year and a level of effort of 6 FTEs is estimated for the first set of predictions. The same duration and a level of effort of 4 FTEs is estimated for the second set of predictions.

Performance Confirmation Data Analyses

It is assumed that performance confirmation data reductions are performed on a continuous basis similar to the current site characterization practices. Consequently, the required duration and level of effort is considered to be part of the data collection rather than the data evaluation. Consequently, the duration and level of effort estimated here is only for the comparison of the performance confirmation data with the baseline data.

It is assumed that the comparisons will be performed annually from now until the end of the first year following the start of subsurface repository construction. After that, the first evaluation is assumed to be needed two years later, then 5 years after that, and then at 10 year-intervals until repository closure. This is a very rough assumption that may have to be revised depending on differences between the "as-built" repository conditions and the license application design and between actually measured data from expected values after the begin of subsurface construction. If the differences are significant, then the evaluations may have to be at shorter intervals. On the other hand, if everything turns out as planned and expected, or close to it, the time intervals between the evaluations may be stretched.

A duration of 3 months and a level of effort of 2 FTEs is estimated each time this activity is performed.

Post-License Application Predictions

The post-license application predictions are assumed to be needed at the same intervals as the performance confirmation data evaluations, but lagging behind by the time required for the data evaluations, currently assumed to be three months. The expected duration and level of effort is similar to the second iteration of the pre-license application predictions, although as experience is gained, both the duration and level of efforts are likely to decrease gradually.

A duration of one year and a level of effort of 4 FTEs is estimated for the first set of predictions, gradually decreasing for subsequent predictions as experience is gained.

Table F-1.
Estimates of Durations and Levels of Efforts for Performance Confirmation Evaluations

Activity	Duration calendar months	Level of effort FTEs	Frequency
Pre-license application predictions - 1st set	12	6	once
Pre-license application predictions - 2nd set	12	4	once
Performance confirmation data analyses - per set	3	2	repeatedly
Post-license application predictions - 1st set	12	4	once
Post-license application predictions - later sets	<12	<4	repeatedly

APPENDIX G

DEFINITION OF PERFORMANCE CONFIRMATION FUNCTIONS

DEFINITION OF PERFORMANCE CONFIRMATION FUNCTIONS

Functions preceding performance confirmation in the Mined Geologic Disposal System (MGDS) functional analysis have not yet been defined. For the sake of completion and prospective, tentative definitions are provided.

1.4.4 Evaluate System Performance (Proposed Definition)

The evaluate system performance function tests and evaluates the design, development and operational performance of the repository for the purpose of verifying design requirements and specifications; evaluating compliance with government regulations; and assessing environmental impact. The function interfaces with all MGDS functions, estimates the ability of the repository system to comply with regulations governing preclosure and postclosure performance objectives and its effect on the environment and uses the estimates in updates to compliance documents and in support of the continuing development of the system. It includes the conduct of performance confirmation and environmental monitoring programs and the planning for postclosure monitoring. The function is initiated during site characterization and ends with termination of the MGDS closure license.

1.4.4.1 Evaluate System Design and Development (Proposed Definition)

The evaluate system design and development function tests and evaluates the performance of the repository for the purpose of verifying design, regulatory, and license requirements. The function is comprised of system and subsystem development and qualifications tests, demonstrations, analyses, assessments, and predictions. The function began with Exploratory Studies Facility and waste package material testing during Site Characterization and ends when the license to operate is received and all repository elements are fully operational.

1.4.4.2 Evaluate System Operation (Proposed Definition)

The evaluate system operation function tests and evaluates the operational performance of the repository, its compliance with government regulations, its impact on the environment while operational, and its compliance with the licensing requirements. The function includes system and subsystem Operational Test and Evaluation activities beginning with the authorization to construct the repository and ends when all operational requirements have successfully been met.

1.4.4.3 Confirm Waste Isolation Performance (Proposed Definition)

The confirm waste isolation function confirms the Confine and Isolate Waste function of MGDS. This includes confirming that actual subsurface conditions encountered and changes in those conditions during construction and waste emplacement operations are within performance limits identified in the license, and confirming the natural and engineered systems for repository operation are within performance limits and consistent with the postclosure performance analytical predictions. The function begins with the collection of critical data during site characterization and ends with the confirmation that the waste isolation system meets required long term performance requirements.

Input: Site Characterization/Baseline Data and their extensions
MGDS Design (Waste Package [WP], Surface, Subsurface)
"As-Built" Repository configuration
Emplaced Waste Characteristics

Output: Monitoring/Test Data Documentation
- Natural environment, including MGDS induced changes
- Effects on design elements
Total System Performance Assessment
- WP Performance
- Internal and External Criticality
- Engineered Barrier Performance
- Natural Barrier Performance
Compliance Evaluation, including compliance with License requirements
Recommended Actions

Interfaces: Site Characterization (1.4.1)
Confine and Isolate Waste (1.4.5)
Evaluate System Design and Development (1.4.4.1)
Evaluate System Operation (1.4.4.2)
Waste Acceptance Functions (1.1)
Operate MGDS (1.4.2)
Prepare for Disposal Operation (1.4.3)
MGDS Design Process

1.4.4.3.1 Develop and Validate Computer Models

The develop and validate computer models function defines those activities related to the development of computer modeling software which predicts the system performance of the Waste Isolation System. This function also includes the necessary steps to validate the software per *Quality Assurance Requirements and Description* (DOE 1996b) requirements. This function begins with results from Site Characterization and ends with the ability to predict Waste Isolation System performance.

1.4.4.3.2 Predict Waste Isolation Performance

The predict waste isolation performance function consists of utilizing approved modeling software to predict the Waste Isolation System performance. The predicted results establish the performance baseline to be utilized in the license application. This function begins with validated computer models available for usage and ends with predicted results available for license application.

1.4.4.3.3 Test Waste Isolation Performance

The test waste isolation performance function will test critical parameters associated with the natural environments, induced environments, and effects on the design elements of the engineered barrier system. The function begins with waste emplacement and ends with the acquisition of data needed for waste isolation performance assessment.

1.4.4.3.4 Evaluate Waste Isolation Performance

The evaluate waste isolation performance function analyzes the critical processes of the natural barrier system and engineered system performance elements and provides a predicted performance calculation as to the performance of the waste isolation system. The function evaluates waste package performance, engineered barrier effectiveness, natural barrier effectiveness, human intrusion, and effects of the natural and induced environments. The function begins with the receipt of critical performance test data and ends with evaluation of the data to confirm the limits defined in the license.

1.4.4.3.5 Implement Corrective Action

The implement corrective action function defines the actions necessary to resolve discrepancies between the test data collected and the analytical evaluation of the modeled processes. The function could involve revision to the process models, updates/revisions to the software coding, enhancement in the test program, or revision to the waste isolation system design. The function begins when discrepancies are identified between the results from the performance confirmation test program and the process modeling and ends when the corrective action is implemented.

1.4.4.3.6 Assess Waste Isolation System Performance

The assess waste isolation system performance function is the analytical execution of verifying the waste isolation system meets or exceeds the required limits. The assessment will utilize qualified software and qualified supporting test data. The function begins with the completion of gathering all applicable test data , resolution of modeling parameters, and final concurrence on the predicted environmental and waste degradation process and ends when the final analytical results are approved and a recommendation for closure is obtained.

1.4.4.3.4.1 Evaluate Waste Package Performance

This function confirms the Confine Waste function (1.4.5.1) of the MGDS. It evaluates the capability of the waste package to contain the waste and limit the release of radionuclides from the waste package boundary.

Input: Emplaced waste characteristics
Disposal container design
Waste package emplacement hardware design
Emplacement drift backfill data
Emplacement drift invert design
WP development test data
WP laboratory and in situ test data
Emplacement drift environment data

Water inflow data
Natural and induced environment evaluation

Output: WP degradation assessment
WP life prediction
WP post-breach material release prediction
WP internal criticality evaluation
WP material special effects evaluation (cathodic protection, microbial activities)

Interfaces: Waste Acceptance records
WP development (including laboratory) and operational testing
WP loading, welding and handling operations
Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Natural and Induced Environmental Effects (1.4.4.3.5)
Measure Natural Environment (1.4.4.3.6)
Measure Induced Environment (1.4.4.3.7)
Test Effects on Design Materials (1.4.4.3.8)

1.4.4.3.4.2 Evaluate Engineered Barrier Performance

This function confirms the Limit Radionuclide Release to the Natural Barrier function (1.4.5.2) of MGDS. It evaluates a) the rate of radionuclide transport from the WP to the natural barrier (after WP breach); b) the effects that the underground environments have on radionuclide transport; c) external criticality; and d) the effectiveness of the total Engineered Barrier System (EBS).

Input: EBS Design (WP Subsurface)
Evaluation of Natural and Induced Environments
"As Built" Repository Configuration
Radionuclide Release from Waste Package

Output: EBS Design (WP, Subsurface) Performance Assessment
Release to Natural Barrier
Induced Thermal effects on repository layout

Interfaces: Evaluate WP Performance (1.4.4.3.1)
Evaluate Natural Barrier Performance (1.4.4.3.3)
Evaluate Natural and Induced Environment Effects (1.4.4.3.5)
Measure Natural Environment (1.4.4.3.6)
Measure Induced Environment (1.4.4.3.7)
Test Effects on Design Element (1.4.4.3.8)
Characterize Site (1.4.1)
Prepare for Waste Disposal (1.4.2)

1.4.4.3.4.3 Evaluate Natural Barrier Performance

This function confirms the Limit Release of Radionuclides to the Accessible Environments function (1.4.5.3) of MGDS. It evaluates a) the rate of radionuclide transport from the Engineered Barrier, through the Natural Barrier, to the Accessible Environments; and b) the potential dose to which the population may be exposed to as a result of the radionuclide release.

Input: Saturated Zone data
Unsaturated Zone data
"As Built" Repository
Induced Environment
Estimated Release from Engineered Barrier
Evaluation of Natural and Induced Environment

Output: Natural Barrier Performance Assessment
Release to Accessible Environments (Gaseous release and dose potentials)

Interfaces: Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Human Intrusion (1.4.4.3.4)
Evaluate Natural and Induced Environment Effects (1.4.4.3.5)
Measure Natural Environments (1.4.4.3.6)
Measure Induced Environments (1.4.4.3.7)
Characterize Site (1.4.1)

1.4.4.3.4.4 Evaluate Human Intrusion

This function confirms the Limit Human Intrusion function (1.4.5.4) of the MGDS. It evaluates changes in human population data and measures for preventing access to the underground repository.

Input: Change in population data
Change in regional economics
Access backfill test data
Access control and security design

Output: Evaluation of access prevention/control
Evaluation of site economic desirability

Interfaces: Evaluate Natural Barrier Performance (1.4.4.3.3)
Measure Natural Environment (1.4.4.3.6)
Test Effects on Design Elements (1.4.4.3.8)

1.4.4.3.4.5 Evaluate Natural and Induced Environment Effects

This function confirms the Limit Natural and Induced Environments function (1.4.5.5) of MGDS. It evaluates the impact of the natural environments on the engineered system and the effects of the system performance on the natural environments.

Input: MGDS Design
Measurements of natural and induced environments
Design elements monitoring and test data

Output: Characterization of the natural and induced environments and impact to be provided as input to performance confirmation (WP, Engineered Barrier, Natural Barrier) performance evaluation functions
Evaluation of impact on subsurface design elements
Evaluation of thermal impact on the surface and natural environments

Interfaces: Evaluate WP Performance (1.4.4.3.1)
Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Natural Barrier Performance (1.4.4.3.3)
Evaluate Human Intrusion (1.4.4.3.4)
Evaluate Natural and Induced Environment Effects (1.4.4.3.5)
Measure Natural Environments (1.4.4.3.6)
Measure Induced Environments (1.4.4.3.7)
Test Effects on Design Elements (1.4.4.3.8)

1.4.4.3.3.1 Measure Natural Environments

This function a) provides test data that extends the site characterization baseline (natural phenomena and rock characteristics), and b) monitors the effects on the site as a result of waste emplacement. The function starts when construction starts and ends with closure.

Input: Test data requirements/needs
- Performance confirmation requirements
- 10 CFR 60 performance confirmation requirements
Results of Developmental Test and Evaluation testing
Results of Operational Test and Evaluation testing
Site Characterization data/baseline
"As Built" Repository Configuration
Operational Data

Output: Test Data
Test Reports

Interfaces: Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Natural Barrier Performance (1.4.4.3.3)
Evaluate Human Intrusion (1.4.4.3.4)
Evaluate Natural and Induced Environment (1.4.4.3.5)
Prepare for MGDS Operation (1.4.2)
Operate MGDS (1.4.3)

1.4.4.3.3.2 Measure Induced Environments

This function provides test and monitoring data of the surface and subsurface environments induces by the disposal of waste. These environments include thermal, thermo-hydrologic, structural-mechanical, thermo-chemical and radiation environments. The function starts with waste emplacement and ends with closure.

Input: Test data requirements/needs
- Performance confirmation requirements
- 10CFR60 performance confirmation requirements

Results of Developmental Test and Evaluation testing
Results of Operational Test and Evaluation testing
Site Characterization data/baseline
"As Built" Repository Configuration
Operational data

Output: Test data
Test reports

Interfaces: Evaluate WP Performance (1.4.4.3.1)
Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Natural Barrier Performance (1.4.4.3.3)
Evaluate Natural and Induced Environments (1.4.4.3.5)
Prepare for MGDS Operation (1.4.2)
Operate MGDS (1.4.3)

1.4.4.3.3.3 Test Effects on Design Elements

This function provides tests of the effects that the natural and induced environments produce on various design elements of the repository. These elements include the waste package, the emplacement drifts construction, backfill and seals. In situ and laboratory testing and experimentation related to these elements is also included. The function starts with waste emplacement and ends with closure.

Interfaces: Evaluate WP Performance (1.4.4.3.1)
Evaluate Engineered Barrier Performance (1.4.4.3.2)
Evaluate Natural Barrier Performance (1.4.4.3.3)
Evaluate Natural and Induced Environments (1.4.4.3.5)
Prepare for MGDS Operation (1.4.2)
Operate MGDS (1.4.3)

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APPENDIX H

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT

Name	Process	YMP Applications	Status
3DEC* Vs 1.5* 1994	Three-dimensional analysis of underground opening stability and ground motion for jointed rock masses; distinct element method	ESF and repository excavation stability analyses	User's manual (Itasca 1994a); maintained by Itasca Consulting Group, Inc.
ABAQUS 1982	Soil and rock mechanics analysis	Geomechanical behavior of large-block test and ESF drift-scale test	Example problems manual (Hibbitt 1982); maintained by Hibbitt, Karlsson and Sorenson, Inc.
ANSYS* Vs 5.0A* Oct 93 Vs 5.1* Sep 94 Vs 5.1HP 1994 Vs 5.2 1996	Multi-dimensional thermal-mechanical analysis of stress, strain, and heat conduction and radiation in solids; includes design optimization; finite element method	Thermal-mechanical analyses in support of waste package development, incl. the multi-purpose canister	Theory and user's manual (Swanson 1993; Kohnke 1994; ANSYS 1994a), verification (Imgrud 1992, ANSYS 1994b); maintained by ANSYS, Inc.
AREST Vs 1.0 Nov 93	Radionuclide release from waste package and engineered barrier system	Engineered barrier system performance analysis in support of total-system performance assessments	Theory (Liebetrau et al. 1987; Engel and McGrail 1993; Engel et al. 1993), user's manual (Buxbaum and Engel 1991); maintained at Pacific Northwest National Laboratory
AREST-CT working version	Coupled reactive chemical transport, radionuclide release, and effects of near-field chemistry on radionuclide transport	Engineered barrier system performance analysis in support of total-system performance assessments	Development aspects (Engel et al. 1994a, 1994b, 1995), see AREST for predecessor documentation; maintained by CRWMS M&O
A-TOUGH	Version of V-TOUGH with atmospheric interaction	Simulation of moisture removal from the repository by ventilation	User's manual (Multimedia 1993); maintained by Multimedia Environmental Technology, Inc.
CLIMATE working version	Heat and mass transport within underground excavations, including water vapor and air ventilation	Analysis of ESF and repository drift ventilation	Development aspects (Danko et al. 1995 1996)

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT (continued)

Name	Process	YMP Applications	Status
COYOTE Vs II 1994	Multi-dimensional nonlinear heat conduction and related general diffusion processes in solids	Analyses of rock temperatures surrounding the potential repository	Documentation (Gartling 1982; Gartling and Hogan 1994); maintained at Sandia National Laboratories
ELFPOINT working version	Rock deformation resulting from shear and tensile faulting	Support of seismic ground-water pumping analysis to compute seismically induced elastic rock deformations	Theory (Okada 1992)
EQ3/6* Vs 7.2a* Aug 94 Vs 7.2b Aug 95	Speciation and solubility in aqueous solutions and geochemical reaction path/ mass transfer	Analyses of ground-water chemistry data, calculations of solubility limits, and determination if certain reactions are in equilibrium or disequilibrium states	Theory and user's manual (Daveler and Wolery 1992, Wolery 1992a, 1992b; Wolery and Daveler 1992); maintained at Lawrence Livermore National Laboratory
FEHM FEHMN* Oct 95	Multi-dimensional multiphase flow and transport of water, water vapor, non-condensible gases, dissolved solids, radionuclides, and heat in porous and fractured media; finite element method	Thermal-hydrologic and radionuclide transport modeling of unsaturated and saturated zone; ground-water travel time calculations	Theory (Zyvoloski et al. 1996a), user's manual (Zyvoloski et al. 1996b), verification and validation (Dash et al. 1996); maintained at Los Alamos National Laboratory
FLAC* Vs 3.22* 1993	Two-dimensional plastic deformation of soil, rock or other solid-material structures; finite difference method	Geomechanical analyses of ESF subsurface design and ESF tests	User's manual (Itasca 1993a); maintained by Itasca Consulting Group, Inc.
FLAC 3D* Vs 1.0* 1994	Three-dimensional plastic deformation of soil, rock or other solid-material structures; finite difference method	Geomechanical analyses of ESF subsurface design, including portal and opening stability	User's manual (Itasca 1994b); maintained by Itasca Consulting Group, Inc.
GENII 1993	Biosphere radionuclide transport and radiation doses to humans by direct exposure, ingestion, and inhalation	Pre- and postclosure radiological exposure and risk calculations	Theory (Napier and Peloquin 1988); user's manual (SNL 1993); maintained at Pacific Northwest National Laboratory
GWRAND working version	Two-dimensional unsaturated ground-water particle tracking, random walk dispersion; semi-analytical method	Unsaturated zone ground-water travel time analyses	Theory (Lu 1994), preliminary documentation (Altman et al. 1996); maintained at Sandia National Laboratories
JAC2D (a.k.a. JAC)* 1993	Large deformation, temperature-dependent, quasi-static mechanics problems in two dimensions	Thermal-mechanical behavior of rock mass for north ramp design 2C package; also for setup of ESF thermal-mechanical tests	User's manual (Biffle 1981) qualified under previous QARD; maintained at SNL

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT (continued)

Name	Process	YMP Applications	Status
JAC3D* 1993	Large deformation, temperature-dependent, quasi-static mechanics problems in three dimensions	Thermal-mechanical behavior of rock mass for north ramp design 2C package; also for ESF single heater test as built predictions	User's manual (Biffle 1993), qualified under previous QARD (DOE 1996b); currently undergoing QA review for complete release; maintained at SNL
LYNX* Vs 1.0* Jul 93 Vs 3.06* Sep 94 Vs 3.10 1996 Vs 4.2(beta) 1996	Three-dimensional modeling of geologic features and mine design	Geology and underground design modeling support of ESF and repository design	User's manual (Lynx 1992, 1993, 1994); maintained by Lynx Geosystems, Inc.
MACCS Vs. 1.5.11.1 Oct 93	Radiation doses to humans	Calculations of radiation doses to workers and the general public	Maintenance release (Chanin et al. 1993), theory (Jow et al. 1990), user's manual (Chanin et al. 1990), programmer's manual (Rollstin et al. 1990); maintained by NRC
MCNP* Vs 4.2* Jan 95 Vs 4A* Jan 95	Criticality and shielding analysis for nuclear/radioactive systems	Criticality and shielding analyses in support of waste package design	Theory (Briesmeister 1993 and 1995); Primer (Harmon 1994); maintained at Los Alamos National Laboratory
MLAEM Vs 4.0 1994	Two-dimensional and quasi-three-dimensional saturated ground-water flow; analytical element method	Regional saturated ground-water flow analysis to establish boundary conditions for site-scale saturated zone modeling in support of site characterization	Basic theory (Strack 1989; Haitjema 1995), user's manual (Strack 1992a); maintained by Strack Engineering; see also SLAEM
MODFLOW 1983	Two-dimensional and quasi-three-dimensional saturated ground-water flow; finite difference method	Regional and site-scale saturated ground-water flow analysis in support of site characterization	Documentation (McDonald and Harbaugh 1988); maintained by U.S. Geological Survey
MPSalsa working version	Two-dimensional two-phase (gas/liquid) flow in heterogeneous porous media; finite element method	Thermal-hydrological modeling of unsaturated zone air and water flow	Theory (Shadid and Moffat, in prep.); user's manual (Shadid et al., in prep.); maintained at Sandia National Laboratories
NUFT working version	Three-dimensional multiphase flow and transport of water, water vapor, gas, dissolved solids, radionuclides, and heat; integrated finite difference method	Thermal-hydrologic modeling of unsaturated and saturated zone in support of site characterization, engineered barrier system design studies, and performance assessment	Reference manual (Nitao 1995); maintained at Lawrence Livermore National Laboratory

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT (continued)

Name	Process	YMP Applications	Status
ORIGEN2 Vs 1.1	Build-up and decay of radioisotopes in nuclear fission reactor and in spent fuel after removal from reactor, including associated heat generation	Generation of list, weight, and radioactivity of radionuclides and of heat generated in support of MGDS design and performance assessment	Theory (Bell 1973); maintained at Oak Ridge National Laboratory
OS3D/GIMRT Vs 1.0 Dec 95	Multi-dimensional multicomponent reactive mass transport	Reactive mass transport modeling (water chemistry, porosity/permeability, and mineralogy) of the altered zone and repository near field	User's and programmer's manual (Steefel and Yabusaki 1995); maintained at University of South Florida, modified at Lawrence Livermore National Laboratory
PIGS working version	Pitting corrosion of waste package containers	Interpretation of pitting corrosion experiments, potential component of waste package and total-system performance assessment models	Not yet documented; being developed at Lawrence Livermore National Laboratory.
RIP Vs 4.04 Nov 95	Total-system postclosure performance assessment for radionuclide releases to accessible environment and radiation doses to the public	Total-system performance assessment of potential Yucca Mountain MGDS	Theory and user's manual (Golder 1995); maintained by Golder Associates, Inc.
SATTRAK working version	Three-dimensional saturated ground-water particle tracking, random walk dispersion; finite element method	Saturated zone ground-water travel time analyses	Development aspects (Altman et al. 1996); maintained at Sandia National Laboratories
SCALE* Vs 4.2* 1993	Criticality safety, shielding, heat transfer, and nuclear decay/fuel depletion analysis for nuclear facilities and waste package designs	Criticality and shielding analysis in support of waste package development	Theory and user's manual (NRC 1993); maintained at Oak Ridge National Laboratory
SLAEM Vs 3.0 1994	Two-dimensional single-layer saturated ground-water flow; analytical element method	Regional saturated ground-water flow analysis to establish boundary conditions for site-scale saturated zone modeling in support of site characterization	Basic theory (Strack 1989; Haitjema 1995), user's manual (Strack 1992b); maintained by Strack Engineering; see also MLAEM
STAFF3D Vs 2.5 1992	Multi-dimensional isothermal flow and radionuclide transport in anisotropic saturated porous and fractured media; finite element method	Hydrothermal analyses in support of site characterization	Theory (Huyakorn et al. 1992); maintained by HydroGeoLogic, Inc.

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT (continued)

Name	Process	YMP Applications	Status
TOSPAC 1992	Total-system performance assessment for radionuclide releases to accessible environment as component of Total System Analyzer	Total-system performance assessment of potential Yucca Mountain MGDS	Theory (Dudley et al. 1988), user's manual (Gauthier et al. 1992); maintained at Sandia National Laboratories
TOUGH2* Vs 1.11* Feb 96	Multi-dimensional multiphase flow and transport of water, water vapor, non-condensible gases, dissolved solids, and heat in porous and fractured media; integrated finite difference method	Thermal-hydrologic modeling of unsaturated and saturated zone; ground-water travel time calculations; design of laboratory and in-situ thermohydrologic experiments	Theory and user's guide (Pruess 1987; Pruess et al. 1991); software qualification (Pruess et al. 1996); conjugate gradient solvers (Moridis and Pruess 1995); maintained at Lawrence Berkeley National Laboratory; see also TOUGH and V-TOUGH
TRACR3D TRACRN 1991	Multi-dimensional isothermal liquid and gas flow and multi-component tracer/radionuclide transport in porous and fractured media; finite difference method	Radionuclide transport modeling in support of site characterization; design of laboratory and in-situ tracer experiments	Documentation (Travis 1984; Birdsell and Travis 1991); maintained at Los Alamos National Laboratory
TSA working version	Collection of programs for total-system performance assessment for radionuclide releases to accessible environment	Total-system performance assessment of potential Yucca Mountain MGDS	Development aspects (Barnard et al. 1992; Wilson et al. 1994); maintained at Sandia National Laboratories
UDEC* Vs 2.0* Mar 94	Two-dimensional response of discontinuous media (such as jointed rock mass) represented as an assemblage of discrete blocks; distinct element method	Analysis of underground openings (in jointed medium) subjected to in-situ and seismic loadings in support of ESF and repository design	User's manual (Itasca 1993b); maintained by Itasca Consulting Group, Inc.
UNWEDGE* Vs 2.2* 1992	Three-dimensional analysis of geometry and stability of wedges defined by intersecting structural discontinuities in underground excavations, incl. rock bolts and shotcrete	ESF and repository excavation stability analyses	User's manual (Carvalho et al. 1992); maintained at University of Toronto
VNETPC* Vs 3.1* 1993	Analysis of subsurface facility ventilation for mine networks, considering fans and emission of gases	Analysis of ESF ventilation system, including hydrocarbon exhausts from diesel locomotives	User's manual (Mine Ventilation Services 1993); maintained by Mine Ventilation Services, Inc.

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

COMPUTER CODES FOR POSTCLOSURE PERFORMANCE ASSESSMENT (continued)

Name	Process	YMP Applications	Status
VTOUGH* Vs. 7.8* Sep 95	Vectorized multi-dimensional multiphase flow and transport of water, water vapor, and heat in porous and fractured media; integrated finite difference method	Thermal-hydrologic modeling of unsaturated and saturated zone in support of thermal loading and engineered barrier system design studies	Theory and user's manual (Nitao 1990); maintained at Lawrence Livermore National Laboratory; see also TOUGH and TOUGH2
WAPDEG working version	Waste package barrier degradation and corrosion	Input to total-system performance assessment of potential repository at Yucca Mountain	Being developed by Joon Lee and Joel Atkins of CRWMS M&O
WEEPTSA working version	Probabilistic analysis of interaction of water flowing in discrete fractures with waste containers, radionuclide release, and transport to the water table	Input to total-system performance assessment of potential repository at Yucca Mountain	Development aspects (Barnard et al. 1992; Wilson et al. 1994); maintained at Sandia National Laboratories
YMIM Vs 2.1 Apr 95	Radionuclide release from waste form and waste packages	Input to total-system performance assessment; design of waste form and waste package experiments	User's manual (Gansemer and Lamont 1995); maintained at Lawrence Livermore National Laboratories

* One or more versions approved for quality-affecting work in accordance with the *Quality Assurance Requirements and Description* (DOE 1996b)

APPENDIX I

SCP PERFORMANCE CONFIRMATION PROGRAM

Table I-1. Selected Portions of SCP Table 8.3.5.16-1. Monitoring Activities Initiated During Site Characterization and Planned to Be Continued As Performance Confirmation.

Test Title	Location*	Purpose	Principle Value for Performance or Design Configuration	SCP Section Providing Information
MONITORING ACTIVITIES SUPPORT PERFORMANCE ISSUE RESOLUTION STRATEGIES IN THE LICENSE APPLICATION				
Precipitation and meteorological monitoring	At and around the site	Continue data collection for precipitation, wind speed, direction, etc.	Improve estimates for recharge and infiltration for ground-water travel time and total system performance	8.3.1.12.2.1.1 8.3.1.2.1.1.1
Seismic network monitoring	regional monitoring	Continue expansion of earthquake catalog	Improve estimate of earthquake probabilities and magnitudes for total system performance	8.3.1.17.4.1.2
Geodetic leveling - Yucca Mountain base station network monitoring	Across the site	Measure station elevations over time	Confirm and evaluate rates of tectonic deformation	8.3.1.17.4.10.1
Surface water runoff monitoring	In and around the site	Continue data collection on runoff	Improve calculations for seal performance and ground-water level time	8.3.1.2.1.2.1
Site vertical borèhole/ unsaturated zone boreholes monitoring	Overlying and adjacent to the primary repository boundary	Expand data base for site hydrologic conditions	Increase confidence in calculation of ground-water travel time	8.3.1.2.2.3.2
Natural infiltration monitoring	In and around the site	Continue infiltration monitoring	Increase confidence in infiltration values used in developing ground-water flow models	8.3.1.2.2.1.2
Site potentiometric-level monitoring	Around the site	Measure water table levels over time	Improve site hydrologic model for total system performance	8.3.1.2.3.1.2
MONITORING ACTIVITIES SUPPORTING DESIGN PARAMETERS IN THE LICENSE APPLICATION				
Drift stability monitoring	exploratory shaft facility and underground facility	Expand data base on shaft and drift convergence	Confirm design assumptions on stability	8.3.1.15.1.8.3
Seismic network monitoring	Regional monitoring (a 150 km radius of Yucca Mountain)	Extend earthquake catalog	Increase confidence in earthquake probabilities and magnitudes	8.3.1.17.4.1.2

* For more specific details on locations of tests to the conducted, see Section 8.4.2.2.3 of the *Site Characterization Plan* (DOE 1988).

Table I-2. Selected Portions of SCP Table 8.3.5.16-2. Testing activities initiated during site characterization and planned to be continued as performance confirmation.

Test Title	Location*	Purpose	Performance Assessment Analysis	SCP Section Providing Information
TESTING ACTIVITIES SUPPORTING PERFORMANCE ISSUE RESOLUTION STRATEGIES IN THE LICENSE APPLICATION				
Intact fracture test	Laboratory exploratory shaft samples	Continue measurements of dispersivity, diffusion, and flow rates in response to changes in stress	Evaluation of discrete fracture flow models for total system calculations	8.3.1.2.2.4.1
Percolation test	Exploratory shaft breakout room	Validation of dual porosity and discrete fracture models	Improve confidence in ground-water travel time and radionuclide transport calculations	8.3.1.2.2.4.2
Bulk permeability test	Exploratory shaft lower breakout zone alcove	Continue measurements of large scale hydrologic parameters, gas permeability	Addresses scale effects important to flow models used for calculations of ground-water travel time and radionuclide transport	8.3.1.2.2.4.3
Near-field thermally perturbed hydrologic properties	Underground facility - repository level and laboratory testing	Improve data base for fluid flow paths and rates in near-field environment	Improve confidence in performance assessments for engineered barrier system and waste package	8.3.4.2.4.4.1
Rock/water interaction tests	Underground facility - repository level and laboratory testing	Continue to measure dispersivity, diffusion, perturbation of rock/water chemistry by thermal effects	Improve confidence in engineered barrier system and waste package performance assessments	8.3.4.2.4.4.2
TESTING ACTIVITIES SUPPORTING DESIGN ISSUE RESOLUTION IN THE LICENSE APPLICATION				
Heated room experiment	Repository level ESF drift	Obtain data base on rock mass deformation and stress changes as a function of temperature, rock thermal conductivity, and heat capacity on the drift scale	Confirm behavior of underground openings - design assumptions for drift size, ground support requirements	8.3.1.15.1.6.5
Near-field thermally perturbed hydrologic properties	Underground facility - repository level and laboratory testing	Determine near-field hydrologic properties	Confirm design assumptions about water inflow to waste package	8.3.1.2.2.4.3
In situ testing of scale [sic] [seal] components	Repository level of ESF	Verify behavior of sealing components under in situ conditions	Improve confidence in seal performance	8.3.3.2.3

* For more specific details on locations of tests to the conducted, see Section 8.4.2.2.3 of the *Site Characterization Plan* (DOE 1988).

APPENDIX J

GLOSSARY

GLOSSARY

Following are definitions of important terms used in the report. Terms shown in ***bold italic*** type in a definition have their own definition.

Accessible environment means the atmosphere, the land surface, surface water, oceans, and the portion of the lithosphere that is outside the ***controlled area***. (10 CFR 60.2)

Advanced conceptual design (ACD) means the design phase that will be used to explore selected design alternatives and will firmly fix and refine the design criteria and concepts to be made final in later design efforts. The project feasibility will be demonstrated, life-cycle costs estimated, preliminary drawings prepared, and a construction schedule developed as required by U.S. Department of Energy Order 6410.1. (DOE 1996a)

Backfill means (1) the general fill that is placed in the excavated areas of the underground facility. Backfill materials may be either excavated tuff or other earthen materials; (2) the material or process used to refill an excavation. (DOE 1996a)

Barrier means any material or structure that prevents or substantially delays the movement of water or radionuclides. (10 CFR 60.2)

Containment means the confinement of radioactive waste within a designated boundary. (10 CFR 60.2)

Controlled area means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the outer boundary of the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be prohibited before and after permanent closure. (DOE 1996a, adapted from 10 CFR 60.2)

Disposal means (1) the isolation of radioactive wastes from the ***accessible environment*** (10 CFR 60.2), (2) the emplacement in a repository of high-level radioactive waste, spent nuclear fuel, or other highly radioactive material with no foreseeable intent of recovery, whether or not such emplacement permits the recovery of such waste, and the isolation of such waste from the accessible environment (DOE 1996a).

Driver means a factor that needs to be considered for a specified purpose.

Engineered barrier system means (1) the waste packages and the underground facility (10 CFR 60.2); (2) the manmade components of a disposal system designed to prevent the release of radionuclides from the underground facility or into the geohydrologic setting. Such term includes the radioactive-waste form, radioactive-waste canisters, materials placed over and around such canisters, any other components of the waste package, and ***barriers*** used to seal penetrations in and into the underground facility (DOE 1996a).

Geologic repository means a system, requiring licensing by the U.S. Nuclear Regulatory Commission, that is intended to be used, or may be used, for the permanent ***disposal*** of radioactive waste (including spent nuclear fuel) in excavated geologic media. A geologic repository includes (1) the geologic repository operations area and (2) the portion of the geologic setting that provides ***isolation*** of the radioactive waste and is located within the ***controlled area***. (DOE 1996a, adapted from 10 CFR 60.2)

Key driver means a major or very important ***driver***.

Key performance confirmation parameter means a ***performance confirmation parameter*** whose data acquisition has to be considered in the MGDS design.

License application means an application by the U.S. Department of Energy for a license from the U.S. Nuclear Regulatory Commission to construct a repository. (DOE 1996a).

Natural barrier means the physical, mechanical, chemical, and hydrologic characteristics of the geologic environment that individually and collectively act to minimize or preclude radionuclide transport. (DOE 1996a)

Near field means the region where the natural geohydrologic system has been significantly perturbed by the excavation of the repository and the emplacement of the waste. (DOE 1996a)

Q-List means in the geologic repository program, a list of structures, systems, and components important to safety, and engineered barriers important to waste isolation, that must be covered under QA requirements of 10 CFR 60, Subpart G. (NRC 1988)

Performance assessment means any analysis that predicts the behavior of a system or system component under a given set of constant and/or transient conditions. Performance assessments will include estimates of the effects of uncertainties in data and modeling. (DOE 1996a)

Performance confirmation means the program of tests, experiments, and analyses which is conducted to evaluate the accuracy and adequacy of the information used to determine with reasonable assurance that the performance objectives for the period after permanent closure will be met. [10 CFR 60.2]

Performance confirmation parameter means a parameter whose values need to be measured, monitored, observed, or tested during ***performance confirmation***.

Performance measure means a physical quantity that describes the performance of a system, system element, structure, component, or process in meeting licensing strategy for an issue. (DOE 1988)

Performance requirement means the measurable criterion that identifies a quality attribute of a function or how well a functional ***requirement*** must be accomplished. [IEEE Std. 1220-1994]

Requirement means a statement identifying a capability, physical characteristic, or quality factor that bounds a product or process need for which a solution will be pursued. [IEEE Std. 1220-1994]

Site characterization means 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, including 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 not including preliminary borings and geophysical testing needed to assess whether site characterization should be undertaken. (DOE 1996a, adapted from 10 CFR 60.2)

Systems engineering means a process for systemically applying science and engineering principles to control a complex total system development effort for the purpose of achieving an optimum balance of all system elements. It is a process that transforms and integrates operational needs and requirements into a description of system ***requirements*** to maintain the overall system effectiveness. (DOE 1996a)

Total system performance assessment means the evaluation of the ability of the overall system to meet the performance objectives specified in applicable regulatory standards. Total system ***performance assessments*** explicitly acknowledge the uncertainty in the process models and parameters and strive to evaluate the impact of this uncertainty on the overall system performance. (CRWMS M&O 1995a)

Unqualified data means data developed prior to the implementation of an NRC approved quality assurance program that meets the Office of Civilian Radioactive Waste Management requirements or data developed outside an approved NRC Quality Assurance Program such as by oil companies, universities, or data published in technical or scientific publications. Unqualified data does not include information accepted by the scientific and engineering community as established fact. (DOE 1996b)

Viability assessment means the CRWMS Program judgement about the prospects for geologic disposal at the Yucca Mountain site, based on repository and waste package designs, a ***total system performance assessment***, a licensing completion plan, and repository cost and schedule estimates. (DOE 1996a)

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