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TECHNICAL SUPPORT DOCUMENT FOR

SECTION 194.32: SCOPE OF PERFORMANCE ASSESSMENTS

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Executive Summary

40 CFR §194.32 mandates the identification of all "processes, events, or sequences and combinations of processes and events" that may affect the disposal system. This Technical Support Document summarizes the Compliance Certification Application (CCA) Features, Events, and Processes (FEP) development process used by DOE, and provides EPA's detailed review of each FEP included in the CCA listing.

DOE began their analysis by assembling FEPs from nine international FEP analyses. This listing is referred to as the Swedish Nuclear Power Inspectorate (SKI) list, and includes approximately 1200 individual FEPs. EPA examined the listing and found it to be a sufficient for derivation of the Draft Compliance Certification Application (DCCA) listing of 900 FEPs. EPA also examined the 900 FEPs included in the DCCA, and concluded that the DOE adequately evaluated the DCCA listing to derive the CCA FEP listing of approximately 240 FEPs. Refer to EPA's **CARD 32--Scope of Performance Assessment** (Docket No. A-93-02, V-B-2) for discussion of EPA's SKI listing and DCCA FEP evaluations.

EPA reviewed each of the nearly 240 FEPs included in the CCA. Table 3 of this Technical Support Document summarizes DOE's evaluation of each FEP, and cross references each FEP (which have been assigned numbers) with EPA's FEP analysis presented in Section 4. As presented in Table 3 and Section 4, DOE divided FEPs into three categories: Natural Systems, Waste and Repository Induced, and Human Induced. EPA concluded that the DOE's FEP screening analysis is technically adequate, based upon information presented in the CCA, additional reference information, and supplemental information submitted by DOE subsequent to the CCA submission.

This Technical Support Document, Section 5, also summarizes those CCA FEPs which were subject to supplemental analysis by DOE. Section 6 presents a table prepared by DOE which cross-references those FEPs retained for analysis in PA with the treatment of that FEP in PA.

1. Introduction

40 CFR §194.32 requires DOE's performance assessments to consider natural processes and events and human-induced (e.g. mining) conditions. Detailed assessment of mining and oil/gas-related activities are to be addressed specifically and in significant detail, but §194.32(e) also mandates the identification of all "processes, event or sequences and combinations of processes and events" that may affect the disposal system. This requirement is based upon the assessment of features, events, and processes (FEPs) potentially relevant to the WIPP, and is a fundamental step in the performance assessment process.

Features, events, and processes can be described in different groupings or categorizations, but DOE has, in the case of the CCA, chosen to group FEPs by those pertinent to natural systems, repository/waste-related conditions, and human induced conditions, which include features (e.g. site stratigraphy), events (e.g.tectonic activity), and processes (e.g. dissolution of salt within strata). Scenarios are combinations of FEPs retained after the FEP screening process, which are instrumental to the PA process because the calculation of probabilities and consequences (CCDF construction), is based upon scenarios generated through FEP analysis.

This Technical Support Document summarizes the CCA FEP development process used by DOE, and provides EPA's detailed review of each FEP included in the CCA listing. The following are included:

- Section 1: Introduction

- Section 2: Swedish Nuclear Power Inspectorate (SKI) FEP list and the DCCA FEP List. Section 2 includes the initial FEP listing examined by DOE compiled by the Swedish which presents over 1200 individual FEPS. This section also presents the DCCA listing derived from the initial 1200 list. Section 2 does not include EPA's review of each listing, as this is summarized in the text of **CARD 32--Scope of Performance Assessment, Section 194.32(e)(1) (Docket No. A-93-02, V-B-2).**

- Section 3: CCA Screening of Features, Events and Processes Summary Table. This table includes each FEP identified by DOE in the CCA and it's subsequent screening classification. DOE has numbered each FEP by category. For example, The Natural Systems FEPs are identified by and "N" followed by a DOE assigned FEP number that corresponds to FEPs discussed in Appendix SCR. Repository/Waste FEPs are designated by a "W", while Human Induced FEPs are prefaced by an "H".

- Section 4: CCA FEP Analysis. This section provides EPA's evaluation of DOE's screening decisions for each of the FEPs identified in the CCA. When possible, EPA's analysis was applied to similar FEP groupings, if the supporting information and subsequent EPA examination were common to all FEPs within that grouping. The last column of the Screening of Features, Events and Processes Summary Table provided in Section 3 presents the EPA's FEP Comment Number (which is equivalent to DOE's FEP number), linking the information presented in Section 3 with that in Section 4.

- Section 5: CCA FEPs That Were Subject to Side Efforts-Summary Table. Section 5 presents a listing of those CCA FEPs that underwent side effort analysis as part of the DOE's DCCA to CCA screening process. This table is a revised version of a similar table prepared by DOE.

- Section 6: Treatment of FEPs Accounted for in Performance Assessment Calculations-Summary Table. Section 6 is a table prepared by the DOE which presents how FEPs retained by DOE for PA are subsequently included in PA. The table has not been revised by EPA.

2. Swedish Nuclear Power Inspectorate (SKI) FEPs List and DCCA FEP List

2.1 Swedish Nuclear Power Inspectorate (SKI) FEPs List

The composite list presented in the following table contains all FEPs from nine national FEP analysis exercises, as presented in Stenhouse, M.J., N.A. Chapman, and T.J. Sumerling, 1993,. SITE-94 Scenario Development FEP Audit List Preparation: Methodology and Presentation. SKI Technical Report 93:27. Stockholm: Swedish Nuclear Power Inspectorate. 1993 (Docket No. A-93-02, III-G-1, Ref. 605). The nine national exercises included in the table are:

- Atomic Energy of Canada, Limited (AECL)
- DOE: Fry Run 3, U.K. Department of Environment (DOE)
- International Atomic Energy Agency: Safety Series (IAEA)
- National Cooperative for the Storage of Radioactive Waste: Nagra, Switzerland (PGA)
- Swedish Nuclear Power Inspectorate Swedish Nuclear Fuel and Waste Management (SKI)
- Sandia National Laboratories, U.S. (SNL)
- U.K. Nuclear Industry Radioactive Waste Executive (UKN)
- U.K. Department of Environment, Sellafield Assessment (HMIP)
- Nuclear Energy Agency: Safety Assessment (NEA)

IDENTIFIER	FEP NAME
AECL1. VAULT FACTORS	
AECL1.1	Backfill characteristics
AECL1.2	Backfill evolution
AECL1.3	Biological activity
AECL1.4	Boundary conditions
AECL1.5	Buffer additives
AECL1.6	Buffer characteristics
AECL1.7	Buffer evolution
AECL1.8	Cave in
AECL1.9	Chemical gradients
AECL1.10	Chemical interactions (expected)
AECL1.11	Chemical interactions (long-term)
AECL1.12	Chemical interactions (other)
AECL1.13	Chemical kinetics
AECL1.14	Climate change
AECL1.15	Colloids
AECL1.16	Complexation by organics
AECL1.17	Concrete
AECL1.18	Container corrosion products
AECL1.19	Container failure (early)
AECL1.20	Container failure (long-term)
AECL1.21	Container failure (other long-term processes)
AECL1.22	Container healing
AECL1.23	Container - partial corrosion
AECL1.24	Convection
AECL1.25	Correlation
AECL1.26	Corrosion
AECL1.27	Coupled processes
AECL1.28	Criticality
AECL1.29	Diffusion
AECL1.30	Dispersion
AECL1.31	Earthquakes
AECL1.32	Electrochemical gradients
AECL1.33	Evolution of buffer
AECL1.34	Excessive hydrostatic pressures
AECL1.35	Explosions
AECL1.36	Faulty buffer emplacement
AECL1.37	Formation of cracks
AECL1.38	Formation of gases
AECL1.39	Galvanic coupling
AECL1.40	Geochemical pump
AECL1.41	Claciation
AECL1.42	Global effects
AECL1.43	Hydraulic conductivity
AECL1.44	Hydraulic head
AECL1.45	Hydride cracking

IDENTIFIER	FEP NAME
AECL1.46	Hydrothermal alteration
AECL1.47	Improper operation
AECL1.48	Incomplete closure
AECL1.49	Incomplete filing of containers
AECL1.50	Interfaces (boundary conditions)
AECL1.51	Intrusion (animal)
AECL1.52	Intrusion (human)
AECL1.53	Inventory
AECL1.54	Other waste (other than vitrified HLW)
AECL1.55	Long-term physical stability
AECL1.56	Long-term transients
AECL1.57	Methylation
AECL1.58	Microbes
AECL1.59	Microorganisms
AECL1.60	Monitoring and remedial activities
AECL1.61	Mutation
AECL1.62	Percolation in shafts
AECL1.63	Pitting
AECL1.64	Preclosure events
AECL1.65	Precipitation and dissolution
AECL1.66	Pseudo-colloids
AECL1.67	Radiation damage
AECL1.68	Radioactive decay
AECL1.69	Radiolysis
AECL1.70	Recharge groundwater
AECL1.71	Reflooding
AECL1.72	Retrievability
AECL1.73	Sabotage and improper operation
AECL1.74	Seal evolution
AECL1.75	Seal failure
AECL1.76	Sorption
AECL1.77	Sorption: non-linear
AECL1.78	Source terms (expected)
AECL1.79	Source terms (other)
AECL1.80	Speciation
AECL1.81	Stability
AECL1.82	Stability of gases
AECL1.83	Swelling pressure
AECL1.84	Temperature rises (unexpected effects)
AECL1.85	Time dependence
AECL1.86	Transport in gases or of gases
AECL1.87	Uncertainties
AECL1.88	Uniform corrosion
AECL1.89	Unmodelled design features
AECL1.90	Unsaturated transport
AECL1.91	Vault geometry

IDENTIFIER	FEP NAME
AECL2. GEOSPHERE FACTORS	
AECL2.1	Blasting and vibration
AECL2.2	Bomb blast
AECL2.3	Borehole - well
AECL2.4	Borehole seal failure/open boreholes
AECL2.5	Boreholes - exploration
AECL2.6	Boreholes - unsealed
AECL2.7	Cavitation
AECL2.8	Climate change
AECL2.9	Colloid formation
AECL2.10	Complexation by organics
AECL2.11	Conceptual model - hydrology
AECL2.12	Correlation
AECL2.13	Dams
AECL2.14	Dewatering
AECL2.15	Diffusion
AECL2.16	Discharge zones
AECL2.17	Dispersion
AECL2.18	Drought
AECL2.19	Earthmoving
AECL2.20	Earthquakes
AECL2.21	Erosion
AECL2.22	Explosion
AECL2.23	Faulting
AECL2.24	Flood
AECL2.25	Fulvic acid
AECL2.26	Gases and gas transport
AECL2.27	Geothermal gradient effects
AECL2.28	Glaciation
AECL2.29	Greenhouse effect
AECL2.30	Groundwater - evolution
AECL2.31	Groundwater composition change
AECL2.32	Humic acid
AECL2.33	Hydraulic properties - evolution
AECL2.34	Intrusion (magmatic)
AECL2.35	Intrusion (mines)
AECL2.36	Isostatic rebound
AECL2.37	Magmatic activity
AECL2.38	Magnetic poles
AECL2.39	Matrix diffusion
AECL2.40	Metamorphic activity
AECL2.41	Meteorite
AECL2.42	Methane
AECL2.43	Microbes
AECL2.44	Mines
AECL2.45	Ozone layer

IDENTIFIER	FEP NAME
AECL2.46	Precipitation - dissolution
AECL2.47	Pseudo - colloids
AECL2.48	Radioactive decay
AECL2.49	Radiolysis, radiation damage
AECL2.50	Recharge groundwater
AECL2.51	Rock properties
AECL2.52	Rock properties - undetected features
AECL2.53	Sabotage
AECL2.54	Salinity effects on flow
AECL2.55	Saturation
AECL2.56	Shaft seal failure
AECL2.57	Solution mining
AECL2.58	Sorption
AECL2.59	Sorption - non-linear
AECL2.60	Speciation
AECL2.61	Topography - current
AECL2.62	Topography - future
AECL2.63	Turbulence
AECL2.64	Uncertainties
AECL2.65	Unsaturated rock
AECL2.66	Vault closure (incomplete)
AECL2.67	Vault heating effects
AECL2.68	Vulcanisms
AECL2.69	Wells
AECL2.70	Wells (high demand)
AECL3. BIOSPHERE FACTORS	
AECL3.1	Acid rain
AECL3.2	Alkali flats
AECL3.3	Animal grooming and fighting
AECL3.4	Animal soil ingestion
AECL3.5	Animals' diets
AECL3.6	Artificial lake mixing
AECL3.7	Ashes and sewage sludge
AECL3.8	Bacteria and microbes (soil)
AECL3.9	Bioconcentration
AECL3.10	Bio gas production
AECL3.11	Biological evolution
AECL3.12	Biotoxicity
AECL3.13	Bioturbation of soils and sediments
AECL3.14	Building materials
AECL3.15	Burrowing animals
AECL3.16	Capillary rise in soil
AECL3.17	Carcasses
AECL3.18	Carcinogenic contaminants
AECL3.19	Charcoal production
AECL3.20	Chemical precipitation

IDENTIFIER	FEP NAME
AECL3.21	Chemical toxicity
AECL3.22	Climate
AECL3.23	Climate - evolution
AECL3.24	Collisions, explosions, impacts
AECL3.25	Colloids
AECL3.26	Convection, tubulence and diffusion (atmospheric)
AECL3.27	Correlation
AECL3.28	Critical group - agricultural labour
AECL3.29	Critical group - clothing and home furnishings
AECL3.30	Critical group - evolution
AECL3.31	Critical group - house location
AECL3.32	Critical group - individuality
AECL3.33	Critical group - leisure pursuits
AECL3.34	Critical group - pets
AECL3.35	Crop fertilization
AECL3.36	Crop storage
AECL3.37	Cure for cancer
AECL3.38	Deposition (wet and dry)
AECL3.39	Dermal sorption - nuclides other than tritium
AECL3.40	Dermal sorption - tritium
AECL3.41	Dispersion
AECL3.42	Dust storms and decertification (massive)
AECL3.43	Earthmoving projects (major)
AECL3.44	Earthquakes
AECL3.45	Erosion - lateral transport
AECL3.46	Erosion - wind
AECL3.47	Fires (agricultural)
AECL3.48	Fires (forest and grass)
AECL3.49	Fish farming
AECL3.50	Flipping of earth’s magnetic poles
AECL3.51	Flood (short-term)
AECL3.52	Flushing of water bodies
AECL3.53	Food preparation
AECL3.54	Game ranching
AECL3.55	Gas leakage into underground living space
AECL3.56	Glaciation
AECL3.57	Greenhouse (food production)
AECL3.58	Greenhouse effect
AECL3.59	Groundshine, treeshine
AECL3.60	Heat storage in lakes or underground
AECL3.61	Herbicides, pesticides, fungicides
AECL3.62	Household dust and fumes
AECL3.63	Houseplants
AECL3.64	Human diet
AECL3.65	Human soil ingestion
AECL3.66	Hydroponics

IDENTIFIER	FEP NAME
AECL3.67	Industrial use of water
AECL3.68	Inject/ingest/inhaling locally produced drugs
AECL3.69	Intrusion (deliberate)
AECL3.70	Intrusion (inadvertent)
AECL3.71	Ionic exchange in soil
AECL3.72	Irrigation
AECL3.73	Lake infilling
AECL3.74	Mutagenic contaminants
AECL3.75	Outdoor spraying of water
AECL3.76	Ozone layer failure
AECL3.77	Peat and leaf litter harvesting
AECL3.78	Plant root systems
AECL3.79	Precipitation (meteoric)
AECL3.80	Radioactive decay
AECL3.81	Radiotoxic contaminants
AECL3.82	Radon emission
AECL3.83	Rivercourse meander
AECL3.84	Runoff
AECL3.85	Saltation
AECL3.86	Scavengers and predators
AECL3.87	Seasons
AECL3.88	Sediment resuspension in water bodies
AECL3.89	Sedimentation in water bodies
AECL3.90	Sensitization to radiation
AECL3.91	Showers and humidifiers
AECL3.92	Smoking
AECL3.93	Soil
AECL3.94	Soil depth
AECL3.95	Soil leaching
AECL3.96	Soil porewater pH
AECL3.97	Soil sorption
AECL3.98	Soil type
AECL3.99	Space heating
AECL3.100	Surface water bodies
AECL3.101	Surface water pH
AECL3.102	Suspension in air
AECL3.103	Technological advances in food production
AECL3.104	Teratogenic contaminants
AECL3.105	Terrestrial surface
AECL3.106	Toxicity of mined rock
AECL3.107	Tree sap
AECL3.108	Uncertainties
AECL3.109	Urbanization on the discharge site
AECL3.110	Water leak into underground living space
AECL3.111	Water management projects (major)
AECL3.112	Water source

IDENTIFIER	FEP NAME
AECL3.113	Wetlands
AECL3.114	Wind
DOE1.1.1	**Structural container metal corrosion**
DOE1.1.1.1	Structural container metal corrosion: Localized
DOE1.1.1.2	Structural container metal corrosion: Bulk
DOE1.1.1.3	Structural container metal corrosion: Crevice
DOE1.1.1.4	Structural container metal corrosion: Stress corrosion cracking
DOE1.1.2	**Physical degradation of concrete**
DOE1.1.2.1	Cracking: concrete
DOE1.1.2.2	Sealing of cracks: concrete
DOE1.1.2.3	Pore blockage: concrete
DOE1.1.2.4	Alkali-aggregate reaction: concrete
DOE1.1.2.5	Cement-sulphate reaction: concrete
DOE1.1.3	**Chemical degradation of concrete**
DOE1.1.3.1	Changes in pore water composition, pH, Eh: concrete
DOE1.1.3.2	Exchange capacity exceeded: concrete
DOE1.1.3.3	Alkali-aggregate reactions: concrete
DOE1.1.3.4	Cement-sulphate reaction: concrete
DOE1.1.4	**Degradation of wastes**
DOE1.1.4.1	Metal corrosion: wastes
DOE1.1.4.2	Leaching: wastes
DOE1.1.4.3	Complex formation: wastes
DOE1.1.4.4	Colloid formation: wastes
DOE1.1.4.5	Microbial degradation of organic wastes: wastes
DOE1.1.4.6	Microbial corrosion: wastes
DOE1.1.4.7	Radiolysis: wastes
DOE1.2.1	**Hydrogen by metal corrosion**
DOE1.2.1.1	Hydrogen: corrosion of structural steel
DOE1.2.1.2	Hydrogen: corrosion of container steel
DOE1.2.1.3	Hydrogen: corrosion of waste steel
DOE1.2.1.4	Hydrogen: corrosion of waste Magnox
DOE1.2.1.5	Hydrogen: corrosion of waste aluminum
DOE1.2.1.6	Hydrogen: corrosion of waste Zircaloy
DOE1.2.1.7	Hydrogen: corrosion of other waste metals
DOE1.2.1.8	Hydrogen: effects of microbial growth on concrete
DOE1.2.2	**Methane and carbon dioxide by microbial degradation**
DOE1.2.2.1	Methane/CO2: degradation of Cellulosics
DOE1.2.2.2	Methane/CO2: degradation of Other susceptible organic materials
DOE1.2.2.3	Methane/CO2 production: Aeorbic degradation
DOE1.2.2.4	Methane/CO2 production: Anaerobic degradation
DOE1.2.2.5	Methane/CO2 production: Effects of temperature
DOE1.2.2.6	Methane/CO2 production: Effects of lithostatic pressure
DOE1.2.2.7	Methane/CO2 production: Effects of microbial growth on properties of concrete
DOE1.2.2.8	Methane/CO2 production: Effects of biofilms
DOE1.2.2.9	Methane/CO2 production: Effects of hydrogen from metal corrosion
DOE1.2.2.10	Methane/CO2 production: Inhibition due to the pressure of toxic materials

IDENTIFIER	FEP NAME
DOE1.2.2.11	Methane/CO2 production: Carbonate/bicarbonate exchange with concrete
DOE1.2.2.12	Methane/CO2 production: Energy and nutrient control of metabolism
DOE1.2.2.13	Methane/CO2 production: Effects of radiation on microbial populations
DOE1.2.3	Gas generation from concrete
DOE1.2.4	**Active gases**
DOE1.2.4.1	Tritiated hydrogen
DOE1.2.4.2	Active methane and carbon dioxide
DOE1.2.4.3	Other active gases
DOE1.2.5	Toxic gases
DOE1.2.6	**Gas transport**
DOE1.2.6.1	Gas transport in the waste container
DOE1.2.6.2	Gas transport in the vaults between containers
DOE1.2.6.3	Gas transport between vaults
DOE1.2.6.4	Gas transport in the near-field, including up and around access shafts and attics
DOE1.2.6.5	Gas transport into and through the far-field
DOE1.2.7	**Flammability**
DOE1.2.7.1	Fires
DOE1.2.7.2	Explosions
DOE1.3.1	Radioactive decay and ingrowth
DOE1.3.2	Nuclear criticality
DOE1.4.1	Canister or container movement
DOE1.4.2	Changes in insitu stress field
DOE1.4.3	Embrittlement
DOE1.4.4	**Subsidence/collapse**
DOE1.4.4.1	Repository induced subsidence
DOE1.4.4.2	Natural subsidence
DOE1.4.5	Rock creep
DOE1.4.6	Fracturing
DOE1.5.1	**Changes in moisture content**
DOE1.5.1.1	Changes in moisture content due to dewatering
DOE1.5.1.2	Changes in moisture content due to stress relief
DOE1.5.2	**Groundwater flow (unsaturated conditions)**
DOE1.5.2.1	Groundwater flow initial conditions
DOE1.5.2.2	Groundwater flow due to gas production
DOE1.5.3	Groundwater flow (saturated conditions)
DOE1.5.4	**Transport of chemically active substances into the near-field**
DOE1.5.4.1	Transport of Inorganic ions into the near-field
DOE1.5.4.2	Transport of Humic and fulvic acids into the near-field
DOE1.5.4.3	Transport of Microbes into the near-field
DOE1.5.4.4	Transport of Organic complexes into the near-field
DOE1.5.4.5	Transport of Colloids into the near-field
DOE1.6.1	Differential elastic response
DOE1.6.2	Non-elastic response
DOE1.6.3	**Fracture changes**
DOE1.6.3.1	Fracture changes: aperture
DOE1.6.3.2	Fracture changes: length

IDENTIFIER	FEP NAME
DOE1.6.4	**Hydrological changes**
DOE1.6.4.1	Hydrological changes: Fluid pressure
DOE1.6.4.2	Hydrological changes: Density
DOE1.6.4.3	Hydrological changes: Viscosity
DOE1.6.5	**Chemical changes**
DOE1.6.5.1	Chemical changes due to Metal corrosion
DOE1.6.5.2	Chemical changes due to Concrete degradation
DOE1.6.5.3	Chemical changes due to Waste degradation
DOE1.6.5.4	Chemical changes due to Gas production
DOE1.6.5.5	Chemical changes due to Complex formation
DOE1.6.5.6	Chemical changes due to Colloid production
DOE1.6.5.7	Chemical changes due to Solubility
DOE1.6.5.8	Chemical changes due to Sorption
DOE1.6.5.9	Chemical changes due to Species equilibrium
DOE1.6.6	**Microbiological effects**
DOE1.6.6.1	Microbiological effects due to Cellulose degradation
DOE1.6.6.2	Microbiological effects due to Microbial activity
DOE1.6.6.3	Microbiological effects due to Microbial product reactions
DOE2.1.1	Meteorite impact
DOE2.2.1	**Regional tectonic**
DOE2.2.1.1	Uplift
DOE2.2.1.2	Subsidence
DOE2.2.1.3	Lateral and/or vertical flexure
DOE2.2.2	**Magmatic**
DOE2.2.2.1	Magmatic: Intrusive
DOE2.2.2.2	Magmatic: Extrusive
DOE2.2.2.3	Magmatic: Hydrothermal
DOE2.2.3	**Metamorphism**
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DOE2.2.3.2	Regional metamorphism
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DOE2.2.7.2	Faulting/fracturing: Generation
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DOE2.2.8	Major incision
DOE2.2.9	Weathering
DOE2.2.10	Effects of natural gases
DOE2.2.11	Geothermal effects
DOE2.3.1	Variation in groundwater recharge

IDENTIFIER	FEP NAME
DOE2.3.2	Groundwater losses (direct evaporation, springflow)
DOE2.3.3	**Rock property changes**
DOE2.3.3.1	Rock property changes: Porosity
DOE2.3.3.2	Rock property changes: Permeability
DOE2.3.3.3	Rock property changes: Microbial pore blocking
DOE2.3.3.4	Rock property changes: Channel formation/closure
DOE2.3.4	**Groundwater flow**
DOE2.3.4.1	Groundwater flow: Darcy
DOE2.3.4.2	Groundwater flow: Non-Darcy
DOE2.3.4.3	Groundwater flow: Intergranular (matrix)
DOE2.3.4.4	Groundwater flow: Fracture
DOE2.3.4.5	Groundwater flow: Effects of solution channels
DOE2.3.4.6	Inorganic colloid transport Porous media
DOE2.3.5	**Inorganic colloid transport: Fractured media**
DOE2.3.5.1	Inorganic colloid transport: Effects of Ph and Eh
DOE2.3.5.2	Inorganic colloid transport: Effects of ionic strength
DOE2.3.5.3	Salinity: implications of evaporite deposits/minerals
DOE2.3.6	Variations in groundwater temperature
DOE2.4.1	Advection
DOE2.4.2	**Diffusion**
DOE2.4.2.1	Bulk diffusion
DOE2.4.2.2	Matrix diffusion
DOE2.4.2.3	Surface diffusion
DOE2.4.3	Hydrodynamic dispersion
DOE2.4.4	**Solubility constraints**
DOE2.4.4.1	Solubility: effects of pH and Eh
DOE2.4.4.2	Solubility: effects of ionic strength
DOE2.4.4.3	Solubility: effects of naturally-occurring complexing agents
DOE2.4.4.4	Solubility: effects of complexing agents formed in the near-field
DOE2.4.4.5	Solubility: effects of naturally-occurring colloids
DOE2.4.4.6	Solubility: effects of colloids formed in the near-field
DOE2.4.4.7	Solubility: effects of major ions migrating from the near-field
DOE2.4.4.8	Solubility: effects of microbial activity
DOE2.4.5	**Sorption**
DOE2.4.5.1	Linear sorption
DOE2.4.5.2	Non-linear sorption
DOE2.4.5.3	Reversible sorption
DOE2.4.5.4	Irreversible sorption
DOE2.4.5.5	Sorption: Effects of pH and Eh
DOE2.4.5.6	Sorption: Effects of ionic strength
DOE2.4.5.7	Sorption: Effects of naturally-occurring organic complexing agents
DOE2.4.5.8	Sorption: Effects of naturally-occurring inorganic complexing agents
DOE2.4.5.9	Sorption: Effects of complexing agents formed in the near-field
DOE2.4.5.10	Sorption: Effects of naturally-occurring colloids
DOE2.4.5.11	Sorption: Effects of colloids formed in the near-field
DOE2.4.5.12	Sorption: Effects of major ions migrating from the near field

IDENTIFIER	FEP NAME
DOE2.4.5.13	Sorption: Effects of microbial activity
DOE2.4.6	Fracture mineralization
DOE2.4.7	**Organic colloid transport**
DOE2.4.7.1	Organic colloid transport Porous media
DOE2.4.7.2	Organic colloid transport Fractured media
DOE2.4.7.3	Organic colloid transport Effects of Ph and Eh
DOE2.4.7.4	Organic colloid transport Effects of ionic strength
DOE2.4.8	**Inorganic colloid transport**
DOE2.4.8.1	Inorganic colloid transport: Porous media
DOE2.4.8.2	Inorganic colloid transport: Fractured media
DOE2.4.8.3	Inorganic colloid transport: Effects of pH and Eh
DOE2.4.8.4	Inorganic colloid transport: Effects of ionic strength
DOE2.4.9	Transport of radionuclides bound to microbes
DOE2.4.10	Isotopic dilution
DOE2.4.11	**Gas transport**
DOE2.4.11.1	Gas transport: solution
DOE1.4.11.2	Gas transport: gas phase
DOE1.4.12	Gas-induced groundwater transport
DOE1.4.13	**Thermally-induced groundwater transport**
DOE1.4.13.1	Repository thermally-induced groundwater transport
DOE1.4.13.2	Naturally thermally-induced groundwater transport
DOE1.4.14	Biogeochemical changes
DOE3.1.1	**Transient greenhouse gas induced warning**
DOE3.1.1.1	Greenhouse-induced Precipitation
DOE3.1.1.2	Greenhouse-induced Temperature
DOE3.1.1.3	Greenhouse-induced Sea level changes
DOE3.1.1.4	Greenhouse-induced Storm surges
DOE3.1.1.5	Greenhouse-induced Ecological effects
DOE3.1.1.6	Greenhouse-induced Potential evaporation
DOE3.1.2	**Glacial/interglacial cycling**
DOE3.1.2.1	Glacial/interglacial cycling: Precipitation
DOE3.1.2.2	Glacial/interglacial cycling: Temperature
DOE3.1.2.3	Glacial/interglacial cycling: Sea level changes (rise/fall)
DOE3.1.2.4	Glacial/interglacial cycling: Storm surges
DOE3.1.2.5	Glacial/interglacial cycling: Ecological effects
DOE3.1.2.6	Glacial/interglacial cycling: Seasonally frozen ground
DOE3.1.2.7	Glacial/interglacial cycling: Permanently frozen ground
DOE3.1.2.8	Glacial/interglacial cycling: Glaciation
DOE3.1.2.9	Glacial/interglacial cycling: Deglaciation
DOE3.1.2.10	Glacial/interglacial cycling: Potential evaporation
DOE3.1.3	**Exit from glacial/interglacial cycling:**
DOE3.1.3.1	Glacial/interglacial exit: greenhouse gas induced
DOE3.1.3.2	Glacial/interglacial exit due to other causes
DOE3.2.1	**Generalized denudation**
DOE3.2.1.1	Generalized denudation: Fuvial
DOE3.2.1.2	Generalized denudation: Aeolian

IDENTIFIER	FEP NAME
DOE3.2.1.3	Generalized denudation: Glacial
DOE3.2.2	**Localized denudation**
DOE3.2.2.1	Localized denudation: Fluvial (valley incision)
DOE3.2.2.2	Localized denudation: Fluvial (weathering/mass movement)
DOE3.2.2.3	Localized denudation: Glacial
DOE3.2.2.4	Localized denudation: Coastal
DOE3.2.3	**Sediment redistribution**
DOE3.2.3.1	Sediment redistribution: Fluvial
DOE3.2.3.2	Sediment redistribution: Aeolian
DOE3.2.3.3	Sediment redistribution: Glacial
DOE3.2.4	**Effects of sea level change**
DOE3.2.4.1	River incision/sedimentation due to seal-level change
DOE3.2.4.2	Coastal erosion due to seal-level change
DOE3.3.1	Seal moisture and evaporation due to seal-level change
DOE3.3.2	**Near-surface runoff processes**
DOE3.3.2.1	Near-surface runoff processes: Overland flow
DOE3.3.2.2	Near-surface runoff processes: Interflow
DOE3.3.2.3	Near-surface runoff processes: Return flow
DOE3.3.2.4	Near-surface runoff processes: Macropore flow
DOE3.3.2.5	Near-surface runoff processes: Variable source area response
DOE3.3.3	Groundwater recharge
DOE3.3.4	**Surface flow characteristics (freshwater)**
DOE3.3.4.1	Surface flow characteristics (freshwater): Stream/river flow
DOE3.3.4.2	Surface flow characteristics (freshwater): Sediment transport
DOE3.3.4.3	Surface flow characteristics (freshwater): Meander migration or other fluvial response
DOE3.3.4.4	Surface flow characteristics (freshwater): Lake formation/sedimentation
DOE3.3.4.5	Surface flow characteristics (freshwater): Effects of sea level change
DOE3.3.5	**Surface flow characteristics (estuarine)**
DOE3.3.5.1	Surface flow characteristics (estuarine): Tidal cycling
DOE3.3.5.2	Surface flow characteristics (estuarine): Sediment transport
DOE3.3.5.3	Surface flow characteristics (estuarine): Successional development
DOE3.3.5.4	Surface flow characteristics (estuarine): Effects of sea level change
DOE3.3.6	**Coastal waters**
DOE3.3.6.1	Coastal waters: Tidal mixing
DOE3.3.6.2	Coastal waters: Residual current mixing
DOE3.3.6.3	Coastal waters: Effects of sea level change
DOE3.3.7	**Ocean waters**
DOE3.3.7.1	Ocean waters: Water exchange
DOE3.3.7.2	Ocean waters: Effects of sea level change
DOE3.4.1	**Terrestrial ecological development**
DOE3.4.1.1	Terrestrial ecological development: Agricultural systems
DOE3.4.1.2	Terrestrial ecological development: Semi-natural systems
DOE3.4.1.3	Terrestrial ecological development: Natural system
DOE3.4.1.4	Terrestrial ecological development: Effects of succession
DOE3.4.2	Terrestrial ecological development: Estuarine
DOE3.4.3	Coastal water

IDENTIFIER	FEP NAME
DOE3.4.4	Oceans
DOE3.5.1	**Erosion**
DOE3.5.1.1	Erosion: Fluvial
DOE3.5.1.2	Erosion: Aeolian
DOE3.5.1.3	Erosion: Glacial
DOE3.5.1.4	Erosion: Coastal
DOE3.5.2	**Groundwater discharge to soils**
DOE3.5.2.1	Groundwater discharge to soils: Advective
DOE3.5.2.2	Groundwater discharge to soils: Diffusive
DOE3.5.2.3	Groundwater discharge to soils: Biotic
DOE3.5.2.4	Groundwater discharge to soils: Volatilisation
DOE3.5.3	Groundwater discharge to wells or springs
DOE3.5.4	Groundwater discharge to freshwaters
DOE3.5.5	Groundwater discharge to estuaries
DOE3.5.6	Groundwater discharge to coastal waters
DOE3.5.7	**Surface water bodies**
DOE3.5.7.1	Surface water bodies: Water flow
DOE3.5.7.2	Surface water bodies: Suspended sediments
DOE3.5.7.3	Surface water bodies: Bottom sediments
DOE3.5.7.4	Surface water bodies: Effects on vegetation
DOE3.5.7.5	Surface water bodies: Effects of fluvial system development
DOE3.5.8	**Estuaries**
DOE3.5.8.1	Estuaries: Water flow
DOE3.5.8.2	Estuaries: Suspended sediments
DOE3.5.8.3	Estuaries: Bottom sediments
DOE3.5.8.4	Estuaries: Effects of salinity variation
DOE3.5.8.5	Estuaries: Effects on vegetation
DOE3.5.8.6	Estuaries: Effects of estuarine development
DOE3.5.8.7	Estuaries: Effects of sea level change
DOE3.5.9	**Coastal waters**
DOE3.5.9.1	Coastal waters: Water transport
DOE3.5.9.2	Coastal waters: Suspended sediment transport
DOE3.5.9.3	Coastal waters: Bottom sediment transport
DOE3.5.9.4	Coastal waters: Effects of sea level change
DOE3.5.9.5	Coastal waters: Effects of estuarine development
DOE3.5.9.6	Coastal waters: Effects of coastal erosion
DOE3.5.9.7	Coastal waters: Effects of sea-level change
DOE3.5.10	**Plants**
DOE3.5.10.1	Plants: Root uptake
DOE3.5.10.2	Plants: Deposition on surfaces
DOE3.5.10.3	Plants: Vapour uptake
DOE3.5.10.4	Plants: Internal translocation and retention
DOE3.5.10.5	Plants: Washoff and leaching by rainfall
DOE3.5.10.6	Plants: Leaf-fall and senescence
DOE3.5.10.7	Plants: Cycling processes
DOE3.5.11	**Animals**

IDENTIFIER	FEP NAME
DOE3.5.11.1	Animals: Uptake by ingestion
DOE3.5.11.2	Animals: Uptake by inhalation
DOE3.5.11.3	Animals: Internal translocation and retention
DOE3.5.11.4	Animals: Cycling processes
DOE3.5.11.5	Animals: Effects of relocation and migration
DOE3.6.1	**External exposure**
DOE3.6.1.1	External exposure: Land
DOE3.6.1.2	External exposure: Sediments
DOE3.6.1.3	External exposure: Water bodies
DOE3.6.2	**Ingestion**
DOE3.6.2.1	Ingestion and Drinking water
DOE3.6.2.2	Ingestion and Agricultural crops
DOE3.6.2.3	Ingestion and Domestic animal products
DOE3.6.2.4	Ingestion and Wild plants
DOE3.6.2.5	Ingestion and Wild animals
DOE3.6.2.6	Ingestion and Soils and sediments
DOE3.6.3	**Inhalation**
DOE3.6.3.1	Inhalation and Soils and sediments
DOE3.6.3.2	Inhalation and Gases and vapours (indoor)
DOE3.6.3.3	Inhalation and Gases and vapours (outdoors)
DOE3.6.3.4	Inhalation and Biotic material
DOE3.6.3.5	Inhalation and Salt particles
DOE4.1.1	**Investigation borehole seal**
DOE4.1.1.1	Borehole seal failure
DOE4.1.1.2	Borehole seal degradation
DOE4.1.2	**Shaft or access tunnel seal**
DOE4.1.2.1	Shaft/tunnel seal failure
DOE4.1.2.2	Shaft/tunnel seal degradation
DOE4.1.3	**Subsidence**
DOE4.1.3.1	Subsidence and fault/fracture induction
DOE4.2.1	Deliberate recovery of wastes or associated materials
DOE4.2.2	Malicious intrusion
DOE4.2.3	Exploratory drilling
DOE4.2.4	Exploitation drilling
DOE4.2.5	Geothermal energy production
DOE4.2.6	Resource mining
DOE4.2.7	Tunelling
DOE4.2.8	Construction of underground storage/disposal facilities
DOE4.2.9	Construction of underground dwelling/shelters
DOE4.2.10	Archaeological investigations
DOE4.2.11	Injection of Liquid wastes
DOE4.2.12	Groundwater abstraction
DOE4.2.13	Underground weapons testing

IDENTIFIER	FEP NAME
IAEA1.1	Climatic change
IAEA1.2	Hydrological change
IAEA 1.3	Sea level change
IAEA 1.4	Denudation
IAEA1.5	Stream erosion
IAEA1.6	Glacial erosion
IAEA1.7	Flooding
IAEA1.8	Sedimentation
IAEA1.9	Diagenesis
IAEA1.10	Diapirism
IAEA1.11	Faulting/seismicity
IAEA1.12	Geochemical change
IAEA1.13.1	Fluid interactions: Groundwater flow
IAEA1.13.2	Fluid interactions: Dissolution
IAEA1.13.3	Fluid interactions: Brine pockets
IAEA1.14.1	Uplift/Subsidence: Organic
IAEA1.14.2	Uplift/Subsidence: Epeirogenic
IAEA1.14.3	Uplift/Subsidence: Isostatic
IAEA1.15.1	Undetected features: Faults, shear zones
IAEA1.15.2	Undetected features: Breccia pipes
IAEA1.15.3	Undetected features: Lava tubes
IAEA1.15.4	Undetected features: Intrusive dykes
IAEA1.15.5	Undetected features: Gas or brine pockets
IAEA1.16.1	Magmatic activity: Extrusive
IAEA1.17	Meteorite impact
IAEA2.1.1	Undetected past intrusion: Boreholes
IAEA2.1.2	Undetected past intrusion: Mine shafts
IAEA2.2.1	Inadequate design: Shaft seal failure
IAEA2.2.2	Inadequate design: Exploration borehole seal failure
IAEA2.3	Improper operation: Improper waste emplacement
IAEA2.4.1	Transport agent introduction: Irrigation
IAEA2.4.2	Transport agent introduction: Reservoirs
IAEA2.4.3	Transport agent introduction: Intentional artificial ground water Recharge or withdrawal
AEA2.4.4	Transport agent introduction chemical liquid waste disposal
IAEA2.5	Climatic change (including climate control)
IAEA2.6	Large-scale hydrological change
IAEA2.7.1	Intentional intrusion: War
IAEA2.7.2	Intentional intrusion: Sabotage
IAEA2.7.3	Intentional intrusion: Waste recovery
IAEA2.8.1	Inadvertent future intrusion: Exploratory drilling
IAEA2.8.2	Inadvertent future intrusion: Archaeological exhumation
IAEA2.8.3	Inadvertent future intrusion: Resource mining (mineral, water, etc) hydrocarbon, geothermal,
IAEA3.1.1	Thermal effects: Differential elastic response
IAEA3.1.2	Thermal effects- Non-elastic response
IAEA3.1.3	Thermal effects: Fluid pressure, density, viscosity changes
IAEA3.1.4	Thermal effects: Fluid migration

IDENTIFIER	FEP NAME
IAEA3.2.1	Chemical effects: Corrosion
IAEA3.2.2	Chemical effects: Interactions of waste package and rock
IAEA3.2.3	Chemical effects: Gas generation
IAEA3.2.4	Chemical effects: Geochemical change
IAEA3.3.1	Mechanical effects: Canister movement
IAEA3.3.2	Mechanical effects: local fracturing
IAEA3.4.1	Radiological effects: Material property changes
IAEA3.4.2	Radiological effects: Radiolysis
IAEA3.4.3	Radiological effects: Decay product gas generation
IAEA3.4.4	Radiological effects: Nuclear criticality

IDENTIFIER	FEP NAME
PGA1. SLOW NATURAL PROCESSES	
PGA1.1	Climate changes
PGA1.2	Sea-level changes
PGA1.3	Erosion (fluvial and glacial)
PGA1.4	Sedimentation
PGA1.5	Tectonic crustal movements
PGA.1.6	Magma intrusion
PGA1.7	Volcanism
PGA1.8	Diaprism
PGA1.9	Diagenesis
PGA1.10	Matamorphosis
PGA1.11	Weathering, mineralization
PGA1.12	Groundwater changes
PGA.2 RAPID NATURAL EVENTS	
PGA2.1	Earthquakes
PGA2.2	Volcanic eruption
PGA2.3	Meteor impact
PGA2.4	Flooding with extreme erosion
PGA2.5	Hurricane, storms
PGA2.6	Movements at faults
PGA2.7	Formation of new faults
PGA3 CAUSED BY DISPOSAL OF WASTE	
PGA3.1	Radiation damage of the matrix
PGA3.2	Radiolysis
PGA3.3	Nuclear criticality
PGA3.4	Canister movement in backfill
PGA3.5	Decompressed zones from mining
PGA3.6	Mechanical canister damage
PGA3.7.1	Differing thermal expansion of glass matrix and canister
PGA3.7.2	Differing thermal expansion of canister and backfill
PGA3.7.3	Differing thermal expansion of backfill and host rock
PGA3.7.4	Differing thermal expansion of host rock zones
PGA3.8	Thermal convection
PGA3.9	Thermally induced chemical changes
PGA3.10	Chemical changes due to corrosion
PGA3.11	Drying out and re-saturation
PGA3.12.1	Geochemical changes in backfill
PGA3.12.2	Geochemical changes in host rock
PGA3.13	Physic-chemical phenomena/effects (e.g. colloid formation)
PGA3.14	Microbiological phenomena/effects
PGA3.15	Gas production
PGA3.16	Failure of shaft sealing
PGA4 CAUSED BY MAN	
PGA4.1	Direct alterations in hydrogeology
PGA4.2	Injection of liquid waste
PGA4.3.1	Drilling: in sediments

IDENTIFIER	FEP NAME
PGA4.3.2	Drilling: in host rock
PGA4.4	Geothermmal energy production in crystalline rock
SKI1.1.1	Criticality
SKI1.1.2	Radioactive decay: hear
SK11.1.3	Recoil of Alpha-decay
SKI1 .1.4	Gas generation: He production
SKI 1.2.1	Radiolysis
SKI 1.2.2	H2/O2 explosions
SKI 1.2.3	Pb-I reactions
SKI 1.2.4	Gas generation
SKI 1.2.5	I. Cs-migration to glass surface
SKI 1.2.6	Solubility within fuel matrix
SKI 1.2.7	Recystallization
SKI 1.2.8	Redox potential
SKI 1.2.9	Dissolution chemistry
SKI 1.3	Damaged of deviating fuel
SKI 1.4	Sudden energy release
SKI 1.5	Release of radionuclides from the failed canister
SKI 2.1.1	Chemical reactions (copper corrosion)
SKI 2.1.2	Coupled effects (electrophoresis)
SKI 2.1.3	Internal corrosion due to waste
SKI 2.1.4	Role of the eventual channeling within the canister
SKI 2.1.5	Role of chlorides in copper corrosion
SKI 2.1.6.1	Repository induced PbCu electrochemical reactions
SKI 2.1.6.2	Natural telluric electrochemical reactions
SKI 2.1.7	Pitting
SKI 2.1.8	Corrosive agents, Sulphides, oxygen, etc.
SKI 2.1.9	Backfill effects on Cu corrosion
SKI 2.1.10	Microbes
SKI 2.2	Creeping of Copper
SKI 2.3.1	Thermal Cracking
SKI 2.3.2	Electro-chemical cracking
SKI 2.3.3	Stress corrosion cracking
SKI 2.3.4	Loss of ductility
SKI 2.3.5	Radiation effects on canister
SKI 2.3.6	Cracking along welds
SKI 2.3.7.1	External stress
SKI 2.3.7.2	Hydrostatic pressure on canister
SKI 2.3.8	Internal pressure
SKI 2.4	Voids in the lead filling
SKI 2.5.1	Random canister defects - quality control
SKI 2.5.2	Common cause canister defects - quality control
SKI 3.1.1	Degradation of the bentonite by chemical reactions
SKI 3.1.2	Saturation of sorption sites
SKI 3.1.3	Effects of bentonite on groundwater chemistry
SKI 3.1.4	Colloid generation - source

IDENTIFIER	FEP NAME
SKI 3.1.5	Coagulation of bentonite
SKI 3.1.6	Sedimentation of bentcrite
SKI 3.1.7	Reactions with cement pore water
SKI 3.1.8	Near fields buffer chemistry
SKI 3.1.9	Radiolysis
SKI 3.1.10	Interactions with corrosion products and waste
SKI 3.1.11	Redox front
SKI 3.1.12	Perturbed buffer material chemistry
SKI 3.1.13	Radiation effects on bentonite
SKI 3.2.1 [NO ENTRY]	
SKI 3.2.1.1	Swelling of bentonite into tunnels and cracks
SKI 3.2.1.2	Uneven swelling of bentonite
SKI 3.2.2	Movement of canister in buffer/backfill
SKI 3.2.3	Mechanical failure of buffer/backfill
SKI 3.2.4	Erosion of buffer/backfill
SKI 3.2.5	Thermal effects on the buffer material
SKI 3.2.6	Diffusion - surface diffusion
SKI 3.2.7	Swelling of corrosion products
SKI 3.2.8	Preferential pathways in the buffer/backfill
SKI 3.2.9	Flow through buffer/backfill
SKI 3.2.10	Soret effect
SKI 3.2.11	Backfill material deficiencies
SKI 3.2.12	Gas transport in bentonite
SKI 4.1.1	Oxidizing conditions
SKI 4.1.2	PH-deviations
SKI 4.1.3	Colloids, complexing agents
SKI 4.1.4	Sorption
SKI 4.1.5	Matrix diffusion
SKI 4.1.6	Reconcentration
SKI 4.1.7	Thermochemical changes
SKI 4.1.8	Changes of groundwater chemistry in nearby rock
SKI 4.1.9	Complexing agents
SKI 4.2.1	Mechanical failure of repository
SKI 4.2.2 [NO ENTRY]	
SKI 4.2.2.1	Excavation/backfill effects on nearby rock
SKI 4.2.2.2	Hydraulic conductivity change - Excavation/backfilling effects
SKI 4.2.2.3	Mechanical effects - Excavation/backfilling effects
SKI 4.2.3	Extreme channel flow of oxidants and nuclides
SKI 4.2.4	Thermal buoyancy
SKI 4.2.5	Changes of groundwater flow
SKI 4.2.6	Faulting
SKI 4.2.7	Thermo-hydro-mechanical effects
SKI 4.2.8	Enhanced rock fracturing
SKI 4.2.9	Creeping of rock mass
SKI 4.2.10	Chemical effects of rock reinforcement
SKI 5.1.	Saline (or fresh) groundwater intrusion

IDENTIFIER	FEP NAME
SKI 5.2	Non-sealed repository
SKI 5.3	Stray materials left
SK15.4	Decontamination materials left
SKI 5.5	Chemical sabotage
SKI 5.6	Co-storage of other waste
SKI 5.7	Poorly designed respository
SKI 5.8	Poorly constructed repository
SKI 5.9	Unsealed boreholes and/or shafts
SKI 5.10	Accidents during operation
SKI 5.11	Degradation of hole-and shaft seals
SKI 5.12	Near storage of other waste
SKI 5.13	Volcanism
SKI 5.14	Resaturation
SKI 5.15	Earthquakes
SKI 5.16	Uplift and subsidence
SKI 5.17	Permafrost
SKI 5.18	Enhanced groundwater flow
SKI 5.19	Effect of plate movements
SKI 5.20	Changes of the magnetic field
SKI 5.21	Future boreholes and undetected past bore holes
SKI 5.22	Accumulation of gases under permafrost
SKI 5.23	Changed hydrostatic pressure on canister
SKI 5.24	Stress changes of conductivity
SKI 5.25	Dissolution of fracture fillings/precipitations
SKI 5.26	Erosion on surface/sediments
SKI 5.27	Human induced actions on ground water recharge
SKI 5.28	Underground dwellings
SKI 5.29	Meteorite
SKI 5.30	Underground test of nuclear devices
SKI 5.31	Change in sea level
SKI 5.32	Desert and unsaturation
SKI 5.33	Waste retrieval, mining
SKI 5.34	Geothermal energy production
SKI 5.35	Other future uses of crystalline rock
SKI 5.36	Resuse of boreholes
SKI 5.37	Archaeological intrusion
SKI 5.38	Explosions
SKI 5.39	Postclosure monitoring
SKI 5.40	Unsuccessful attempt of site improvement
SKI 5.41	Water producing well
SKI 5.42	Glaciation
SKI 5.43	Methane instrusion
SKI 5.44	Solubility and precipitation
SKI 5.45	Colloid generation and transport
SKI 5.46	Groundwater recharge/discharge

IDENTIFIER	FEP NAME
SKI 6.1	Undetected fracture zones
SKI 6.2	Gas transport
SKI 6.3	Far field hydrochemistry - acids, oxidants, nitrate
SKI 6.4	Dispersion
SKI 6.5	Dilution
SKI 6.6	Weathering of flow paths
SKI 6.7	Nuclear war
SKI 6.8	Human induced climate change
SKI 6.9	River meandering
SKI 6.10	No ice age
SKI 6.11	Intruding dykes
SKI 6.12	Undetected discontinuities
SKI 6.13	Geothermally induced flow
SKI 6.14	Tectonic activity - large scale
SKI 7.1	Accumulation in sediments
SKI 7.2	Accumulation in peat
SKI 7.3	Intrusion in accumulation zone in the biosphere
SKI 7.4	Chemical toxicity of wastes
SKI 7.5	Isotopic dilution
SKI 7.6	**[NO ENTRY[**
SKI 7.7	Human induced changes in surface hydrology
SKI 7.8	Altered surface water chemistry by humans
SKI 7.9	Loss of records
SKI 7.10	Diagenesis
SKI 7.11	City on the site

IDENTIFIER	FEP NAME
SNL1.1	Meteorite Impact
SNL2.1	Erosion/Sedimentation
SNL2.2	Glaciation
SNL2.3	Pluvial Periods
SNL2.4	Sea-Level Variations
SNL2.5	Hurricanes
SNL2.6	Seiches
SNL2.7	Tsunamis
SNL2.8	Regional Subsidence of Uplift (also applies to subsurface)
SNL2.9	Mass Wasting
SNL2.10	Flooding
SNL3.1	Diapirism
SNL3.2	Seismic Activity
SNL3.3	Volcanic Activity
SNL3.4	Magmatic Activity
SNL3.5	Formation of Dissolution Cavities
SNL3.6	Formation of Interconnected Fracture System
SNL3.7	Faulting
SNL4.1	Inadvertent Intrusion: Explosions
SNL4.2	Inadvertent Intrusions: Drilling
SNL4.3	Inadvertent Intrusions: Mining
SNL4.4	Inadvertent Intrusions: Injection Wells
SNL4.5	Inadvertent Intrusions: Withdrawal Wells
SNL5.1	Hydrologic Stresses: Irrigation
SNL5.2	Hydrologic Stresses: Damming of Streams of Rivers
SNL6.1	Subsidence of Caving
SNL6.2	Shaft and Borehole Seal Degradation
SNL6.3	Thermally Induced Stress Fracturing in Host Rock
SNL6.4	Excavation-induced Stress/Fracturing in Host Rock

IDENTIFIER	FEP NAME
UKN1.1.1	Meteorite Impact
UKN1.1.2	Solar insolation
UKN1.2.1	Plate movement/tectonic change
UKN1.2.2	Changes in the Earth's magnetic field
UKN1.2.3	Magmatic activity (intrusive, extrusive)
UKN1.2.4	Metamorphic activity
UKN1.2.5	Diagenesis
UKN1.2.6	Uplift and subsidence (e.g. organic, isostatic)
UKN1.2.7	Diapirism
UKN1.2.8	Seismicity
UKN1.2.9	Fault activation
UKN1.2.10	Fault generation
UKN1.2.11	Rock heterogeneity (e.g. permeability, mineralogy) affecting water and gas flow
UKN1.2.12	Undetected features (e.g. faults, fracture networks, shear zones, brecciation, gas pockets
UKN1.2.13	Natural gas intrusion
UKN1.3.1	Precipitation, temperature and soil water balance
UKN1.3.2	Extremes of precipitation, snow melt and associated flooding
UKN1.3.3	Coastal surge, storms and hurricanes
UKN1.3.4	Sea-level rise/fall
UKN1.3.5	Periglacial effects (e.g. permafrost, high seasonability)
UKN1.3.6	Glaciation (erosion/deposition, glacial loading. Hydrogeological change)
UKN1.3.7	No ice age
UKN1.4.1	Land slide
UKN1.4.2	Denudation (aeolian and fuvial)
UKN1.4.3	River, stream, channel erosion (downcutting)
UKN1.4.4	River meander
UKN1.4.5	Freshwater sediment transport and deposition
UKN1.4.6	Coastal erosion and estuarine development
UKN1.4.7	Marine sediment transport and deposition
UKN1.4.8	Frost weathering and sellfluction
UKN1.4.9	Chemical denudation weathering
UKN1.4.10	Frost weathering
UKN1.5.1	River flow and lake level changes
UKN1.5.2	Site flooding
UKN1.5.3	Recharge to groundwater
UKN1.5.4	Groundwater discharge (to surface water, to springs, to soils, to wells and to marine)
UKN15.5	Ground flow (Darcy, non-Darcy, intergranular fracture, channeling and path passage ways)
UKN1.5.6	Groundwater conditions (saturated/unsaturated)
UKN1.5.7	Saline or freshwater intrusion
UKN1.5.8	Effects at saline-freshwater interface
UKN1.5.9	Natural thermal effects
UKN1.6.1	Advection and dispersion
UKN1.6.2	Diffusion
UKN1.6.3	Matrix Diffusion
UKN1.6.4	Gas mediated transport
UKN1.6.5	Multiphase flow and gas driven flow

IDENTIFIER	FEP NAME
UKN1.6.6	Solubility limit
UKN1.6.7	Sorption (linear/non-linear, reversible/irreversible)
UKN1.6.8	Dissolution, precipitation crystallization
UKN1.6.9	Colloid formation, dissolution and transport
UKN1.6.10	Complexing agents
UKN1.6.11	Fracture mineralization and weathering
UKN1.6.12	Accumulation in soils and organic debris
UKN1.6.13	Mass isotopic and species dilution
UKN1.6.14	Chemical gradients (electrochemical effects and osmosis)
UKN1.7.1	Plant uptake
UKN1.7.2	Animal uptake
UKN1.7.3	Uptake by deep rooting species
UKN1.7.4	Soil and sediment bioturbation
UKN1.7.5	Pedogenesis
UKN1.7.6	Chemical transformations
UKN1.7.7	Microbial interactions
UKN1.7.8	Ecological change, eg. Forest fire cycles
UKN1.7.9	Ecological response to climate, eg desert formation
UKN1.7.10	Plants and animal evolution
UKN2.1.1	Undetected past intrusions (eg. boreholes, mining)
UKN2.1.2	Investigation borehole seal failure and degradation
UKN2.1.3	Shaft or access tunnel seal failure and degradation
UKN2.1.4	Stress field changes, setting, subsidence or caving
UKN2.1.5	Dewatering of host rock
UKN2.1.6	Material defects, eg. early canister failure
UKN2.1.7	Common cause failures
UKN2.1.8	Poor quality construction
UKN2.1.9	Design modification
UKN2.1.10	Thermal effects (eg. concrete hydration)
UKN2.2.1	Radioactive waste disposal error
UKN2.2.2	Inadequate backfill or compaction, voidage
UKN2.2.3	Co-disposal of reactive wastes (deliberate)
UKN2.2.4	Inadvertent inclusion of undesirable materials
UKN2.2.5	Heterogeneity of waste forms (chemical, physical)
UKN2.2.6	Accidents during operation
UKN2.2.7	Sabotage
UKN2.2.8	Repository flooding during operation
UKN2.2.9	Abandonment of unsealed repository
UKN2.2.10	Poor closure
UNN2.2.11	Post-closure monitoring
UKN2.2.12	Effects of phased operation
UKN2.3.1	Recovery of repository materials
UKN2.3.2	Malicious intrusion eg. sabotage, act of war
UKN2.3.3	Exploratory drilling
UKN2.3.4	Exploration drilling
UKN2.3.5	Geothermal energy production

IDENTIFIER	FEP NAME
UKN2.3.6	Resource mining
UKN2.3.7	Tunneling
UKN2.3.8	Underground construction
UKN2.3.9	Archaeological investigation
UKN2.3.10	Injection of liquid wastes
UKN2.3.11	Groundwater abstraction
UKN2.3.12	Underground nuclear testing
UKN2.4.1	Loss of records
UKN2.4.2	Dams and reservoirs, built/drained
UKN2.4.3	River rechannelled
UKN2.4.4	Irrigation
UKN2.4.5	Altered soil or surface water chemistry
UKN2.4.6	Land use changes
UKN2.4.7	Agricultural and fisheries practice changes
UKN2.4.8	Demographic change, urban development
UKN2.4.9	Anthropogenic climate change (greenhouse effect)
UKN2.4.10	Quarrying, peat extraction
UKN3.1.1	Differential elastic response
UKN3.1.2	Non-elastic response
UKN3.1.3	Host rock fracture aperture changes
UKN3.1.4	Induced hydrological changes (fluid pressure, density convection, viscosity)
UKN3.1.5	Induced chemical changes (solubility, sorption, species equilibrium, mineralization)
UKN3.2.1	Metalic corrosion (pitting/uniform, internal/external agents, gas generation, eg. H2)
UKN3.2.2	Interactions of host materials and groundwater with repository material (eg. concrete carbon)
UKN3.2.3	Interactions of waste and repository materials with host materials (eg electrochemical)
UKN3.2.4	Non-radioactive solute plume in geosphere (effect on redox, effect on pH sorption)
UKN3.2.5	Cellulosic degradation
UKN3.2.6	Introduced complexing agents and cellulosics
UKN3.2.7	Microbiological effects (on corrosion/degradation on solubility/complexation, gas generation)
UKN3.3.1	Canister or container movement
UKN3.3.2	Changes in in-situ stress field
UKN3.3.3	Embrittlement and cracking
UKN3.3.4	Subsidence/collapse
UKN3.3.5	Fracturing
UKN3.3.6	Gas effects (pressuration, disruption, explosion, fire)
UKN3.4.1	Radiolysis
UKN3.4.2	Material property changes
UKN3.4.3	Nuclear criticality
UKN3.4.4	Radioactive decal and ingrowth (chain decay)

IDENTIFIER	FEP NAME
HMIP1. NEAR FIELD	
HMIP1.1 **Chemical/physical degration**	
HMIP1.1.1	Container metal corrosion
HMIP1.1.2	Physio-chemical degradation of concrete
HMIP1.1.3	Physio-chemical degradation of wastes and transport to the far-field
HMIP1.1.4	Electrical effects of metal corrosion
HMIP1.2 Gas production, transport and flammability	
HMIP1.2.1	Hydrogen by metal corrosion
HMIP1.2.2	Methane and carbon dioxide by microbial degradation
HMIP1.2.3	Gas generation from concrete
HMIP1.2.4	Radioactive gases
HMIP1.2.5	Chemotoxic gases
HMIP1.2.6	Gas transport
HMIP1.2.7	Flammability
HMIP1.2.8	Thermo-chemical effects
HMIP1.3 Radiation pheonomens	
HMIP1.3.1	Radioactive decay and ingrowth
HMIP1.3.2	Nuclear criticality
HMIP1.4 Structural integrity	
HMIP1.4.1	Waste-form and backfill consolidation
HMIP1.4/2	Vault collapse
HMIP1.5 Hydrogeological effects	
HMIP1.5.1	Desaturation (pumping) effects
HMIP1.5.2	Disturbed zone (hydrochemical) effect
HMIP1.5.3	Gas production (unsaturated flow)
HMIP1.5.4	Saturated ground water flow
HMIP1.5.5	Transport of chemically active substances into the near-field
HMIP1.6 Thermal Effects	
HMIP1.6.1	Thermal effects and Rock-mass changes
HMIP1.6.2	Thermal effects and Hydrogeological changes
HMIP1.6.3	Thermal effects and Chemical changes
HMIP1.6.4	Thermal effects and Transport (diffusion) effects
HMIP2. FAR-FIELD	
HMIP2.1 Geological	
HMIP2.1.1	Regional tectonic
HMIP2.1.2	Magmatic activity
HMIP2.1.3	Metamorphism
HMIP2.1.4	Diagenesis
HMIP2.1.5	Diapirism
HMIP2.1.6	Seismicity
HMIP2.1.7	Fault/Fracturing
HMIP21.8	Major incision
HMIP2.1.9	Effects of natural gases
HMIP2.2 Hydrogeological	
HMIP2.2.1	Changes in geometry and driving forces of the flow system
HMIP2.2.2	Rock property changes

IDENTIFIER	FEP NAME
HMIP2.2.3	Groundwater flow
HMIP2.3	**Transport and geochemical**
HMIP2.3.1	Adverction
HMIP2.3.2	Diffusion
HMIP2.3.3	Hydrodynamic dispersion
HMIP23.4	Solubility constraints
HMIP2.3.5	Sorption including ion-exchange
HMIP2.3.6	Changes in sorptive surfaces
HMIP2.3.7	Changes in groundwater chemistry and flow direction
HMIP2.3.8	Colloid transport
HMIP2.3.9	Transport of radionuclides bound to microbes
HMIP2.3.10	Transport of active gases
HMIP2.3.11	Gas induced groundwater transport
HMIP23.12	Thermal effects on hydrochemistry
HMIP2.3.13	Biogeochemical changes

IDENTIFIER	FEP NAME
HMIP2.4 Geomorphology	
HMIP2.4.1	Generalized denudation
HMIP2.4.2	Localized denudation
HMIP3. CLIMATOLOGY	
HMIP3.1 Climate change	
HMIP31.1	Human induced climate change
HMIP3.1.2	Natural climate change
HMIP3.1.3	Exit from glacial/interglacial cycling
HMIP3.1.4	Intensification of natural climate change
HMIP4 BIOSPHERE	
HMIP4.1 Radionuclide entry points to the biosphere	
HMIP4.1.1	Groundwater discharge to soils and surface waters
HMIP4.1.2	Solid discharge via erosional processes
HMIP4.1.3	Gas discharge
HMIP4.2 Transfer (concentration/dilution) mechanisms	
HMIP4.2.1	Soil moisture and evaporation
HMIP4.2.2	Surface water mixing
HMIP4.2.3	Sediment transport including bioturbation
HMIP4.2.4	Sediment/water/gas/interaction with the atmosphere
HMIP4.2.5	Bioaccumulation and translocation
HMIP4.2.6	Biogeochemical processes
HMIP4.3 Land and surface water use	
HMIP4.3.1	Terrestrial water use
HMIP4.3.2	Estuarine water use
HMIP4.3.3	Coastal waters and water use
HMIP4.3.4	Seas and water use
HMIP4.4 Human exposure	
HMIP4.4.1	External exposure
HMIP4.4.2	Ingestion
HMIP4.4.3	Inhalation
HMIP5. **SHORT CIRCUIT PATHWAYS**	
HMIP5.1 **Related to repository construction**	
HMIP5.1.1	Loss of integrity of borehole seals
HMIP5.1.2	Loss of integrity of shaft or access tunnel seals
HMIP5.1.3	Incomplete near-field chemical conditioning
HMIP5.2 Unrelated to repository construction	
HMIP5.2.1	Meteorite impact
HMIP5.2.2	Deliberate intrusion
HMIP5.2.3	Malicious intrusion
HMIP5.2.4	Accidental intrusion

IDENTIFIER	FEP NAME
NEA1. NATURAL PHENOMENA	
NEA1.1 Extra Terrestrial	
NEA1.1.1	Meteorite impact
NEA1.1.2	Solar insolation
NEA1..2 GEOLOGICAL	
NEA1.2.1	Plate movements/tectonic change
NEA1.2.2	Changes in the Earth's magnetic field
NEA1.2.3	Magnetic activity (intrusive, extrusive)
NEA1.2.4	Metamorphic activity
NEA1.2.5	Diagenesis
NEA1.2.6	Uplift and subsidence (organic, isostatic)
NEA1.2.7	Diapirism
NEA1.2.8	Seismicity
NEA1.2.9	Fault activation
NEA1.2.10	Fault generation
NEA1.2.11	Rock heterogeneity (permeability, mineralogy), affecting water and gas flow
NEA1.2.12	Undetected features (faults, fracture, networks, shear zones, brecciation, gas pocket)
NEA1.2.13	Natural gas intrusion
NEA1.3 CLIMATOLOGICAL	
NEA1.3.1	Precipitation, temperature and soil water balance
NEA1.3.2	Extremes of precipitation, snow melt and associated flooding
NEA1.3.3	Coastal surge, storms and hurricanes
NEA1.3.4	Sea-level rise/fall
NEA1.3.5	Periglacial effects (permafrost, high seasonability)
NEA1.3.6	Glaciation (erosion/deposition, glacial loading, hydrogeological change)
NEA1.3.7	No ice age
NEA1.4 GEOMORPHOLOGICAL	
NEA1.4.1	Land slide
NEA1.4.2	Denudation (aeolian and fluvian)
NEA1.4.3	River, stream, channel erosion (downcutting)
NEA1.4.4	River meander
NEA1.4.6	Freshwater sediment transport and deposition
NEA1.4.7	Marine sediment transport and deposition
NEA1.4.8	River meander (Repeat - See 1.4.4)
NEA1.4.9	Chemical denudation and weathering
NEA1.4.10	Frost weathering
NEA1.5 HYDROLOGICAL	
NEA1.5.1	River flow and lake level changes
NEA1.5.2	Site flooding
NEA1.5.3	Recharge to groundwater
NEA1.5.4	Groundwater discharge (to surface water, springs, soils, wells and marine0
NEA1.5.5	Groundwater floe (Darcy, non-Darcy, intergranular fracture, channeling and preferential
NEA1.5.6	Groundwater conditions (saturated/unsaturated)
NEA1.5.7	Saline or freshwater interface
NEA1.5.8	Effects at saline-freshwater interface
NEA1.5.9	Natural thermal effects

IDENTIFIER	FEP NAME
NEA1.6 TRANSPORT AND GEOCHEMICAL	
NEA1.6.1	Advection and dispersion
NEA1.6.2	Diffusion
NEA1.6.3	Matrix diffusion
NEA1.6.4	Gas mediated transport
NEA1.6.5	Multiphase flow and gas-driven flow
NEA1.6.6	Solubility limit
NEA1.6.7	Sorption (linear/non-linear, reversible/irreversible)
NEA1.6.8	Dissolution, precipitation and crystallization
NEA1.6.9	Colloid formation, dissolution and transport
NEA1.6.10	Complexing agents
NEA1.6.11	Fracture mineralization
NEA1.6.12	Accumulation in soils and organic debris
NEA1.6.13	Mass, isotopic and species dilution
NEA1.6.14	Chemical gradients (electrochemical effects and osmosis)
NEA1.7 ECOLOGICAL	
NEA1.7.1	Plant uptake
NEA17.2	Animal uptake
NEA1.7.2	Uptake by deep rooting species
NEA1.7.4	Soil and sediment bioturbation
NEA1.7.5	Prodogenesis
NEA17.6	Chemical transformations
NEA1.7.7	Microbial interactions
NEA1.7.8	Ecological change (eg. forest fire cycles)
NEA1.7.9	Ecological response to climate (eg. desert formation)
NEA1.7.10	Plant and animal evolution
NEA2 HUMAN ACTIVITIES	
NEA2.1 Design and Construction	
NEA2.1.1	Undetected past intrusion (boreholes, mining)
NEA2.1.2	Investigation borehole seal failure and degradation
NEA2.1.3	Shaft or access tunnel seal failure and degradation
NEA21.4	Stress field changes, setting subsidence of caving
NEA2.1.5	Dewatering of host rock
NEA2.1.6	Mineral defects (eg. early canister failure)
NEA21.7	Common cause failures
NEA2.1.8	Poor quality construction
NEA2.1.9	Design modification
NEA21.10	Thermal effects
NEA2.2 OPERATION AND CLOSURE	
NEA2.2.1	Radioactive waste disposal error
NEA2.2.2	Inadequate backfill or compaction voidage
NEA 2.2.3	Co-disposal of reactive wastes (deliberate)
NEA2.2.4	Inadvertent inclusion of undesirable minerals
NEA2.2.5	Heterogeneity of wast forms (chemical physical)
NEA2.2.6	Accidents during operation
NEA2.2.7	Sabotage

IDENTIFIER	FEP NAME
NEA2.2.8	Repository flooding during operation
NEA2.2.9	Abandonment of unsealed repository
NEA2.2.10	Poor closure
NEA2.2.11	Post-closure monitoring
NEA2.2.12.	Effects of phased operation
NEA2.3	**POST-CLOSURE SUBSURFACE ACTIVITIES (INTRUSION)**
NEA2.3.1	Recovery or repository
NEA2.3.2	Malicious intrusion (sabotage, act of war)
NEA2.3.3	Exploratory drilling
NEA2.3.4	Exploitation drilling
NEA2.3.5	Geothermal energy production
NEA2.3.6	Resource mining
NEA2.3.7	Tunneling
NEA2.3.8	Underground construction
NEA2.3.9	Archaeological investigation
NEA2.3.10	Injection of liquid wastes
NEA2.3.11	Groundwater abstraction
NEA2.3.12	Underground nuclear testing
NEA2.4	**POST-CLOSURE SURFACE ACTIVITIES**
NEA2.4.1	Loss of records
NEA2..4.2	Dams and reservoirs, built/drained
NEA2.4.3	Rivers rechanneled
NEA2.4.4	Irrigation
NEA2.4.5	Altered soil or surface water chemistry
NEA2.4.6	Land use changes
NEA2.4.7	Agricultural and fisheries practice changes
NEA2..4.8	Demographic change, urban development
NEA2.4.9	Climate change (greenhouse effect)
NEA2.4.10	Quarrying, eary surface extraction
NEA 3.	**WASTE AND REPOSITORY EFFECTS**
NEA3.1	**THERMAL**
NEA 3.1.1	Differential elastic response
NEA3.1..2	Non-elastic response
NEA3.1.3	Host rock fracture aperture changes
NEA3.1.4	Induced hydrological changes (fluid pressure, density convection, viscosity)
NEA3.1.5	Induced chemical changes (solubility, sorption, species, equilibrium mineralization)
NEA3.2	**CHEMICAL**
NEA3.2.1	Metallic corrosion (pitting/uniform, internal and external agents, gas generation eg. H2)
NEA3.2.2	Interactions of host materials and ground water with repository material (eg. concrete carbon)
NEA3.2.3	Interactions of waste and repository materials with host materials (electrochemical, corrosive)
NEA3.2.4	Non-radioactive solute plume in geosphere (effect of redox, pH and sorption)
NEA3.2.5	Cellulosic degradation
NEA3.2.6	Introduced complexing agents and cellulosics
NEA3.2.7	Microbiological (effects on corrosion/degradation, solubility/complexation, gas generation)
NEA3.3	**MECHANICAL**
NEA3.3.1	Canister or container movement

IDENTIFIER	FEP NAME
NEA3.3.2	Changes in-situ stress field
NEA3.3.3	Embrittlement and cracking
NEA3.3.4	Subsidence/collapse
NEA3.3.5	Fracturing
NEA3.3.6	Gas effects (pressurization, disruption, explosion, fire)
NEA3.4 RADIOLOGICAL	
NEA3.4.1	Radiolysis
NEA3.4.2	Material property changes
NEA3.4.3	Nuclear criticality
NEA3.4.4	Radioactive decay and ingrowth (chain decay)

2.2 DCCA FEP List

The following attachment presents the complete list of FEPs generated by DOE as part of the Draft Compliance Certification Application, which was developed from the SKI listing(s). They are categorized according to the following sub-systems:

- 1.0 - Waste
- 2.0 - Canister
- 3.0 - Backfill
- 4.0 - Seal Systems
- 5.0 - Near-Field
- 6.0 - Far-Field
- 7.0 - Biosphere
- 8.0 - Geology/Climate Change
- 9.0 - Human Influences

1. WASTE

1.1 Waste: characteristics (initial)

Inventory: radionuclides
Inventory: hazardous constituents (e.g. VOCS, heavy metals)
Long-term physical stability
Heterogeneity of waste forms (chemical, physical)
Stability of glass
Teratogenic contaminants

1.2 Waste: radionuclide decay and ingrowth

Waste: radionuclide decay and ingrowth

1.3 Waste: radiological/radiation effects

Radiolysis
Recoil of alpha-decay
Release of stored energy
Nuclear criticality (preclosure)
Nuclear criticality (postclosure)
Radiation damage of the matrix including embrittlement

1.4 Waste: gas generation and effects

Gas generation: He production
Methane and carbon dioxide by microbial degradation of cellulose and other organic wastes
Active methane, carbon dioxide, radon, tritiated hydrogen and other active gases
Hydrogen by metal corrosion
Gas effects: pressurization
Gas effects: disruption
Gas effects: explosions
Gas effects: fire
Chemical changes due to gas production
Hydrogen: effects of microbial growth on concrete
Methane/CO_2 production: aerobic degradation
Methane/CO_2 production: effects of temperature
Methane/CO_2 production: effects of lithostatic pressure
Methane/CO_2 production: energy and nutrient control of metabolism
Methane/CO_2 production: effects of radiation on microbial populations
Microbiological effects due to cellulose degradation
Gas generation from concrete
Methane/CO_2 production: anaerobic production
Methane/CO_2 production: Inhibition due to the pressure of toxic materials
Methane/CO_2 production: Effects of biofilms
Methane/CO_2 production: Carbonate/bicarbonate exchange with concrete

1.5 Waste: heat generation

Radioactive decay: heat
Nuclear criticality: heat
Material property changes: heat

1.6 Waste: thermomechanical effects

Thermal cracking
Material property changes
Differing thermal expansion of glass matrix and canister

1.7 Waste: thermochemical effects

Thermally induced chemical changes (water chemistry)

1.8 Waste: electrochemical effects

Electrochemical gradients
Electrical effects of metal corrosion
Galvanic coupling

1.9 Waste: degradation/corrosion/dissolution

Dissolution
Precipitation
Source terms
Source terms (hazardous constituents)
Degradation of plastics and cellulosics
Release of sorbed VOCs
Metal corrosion: wastes
Leaching: wastes
Rinse
Internal corrosion due to waste
Fracturing
External stress

1.10 Waste: geochemical reactions/regime

Chemical gradients, osmosis
Chemical kinetics
Complex formation: wastes
Chemical changes due to metal corrosion
Chemical changes due to gas production
Chemical effects: geochemical change
Recrystallization
Redox potential
Dissolution chemistry
Interactions with corrosion products and waste
Solubility with fuel matrix

1.11 Waste: radionuclide and contaminant chemistry

Speciation
Complex formation: wastes
Solubility within fuel matrix
Recrystallization
Solubility
Precipitation
Solubility, speciation, precipitation: hazardous constituents

1.12 Waste: Others

Colloid formation: wastes
Damaged or deviating waste contents
Role of eventual channelling within the canister
1, Cs-migration to fuel surface
Boundary conditions
Correlation
Sudden energy release
Waste incompatibility
Design modifications: waste (e.g. buffer additives)
Nuclear criticality: explosions
Capillary action

2. CANISTER

2.1 Canister: materials/construction

Inventory

2.2 Canister: corrosion/degradation processes

Container failure (early)
Container failure (long term)
Container healing
Corrosion (including partial corrosion)
Pitting
Radiation damage to container (embriftlement)
Uniform corrosion
Structural container metal corrosion: localized
Structural container metal corrosion: bulk
Structural container metal corrosion: crevice
Structural container metal corrosion: stress corrosion cracking
Chemical changes due to metal corrosion
Chemical reactions (copper corrosion)
Role of chlorides in copper corrosion
Corrosive agents, sulphides, oxygen, etc.
Backfill effects on container corrosion
Swelling of corrosion products

2.3 Canister: gas generation and effects

Hydrogen: corrosion of container steel

Gas transport in the waste container
Gas effects: pressurization
Gas effects: disruption
Gas effects: explosions
Gas effects: fire

2.4 Canister: microbiological effects/microbial activity
Canister: microbiological effects/microbial activity

2.5 Canister: thermomechanical effects
Differing thermal expansion of canister and backfill
Thermal cracking
Differing thermal expansion of materials (glass, canister)

2.6 Canister: electrochemical effects
Electrochemical gradients
Coupled effects (electrophoresis)
Natural telluric electrochemical reactions
Electrochemical cracking
Galvanic coupling

2.7 Canister: stress/mechanical effects
Canister movement
Mechanical canister damage (failure)
Creeping of copper
Stress corrosion cracking
Loss of ductility
Cracking along welds
External stress
Hydrostatic pressure on canister
Internal pressure
Swelling of corrosion products
Hydride cracking

2.8 Canister: geochemical reactions/regime
Chemical kinetics
Container corrosion products
Precipitation
Dissolution
Speciation of corrosion products (include in water chemistry)
Chemical effects: Interactions of waste canister and rock
Chemical gradients (electrochemical effects and osmosis)

2.9 Canister: Radionuclide and contaminant transport through containers

Release of radionuclides from the failed canister
Release of hazardous constituents from the failed canister

2.10 Canister: others

Channelling within the canister (preferential pathways)
Radiation effects on canister
Random canister defects - quality control
Common cause canister defects - quality control
Material defects, e.g. early canister failure
Incomplete filling of canisters
Boundary conditions
Correlation
Time dependence
Design modifications: canister
Nuclear criticality: explosions

3. BACKFILL

3.1 Backfill: characteristics

Backfill characteristics (e.g. hydraulic conductivity)
Long-term physical
Buffer additives

3.2 Backfill: resaturation/desaturation

Backfill: resaturation/desaturation

3.3 Backfill: mechanical effects

Preferential pathways in the backfill
Mechanical effects: local fractures/cracks (preferential pathways)
Mechanical failure of backfill (preferential pathways)
Swelling pressure
Movement of canister in backfill
Uneven swelling of bentonite
Swelling of corrosion products
Cracking: concrete
Sealing of cracks: concrete
External stress

3.4 Backfill: thermal effects

Convection (contaminant transport)
Hydrothermal alteration
Variations in groundwater temperature
Differing thermal expansion (canister-backfill, buff er-host rock)
Thermal effects on the backfill material
Soret effect
Natural thermal effects
Thermal effects (e.g. concrete hydration)

Thermochemical effects

3.5 Backfill: electrochemical effects

Natural telluric electrochemical reactions

3.6 Backfill: gas effects and transport

Groundwater flow due to gas production
Gas transport in the near field as gas phase and insolution
Chemical effects: gas generation
Transport of active gases
Methane/CO_2 production
Effects of hydrogen from metal corrosion
Gas effects: pressurization
Gas effects: disruption
Gas effects: explosions
Gas effects: fire
Methane/CO_2 production: effects of hydrogen from metalcorrosion
Gas generation from concrete

3.7 Backfill: microbiological effects/microbial activity

Backfill: microbiological effects/microbial activity
Hydrogen: effects of microbial growth on concrete

3.8 Backfill: degradation

Degradation of the bentonite by chemical reactions
Coagulation of bentonite
Radiation effects on bentonite
Erosion of backfill
Alkali-aggregate reaction

3.9 Backfill: geochemical regime

Chemical gradients
Chemical kinetics
Precipitation
Dissolution
Chemical changes due to waste degradation
Chemical changes due to gas production
Chemical changes due to complex formation
Chemical changes due to colloid production
Chemical changes due to sorption
Chemical changes due to speciation
Isotopic dilution
Chemical changes due to corrosion
Saturation of sorption sites
Effects of bentonite on groundwater chemistry
Reactions with cement pore water (include in chemical degradation)
Redox front
Thermochemical changes
Saline groundwater intrusion

Effects at saline-freshwater interface
Natural changes in groundwater flow direction
Biogeochemical changes
Exchange capacity exceeded
Cement sulphate reaction

3.10 Backfill: Radionuclide and contaminant transport processes

Groundwater and gas flow
Advection/dispersion: radionuclides
Advection/dispersion: hazardous constituents
Diffusion: radionuclides
Diffusion: hazardous constituents
Unsaturated transport
Transport of chemically active substances into the near-field
Transport of radionuclides bound to microbes

3.11 Backfill: radionuclide and contaminant chemistry

Precipitation, reconcentration
Recrystallization
Dissolution
Sorption (linear, nonlinear, irreversible)
Speciation
Solubility effects (pH and Eh, ionic strength, complexing agents, colloids)
Dissolution, speciation, sorption, precipitation; hazardous constituents
Sorption effects (pH and Eh, ionic strength, complexing agents, colloids)
Changes in sorptive surfaces
Radiolysis

3.12 Backfill: others

Faulty backfill emplacement
Colloid transport (inorganic and organic)
Extreme channel flow of oxidants and nuclides (preferential pathways)
Inadequate backfill or compaction, voidage
Anion exchange
Groundwater flow: initial conditions
Backfill material deficiencies
Boundary conditions
Correlation
Time dependence
Nuclear criticality: explosions
Nuclear criticality: heat
Design modifications: backfill
Capillary action

4. SEALS

4.1 Seals: characteristics

Seal characteristics (e.g. hydraulic conductivity)
Long-term physical stability

Concrete
Buffer additives

4.2 Seals: resaturation/desaturation

Seals: resaturation/desaturation

4.3 Seals: mechanical effects

Preferential pathways in the seals
Mechanical effects: local fractures/cracks (preferential pathways)
Mechanical failure of seals (preferential pathways)
Swelling pressure
External stress
Movement of canister
Uneven swelling of bentonite
Swelling of corrosion products
Cracking: concrete
Sealing of cracks: concrete

4.4 Seals: thermal effects

Convection (contaminant transport)
Hydrothermal alteration
Variations in groundwater temperature
Differing thermal expansion (canister-seal, buffer-host rock)
Thermal effects on the seal material
So ret effect
Natural thermal effects
Thermal effects (e.g. concrete hydration)
Thermochemical effects

4.5 Seals: electrochemical effects

Natural telluric electrochemical reactions

4.6 Seals: gas effects and transport

Groundwater flow due to gas production
Gas transport in the near field as gas phase and in solution
Chemical effects: gas generation
Transport of active gases
Methane/CO, production
Effects of hydrogen from metal corrosion
Gas effects: pressurization
Gas effects: disruption
Gas effects: explosions
Gas effects: fire
Methane/CO_2 production: effects of hydrogen from metal corrosion
Gas generation from concrete

4.7 Seals: microbiological effects/microbial activity

Seal: microbiological effects/microbial activity
Hydrogen: effects of microbial growth on concrete

4.8 Seals: degradation

Degradation of the bentonite by chemical reactions
Coagulation of bentonite
Radiation effects on bentonite
Erosion of seals
Alkali-aggregate reaction

4.9 Seals: geochemical regime

Chemical gradients
Chemical kinetics
Precipitation
Dissolution
Chemical changes due to waste degradation
Chemical changes due to gas production
Chemical changes due to complex formation
Chemical changes due to colloid production
Chemical changes due to sorption
Chemical changes due to speciation
Isotopic dilution
Chemical changes due to corrosion
Saturation of sorption sites
Effects of bentonite on groundwater chemistry
Reactions with cement pore water (include in chemical degradation)
Redox front
Thermochemical changes
Saline groundwater intrusion
Effects at saline-freshwater interface
Natural changes in groundwater flow direction
Biogeochemical changes
Exchange capacity exceeded
Cement sulphate reaction

4.10 Seals: Radionuclide and contaminant transport processes

Groundwater and gas flow
Advection/dispersion: radionuclides
Advection/dispersion: hazardous constituents
Diffusion: radionuclides
Diffusion: hazardous constituents
Unsaturated transport
Transport of chemically active substances into the near-field
Transport of radionuclides bound to microbes

4.11 Seals: radionuclide and contaminant chemistry

Precipitation, reconcentration
Sorption (linear, nonlinear, irreversible)
Speciation
Solubility effects (pH and Eh, ionic strength, complexing agents, colloids)
Sorption effects (pH and Eh, ionic strength, complexing agents, colloids)
Changes in sorptive surfaces
Radiolysis
Dissolution
Recrystallization
Dissolution, speciation, sorption, precipitation; hazardous constituents

4.12 Seals: others

Faulty seal emplacement
Colloid transport (inorganic and organic)
Extreme channel flow of oxidants and nuclides (preferential pathways)
Inadequate seal or compaction, voidage
Anion exchange
Groundwater flow: initial conditions
Seal material deficiencies
Boundary conditions
Investigation borehole seal failure/degradation
Shaft seal failure/degradation
Design modifications: seals
Correlation
Time dependence
Nuclear criticality: explosions
Nuclear criticality: heat

5. NEAR-FIELD

5.1 Near-field rock: elements/materials

Disposal geometry
Rock properties (porosity, permeability, hydraulic head, conductivity)
Colloids

5.2 Near-field rock: degradation

Rock property changes (hydraulic conductivity, fractures, pore blocking, channel formation/closure)
Creeping of rock mass
Caving/roof collapse
Physico-chemical degradation of concrete

5.3 Near-field rock: hydraulic effects/groundwater flow

Unsaturated transport
Groundwater flow due to gas production
Groundwater flow (saturated conditions, including fracture flow)
Groundwater flow, effects of solution channels (preferential pathways)
Repository thermally-induced groundwater transport
Naturally thermally-induced groundwater transport
Thermo-hydro-mechanical effects
Resaturation
Disturbed zone (hydromechanical) effects
Natural changes in groundwater chemistry and flow direction
Repository-induced changes in groundwater flow direction

5.4 Near-field rock: mechanical effects

Formation of cracks
Changes in in-situ stress field
Changes in moisture content due to stress relief
Differential elastic response
Non-elastic response
Repository-induced seismicity
Externally-induced seismicity
Differing thermal expansion of host rock zones
Uneven swelling of bentonite
Thermally-induced stress/fracturing in host rock
Excavation-induced stress/fracturing in host rock

5.5 Near-field rock: thermal effects

Convection
Hydrothermal alteration
Variations in groundwater temperature
Thermal effects (e.g. concrete hydration)
Thermal effects and transport (diffusion) properties
Thermal effects on hydrochemistry
Thermal differential elastic response
Thermal non-elastic response

5.6 Near-field rock: gas effects and transport

Gas effects: pressurization
Gas effects: disruption
Gas effects: explosions
Gas effects: fire

Gas transport in the near field as gas phase and in solution
Methane/CO_2 production: effects of microbial growth on properties of concrete
Accumulation of gases under permafrost
Methane intrusion
Transport of active gases
Methane CO_2 production: effects of lithostatic pressure
Methane CO_2 production: effects of hydrogen from metal corrosion
Methane CO_2 production: effects of radiation on microbial populations
Methane and CO_2 production: energy and nutrient control of metabolism

5.7 Near-field rock: microbiological/biological activity
Natural microbial activity
Transport of microbes into the near-field
Rock property changes: microbial pore blocking
Biogeochemical changes

5.8 Near-field rock: geochemical regime
Chemical gradients
Chemical kinetics
Pore blockage: concrete
Cement-sulphate reaction: concrete
Changes in pore water composition, pH, Eh: concrete
Chemical changes due to colloid production (chemical changes)
Chemical changes due to sorption (chemical changes)
Chemical changes due to speciation (chemical changes)
Fracture mineralization
Fluid interactions: dissolution
Chemical effects: interactions of waste canister and rock
Physico-chemical phenomena/effects (e.g. colloid formation)
Reconcentration
Thermochemical changes
Chemical effects of rock reinforcement
Saline (or fresh) groundwater intrusion
Effects at saline-freshwater interface
Non-radioactive solute plume in geosphere (effect on redox, effect on pH, sorption)
Physico-chemical degradation of concrete
Changes in groundwater flow direction

5.9 Near-field rock: radionuclide and contaminant chemistry
Precipitation, reconcentration
Dissolution
Recrystallization
Sorption (linear, nonlinear, irreversible)
Speciation
Dissolution, speciation, sorption, precipitation; hazardous constituents
Solubility effects (pH and Eh, ionic strength, completing agents, colloids)
Sorption effects (pH and Eh, ionic strength, completing agents, colloids)
Changes in sorptive surfaces
Dilution (mass, isotopic, species)

5.10 Near-field rock: Radionuclide and contaminant transport processes

Groundwater and gas flow
Advection/dispersion: radionuclides
Advection/dispersion: hazardous constituents
Diffusion: radionuclides
Diffusion: hazardous constituents
So ret effect
Transport of radionuclides bound to microbes
Colloid transport

5.11 Near-field rock: others

Incomplete repository or borehole closure
Unmodeled design features
Inadequate design: shaft seal and exploration borehole
seal failure
Open boreholes
Extreme channel flow of oxidants and nuclides (preferential pathways)
Poor quality construction
Abandonment of unsealed repository
Effects of phased operations
Repository flooding during operations
Dehydration of salt minerals
Release of stored energy
Nuclear criticality: heat
Methylation
Cavitation
Improper operation
Monitoring and remedial activities
Preclosure events
Retrievability
Blasting and vibration
Design modification: geometry
Design modification: DRZ (e.g. grouting)
Accidents during operation
Mutation
Boundary conditions
Correlation
Time-dependence
Sabotage
Nuclear criticality: explosions

6. FAR-FIELD

6.1 Rock properties

Rock properties (porosity, permeability, discharge zones, f ractures)

6.2 Hydrogeological effects

Natural rock property changes (porosity, permeability, fractures, pore blocking)

Dewatering
Geothermal gradient effects
Salinity effects on flow
Saturated groundwater flow
Variations in groundwater temperature
Gas-induced groundwater transport
Groundwater recharge
Thermal effects: fluid pressure, density, viscosity changes
Thermal effects: fluid migration
Saline groundwater intrusion
Fresh groundwater intrusion
Groundwater conditions (saturated/unsaturated)
Changes in geometry of the flow system
Changes in driving forces of the flow system
Changes in groundwater flow direction
Borehole - well

6.3 Physical/mechanical effects

Repository-induced seismicity
Externally-induced seismicity
Fault activation
Differential elastic response
Subsidence
Non-elastic response

6.4 Thermal effects

Geothermal gradient effects
Thermal differential elastic response
Thermal non-elastic response

6.5 Gas effects and transport

Gas transport into and through the far-field (gas phase and in solution)
Multiphase flow and gas-driven flow
Effects of natural gases
Transport of active gases

6.6 Microbiological/biological activity

Microbial activity
Transport of radionuclides bound to microbes
Biogeochemical changes

6.7 Geochemical regime

Groundwater composition changes (pH, Eh, chemical composition)
Fracture mineralization
Weathering, mineralization
Dissolution of fracture fillings, precipitation
Far field hydrochemistry - acids, oxidants, nitrates
Effects at saline-freshwater interface
Chemical gradients (electrochemical effects and osmosis)

Non-radioactive solute plume in geosphere (effect on redox, effect on pH, sorption)
Salinity: implications of evapo6te deposits/minerals\

6.8 Radionuclide and contaminant chemistry

Complexation by organics (including humic and fulvic acids)
Precipitation, dissolution, recrystallization, reconcentration
Sorption (linear, nonlinear, irreversible)
Speciation
Solubility effects (pH and Eh, ionic strength, complexing agents, colloids)
Sorption effects (pH and Eh, ionic strength, complexing agents, colloids)
Changes in sorptive surfaces
Dilution (mass, isotopic, species)

6.9 Radionuclide and contaminant transport processes

Groundwater flow, advection/dispersion (saturated conditions)
Diffusion (bulk, matrix, surface)
Unsaturated transport
Groundwater flow: fracture
Groundwater flow: effects of solution channels (preferential pathways)
So ret effect
Transport of radionuclides bound to microbes
Gas mediated transport
Colloids: formation & effects (including inorganic and organic colloid transport)

6.10 Others

Boreholes unsealed
Incomplete vault closure
Inadequate design: exploration borehole seal failure
Undetected features (e.g. faults, fracture networks, shear zones, discontinuities, gas)
Radiolysis, radiation damage
Cavitation
Correlation
Nuclear criticality
Explosion

7. BIOSPHERE

7.1 Human considerations

Space heating
Charcoal production
Land use changes
Demographic change, urban development
Crop fertilization
Crop storage
Peat and leaf litter harvesting
Hydroponics
Water leak into underground living space

7.2 Ecological factors

Animal habits (grooming and fishing, soil ingestion, diets, scavengers/predators)
Houseplants
Tree sap
Terrestrial ecological development: natural and agricultural systems
Terrestrial ecological development: Effects of succession
Terrestrial ecological development: Estuarine
Plants: Root uptake, including deep rooting species
Plants: Deposition on surfaces
Plants: Vapor uptake
Plants: Internal translocation and retention
Plants: Washoff and leaching by rainfall
Plants: Leaf-fall and senescence
Plants: Cycling processes
Animals: Uptake by ingestion
Animals: Uptake by inhalation
Animals: Internal translocation and retention
Animals: Cycling processes
Animals: Effects of relocation and migration
Precipitation, temperature and soil water balance
Ecological change (e.g. forest fire cycles)
Ecological response to climate, including glacial/interglacial cycling, (e.g. desert formation)
Biological evolution
Intrusion (animal)

7.3 Soil/sediment effects

Lake infilling
Erosion - wind
Alkali flats
Capillary rise in soil
Soil properties (type, depth, porewater pH, moisture, sorption)
Soil leaching
Ionic exchange in soil
Sediment resuspension in water bodies
Sedimentation in water bodies
Groundwater discharge to soils: advective, diffusive, biotic, volatilization
Accumulation in sediments
Accumulation in soils and organic debris, including peat
Pedogenesis
Evaporation of soil moisture
Solid discharge via erosional processes
Saltation

7.4 Surface/near-surface water processes

Groundwater discharge (to surface water)
Groundwater discharge (springs)
Groundwater discharge (wells)

Flushing of water bodies
Surface water bodies: properties (e.g., pH)
Near-surface runoff processes: overland flow, interflow, return flow, macropore flow
Near-surface runoff processes: variable source area response
Surface flow characteristics: stream/river flow
Surface flow characteristics: sediment transport
Surface flow characteristics: meander migration or other fluvial response
Surface flow characteristics: lake formation/sedimentation
Surface flow characteristics: effects of sea level change
Estuarine surface flow characteristics: tidal cycling, sediment transport, successional development, effects of sea level change
Surface water bodies: water flow
Surface water bodies: suspended sediments
Surface water bodies: bottom sediments
Surface water bodies: effects on vegetation
Surface water bodies: effects of fluvial system development
Surface water mixing
Sediment/water/gas interaction with the atmosphere
Terrestrial water use (including wells and dams)
River flow and lake level changes
Dams
River course meander
Wetlands
Flood (short-term)
Acid rain
Artificial lake mixing
Drought

7.5 Coastal water/ocean processes

Coastal waters: tidal mixing, residual current mixing, effects of sea level change
Ocean waters: water exchange, effects of sea level change
Groundwater discharge to marine waters including coastal
Estuaries: water flow, suspended sediments, bottom sediments, effects of salinity variation, effects on vegetation, estuarine development and sea level change
Coastal waters: water transport, bottom and suspended sediment transport, effects of sea level change, estuarine development and coastal erosion
Estuarine water use
Coastal water use
Sea water use

7.6 Gas effects and transport

Gas leakage into underground living space
Radon emission
Gas transport: gas phase and in solution
Gas discharge

7.7 Microbiological/biological activity

Microbial activity
Bioaccumulation and translocation

Biotoxicity
Soil and sediment transport including bioturbation
Burrowing animals
Transport of radionuclides bound to microbes
Biogeochemical changes
7.8 Geochemical regime (general)
Soil and surface water chemistry (pH, Eh)
Fluid interactions: dissolution, precipitation
Weathering, mineralization
Physico-chemical phenomena/effects (e.g. colloid formation)
Altered soil or surface water chemistry (pH, Eh)
Thermal effects on hydrochemistry
Chemical gradients (electrochemical effects and osmosis)
Colloids, complexing agents

7.9 Radionuclide and contaminant chemistry

Complexation by organics (including humic and fulvic acids)
Precipitation, dissolution, recrystallization, reconcentration
Sorption (linear, nonlinear, irreversible)
Speciation
Chemical changes due to sorption, complex formation, speciation, gas, solubility
Solubility effects (pH and Eh)
Sorption effects (pH and Eh)
Changes in sorptive surfaces
Dilution (mass, isotopic, species)

7.10 Radionuclide and contaminant transport processes

Water flow: advection and dispersion
Diffusion (bulk, matrix, surface)
Gas-mediated transport
Transport of active gases: gas phase and in solution
Transport of radionuclides bound to microbes

7.11 Radiological factors

Building materials
Carcasses
Carcinogenic contaminants
Convection, turbulence and diffusion (atmospheric)
Critical group - agricultural labor,
    clothing and home furnishings
    evolution
    house location
    individuality
    leisure pursuits
    pets
Dermal sorption - nuclides other than tritium
Household dust and fumes
Human diet

Food preparation
Human soil ingestion
Precipitation (meteoric)
Deposition (wet and dry)
Radiotoxic contaminants
Showers and humidifiers
Suspension in air
Wind
External exposure: land, sediments, water bodies
Ingestion and drinking water
Ingestion and agricultural crops
Ingestion and domestic animal products
Ingestion and wild plants
Ingestion and wild animals
Ingestion and soils and sediments
Inhalation and soils and sediments
Inhalation and gases and vapors (indoor/outdoor)
Inhalation and biotic material
Inhalation and salt particles
Sediment/water/gas interaction with the atmosphere
Mutagenic contaminants
Dermal sorption - tritium
Sensitization to radiation
Radioactive decay

7.12 Others

Colloids: formation and effects (including inorganic and organic colloid transport)
Greenhouse-induced ecological effects (including food production)
Smoking
Boreholes - unsealed
Loss of integrity of borehole seals: sea] failure or degradation
Inadequate design: exploration borehole seal failure
Intrusion in accumulation zone in the biosphere (animals)
Chemical toxicity
Correlation
Seasons
Terrestrial surface
Uncertainties
Toxicity of mined rock
Ozone layer failure
Herbicides, pesticides, fungicides

8. GEOLOGY / CLIMATE CHANGES

8.1 Seismic Events/major land movement

Earthquakes
Regional uplift and subsidence (e.g. orogenic, isostatic)
Externally-induced seismicity
Natural seismicity

8.2 Rock deformation

Salt deformation/diapirism
Faulting/fracturing: change of properties - natural
Faulting/fracturing: change of properties - human-induced
Major incision
Movements at faults
Formation of new faults
Formation of interconnected fracture systems

8.3 Metamorphic and igneous processes

Metamorphic activity
Magmatic activity
Volcanism

8.4 Erosion/weathering (surface)

Aeolian and fluvial denudation
Mass wasting
Changes in topography
Weathering
Extreme erosion and denudation: glacial-induced (e.g. coastal/stream erosion)
Coastal erosion due to sea level change
Erosion: glacial
Stream erosion
Sedimentation
Land slide
Freshwater sediment transport and deposition
Marine sediment transport and deposition

8.5 Groundwater flow and effects

Variation in groundwater recharge

8.6 Surface water flow and effects

Hydrological change
Flooding
Precipitation, temperature and soil water balance
Snow melt
River flow and lake level changes
Alkali flats
River course meander

8.7 Sea level effects

Sea level change
River incision/sedimentation due to sea level change

8.8 Magnetic effects

Changes in the Earth's magnetic field

8.9 Glaciation/glacial effects

Glaciation
Glacial/Interglacial cycling effects (including sea level changes)
Permafrost
Accumulation of gases under permafrost
No ice age

8.10 Climate effects (natural)

Drought
Dust storms and desertification (massive)
Climate change
Insolation
Ozone layer (failure)
Acid rain

8.11 Others

Anthropogenic climate change drought (greenhouse effect)
Greenhouse-induced effects (e.g. sea level change, precipitation, temp.)
Hurricanes
Tsunamis
Seiches
Meteorite impact
Diagenesis
Greenhouse-induced storm surges
Global effects
Terrestrial surface
Formation of dissolution cavities

9. HUMAN INFLUENCES

9.1 Inadvertent intrusion into repository

Archeological investigations
Exploratory boreholes (oil, gas)
Resource exploitation (e.g. hydrocarbon, geothermal)
Reuse of boreholes
Intrusion in accumulation zone in the biosphere
Injection wells
Intrusion (deliberate)
- recovery of wastes or associated materials (mining)
- malicious (sabotage, act of war (nuclear))
- recovery of repository materials

9.2 Surface activities

Earthmoving
Altered soil or surface water chemistry by human activities
Human-induced changes in surface hydrology
Heat storage in lakes
Hydrologic stresses: damming of streams or rivers
Quarrying, peat extraction
Quarrying, near surface extraction
Artificial lake mixing
Ashes and sewage sludge
Crop fertilization
Crop storage
Herbicides, pesticides, fungicides
Inject/ingest/inhaling locally produced drugs
Peat and leaf lifter harvesting
Biogas production
Earth moving projects
Lake infilling
Blasting and vibration
Hydroponics
Technological advances in food production
Other future uses of crystalline rock
Near storage of other waste

9.3 Subsurface activities

Exploratory boreholes (oil, gas): nonintrusive
Drilling: enhanced oil/gas production: nonintrusive
Drilling: liquid waste disposal: nonintrusive
Drilling: hydrocarbon storage: nonintrusive
Drilling: archeology: nonintrusive
Exploratory boreholes (water, potash)
Dewatering
Wells
Wells (high demand)
Resource exploitation (intersection of zone of contamination)

Heat storage underground
Geothermal energy production
Tunneling
Construction of underground storage/disposal facilities (e.g. gas storage)
Construction of underground dwellings/shelters
Injection of liquid wastes: nonintrusive
Potash mining
Solution mining
Underground weapons testing (nuclear device)
Mining other than potash
Geothermal energy exploration (and other unidentified resources)
Resource exploitation following intrusion
Injection wells: enhanced oil/gas production, hydrocarbon storage: nonintrusive

9.4 Water use

Industrial use of water
Outdoor spraying of water
Groundwater extraction
Irrigation
Reservoirs
Intentional artificial groundwater recharge or withdrawal

9.5 Agricultural and fisheries practices

Fish farming
Ranching
Agricultural and fisheries practice changes

9.6 Radiological factors (smoking, transport agents)

Radiological factors (smoking, transport agents)

9.7 Others

Demographic change, urban development
Undetected repository intrusions (boreholes, mining)
Undetected boreholes (existing): nonintrusive
Stray materials left
Decontamination materials left
Loss of records
Radioactive waste disposal error
Inadvertent inclusion of undesirable materials
Poor quality construction
Design modifications
Accidents during operation
Backfill/seal material deficiencies
Postclosure monitoring
Unsuccessful attempt of site improvement
Poorly designed repository
Cure for cancer
Sabotage
Acid rain

Sudden energy release
Chemical sabotage
Explosions (resource recovery)
Borehole-induced solution and subsidence
Explosions (act of war)

3. CCA Screening of Features, Events and Processes - Summary Table

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N1	Stratigraphy	Disposition and properties of geological formations control system performance	UP		**SCR.1.1.1** Section 2.1.3 Section 6.4.2 Appendix GCR, Section 4.3 Appendix BH Appendix PAR, Table PAR-57, Appendix FAC, HYDRO, SUM	Insert select examples from Rl in Z, W/asterisk that these are only select.	N1
N2	Brine reservoirs	Pressurized brine reservoirs may be present in the Castile beneath the controlled area	DP		**SCR.1.1.1** Section 2.1.3 Section 6.4.12.6 Section 6.4.8 Appendix PAR, Parameters 27, 28, 29, and 31, and Table PAR-30, DEF	Anderson Bachman Chapman Beauheim (memo)	N2
N3	Changes in regional stress	Tectonic activity on a regional scale may change levels of stress	SO-C		**SCR.1.1.2** Section 2.1.5		N3-N5
N4	Regional tectonics	Tectonic setting of the region governs current level of stress	SO-C		**SCR.1.1.2** Section 2.1.5 Appendix FAC, Section 6.4	King 1948, 120-121 Schiel 1994 Borns et al. 1983, 58-60 Muehlberger et al. 1978, 338	N3-N5
N5	Regional uplift and subsidence	Tectonic activity on a regional scale could cause uplift and subsidence	SO-C		**SCR.1.1.2** Section 2.1.5	King, 1948	N3-N5

Legend:

UP	FEPs accounted for in the assessment calculations for undisturbed performance for 40 CFR § 191.13 (as well as 40 CFR § 191.15 and Subpart C of 40 CFR Part 191).
DP	FEPs accounted for (in addition to all UP FEPs) in the assessment calculations for disturbed performance for 40 CFR § 191.13.
SO-R	FEPs eliminated from performance assessment calculations on the basis of regulations provided in 40 CFR Part 191 and criteria provided in 40 CFR Part 194.
SO-C	FEPs eliminated from performance assessment (and compliance assessment) calculations on the basis of consequence.
SO-P	FEPs eliminated from performance assessment (and compliance assessment) calculations on the basis of low probability of occurrence.
NA	FEPs not applicable to the particular category.
HCN	Historical, Current and Near-Future human-initiated events and processes (EPs)
Future	Future human-initiated EPs

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N6	Salt deformation	Salt formations may deform under gravity or other forces	SO-P	UP near repository.	**SCR.1.1.3.1** Section 2.1.6.1 Appendix DEF, Section 2.3		N6-N7
N7	Diapirism	Buoyancy forces may cause salt to rise through denser rocks	SO-P		**SCR.1.1.3.1** Appendix DEF, Section 3.1 Appendix DEF, Section 2	Gera 1974	N6-N7
N8	Formation of fractures	Changes in stress may cause new fracture sets to form	SO-P	UP near repository.	**SCR.1.1.3.2** Section 2.1.5		N8-N9
N9	Changes in fracture properties	Changes in the local stress field may change fracture properties such as aperture and asperity	SO-C	UP near repository.	**SCR.1.1.3.2** Section 2.1.5.2 *Section 2.2.1* *Section 6.4.6.2*		N8-N9
N10	Formation of new faults	Tectonic activity on a regional scale could cause new faults to form	SO-P		**SCR.1.1.3.3**		N10-N12
N11	Fault movement	Movement along faults in the Rustler or in units below the Salado could affect the hydrogeology	SO-P		**SCR.1.1.3.3** *Section 2.1.5.2* Section 2.1.5.3 Appendix GCR, Section 4.4 Appendix FAC, Section 6.4	Schiel 1994 Muehlberger et al. 1978, 338	N10-N12
N12	Seismic activity	Groundshaking may give rise to cracking at free surfaces such as the roof of the repository	UP		**SCR.1.1.3.4** Section 2.6.2 Section 6.4.5.3 Appendix PAR, Table PAR-37 Appendix GCR, Section 5	Wallner, 1981, 244 Dowding & Rozen 1978 Lenhardt, 1988, 392	N10-N12
N13	Volcanic activity	Igneous material feeding volcanoes or surface flows could affect disposal system performance	SO-P		**SCR.1.1.4.1** Appendix GCR, Section 3.5		N13-N15
N14	Magmatic activity	Subsurface intrusion of igneous rocks could affect disposal system performance	SO-C		**SCR.1.1.4.1** Section 2.1.5.4 Appendix GCR, Section 3.5		N13-N15

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N15	Metamorphic activity	High pressures and/or temperatures could cause solid state recrystallisation changes	SO-P		**SCR.1.1.4.2**		N13-N15
N16	Shallow dissolution	Percolation of groundwater and dissolution in the Rustler may increase transmissivity	UP		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.3 Section 6.4.6.2 Appendix PAR, Parameters 35, 50, 51	Bachman, 1985	N16-N21
N17	Lateral dissolution	Dissolution at the Rustler - Salado contact may create pathways and/or increase transmissivity	SO-C		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.2 Appendix FAC, Sections 3.1.2 , 4.1.1 and 8.9	Bachman et al. 1973, 39 Bachman 1974, 71 Bachman 1980, 97 Bachman 1981, 3 Lambert 1983 Bachman 1984 Lowenstein 1987	N16-N21
N18	Deep dissolution	Dissolution in the Castile or at the base of the Salado may create pathways	SO-P		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.1	Anderson et al. 1972, 81 Anderson 1978	N16-N21
N19`	Solution chimneys	Dissolution cavities in the Castile or at the base of the Salado may propagate towards the surface	SO-P		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.1	Anderson 1978, 52 Snyder et al. 1982, 65 Nicholson & Clebsch 1961, 14	N16-N21
N20	Breccia pipes	Formations above deep dissolution cavities may fracture	SO-P		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.1		N16-N21
N21	Collapse breccias	Dissolution may result in collapse of overlying units	SO-P		**SCR.1.1.5.1** Section 2.1.6.2 Appendix DEF, Section 3.1 Appendix FAC, Section 7.2.4	Anderson et al. 1972 Robinson & Powers 1987, 78 Davies 1983, 45 Borns & Shaffer 1985	N16-N21

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N22	Fracture infills	Precipitation of minerals as fracture infills can reduce hydraulic conductivities	SO-C		**SCR.1.1.5.2** Appendix FAC, Section 8.8	Siegel et al. 1991, 5-53 to 5-57 Chapman 1986, 31 Lambert & Harvey 1987, 207	N22
N23	Saturated groundwater flow	Groundwater flow beneath the water table is important to disposal system performance	UP		**SCR.1.2.1** Section 2.2.1 Section 6.4.5 Section 6.4.6 Appendix HYDRO Appendix BRAGFLO, Sections 4.1 to 4.4 Appendix SECOFL2D, Section 3		N23-N30
N24	Unsaturated groundwater flow	The presence of air or other gas phases may influence groundwater flow	UP	SO-C in Culebra.	**SCR.1.2.1** Section 2.2.1 Section 6.4.6 Appendix HYDRO Appendix BRAGFLO, Sections 4.8 and 4.9		N23-N30
N25	Fracture flow	Groundwater may flow along fractures as well as through interconnected pore space	UP		**SCR.1.2.1** Section 6.4.6.2 Appendix MASS, Section 15 Appendix SECOTP2D, Sections 2 and 3.4		N23-N30
N26	Density effects on groundwater flow	Spatial variability of groundwater density could affect flow directions	SO-C		**SCR.1.2.1** Section 2.2.1.4.1.2	Davies 1989, 53	N23-N30
N27	Effects of preferential pathways	Groundwater flow may not be uniform, and may occur along particular pathways	UP	UP in Salado and Culebra.	**SCR.1.2.1** Section 6.4.6.2 Appendix TFIELD, Sections 2.2 and 4 Appendix PAR, Parameters 35, 50, 51		N23-N30

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N28	Thermal effects on groundwater flow	Natural temperature variability could cause convection or otherwise affect groundwater flow	SO-C		**SCR.1.2.2**		N23-N30
N29	Saline intrusion [hydrogeological effects]	The introduction of more saline water into the Rustler could affect groundwater flow	SO-P		**SCR.1.2.2**		N23-N30
N30	Freshwater intrusion [hydrogeological effects]	The introduction of freshwater into the Rustler could affect groundwater flow	SO-P		**SCR.1.2.2**		N23-N30
N31	Hydrological response to earthquakes	Fault movement can affect groundwater flow directions and pressure changes can affect groundwater levels and movement	SO-C		**SCR.1.2.2** Section 2.6.2 Appendix GCR, Section 5	Bredehoeft et al. 1987, 139	N31
N32	Natural gas intrusion	The introduction of natural gas from formations beneath the repository could affect groundwater flow	SO-P		**SCR.1.2.2** Section 2.3.1.2		N32
N33	Groundwater geochemistry	Groundwater geochemistry influences actinide retardation and colloid stability	UP		**SCR.1.3.1** Section 2.2.1 Section 2.4 Section 6.4.3.4 Section 6.4.6.2 Appendix PAR, Parameters 36 to 47, 52 to 57, Table PAR-39		N33-N38
N34	Saline intrusion [geochemical effects]	The introduction of more saline water into the Rustler could affect actinide retardation and colloid stability	SO-C		**SCR.1.3.2**		N33-N38
N35	Freshwater intrusion [geochemical effects]	The introduction of freshwater into the Rustler could affect actinide retardation and colloid stability	SO-C		**SCR.1.3.2**		N33-N38
N36	Changes in groundwater Eh	Changes in oxidation potentials could affect radionuclide mobilization	SO-C		**SCR.1.3.2**		N33-N38

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N37	Changes in groundwater pH	Changes in pH could affect colloid stability and the mobility of radionuclides	SO-C		**SCR.1.3.2**		N33-N38
N38	Effects of dissolution	Dissolution could affect groundwater chemistry and hence radionuclide transport	SO-C		**SCR.1.3.2**		N33-N38
N39	Physiography	The physiography of the area is a control on the surface water hydrology	UP		**SCR.1.4.1** Section 2.1.4 Section 6.4.2 Appendix PAR, Table PAR-57		N39
N40	Impact of a large meteorite	A large meteorite could fracture the rocks above the repository	SO-P		**SCR.1.4.2**	Grieve 1987, 248, 257, 263 Dence et al. 1977, 263 Dietz, 1961 Hartmann 1965, 161 Halliday 1964, 267-277 Hartmann 1979 Kärnbränslesakerhet 1978 Claiborne & Gera 1974 Cranwell et al. 1990 Thorne 1992	N40
N41	Mechanical weathering	Processes such as freeze -thaw affect the rate of erosion	SO-C		**SCR.1.4.3.1**		N41-N49
N42	Chemical weathering	Breakdown of minerals in the surface environment affects the rate of erosion	SO-C		**SCR.1.4.3.1**		N41-N49
N43	Aeolian erosion	The wind can erode poorly consolidated surface deposits	SO-C		**SCR.1.4.3.2**		N41-N49
N44	Fluvial erosion	Erosion by rivers and streams could affect surface drainage	SO-C		**SCR.1.4.3.2**		N41-N49
N45	Mass wasting [erosion]	Gravitational processes can erode material on steep slopes	SO-C		**SCR.1.4.3.2**		N41-N49

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N46	Aeolian deposition	Sand dunes and sheet sands may be deposited by the wind and affect surface drainage	SO-C		**SCR.1.4.3.3**		N41-N49
N47	Fluvial deposition	Rivers and streams can deposit material and affect surface drainage	SO-C		**SCR.1.4.3.3**		N41-N49
N48	Lacustrine deposition	Lakes may be infilled by sediment and change the drainage pattern	SO-C		**SCR.1.4.3.3**		N41-N49
N49	Mass wasting [deposition]	Land slides could block valleys and change the drainage pattern	SO-C		**SCR.1.4.3.3**		N41-N49
N50	Soil development	Vegetation and surface water movement is affected by the types of soil present	SO-C		**SCR.1.4.4**	Lappin et al. 1989, 2-4 Rosholt & McKinney 1980, Table 5	N50
N51	Stream and river flow	The amount of flow in streams and rivers affects erosion and deposition	SO-C		**SCR.1.5.1** Section 2.2.2 Appendix GCR, Section 6.2.1	Bachman 1974 Bachman 1981 Bachman 1987	N51
N52	Surface water bodies	The disposition of lakes is a control on the surface hydrology	SO-C		**SCR.1.5.2** Section 2.2.2 Appendix GCR, Section 6.2.1	Bachman 1974 Bachman 1981 Bachman 1987	N52
N53	Groundwater discharge	The amount of water leaving the groundwater system to rivers, springs and seeps affects the groundwater hydrology	UP		**SCR.1.5.3** Section 2.2.1.1 Section 2.2.1.4 Section 2.2.2 Section 6.4.10.2 Appendix PAR, Parameter 35, Table PAR-30 Appendix TFIELD, Section 3		N53-N56

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N54	Groundwater recharge	The amount of water passing into the saturated zone affects the groundwater hydrology	UP		**SCR.1.5.3** Section 2.2.1.1 Section 2.2.1.4 Section 6.4.6.2 Section 6.4.10.2 Appendix MASS, Section 14.2 Appendix PAR, Parameter 35, Table PAR-30 Appendix TFIELD, Section 3		N53-N56
N55	Infiltration	The amount of water entering the unsaturated zone controls groundwater recharge	UP	UP for climate change effects.	**SCR.1.5.3** Section 2.2.2 Section 6.4.10.2 Appendix PAR, Parameter 35, Table PAR-30 Appendix TFIELD, Section 3		N53-N56
N56	Changes in groundwater recharge and discharge	Changes in climate and drainage pattern may affect the amount of water entering and leaving the groundwater system	UP		**SCR.1.5.4** Section 2.2.1.4 Section 2.5 Section 6.4.9 Appendix MASS, Section 14.2 Appendix PAR, Parameter 48		N53-N56
N57	Lake formation	Formation of new lakes will affect the surface hydrology	SO-C		**SCR.1.5.4**		N57-N58
N58	River flooding	Flooding will affect the area over which infiltration takes place	SO-C		**SCR.1.5.4**		N57-N58
N59	Precipitation [e.g. rainfall]	Rainfall is the source of water for infiltration and stream flow	UP		**SCR.1.6.1** Section 2.5 Section 6.4.9 Appendix PAR, Parameter 48		N59-N63

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N60	Temperature	The temperature influences how much precipitation evaporates before it reaches streams or enters the ground	UP		**SCR.1.6.1** Section 2.5 Section 6.4.9 Appendix PAR, Parameter 48		N59-N63
N61	Climate change	Temperature and precipitation will vary as natural changes in the climate take place	UP		**SCR.1.6.2.1** Section 2.2.1.4 Section 2.5 Section 6.4.9 Appendix CLI Appendix PAR, Parameter 48		N59-N63
N62	Glaciation	Natural climate change could lead to the growth of glaciers and ice sheets	SO-P		**SCR.1.6.2.2** Appendix CLI	Imbrie & Imbrie 1980, 951	N59-N63
N63	Permafrost	The regions in front of advancing ice sheets will be subject to frozen ground preventing infiltration	SO-P		**SCR.1.6.2.2**		N59-N63
N64	Seas and oceans	The volume and circulation patterns in seas and oceans would affect the distribution of radionuclides	SO-C		**SCR.1.7.1**		N64-N67
N65	Estuaries	Water movement in estuaries would affect the distribution of radionuclides	SO-C		**SCR.1.7.1**		N64-N67
N66	Coastal erosion	Coastal erosion could affect the local groundwater system	SO-C		**SCR.1.7.2**		N64-N67
N67	Marine sediment transport and deposition	Transport and deposition could affect the distribution of radionuclides	SO-C		**SCR.1.7.2**		N64-N67
N68	Sea level changes	Sea level change would affect coastal aquifers	SO-C		**SCR.1.7.3**	Chappell & Shackleton 1986, 138 Warrick & Oerlemans 1990, 278	N68

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
N69	Plants	Plants play a role in the hydrological cycle by taking up water	SO-C		**SCR.1.8.1** Section 2.4.1		N69-N70
N70	Animals	Burrowing animals can affect the structure of surface sediments	SO-C		**SCR.1.8.1** Section 2.4.1		N69-N70
N71	Microbes	Microbes can be important in soil development. Microbes in groundwater may sorb radionuclides	SO-C	UP for colloidal effects and gas generation	**SCR.1.8.1** Appendix MASS, Section 15.3.2		N71
N72	Natural ecological development	Changes in climate may cause changes in the types of vegetation and animals present	SO-C		**SCR.1.8.2** Appendix CLI		N72
W1	Disposal geometry	WIPP repository disposal geometry will influence flow and transport patterns	UP		**SCR.2.1.1** Section 3.2 Section 6.4.2.1 *Section 6.4.3*		W1
W2	Waste inventory	The quantity and type of radionuclides emplaced in the repository will dictate performance requirements	UP		**SCR.2.1.2** Section 4.1 Section 6.4.3.5 Section 6.4.3.3 Appendix BIR Appendix WCA, Sections 3.2, 8.2 and 8.3 Appendix PAR, Table PAR-41		W2
W3	Heterogeneity of waste forms	The distribution of radionuclides within the different waste types could affect release patterns	DP		**SCR.2.1.2** Section 6.4.7 Section 6.4.12.4 Appendix WCA, Section 3.2.1	Sanchez et al. 1996	W2-W3
W4	Container form	The type and shape of waste container will affect heat dissipation and container strength	SO-C		**SCR.2.1.3** Appendix DVR, Section 12.2		W4

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W5	Container material inventory	Steel and other materials will corrode and affect the amount of gas generated	UP		**SCR.2.1.3** Chapter 4, Table 4-4 Section 6.4.3.3 Appendix BIR Appendix SOTERM, Section 2.2.3 Appendix PAR, Parameter 1, Table PAR-43	Wang & Brush 1996	W5
W6	Seal geometry	Size, location, and materials of shaft seals, and panel and drift closures will affect flow patterns and transport pathways	UP		**SCR.2.1.4** Section 3.3 Appendix SEAL Section 6.4.4 Appendix PAR, Figure PAR-2		W6-W7
W7	Seal physical properties	Porosity and permeability of seals will control flow rates	UP		**SCR.2.1.4** Section 3.3.1 Section 3.3.2 Appendix SEAL Section 6.4.4 Appendix PAR, Parameters 9 to 11, Tables PAR-16 to PAR-24		W6-W7
W8	Seal chemical composition	The chemistry of seal materials could affect actinide speciation and mobility	SO-C	Beneficial SO-C	**SCR.2.1.4** SCR.2.5.2	Bennett et al. 1992	W8
W9	Backfill physical properties	The amount and distribution of backfill could affect porosity and permeability in disposal rooms	SO-C		**SCR.2.1.5** Appendix BACK, Section 3.2	WIPP PA 1993a, b	W9

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W10	Backfill chemical composition	The chemical behavior of the backfill will affect actinide speciation and mobility	UP		**SCR.2.1.5** Section 6.4.3.4 Appendix BACK, Section 1 Appendix SOTERM, Section 2.2.2 Appendix WCA, Sections 4.1.2, 8.9 and 8.10 Appendix PAR, Parameters 36 to 47, Table PAR-39	Wang 1996a, b	W10
W11	Postclosure monitoring	Inappropriate monitoring after closure could affect performance	SO-C		**SCR.2.1.6** Appendix MON, Section 6		W11
W12	Radionuclide decay and ingrowth	Radioactive decay of waste will change and decrease the inventory with time	UP		**SCR.2.2.1** Section 6.4.12.4 Section 6.4.5.4.2 Appendix BIR, Section 3.2 Appendix NUTS, Section 4.3.7 Appendix SECOTP2D, Section 2 Appendix PANEL, Section 4.6		W12
W13	Heat from radioactive decay	Radioactive decay of waste will generate heat in the repository	SO-C		**SCR.2.2.2**	DOE 1980, 9-149 to 9-150 Thorne & Rudeen 1981 Sanchez & Trellue 1996	W13
W14	Nuclear criticality: heat	A sustained fission reaction would generate heat	SO-P		**SCR.2.2.3** *Section 6.4.6.2* *Section 6.4.5.2* *Appendix MASS*	Rechard 1996	W14
W15	Radiological effects on waste	Radiation can change the physical properties of many materials	SO-C		**SCR.2.2.4** *Section 6.4.3.4* *Section 6.4.3.5* *Section 6.3.3.6*		W15-W17

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W16	Radiological effects on containers	Radiation can change the physical properties of many materials	SO-C		**SCR.2.2.4** *Section 6.4.3.4* *Section 6.4.3.5* *Section 6.3.3.6*		W15-W17
W17	Radiological effects on seals	Radiation can change the physical properties of many materials	SO-C		**SCR.2.2.4** *Section 6.4.3.4* *Section 6.4.3.5* *Section 6.3.3.6*		W15-W17
W18	Disturbed rock zone	Repository construction has led to fracturing of rock around the opening	UP		**SCR.2.3.1** Section 3.3.1.5 Section 6.4.5.3 Appendix SEAL, Sections 7.5 and 8, Appendices C and D Appendix MASS, Section 13.4 Appendix PAR, Parameter 12, Tables PAR-2, PAR-3, PAR-37	Vaughn et al. 1995	W18
W19	Excavation-induced changes in stress	Repository construction has led to changes in stress around the opening	UP		**SCR.2.3.1** Section 3.3.1.5 Section 6.4.3.1 Appendix SEAL, Section 7 Appendix PAR Table PAR-38 Appendix PORSURF, Attachment PORSURF-6		W19
W20	Salt creep	Salt creep will consolidate seal components and close the disposal rooms, thereby compacting the waste	UP		**SCR.2.3.2** Section 6.4.3.1 Appendix BRAGFLO, Section 4.11 Appendix PAR Table PAR-38 Appendix PORSURF, Attachment PORSURF-6	Freeze 1996 Freeze et al. 1995 Butcher et al. 1991, 65-76 Luker et al. 1991	W20-W21

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W21	Changes in the stress field	Salt creep will affect the stress field around the repository opening	UP		**SCR.2.3.2** Section 6.4.3.1 Appendix BRAGFLO, Section 4.11 Appendix PAR Table PAR-38 Appendix PORSURF, Attachment PORSURF-6	Freeze 1996 Freeze et al. 1995 Butcher et al. 1991, 65-76 Luker et al. 1991	W20-W21
W22	Roof falls	Instability of the DRZ could lead to roof falls	UP		**SCR.2.3.3** Section 6.4.5.3 Appendix PAR, Table PAR-37		W18-W22
W23	Subsidence	Salt creep and roof falls could lead to subsidence of horizons above the repository	SO-C		**SCR.2.3.4** *Section 2.2.1.4.1.2* *Appendix TFIELD*	Westinghouse 1994, 2-17 to 2-23, 3-4 to 3-23, Table 3-13, Fig 3-39, Fig 3-40, 4-1 to 4-2 Peake 1996 EPA 1996, 9-38 to 9-60 Witherspoon et al. 1980	W23
W24	Large scale rock fracturing	Salt creep and roof falls could lead to fracturing between the repository and higher units or the surface	SO-P		**SCR.2.3.4**		W24
W25	Disruption due to gas effects	Increased gas pressures may lead to fracturing of Salado interbeds	UP		**SCR.2.3.5** Section 6.4.5.2 Appendix BRAGFLO, Section 4.10 Appendix MASS, Section 13.3 and Attachment 13-2 Appendix PAR, Table PAR-36	Mendenhall & Gersthe 1993	W25-W27

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W26	Pressurization	Increased gas pressures may slow the rate of salt creep	UP		**SCR.2.3.5** Section 6.4.3.1 Appendix BRAGFLO, Section 4.11 Appendix PORSURF, Attachment PORSURF-6	Freeze 1996 Freeze et al. 1995 Butcher et al. 1991, 65-76 Luker et al. 1991	W25-W27
W27	Gas explosions	Explosion of gas mixtures in the repository could affect the DRZ	UP		**SCR.2.3.6** Section 6.4.5.3 Appendix PCS, Section 2.2.3 Appendix PAR, Table PAR-37		W25-W27
W28	Nuclear explosions	A critical mass of plutonium in the repository could explode if rapidly compressed	SO-P		**SCR.2.3.6**	Rechard 1996	W28
W29	Thermal effects on material properties	Temperature rises could lead to changes in porosity and permeability	SO-C		**SCR.2.3.7** Appendix SEAL, Section 7.4	*DOE 1980* *Sanchez & Trellue 1996* Loken 1994 Loken & Chen 1995 Wakeley et al. 1995 Bennett et al. 1996	W29-W31
W30	Thermally-induced stress changes	Elevated temperatures could change the local stress field and alter the rate of salt creep	SO-C		**SCR.2.3.7**	Argüello & Torres 1988 Thorne & Rudeen 1981	W29-W31
W31	Differing thermal expansion of repository components	Stress distribution and strain changes can depend on differing rates of thermal expansion between adjacent materials	SO-C		**SCR.2.3.7**	*DOE 1980* *Sanchez & Trellue 1996* Loken 1994 Loken & Chen 1995 Wakeley et al. 1995 Bennett et al. 1996	W29-W31

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W32	Consolidation of waste	Salt creep and room closure will change waste permeability	UP		**SCR.2.3.8** Section 6.4.3.1 Section 6.4.3.2 Appendix WCA, Section 5.2 Appendix PAR, Table PAR-38 Appendix PORSURF, Attachment PORSURF-6	Vaughn et al. 1995 Butcher et al. 1991 Luker et al. 1991, 693-702	W32
W33	Movement of containers	Density differences or temperature rises could lead to movement of containers within the salt	SO-C		**SCR.2.3.8**	Dawson & Tillerson 1978, 22 *Sandia WIPP Project 1992, Vol 3*	W33
W34	Container integrity	Long-lived containers could delay dissolution of waste	SO-C	Beneficial SO-C	**SCR.2.3.8** Section 6.5.4		W34
W35	Mechanical effects of backfill	Backfill in disposal rooms will act to resist creep closure	SO-C		**SCR.2.3.8** Appendix BACK, Section 3.2	Westinghouse 1994 WIPP PA 1993a, b	W35
W36	Consolidation of seals	Salt creep will consolidate long-term seal components, reducing porosity and permeability	UP		**SCR.2.3.8** Section 6.4.4 Appendix SEAL, Appendix D Appendix PAR, Parameters 9 to 11 and 13, Tables PAR-16 to PAR-24	Hansen and Ahrens 1996 Callahan et al. 1996 Brodsky et al.. 1996	W36-W47
W37	Mechanical degradation of seals	Gas pressurization, clay swelling, and cracking of concrete could affect seal properties	UP		**SCR.2.3.8** Section 6.4.4 Appendix SEAL, Appendix A Appendix PAR, Parameters 9 to 11 and 13, Tables PAR-16 to PAR-24		W36-W47

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W38	Investigation boreholes	Improperly sealed investigation boreholes near the repository could act as release pathways	SO-C		**SCR.2.3.8** *Section 6.4.4* Appendix DEL *Appendix MASS*	Corbet 1995	W38-W39
W39	Underground boreholes	Improperly sealed boreholes drilled from the repository could provide pathways to the interbeds	UP		**SCR.2.3.8** Section 6.4.5.3 Appendix PAR, Table PAR-37		W38-W39
W40	Brine inflow	Brine will enter the disposal rooms through the interbeds, impure halite and clay layers	UP		**SCR.2.4.1** Section 6.4.3.2 Appendix BRAGFLO, Section 4.8		W40
W41	Wicking	Capillary rise is a mechanism for brine flow in unsaturated zones in the repository	UP		**SCR.2.4.1** Section 6.4.3.2 Section 6.4.3.3 Appendix MASS, Section 7 Appendix PAR, Parameter 8 Appendix BRAGFLO, Section 7.2.9	Vaughn et al. 1995	W41
W42	Fluid flow due to gas production	Increases in gas pressure could affect the rate of brine inflow	UP		**SCR.2.4.2** Section 6.4.3.2 Appendix MASS, Section 7 Appendix BRAGFLO, Sections 4.8		W42
W43	Convection	Temperature differentials in the repository could lead to convection cells	SO-C		**SCR.2.4.3**	*DOE 1980, 9-149* *Sanchez & Trellue 1996* *Loken 1994* *Loken & Chen 1995* *Wakeley et al. 1995* Bennett et al. 1996 Hicks 1996 Batchelor 1973, 594, 596 Rechard et al. 1990, a-19	W42

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W44	Degradation of organic material	Microbial breakdown of cellulosic material in the waste will generate gas	UP		**SCR.2.5.1.1** Section 6.4.3.3 Appendix SOTERM, Section 2.2.2 Appendix WCA, Section 5.1 Appendix BRAGFLO, Section 4.13 Appendix MASS, Section 8 and Attachment 8-2	Wang & Brush 1996	W44
W45	Effects of temperature on microbial gas generation	Temperature rises could affect the rate of microbial gas generation	UP		**SCR.2.5.1.1** *Section 6.4.3.3* Appendix PAR, Parameters 3 to 5, Table PAR-43	Molecke 1979, 4, 7 Francis & Gillow, 1994 Bennett et al. 1996	W45
W46	Effects of pressure on microbial gas generation	Increases in gas pressure could affect microbial populations and gas generation rates	SO-C		**SCR.2.5.1.1**	*Kato 1994, 94*	W46
W47	Effects of radiation on microbial gas generation	Radiation could affect microbial populations and, therefore, gas generation rates	SO-C		**SCR.2.5.1.1**	Barnhart et al. 1980 Francis 1985	W47
W48	Effects of biofilms on microbial gas generation	Biofilms serve to maintain optimum conditions for microbial populations and affect gas generation rates	UP		**SCR.2.5.1.1** *Section 6.4.3.3* Appendix PAR, Parameters 3 to 5, Table PAR-43	*Stroes-Gascoyne & West 1994, 9-10* Molecke 1979, 4, 7 Francis & Gillow, 1994, 59	W48
W49	Gases from metal corrosion	Anoxic corrosion of steel will produce hydrogen	UP		**SCR.2.5.1.2** Section 6.4.3.3 Appendix SOTERM, Section 2.2.3 Appendix WCA, Section 5.1 Appendix BRAGFLO, Section 4.13 Appendix MASS, Section 8 and Attachment 8-2		W49
W50	Galvanic coupling	Potential gradients between metals could affect corrosion rates	SO-P		**SCR.2.5.1.2** *Appendix GCR*		W50

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W51	Chemical effects of corrosion	Corrosion reactions will lower the oxidation state of brines and affect gas generation rates	UP		**SCR.2.5.1.2** *Section 6.4.3.3* Appendix WCA, Section 4.1.1 Appendix PAR, Parameter 1, Table PAR-43	Molecke 1979, 4 Telander & Westerman 1993	W51
W52	Radiolysis of brine	Alpha particles from decay of plutonium can split water molecules to form hydrogen and oxygen	SO-C		**SCR.2.5.1.3** Section 6.4.3.3 *Section 6.4.3.5* *Section 6.4.3.6* Appendix MASS, Section 8	Reed et al. 1993, 432 *Sandia WIPP Project 1992* Vaughn et al. (1995) Trauth et al. 1992	W52-W53
W53	Radiolysis of cellulose	Alpha particles from decay of plutonium can split cellulose molecules and affect gas generation rates	SO-C		**SCR.2.5.1.3**	Molecke 1979, 4	W52-W53
W54	Helium gas production	Reduction of alpha particles emitted from the waste will form helium	SO-C		**SCR.2.5.1.3** *Section 6.4.3.3* *Appendix BIR*	Wang & Brush 1996	W54
W55	Radioactive gases	Radon will form from decay of plutonium. Carbon dioxide and methane may contain radioactive ^{14}C	SO-C		**SCR.2.5.1.3** Appendix BIR	Bennett 1996	W55
W56	Speciation	Speciation is the form in which elements occur under particular conditions. This form controls mobility and the reactions that are likely to occur	UP	UP in disposal rooms and Culebra. SO-C elsewhere, and beneficial SO-C in cementitious seals.	**SCR.2.5.2** Section 6.4.3.4 Section 6.4.3.5 Section 6.4.6.2.1 Appendix SOTERM, Sections 3 AND 4 Appendix PAR, Parameters 36 to 47, 52 to 57, Table PAR-39	*Bennett et al. 1992, 315-325* Trauth et al. 1992	W56

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W57	Kinetics of speciation	Reaction kinetics control the rate at which particular reactions occur thereby dictating which reactions are prevalent in non-equilibrium systems	SO-C		**SCR.2.5.2**	*Lasaga et al. 1994, 2361*	W57
W58	Dissolution of waste	Dissolution of waste controls the concentrations of radionuclides in brines and groundwaters	UP		**SCR.2.5.3** Section 6.4.3.5 Appendix PAR, Parameters 36 to 47, Table PAR-39		W58
W59	Precipitation [secondary minerals]	Precipitation of secondary minerals could affect the concentrations of radionuclides in brines and groundwaters	SO-C	Beneficial SO-C	**SCR.2.5.3**	*Bruno & Sandino 1987, 12*	W59
W60	Kinetics of precipitation and dissolution	The rates of dissolution and precipitation reactions could affect radionuclide concentrations	SO-C	Kinetics of waste dissolution is a beneficial SO-C	**SCR.2.5.3**	*Berner 1981, 117*	W59
W61	Actinide sorption	Actinides may accumulate at the interface between a solid and a solution. This affects the rate of transport of actinides in brines and groundwaters	UP	UP in the Culebra and Dewey Lake. Beneficial SO-C elsewhere	**SCR.2.5.4** *Chapter 3* Section 6.4.3.6 Section 6.4.6.2.1 Section 6.4.6.6 *Appendix SEAL* Appendix MASS, Section 15.2 and Attachment 15-1 Appendix SECOTP2D, Section 2	*Serne 1992, 238-239* Wallace et al. 1995	W61
W62	Kinetics of sorption	The rate at which actinides are sorbed can affect radionuclide concentrations	UP		**SCR.2.5.4** Appendix MASS, Section 15.2, Attachment 15-1 Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	*Davis & Kent 1990, 202*	W62

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W63	Changes in sorptive surfaces	Changes in mineralogy along fracture walls could change the extent of sorption	UP		**SCR.2.5.4** Appendix MASS, Section 15.2, Attachment 15-1 Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39		W63
W64	Effect of metal corrosion	Metal corrosion will have an effect on chemical conditions in the repository by absorbing oxygen	UP		**SCR.2.5.5** Section 6.4.3.5 Appendix SOTERM, Sections 2.2.3 and 4 Appendix WCA, Section 4.1.1 Appendix PAR, Parameters 36 to 47, Table PAR-39	Brush 1990	W64
W65	Reduction-oxidation fronts	Redox fronts may affect the speciation and hence migration of radionuclides	SO-P		**SCR.2.5.5**	*Waber 1991* *Snelling 1992, 21-22*	W65
W66	Reduction-oxidation kinetics	Reduction-oxidation reactions may not be in thermodynamic equilibrium thereby affecting speciation	UP		**SCR.2.5.5** Section 6.4.3.5 Appendix SOTERM, Sections 2.2.3 and 4 Appendix PAR, Parameters 36 to 47, Table PAR-39	*Wolery 1992, 27*	W66
W67	Localized reducing zones	Localized reducing zones, bounded by reduction-oxidation fronts, may develop on metals undergoing corrosion	SO-C		**SCR.2.5.5**		W67
W68	Organic complexation	Aqueous complexes between radionuclides and organic materials may enhance the total dissolved radionuclide load	SO-C		**SCR.2.5.6** Section 6.4.3.5 Appendix SOTERM, Section 5 Appendix WCA, Section 4.1.3	*Tipping 1993, 520* Novak et al. 1996 Moore 1996	W68

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W69	Organic ligands	Increased concentrations of organic ligands favor the formation of complexes	SO-C		**SCR.2.5.6** Section 6.4.3.5 Appendix SOTERM, Section 5 Appendix WCA, Sections 4.1.3, 8.11 and 8.12 Appendix BIR	Drez 1991 Brush 1990 Choppin 1988 DOE 1996, 3-12	W69
W70	Humic and fulvic acids	High molecular weight organic ligands, including humic and fulvic acids may be present in soil waste	UP		**SCR.2.5.6** Section 6.4.3.6 Section 6.4.6.2.2 Appendix SOTERM, Section 6.3.3 Appendix PAR, Parameter 46, Table PAR-39	*Tipping 1993, 520*	W70
W71	Kinetics of organic complexation	The rates of complex dissociation may affect radionuclide uptake and other reactions	SO-C		**SCR.2.5.6**	*Rate et al. 1993, 1408, 1414*	W71
W72	Exothermic reactions	Exothermic reactions, including concrete and backfill hydration, and aluminum corrosion, may raise the temperature of the disposal system	SO-C		**SCR.2.5.7** *Section 6.4.3.5* Appendix WCA, Section 5.3.1	Bennett et al. 1996	W72-W73
W73	Concrete hydration	Hydration of concrete in seals will enhance rates of salt creep and may induce thermal cracking	SO-C		**SCR.2.5.7** Appendix SEAL, Section 7.4.1.1	Wakeley et al. 1995 Loken 1994 Loken & Chen 1995 Bennett et al. 1996	W72-W73
W74	Chemical degradation of seals	Reaction of cement with brine and groundwater may affect seal permeability	UP		**SCR.2.5.8** Section 6.4.4 Appendix SEAL, Appendix A Appendix PAR, Parameter 10, Table PAR-19		W74
W75	Chemical degradation of backfill	Reaction of the MgO backfill with CO_2 and brine may affect disposal room permeabilities	SO-C		**SCR.2.5.8** Appendix BACK, Section 3.2		W75

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W76	Microbial growth on concrete	Acids produced by microbes could accelerate concrete seal degradation	UP		**SCR.2.5.8** Appendix PAR, Parameter 10, Table PAR-19	*Pedersen & Karlsson 1995, 75*	W76
W77	Solute transport	Radionuclides may be transported as dissolved species or solutes	UP		**SCR.2.6.1** Section 6.4.5.4 Section 6.4.6.2.1 Appendix MASS, Sections 13.5 and 15.2 Appendix NUTS, Section 4.3 Appendix SECOTP2D, Section 2		W77
W78	Colloid transport	Colloid transport, with associated radionuclides, may occur at a different rate to dissolved species	UP		**SCR.2.6.2** Section 6.4.6.2.2 Appendix MASS, Section 15.3 and Attachments 15-2 and 15-8 Appendix SECOTP2D, Section 2		W78-W81
W79	Colloid formation and stability	The formation and stability of colloids is dependent upon chemical conditions such as salinity	UP		**SCR.2.6.2** Section 6.4.3.6 Appendix SOTERM, Section 6 Appendix BACK, Section 3.4 Appendix WCA, Section 4.2 Appendix PAR, Parameter 46, Table PAR-39	Papenguth 1996a,b,c,d *Numerous background references in SOTERM.6*	W78-W81
W80	Colloid filtration	Colloids with associated radionuclides may be too large to pass through pore throats in some media	UP		**SCR.2.6.2** Section 6.4.6.2.2 Appendix MASS, Section 15.3 and Attachments 15-8 and 15-9		W78-W81

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W81	Colloid sorption	Colloids with associated radionuclides may be physically or chemically sorbed to the host rock	UP		**SCR.2.6.2** Section 6.4.6.2.2 Appendix SECOTP2D, Section 2 Appendix MASS, Section 15.3 and Attachment 15-8 Appendix PAR, Parameters 52-57		W78-W81
W82	Suspensions of particles	Rapid brine flow could transport active particles in suspension	DP	SO-C for undisturbed conditions	**SCR.2.6.3** Section 6.4.7.1 Appendix CUTTINGS, Appendix A.2		W82-W83
W83	Rinse	Rapid brine flow could wash active particulates from waste surfaces	SO-C		**SCR.2.6.3**		W82-W83
W84	Cuttings	Waste material intersected by a drill bit could be transported to the ground surface	DP	Repository intrusion only	**SCR.2.6.3** Section 6.4.7.1 Appendix CUTTINGS, Appendix A.2		W84-W86
W85	Cavings	Waste material eroded from a borehole wall by drilling fluid could be transported to the ground surface	DP	Repository intrusion only	**SCR.2.6.3** Section 6.4.7.1 Appendix CUTTINGS, Appendix A.2		W84-W86
W86	Spallings	Waste material entering a borehole through repository depressurization could be transported to the ground surface	DP	Repository intrusion only	**SCR.2.6.3** Section 6.4.7.1 Appendix CUTTINGS, Appendix A.2		W84-W86
W87	Microbial transport	Radionuclides may be bound to or contained in microbes transported in groundwaters	UP		**SCR.2.6.4** Section 6.4.6.2.2 Appendix SOTERM, Section 6.3.4 Appendix MASS, Section 15.3 and Attachment 15-9		W87
W88	Biofilms	Biofilms may retard microbes and affect transport of radionuclides	SO-C	Beneficial SO-C	**SCR.2.6.4**	Francis & Gillow 1994	W88

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W89	Transport of radioactive gases	Gas phase flow could transport radioactive gases	SO-C		**SCR.2.6.5** SCR.2.5.1.3	Bennett 1996	W89
W90	Advection	Dissolved and solid material can be transported by a flowing fluid	UP		**SCR.2.7.1** Section 6.4.5.4 Section 6.4.6.2 Appendix NUTS, Sections 4.3.1 and 4.3.2 Appendix SECOTP2D, Section 2		W90-W92
W91	Diffusion	Dissolved and solid material can be transported in response to Brownian forces	UP		**SCR.2.7.2** Section 6.4.6.2 Section 6.4.5.4 Appendix MASS, Attachment 15-3 Appendix SECOTP2D, Section 2 Appendix NUTS, Section 4.3.3		W90-W92
W92	Matrix diffusion	Dissolved and solid material may be transported transverse to the direction of advection in a fracture and into the rock matrix	UP		**SCR.2.7.2** Section 6.4.6.2 Appendix MASS, Attachment 15.6 Appendix SECOTP2D, Sections 2, 3.5 and 3.6		W90-W92
W93	Soret effect	There will be a solute flux proportional to any temperature gradient	SO-C		**SCR.2.7.3**	Bennett et al. 1996 *DOE 1980, 9-149* *Sanchez & Trellue 1996* *Wakeley et al. 1995*	W93
W94	Electrochemical effects	Potential gradients may exist as a result of electrochemical reactions and groundwater flow and affect radionuclide transport	SO-C		**SCR.2.7.4**	*Telford et al. 1976, 458*	W94-W96

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W95	Galvanic coupling	Potential gradients may be established between metal components of the waste and containers and affect radionuclide transport	SO-P		**SCR.2.7.4** Appendix GCR		W94-W96
W96	Electrophoresis	Charged particles and colloids can be transported along electrical potential gradients	SO-C		**SCR.2.7.4**	Telander & Westerman 1993	W94-W96
W97	Chemical gradients	Chemical gradients will exist at interfaces between different parts of the disposal system and may cause enhanced diffusion	SO-C	p. SCR-87 incorrectly states that gradients are UP.	**SCR.2.7.5**		W97
W98	Osmotic processes	Osmosis may allow diffusion of solutes across a salinity interface	SO-C	Beneficial SO-C	**SCR.2.7.5**		W98
W99	Alpha recoil	Recoil of the daughter nuclide upon emission of an alpha-particle during radioactive decay at the surface of a solid may eject the daughter into groundwater	SO-C		**SCR.2.7.5**		W99
W100	Enhanced diffusion	Chemical gradients may locally enhance rates of diffusion	SO-C		**SCR.2.7.5**		W100
W101	Plant uptake	Radionuclides released into the biosphere may be absorbed by plants	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.1** Section 6.5.3 Figure 6.41		W101-W103
W102	Animal uptake	Animals may eat or drink radionuclides released into the biosphere	SO-R		**SCR.2.8.1** Section 6.5.3 Figure 6.41		W101-W103
W103	Accumulation in soils	Radionuclides released into the biosphere may accumulate in soil	SO-C	Beneficial SO-C	**SCR.2.8.1** Section 6.5.3 Figure 6.41		W101-W103

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
W104	Ingestion	Humans may receive a radiation dose from radionuclides in food or drink	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.2** Section 8.1.1 Section 8.1.2 *Section 8.2.3*	DOE 1988 40 CFR § 194.52	W104-W108
W105	Inhalation	Humans may receive a radiation dose from air taken into the lungs	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.2** Section 8.1.1 Section 8.1.2 *Section 8.2.3*	DOE 1988 40 CFR § 194.52	W104-W108
W106	Irradiation	Humans may receive a radiation dose from radionuclides external to the body	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.2** Section 8.1.1 Section 8.1.2 *Section 8.2.3*	DOE 1988 40 CFR § 194.52	W104-W108
W107	Dermal sorption	Humans may receive a radiation dose from radionuclides absorbed through the skin	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.2** Section 8.1.1 Section 8.1.2 *Section 8.2.3*	DOE 1988 40 CFR § 194.52	W104-W108
W108	Injection	Humans may receive a radiation dose from radionuclides injected beneath the skin	SO-R	SO-C for 40 CFR § 191.15	**SCR.2.8.2** Section 8.1.1 Section 8.1.2 *Section 8.2.3*	DOE 1988 40 CFR § 194.52	W104-W108
H1	Oil and gas exploration	Oil and gas exploration is a reason for drilling in the Delaware Basin	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.2.1** Section 2.3.1.2 *Section 6.4.7* Section 6.4.12.2 Appendix GCR, Section 8.4.8 Appendix DEL, Sections 4.2 and 7.4 Appendix PAR, Table PAR-53	NMBMMR 1995, Chapter XI	H1 (et. al.)

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H2	Potash exploration	Potash exploration is a reason for drilling in the Delaware Basin	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.2.1** Section 2.3.1.1 *Section 6.4.7* Section 6.4.12.2 Appendix GCR, Section 8.4.7 Appendix DEL, Sections 4.2 and 7.4 Appendix PAR, Table PAR-53	NMBMMR 1995, Chapter VII	H2
H3	Water resources exploration	Water resources exploration is a reason for drilling in the Delaware Basin	SO-C (HCN) SO-C (Future)		**SCR.3.2.1** Section 2.3.1.3 Appendix DEL, Sections 4.2 and 7.4 Appendix USDW, Section 3		H3 (et. al.)
H4	Oil and gas exploitation	Oil and gas exploitation is a reason for drilling in the Delaware Basin	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.2.1** Section 2.3.1.2 Section 2.3.2.2 *Section 6.4.7* Section 6.4.12.2 Appendix DEL, Sections 4.2 and 7.4 Appendix PAR, Table PAR-53		H1 (et. al.)
H5	Groundwater exploitation	Groundwater exploitation is a reason for drilling in the Delaware Basin	SO-C (HCN) SO-C (Future)		**SCR.3.2.1** Section 2.3.1.3 Appendix DEL, Sections 4.2 and 7.4 Appendix USDW, Section 3		H3 (et. al.)

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H6	Archeological investigations	Archeological investigations could be a reason for drilling	SO-R (HCN) SO-R (Future)		**SCR.3.2.1** Section 2.3.2.3		H3 (et. al.)
H7	Geothermal	Geothermal energy could be a reason for drilling	SO-R (HCN) SO-R (Future)		**SCR.3.2.1**		H3 (et. al.)
H8	Other resources	Exploration for other resources could be a reason for drilling	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.2.1** Section 2.3.1.3 *Section 6.4.7* Section 6.4.12.2 Appendix GCR, Section 8.4 Appendix DEL, Sections 4.2 and 7.4 Appendix PAR, Table PAR-53		H1 (et. al.)
H9	Enhanced oil and gas recovery	Enhanced oil and gas recovery is a reason for drilling in the Delaware Basin	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.2.1** Section 2.3.1.2 *Section 6.4.7* Section 6.4.12.2 Appendix DEL, Sections 5.4 and 7.4 Appendix PAR, Table PAR-53	NMBMMR 1995	H1 (et. al.)
H10	Liquid waste disposal	Liquid waste disposal could be a reason for drilling	SO-R (HCN) SO-R (Future)		**SCR.3.2.1** Appendix DEL Section 5.4		H1 (et. al.)

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H11	Hydrocarbon storage	Hydrocarbon storage could be a reason for drilling	SO-R (HCN) SO-R (Future)		**SCR.3.2.1**	Burton et al. 1993, 66-67	H1 (et. al.)
H12	Deliberate drilling intrusion	Deliberate investigation of the repository could be a reason for drilling	SO-R (HCN) SO-R (Future)		**SCR.3.2.1**		H12
H13	Potash mining	Potash mining is a reason for excavations in the region around WIPP	UP (HCN) DP (Future)	UP for mining outside the controlled area. DP for mining inside the controlled area.	**SCR.3.2.2** Section 2.3.1.1 Section 6.4.6.2.3 Section 6.4.12.8 Section 6.4.13.8 Appendix DEL, Section 7.4 Appendix MASS, Attachment 15-4 Appendix PAR, Parameter 34		H13
H14	Other resources	Mining of other resources could be a reason for excavations	SO-C (HCN) SO-R (Future)		**SCR.3.2.2**		H14-H20
H15	Tunneling	Tunneling could be a reason for excavations	SO-R (HCN) SO-R (Future)		**SCR.3.2.2**		H14-H20
H16	Construction of underground facilities (for example storage, disposal, accommodation)	Construction of underground facilities could be a reason for excavations	SO-R (HCN) SO-R (Future)		**SCR.3.2.2**	Burton et al. 1993, 66-67	H14-H20
H17	Archeological excavations	Archeological investigations could be a reason for excavations	SO-C (HCN) SO-R (Future)		**SCR.3.2.2** Section 2.3.2.3		H14-H20
H18	Deliberate mining intrusion	Deliberate investigation of the repository could be a reason for excavations	SO-R (HCN) SO-R (Future)		**SCR.3.2.2**		H14-H20

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H19	Explosions for resource recovery	Underground explosions could affect the geological characteristics of surrounding units	SO-C (HCN) SO-R (Future)		**SCR.3.2.3.1**		H14-H20
H20	Underground nuclear device testing	Underground nuclear device testing could affect the geological characteristics of surrounding units	SO-C (HCN) SO-R (Future)		**SCR.3.2.3.2**	Rawson et al. 1965, 5, 8, 35	H14-H20
H21	Drilling fluid flow	Drilling within the controlled area could result in releases of radionuclides into the drilling fluid.	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste. SO-C for other future drilling.	**SCR.3.3.1.1** Section 6.3.2.2 Section 6.4.7.1 Appendix DEL Sections 5.1.3 and 6.1.2.1, and Attachment 1 Appendix CUTTINGS, Appendix A.2.2 Appendix MASS, Attachment 16-2	Economy 1996	H21-H23
H22	Drilling fluid loss	Borehole circulation fluid could be lost to thief zones encountered during drilling	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste. SO-C for other future drilling.	**SCR.3.3.1.1** Section 6.4.7.1.1 Appendix PAR, Parameters 1 and 3, Table PAR-43	*Wallace 1996a*	H21-H23
H23	Blowouts	Fluid could flow from pressurized zones through the borehole to the land surface	SO-C (HCN) DP (Future)	DP for boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future drilling.	**SCR.3.3.1.1** Section 2.2.1.3 Section 6.4.12.6 Section 6.4.7.1.1 Appendix DEL, Section 7.5 Appendix CUTTINGS, Appendix A.2.4.1 Appendix MASS, Attachment 16-2	*Wallace 1996a*	H21-H23

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H24	Drilling-induced geochemical changes	Movement of brine from a pressurized zone, through a borehole, into potential thief zones such as the Salado interbeds or the Culebra, could result in geochemical changes	UP (HCN) DP (Future)	SO-C for units other than the Culebra.	**SCR.3.3.1.1** *Section 6.4.3.6* Section 6.4.6.2 Section 6.4.6.6 Appendix MASS, Section 15.2 and Attachment 15-1 Appendix PAR Parameters 47 and 52 to 57, Table PAR-39 *Appendix SOTERM*	Wallace et al. 1995	H24
H25	Oil and gas extraction	Extraction of oil and gas could alter fluid-flow patterns in the target horizons, or in overlying units as a result of a failed borehole casing. Removal of confined fluids from oil- or gas-bearing units can cause compaction, potentially resulting in subvertical fracturing and surface subsidence	SO-C (HCN) SO-R (Future)		**SCR.3.3.1.2**	Brausch et al. 1982, 52,61	H25-H26
H26	Groundwater extraction	Groundwater extraction from formations above the Salado could affect groundwater flow	SO-C (HCN) SO-R (Future)		**SCR.3.3.1.2** Section 2.2.1.4.2.1 Section 2.3.1.3 Section 6.4.6.6 Section 8.2	Wallace 1996b	H25-H26
H27	Liquid waste disposal	Injection of fluids could alter fluid flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone	SO-C (HCN) SO-R (Future)		**SCR.3.3.1.3** *Section 2.3.1.1* Section 6.4.7.2 Appendix DEL, Sections 5.5 and 6	Stoelzel & O'Brien 1996 Wilmot & Galson 1996 *Wallace 1996c* *Davies 1989, 28*	H27-H28

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H28	Enhanced oil and gas production	Injection of fluids could alter fluid flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone	SO-C (HCN) SO-R (Future)		**SCR.3.3.1.3** *Section 2.3.1.1* Section 6.4.7.2 Appendix DEL, Sections 5.5 and 6	Brausch et al. 1982, 29-30 Silva 1994, 67-68 Stoelzel & O'Brien 1996 Wilmot & Galson 1996 *Wallace 1996c* *Davies 1989, 28, 32, 42, 47-48* *Popielak et al. 1983, Table C-2*	H27-H28
H29	Hydrocarbon storage	Injection of fluids could alter fluid flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone	SO-C (HCN) SO-R (Future)		**SCR.3.3.1.3**	Burton et al. 1993, 66-67 Stoelzel & O'Brien 1996 Wilmot & Galson 1996 *Wallace 1996c* *Davies 1989, 28*	H29
H30	Fluid-injection induced geochemical changes	Injection of fluids through a leaking borehole could affect geochemical conditions in thief zones, such as the Culebra or the Salado interbeds	UP (HCN) SO-R (Future)	SO-C for units other than the Culebra	**SCR.3.3.1.3** Section 6.4.6.2 Section 6.4.6.6 Appendix MASS, Section 15.2 and Attachment 15-1 Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39		H30
H31	Natural borehole fluid flow	Natural borehole flow through abandoned boreholes could alter fluid pressure distributions	SO-C (HCN) DP (Future)	DP for boreholes that penetrate Castile brine underlying the waste disposal region. SO-C for other future boreholes.	**SCR.3.3.1.4** Section 6.4.7.2 Section 6.4.8 *Section 6.4.12.2* Section 6.4.12.7 Appendix MASS, Section 16.3 and Attachments 16-1 and 16-3 Appendix DEL, Sections 5.5 and 6 Appendix BRAGFLO, Section 4.8	Wallace 1996a Wallace 1996c Wilmot & Galson 1996 WIPP PA Division 1991, B-26 to B-27 Corbet 1995 Davies 1989, 50	H31

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H32	Waste-induced borehole flow	Abandoned boreholes that intersect a waste panel could provide a connection for transport away from the repository horizon	SO-R (HCN) DP (Future)	DP for boreholes that penetrate the waste. SO-C for other future boreholes.	**SCR.3.3.1.4** Section 6.4.7 Section 6.4.2.1 Section 6.4.12.7 Appendix MASS, Section 16.3 and Attachments 16-1 and 16-3 Appendix DEL, Sections 5.5 and 6 Appendix BRAGFLO, Section 4.8	Wallace 1996a	H32
H33	Flow through undetected boreholes	Undetected boreholes that are inadequately sealed could provide pathways for radionuclide transport	SO-P (HCN) NA (Future)		**SCR.3.3.1.4**		H33
H34	Borehole-induced solution and subsidence	Boreholes could provide pathways for surface-derived water or groundwater to percolate into formations containing soluble minerals. Large-scale dissolution through this mechanism could lead to subsidence and to changes in groundwater flow patterns	SO-C (HCN) SO-C (Future)		**SCR.3.3.1.4** Section 3.3.4 Section 6.4.7.2 Appendix DEL, Sections 5.5 and 6	Johnson 1987 Beauheim 1986, 72 Christensen et al. 1983, 19	H34
H35	Borehole-induced mineralization	Fluid flow through a borehole between hydraulically conductive horizons could cause mineral precipitation to change permeabilities	SO-C (HCN) SO-C (Future)		**SCR.3.3.1.4**		H35

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H36	Borehole-induced geochemical changes	Movement of fluids through abandoned boreholes could change the geochemistry of units such as the Salado interbeds or Culebra	UP (HCN) DP (Future)	SO-C for units other than the Culebra	**SCR.3.3.1.4** *Section 6.4.3.6* Section 6.4.6.2 Section 6.4.6.6 Appendix MASS, Section 15.2 and Attachment 15-1 Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39		H36
H37	Changes in groundwater flow due to mining	Fracturing and subsidence associated with excavations may affect groundwater flow patterns through increased hydraulic conductivity within and between units	UP (HCN) DP (Future)	UP for mining outside the controlled area. DP for mining inside the controlled area.	**SCR.3.3.2** Section 2.3.1.1 Section 6.4.6.2.3 Section 6.4.12.8 Section 6.4.13.8 Appendix CCDFGF, Section 3.2 Appendix DEL, Section 4.2.4 Appendix PAR, Parameter 34	Westinghouse 1994, 2-17 to 2-19, 2-22 to 2-23 Davies 1989, 43, 77-81 Wallace 1996c	H37
H38	Changes in geochemistry due to mining	Fluid flow and dissolution associated with mining may change brine densities and geochemistry	SO-C (HCN) SO-R (Future)		**SCR.3.3.2** Section 2.3.1.1		H38
H39	Changes in groundwater flow due to explosions	Fracturing associated with explosions could affect groundwater flow patterns through increased hydraulic conductivity within and between units	SO-C (HCN) SO-R (Future)		**SCR.3.3.3**		H39
H40	Land use changes	Land use changes could have an effect upon the surface hydrology	SO-R (HCN) SO-R (Future)		**SCR.3.4.1**		H40-H41
H41	Surface disruptions	Surface disruptions could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.4.1**		H40-H41

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H42	Damming of streams or rivers	Damming of streams or rivers could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.5.1**		H42-H44
H43	Reservoirs	Reservoirs could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.5.1**		H42-H44
H44	Irrigation	Irrigation could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.5.1**		H42-H44
H45	Lake usage	Lake usage could have an effect upon the surface hydrology	SO-R (HCN) SO-R (Future)		**SCR.3.5.1**		H45
H46	Altered soil or surface water chemistry by human activities	Surface activities associated with potash mining and oil fields could affect the movement of radionuclides in the surface environment	SO-C (HCN) SO-R (Future)		**SCR.3.5.1**		H46
H47	Greenhouse gas effects	Changes in climate resulting from increase in greenhouse gases could change the temperature and the amount of rainfall	SO-R (HCN) SO-R (Future)		**SCR.3.6.1**		H47-H49
H48	Acid rain	Acid rain could change the behavior of radionuclides in the surface environment	SO-R (HCN) SO-R (Future)		**SCR.3.6.1**		H47-H49
H49	Damage to the ozone layer	Damage to the ozone layer could affect the flora and fauna and their response to radioactivity	SO-R (HCN) SO-R (Future)		**SCR.3.6.1**		H47-H49
H50	Coastal water use	Coastal water usage could affect the uptake of radionuclides by animals and humans	SO-R (HCN) SO-R (Future)		**SCR.3.7.1**		H50-H52
H51	Sea water use	Sea water usage could affect the uptake of radionuclides by animals and humans	SO-R (HCN) SO-R (Future)		**SCR.3.7.1**		H50-H52

EPA FEP No.	FEP Name	Issue	Screening Classification (see legend)	Comments on Classification	CCA Cross References	Supporting References	Comment No.
H52	Estuarine water use	Estuarine water usage could affect the uptake of radionuclides by animals and humans	SO-R (HCN) SO-R (Future)		**SCR.3.7.1**		H50-H52
H53	Arable farming	Arable farming could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.8.1**		H53-H54
H54	Ranching	Ranching could have an effect upon the surface hydrology	SO-C (HCN) SO-R (Future)		**SCR.3.8.1** Section 2.3.2.2		H53-H54
H55	Fish farming	Fish farming could affect the uptake of radionuclides by animals and humans	SO-R (HCN) SO-R (Future)		**SCR.3.8.1**		H55
H56	Demographic change and urban development	Demographic change and urban development could have an effect upon the surface hydrology	SO-R (HCN) SO-R (Future)		**SCR.3.8.2** Section 2.3.2.1		H56
H57	Loss of records	Loss of records could change the effectiveness of institutional controls	NA (HCN) DP (Future)		**SCR.3.8.2** *Section 6.3* Section 6.4.7 Section 6.4.12.1 Section 6.4.12.2 Section 7.3 Appendix EPIC, Section 6 Appendix PAR, Table PAR-53		H57

4. FEP Analysis

Each feature, event and process identified in Appendix SCR has been evaluated by EPA, with results presented in this section. For each FEP, the FEP number and FEP title/description are presented. To simplify assessments and evaluations, a number of related FEPs were sometimes grouped into a single comment (e.g. N3-N5 is a single comment that addresses FEP Nos. N3, N4 and N5). The FEP description is followed by the section in Appendix SCR and screening classification: UP-included by the DOE in undisturbed system performance assessment; DP-included by the DOE in disturbed system performance assessment; SO-C-screened out by the DOE, based on low consequence; SO-P-screened out by the DOE, based on low probability; and SO-R screened out by the DOE, based on regulatory reasons. If a single SCR section or screening category is listed for a FEP group comment, it applies to all FEPs in that grouping. The EPA results are summarized in bold-face type.

4.1. Natural FEPs Assessment

N1 Stratigraphy (Section SCR 1.1.1, UP). The screening argument in Section 1.1.1 appears reasonable to EPA. Site stratigraphy appears to be sufficiently characterized by data from boreholes in and around the WIPP. Additional boreholes for the sole purpose of defining site stratigraphy (i.e., stratigraphic layering) do not appear to be warranted. This does not mean that stratigraphic details, including fracture occurrence/distribution in various layers are addressed in detail in the stratigraphic column used in PA. Refer to **CARD 14--Content of Compliance Application** for discussion and resolution of castile brine occurrence issues [Docket No. A-93-02, V-B-2, Section 194.14 (a)(2)]. It also does not mean that all geologic features below the WIPP (e.g., Castile brine pockets) have been identified and characterized in the CCA. However, available geologic data suggest that the general stratigraphic column is sufficiently understood in the WIPP area for implementation in performance assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.3 and 6.4.2, and Appendices SCR.1.1.1; GCR, 4.3; BH; PAR, Table PAR-57; FAC; HYDRO; SUM)

N2 Brine Reservoirs (Section SCR 1.1.1, DP). The DOE's screening argument appears reasonable to EPA. The DOE's presentation regarding brine reservoirs is highlighted in Section 1.1.1, although the evaluation for this FEP is not clearly presented in Appendix SCR, Chapters 2 and 6, and Appendices MASS and DEF present information pertinent to the occurrence of brine reservoirs. The DOE assumes an 8% probability of encountering a brine pocket below the WIPP as part of the disturbed performance evaluations. However, some data (TDEM studies) indicate that a probability as high as 60% may be possible. A higher probability has been sampled in the EPA-Mandated Performance Assessment. The DOE has therefore appropriately used this FEP as a part of the disturbed performance assessment. Refer to the **CARD 14--Content of Compliance Application** [Docket No. A-93-02, V-B-2, Section 194.14 (a)(2)] for more detailed discussion of brine pockets.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.3, 6.4.12, and 6.4.8, and Appendices SCR.1.1.1; PAR; Parameters 27, 28, 29, and 31; and Table PAR-30, DEF; Anderson, R.Y., Dean, W.E., Jr., Kirkland, D.W., and Snider, H.I. 1972. Permian Castile Varved Evaporite Sequence, West Texas and New Mexico. *Geological Society of America* Bulletin, Vol. 83, No. 1, pp. 59 - 85; Bachman, G.O. 1974. *Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico.* Open-File Report 74-194. U.S. Geological Survey, Denver, CO; Bachman 1980. *Regional Geology and Cenozoic History of Pecos Region, Southeastern New Mexico.* Open-File Report 80-1099. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1981. *Geology of Nash Draw, Eddy County, New Mexico.* Open-File Report 81-31. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1984. *Regional Geology of Ochoan Evaporites, Northern Part of Delaware Basin.* Circular 184, pp. 1 - 27. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM; Bachman, G.O. 1987. *Karst in Evaporites in Southeastern New Mexico.* SAND86-7068. Sandia National Laboratories, Albuquerque, NM. WPO 24006; Bachman, G.O., Johnson, R.B., and Swenson, F.A. 1973. *Stability of Salt in the Permian Salt Basin of Kansas, Oklahoma, Texas, and New Mexico.* Open-File Report 4339-4. U.S. Geological Survey, Denver, CO; Chapman, J.B. 1986. *Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area.* EEG-35, the DOE/AL/10752-35. Environmental Evaluation Group, Santa Fe, NM; Beauheim, R.L. 1986. *Hydraulic-Test Interpretations for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site.* SAND86-1364. Sandia National Laboratories, Albuquerque, NM. WPO 27565.)

N3-N5 <u>Changes in Regional Stress, Regional Tectonics, Regional Uplift and Subsidence (SCR 1.1.2, SO-C).</u> The screening argument in Section 1.1.2 appears reasonable to EPA. The DOE's screening designation for WIPP area tectonics appears to be technically valid. Data presented in the CCA, as well as other publications, confirms the DOE's assertion that the WIPP occurs within the Southern Great Plains province adjacent to the more tectonically active Basin and Range province. While it is true, geologically, that regional stress regimes change through time, data presented in the CCA indicate that the current stress provinces in the WIPP area have been present for several million years, and tectonic/ geologic data do not suggest that tectonic forces or conditions are such that the specific geologic regime will change in a 10,000 year period. Geologic data presented in Chapter 2 of the CCA confirm that the Southern Great Plains province (in which WIPP occurs) is not subject to the tectonic stresses similar to, for example, the San Andreas area in western California (characterized by subduction zone activity). Although there have been relatively low intensity earthquakes in the general WIPP area [refer to **CARD 14--Content of Compliance Application, Docket No. A-93-02, V-B-2, Section 194.14 (a)(2)]**, this does not necessarily mean that the WIPP is in an area of regional tectonic stress.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.5, 6.4, and Appendices SCR.1.1.2; FAC; King, P.B. 1948. *Geology of the Southern Guadalupe Mountains, Texas.* Professional Paper 215. U.S. Geological Survey, Washington, D.C., 120 - 121; Schiel, K.A. 1994. A New Look at the Age, Depositional Environment and Paleogeographic Setting of the Dewey Lake Formation (Late Permian). *West Texas Geological Society Bulletin,* Vol. 33, No. 9, pp. 5 - 13. WPO 20465; Borns, D.J., Barrows, L.J., Powers, D.W., ad Snyder, R.P. 1983. *Deformation of Evaporites Near the Waste Isolation Pilot Plant (WIPP) Site.* SAND82-1069. Sandia National Laboratories, Albuquerque, NM. WPO 27532; Muehlberger, W.R., Belcher, R.C., and Goetz, L.K. 1978. Quaternary Faulting on Trans-Pecos, Texas. *Geology,* Vol. 6, No. 6, pp. 338)

N6-N7 Salt Deformation, Diapirism (SCR 1.1.2, 1.1.3.1, SO-C, SO-P). The screening argument in Sections 1.1.2 and 1.1.3 appears reasonable to EPA. The CCA presents information pertaining to the occurrence of deformational features in the Castile, noting that these features have been postulated to have been formed by processes including gravity foundering, dissolution, gravity sliding, gypsum dehydration, and depositional processes. Of these, the DOE believes that gravity foundering is the most comprehensive and best accepted hypothesis for the formation of these features. Evaluation of information presented in Section 2.1.6, Appendix DEF, and associated references and Appendices indicates that gravity foundering does appear to be a probable origin of observed features. The anhydrite-halite sequences within the Castile would be amenable to the formation of gravity/density related structures. The formation of “salt domes” due to gravity foundering is common in many geologic sequences (e.g., southern Texas). While deep dissolution is a possible mechanism for Castile structure formation, the distribution of Castile deformational features is not necessarily proximal to basin margins, where dissolution appears to be more prevalent, nor is the upsection rock unit disruption in the Salado and Castile as would be expected if deeper dissolution were the cause of the structures. Gravity sliding, while also a possibility, would have caused relatively profound structural effects within both the Castile and overlying units (depending upon when the sliding took place), but data indicate that the Castile disturbed zone appears to decrease upsection. Gravity sliding, too, would appear to have more prominent and consistent effects of unit thickening and thinning nearer the basin margins, but observed Castile features do not consistently coincide with the anticipated structure effects of gravity sliding. Rehydration/dehydration of calcium sulfate minerals can occur. From a depositional perspective, anhydrite rather than gypsum would be the primary depositional mineral, which would be re-hydrated to form gypsum. Subsequent dehydration may occur, and the effects of this would result in fracturing/volumetric changes in the calcium sulfate beds. However, it is probably unlikely that this mechanism alone could result in the observed Castile structures, nor is it clear that the necessary rehydration-dehydration sequence is supported entirely by the rock record. Note that the DOE states the Culebra at ERDA 6, northeast of the WIPP site, exhibits structural elevation correlatable to underlying Castile structures.

While available data indicate that gravity foundering is a probable cause of Castile structures, this does not rule out the possibility that the other mechanisms, to some degree, have not contributed. One element of the Castile features that no mechanisms explains fully is the distribution of the Castile disturbed features in the WIPP area. That is, why the features occur exactly where they do remains unanswered, although the DOE has hypothesized that the occurrence could be related to depositional variation with the Castile that responds differently to gravity foundering or other processes, which appears to be a reasonable hypothesis. The importance of this question would be heightened if the features are postulated to form during the 10,000 year regulatory time frame, but the DOE does not believe this occurs, and the EPA agrees with the DOE's conclusion [refer to **CARD 14--Content of Compliance Application**, Docket No. A-93-02, V-B-2, Section 194.14 (a)(2)].

Performance assessment assumes an 8% probability of encountering a Castile brine pocket. Data presented within Appendix MASS and the TDEM study imply that this probability could be higher, but a question that is not answered is whether the Castile features could form below the WIPP during the regulatory time period. The DOE assumption that the mechanisms which form Castile features are still active today is sound. The DOE also indicates that the brines present in known Castile structures at wells ERDA-6 and WIPP-12 were calculated to have moved most recently about 800,000 years ago. The DOE also states, on page DEF-17, that "one set of reasonable assumptions about brine chemistry and interactions with the rock leads to calculated residence times of about 25,000 to 50,000 years for these brines," but provides no reference for these statements. Therefore, although DOE does not provide extensive substantiation of its assertions regarding the timing of brine movement or Castile feature formation, their timing arguments appear logical. The DOE goes on to state that "some modeling" indicates that the kinds of structure observed in the disturbed zone may require periods on the order of 700,000 years to form.

In summary, the most probable mechanism responsible for Castile feature formation is gravity foundering, although other mechanisms could occur to some degree. The DOE's conclusions regarding timing of feature formation or brine movement within these features and their assertions appear reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October, 1996, Section 2.1.6 and Appendices SCR.1.1.3.1; DEF, Sections 2, 2.3, and 3.1; Gera, F. 1974. "On the Origin of the Small Hills in Nash Draw and Clayton Basin, Southeastern New Mexico," ORNL 74-2-29, Oak Ridge, TN: Oak Ridge National Laboratory.)

N8- N9 Formation of Fractures, Changes in Fracture Properties (SCR 1.1.3.1, 1.1.3.2, SO-P, SO-P). The screening argument in Sections 1.1.3.1 and 1.1.3.2 appears reasonable to EPA. It is logical to assume that current stress regimes will not induce fracturing within the Salado Formation. Evidence to this end is not presented or referenced in Appendix SCR, but Peer Review concurred with the DOE′s assertions regarding the development of fractures, and EPA also concurs, because current stress regimes are not conducive to formation of significant fractures during the regulatory time period. That is, although mechanisms such as salt diaphirism could impact fracturing in the Salado, it is highley unlikely that this process will induce significant fractures during the regulatory time period. The DOE's argument pertaining to changes in fracture properties in the Salado Formation via regional stress therefore appears reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.5, 2.2.1 and 6.4.6, and Appendix SCR.1.1.3.2.)

N10-N12 Formation of New Faults, Fault Movement, Seismic Activity (SCR 1.1.3.3, 1.1.3.4, SO-P, SO-P, UP). The screening argument in Sections 1.1.3.3 and 1.1.3.4 appears reasonable to EPA. The DOE has assessed, through numerous site and regional studies, the occurrence of faults in the WIPP area. The DOE has presented information which indicates that there are faults in the WIPP area that occur throughout the stratigraphic section, as presented in several figures and tables in Chapter 2 (Figure 2-6), Appendix GCR (Figures 3.4-1, 4.4-1 through 4.4-15). While it is apparent that numerous faults occur in the area that have affected unit thickness and depositional history of the rock column over the past several hundred million years, available data do not indicate that a fault is present at the WIPP that could impact the containment capability of the WIPP (e.g. through preferential groundwater flow). There is also no stratigraphic evidence that faults in the WIPP area have formed recently or are likely to form in the near future which, in geologic terms, includes the next 10,000 years.

The DOE stated that is has accounted for the effects of seismic activity by including a DRZ in PA modeling, and EPA agrees with DOE's screening decision. EPA notes that the DRZ is present regardless of seismic activity, and the DOE does not indicate in Appendix SCR, whether modifications to DRZ porosity/permeability to account for a seismic event would be necessary. Instead, the DOE states that the occurrence of the DRZ, as a zone of permanent relatively higher permeability, accounts for the possibility of enhanced down-hole collapse and fracturing due to ground accelerations caused by seismic activity. Refer to **CARD 23--Models and Computer Codes**, Docket No. A-93-02, V-B-2, Section 194.23 (a)(1), for discussion of the DRZ as implemented in PA.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.5, 2.6.2 and 6.4.5, and Appendices SCR.1.1.3.3; PAR, Table PAR-37; GCR, Section 5; Schiel, K.A. 1994. A New Look at the Age, Depositional Environment and Paleogeographic Setting of the Dewey Lake Formation (Late Permian). *West Texas Geological Society Bulletin,* Vol. 33, No. 9, pp. 5 - 13. WPO 20465; Muehlberger, W.R., Belcher, R.C., and Goetz, L.K. 1978. Quaternary Faulting on Trans-Pecos, Texas. *Geology,* Vol. 6, No. 6, pp. 338)

N13-N15 Volcanic Activity, Magmatic Activity, Metamorphic Activity (SCR 1.1.4.1, 1.1.4.2, SO-P, SO-C, SO-P). The screening argument in Sections 1.1.4.1 and 1.1.4.2 appears reasonable to EPA. The CCA and Appendix SCR discuss the regional occurrence of volcanic and magmatic activity, including the identification of a magnetic-anomaly that trends northeast and occurs to the west of the WIPP site. Given the geologic province and history of the area, the occurrence of volcanic/magmatic activity in the region and associated metamorphism appears very unlikely during the next 10,000 years.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.1.5 and Appendix GCR, Section 3.5)

N16-N21 Shallow Dissolution, Lateral Dissolution, Deep Dissolution, Solution Chimneys, Breccia Pipes, Collapse Breccias. (SCR 1.1.5.1, UP, SO-C, SO-P (N18-N21). The screening argument in Section 1.1.5.1 appears reasonable to EPA. The CCA and Appendix DEF indicate that there are three dissolution processes possible at the WIPP: deep dissolution (including point source breccia pipes), lateral dissolution, and shallow dissolution including karst and dissolution of fracture fill. The DOE concludes that none of these processes will impact the WIPP during the regulatory 10,000 year time frame.

The DOE indicated that deep dissolution is a process that could explain removal of evaporite section and formation of breccia pipes. The DOE′s conclusion that the breccia pipes result from dissolution associated with upward movement of fluids from permeable units underlying the Salado where the Castile is absent (i.e., above the Capitan Formation) appears to be supported by the geologic data. Available data indicate that the breccia pipes discussed in the CCA occur above the Capitan Formation. Also, the DOE′s contention that the features form due to enhanced hydraulic conductivity/transmissivity of the Capitan Formation and subsequent dissolution of overlying sediments appears to be plausible. Other authors (Anderson) have pointed out that additional information which indicates breccia pipes occur within the Salado that are not associated with the Capitan aquifer, are selectively excluded from the CCA. Recent additional information was provided by the DOE in response to EPA completeness comments, which adequately addresses this issue [refer to **CARD 14--Content of Compliance Application**, Docket No. A-93-02, V-B-2, Section 194.14 (a)(2)].

The DOE further indicates that flow of unsaturated groundwater within the Bell Canyon could provide a source of water that could lead to deep dissolution of the overlying Castile Formation. However, the DOE also concludes that “there is not unequivocal information that supports the possibility of localized deep dissolution occurring anywhere other than at the edge of the Capitan Reef.” This conclusion was not shared by Anderson (1978), who stated that deep-seated dissolution could be the cause of large volumes of halite removal in the Delaware Basin. (He also indicated that the presence of breccia within the Salado and Castile at the Delaware Basin boundary support the occurrence of deep dissolution.) The occurrence of deep seated dissolution processes below the WIPP cannot be wholly ruled out, due to the presence of more permeable, non-halite saturated rock units immediately below evaporite units. However, while the deep dissolution mechanisms may be operating, available data presented in the CCA and other references do not indicate that this mechanism would be sufficiently rapid to fracture overlying salts (i.e. ductile response of salt beds is instead anticipated). Therefore, available data indicate that this dissolution mechanism, while possible, would not be of sufficient magnitude to compromise the containment capabilities of the disposal system during the 10,000 year regulatory time frame.

The CCA contends that lateral dissolution of halite within the Rustler Formation or along the Rustler-Salado contact is not a process of concern during the regulatory time frame. The DOE indicates that while lateral dissolution within supra-Salado units has occurred in the WIPP area (e.g. Nash Draw), the current distribution of salt within supra-Salado units above the WIPP is depositional rather than dissolutional in origin, and the dissolution front extending from Nash Draw to the WIPP does not pose a threat to the repository. The CCA states, for example, on page 2-93, that the dissolution rates “indicate no hazard to the WIPP related to the Nash Draw dissolution”. Page DEF-29 states that interpretations regarding shallow dissolution would “not appear to predict threats to the integrity of the disposal system over the regulatory period”. In addition, DOE’s assertions about the distribution of halite within supra-Salado units are not universally supported by data presented in the CCA. The EPA concludes that the depositional origin, in combination with a dissolutional effect would result in the observed Rustler halite distribution.

Although the DOE contended that isopachous, stratigraphic, sedimentologic, and other data support Holt and Powers’ contention that the distribution of salt within the Rustler is depositional in origin, other statements within the CCA question this conclusion. For example, the CCA states, on page 2-38 that the six order of magnitude variation in transmissivity within the Rustler correlates to salt thickness/occurrence within the Rustler, but states that Holt and Powers’ work refutes this correlation. The DOE further implied that this work indicates unloading salt, dissolution immediately below the Rustler, and fracture infill could have caused this hydraulic conductivity variation, but failed to state specifically when/how dissolution along the Rustler/Salado contact occurred. The CCA infers that fractures within the Culebra are pervasive with preferential dissolution of fracture fill accounting for the observed transmissivities. The EPA concludes that while it would appear that information pertaining to isopachous variation, potential depocenters, sedimentary fabrics, etc., could support the depositional distribution of salts, it is also quite possible that a combination of sedimentation and dissolution could account for the observed salt distribution.

References cited within the CCA (e.g. Bachman, 1976) further referenced work not in the CCA. These references indicated that the lateral dissolution rate for salts in the western part of the Delaware Basin is about 300 - 400 ft/10,000 years, which was translated by Jones to represent a vertical dissolution rate of about 5 ft/10,000 years. Bachman (1976) also indicated that a vertical subsidence rate of 3.3 ft per 10,000 years can be calculated, based upon geologic information which indicates Nash Draw has subsided approximately 180 feet since formation of the Mescalero Caliche some 600,000 years ago . Bachman goes on to state, however, that this subsidence rate is not uniform through time or location. Later publications by Bachman (1981) stated that these rates are invalid (i.e. too rapid) because assumptions were made that dissolution occurred only during Cenozoic and Quaternary times (not earlier). This information would appear to indicate that according to Jones and Bachman, dissolution has little chance of impacting the repository directly during the 10,000 year regulatory period. The DOE indicates that conditioned transmissivities in TFIELD accounts for any effects that disruption of the upper Rustler units would have on the Culebra. The EPA has reviewed available data and concludes that lateral dissolution will likely have little effect on the containment capabilities of the WIPP during the regulatory time period, and possible effects have been considered and are incorporated as part of the Culebra transmissivity uncertainties.

The CCA included little information regarding why the DOE believed fracture infill dissolution would be of little concern. However, the DOE submitted information in response to the EPA comments that explained this more thoroughly. The DOE indicated that their new groundwater basin model indicated very slow infiltration of water through the Rustler to the Culebra. This slow infiltration rate would allow time for infiltrating waters to become saturated with respect to calcium sulfate, which is the Culebra fracture infill mineral. These waters, therefore, would have little ability to dissolve fracture infill, resulting in increased Culebra transmissivity. The EPA has reviewed the DOE′s information and finds it reasonable. [Refer to **CARD 14--Content of Compliance Application**, Docket No. A-93-02, V-B-2, Section 194.14 (a)(2) and (3).]

Karst features, such as Nash Draw, have formed via shallow (surface down) dissolution in the WIPP area. The DOE has indicated that the development of karst features near and above the WIPP has been the subject of considerable study, and concluded that development of karst does not pose a threat to the containment capabilities of the disposal system. Examination of information presented within the CCA, as well as other information, indicates that karst features are present in the WIPP area (particularly Nash Draw). Although evidence of karst development at

WIPP-33 is discussed only briefly in the CCA, as are opinions by others regarding the development of karst features, the EPA has reviewed all available data and concurs that the lack of pervasive WIPP-site karst, dry climate (including future precipitation projections), and pervasive Mescalero Caliche supports the DOE′s conclusion with regard to karst.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.1.6, and 6.4.6, and Appendices SCR.1.1.5.1; DEF, Section 3.1, 3.2; FAC, Sections 3.1.2, 4.1.1, 7.2.4, and 8.9; Bachman, G.O. 1974. *Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico.* Open-File Report, 74 - 194, 71. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1980. *Regional Geology and Cenozoic History of Pecos Basin, Southeastern New Mexico.* Open -File Report 80-1099. U.S. Geological Survey, Denver, CO, 97; Bachman, G.O. 1981. *Geology of Nash Draw, Eddy County, New Mexico.* Open-File Report 81 - 31. U.S. Geological Survey, Denver, CO, 3; Lambert, S.J. 1983. *Dissolution of Evaporites in and around the Delaware Basin, Southeastern New Mexico and West Texas.* SAND82-0461. Sandia National Laboratories, Albuquerque, NM. WPO 27520; Bachman, G.O. 1984. *Regional Geology of Ochoan Evaporites, Northern Part of Delaware Basin.* Circular 184, pp. 1 - 27. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM; Lowenstein, T.K. 1987. *Post Burial Alteration of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico: Textural, Stratigraphic and Chemical Evidence.* EEG-36, the DOE/AL?10752-36. Environmental Evaluation Group, Santa Fe, NM; Anderson, R.Y., Dean, W.E., Jr., Kirkland. D.W., and Snider, H.I. 1972. Permian Castile Varved Evaporite Sequence, West Texas and New Mexico. *Geological Society of America Bulletin,* Vol. 83, No. 1, pp.59 - 85, 81; Anderson, R.Y. 1978. *Deep Dissolution of Salt, Northern Delaware Basin, New Mexico.* Report to Sandia National Laboratories, Albuquerque, NM. WPO 29527 - 29530; Snyder, R.P., Gard, Jr., L.M., and Mercer, J.W. 1982. *Evaluation of Breccia Pipes in Southeastern New Mexico and Their Relation to the Waste Isolation Pilot Plant (WIPP) Site.* Open-File Report 82-968. U.S. Geological Survey, Denver, CO 65; Nicholson, A., Jr., and Clebsch, A., Jr. 1961. *Geology and Ground-Water Conditions in Southern Lea County, New Mexico.* Ground-Water Report 6. New Mexico Bureau of Mines and Mineral Resources, Within the Lower Castile Formation, Western Delaware Basin, New Mexico. In *Geology of the Western Delaware Basin, West Texas and Southeastern new Mexico,* D.W. Powers and W.C. James, eds. El Paso Geological Society Guidebook 18. El Paso Geological Society, El Paso, TX, pp. 69 - 79, 78; Davies, P.B. 1983. Assessing the Potential for Deep-Seated Salt Dissolution and Subsidence at the Waste Isolation Pilot Plant (WIPP). In *State of New Mexico Environmental Evaluation Group Conference, WIPP Site Suitability for Radioactive Waste Disposal, Carlsbad, NM;* Borns, D.J., and Shaffer, S.E. 1985. *Regional Well-Log Correlation in the New Mexico Portion of the Delaware*

Basin. SAND83-1798. Sandia National Laboratories, Albuquerque, NM. WPO 24511.)

N22 Fracture Infills (SCR 1.1.5.2, SO-C). The screening argument in Section 1.1.5.2 appears reasonable to EPA. The argument that fracture infill via mineralization would be universally beneficial is not necessary the case, particularly as such infill could result in channeling that would cause "pipeline" effects within the Rustler. However, DOE has provided information supplemental to the CCA which indicates that groundwater entering the Culebra from vertical infiltration will be saturated (or near so) with respect to calcium sulfate. It is possible the such waters - if at saturation or supersaturation - could precipitate calcium sulfate. However, the low infiltration rates and long residence times in the Rustler Formation would allow time for the solutions to reach chemical equilibrium, which would lessen the likelihood of either mineralization or dissolution of fracture fill. As such, the EPA concurs with DOE's screening of this FEP. [Refer to **CARD 14--Content of Compliance Application,** Docket No. A-93-02, V-B-2, Section 194.14 (a)(2) and (3).]

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.1.5.2; FAC, Section 8.8; Siegel, M.D., Lambert, S.J., and Robinson, K.L. eds. 1991. *Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the Waste Isolation Pilot Plant Area, Southeaster New Mexico.* SAND88-0196. Sandia National Laboratories, Albuquerque, NM; Chapman, J.B. 1986. *Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area.* EEG-35, DOE/AL/10752-35/ Environmental Evaluation Group, Santa Fe, NM; *Stable-Isotope Geochemistry of Groundwaters in the Delaware Basin of Southeastern New Mexico.* SAND87-0138. Sandia National Laboratories, Albuquerque, NM. WPO 24150.)

N23- N-30 Saturated Groundwater Flow, Unsaturated Groundwater Flow, Fracture Flow, Density Effects on Groundwater Flow, Effects of Preferential Pathways, Thermal Effects on Groundwater Flow, Saline Intrusion, Freshwater Intrusion. (SCR 1.2.1, 1.2.2, UP, UP, UP, SO-C, UP, SO-C, SO-P, SO-P). The screening argument in Sections 1.2.1 and 1.2.2 appears reasonable to EPA. The DOE′s screening evaluation appears to be technically valid relative to the need to include saturated groundwater flow, unsaturated groundwater flow, and fracture flow in performance assessment. Refer to **CARD 23--Models and Computer Codes,** Docket No. A-93-02, V-B-2, Section 194.23 (a), for EPA's evaluation of DOE's treatment of these in PA.

The CCA screened out density effects on groundwater flow on the basis of low consequence to the performance of the disposal system. If density gradients were significant enough in the Culebra, groundwater flow vectors would rotate towards the east (down-dip) away from the high transmissivity zone predicted to exist within the Culebra. Therefore, excluding density effects on groundwater flow appears to be a conservative approach.

The CCA screens out changes in groundwater flow arising from saline intrusion into units above the Salado on the basis of low probability of occurrence over the 10,000 years. This is because no natural events or processes have been identified that could result in saline intrusion into units above the Salado or cause a significant increase in fluid density. This argument also appears reasonable.

The CCA screens out changes in groundwater flow arising from natural thermal effects on the basis of low consequence to the performance of the disposal system. The CCA states that the vertical geothermal gradient in the region of the WIPP has been measured at approximately 50°C per mile. This gradient equates to approximately 0.03°C per meter. Based on the thickness of the transmissive units above the Salado, it seems reasonable to conclude that natural thermal gradients will not affect groundwater flow within the WIPP region. Likewise, the screening of saline intrusion appears reasonable, considering there is no natural source for such brine to enter the Culebra.

EPA initially questioned how the DOE treated infiltration and fracture flow in performance assessment. Examination of the DOE references (e.g. Corbett and Knupp, 1996) indicated that modeling of saturated, unsaturated, and fracture flow in the performance assessment is appropriate [refer to **CARD 23--Models and Computer Codes**, Docket No. A-93-02, V-B-2, Section 194.23 (a)]. The CCA screens out changes in groundwater flow arising from freshwater intrusion on the basis of low probability of occurrence over the 10,000 years. The CCA maintains that because of the low transmissivities of the Dewey Lake and the Rustler, not enough fresh water could infiltrate into the system within the 10,000 year period to significantly affect groundwater flow. However, the DOE has also recognized groundwater flow velocity and direction changes over time due to freshwater intrusion. EPA has examined these data, and determined that while the DOE has included transmissivity and flow velocity variations in the Culebra that lead to flow direction changes. Therefore, the DOE has indeed included the possibility of increased flow in the Culebra performance assessment modeling.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.2.1, 6.4.5, and 6.4.6, and Appendices SCR.1.2.1; HYDRO; BRAGFLO, Sections 4.1 to 4.4; SECOFL2D, Section 3; MASS, Section 15; SECOTP2D, Sections 2 and 3.4; TFIELD, Sections 2.2 and 4; PAR, Parameters 35, 50 and 51; Davies, P.B. 1989. *Variable Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open File Report 88-490. U.S. Geological Survey; Corbett and Knupp, 1996, *The Role of Regional Groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico*.

N-31 <u>Hydrological Response to Earthquakes (SCR1.2.2, SO-C)</u>. The DOE screened this FEP because it believed the hydrologic effect of an earthquake on the WIPP would be small, and the expected level of seismic activity is low. This argument appears reasonable and is consistent with other seismic-related screening results.

(References: Appendix SCR, Section 1.2.2)

N32 <u>Natural Gas Intrusion (SCR1.2.2, SO-P).</u> The screening argument in Section 1.2.2 appears reasonable to EPA. The invasion of natural gas into the repository from deeper formations due to <u>natural</u> processes was screened out based on low probability of occurrence. Although no supporting documentation regarding the conclusion is presented in SCR.1.2.2.4, the conclusion appears technically valid, as EPA agrees that natural pathways for gas intrusion to enter the repository during the regulatory time period, noting that EPA agrees with DOE screening of said pathways, such as active faults and open Salado fractures.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.1 and Appendix SCR.1.2.2.)

N33-N38 <u>Groundwater Geochemistry, Saline Intrusion, Freshwater Intrusion, Changes in Groundwater Eh, Changes in Groundwater pH, Effects of Dissolution (SCR1.3.1, 1.3.2, UP(N33), SO-C (N34-N38)).</u> The screening argument in Sections 1.3.1 and 1.3.2 appears reasonable to EPA. Although the current hydrologic system geochemistry is accounted for when determining waste solubility/occurrence in groundwater, changes in Culebra groundwater chemistry relative to changes in groundwater Eh, pH, and saline/freshwater intrusion, were not addressed in great detail, in either Appendix SCR and referenced sections of Chapter 2. Specifically, the origin and nature of infiltration is not well presented/modeled, which would impact water quality in units overlying the Salado Formation. The current groundwater quality distribution in the Culebra also was not extensively discussed in the CCA.

The CCA originally indicated that numerous assessments have been performed regarding the origin and current distribution of the Culebra hydrochemical zones, but did not detail these results. The CCA concludes that the current distribution presented in Figure 2-40 is due, in part, to vertical leakage of brines from the Tamarisk (apparently associated with Zone A), but did not discuss the origin of other groundwater quality within zones B, C, and D. However, EPA notes that others questioned DOE's initial interpretation. For example, Chapman believed that groundwater quality data in the Culebra are indicative of recent recharge events, and has questioned the relatively old age of groundwaters in the Culebra put forth by DOE. Also, the DOE has, in the past, believed that the current distribution of groundwater quality is remnant of an "old" westward recharge event that is not reflective of current groundwater flow directions within the Culebra. Still others (Corbet and Knupp, 1996) have performed modeling that indicates an east to west recharge event. As such, the CCA did not adequately address the origin of hydrochemical facies within the Culebra, which could be indicative of recharge/discharge events that could change supra-Salado groundwater quality conditions. However, DOE has submitted additional information supplemental to the CCA which discusses groundwater infiltration geochemistry and Culebra groundwater geochemistry more thoroughly. The supplemental information provided by the DOE explained the origin of the four hydrochemical facies of the Culebra, concluding that infiltration accounts for the geochemistry in some areas. The location of infiltration differs for the four facies, and residence time in each is related to permeability. The EPA has reviewed the DOE′s supplemental information, and finds it addresses many initial FEP treatment issues. It should be noted the DOE has taken existing geochemical conditions in the Salado and Culebra into account relative to actinide solubility. The screening argument appears technically valid. Refer to **CARD 14--Content of Compliance Application** [Docket No. A-93-02, V-B-2, Section 194.14 (a)(2) and (3)], for additional discussion of EPA's position and DOE's supplemental information.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.2.1, 2.4, 6.4.3. 6.4.6, and Appendices SCR.1.3.1; PAR, Parameters 36 to 47, 52 to 57, Table PAR-39, Corbett and Knupp, 1996, *The Role of Regional groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico*.)

N39 Physiography (SCR 1.4.1, UP). The DOE′s screening evaluation is technically reasonable to EPA. Refer to N41-49, below.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP,

October 1996, Sections 2.1.4 and 6.4.2, and Appendices SCR.1.4.1 and PAR, Table PAR-57.)

N40 Impact of a Large Meteorite (SCR 1.4.2, SO-P). The screening argument in Section 1.4.2 appears reasonable to EPA. The DOE has considered the probability of meteorite impact not only directly above the WIPP repository, but also near the repository, and found the probability to be significantly less than one in one million (in 10,000 years). Calculations were based upon observed meteorite impact occurrence in the geologic past. DOE's screening argument is reasonable and well supported.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.4.2.

N41-N49 Mechanical Weathering, Chemical Weathering, Aeolian Erosion, Fluvial Erosion, Mass Wasting, Aeolian deposition, Fluvial Deposition, Mass Wasting (Deposition) (SCR 1.4.3.1,1.4.3.2, 1.4.3.3 all: SO-C). The screening argument in Sections 1.4.3.1, 1.4.3.2 and 1.4.3.3 appears reasonable to EPA. While the DOE has indicated that erosional processes including mechanical, chemical, aeolian, and fluvial erosion/weathering, as well as mass wasting, can occur in the WIPP area, EPA concurs with DOE that the possibility that these processes would significantly affect the repository is very remote.

Weathering has been screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. This seems reasonable since mechanical and chemical weathering should be limited to the surface and near surface environment and have little effect on the WIPP performance.

Erosion and sedimentation have been screened out of the performance assessment calculations based on low consequence to disposal system performance. Aeolian erosion/deposition will continue to occur over the WIPP site and surrounding area; however, no significant changes in the overall thickness of aeolian material is likely to occur within the performance period. The limited extent of water courses within the WIPP area will limit the amount of fluvial and lacustrine erosion/deposition. Mass wasting could be significant if it results in dams or modifies streams. However, the Pecos River is located approximately 12 miles from the WIPP site in a broad valley, which precludes either significant mass wasting or large impoundments from forming that could be of sufficient size or volume to impact the WIPP. The DOE's explanations appear reasonable and adequate for screening out erosion and sedimentation from the performance assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.4.3.2 and SCR.1.4.3.3)

N50 Soil Development (SCR 1.4.4, SO-C). The screening argument in Section 1.4.4 appears reasonable to EPA. Soil development has been screened out of the performance assessment calculations by the DOE, based on low consequence to the performance of the disposal system. The Mescalero Caliche lies directly beneath the surficial soils at the WIPP site. The Mescalero Caliche has been dated at 410,000 to 510,000 years old. Berino soil, which makes up a thin horizon over the Mescalero caliche, is interpreted to be 333,000 years old. These relationships indicate a period of relative stability of the WIPP area for the past 500,000 years. This interpretation appears to be reasonable for screening out soil development from the performance assessment calculations. The CCA concedes that surface soils appear to play a role in the infiltration of precipitation and refers the reader to Appendix HYDRO. Appendix HYDRO discusses the transmissivity and hydraulic conductivity values for alluvium within the Pecos River. While Appendix SCR does not estimate or reference the transmissivity and hydraulic conductivity values for the surficial soils near the WIPP site, but this is addressed in the groundwater basin model (Corbett and Knupp, 1996). Considering this information, the screening argument appears technically valid.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October, 1996, Appendices SCR.1.4.4; Corbett and Knupp, 1996, *The Role of Regional groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico*.)

N51 Stream and River Flow (SCR.1.5.1, SO-C). The DOE's screening evaluation appears technically reasonable to EPA. The CCA screens out streams and river flow on the basis of low consequence to the performance of the disposal system. This section maintains that no streams or rivers have existed near the WIPP since the Pleistocene. This does not mean that streams and rivers can not exist at the WIPP in the future, especially if there is a change in climatic conditions. Section SRC.1.4.3.2 indicates that the existence of perennial streams at the WIPP site could occur if a climatic change occurred. However, DOE concluded that the consequence of stream and river flow would be low, even considering predicted climate changes. This appears reasonable and technically valid.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.2.2, Appendices SCR.1.5.1; GCR, Section 6.2.1; Bachman, G.O. 1974. *Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico.* Open-File Report 74-194. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1981. *Geology of Nash Draw, Eddy County, New Mexico.* Open-File Report 81-31. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1987. *Karst in Evaporites in Southeastern New Mexico.* SAND86-7078. Sandia National Laboratories, Albuquerque, NM. WPO 24006.)

N52 Surface Water Bodies (SCR.1.5.2, SO-C). The screening argument in Section 1.5.2

appears reasonable to EPA. The CCA screens out the effects of surface water bodies on the basis of low consequence to the performance of the disposal system (although it could be argued that it should be screened based on probability rather than consequence). This section maintains that no standing surface water bodies have existed near the WIPP since the Pleistocene. This does not mean that surface water bodies can not exist at the WIPP in the future, especially if there is a change in climatic conditions. Section SRC.1.4.3.2 infers that standing surface water bodies at the WIPP site could occur if a climatic change occurred. However, DOE indicates that even if small lakes and ponds developed, they would have little effect on the performance of the disposal system. The DOE concluded that given the predicted climate variations, development of standing bodies of water (i.e., due to a greatly elevated water table) would not have major consequences. This argument appears reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.2.2, Appendices SCR.1.5.2; GCR, Section 6.2.1; Bachman, G.O. 1974. *Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico.* Open-File Report 74-194. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1981. *Geology of Nash Draw, Eddy County, New Mexico.* Open-File Report 81-31. U.S. Geological Survey, Denver, CO; Bachman, G.O. 1987. *Karst in Evaporites in Southeastern New Mexico.* SAND86-7078. Sandia National Laboratories, Albuquerque, NM. WPO 24006.)

N53-N56 Groundwater Discharge, Groundwater Recharge, Infiltration, Changes in Groundwater Recharge and Discharge. (SCR1.5.3, 1.5.4 UP). The DOE's screening argument appears technically reasonable to EPA because the DOE has assessed recharge/discharge and has included this assessment in the groundwater basin modeled for the Culebra. Refer to **CARD 23--Models and Computer Codes** [Docket No. A-93-02, V-B-2, Section 194.23 (a)] for discussion of the groundwater basin model as it pertains to conceptual model development.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.2.1, 2.2.2, 2.5, 6.4.6, 6.4.9, 6.4.10, and Appendices PAR, Parameter 35, Table PAR-30; TFIELD, Section 3; MASS, Section 14.2; PAR, Parameter 48)

N57-58 Lake Formation, River Flooding (SCR 1.5.4, SO-C). The DOE's screening evaluation is technically valid (although it could be argued that these should be screened based on probability rather than consequence). EPA agrees that the probability of lakes or rivers forming directly over the WIPP is small.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.1.5.4)

N59-63 Precipitation, Temperature, Climate Change, Glaciation, Permafrost (SCR 1.6.1,1.6.2.1, 1.6.2.2, UP N59-61, SO-P N62 and N63). The screening argument in Sections 1.6.1.1, 1.6.2.1 and 1.6.2.2 appears reasonable to EPA. The DOE has considered the impact of precipitation, and temperature as part of climate change, and has included this impact in the performance assessment (through inclusion of a sampled parameter for scaling Culebra flow velocity). The DOE has eliminated the potential direct (non-climatic) effects of glaciation and permafrost development based upon historic glacial distribution data. EPA agrees that this approach by DOE is reasonable.

An important aspect of the climate conditions at the WIPP lies in assessing the recharge component of the hydrologic cycle. The current climate at the WIPP may be characterized as semi-arid, with generally mild temperatures, low precipitation and humidity and a high evaporation rate. This combination of climatic conditions results in a relatively small component of recharge. This characterization appears to be supported by available data on recent climate conditions at the WIPP.

Review of the CCA, related supporting references, and Appendix CLI suggest that the climate index parameter presented and discussed in Appendix PAR and derived from Historic Meteorological Climatic Condition data, is appropriate. The described historic range of 90 to 200% of current precipitation levels is captured in the climate index parameter with the specified range of 100 to 225% of current levels. The Natural Barriers Data Qualification Peer Review Panel considered the characterization of climate presented in the CCA and determined that the value and distribution of the climate index parameter used in the performance assessment is conservative.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.2.1, 2.5, and 6.4.9, and Appendices SCR.1.6.1; PAR, Parameter 48; and CLI)

N64-N67 Seas and Oceans, Estuaries, Coastal Erosion, Marine Sediment Transport and Deposition (SCR 1.7.1, 1.7.2, SO-C). The screening argument in Sections 1.7.1 and 1.7.2 appears reasonable to EPA. The DOE indicated that the effects of estuaries, seas, oceans, coastal erosion and marine sediment transport and deposition have been eliminated from performance assessment calculations on the basis of low consequences, since the WIPP site is located more than 480 miles from the nearest marine surface water body (i.e., Pacific Ocean and Gulf of Mexico). This argument appears technically reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices, SCR.1.7.1, SCR.1.7.2)

N68 Sea Level Changes (SCR 1.7.3, SO-C). The screening argument in Section 1.7.3 appears reasonable to EPA. The DOE stated that the effects of both long-term and short-term sea level changes have been eliminated from the performance assessment on the basis of low consequence to the performance of the disposal system, since the WIPP site is located approximately 3,330 feet above sea level. The DOE supported their assumption with references to Chappell and Shackleton (1986, 138) which indicate that over the next 10,000 years global sea level changes could be expected to drop approximately 460 feet, but that this drop in sea level would not be expected to affect the groundwater system at the WIPP site. The DOE further stated that a long-term rise in sea level as a result of global warming would only be expected to be in the magnitude of a few meters as is stated in Warrick and Oerlemans (1990, 278). A rise in sea level of a few meters is also not expected to impact the groundwater system in the WIPP region.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.7.3; Chappell, J., and Shackleton, N.J. 1986. Oxygen Isotopes and Sea Level. *Nature,* Vol. 324, No. 6093, pp. 138; Warrick, R., and Oerlemans, J. 1990. "Sea Level Rise." In *Climate Change: The IPCC Scientific Assessment,* J.T. Houghton, G.J. Jenkins, and J.J. Ephraums, eds., pp. 278. Intergovernmental Panel on Climate Change, Sweden, pp. 257 - 281.)

N69-N70 Plants, Animals (SCR 1.8.1, SO-C). The DOE has stated that the effects of flora and fauna have been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. This conclusion appears reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.4.1 and Appendix SCR.1.8.1.)

N71 Microbes (SCR 1.8.1, SO-C). The DOE's screening argument appears reasonable to EPA. The CCA text, on page SCR-32, states that microbes are presumed to be present in the thin soil horizons. The FEP Summary Table (Table 1) indicates that the effects of microbes have been eliminated from the performance assessment on the basis of low consequence, and that supporting evidence is included in Appendix MASS, Section 15.3.2. Review of these references indicates that this argument appears reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.8.1 and MASS, Section 15.3.2.)

N72 Natural Ecological Development (SCR 1.8.2, SO-C). The screening argument in Section 1.8.2 appears reasonable to EPA. The DOE stated that natural ecological development has been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. As indicated in both Appendix CLI and by Swift 1992, currently the region surrounding the WIPP site is sparsely vegetated as a result of the arid climate and poor soil quality and under a worst case scenario rainfall is not expected to more than double the current average of 13 inches per year over the next 10,000 years. Therefore, the magnitude of the increase in rainfall will not result in significant changes in the types and number of vegetation and animals present at the site, which appears to be a reasonable conclusion.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.1.8.2 and CLI.)

4.2. Waste and Repository Induced FEPs Assessment

W1 Disposal Geometry, (SCR2.1.1, UP). The DOE's screening evaluation appears to be technically reasonable to EPA, as disposal area geometry is included in the performance assessment through GENMESH realizations. Representation of this geometry within the performance assessment is presented in **CARD 23--Models and Computer Codes** [Docket No. A-93-02, V-B-2, Section 194.23 (b)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 3.2, 6.4.2, and 6.4.3, and Appendix SCR.2.1.1.)

W2-W3 Waste Inventory, Heterogeneity of Waste Forms, (SCR 2.1.2, UP, DP). The DOE's screening argument appears to be technically reasonable to EPA. The waste inventory and heterogeneous nature of this inventory are described in Appendix BIR of the CCA; information from this document was used to determine the waste unit factor and other related waste representations (i.e. EPA Units). Specifically, radionuclide content, waste material parameter content, and RCRA constituent content are among those elements identified on a site-specific waste stream basis in the CCA. Treatment of these heterogeneities as they relate to: radionuclides in brine (as described in SOTERM); important waste components that impact actinide concentration in brine (again described in SOTERM); and random waste sampling in CUTTINGS analysis; etc., are included in performance assessment.

The EPA requested clarification regarding waste loading, asking whether the current random loading scheme should instead consider preferential intrusion into three containers of a waste stream in CUTTINGS releases. The DOE provided supplemental information which indicated the three-drum "preferential" loading would not impact compliance. The DOE concludes that DOE's decision to include waste heterogeneity in performance assessment is appropriate.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 4.1, 6.4.3, 6.4.7 and 6.4.12, and Appendices SCR.2.1.2; BIR; WCA, Sections 3.2, 8.2 and 8.3; PAR, Table PAR-41; Sanchez, L.C., and Trellue, H.R., 1996. Estimation of Maximum RH-TRU Thermal Heat Load for WIPP. Memo to T. Hicks (Galson Sciences Ltd.), January 17, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31165.)

W4 Container Form, (SCR 2.1.3, SO-C). The DOE′s screening evaluation appears reasonable to EPA. Containers are accounted for in the performance assessment by including container material (iron) in the gas generation performance assessment-related models. The particular form or shape of the container may affect its strength or heat dissipation characteristics, but these factors are not expected to be important in the PA.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.1.3 and DVR, Section 12.2.)

W5 Container Material Inventory, (SCR 2.1.3, UP). The screening argument in Section 2.1.3 appears reasonable to EPA. Container material is accounted for in PA, as the iron within waste containers is assumed to provide, through corrosion, metals such as nickel which preferentially complex (relative to actinides) with organic ligands in waste. In addition, DOE indicates that containers will provide sufficient iron to ensure reducing conditions in the repository, which impacts the oxidation states of actinides. Therefore, DOE accounts for container material in PA through calculations of iron present to ensure sufficient alternative complexants for organic ligands, which decreases the actinide concentration in brine and through the assumption that container iron will cause reducing conditions within the repository. EPA has reviewed the CCA and agrees with DOE's determination that container material should be included in performance assessment. Refer to **CARD 24--Waste Characterization, for EPA's assessment of DOE's treatment of waste containers in PA** [Docket No. A-93-02, V-B-2, Section 194.24 (b)(2)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3 and Appendices SCR.2.1.3, Chapter 4, Table 4-4; BIR; SOTERM, Section 2.2.3; PAR, Parameter 1, Table PAR-43; Wang, Y. and Brush, .H. 1996. *Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment*. Memo to Martin S. Tierney, January 26, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31943.)

W6,W7 Seal Physical Properties, Seal Chemical Composition (SCR 2.1.4, UP). The screening argument in Section 2.1.4 appears reasonable to EPA. The DOE has integrated seal geometry in performance assessment through modeled permeability variation of seal components with time. EPA concurred with DOE's decision to include these parameters in performance assessment. However, the EPA also reviewed these permeability data, and concluded that the "lower-end" permeability used by the DOE was too permeable, and required modification of this parameter in the EPA-Mandated

Performance Assessment. Also, the EPA reviewed seal design and concluded that while the design appeared sufficient, the DOE had not demonstrated that brine inflow from the Salado to shaft seals would cease. This issue was resolved by the EPA-mandated performance assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 3.3.1 and 3.3.2, and Appendices SCR.2.1.4; SEAL, Section 6.4.4; PAR, Figure PAR-2; PAR, Parameters 9 to 11, Tables PAR-16 to PAR-24.)

W8 <u>Seal Chemical Composition (SCR 2.1.4, SO-C).</u> The screening argument in Section 2.1.4 appears reasonable to EPA. Seal chemical composition was screened out on the basis of predicted beneficial consequences, which are not credited in performance assessment calculations. EPA agrees that this approach appears to be reasonable, since some degree of sorption of contaminants would undoubtedly occur if a flow path from the repository up a (sealed) shaft were to become established. Ignoring adsorption simplifies the PA calculations, and is expected to produce somewhat more conservative results. However, because little or no upward flow is predicted to occur through the seals, the overall effect on PA results may not be significant.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.1.4; SCR.2.5.2; Bennett, D.G., Read, D., Atkins, M., Glasser, F.P. 1992. A Thermodynamic Model for Blended Cements II: Cement Hydrate Phases; Thermodynamic Values and Modeling Studies. *Journal of Nuclear Materials,* Vol. 190, pp. 315.)

W9 <u>Backfill Properties (SCR2.1.5, SO-C).</u> The screening argument in Section 2.1.5 appears reasonable to EPA. Appendix SCR, Section 2.1.5 (page SCR-39), of the CCA indicates that backfill physical properties have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The Screening of FEPs Summary Tables (Part 1) cross references Appendix BACK, Section 3.2, of the CCA as the location of information to support the screening classification. EPA concluded that DOE's screening of physical backfill properties from consideration is appropriate, as detailed below.

The presence of backfill within a disposal room could affect the rate and amount of creep closure that will occur over time, which in turn could affect the porosity and permeability in the disposal room over time. Section 6.4.3.1 and Appendix PORSURF, Section 3, of the CCA indicate that backfill in the disposal rooms has not been incorporated into the models (SANTOS) for disposal room closure that are used to support the current CCA performance assessment calculations.

A. Appendix SCR, Section 2.1.5, of the CCA indicates that the use of backfill within the disposal rooms will result in an initial permeability for the disposal room lower than that of an empty cavity, so neglecting the hydrological effects of backfill is a conservative assumption with regard to brine inflow and radionuclide migration. Information to support this statement is provided in Appendix BACK, Section 3.2 and Figure BACK-1, of the CCA. Appendix BACK, Figure BACK-1, provides a graphical comparison of a closure curve (change in porosity with time) for a disposal room with no backfill and a closure curve for a disposal room with a salt backfill included. The figure shows that the initial porosity of a disposal room with salt backfill is lower than a room without backfill, and that the porosity of the backfilled disposal room decreases faster and attains a lower overall porosity than a disposal room without backfill. The text of Appendix BACK indicates that since the amount of MgO backfill specified in the proposed backfill design will not initially fill all of the void spaces in a disposal room (as assumed when deriving the salt backfill curve in Figure BACK-1), the net effect will be a closure curve intermediate between the no backfill curve and the salt backfill included curve. The statements provided in Appendix SCR, Section 2.1.5, and Appendix BACK, Section 3.2, regarding the effect of backfill on the disposal system porosity appear to be technically valid.

B. Appendix BACK, Section 3.2 (page BACK-4) concludes that "The DOE believes that the effect of the closure rate arising from emplacement of the current backfill system will have minimal impact on the performance assessment calculation." The DOE supports this by stating that previous performance assessment calculations have shown that the porosity of backfill in the drifts, experimental regions, and the shaft below the seal, and the volume fractions of materials that are expected to have an impact on final room porosity are less important parameters to compliance.

C. Appendix SCR, Section 2.1.5, of the CCA states that "Backfill will result in an initial permeability for the disposal room lower than that of an empty cavity, so neglecting the hydrological effects of backfill is a conservative assumption with regard to brine inflow and radionuclide migration. Thus, backfill physical properties have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system." In this argument, the DOE appears to be using the second "consequence" criteria described in Section 6.2.2.1 (page 6-39, lines 39-43) of the CCA that indicates that FEPs that are potentially beneficial to the subsystem performance may be eliminated from the performance assessment calculations if necessary to simplify the analysis. The CCA provides documentation that the use of backfill in a disposal room is potentially beneficial to the subsystem performance.

D. The DOE has indicated in its February 26, 1997 response to EPA completeness comments that preliminary MgO backfill placement tests have been performed using both mini-sacks and super sacks in the repository setting to demonstrate that backfill can be emplaced, as described in Section 3.3.3 of the CCA, without significant impact to waste handling operations. The DOE response also indicated that waste handling procedure WH-1011, Revision 2, dated October 1, 1996, has been prepared to describe the emplacement procedure for mini-sacks of MgO in the void spaces between the waste drums in the 7-pack configuration.

The DOE also referenced Sections 6.4.3 and 3.3.3 of the CCA as the location of information regarding the conceptual model for emplacement of MgO backfill in the repository and the documentation that the appropriate amount of backfill can actually be emplaced in the disposal rooms. The response provides general calculations used to determine the amount of MgO that will be required (43,700 tons) to react with the maximum estimate of carbon dioxide production. The response then indicated that from calculations provided in Section 3.3.3 of the CCA, approximately 85,600 tons of backfill will be placed in the repository. As a result, it appears that the response is indicating that Section 3.3.3 of the CCA already provided the demonstration that the proposed volume of backfill can actually be accommodated within the repository. A review of Section 3.3.3 indicates that while the results of calculations showing the volume of backfill that can be emplaced in the repository were provided, no actual example calculations were provided. In addition, neither Section 3.3.3 or Appendix BACK of the CCA provided the dimensions of the super sacks, which is a crucial piece of information for calculating the volume of backfill that can be emplaced.

However, while the response to the comment did not provide calculations verifying that the proposed volume of backfill can actually be accommodated in the repository, the EPA was able to verify by calculations that the repository is capable of accommodating the proposed volume of backfill. The verification calculations were performed using the assumptions of panel size, room size, waste stacking, and backfill emplacements provided by the DOE in Section 3.3.3. The dimensions of the super sacks (6 feet by 5 feet by 1.5 feet) were obtained from Chapter D of the WIPP RCRA Part B Permit Application (Revision 6, April 1996).

E. The DOE has submitted a memorandum to EPA entitled “Implementation of Chemical Controls through a Backfill System for the Waste Isolation Pilot Plant (WIPP)” (Bynum, et. al., March, 1997). The DOE indicates in this paper that sorel cement will form when backfill reacts with CO_2/brine. This cement has very high strength and, presumably, low brine permeability. This material would further decrease the permeability of disposal rooms, and the DOE conservatively does not take this into account (beneficial aspect of backfill).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP,

October 1996, Appendices SCR.2.1.5; BACK, Section 3.2.)

W10 Backfill Chemical Composition (SCR 2.1.5, UP). The DOE′s screening argument appears reasonable to EPA. However, EPA initially questioned whether DOE had adequately considered and justified it's assumptions regarding the efficac of backfill material. Specifically, EPA questioned in it's December 19, 1997 and March 19, 1997 letters the effectiveness of MgO as a sequestering agent and lack of experimental data backing up the assessment . The EPA requested additional information regarding efficiency and viability of MgO, and the DOE submitted new experimental data which indicated that MgO would behave as predicted (Van Bynum, 1997). The EPA initially questioned the metastable magnesium oxide mineral species used to calculate actinide solubilities; as a result, the EPA required new solubility values to be used in the EPA-Mandated Performance Assessment. Refer to **CARD 24--Waste Characterization [Docket No. A-93-02, V-B-2, Section 194.24 (a)], for additional information.**.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3 and Appendices SCR.2.1.5; BACK, Section 1; SOTERM, Section 2.2.2; WCA, Sections 4.1.2, 8.9 and 8.10; PAR, Parameters 36 to 47, Table PAR-39; Wang, Y. 1996. *Evaluation of the Thermal Effect of MgO Hydration for the Long-Term WIPP Performance Assessment.* Memo of May 9, 1996. Sandia National Laboratories, Albuquerque, NM. SWCF-A (Org.6352), WBS 1.1.09.1.1(RC). WPO 37743.)

W11 Postclosure Monitoring. (SCR 2.1.6, SO-C). The screening argument in Section 2.1.6 appears reasonable to EPA. Page SCR-40 of the CCA indicated that the potential effects of postclosure monitoring have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Appendix SCR, Section 2.1.6 cross references Appendix MON of the CCA as the location of information to support the screening classification. EPA concurs with DOE's decision to screen out post closure monitoring, as discussed in detail below.

DOE concluded, and EPA concurred that inappropriate monitoring after the closure of the WIPP could affect the performance of the disposal system. A requirement of 40 CFR 194.42(d) is that postclosure monitoring be conducted with techniques that do not jeopardize the containment of waste in the disposal system. Thus, if DOE adequately documents compliance with this requirement of 40 CFR 194.42(d), they will also document the appropriateness of the screening classification for postclosure monitoring.

The CCA acknowledged the 40 CFR 194.42(d) requirement to ensure that postclosure monitoring is conducted with techniques that will not jeopardize the containment of waste in the disposal system in Sections 7.2.1, 7.2.2.4 and Appendix MON, Sections 1, 5.2, and 6. Section 7.2.3 and Table 7-7 of the CCA indicate that the following parameters will be monitored during postclosure: Culebra groundwater composition and Culebra change in groundwater flow (groundwater monitoring); probability of encountering a castile brine reservoir and drilling rate (observation of drilling activities in the Delaware Basin), and subsidence (subsidence monitoring using surveying techniques). In addition, radiological environmental monitoring will be conducted during the first few years after closure.

A review of the postclosure monitoring procedures proposed in Section 7.2.3, and Appendices GWMP, DMP, SMP, and EMP of the CCA indicates that none of the proposed techniques will jeopardize the disposal system performance. The postclosure observation of drilling activities techniques, subsidence monitoring techniques and environmental monitoring techniques described in Appendices DMP, SMP, and EMP will only involve non-intrusive activities conducted at the ground surface. The postclosure groundwater monitoring techniques described in Appendix GWMP will involve intrusive activity in the vicinity of the repository since groundwater monitoring wells will be installed in the Culebra Member of the Rustler Formation. However, none of the boreholes for constructing the monitoring wells will penetrate into the Salado Formation and all of the proposed monitoring wells are located at least 0.5 miles from the edge of the repository footprint.

Based on the information provided in the CCA, it EPA concluded that the DOE has provided a reasonable technical screening argument for eliminating the potential effects of postclosure monitoring (FEP W11) from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 7.2.1 (page 7-39), 7.2.2.4 (page 7-47), 7.2.3 (pages 7-58 through 7-63), and Appendices SCR, Section 2.1.6 (page SCR-40); MON, Sections 1 (page MON-1), 4.2 (pages MON-15 through MON-25), 5 (pages MON-28 through MON-33) and 6 (MON-33 through MON-60); GWMP; DMP; SMP; and EMP.)

W12 Radionuclide Decay and Ingrowth (SCR 2.2.1, UP). The screening argument in Section 2.2.1 appears reasonable to EPA. DOE has included radionuclide decay and ingrowth in performance assessments, and EPA concurs with DOE's decision. EPA notes that some of the decay and ingrowth calculations are described in the reference provided with the CCA on the EPAUNI code, which was reviewed separately by EPA. This reference (EPAUNI) calculates the time-dependent inventory using the standard Bateman equations and expresses the results in terms of EPA units. EPA concluded that the decay calculations used by DOE in PA are sufficient; refer to the EPA's **Technical Support Document for Section 194.23: Models and Computer Codes (Docket No. V-B-6)** for additional information.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP,

October 1996, Sections 6.4.5 and 6.4.12, and Appendices SCR.2.2.1; BIR Section 3.2; NUTS, Section 4.3.7; SECOTPWD, Section 2; PANEL, Section 4.6.)

W13 Heat From Radioactive Decay (SCR 2.2.2, SO-C). The screening argument in SCR.2.2.2 appears reasonable to EPA because the waste acceptance criteria for the WIPP do not allow the thermal load of the WIPP to exceed 10 kilowatts per acre. EPA notes that the waste acceptance criteria also restrict the thermal load from RH-TRU waste containers to no more than 300 watts per container. However, the limit on the surface dose equivalent rate of the RH-TRU containers (1,000 rem/hr) is more restrictive and equates to a thermal load of only about 60 watts per container. Based on the thermal loads permitted, the maximum temperature rise in the repository from radioactive decay heat should be less than two degrees Celsius.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.2.2; the DOE(U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. The DOE/EIS-0026. Vol.1-2. Washington, DC. WPO 38835, 38838 - 38839; Thorne, B.J., and Rudeen, D.K. 1981. *Regional Effects of TRU Repository Heat.* SAND80-7161. Sandia National Laboratories, Albuquerque, NM. WPO 10281; Sanchez, L.C., and Trellue, H.R. 1996. Estimation of Maximum RH-TRU Thermal Heat Load for WIPP. Memo to T. Hicks (Galson Sciences Ltd.), January 17, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31165.)

W14 Nuclear Criticality: Heat (SCR 2.2.3 SO-P). The screening argument in SCR.2.2.3 appears reasonable to EPA because the concentrations of fissile nuclides (mainly Pu-239) in the repository are far below the concentrations necessary to sustain a nuclear chain reaction. In addition, there are no known processes that could selectively concentrate the fissile nuclides in the repository. Also, neutron absorbers are abundant in the TRU waste and would prevent the necessary flux of neutrons from developing. The possibility of nuclear criticality in the far field away from the repository is even less likely because of environmental dilution as the nuclides are transported from the repository. It is not possible to achieve a critical fissile nuclide density in a porous medium such as the Culebra.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.5 and 6.4.6, and Appendices SCR.2.2.3; MASS; Rechard, R.P., Stockman, C.T., Sanchez, L.C., Liscum-Powell, J., and Rath, J.S. 1996. Nuclear Criticality in Near Field and Far Field. Summary Memo of Record for RNT-1. SWCF-A:1.2.07.3:PA:QA:TSK:RNT-1. Sandia National Laboratories, Albuquerque, NM.)

W15-17 Radiological Effects on Waste , Radiological Effects on Containers, Radiological Effects on Seals (SCR 2.2.4, SO-C). The screening argument in SCR.2.2.4 appears reasonable to EPA because the repository will not have a high radiation field. This is because most of the waste is CH-TRU waste, which means the radiation dose at the container surface is no more than 200 mrem/hr. This is far below the radiation rate necessary to cause significant physical effects on waste, containers, or seals.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3, Appendix SCR.2.2.4.)

W18 Disturbed Rock Zone (SCR2.3.1, UP). The screening argument in SCR 2.3.1 appears reasonable to EPA. The Shaft DRZ permeability determination is well documented, based on published field and laboratory testing, and its use in performance assessment calculations is explained fairly clearly. The DRZ has been extensively investigated since the excavation of the initial WIPP underground openings. Field conductivity testing with gas and brine have been performed in the WIPP experimental and repository zones, and recently (1996) in the Air Intake Shaft. A conservative (median) value based on field and laboratory testing is used in developing the composite or combined effective permeability of the sealed shafts after closure, at multiple time steps, as described in Section 6.4.5.3 and Appendix PAR (Parameter 12; Tables PAR-2, 3, and 37). Appendix SEAL (Appendix D, Chapter 5) describes the basic properties and engineering design considerations of the DRZ. References 155, 368 and 646 describe field and laboratory permeability testing. Reference 356 describes seal system parameters used in BRAGFLO calculations. The effective permeability is used in BRAGFLO calculations to predict movement (or lack of movement) of brine up the shafts. Calculation of the composite permeability of the shaft sealing materials and DRZ, as a function of time, is mathematically complex but conceptually straightforward. EPA notes that the treatment of the DRZ in PA was questioned by EPA in it's March 19, 1997 letter. For example, EPA suggested that DOE reconsider how it included the DRZ in it's fluid injection analysis, and DOE addressed EPA's concern in a subsequent DOE fluid injection analysis report (Stoelzel and Swift, 1997).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 3.3.1 and 6.4.5, and Appendices SCR.2.3.1; SEAL, Sections 7.5 and 8, Appendices C and D; MASS, Section 13.4; PAR, Parameter 12, Tables PAR-2; PAR-3; PAR-37; Vaughn, P., Lord, M., Garner, J. and MacKinnon, R. 1995. *Radiolysis of Brine.* Errata to Summary Memo of Record GG-1, SWCF-A:1.1.6.3:PA:QA:TSK:GG1,S7, December 21, 1995. Sandia National Laboratories, Albuquerque, NM. WPO 30786, II-I-36b, Stoelzel, D.M., and P.N. Swift, 1997, Supplemental Analysis of the Effects of Salt Waterflooding on the WIPP, Sandia National Laboratories, WPO #44158, Rev. 1.0)

W19 Excavation-induced Changes in Stress (SCR.2.3.2, UP). The screening argument in SCR 2.3.2 appears valid to EPA. Extensive discussion of the assumptions on which the model (SANTOS) is based, the mathematical algorithms, the model itself, and the linkage between gas generation and room closure, are provided in Section 6.4.3.1

(Creep Closure), Appendix PORSURF Section PORSURF.3 (SANTOS Numerical Analyses), Appendix PORSURF Attachment 7 (SANTOS Code Documentation), and Appendix PORSURF Section PORSURF.2 and Attachment 1, respectively.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 3.3.1 and 6.4.3, and Appendices SCR.2.3.1; SEAL, Section 7; PAR, Table PAR-38; PORSURF, Attachment PORSURF-6)

W20-W21 Salt Creep, Changes in the Stress Field (SCR2.3.2, UP). The screening argument in SCR2.3.2 appears valid to EPA. Salt creep and changes in the stress field are accounted for in the SANTOS model by calculating the response of salt and anhydrite (in MB139 only) around the idealized disposal room to the unbalanced forces of gravity (lithostatic pressure) against the time-varying pressure of gas and wastes within the room. The model is supported by extensive salt testing. Appendix BRAGFLO (Section 4.11) explains how the flow model accounts for creep closure (resulting in rock porosity and permeability changes) against varying gas pressures by reference to the porosity surface look-up table.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3 and Appendices SCR.2.3.2; BRAGFLO, Section 4.11; PAR, Table PAR-38; PORSURF, Attachment PORSURF-6; Freeze,

W22 Roof Falls (SCR2.3.3, UP). The screening argument in SCR 2.3.3 appears valid to EPA. Roof falls may result in some damage to waste containers, and extension of the DRZ above the disposal rooms, but these events will have little or no effect on long term performance, assuming that the panel closures have been constructed. If a roof fall occurs in an "active" disposal room prior to installation of panel closures (unlikely, considering the extent of bolting and geomechanical monitoring), operations could be temporarily disrupted. Decontamination operations could conceivably be necessary in the downstream air pathway. However, such an event would not affect long-term performance of the repository.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.5 and Appendices SCR.2.3.3; and PAR, Table PAR-37.)

W23 Subsidence, (SCR 2.3.5, SO-C). The screening argument in SCR 2.3.5 appear valid to EPA. Subsidence was screened out on the basis of (minor) predicted consequences. Extensive research on subsidence in similar mines, and computer modeling by DOE, indicates that a maximum of two feet of subsidence should be expected at the surface above the repository (assuming no backfill). DOE concluded that this amount of subsidence would not produce permeable fractures in the Salado extending more than a few tens of meters above the repository.

Potential permeability increases in the more brittle Culebra member of the Rustler

Formation due to WIPP subsidence were analyzed by DOE via distributing the predicted actual subsidence over the repository area and calculating the resulting increases in average fracture openings. The increase in permeability in the Culebra was estimated to be a maximum of one order of magnitude. The Culebra permeability naturally varies by about four orders of magnitude in the vicinity of the WIPP; EPA concluded that the subsidence associated with the WIPP repository itself will likely be small, and resulting impact to the overlying Culebra will be minimal and could be "overshadowed" by the natural transmissivity variations in this unit.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.2.1 and Appendices SCR.2.3.4; TFIELD; Westinghouse Electric Corporation. 1994. *Backfill Engineering Analysis Report Waste Isolation Pilot Plant.* Westinghouse Electric Corporation, Carlsbad, NM. WPO 37909, 2-17 to 2-23, 3-4 to 3-23 Table 3-13, Fig 3-39, Fig 3-40, 4-1 to 4-2; Peake, T. 1996. *WIPP -- Examination of Mining and Hydraulic Conductivity.* Memo to Public Rulemaking Docket A-92-56. January 31, 1996.)

W24 <u>Large Scale Rock Fracturing (SCR 2.3.4, SO-P).</u> The screening argument in SCR 2.3.4 appears reasonable to EPA. Large scale rock fracturing between the repository and ground surface was screened out on the basis of low probability by DOE, and EPA concurs with this screening decision. The low extraction ratio in the repository (22%), the effects of filling the mined area with wastes and backfill, and the properties of salt (creep and healing) are predicted to limit the extent of fractures and subsidence. The DOE investigation of subsidence at existing potash mines in the region (which are all at least 490 feet above the repository strata) confirmed the absence of large scale fracturing, even though potash mines typically have extraction ratios about three times greater than the WIPP.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.3.4.)

W25-W27 <u>Disruption Due to Gas Effects, Pressurization, Gas Explosion (SCR.2.3.5, 2.3.6, UP).</u> The DOE's screening evaluation appears to be technically reasonable to EPA. The DOE included the effect of gas pressurization (primarily hydrogen gas generation via corrosion) in performance assessment modeling, including porosity surface determinations for SANTOs modeling as input to BRAGFLO. The DOE also has shown that carbon dioxide gas generation is mitigated through the addition of MgO backfill.

Disruption of the disposal system, as a whole, due to gas generation is accounted for in performance assessment through evaluation of gas pressurization effects on creep closure of the disposal panels and pressure sensitive marker bed permeability (the later of which has been questioned by the EPA; refer to **CARD 23--Models and**

Computer Codes, Docket No. A-93-02, V-B-2, Section 194.23 (a). In addition, the disposal system is impacted by gas generation through modeled pressure sensitive permeabilities of the anhydrite interbeds (undisturbed conditions).

The effects of gas explosions (i.e. methane, hydrogen, oxygen) are assumed to be similar to that of a roof fall, which is included in PA (FEP no. W22). However, DOE also noted that these explosions would occur under oxic conditions, and the WIPP will be anoxic for almost all of the 10,000 year regulatory period. The DOE also indicated that the most explosive mixture of these gases will be present in void space approximately 20 years after panel closure emplacement, but in order for explosions to occur an ignition source as well as sufficient oxygen must be in place. Although not well documented in the CCA, the DOE indicated in the WIPP Part B Permit application, through use of brattice cloth room closures, that anoxic conditions will actually develop in the rooms long before panel closure emplacement (on the order of a few months).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.5, and Appendices SCR.2.3.5; SCR.2.3.6; BRAGFLO, Sections 4.10 and 4.11; MASS, Section 13.3 and Attachment 13-2; PAR, Table PAR-36; PORSURF, Attachment PORSURF -6; PCS, Section 2.2.3; PAR, Table PAR-37; WIPP Part B Permit Application, Rev.6.0, 1996.)

W28 Nuclear Explosions (SCR 2.3.6, SO-P). The screening argument in SCR.2.3.6 is reasonable to EPA because there appears to be no mechanism that could concentrate a critical mass of fissile material, much less maintain it at the high compression required to initiate a nuclear explosion.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.3.6; Rechard, R.P., Stockman, C.T., Sanchez, L.C., Liscum-Powell, J., and Rath, J.S. 1996. Nuclear Criticality in Near Field and Far Field. Summary Memo of Record for RNT-1. SWCF-A:1.2.07.3:PA:QA:TSK:RNT-1. Sandia National Laboratories, Albuquerque, NM. WPO 40818.)

W29-W31 Thermal Effects on Material Properties, Thermally-Induced Stress Changes, Differing Thermal Expansion of Repository Components (SCR 2.3.7, SO-C). The screening argument in SCR.2.3.7 appears reasonable to EPA because all potential sources of heat and elevated temperature have been evaluated and found not to produce high enough temperature changes to affect the repository's performance. Sources of heat within the repository include radioactive decay and exothermic chemical reactions such as backfill hydration and metal corrosion. The rates of these exothermic reactions are limited by the availability of brine in the repository. Concrete hydration in the seals is a significant source of heat, but it is relatively short-lived. The sources of heat do not appear to be great enough to jeopardize the performance of the disposal system.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.3.7; SEAL, Section 7.4; the DOE(U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. The DOE/EIS-0026. Vol. 1-2. Washington, D.C. WPO 38835, 38838-38839; Sanchez, L.C., and Trellue, H.R. 1996. Estimation of Maximum RH-TRU Thermal Heat Load for WIPP. Memo to T. Hicks (Galson Sciences Ltd.), January 17, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31165; Loken, M.C. 1994. SMC Thermal Calculations, RSI Calculation No. A141-GE-05, prepared for Parsons Brinckerhoff, San Francisco, CA; Loken, M.C. and Chen, R. 1994. Rock Mechanics of SMC, RSI Calculation No. A141-GE-07, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC Inc., Rapid City, SD; Wakeley, L.D., Harrington, P.T., and Hansen, F.D. 1995. *Variability in Properties of Salado Mass Concrete.* SAND94-1495. Sandia National Laboratories, Albuquerque, NM. WPO 22744; Bennett, D.G., Wang, Y., and Hicks, T.W. 1996. An Evaluation of Heat Generation Processes for the WIPP. Memo of 20 August, 1996. SWCF-A (Org. 6352), WBS 1.1.09.1 (RC); Arguello, J.G., and Torres, T.M. 1988. *Thermal Effects of RH-TRU Waste Emplacement on WIPP Storage Room Thermal/Structural Response.* SAND88-2217. Sandia National Laboratories, Albuquerque, NM; Thorne, B.J., and Rudeen, D.K. 1981. *Regional Effects of TRU Repository Heat.* SAND80-7161. Sandia National Laboratories, Albuquerque, NM. WPO 10281.)

W32 Consolidation of Waste (SCR 2.3.8.1, UP). The screening argument in SCR.2.3.8.1 appears reasonable to EPA because waste consolidation is included in the modeling of creep closure of the repository. The resistance of the waste to the forces of creep closure has been incorporated in the porosity surface model for creep closure.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3 and Appendices SCR.2.3.8; WCA, Section 5.2; PAR, Table PAR-38; PORSURF, Attachment PORSURF-6; Vaughn, P., Lord, M., Garner, J., and MacKinnon, R. 1995. *Radiolysis of Brine.* Errata to Summary Memo of Record GG-1, SWCF-A:1.1.6.3:PA:QA:TSK:GG1, S7, December 21, 1995. Sandia National Laboratories, Albuquerque, NM. WPO 30786.)

W33 Movement of Containers (SCR 2.3.8.1, SO-C). The screening argument in SCR.2.3.8.1 appears reasonable to EPA because the waste containers are unlikely to move away from the repository horizon. Density differences are the driving force for such movements. However, after closure, the waste materials should approach a density of about 2,000 kg/m3. This differs from the density of the surrounding Salado formation by less than ten percent. This small difference in density is not enough to overcome the drag forces and cause vertical movement of waste through the Salado due to buoyancy.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.3.8; Dawson, P.R. and Tillerson, J.R. 1978.

Nuclear Waste Canister Thermally Induced Motion. SAND-78-0566. Sandia National Laboratories, Albuquerque, NM. WPO 27328, 22; Sandia WIPP Project. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992. Volume 3: Model Parameters.* SAND92-0700/3, Sandia National Laboratories, Albuquerque, NM. WPO 28529.)

W34 Container Integrity (SCR 2.3.8.1, SO-C). The screening argument in SCR.2.3.8.1 appears reasonable to EPA because waste dissolution and release calculations take no credit for waste containers. The containers should provide a benefit by slowing the dissolution and release processes, but these beneficial effects have not been included in the modeling.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.5.4, Appendix SCR.2.3.8.)

W35 Mechanical Effects of Backfill (SCR 2.3.8.1, SO-C). The screening argument in SCR.2.3.8.1 appears reasonable to EPA because the backfill to waste volume ratio is relatively small. Although the backfill will provide additional resistance to creep closure, most of the resistance will be provided by the waste. Therefore, inclusion of backfill does not significantly reduce the total subsidence in the waste rooms, and screening based on low consequence appears appropriate..

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.3.8; BACK, Section 3.2; Westinghouse Electric Corporation. 1994. *Backfill Engineering Analysis Report, Waste Isolation Pilot Plant.* Westinghouse Electric Corporation, Carlsbad, NM. WPO 37909)

W36-W37 Consolidation of Seals, Mechanical Degradation of Seals (SCR 2.3.8.2, UP). The screening argument in SCR.2.3.8.2 appears reasonable to EPA because these effects have been accounted for in the modeling by variations in the permeability of the seal system and the surrounding DRZ. Information to support the permeability choices is given in Appendix PAR. The consolidation capabilities of salt are sufficient if water inflow from either adjacent salts or overlying units is low. Refer to **CARD 14--Content of Compliance Application** [Docket No. A-93-02, V-B-2, Section 194.14 (b)] and FEP W7.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.4 and Appendices SCR.2.3.8; SEAL, Appendix D; PAR, Parameters 9 to 11 and 13, Tables PAR-16 to PAR-24)

W40 Brine Inflow (SCR 2.4.1, UP). The screening argument in SCR.2.4.1 appears reasonable to EPA because brine inflow is included in the assessments. Two-phase brine and gas flow has been modeled with the BRAGFLO code, which has been reviewed and commented upon. In general, the BRAGFLO implementation has been found adequate for modeling brine inflow. Refer to **CARD 23--Models and Computer Codes** [Docket No. A-93-02, V-B-2, Section 194.23 (b)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3, Appendices SCR.2.4.1; BRAGFLO, Section 4.8.)

W41 Wicking (SCR 2.4.1, UP). The screening argument in SCR.2.4.1 appears reasonable to EPA because capillary rise of liquid in the repository waste has been included in the assessment. The rise of liquid into the waste affects the corrosion and biodegradation reactions which produce gas.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3, Appendices SCR.2.4.1; MASS, Section 7; PAR, Parameter 8; BRAGFLO, Section 7.2.9; Vaughn, P., Lord, M., Garner, J. and MacKinnon, R. 1995. *Radiolysis of Brine.* Errata to Summary Memo of Record GG-1, SWCF-A:1.1.6.3:PA:QA:TSK:GG1, S7, December 21, 1995. Sandia National Laboratories, Albuquerque, NM. WPO 30786.)

W42 Fluid Flow Due to Gas Production (SCR 2.4.2, UP). The screening argument in SCR.2.4.2 appears reasonable to EPA because both fluid and gas flow are included in the assessments. Two-phase brine and gas flow has been modeled with the BRAGFLO code, which has been reviewed by EPA. In general, the BRAGFLO implementation has been found adequate for modeling the two-phase flow of fluid and gas. Refer to the **CARD 23--Models and Computer Codes [Docket No. A-93-02, V-B-2, Section 194.23 (b)], for discussion of BRAGFLO modeling**.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.4.2; MASS, Section 7; BRAGFLO, Section 4.8.)

W43 Convection (SCR 2.4.2, SO-C). The screening argument in SCR.2.4.3 appears reasonable to EPA because thermal convection will have minimal effects at the temperature gradients expected in the repository. Most of the processes that will generate heat in the repository will not cause thermal gradients in the repository because they will not be localized heat sources. One exception to this generality is the heat from concrete hydration in the seals, which could increase the temperature of the Salado by 38 degrees Celsius in the immediate vicinity of the seals. Smaller temperature gradients could exist in the DRZ around the disposal rooms. However, the DOE has calculated that a temperature increase of 25 degrees Celsius would induce a convective Darcy velocity of only 2×10^{-7} m/yr in the seals. This velocity is negligible compared to the velocities induced by gas generation and pressurization.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.4.3; the DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. The DOE/EIS-0026. Vol. 102. Washington, DC. WPO 38835, 38838-38839; Sanchez, L.C., and Trellue, H.R. 1996. Estimation of Maximum RH-TRU Thermal Heat Load for WIPP. Memo to T. Hick (Galson Sciences Ltd.), January 17, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31165; Loken, M.C. 1994. SMC Thermal Calculations, RSI Calculation No. A141-GE-05, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC, Inc., Rapid City, SD; Loken, M.C. and Chen, R. 1994. Rock Mechanics of SMC, RSI Calculation No. A141-GE-07, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC Inc., Rapid City, SD; Wakeley, L.D., Harrington, P.T., and Hansen, F.D., 1995. *Variability in Properties of Salado Mass Concrete.* SAND94-1495. Sandia National Laboratories, Albuquerque, NM. WPO 22744; Bennett, D.G., Read, D., Atkins, M., Glasser, F.P. 1992. A Thermodynamic Model for Blended Cements II: Cement Hydrate Phases; Thermodynamic Values and Modeling Studies. *Journal of Nuclear Materials,* Vol. 190, pp 315; Hicks, T.W. 1996. *Thermal Convection and Effects of Thermal Gradients. Summary Memo of Record for GG-4 and S-10.* Memo of 29 May, 1996. SWCF-A 1.2.07.3: PA:QA:TSK: S10,GG4. Sandia National Laboratories, Albuquerque, NM. WPO 31290; Batchelor, G.K. 1973. *An Introduction to Fluid Dynamics.* First paperback edition. Cambridge University Press, London, UK; Rechard, R.P., Stockman, C.T., Sanchez, L.C., Liscum-Powell, J., and Rath, J.S. 1996. Nuclear Criticality in Near Field and Far Field. Summary Memo of Record for RNT-1. SWCF-A:1.2.07.3:PA:QA:TSK:RNT-1. Sandia National Laboratories, Albuquerque, NM. WPO 40818.)

W44 Degradation of Organic Material (SCR 2.5.1.1, UP). The screening argument in SCR.2.5.1.1 appears reasonable to EPA because organic degradation is potentially important due to the amounts of cellulose, plastic, and rubber in the waste. The degradation of these materials by microbes and the resulting gases (mainly CO_2, but also N_2O, N_2, H_2S, and CH_4) have been accounted for in the PA.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; SOTERM, Section 2.2.2; WCA, Section 5.1; BRAGFLO, Section 4.13; MASS, Section 8 and Attachment 8-2; Wang, Y., and Brush, L.H. 1996. *Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment.* Memo to Martin S. Tierney, January 26, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31943.)

W45 Effects of Temperature on Microbial Gas Generation (SCR 2.5.1.1, UP). The screening argument in SCR.2.5.1.1.1 appears reasonable to EPA. Temperature effects are implicitly included in the assessments by the gas generation rates used in the calculations. Microbial gas generation increases with temperature from ambient up to about 40 or 50 degrees Celsius. Gas generation experiments by Francis and Gillow (1994) bracket the range of expected repository conditions and form the basis for the gas generation rates in the CCA.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; PAR, Parameters 3 to 5, Table PAR-43; Molecke, M.A. 1979. *Gas Generation from Transuranic Waste Degradation.* SAND79-0911C. Sandia National Laboratories, Albuquerque, NM. WPO 28093; Francis, A.J., and Gillow, J.B. 1994. *Effects of Microbial Gas Processes on Generation Under Expected Waste Isolation Pilot Plant Repository Conditions, Progress Report Through 1992.* SAND93-7036. Sandia National Laboratories, Albuquerque, NM. WPO 26555; Bennett, D.G., Read, D., Atkins, M., Glasser, F.P. 1992. A Thermodynamic Model for Blended Cements II: Cement Hydrate Phases; Thermodynamic Values and Model Studies. *Journal of Nuclear Materials,* Vol. 190, pp. 315.)

W46 <u>Effects of Pressure on Microbial Gas Generation (SCR 2.5.1.1.2, SO-C).</u> The screening argument in SCR.2.5.1.1.2 appears reasonable to EPA because studies of microbial activity in deep-sea environments show that microbial gas generation is less pressure dependent than inorganic gas generation reactions, such as corrosion. Therefore, the effects of pressure on microbial gas generation are considered to be negligible.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.1; Kato, C., Sato, T., Smorawinska, M. and Horikoshi, K. 1994. "High Pressure Conditions Stimulate Expression of Chloramphenicol Acetyltransferase Regulated by the *Iac* Promoter in *Escherichia coli*," *FEMS Microbiology Letters,* Vol. 122, nos. 1-2, 91-96.)

W47 <u>Effects of Radiation on Microbial Gas Generation (SCR 2.5.1.1, SO-C).</u> The screening argument in SCR.2.5.1.1.3 appears reasonable to EPA because studies presented in the CCA, which EPA reviewed have shown that alpha radiation, at the level expected in the WIPP repository. EPA concurs that this information reasonably supports DOE's argument that radiation has little effect on microbial gas generation.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.1; Barnhart, B.J., Cambell, E.W., Martinez, E., Caldwell, D.E., and Hallett, R. 1980. *Potential Microbial Impact on Transuranic Wastes Under Conditions Expected in the Waste Isolation Pilot plant (WIPP), Annual Report, October 1, 1978 - September 30, 1979.* LA-8297-PR. Los Alamos National Laboratory, Los Alamos, NM; Francis, A.J. 1985. *Low-Level Radioactive Wastes in Subsurface Soils, In Soil Reclamation Processes: Microbiological Analyses and Applications.* R.L. Tate, III, and D.A. Klein, eds. Marcel DeKker, Inc., New York, pp. 279 - 331.)

W48 <u>Effects of Biofilms on Microbial Gas Generation (SCR2.5.1.1.4, UP).</u> The screening argument in SCR.2.5.1.1.4 appears reasonable to EPA because biofilms could potentially form on surfaces in the repository rooms where nutrients are available. Biofilm effects are implicitly included in the assessment through the choice of microbial gas generation rates, which EPA concurs are appropriate (refer to **CARD 24-- Waste Characterization [Docket No. A-93-02, V-B-2, Section 194.24 (b)(1)], for additional discussion.** With respect to contaminant transport, biofilms may be beneficial by impeding the transport of radionuclides in the repository. This beneficial effect of biofilms has not been included in the assessments.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices PAR, Parameters 3 to 5, Table PAR-43; Stroes-Gascoyne, S., and West, J.M. 1994. *Microbial Issues Pertaining to the Canadian Concept for the Disposal of Nuclear Fuel Waste.* AECL Report No. AECL-10808, COG-93-54. Atomic Energy of Canada Ltd., Whiteshell Labs, Pinawa, Manitoba, Canada, pp. 9-10; Molecke, M.A. 1979. *Gas Generation from Transuranic Waste Degradation.* SAND79-0911C. Sandia National Laboratories, Albuquerque, NM. WPO 28093, pp 4, 7; Francis, A.J., and Gillow, J.B. 1994. *Effects of Microbial Gas Processes on Generation Under Expected Waste Isolation Pilot Plant Repository Conditions, Progress Report Through 1992.* SAND93-7036. Sandia National Laboratories, Albuquerque, NM. WPO 26555, pp 59.)

W49 Gases From Metal Corrosion (SCR 2.5.1.2, UP). The screening argument in SCR.2.5.1.2 appears reasonable to EPA because metal corrosion is very likely to occur in the repository and it has been included in the PA. Under repository conditions, anoxic metal corrosion and the production of hydrogen gas is very likely. In the CCA, the corrosion rate is linked with the availability of brine, which is consumed in the corrosion reaction.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; SOTERM, Section 2.2.3; WCA, Section 5.1; BRAGFLO, Section 4.13; MASS, Section 8 and Attachment 8-2.)

W50 Galvanic coupling (SCR 2.5.1.2.1, SO-P). The screening argument in SCR.2.5.1.2.1 appears reasonable to EPA because galvanic coupling is unlikely to occur on a large scale. On a very small scale, galvanic coupling could occur whenever two dissimilar metals are in contact and a conducting medium is present. However, the resulting corrosion would cause the same effects as the other corrosion processes already included in the assessments. Thus, galvanic coupling, as a distinct corrosion mechanism, would have negligible effects on the outcome of the assessments.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.1; GCR.)

W51 Chemical Effects of Corrosion (SCR 2.5.1.2.2, UP). The screening argument in

SCR.2.5.1.2.2 appears reasonable to EPA because corrosion affects the repository chemistry by lowering the oxidation state of the repository and helping maintain reducing conditions. Anoxic corrosion generates hydrogen gas and consumes brine. The corrosion effects are therefore linked to the pressurization of the repository and the brine flow calculations implemented in the BRAGFLO code.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; WCA, Section 4.1.1; PAR, Parameter 1, Table PAR-43; Molecke, M.A. 1979. *Gas Generation from Transuranic Waste Degradation.* SAND79-0911C. Sandia National Laboratories, Albuquerque, NM. WPO 28093; Telander, M.R., and Westerman, R.E. 1993. *Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot plant Environments: Progress Report for the Period November 1989 through 1992.* SAND92-7347. Sandia National Laboratories, Albuquerque, NM. WPO 23456.)

W52-W53 Radiolysis of Brine, Radiolysis of Cellulose (SCR 2.5.1.3, SO-C). The screening argument in SCR.2.5.1.3 appears reasonable to EPA because radiolysis of brine and cellulose is not likely to produce anywhere near the volume of gases that will be generated by corrosion or microbial action. Most brine is likely to be rapidly consumed by metal corrosion reactions, making it unavailable for radiolysis. For cellulose, microbial degradation produces orders of magnitude more gas than radiolysis. In addition, information presented in the CCA shows that if gas were generated by radiolysis, it would have little effect on the final CCDF for compliance with the containment requirement.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; MASS, Section 8; Reed, D.T., Okajima, S., Brush, L.H., and Molecke, M.A. 1993. *Radiolytically-Induced Gas Production in Plutonium-Spiked WIPP Brine.* Scientific Basis for Nuclear Waste Management XVI, Materials Research Society Symposium Proceedings, Boston, MA, November 30-December 4, 1992. C.G. Interrante and R.T. Pabalan, eds. SAND92-7283C. Materials Research Society, Pittsburgh, PA. Vol. 294, pp 432; Sandia WIPP Project. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992. Volume 3: Model Parameters.* SAND92--0700/3, Sandia National Laboratories, Albuquerque, NM. WPO 31165; Vaughn, p., Lord, M., Garner, J. and MacKinnon, R. 1995. *Radiolysis of Brine.* Errata to Summary Memo of Record GG-1, SWCF-A:1.1.6.3:PA:QA:TSK:GG1, S7, December 21, 1995. Sandia National Laboratories, Albuquerque, NM. WPO 30786.)

W54 Helium Gas Production (SCR 2.5.1.3.3, SO-C). The screening argument in SCR.2.5.1.3.3 appears reasonable to EPA. EPA performed a simple calculation regarding gas helium gas generation from alpha decay which shows that the rate of helium production from alpha decay is only about three liters per year. This assumes a temperature of 30 degrees Celsius and a pressure of 14.8 megapascals. This volume of gas is very small compared to the volumes generated by microbial action and metal corrosion; therefore, DOE's screening of this gas source based on consequence is appropriate.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.1; BIR; Molecke, M.A. 1979. *Gas Generation from Transuranic Waste Degradation.* SAND79-0911C. Sandia National Laboratories, Albuquerque, NM. WPO 28093; Wang, Y. and Brush, L.H. 1996. *Estimates of Gas-Generation Parameters for the Long-Term WIPP Performance Assessment.* Memo to Martin S. Tierney, January 26, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31943.)

W55 <u>Radioactive Gases (SCR 2.5.1.3.4, SO-C).</u> The screening argument in SCR.2.5.1.3.4 appears reasonable to EPA because radioactive gases will be generated only in small amounts. For radon gas, the volume generated must be less than the volume of helium gas calculated in SCR.2.5.1.3.3, since only a fraction of the decays that generate helium also generate radon. In addition, radon gas will decay quickly because of its short half-life. The only other potential gaseous radioisotope is C-14. It is not a concern because the total inventory of C-14 in the WIPP is only about 13 curies. This is insignificant compared to the C-14 release limit, which is over 500 curies.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.1; BIR; Bennett, D.G. 1996. *Formation and Transport of Radioactive Gases. Summary Memo of Record for GG-8 and RnT-26.* Memo of 16 May 1996. SWCF-A 1.2.07.3:PA:QA:TSK:GG-8, RNT-26, Sandia National Laboratories, Albuquerque, NM 39406.)

W56 <u>Speciation (SCR 2.5.2, UP).</u> The screening argument in SCR.2.5.2 appears reasonable to EPA because chemical speciation is very likely to occur in the repository. Speciation is included through the assumption of different oxidation states for the various radioactive elements in the waste. Uncertainties in the distribution of chemical species are accounted for by assuming a range of oxidation states for each radioactive element in the analysis.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.6; Appendices SCR.2.5.2; SOTERM, Sections 3 and 4; PAR, Parameters 36 to 47, 52 to 57, Table PAR-39; Bennett, D.G., Read, D., Atkins, M., Glasser, F.P. 1992. A Thermodynamic Model for Blended Cements II: Cement Hydrate Phases; Thermodynamic Values and Modeling Studies. *Journal of Nuclear Materials,* Vol. 190, pp 315 - 325.)

W57 <u>Kinetics of speciation (SCR 2.5.2, SO-C).</u> The screening argument in SCR.2.5.2 appears reasonable to EPA . Initially, EPA thought this determination was questionable because kinetics of chemical speciation could potentially effect on repository conditions. For example, the DOE's screening argument assumes rapid chemical equilibrium, which may not always be the case. Specifically, the reaction of CO_2 and MgO may not proceed to rapid completion because of limited MgO availability. In contrast to the assumption of rapid chemical equilibrium in this screening argument, other FEPs screening arguments in Appendix SCR rely on non-equilibrium, such as the oxidation/reduction conditions, which appeared contradictory. However, DOE has since provided information (Bynum, 1997) regarding experimental reaction rates for MgO and MgO availability, which indicates that MgO will be available in adequate amounts for reaction. The EPA has re-examined this screening argument in light of this evidence and in conjunction with assumptions made regarding PA, and now concludes that this screening argument assumption is conservative and reasonably represent conditions in the repository sufficiently for PA purposes.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.2; Lasaga, A.C., Soler, J.M., Ganor, J., Burch, T.E., and Nagy, K.L. 1994. Chemical Weathering Rate Laws and Global Geochemical Cycles. *Geochemical et Cosmochimica Acta,* Vol. 58, No. 1, pp. 2361, Bynum, R.V., 1996, Memorandum to Martin Tierney and Christine Stockman, RE: Revised Update of Uncertainty Range and Distribution for Actinide Solubility to be used in CCA NUTS Calculations, May 23, 1996, WPO #37794.)

W58 Dissolution of Waste (SCR 2.5.3, UP). The screening argument in SCR.2.5.3 appears reasonable to EPA because waste dissolution is likely to occur in the repository. The modeling assumes that dissolution is instantaneous, which is a conservative assumption. Likewise, no credit is taken for waste containers to impede dissolution. Dissolution is implemented in the NUTS computer code and is described in Appendix SOTERM. EPA questioned the actinide solubility values calculated by the DOE, which were reevaluated in the subsequent EPA-mandated performance assessment. Refer to **CARD 24--Waste Characterization for discussion of nuclide solubility** [Docket No. A-93-02, V-B-2, Section 194.24 (b)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices PAR, Parameters 36 to 47, Table PAR-39.)

W59 Precipitation (Chemical) (SCR 2.5.3, SO-C). The screening argument in SCR.2.5.3 appears reasonable to EPA. Initially, EPA felt DOE's argument appeared questionable because chemical precipitation may alter the groundwater flow field in the repository. Although this is acknowledged in SCR.2.5.3, precipitation is assumed to be uniform and beneficial by slowing the groundwater flow. This is consistent with how permeability and porosity are modeled in the repository. The discussion does not consider that mineral precipitation may restrict only part of the porous medium and lead to channeling of the flow, but EPA recognizes that this would be extremely difficult to predict and model assuming random waste loading (which is appropriate) and necessary assumptions regarding was porosity and permeability, and probably would not change modeling results when considered on a repository scale. While channeling could enhance the flow in certain regions and reduce the radionuclide travel times in others, the EPA concluded that precipitation could also lead to reductions in nuclide concentrations via the formation of radionuclide precipitates. Therefore, EPA re-examined DOE's argument considering all aspects of the argument and the broader effects on PA, and concluded that the DOE′s screening of this FEP is appropriate.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.3; Bruno, J., and Sandino, A. 1987. *Radionuclide Co-precipitation.* SKB Technical Report, No. 87-23, pp 12. Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden.)

W60 Kinetics of Precipitation and Dissolution (SCR 2.5.3, SO-C). The screening argument in SCR.2.5.3 appears reasonable to EPA. Initially, EPA thought the argument appeared questionable because the CCA assumed that precipitation reactions are always rapid and complete. As a result, the EPA questioned the gas pressures in the repository, the chemical conditions, and the actinide solubilities. The DOE has since submitted experimental results indicating that the predicted reactions occur and time frames are somewhat rapid (e.g. Bynum, 1997). The EPA reconsidered this assessment and concluded that the precipitation assumptions are necessary (and conservative), and are supported by experimental data.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.3; Berner, R.A. 1981. Kinetics of Weathering and Diagenesis. In *Kinetics of Geochemical Processes.* A.C. Lasaga, and R.J. Kirkpatrick, eds. Reviews in Mineralogy, Mineralogical Society of America, Washington, D.C. Vol. 8, pp. 117, Bynum, R.V., 1996, Memorandum to Martin Tierney and Christine Stockman, RE: Revised Update of Uncertainty Range and Distribution for Actinide Solubility to be used in CCA NUTS Calculations, May 23, 1996, WPO #37794.)

W61 Actinide Sorption (SCR 2.5.4, UP). The screening argument in SCR.2.5.4 appears reasonable to EPA. Actinide sorption has been included in the modeling of the geologic units above the Salado. Sorption in the repository and the shafts and seals has not been included, but its effects would be beneficial by retarding the movement of radionuclides. Issues pertaining to Culebra K_ds, including questions pertaining to K_d distribution as modeled, are included in **CARD 23--Models and Computer Codes [Docket No. A-93-02, V-B-2, Section 194.23 (b) and EPA's Technical Support Document for Section 194.14: Assessment of K_ds used in the CCA (Docket No. A-93-02, V-B-4).**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.6; Appendices SCR.2.5.4, Chapter 3; SEAL, MASS, Section 15.2 and Attachment 15-1; SECOTPWD, Section 2; Serne, R.J. 1992. "Current Adsorption Models and Open Issues Pertaining to Performance Assessment." In *Proceedings of the DOE/Yucca Mountain Site Characterization Project Radionuclide Adsorption Workshop at Los Alamos National Laboratory, September 11-12, 1990.* Comp. J.A. Canepa. LA-12325-C. Los Alamos National Laboratory, Los Alamos, NM. pp. 238-239; Wallace, M., Beauheim, R., Stockman, C., Alena Martell, M., Brinster, K., Wilmot, R., and Corbert, T. 1995. Dewey Lake Data Collection and Compilation. Summary Memo of Record for NS-1. SWCF-A 1.1.6.3:PA:QA:TSK:NS-1. Sandia National Laboratories, Albuquerque, NM., USEPA, 1997 (Technical Support Document for Section 194.14: Assessment of Kds used in the CCA, Docket No. V-B-4)

W62 Kinetics of Sorption (SCR 2.5.4, UP). The screening argument in SCR.2.5.4 appears reasonable to EPA because a linear sorption isotherm is used to calculate retardation factors. This is the most common and widely used method of calculating sorption effects. Sorption in the repository, shafts, and seals, however, is not included, but its effects would be beneficial to the performance of the disposal system. **Refer to EPA's Technical Support Document for Section 194.14: Assessment of Kds used in the CCA for additional justification of the linear isotherm** (Docket No. A-93-02, V-B-4)**.**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.4; MASS, Section 15.2, Attachment 15-1; PAR, Parameters 47 and 52 to 57, Table PAR-39; Davis, J.A. and Kent, D.B. 1990. Surface Complexation Modeling in Aqueous Geochemistry. *Mineral-Water Interface Geochemistry,* M.F. Hochella and A.F. White, eds. Reviews in Mineralogy, Mineralogical Society of America, Washington, DC, Vol. 23, pp.202., USEPA, 1997, Technical Support Document for Section 194.14: Assessment of Kds used in the CCA, Docket No. V-B-4)

W63 Changes in Sorptive Surfaces (SCR 2.5.4, UP). The screening argument in SCR.2.5.4 appears reasonable to EPA because changes in sorptive surfaces are accounted for in the modeling. The effect is implemented implicitly in the ranges of K_ds used in the Culebra transport model. The range of K_ds encompasses the potential effects of reaction kinetics and adsorption **processes. Refer to EPA's Technical Support Document for Section 194.14: Assessment of Kds used in the CCA (Docket No. A-93-02, V-B-4) for additional information.**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.4; MASS, Section 15.2, Attachment 15-1; PAR, Parameters 47 and 52 to 57, Table PAR-39, USEPA, 1997, Technical Support Document for Section 194.14: Assessment of Kds used in the CCA, Docket No. V-B-

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W64 Effect of Metal Corrosion (SCR 2.5.5.2 UP). The screening argument in SCR.2.5.5.2 appears reasonable to EPA. The main effects of metal corrosion are to generate gas, consume brine, and help maintain reducing conditions in the repository. Metal corrosion effects are implemented in the BRAGFLO code for brine and gas flow and have a major effect on the repository chemistry and actinide source term models.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SOTERM, Sections 2.2.3 and 4; WCA, Section 4.1.1; PAR, Parameters 36 to 47, Table PAR-39)

W65 Reduction-Oxidation Fronts (SCR 2.5.5.3, SO-P). The DOE's screening argument appears reasonable to EPA because reduction-oxidation fronts are not likely to occur over a large scale in the repository. Chemical conditions should be fairly uniform throughout the repository if wastes and repository conditions among the various rooms are similar. Given the relative uniformity of expected conditions in the various repository rooms, the formation and persistence of large-scale reduction-oxidation fronts are very unlikely.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.5; Waber, N. 1991. *Mineralogy, Petrology and Geochemistry of the Pocos de Calda Analogue Study Sites, Mina Gerais, Brazil, I. Osamu Utsumi Uranium Mine.* Nagra Report NTB-90-20. National Genossen Schaft fur die Lagerung Radioaktiver Abfalle (NAORA), Baden, Switzerland; Snelling, A.A. 1992; Snelling, A.A. 1992. *Alligator Rivers Analogue Project Final Report, Volume 2, Geologic Setting.* UK DOE Report DOE/HMIP/RR/92/072, SKI Report SKI TR 92:20-2, ISBN 0-647-59928-9. Her Majesty's Inspectorate of Pollution of the Department of the Environment, London; Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden.)

W66 Reduction-Oxidation Kinetics (SCR 2.5.5.1, UP). The screening argument in SCR 2.5.5.1 appears reasonable to EPA. Reduction-oxidation conditions are uncertain in the repository environment and conditions may vary over small distances (the size of a waste drum). In order to account for both the variability of conditions and the uncertainty in those conditions, a range of oxidation states was used to represent each of the important radionuclides. The range and distribution of the assumed oxidation states expresses the effects of reduction-oxidation kinetics.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.5; SOTERM, Sections 2.2.3 and 4; PAR, Parameters 36 to 47, Table PAR-39; Wolery, T.J. 1992. *EQ3NR, A Computer Program for Geochemical Aqueous Speciation-Solubility Calculations: Theoretical Manual, Users' Guide, and Related Documentation*

(Version 7.0). Lawrence Livermore National Report No. UCRL-MA-110662 PT III, pp. 27.)

W67 Localized Reducing Zones (SCR 2.5.5.3, SO-C). The screening argument in SCR.2.5.5.3 appears reasonable to EPA because any localized reducing zones within the repository should have minimal effects relative to the PA results. Each such reducing zone would be bounded by a reduction-oxidation front and would not be capable of influencing radionuclide dissolution or transport over a long distance. The repository average conditions are more important for dissolution and transport considerations. Localized reducing zones, while potential present, should have minimal impact on overall repository performance.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.5.5.)

W68 Organic Complexation, (SCR 2.5.6, SO-C). The screening argument in SCR 2.5.6 appears reasonable to EPA. Of the approximately 60 organic ligands and complexing agents identified in TRU waste, the DOE indicates only about ten will increase radionuclide solubility (SOTERM.5). A more important factor regarding the potential for organic ligand-nuclide complexation is the abundance of nonradioactive metals in the repository. The quantities of metals, like iron, will overwhelm the absorption sites provided by the ligands and organic complexing agents, so the net effect on actinides should be small. Questions were raised regarding the validity of SOTERM arguments, given that they pertain only to EDTA and results acquired in a non-hypersaline environment. The DOE has since submitted supplemental information (refer to minutes of July 30, 1997 Kd meeting, WPO # 47414). Refer to **Section 194.24(b)(3) of CARD 24 for additional information regarding organic ligand screening.**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SOTERM, Section 5; WCA, Sections 4.1.3; Tipping, E. 1993. Modeling the Competition Between Alkaline Earth Cations and Trace Metal Species for Binding by Humic Substances. *Environmental Science & Technology* Vol. 27, pp. 520; DOE, 1997, WIPP DOE/EEG Meeting on Chemical Retardation, July 30, 1997, WPO # 47414.

W69 Organic Ligands (SCR 2.5.6, SO-C). In the initial CCA submittal, the DOE did not provide comprehensive information pertaining to organic ligand concentrations in the entire waste inventory and how this was used to assess the effects of organic complexation. Additional information was needed regarding the complexation capability of competing metals and quantity of organic ligands. The DOE has since submitted supplemental information in it’s July 31 Kd meeting regarding the important of organic ligands, and included how assumptions regarding organic ligand quantities present in waste were used to assess the impact of organic ligan-nuclide complexation. DOE concluded, and EPA concurs, that these data indicate that the assumed inventory for complexation calculations was conservative relative to that reported by a major generator site. Further, EPA also evaluated availability of alternative complexation metals (Coles, 1997), and concluded that sufficient competing metals would be present.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.6; SOTERM, Section 5; WCA, Sections 4.1.3, 8.11 and 8.12; BIR.)

W70 Humic and Fulvic Acids (SCR 2.5.6 UP). The screening argument in SCR.2.5.6 appears reasonable. Humic and fulvic acids are derived from soil wastes. Their effects are included in the assumed mobilities of the actinides and in their transport by humic colloids. Refer to **CARD 24--Waste Characteristics, for EPA's evaluation of these waste components** [Docket No. A-93-02, V-B-2, Section 194.24 (b)(1)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3 and 6.4.6; Appendices SCR.2.5.6; SOTERM, Section 6.3.3; PAR, Parameter 46, Table PAR 39; Tipping, E. 1993. Modeling the Competition Between Alkaline Earth Cations and Trace Metal Species for Binding by Humic Substances. *Environmental Science & Technology* Vol. 27, pp. 520.)

W71 Kinetics of Organic Complexation (SCR 2.5.6 SO-C). The screening argument in SCR.2.5.6 appears reasonable because the little data that exist on the kinetics of organic complexation indicate that it is influenced by pH, ionic strength, and reaction time. The inclusion of humic and fulvic acids in the assessments provides a conceptual model for treating enhanced mobility of organic complexes. The abundance of nonradioactive metals in the repository should provide enough metal ions to overwhelm the absorption sites provided by the ligands and organic complexes. Given this information on complexation, its exclusion from the modeling is appropriate.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.6; Rate, A.W., McLaren, R.G., and Swift, R.S. 1993. Response of Copper(II)-Humic Acid Dissociation Kinetics to Factors Influencing Complex Stability and Macromolecular Conformation. *Environmental Science Technology,* Vol. 27, pp.1408 - 1414.

W72-W73 Exothermic Reactions ,Concrete Hydration (SCR 2.5.7, SO-C). The screening argument in SCR.2.5.7 appears reasonable to EPA. The heat generated by exothermic reactions (corrosion, biodegradation, backfill hydration) and concrete hydration in the seals will not cause significant long-term effects on the repository performance.

Concrete hydration generates the highest temperatures and occurs in the shaft seals. The temperature of the surrounding salt could be raised to 38 degrees Celsius for a short period of time, perhaps a few years or a few decades. The thermal stresses from these temperatures and the temperatures in the concrete itself have been calculated to be below the design compressive strength for the concrete. Thus, thermal stresses should not degrade the long-term performance of the seals. Thermal loading in the repository from exothermic reactions is much lower than the heat produced from the concrete seal hydration and should also have minimal effects.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.3; Appendices SCR.2.5.7; WCA, Section 5.3.1; SEAL, Section 7.4.1; Bennett, D.G., Wang, Y., and Hicks, T.W. 1996. An Evaluation of Heat Generation Processes for the WIPP. Memo of 20 August, 1996. SWCF-A (Org. 6352), WBS 1.1.09.1(RC); Wakeley, L.D., Harrington, P.T., and Hansen, F.D., 1995. *Variability in Properties of Salado Mass Concrete.* DSNF94-1495. Sandia National Laboratories, Albuquerque, NM. WPO 22744; Loken, M.C. 1994. SMC Thermal Calculations, RSI Calculation No. A141-GE-05, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC Inc., Rapid City, SD; Loken, M.C. and Chen, R. 1994. Rock Mechanics of SMC, RSI Calculation No. A141-GE-07, prepared for Parsons Brinckerhoff, San Francisco, CA. RE/SPEC Inc., Rapid City, SD.)

W74 <u>Chemical Degradation of Seals (SCR 2.5.8, UP).</u> The screening argument in SCR.2.5.8 appears reasonable to EPA because the seals may be affected by brine infiltration. Degradation of the panel seals is accounted for in the model by giving the panel seals the same permeability as the surrounding DRZ.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.4; Appendices SCR.2.5.8; SEAL, Appendix A; PAR, Parameter 10, Table PAR-19.)

W75 <u>Chemical Degradation of Backfill (SCR 2.5.8, SO-C).</u> The screening argument in SCR.2.5.8 appears reasonable to EPA. The chemical degradation of the backfill is a direct result of its functioning properly. As it degrades chemically, its physical properties also change. The most obvious change in the backfill is its increase in volume as it changes from magnesium oxide to magnesium carbonate. The DOE has provided a paper by Bynum et. al., (March 1997) which summarizes the experimental results pertaining to chemical degradation of backfill acquired to date. Although, detailed test plans, etc., are not included, the experimental data presented show that MgO will essentially behave as modeled and generally predicted.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.8; BACK, Section 3.2.)

W76 <u>Microbial Growth on Concrete (SCR 2.5.8, UP).</u> The screening argument in

SCR.2.5.8 appears reasonable to EPA because there is a possibility that microbes could grow in the concrete seals. However, EPA believes their effects would be limited by the availability of oxygen and nitrogen in the brines. Although the microbial effects on concrete will probably be small, the effects are included implicitly in the range of permeabilities for the concrete components.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.8; PAR, Parameter 10, Table PAR-19; Pedersen, K., and Karlsson, F. 1995.*Investigations of Subterranean Microorganisms: Their Importance for Performance Assessment of Radioactive Waste Disposal.* SKB Technical Report 95-10, Swedish Nuclear Fuel and Waste Management Co., Stockholm, Sweden, pp.75.)

W77 Solute Transport (SCR 2.6, UP). The screening argument in SCR.2.6 appears reasonable to EPA because transport of soluble radionuclides will be the predominant transport mechanism. It is widely established and commonly used as the prime mechanism for radionuclide transport. Questions were raised by EPA regarding actinide solubilities [refer to **CARD 24--Waste Characterization for additional discussion of solubility issues and resolution** (Docket No. A-93-02, V-B-2, Section 194.24 (b)(1)], prompting the EPA to calculate alternative solubilities for use in the EPA-Mandated Performance Assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.5 and 6.4.6; Appendices SCR.2.6.1; MASS, Sections 13.5 and 15.2; NUTS, Section 4.3; SECOTP2D, Section 2.)

W78-W81 Colloid Transport, Colloid Formation and Stability, Colloid Filtration, Colloid Sorption (SCR 2.6.2, UP). The screening argument in SCR.2.6.2 appears to be technically reasonable to EPA because the formation and transport of colloids is considered in PA modeling. DOE considered the formation of microbial, mineral, humic, and actinide intrinsic colloids in it's evaluations; DOE's results are summarized in Appendix SOTERM. EPA concluded that DOE's treatment of the individual colloids is sufficient for PA; refer to **CARD 24--Waste Characterization for EPA's evaluation of colloid treatment in PA** [Docket No. A-93-02, V-B-2, Section 194.24 (b)(1)]. Colloid sorption in the Culebra is also considered. Refer to **CARD 23--Models and Computer Codes** [Docket No. A-93-02, V-B-2, Section 194.23 (b)] for commentary on Culebra K_ds.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.6; Appendices SCR.2.6.2; MASS, Section 15.3 and Attachments 15-2, 15-8 and 15-9; SECOTP2D, Section 2; SOTRM, Section 6; BACK, Section 3.4; WCA, Section 4.2; PAR, Parameter 46, Table PAR-39 and Parameters 52- 57; Papenguth, H.W., and Behl, Y.K. 1996. Test Plan for Evaluation of Colloid-Facilitated Actinide Transport at the WIPP. TP 96-01, Sandia National

Laboratories, Albuquerque, NM. WPO 31337.)

W82-W83 Suspensions of Particles, Rinse (SCR 2.6.3, DP, SO-C). The screening argument in SCR.2.6.3 appears reasonable to EPA. Suspension of particles larger than colloids are generally unstable and could not persist for very long. The rinse process likely cannot occur under undisturbed conditions because brine flow would not be rapid enough to create a suspension of particles and transport them to the accessible environment. The only reasonable conditions where suspensions could be formed is during a drilling event where particles of waste are carried to the surface suspended in the drilling fluid. This effect is covered in the modeling of cavings releases.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.7; Appendices SCR.2.6.3; CUTTINGS, Appendix A.2.)

W84 Cuttings, Cavings, Spallings (SCR 2.6.3, DP). The screening argument in SCR.2.6.3 appears reasonable because cuttings, cavings and spallings are all likely consequences of a drilling intrusion event. They are included in the assessments and implemented mainly in the CUTTINGS computer code. Questions were raised initially on the spallings modeling. The DOE has since conducted a spallings verification analysis, which confirmed that PA results were reasonable. The EPA also conducted its own analysis, and reached similar conclusions. Refer to **CARD 23--Models and Computer Codes [Docket No. A-93-02, V-B-2, Section 194.23 (a) and (b)]**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.7; Appendices SCR.2.6.3; CUTTINGS, Appendix A.2.,

W87 Microbial Transport (UP). The screening argument in SCR.2.6.4 appears reasonable because microbes may possibly affect the transport of radionuclides. Radionuclides bound to microbes may be transported at different rates than other radionuclides. The mobility of microbial radionuclides in the Culebra is modeled in the same way as radionuclides on mineral fragments, as both are assumed to be filtered by the small pore sizes in the Culebra dolomite. Refer to W78-W81 for additional discussion of colloids.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.6; Appendices SCR.2.6.4; SOTERM, Section 6.3.4; MASS, Section 15.3 and Attachment 15-9.)

W88 Biofilms (SCR 2.6.4. SO-C). The screening argument in SCR 2.6.4 appears reasonable to EPA. Biofilms would have a beneficial effect on radionuclide containment as they would tend to retain nuclides and retard the migration of radioactivity.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP,

October 1996, Appendices SCR.2.6.4; Francis, A.J., and Gillow, J.B. 1994. *Effects of Microbial Gas Processes on Generation Under Expected Waste Isolation Pilot Plant Repository Conditions, Progress Report through 1992.* SAND93-7036. Sandia National Laboratories, Albuquerque, NM. WPO 26555.)

W89 Transport of Radioactive Gases (SCR 2.6.5 SO-C). The argument presented in SCR.2.6.5 appears reasonable to EPA because the potential inventory of radioactive gases is small. Radon gas could not escape from the repository in significant quantities because of its short half-life and because its inventory would be very small. The other potential gaseous radionuclide, carbon-14, while long-lived, has a total inventory in the WIPP of about 13 curies, compared to its release limit of over 500 curies. Thus, any potential carbon-14 releases would be far below the EPA release limit.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.5.1; SCR 2.6.5; Bennett, D.G. 1996. *Formation and Transport of Radioactive Gases. Summary Memo of Record for GG-8 and RNT-26.* Memo of 16 May 1996. SWCF-A 1.2.07.3:PA:QA:TSK:GG-8, RNT-26, Sandia National Laboratories, Albuquerque, NM 38406.)

W90-W92 Advection, Diffusion, Matrix Diffusion (SCR 2.7.1, 2.7.2, UP). The screening arguments in SCR.2.7.1 and SCR.2.7.2 appear reasonable to EPA because advection, diffusion, and matrix diffusion are standard processes that are typically considered in radionuclide transport calculations, including those for the undisturbed system performance. All three of these transport phenomena are included in the calculations for the Culebra, as implemented in the SECOTP2D code. In the repository, the NUTS code considers only advection.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.5 and 6.4.6; Appendices SCR.2.7.1; SCR.2.7.2; NUTS, Sections 4.3.1, 4.3.2 and 4.3.3; SECOTP2D, Sections 2, 3.5 and 3.6; MASS, Attachment 15-3 and 15-6.)

W93 Soret Effect (SCR 2.7.3, SO-C). The screening argument in SCR.2.7.3 appears reasonable to EPA because the Soret effect (temperature-driven diffusion) is generally an insignificant contributor to radionuclide transport. Soret diffusion is negligible compared to the other radionuclide transport processes. The maximum temperature gradient at the WIPP occurs near the shaft seals shortly after placement of the concrete. No enhanced radionuclide transport is anticipated from the heat of hydration because the concrete has its lowest (intact) permeability at this time.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.7.3; Bennett, D.G., Wang, Y., and Hicks, T.W. 1996. An Evaluation of Heat Generation Processes for the WIPP. Memo of 20

August, 1996. SWCF-A (Org. 6352), WBS 1.1.09.1(RC); the DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. The DOE/EIS-0026. Vol. 1-2. Washington, DC./ WPO 38835, 38838-38839; Sanchez , L.C., and Trellue, H.R. 1996. Estimation of Maximum RH-TRU Thermal Heat Load for WIPP. Memo to T. Hicks (Galson Sciences Ltd.), January 17, 1996. Sandia National Laboratories, Albuquerque, NM. WPO 31165; Wakeley, L.D., Harrington, P.T., and Hansen, F.D., 1995. *Variability in Properties of Salado Mass Concrete.* SAND94-1495. Sandia National Laboratories, Albuquerque, NM. WPO 22744.)

W94-W96 Electrochemical Effects , Galvanic Coupling , Electrophoresis (SCR 2.7.4, SO-C, SO-P, SO-C). The screening argument in SCR.2.7.4 appears reasonable to EPA because electrochemical potentials in the repository are generally small and galvanic coupling can occur only over very short ranges (possibly the size of a waste drum). Given these conditions, radionuclide transport by electrophoresis, which requires an electric current, could not occur over long distances, if at all. Thus, since electrochemical and galvanic effects can occur only over a very limited range, any radionuclide transport associated with them is similarly limited to very short distances.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.2.7.4; GCR.)

W97 Chemical Gradients (SCR 2.7.5.2, SO-C). The screening argument in SCR.2.7.5.2 appears reasonable to EPA because although chemical gradients will exist in the repository, the Salado, and the Culebra, their effects should be over only a short range. Any chemical fronts or gradients are likely to be confined to small regions around or within waste packages or at boundaries between different geologic media. Due to the limited spatial extent of chemical gradients, their effect on radionuclide transport should be small.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.7.5.)

W98 Osmotic Processes (SCR 2.7.5.2, SO-C). The screening argument in SCR.2.7.5.2 appears reasonable to EPA because osmotic processes should only occur at interfaces between waters of different salinities. Osmotic processes may tend to concentrate radionuclides along these interfaces. The net effect of osmotic processes would be to further retard the migration of radionuclides. It is not included in the modeling because waters are of comparable salinities and osmotic effects are considered beneficial in limiting radionuclide migration.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.7.5.)

W99 Alpha Recoil (SCR 2.7.5.1, SO-C). The screening argument in SCR.2.7.5.1 appears reasonable to EPA because alpha recoil will probably have only a minor effect in preferentially leaching U-234. The effect of alpha recoil in natural uranium-bearing groundwater systems is often not measurable due to the heterogeneous distribution of radioactivity. Thus, its effect is not likely to be significant at the WIPP.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.7.5.)

W100 Enhanced Diffusion (SCR 2.7.5.2, SO-C). The screening argument in SCR.2.7.5.2 appears reasonable to EPA because enhanced diffusion could only occur where there are higher than average chemical gradients. As stated above, the spatial extent of chemical gradients should be quite limited and as enhanced diffusion occurs, it will tend to reduce the chemical gradient. Thus, the driving force for the enhanced diffusion will be reduced and eventually eliminated as the system approaches steady state or equilibrium conditions. Due to the limited spatial extent of enhanced diffusion, its effect on radionuclide transport should be small.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.2.7.5.)

W101-W103 Plant Uptake, Animal Uptake, Accumulation in Soils (SCR 2.8.1, SO-R). The screening argument presented in SCR 2.8.1. appears reasonable to EPA. DOE stated on page SCR-90 that FEPs that relate to plant uptake, animal uptake and accumulation in soils have been eliminated from the compliance assessment calculations on the basis of low consequence. DOE indicated that the screening of these FEPs is justified based upon the results of performance assessment calculations presented in Section 6.5 which show that releases to the accessible environment under undisturbed conditions are restricted to lateral migration through anhydrite beds within the Salado Formation. Refer also to FEP Comment Nos. W104-W108. The DOE stated that accumulation in soils that may occur within the controlled area would reduce releases to the accessible environment and can therefore, be eliminated from the performance assessment calculations on the basis of beneficial consequence.

The DOE has stated that plant uptake and animal uptake in the accessible environment have been eliminated from the performance assessment calculations on the basis of regulatory grounds. This is supported by the criteria outlined in 40 CFR §191.13. As such, the DOE′s screening evaluation for these FEPs appears to be technically valid.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.5.3, Figure 6.41; Appendix SCR.2.81.)

W104-W108 Ingestion, Inhalation, Irradiation, Dermal Sorption, Injection (SCR 2.8.2, SO-R).

The screening argument presented in SCR 2.8.2 appears reasonable to EPA. DOE has stated that human uptakes via ingestion, inhalation, external irradiation, dermal sorption, and injection have been eliminated from the compliance assessment calculations on the basis of low consequence. In support of eliminating these exposure pathways, the DOE has stated in Section 8.1.1. that the results of the performance assessment calculations indicate that releases to the accessible environment under undisturbed conditions are restricted to lateral migration through anhydrite beds within the Salado Formation. The DOE further states that based upon the bounding approach taken for evaluating compliance with EPA′s individual protection requirements in 40 CFR §191.15 and the groundwater protection requirements in Subpart C of 40 CFR §191, these above mentioned exposure pathways were found to be of low consequence. However, the CCA did not provide sufficient information and analysis in Chapter 8 to adequately demonstrate that the requirements of 40 CFR §194.51 have been met. The compliance assessment did not include all possible pathways for exposure as is required by 40 CFR §194.52. The only exposure pathway was consumption of potable water. The analysis did not include analysis of doses from other potential exposure pathways such as stock consumption or irrigation. These weaknesses were remedied by DOE's submittal of a more detailed dose analysis which included all of the appropriate additional pathways.

The EPA conducted its own dose verification modeling for the additional exposure pathways. The EPA′s results show that the doses from these exposure pathways are within regulatory limits. Refer to EPA's **Technical Support Document for Sections 194.51, 194.52, and 194.55: Dose Verification Evaluation, 1997, (Docket No. A-93-02, V-B-26) for EPA's additional exposure pathway analysis.**

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 8.1.1, 8.1.2, and 8.2.3; Appendices SCR.2.8.2; **EPA, 1997, Technical Support Document for Sections 194.51, 194.52, and 194.55: Dose Verification Evaluation**, **1997, Docket No. A-93-02, V-B-26**)

4.3 Human-Induced EP s Assessment

H1,H2,H4,H8
H9,H10,H11 Oil and Gas Exploration, Potash Exploration, Oil and Gas Exploitation, Other Resources, Enhanced Oil and Gas Recovery, Liquid Waste Disposal, Hydrocarbon Storage (SCR 3.2.1, SO-C/DP (H1, H2, H4, H8 and H9), SO-R/SO-R (H10,H11)). The screening arguments presented in SCR 3.2.1 appear reasonable to EPA. Drilling for the purpose of oil and gas resource exploration (H1) and potash exploration,(H2) as well as oil and gas exploitation (H4), other resources(H8) and enhanced oil and gas recovery (H9) were screened out on the basis of low consequence during site history and anticipated operations. In the future, the FEPs H1, H2, H4, H8 and H9 were accounted for in performance assessment in that boreholes that penetrate the waste and boreholes that penetrate Castile brine underlying the waste disposal region were

included in disturbed performance assessments. DOE argued this screening approach is valid by stating that drilling within the LWA will be controlled by active and passive institutional controls, and therefore drilling in the WIPP area for each of these FEPs during the historic, ongoing and near future time period would be of little consequence. DOE did recognize, however, that future activities must consider the possibility of repository/Castile brine pocket penetration by a borehole intrusion, and DOE therefore concluded that drilling for the above FEPs must be considered in the more distant future. EPA concurs with DOE's decision to include borehole intrusions in the more distant future (i.e. disturbed scenario). EPA questioned whether exclusion of drilling intrusions during the historic, ongoing, and near future time period is appropriate because EPA questioned the validity of passive institutional controls. EPA required DOE to perform PAVT modelling without consideration of passive institutional controls. Results of the PAVT indicate that while the CCDF curves calculated are approximately twice as high as those presented in the CCA, the removal of passive institutional controls does not impact compliance of the WIPP. Therefore, EPA concluded that DOE's screening of these FEPs during the historic, ongoing, and near future is sufficient for performance assessment purposes.

Drilling involved with fluid disposal by injection (H10) and for hydrocarbon storage (H11) was screened out on the basis of regulatory considerations during the historic, ongoing, and near future time periods. Consequently, DOE also screened both from consideration in the more distant future based upon regulatory considerations. DOE stated that neither of these FEPs required installation of boreholes exclusive of these purposes; boreholes previously used for other purposes (i.e. oil/gas extraction) are instead re-used for hydrocarbon storage and waste disposal by injection. DOE also stated that drilling for liquid waste disposal purposes and hydrocarbon storage has not occurred in the Delaware Basin (Appendix SCR, page SCR-103). EPA concurs with DOE's conclusion that drilling exclusively for waste fluid injection and gas storage alone generally does not occur. As such, EPA's consideration of the impacts of drilling that could ultimately result in waste fluid injection and gas storage is the same as for FEPs H1, H2, H4, H8, and H9, as discussed above. EPA agrees that DOE need not consider installation of boreholes exclusively for liquid waste disposal and gas storage in the more distant future; boreholes that could ultimately be used for these purposes are included in H1, H2, H4, H8, and H9 considerations.

Although the CCA considers oil and gas exploration/exploitation and potash exploration/exploitation in the PA, as well as sulfur exploration boreholes, it did not initially consider the possibility of brine mining (solution mining), even though this has occurred in the Delaware Basin. Additional justification for excluding this other resource was requested by EPA in it's March 19, 1997 letter to DOE. The DOE responded with a memorandum prepared by Hicks, as well as other supporting information in response to public comments. The additional information supports the screening classification for this halite solution mining. **Refer to CARD 32--Scope of Performance Assessment [Docket No. A-93-02, V-B-2, Section 194.32 (b)], for**

additional information regarding halite brine mining.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.3.1; 2.3.2 6.4.7; and 6.4.12; Appendices GCR, Section 8.4.8; DEL, Sections 4.2, 5.4 and 7.4; PAR, Table PAR-53; USDW, Section 3; Sections 2.3.1; 6.4.7; and 6.4.12; Appendices 3.2.1; GCR, Section 8.4.7; DEL, Sections 4.2 and 7.4; PAR, Table PAR-53; NMBMMR (New Mexico Bureau of Mines and Mineral Resources). 1995. *Final Report of Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site.* NMBMMR, Campus Station, Socorro, NM, Chapter XI ; Burton, P.L., Adams, J.W., and Engwall, C. 1993. "History of the Washington Ranch, Eddy County, New Mexico," *New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region, New Mexico and West Texas.* Eds. D.W. Love, J.W. Hawley, B.S. Kues, J.W. Adams, G.W. Austin, and J.M. Barker. SAND93-1318J. New Mexico Geological Society, Roswell, NM, 66-67.)

H3, H5,
H6, H7 Water Resources Exploration, Groundwater Exploitation, Archeological, Geothermal (SCR3.2.1, SO-C/ SO-C (H3 and H5), SO-R/SO-R (H6 and H7). The screening argument presented in SCR 3.2.1 appears reasonable to EPA. The DOE has indicated that because of minimal water resources in the WIPP vicinity, extensive drilling would not occur and consequences would be low, during both the historic, ongoing, near future, and more distant future time periods. EPA notes that while potential USDWs are present in the WIPP area, geologic strata are not typically used to provide water for domestic consumption in the WIPP area, which is not likely to change in the more distant future. EPA also believes that installation of water wells and subsequent exploitation would take place in shallower horizons above the Salado Formation that encases the WIPP and, hence, the impact that these borehole would have on disposal system performance is significantly less than deeper boreholes installed through the disposal panels. EPA concurs with DOE's screening decision, which has resulted in the exclusion of shallow drilling rates for resources such as water in performance assessment. **Refer to CARD 33--Consideration of drilling in performance assessment, for additional information** [Docket No. A-93-02, V-B-2, Section 194.33 (a)]**.**

DOE screened geothermal drilling on regulatory grounds for both the historic, ongoing, near future and more distant future time frames. DOE states that geothermal energy is "not considered to be a potentially exploitable resource because economically attractive geothermal conditions do not exist int he northern Delaware Basin" (Appendix SCR, page SCR-103). EPA concurs with DOE's conclusion. Detailed examination of geologic conditions in the WIPP area do not indicate significant faulting, tectonic stresses, or other conditions that would promote the use of geothermal energy.

The DOE indicates that drilling associated with archeological investigations will be controlled, and typically involves minimal surface disruption. It is controlled within the site currently and is expected to be controlled during the period of active institutional controls. EPA agrees with this conclusion, and with DOE's subsequent screening of archeological investigations from PA. Further, EPA concurs with DOE in that archeological exploration would likely occur at only surficial to very shallow depths, and does not involve drilling that would disrupt the disposal system.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.2., Section 2.3.1; Appendices SCR.3.2.1; DEL, Sections 4.2 and 7.4; USDW, Section 3, Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.3.1, 6.4.7 and 6.4.12; Appendices DEL, Sections 5.4 and 7.4; PAR, Table PAR-53; NMBMMR (New Mexico Bureau of Mines and Mineral Resources). 1995. *Final Report of Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site.* NMBMMR, Campus Station, Socorro, NM, Chapter XI.)

H12 Deliberate Drilling Intrusion (SCR 3.2.1, SO-R/SO-R). The DOE screening analysis appears reasonable to EPA. The DOE assumes that future intentional drilling is screened based upon 194.33(b)(1), which states that inadvertent drilling (rather than deliberate drilling) is the most severe intrusion scenario, but this does not necessarily mean that other drilling should be eliminated. EPA concludes that consideration of deliberate drilling into the repository is need not be considered, as exclusion is appropriate as per §194.33(b)(1) requirements.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.2.1.)

H13 Potash Mining (SCR 3.2.2, UP/DP). The screening argument appears reasonable to EPA. Mining both within and outside of the controlled area is considered under the appropriate scenario (UP and DP). Mining is included within the controlled area in the future, but not in the present/near future, which would appear to be appropriate. Refer to **CARD 32--Scope of Performance Assessments** [Docket No. A-93-02, V-B-2, Section 194.32 (b)] for information on treatment of mining in the performance assessment (e.g. justification of the angle of draw and transmissivity multipliers), as well as the application of transmissivity variations solely to the Culebra member of the Rustler Formation.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.3.1, 6.4.6, 6.4.12, and 6.4.13; Appendices SCR.3.2.2; DEL, Section 7.4; MASS, Attachment 15-4; PAR, Parameter 34.)

H14-20 Other Resources, Tunneling, Construction of Underground Facilities, Archaeological Excavations, Deliberate Mining Intrusion, Explosions for Resource Recovery, Underground Nuclear Device Testing (SCR 3.2.2, 3.2.3.1, 3.2.3.2, 3.3.1.1, SO-C/DP(H14), SO-R/SO-R(H15,H16, H18), SO-C/SO-R (H17, 19, 20). The screening arguments presented in SCR 3.2.2, 3.2.3, and 3.3.1 appear reasonable to EPA. These seven "excavation" FEPs have been screened out, primarily using the regulatory criteria in 40 CFR 194.25 (a), 194.32(a), and 194.33, or due to low consequences. Historical, current or near-future mining for resources other than potash, archaeological excavations, explosions for resource recovery, and underground nuclear device testing were all eliminated from consideration since they have not significantly affected the WIPP site or the Delaware Basin in general, and are not likely to do so in the predictable future. Exclusion of all seven types of "excavation" from long-term future PA consideration appears to be appropriate, and in accordance with the criteria in 40 CFR 194. Potash mining is the exception, and is included in future PA scenarios and calculations.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.2; Appendices SCR.3.2.2; Burton, P.L., Adams, J.W., and Engwall, C. 1993. AHistory of the Washington Ranch, Eddy County, New Mexico,@ *New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region, New Mexico and West Texas.* Eds. D.W. Love, J.W. Hawley, B.S. Kues, J.W. Adams, G.W. Austin, and J.M. Barker. SAND93-1318J. New Mexico Geological Society, Roswell, NM. 66-67; Rawson, D., Boardman, C., and Jaffe-Chazan, N. 1965. *Project Gnome, the Environment Created by a Nuclear Explosion in Salt.* PNE-107F. Lawrence Radiation Laboratory, University of California, Livermore, CA; Available from National Technical Information Service, Springfield, VA.)

H21-H23 Drilling Fluid Flow, Drilling Fluid Loss, Blowouts (SCR 3.3.1, SO-C/ DP). The screening arguments in SCR.3.3.1 appear reasonable to EPA because drilling fluid flow, drilling fluid loss, and gas blowouts may affect the hydrology of the disposal system in the future. Drilling fluid flow, fluid loss, and gas blowouts are short-term events that can result in the flow of pressurized fluid from one geologic stratum to another. For the near future, these events may occur in the vicinity of the WIPP but are not likely to affect the disposal system because of their distance from the waste panels, assuming that passive and active institutional controls are in place which restrict borehole installation to outside the LWA. For the future, the drill holes may intersect the waste disposal region and their effects could be more profound. Thus, they are included in the assessment of future activities.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.3.2 and 6.4.7; Appendices SCR.3.3.1; DEL, Sections 5.1.3, 6.1.2 and Attachment 1, and 7.5; CUTTINGS, Appendices A.2.2 and A.2..4.1; MASS, Attachment 16-2; PAR, Parameters 1 and 3, Table PAR-43; Economy, K.E., 1996. *Drilling into a Salado Zone of Contamination Within the Controlled Area; Drilling into a Non-Salado Zone of Contamination Within the Controlled Area. Summary Memo of Record for S-9 and NS-6.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-6,S-9. Sandia

National Laboratories, Albuquerque, NM. WPO 39495; Wallace, M. 1996a. Leakage from abandoned boreholes. Summary Memo of Record for NS-7b. SWCF-A 1.1.6.3:PA:QA:TSK:NS-7b. Sandia National Laboratories, Albuquerque, NM. WPO 40819.)

H24 Drilling-Induced Geochemical Changes (SCR 3.3.1, UP/ DP). The screening argument in SCR.3.3.1 appears reasonable to EPA because a drill hole near the WIPP could allow fluid from deep formations to enter the Salado interbeds or the Culebra and change the geochemistry. This possibility is included in performance assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.6; Appendices SCR.3.3.1; MASS, Section 15.2 and Attachment 15-1; PAR Parameters 47 and 52 to 57, Table PAR-39; SOTERM; Wallace, M., Beauheim, R., Stockman, C., Alena Martell, M., Brinster, K., Wilmot, R., and Corbert, T. 1995. Dewey Lake Data Collection and Compilation. Summary Memo of Record for NS-1. SWCF-A 1.1.6.3:PA:QA:TSK:NOS-1. Sandia National Laboratories, Albuquerque, NM.)

H25-H26 Oil and Gas Extraction, Groundwater Extraction (SCR 3.3.1.2, SO-C/SO-R). The screening arguments presented in SCR 3.3.1.2 appear reasonable to EPA. The extraction of hydrocarbons from the area was screened out on the basis of low consequence during site history and anticipated operations. In the future, the FEP was screened out on the basis of regulatory requirements. FEP screening appears to have considered the possibility of both subsidence and pressure gradients in a system due to extraction, and indicate that the effects of subsidence and pressure gradients would be minimal. Based on this discussion, EPA concludes that the screening argument appears to have considered the appropriate issues. It is likely that the technical conclusions reached are valid for the past and present.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.3.3.1; Brausch, L.M., Kuhn, A.KI., Register, J.K. 1982. *Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico.* WTSD-TME-356. U.S. Department of Energy, Waste Isolation Pilot Plant, 52, 61; Wallace, M. 1996b. *Pumping from the Culebra Outside the Controlled Area. Summary Memo of Record for NS-5.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-5. Sandia National Laboratories, Albuquerque, NM. WPO 40819.)

H27-H28 Liquid Waste Disposal, Enhanced Oil and Gas Production (SCR 3.3.1.3, SO-C/ SO-R). The screening argument presented in SCR 3.3.1.3 appears reasonable to EPA. However, EPA initially questioned this screening and requested additional information from DOE regarding fluid injection analysis (EPA, March 1997). Concurrently, EPA performed it's own analysis of fluid injection (EPA, 1997). DOE provided alternative analysis of fluid injection (Stoelzel and Swift, 1997), which addressed EPA concerns regarding duration of injection activities and fracture characteristics. These reports are discussed below.

DOE presented it's initial injection well analysis, which EPA questioned, in Stoelzel and O'Brien, 1996. In this document, the authors evaluated the effects of fluid injection/waterflooding from two hypothetical boreholes near the WIPP using the BRAGFLO code, with some modified parameters and assumptions to fit the water flood conditions (e.g., a modified grid system). Stoelzel and O'Brien, 1996, concluded that although a worst case realization did result in brine inflow from the injection location to the repository over an approximately two-mile distance within anhydrite interbeds of the Salado, the value of cumulative brine inflow was relatively small and within the bounds of brine inflow values calculated for the undisturbed scenario. Therefore, DOE eliminated the water flood FEP based upon low consequence. DOE revisited this scenario (Stoelzel and Swift, 1997) assuming a modified injection simulation period, increased Bell Canyon (injection zone) transmissivity, and reduced disturbed rock zone (DRZ) volume. DOE still concluded that water flood could be eliminated from the PA based on low consequence.

EPA reviewed information presented by DOE and performed it's own analysis. EPA's analysis indicates that the realistic consequences of fluid injection are very low, but EPA also concluded that the necessary combinations of event that could lead to an impact are highly improbable. Refer to EPA's **Technical Support Document for Section 194.32: Fluid Injection Analysis (Docket No. A-93-02, V-B-22)** for additional information pertaining to EPA's fluid injection analysis.

EPA also examined concerns by stakeholders regarding fluid injection. The New Mexico Attorney General (NMAG) (comment A-93-02, II-H-28) submitted a report indicating that fluid injection activities could overwhelm the WIPP with brine, contradicting the DOE modeling that shows low consequence (Stoelzel and O'Brien, 1996, Reference No. 611). EPA reviewed the report and considered its implications in preparation for the compliance determination decision. The NMAG report highlighted concerns about anhydrite fracturing and some aspects of the DOE modeling, such as the time period for injection. EPA used the NMAG report, in part, in its 3/19/97 request for more information on the fluid injection scenario. The original and supplementary information presented by DOE regarding fluid injection both show that there is little consequence of fluid injection activities. The supplemental information provided by DOE (Stoelzel and Swift, 1997) indicates that current well construction makes it unlikely that there could be a well failure of the nature that occurred in the Rhodes-Yates field near the WIPP but outside the Delaware Basin. DOE used reasonable estimates and concepts in its consequence analysis to rule out the fluid injection scenario based on consequences. Although DOE did not use probability to rule out fluid injection, DOE's analysis of the well construction and operating practices around WIPP also indicate that there is a very low probability that a well would suffer a complete failure as required by the NMAG report.

EPA has reviewed the NMAG report and considers it to model highly unrealistic conditions in the WIPP area. In addition, the NMAG report models scenarios not required by 194.32(c). For example, the NMAG report assumes, for all modeled scenarios, that all injected brine is directly injected into the anhydrite marker beds. This approach ignores the fact that well operators are trying to inject brine into certain formations thousands of feet (hundreds of meters) below the Salado; continuous injection into one several foot thick anhydrite layer is not a viable operational likelihood, especially when the intended effect is to increase oil production from units far below. The NMAG report considers fractures in the anhydrite to extend for three or more kilometers and to remain open; however, a prerequisite for this unlikely condition is high pressure. The report states (p. 21) that "We can only get high pressure over the entire region if the repository pressure is also high." The report further states (p. 21) that "If the pressure in WIPP is below lithostatic, then the area where a fracture might remain continuously open is restricted to close into the injection well. The fracture will not be continuously open all the way to WIPP; however, it might pulse open and closed..." However, lithostatic (high pressure) conditions occur infrequently in DOE's conditions in the CCA and EPA Mandated Performance Assessment Verification Test. According to DOE's calculations of brine flow into the waste panels and subsequent gas generation that relies on brine, high pressure won't occur for several hundred years, if at all. This is after the time ("near future") that fluid injection activities could be expected to occur in the vicinity of the WIPP. Another NMAG report indicates that the DOE estimate of infrequent high lithostatic conditions may even be much less likely due to MgO hydration effects that use existing brine in the waste area **(see CARD 24--Waste Characterization,** Docket No. A-93-02, V-B-2, Section 194.24 (b) for more on the topic of MgO effects). Chapter 8 of the NMAG report models a high pressure scenario that "does not occur until the pressure within the repository builds up to near lithostatic," (p.29). Since high pressure doesn't occur until after fluid injection activities are assumed to cease, this scenario is highly implausible.

EPA notes that the nature of anhydrites, duration of injection activities, and the presence of leaking boreholes are important considerations for injection well analyses. EPA also notes that no detailed documentation regarding Salado anhydrite fracture density or Salado Formation homogeneity were found in the discussion in the Stoelzel, 1996 document. DOE included additional information in response to EPA Completeness Comments (Stoelzel and Swift, 1997), but DOE did not demonstrate conclusively the homogeneity of anhydrite fractures. EPA independently assessed homogeneity of fractures in marker beds, both on a local and regional scale (Docket No. A-93-02, V-B-22). Fracture parameters are the principal determining factor of interbed fluid flow. EPA noted that the repository could theoretically experience significant increases in pressure and brine movement if fractures are oriented in a preferential direction with a dominant pathway from the injection area toward the repository. EPA noted that if radial flow within the interbeds does not exist, but regions of higher permeability are present, the impact on the WIPP is uncertain. EPA examined fluid flow within marker beds on both micro and macro scales. EPA concluded that it is possible that fracture and fluid flow characteristics within marker beds are anisotropic and inhomogeneous on a small scale. However, when the entire Salado system in the WIPP area is considered, the overall system response is that of a more homogenous system.

In summary, EPA's initial assessment of DOE's screening results indicated that fluid injection FEPs, including enhanced oil recovery and salt water disposal (Class 2) were not appropriately modeled. The screening assessment approach used by DOE appeared to be inadequate for injection-related activities, including liquid waste disposal. EPA performed its own independent analysis which showed that the injection analysis must include the nature of anhydrites, duration of injection activities, and presence of leaking boreholes (EPA, 1997, Docket No. A-93-02, V-B-22). DOE also performed additional modeling, and EPA also conducted modeling of the injection well scenario (Docket No. A-93-02, V-B-22). EPA concluded through analysis and additional modeling, that although scenarios can be constructed that move fluid to the repository via injection, the probability of such an occurrence, given the necessary combination of natural and human-induced events, is less than one in 10,000. Refer to EPA's **Technical Support Document for Section 194.32: Fluid Injection Analysis** (Docket No. A-93-02, V-B-2) for detailed results of EPA's analysis.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.3.1 and 6.4.7; Appendices SCR.3.3.1; DEL, Sections 5.5 and 6; Stoelzel, D.M., and O′Brien, D.G. 1996. The Effects of Salt Water Disposal and Waterflooding on WIPP. Summary Memo of Record for NS-7a. Sandia National Laboratories, Albuquerque, NM. WPO 40837; Wilmot, R.D., and Galson, D.A. 1996. *Human-Initiated Brine Density Changes. Summary Memo of Record for NS17 and NS18.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-17, NS-18. Sandia National Laboratories, Albuquerque, NM. WPO 39424; Wallace, M. 1996c. *Subsidence Associated with Mining Inside or Outside the Controlled Area. Summary Memo of Record for NS-11.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-11. Sandia National Laboratories, Albuquerque, NM, Planning Memo of Record. WPO 40816; Davies, P.B. 1989. *Variable Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open File Report 88-490. U.S. Geological Survey, 28, 32, 42, 47-48; Brausch, L.M., Kuhn, A.KI., Register, J.K. 1982. *Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico.* WTSD-TME-356. U.S. Department of Energy, Waste Isolation Pilot Plant, 67-68; Silva, M.K. 1994. *Implications of the Presence of Petroleum Resources on the Integrity of the*

WIPP. EEG-55. Environmental Evaluation Group, Albuquerque, NM; Wilmot, R.D., and Galson, D.A. 1996. *Human-Initiated Brine Density Changes. Summary Memo of Record for NS17 and NS18.* SWCF-A 1.1.6.3:PA:QA:TSK: NS-17, NS-18. Sandia National Laboratories, Albuquerque, NM. WPO 39424; Popielak, R.S., Beauheim, R.L., Black, S.R., Coons, W.E., Ellingson, C.T., and Olsen, R.L. 1983. *Brine Reservoirs in the Castile Formation, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico.* TME-3153. U.S. Department of Energy, Carlsbad, NM, Table C-2. Technical Support Document for Section 194.32: Fluid Injection Analysis, Docket No. A-93-02, V-B-22).

H29 Hydrocarbon Storage (SCR 3.3.1.3, SO-C, SO-R). The DOE screening assessment appears to be technically reasonable to EPA, although the discussion is brief. Induced system changes due to hydrocarbon storage operations in the area were screened out on the basis of low consequence during site history and anticipated operations. In the long term PA, DOE screened out this FEP on the basis of regulatory requirements, since EPA does not require DOE to consider, in the long term those FEPs screened in the near term. EPA concluded that this screening appears appropriate because hydrocarbon storage would occur in rock units well below the Salado Formation, and well failure that could occur in a hydrocarbon storage system would have effects similar to hydrocarbon injection analysis, discussed in H28 and H27, above.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendices SCR.3.3.1; Burton, P.L., Adams, J.W., and Engwall, C. 1993. "History of the Washington Ranch, Eddy County, New Mexico," *New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region, New Mexico and West Texas.* Eds. D.W. Love, J.W. Hawley, B.S. Kues, J.W. Adams, G.W. Austin, and J.M. Barker. SAND93-1318J. New Mexico Geological Society, Roswell, NM; Stoelzel, D.M., and O'Brien, D.G. 1996. The Effects of Salt Water Disposal and Waterflooding on WIPP. Summary Memo of Record for NS-7a. Sandia National Laboratories, Albuquerque, NM. WPO 40837; Wilmot, R.D., and Galson, D.A. 1996. *Human-Initiated Brine Density Changes. Summary Memo of Record for NS17 and NS18.* SWCF-A 1.1.6.3:PA:QA:TSK: NS-17, NS-18. Sandia National Laboratories, Albuquerque, NM. WPO 39424; Wallace, M. 1996c. *Subsidence Associated with Mining Inside or Outside the Controlled Area. Summary Memo of Record for NS-11.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-11. Sandia National Laboratories, Albuquerque, NM, Planning Memo of Record. WPO 40816; Davies, P.B. 1989. *Variable Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open File Report 88-490. U.S. Geological Survey, 28.)

H30 Fluid Injection Induced Geochemical Changes (SCR 3.3.1.3, UP/SO-R). The screening argument presented in SCR 3.3.1.3 appears reasonable to EPA. Induced geochemistry changes due to injection activity was reported to be accounted for in the undisturbed case performance assessments during historical and anticipated operations. In the future, the FEP was screened out on the basis of regulatory requirements. In SCR 3.3.1.3.1, the screening of geochemical effects of injection borehole leakage is discussed. Although only sparse details are provided, the discussion appears to be technically valid.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 6.4.6; Appendices MASS, Section 15.2 and Attachment 15-1; PAR, Parameters 47 and 52 to 57, Table PAR-39.)

H31 Natural Borehole Fluid Flow (SCR 3.3.1.4, SO-C/ DP). The screening argument in SCR.3.3.1.4 appears reasonable to EPA. The assessments include calculations of fluid flow through a borehole that penetrates through a waste panel and into a Castile brine reservoir. If the borehole plug degrades with time, fluid can flow from the Castile into the repository and dissolve radionuclides or otherwise affect the system's performance. DOE did not consider the effects of natural borehole fluid flow during the historic/ongoing/near future time period because boreholes present currently at the WIPP do not penetrate the repository and active/passive institutional controls would mitigate installation of boreholes through the repository up to 700 years in the future. In addition, DOE's inclusion of this FEP in the more distant future appears appropriate.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.7, 6.4.6 and 6.4.12; Appendices MASS, Section 16.3 and Attachments 16-1 and 16-3; DEL, Sections 5.5 and 6; BRAGFLO, Section 4.8; Wallace, M. 1996a. Leakage from abandoned boreholes. Summary Memo of Record for NS-7b. SWCF-A 1.1.6.3:PA:QA:TSK:NS-7b. Sandia National Laboratories, Albuquerque, NM. WPO 40819; Wallace, M. 1996c. *Subsidence Associated with Mining Inside or Outside the Controlled Area. Summary Memo of Record for NS-11.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-11. Sandia National Laboratories, Albuquerque, NM, Planning Memo of Record. WPO 40816; Wilmot, R.D., and Galson, D.A. 1996. *Human-Initiated Brine Density Changes. Summary Memo of Record for NS17 and NS18.* SWCF-A 1.1.6.3:PA:QA:TSK: NS-17, NS-18. Sandia National Laboratories, Albuquerque, NM. WPO 39424; Corbet, T. 1995. *Two-Dimensional Assumption for Culebra Calculations. Summary Memo of Record for NS-9.* Memo of 21 September 1995. SWCF-A 1.1.6.3:PA:QA:MGT:FSD. Sandia National Laboratories, Albuquerque, NM; Davies, P.B. 1989. *Variable Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open File Report 88-490. U.S. Geological Survey, 28)

H32 Waste-Induced Borehole Flow (SCR 3.3.1.4, SO-R, DP). The screening argument in SCR.3.3.1.4 appears reasonable to EPA because, for future simulations, a borehole (or boreholes) is postulated to intersect a waste panel and allow flow of fluid and radioactivity to the overlying formations. The likelihood of such a borehole is quite high after active and passive institutional control of the site has ceased. The more distant - future effects are included in the performance assessment.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.2, 6.4.7, and 6.4.12; Appendices MASS, Section 16.3 and Attachments 16-1 and 16-3; DEL, Sections 5.5 and 6; BRAGFLO, Section 4.8; Wallace, M. 1996a. Leakage from abandoned boreholes. Summary Memo of Record for NS-7b. SWCF-A 1.1.6.3:PA:QA:TSK:NS-7b. Sandia National Laboratories, Albuquerque, NM. WPO 40819.)

H33 Flow Through Undetected Boreholes (SCR 3.3.1.4, SO-P/ NA). The screening argument in SCR.3.3.1.4 appears reasonable to EPA because no previously unknown boreholes have been found during the WIPP site characterization activities. Thus, the probability of such boreholes, if any exist, should be quite low. Even if there are any as yet undetected boreholes, their effects on the disposal system would be small, according to the same argument used for the abandoned boreholes.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.3.1.)

H34 Borehole-Induced Solution and Subsidence (SCR 3.3.1.4, SO-C/ SO-C). The screening argument presented in SCR 3.3.1.4 appears reasonable to EPA. In order to have borehole-induced solution and subsidence, three conditions must be met: first, a borehole from the ground surface to an underlying unit must be present and be inappropriately sealed; second, a gradient to drive the fresh water downward through the heavier brine must be present; and third, a conduit to allow brine to move away from the site of dissolution should be present. These three conditions are not likely to exist simultaneously at the WIPP site. In particular, there is no known natural conduit for saturated brine to leave the salt formation. The screening argument in SCR 3.3.1.4 appears reasonable.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 3.3.4 and 6.4.7; Appendices DEL, Sections 5.5 and 6; Johnson, K.S. 1987. Development of the Wink Sink in West Texas Due to Salt Dissolution and Collapse. In *Karst Hydrology. Proc. 2nd Conference, Orlando, 1987.* B.F. Beck, W.L. Wilson, eds. Oklahoma Geological Survey, Norman, USA. Balkema. pp. 127-136; Beauheim, R.L. 1986. *Hydraulic-Test Interpretations for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site.* SAND86-1364. Sandia National Laboratories, Albuquerque, NM. WPO 27565; Christensen, C.L., Gulick, C.W., and Lambert, S.J., 1983. *Sealing Concepts for the Waste Isolation Pilot Plant (WIPP) Site.* SAND81-2195. Sandia National Laboratories, Albuquerque, NM. WPO 24405., 19.)

H35 Borehole-Induced Mineralization (SCR 3.3.1.4, SO-C/ SO-C). The screening argument in SCR.3.3.1.4 appears reasonable to EPA because the injection of Salado or Castile brines into the Culebra will likely not significantly alter the existing spatial variability of permeability within the Culebra. As such, it is a logical extension to conclude that associated mineralization is not anticipated. EPA recognizes that mineralization can occur in drill holes, but the chemistry of the Salado and Castile may not promite precipitation that is commonly seen in oil industry wells.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.3.1.)

H36 Borehole-Induced Geochemical Changes (SCR 3.3.1.4, UP/ DP). The screening argument in SCR.3.3.1.4 appears reasonable to EPA because fluids could migrate through boreholes to receiving units such as the Salado interbeds or the Culebra. These effects are included in the modeling.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.4.3 and 6.4.6; Appendices SCR.3.3.1; MASS, Section 15.2 and Attachment 15-1; PAR, Parameters 47 and 52 to 57, Table PAR-39.)

H37 Changes in Groundwater Flow Due to Mining (SCR 3.3.2, UP/ DP). Mining for potash is a relatively likely event, given past experience in the Delaware Basin. Mining outside and inside the controlled area was included in the analyses by increasing the permeability of portions of the Culebra above the mined areas. The increased permeability was modeled in the SECOFL2D code and subsequently in the SECOTP2D code. The effects of mining are to shift the groundwater flow and radionuclide transport paths toward the southwest or west, usually increasing the radionuclide travel times to the accessible environment. Refer to **CARD 23-- Models and Computer Codes for implementation of SECO codes** [Docket No. A-93-02, V-B-2, Section 194.23 (b)].

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 2.3.1, 6.4.6, 6.4.12 and 6.4.13; Appendices SCR.3.3.2; CCDFGF, Section 3.2; DEL, Section 4.2.4; PAR, Parameter 34; Westinghouse Electric Corporation. 1994. *Backfill Engineering Analysis Report, Waste Isolation Pilot Plant.* Westinghouse Electric Corporation, Carlsbad, NM. WPO 37909, 2-17 to 2-19, 2-22 to 2-23; Davies, P.B. 1989. *Variable Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open File Report 88-490. U.S. Geological Survey, 43, 77-81; Wallace, M. 1996c. *Subsidence Associated with Mining Inside or Outside the Controlled Area. Summary Memo of Record for NS-11.* SWCF-A 1.1.6.3:PA:QA:TSK:NS-11. Sandia National Laboratories, Albuquerque, NM, Planning Memo of Record. WPO 40816.)

H38 Changes in Geochemistry Due to Mining (SO-C, SO-R). The screening argument presented in SCR 3.3.2 appears reasonable to EPA. It appears unlikely that mining will impact the site geochemistry during the near future (that is, during the time of passive institutional controls), and a conclusion of no near-term consequence is screened from future events as per 194.25.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.1; Appendix SCR.3.3.2.)

H39 Changes in Groundwater Flow Due to Explosions (SO-C, SO-R). The screening argument in SCR.3.3.3 appears reasonable to EPA. Underground explosions (i.e., use of explosives to fracture a formation) have been used in the past to enhance oil and gas recovery. The increased permeability caused by the explosion allows greater recovery but the effect extends only a few hundred feet, at a maximum, from the borehole. Past explosions have been too far from the WIPP to affect the disposal system. For the near future, explosions have been eliminated because of low consequences. For the future, consistent with 40 CFR §194.33(d), the DOE is not required to analyze the effects of resource recovery techniques after the drilling of a future borehole.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.3.3.)

H40-H41 Land Use Changes, Surface Disruptions (SCR 3.4.1, SO-R/SO-R, SO-C-SO-R). The screening argument presented in SCR 3.4.1 appears reasonable to EPA. DOE has eliminated the effects of future surface disruptions and land use changes from the performance assessment calculations on the basis of regulatory grounds. This assumption is consistent with the criteria in 40 CFR §194.25 (a), which state that predictions concerning future states of society shall assume the characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions. Additional regulatory criteria outlined in 40 CFR §194.32 (c) and 40 CFR §194.54 (b) also limit the scope of performance assessments to mining, deep drilling and shallow drilling that may affect the disposal system during the regulatory time frame. The elimination of the effects of future surface disruptions and land use changes on the basis of regulatory grounds is also supported by the CAG.

The DOE has eliminated historical, current and near future surface disruptions from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. As stated on page SCR-138, Section 3.4.1.1. surface activities conducted at the WIPP include potash mining, oil and gas reservoir development, water extraction and grazing, as well as a number of archeological investigations. The DOE states that although these activities involved surface disruptions within the Delaware Basin, these activities have not altered the characteristics of the disposal system, and they have therefore been eliminated from the performance assessment on the basis of low consequence.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.4.1.)

H42-H44 Damming of Streams or Rivers, Reservoirs, Irrigation (SCR 3.5.1, SO-C/SO-R). The DOE screening assessment appears reasonable to EPA. The DOE has eliminated the effects of historical, current and near future damming of streams and rivers, reservoirs, and irrigation from performance assessment calculations on the basis of low consequence. The discussions presented in Appendix SCR, Section SCR.3.5.1.1. indicate that in the vicinity of the WIPP site, dams and reservoirs currently exist only along the Pecos River and that because the Pecos River is located 12 miles from the WIPP site, the effects can be eliminated. Appendix SCR further indicates that although small scale irrigation does take place in the Delaware Basin (but not in the vicinity of the WIPP site) the extent of irrigation is not expected to have a significant effect on the performance of the disposal system.

The DOE's screening evaluation pertaining to the effects of future damming of streams and rivers, reservoirs and irrigation appears to be technically valid. The DOE has stated that the future effects of these activities have been eliminated from the performance assessment calculations on the basis of regulatory grounds. The DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.32 (a).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.5.1.)

H45 Lake Usage (SCR 3.5.1, SO-R/SO-R). The screening argument presented in SCR 3.5.1 appears reasonable to EPA. The DOE has stated that historical, current, near-future and future human initiated effects from lake usage have been eliminated from the performance assessment calculations based upon regulatory grounds. The DOE has stated on page SCR-140 that there are no large lakes in the vicinity of the WIPP. DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.32(c) and §194.54 (b).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.5.1)

H46 Altered Soil or Surface Water Chemistry by Human Activity (SCR 3.5.1, SO-C/SO-R). The DOE's screening evaluation appears to be technically reasonable to EPA. The DOE has eliminated the historical, current and near-future effects from activities such as potash mining and runoff from oil fields from the performance assessment calculations on the basis of low consequence. The DOE states on page SCR-140 that the performance of the disposal system will not be sensitive to soil or surface water chemistry. However, the DOE has not provided references or information to justify this statement.

The DOE's screening evaluation concerning the future effects of human activities which result in altered soil and surface water chemistry have been eliminated from the performance assessment calculations on the basis of regulatory grounds. The DOE's evaluation is supported by the criteria outlined in 40 CFR §194.32 (a). Therefore, DOE's screening evaluation pertaining to future effects appears to be technically valid.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.5.1.)

H47-H49 <u>Greenhouse Gas Effects, Acid Rain, Damage to the Ozone (SCR 3.6.1, SO-R/SO-R).</u> The screening argument presented in SCR 3.6.1 appears reasonable to EPA. DOE has indicated on page SCR-140 that the effects of current climate and natural climatic changes are accounted for in the performance assessment calculations. The DOE further states that the future effects of climate change (i.e., acid rain, greenhouse gas effects and damage to the ozone layer) have been eliminated from the performance assessment calculations on the basis of regulatory grounds. DOE's assumption is valid and is supported by the criteria outlined in 40 CFR §194.25(b) (3).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.6.1.)

H50-H52 <u>Coastal Water Use, Sea Water Use, Estuarine Water Use (SCR 3.7.1, SO-R/SO-R).</u> The DOE's screening evaluation appears to be technically reasonable to EPA. The DOE has stated that historical, current, near-future and future human initiated effects from coastal water use, seawater use and estuarine water use have been eliminated from the performance assessment calculations based upon regulatory grounds. The DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.32(a) and (c) and §194.54(b).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.7.1.)

H53-H54 <u>Arable Farming, Ranching (SCR 3.8.1, SO-C/SO-R).</u> The screening argument presented in SCR 3.8.1 appears reasonable to EPA. DOE has stated that the historical, current, and near-future effects of arable farming and ranching have been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. The CCA states on page SCR-142 that although grazing and related crop production have had some influence on the vegetation at the WIPP site, these activities are unlikely to have affected subsurface hydrological or geochemical conditions.

The DOE's screening evaluation with respect to future effects of arable farming and ranching appear to be technically valid. The DOE has stated that future human initiated effects from arable farming and ranching have been eliminated from the performance assessment calculations based upon regulatory grounds. The DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.32(a) and (c) and §194.54 (b).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.2; Appendix SCR.3.8.1.)

H55 Fish Farming (SCR 3.8.1, SO-R/SO-R). The screening argument presented in SCR 3.8.1 appears reasonable to EPA. DOE has stated that historical, current, near-future and future human initiated effects from fish farming have been eliminated from the performance assessment calculations based upon regulatory grounds. The DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.32(a) and (c) and §194.54 (b).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Appendix SCR.3.8.1.)

H56 Demographic Change and Urban Development (SCR 3.8.2, SO-R/SO-R). The screening argument presented in SCR 3.8.2 appears reasonable to EPA;. The DOE has stated that near-future and future demographic change and urban development have been eliminated from the performance assessment calculations based upon regulatory grounds. DOE's screening evaluation is supported by the criteria outlined in 40 CFR §194.25 (a).

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Section 2.3.2; Appendix SCR.3.8.1.)

H57 Loss of Records (SCR 3.8.2, NA/DP). The screening argument presented in SCR 3.8.2 appears reasonable to EPA. DOE has stated that the ineffectiveness of institutional controls in the future (i.e., loss of records) has been accounted for in the performance assessment calculations. This approach is consistent with the criteria outlined in 40 CFR §194.43 (c) which states that in no case shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely.

(References: Title 40 Part 191, Compliance Certification Application for the WIPP, October 1996, Sections 6.3, 6.4.7, 6.4.12 and 7.3; Appendices SCR.3.8.2; EPIC, Section 6; PAR, Table Par-53.)

5. CCA FEPS That Were Subject to Side Effort

FEP No.	FEP Name	SNL Side Effort Number	WPO Number for final CCA supporting documentation	Is FEP Screening Based on Use of WIPP PA Code?	FEP Analysis Plan Number	EPA Assessment of Analysis Process
N26	Density effects on groundwater flow	NS19	40021	No	5-4	
N29	Saline intrusion	NS20	30498	No	5-2	
N30	Freshwater intrusion	NS20	30498	No	5-2	
N61	Climate change	NS8 NS8/9	30802 (Phase 1) 30801 (ERRATA) 36671 (Clarification memo)	**Yes (BRAGFLO, SECOFL2D, PANEL, SECOTP2D)**	5-2	
W14	Nuclear criticality: heat	RNT1	40818	No	5-4	
W23	Subsidence	S15a	39409	No	5-4	
W25	Disruption due to gas effects	SP1	39395 (Exemption memo.)	No	N/A	
W30	Thermally-induced stress changes	S11 RM1	31292 31292	No No	5-4 5-4	
W31	Differing thermal expansion of repository components	SP6	31292	No	5-4	
W37	Mechanical degradation of seals	SP2 SP4	39395 (Exemption memo.) 31350	No No	N/A 5-4	
W38	Investigation boreholes	SP10	31300	No	5-4	
W43	Convection	GG4 S10	31290 31290	No No	5-4 5-4	
W45	Effects of temperature on microbial gas generation	GG9	31549	No	5-4	
W46	Effects of pressure on microbial gas generation	GG10	31508	No	5-4	
W48	Effects of biofilms on microbial gas generation	GG14	31485	No	5-4	
W49	Gases from metal corrosion	GG13	31491	No	5-4	

FEP No.	FEP Name	SNL Side Effort Number	WPO Number for final CCA supporting documentation	Is FEP Screening Based on Use of WIPP PA Code?	FEP Analysis Plan Number	EPA Assessment of Analysis Process
W50	Galvanic coupling	GG12	31498	No	5-4	
W51	Chemical effects of corrosion	GG6	31560	No	5-4	
W52	Radiolysis of brine	GG1	30786	**Yes (BRAGFLO)**	5-4	
W53	Radiolysis of cellulose	GG11	31502	No	5-4	
W54	Helium gas production	GG5	31587	No	5-4	
W55	Radioactive gases	GG8	31557	No	5-4	
W56	Speciation	GG3 SP9	31812 31811	No No	5-4 5-4	
W59	Precipitation	RNT7	31809	No	5-4	
W72	Exothermic reactions	GG7	31301	No	5-4	
W73	Concrete hydration	SP7	31301	No	5-4	
W74	Chemical degradation of seals	SP5	31298	No	5-4	
W76	Microbial growth on concrete	SP8	31298	No	5-4	
W93	Soret effect	RNT24	31814	No	5-4	
W94	Electrochemical effects	DR15 DR16 RNT25	31302 31302 31302	No No No	5-4 5-4 5-4	
W97	Chemical gradients	RNT20	31813	No	5-4	
H21	Drilling fluid flow	RI2 RI3 RI4 RI9 NS6 NS21 S9	35396 36951 36951 35396 39495 40837 39495	No No No No **Yes (BRAGFLO, NUTS, SECOFL2D, SECOTP2D)** No **Yes (BRAGFLO, NUTS)**	5-4 5-4 5-4 5-4 5-4 5-4 5-4	

FEP No.	FEP Name	SNL Side Effort Number	WPO Number for final CCA supporting documentation	Is FEP Screening Based on Use of WIPP PA Code?	FEP Analysis Plan Number	EPA Assessment of Analysis Process
H22	Drilling fluid loss	RI2 RI3 RI4 RI9 NS21	35396 36951 36951 35396 40837	No No No No No	5-4 5-4 5-4 5-4 5-4	
H25	Oil and gas extraction	RI5	37473	No	5-4	
H26	Groundwater extraction	RI5 RI6 RI7 RI8 RI10 NS4a NS4b NS5a NS5b	37473 36951 36951 36951 35442 42037 42037 40831 30758 (Phase 1)	No No No No No No No No No	5-4 5-4 5-4 5-4 5-4 5-4 5-4 5-4 5-2	
H27	Liquid waste disposal	RI5 RI10 NS7a NS17 NS18	37473 35442 40837 39424 39424	No No **Yes (BRAGFLO)** No No	5-4 5-4 5-4 5-4 5-4	
H28	Enhanced oil and gas production	RI5 RI10 NS7a NS17 NS18	37473 35442 40837 39424 39424	No No **Yes (BRAGFLO)** No No	5-4 5-4 5-4 5-4 5-4	
H29	Hydrocarbon storage	RI5 RI10 NS7a NS17 NS18	37473 35442 40837 39424 39424	No No **Yes (BRAGFLO)** No No	5-4 5-4 5-4 5-4 5-4	

FEP No.	FEP Name	SNL Side Effort Number	WPO Number for final CCA supporting documentation	Is FEP Screening Based on Use of WIPP PA Code?	FEP Analysis Plan Number	EPA Assessment of Analysis Process
H31	Natural borehole fluid flow	RI1 RI9 NS21 NS2 NS3 NS7b NS17 NS18	35396 35396 40837 40820 40821 40819 39424 39424	No No No No No **Yes (SECOFL2D)** No No	5-4 5-4 5-4 5-4 5-4 5-4 5-4 5-4	
H32	Waste-induced borehole flow	RI2 RI9 NS21	35396 35396 30659	No No No	5-4 5-4 5-4	
H33	Flow through undetected boreholes	RI13	35442	No	5-4	
H34	Borehole-induced solution and subsidence	RI1	35396	No	5-4	
H35	Borehole-induced mineralization	RI1	35396	No	5-4	
H36	Borehole-induced geochemical changes	RI1	35396	No	5-4	
H37	Changes in groundwater flow due to mining	NS11 S15b	40816 42716	**Yes (SECOFL2D)** No	5-4 5-4	
H47	Greenhouse gas effects	RI11	35448	No	5-4	

6. Treatment of FEPs Accounted for in Performance Assessment Calculations

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
N1	Stratigraphy	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO model geometry	2.1.3 6.4.2	Appendix PAR, Table PAR-57	See also Chapter 6, Figures 6-13 and 6-14
N2	Brine reservoirs	E1	Model	Accounted for in BRAGFLO for E scenarios	6.4.8 6.4.12.6		See Chapter 6, Figure 6-14 for model setup, and Appendix MASS, Section 18 and Appendix PAR, Parameters 27, 28, 29, 31 and Table PAR-50 for FEP treatment
N12	Seismic activity	UP, M, E1, E2	Parameter	Accounted for in the DRZ permeability used by BRAGFLO	6.4.5.3	Appendix PAR, Table PAR-37	
N16	Shallow dissolution	UP, M, E1, E2	Parameter	Accounted for in the Culebra transmissivity fields	6.4.6.2	Appendix PAR, Parameters 35, 50, 51	
N23	Saturated groundwater flow	UP, M, E1, E2	Model	Accounted for in BRAGFLO treatment of two-phase flow, and in SECOFL2D representation of flow in the Culebra	2.2.1 6.4.5 6.4.6	Appendix BRAGFLO, Sections 4.1 to 4.4 Appendix SECOFL2D, Section 3	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
N24	Unsaturated groundwater flow	UP, M, E1, E2	Model	Accounted for in BRAGFLO treatment of two-phase flow	2.2.1 6.4.6	Appendix BRAGFLO, Sections 4.8 and 4.9	
N25	Fracture flow	UP, M, E1, E2	Model	Accounted for in SECOTP2D treatment of flow in the Culebra	6.4.6.2	Appendix SECOTP2D, Sections 2 and 3.4	
N27	Effects of preferential pathways	UP, M, E1, E2	Parameter	Accounted for in the Culebra transmissivity fields	6.4.6.2	Appendix PAR, Parameters 35, 50, 51	
N33	Groundwater geochemistry	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model, and in the actinide transport and retardation model used by SECOTP2D	2.2.1 6.4.6.2 6.4.3.4	Appendix PAR, Parameters 36 to 47, 52 to 57, Table PAR-39	
N39	Physiography	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO model geometry	2.1.4 6.4.2	Appendix PAR, Table PAR-57	
N53	Groundwater discharge	UP, M, E1, E2	Parameter	Accounted for in specification of boundary conditions to SECOFL2D	2.2.2 6.4.10.2	Appendix PAR, Parameter 35, Table PAR-30	See also Appendix TFIELD, Section 3
N54	Groundwater recharge	UP, M, E1, E2	Parameter	Accounted for in specification of boundary conditions to SECOFL2D	2.2.1.1 6.4.10.2	Appendix PAR, Parameter 35, Table PAR-30	See also Appendix TFIELD, Section 3
N55	Infiltration	UP, M, E1, E2	Parameter	Accounted for in specification of boundary conditions to SECOFL2D	2.2.2 6.4.10.2	Appendix PAR, Parameter 35, Table PAR-30	See also Appendix TFIELD, Section 3

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
N56	Changes in groundwater recharge and discharge	UP, M, E1, E2	Parameter	Accounted for by the climate change model	2.5 6.4.9	Appendix PAR, Parameter 48	
N59	Precipitation (for example, rainfall)	UP, M, E1, E2	Parameter	Accounted for by the climate change model	2.5 6.4.9	Appendix PAR, Parameter 48	
N60	Temperature	UP, M, E1, E2	Parameter	Accounted for by the climate change model	2.5 6.4.9	Appendix PAR, Parameter 48	
N61	Climate change	UP, M, E1, E2	Parameter	Accounted for by the climate change model	2.5 6.4.9	Appendix PAR, Parameter 48	
W1	Disposal geometry	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO model geometry	3.2 6.4.2.1		See Chapter 6, Figures 6-13 and 6-14
W2	Waste inventory	UP, M, E1, E2	Parameter	Accounted for in the actinide isotope inventory	4.1 6.4.3.5 6.4.3.3	Appendix PAR, Table PAR-41	
W3	Heterogeneity of waste forms	E1, E2	Parameter	Accounted for in the waste activity probabilities used by CCDFGF	6.4.12.4		See Chapter 6, Figure 6-31
W5	Container material inventory	UP, M, E1, E2	Parameter	Accounted for in CDFs for gas generation rates used by BRAGFLO	6.4.3.3	Appendix PAR, Parameter 1, Table PAR-43	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W6	Seal geometry	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO model geometry	3.8 6.4.4		See Appendix PAR, Figure PAR-2 and Chapter 6, Figures 6-13 and 6-14
W7	Seal physical properties	UP, M, E1, E2	Parameter	Accounted for in seal parameter values used by BRAGFLO	6.4.4 6.4.3	Appendix PAR, Parameters 9 to 11, Tables PAR-16 to PAR-24	
W10	Backfill chemical composition	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model	6.4.3.4	Appendix PAR, Parameters 36 to 47, Table PAR-39	
W12	Radionuclide decay and ingrowth	UP, M, E1, E2	Model	Accounted for in NUTS, PANEL and SECOTP2D	6.4.12.4 6.4.5.4.2	Appendix NUTS, Section 4.3.7 Appendix SECOTP2D, Section 2 Appendix PANEL, Section 4.6	See also Appendix BIR, Rev. 3, Section 3.2
W18	Disturbed rock zone	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO parameter values and materials definition	6.4.5.3	Appendix PAR, Parameter 12, Tables PAR-2, PAR-3, PAR-37	
W19	Excavation-induced changes in stress	UP, M, E1, E2	Parameter	Accounted for in the creep closure model in BRAGFLO	6.4.3.1	Appendix PAR Table PAR-38	See also Appendix PORSURF, Attachment PORSURF-6

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W20	Salt creep	UP, M, E1, E2	Parameter	Accounted for in the creep closure model in BRAGFLO	6.4.3.1	Appendix PAR Table PAR-38	See also Appendix PORSURF, Attachment PORSURF-6
W21	Changes in the stress field	UP, M, E1, E2	Parameter	Accounted for in the creep closure model in BRAGFLO	6.4.3.1	Appendix PAR Table PAR-38	See also Appendix PORSURF, Attachment PORSURF-6
W22	Roof falls	UP, M, E1, E2	Parameter	Accounted for in the permeability of the DRZ used by BRAGFLO	6.4.5.3	Appendix PAR, Table PAR-37	
W25	Disruption due to gas effects	UP, M, E1, E2	Model	Accounted for in BRAGFLO fracture model for Salado interbeds	6.4.5.2	Appendix BRAGFLO, Section 4.10	See also Appendix MASS, Attachment 13-2
W26	Pressurization	UP, M, E1, E2	Model	Accounted for in the creep closure model in BRAGFLO	6.4.3.1	Appendix BRAGFLO, Section 4.11	See also Appendix PORSURF, Attachment PORSURF-6
W27	Gas explosions	UP, M, E1, E2	Parameter	Accounted for in the permeability of the DRZ used by BRAGFLO	6.4.5.3	Appendix PAR, Table PAR-37	
W32	Consolidation of waste	UP, M, E1, E2	Parameter	Accounted for in the creep closure model in BRAGFLO	6.4.3.1	Appendix PAR, Table PAR-38	See also Appendix PORSURF, Attachment PORSURF-6

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W36	Consolidation of seals	UP, M, E1, E2	Parameter	Accounted for in seal parameters used by BRAGFLO	6.4.4	Appendix PAR, Parameters 9 to 11 and 13, Tables PAR-16 to PAR-24	
W37	Mechanical degradation of seals	UP, M, E1, E2	Parameter	Accounted for in seal parameters used by BRAGFLO	6.4.4	Appendix PAR, Parameters 9 to 11 and 13, Tables PAR-16 to PAR-24	
W39	Underground boreholes	UP, M, E1, E2	Parameter	Accounted for in the permeability of the DRZ used by BRAGFLO	6.4.5.3	Appendix PAR, Table PAR-37	
W40	Brine inflow	UP, M, E1, E2	Model	Accounted for in BRAGFLO treatment of two-phase flow	6.4.3.2	Appendix BRAGFLO, Section 4.8	
W41	Wicking	UP, M, E1, E2	Parameter	Accounted for in BRAGFLO gas generation model	6.4.3.2	Appendix PAR, Parameter 8	
W42	Fluid flow due to gas production	UP, M, E1, E2	Model	Accounted for in BRAGFLO treatment of two-phase flow	6.4.3.2	Appendix BRAGFLO, Section 4.8	
W44	Degradation of organic material	UP, M, E1, E2	Model	Accounted for in BRAGFLO gas generation model	6.4.3.3	Appendix BRAGFLO, Section 4.13	See also Appendix MASS, Attachment 8-2

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W45	Effects of temperature on microbial gas generation	UP, M, E1, E2	Parameter	Accounted for in CDFs for gas generation rates used by BRAGFLO	6.4.3.3	Appendix PAR, Parameters 3 to 5, Table PAR-43	
W48	Effects of biofilms on microbial gas generation	UP, M, E1, E2	Parameter	Accounted for in CDFs for gas generation rates used by BRAGFLO	6.4.3.3	Appendix PAR, Parameters 3 to 5, Table PAR-43	
W49	Gases from metal corrosion	UP, M, E1, E2	Model	Accounted for in BRAGFLO gas generation model	6.4.3.3	Appendix BRAGFLO, Section 4.13	See also Appendix MASS, Attachment 8-2
W51	Chemical effects of corrosion	UP, M, E1, E2	Parameter	Accounted for in CDFs for gas generation rates used by BRAGFLO	6.4.3.3	Appendix PAR, Parameter 1, Table PAR-43	
W56	Speciation	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model, and in actinide transport and retardation model in SECOTP2D	6.4.3.4 6.4.3.5 6.4.6.2	Appendix PAR, Parameters 36 to 47, 52 to 57, Table PAR-39	
W58	Dissolution of waste	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model	6.4.3.5	Appendix PAR, Parameters 36 to 47, Table PAR-39	
W61	Actinide sorption	UP, M, E1, E2	Model	Accounted for in actinide retardation model in SECOTP2D	6.4.3.6 6.4.6.2.1	Appendix SECOTP2D, Section 2	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W62	Kinetics of sorption	UP, M, E1, E2	Parameter	Accounted for in actinide retardation parameters in SECOTP2D	6.4.6.2.1	Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	
W63	Changes in sorptive surfaces	UP, M, E1, E2	Parameter	Accounted for in actinide retardation parameters in SECOTP2D	6.4.6.2.1	Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	
W64	Effect of metal corrosion	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model	6.4.3.5	Appendix PAR, Parameters 36 to 47, Table PAR-39	
W66	Reduction-oxidation kinetics	UP, M, E1, E2	Parameter	Accounted for in the actinide source term model	6.4.3.5	Appendix PAR, Parameters 36 to 47, Table PAR-39	
W70	Humic and fulvic acids	UP, M, E1, E2	Parameter	Accounted for in estimates of the colloidal actinide source term	6.4.3.6 6.4.6.2.2	Appendix PAR, Parameter 46, Table PAR-39	
W74	Chemical degradation of seals	UP, M, E1, E2	Parameter	Accounted for in seal parameters in BRAGFLO	6.4.4	Appendix PAR, Parameter 10, Table PAR-19	
W76	Microbial growth on concrete	UP, M, E1, E2	Parameter	Accounted for in seal parameters in BRAGFLO	6.4.4	Appendix PAR, Parameter 10, Table PAR-19	
W77	Solute transport	UP, M, E1, E2	Model	Accounted for by NUTS in the Salado and SECOTP2D in the Culebra	6.4.5.4 6.4.6.2.1	Appendix NUTS, Section 4.3 Appendix SECOTP2D, Section 2	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W78	Colloid transport	UP, M, E1, E2	Model	Advection and diffusion of humic colloids in the Culebra is estimated with SECOTP2D	6.4.6.2.2	Appendix SECOTP2D, Section 2	See also Appendix MASS, Section 15.3 and Attachments 15-2 and 15-8
W79	Colloid formation and stability	UP, M, E1, E2	Parameter	Accounted for in the colloidal actinide source term model	6.4.3.6	Appendix PAR, Parameter 46, Table PAR-39	
W80	Colloid filtration	UP, M, E1, E2	Model	Accounted for in treatment of transport for microbial and mineral fragment colloidal particles	6.4.6.2.2		See Appendix MASS, Section 15.3 and Attachment 15-9
W81	Colloid sorption	UP, M, E1, E2	Model	Accounted for in estimates of humic colloid retardation used by SECOTP2D	6.4.6.2.2	Appendix SECOTP2D, Section 2	See also Appendix MASS, Section 15.3 and Attachment 15-8
W82	Suspensions of particles	E1, E2	Model	Accounted for in CUTTINGS_S treatment of releases through boreholes	6.4.7.1	Appendix CUTTINGS, Appendix A.2	
W84	Cuttings	E1, E2	Model	Accounted for in CUTTINGS_S treatment of releases through boreholes	6.4.7.1	Appendix CUTTINGS, Appendix A.2.1	
W85	Cavings	E1, E2	Model	Accounted for in CUTTINGS_S treatment of releases through boreholes	6.4.7.1	Appendix CUTTINGS, Appendix A.2.2	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
W86	Spallings	E1, E2	Model	Accounted for in CUTTINGS_S treatment of releases through boreholes	6.4.7.1	Appendix CUTTINGS, Appendix A.2.4	
W87	Microbial transport	UP, M, E1, E2	Model	Accounted for by treatment of microbes as colloid	6.4.6.2.2		See Appendix SOTERM, Section 6.3.4
W90	Advection	UP, M, E1, E2	Model	Accounted for by NUTS in the Salado and SECOTP2D in the Culebra	6.4.5.4 6.4.6.2	Appendix NUTS, Sections 4.3.1 and 4.3.2 Appendix SECOTP2D, Section 2	
W91	Diffusion	UP, M, E1, E2	Model	Accounted for by SECOTP2D in the Culebra	6.4.6.2 6.4.5.4	Appendix SECOTP2D, Section 2	Also discussed in Appendix NUTS, Section 4.3.3
W92	Matrix diffusion	UP, M, E1, E2	Model	Accounted for by SECOTP2D in the Culebra	6.4.6.2	Appendix SECOTP2D, Sections 2, 3.5 and 3.6	
H1	Oil and gas exploration	E1, E2	Parameter	Drilling of deep boreholes[a] is accounted for in estimates of drilling frequency used by CCDFGF	2.3.1.2 6.4.7 6.4.12.2	Appendix PAR, Table PAR-53	
H2	Potash exploration	E1, E2	Parameter	Drilling of deep boreholes is accounted for in estimates of drilling frequency used by CCDFGF	2.3.1.1 6.4.7 6.4.12.2	Appendix PAR, Table PAR-53	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
H4	Oil and gas exploitation	E1, E2	Parameter	Drilling of deep boreholes is accounted for in estimates of drilling frequency used by CCDFGF	2.3.1.2 6.4.7 6.4.12.2	Appendix PAR, Table PAR-53	
H8	Other resources	E1, E2	Parameter	Drilling of deep boreholes is accounted for in estimates of drilling frequency used by CCDFGF	2.3.1.3 6.4.7 6.4.12.2	Appendix PAR, Table PAR-53	
H9	Enhanced oil and gas recovery	E1, E2	Parameter	Drilling of deep boreholes is accounted for in estimates of drilling frequency used by CCDFGF	2.3.1.2 6.4.7 6.4.12.2	Appendix PAR, Table PAR-53	
H13	Potash mining	UP, M, E1, E2	Parameter	Potash mining outside the controlled area is accounted for in all scenarios by modifying the Culebra transmissivity fields used by SECOFL2D. Future potash mining inside the controlled area is accounted for in disturbed performance scenarios by modifying the Culebra transmissivity fields used by SECOFL2D	6.4.6.2.3 6.4.12.8 6.4.13.8	Appendix PAR, Parameter 34	

[a] Deep drilling means those drilling events in the Delaware Basin that reach or exceed a depth of 2,150 feet below the surface relative to where such drilling occurred.

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
H21	Drilling fluid flow	E1, E2	Model	Accounted for in spallings and direct brine release models	6.4.7.1	Appendix CUTTINGS, Appendix A.2.2 Appendix MASS, Attachment 16-2	Appendix MASS, Attachment 16-2 is the description of BRAGFLO_DBR
H22	Drilling fluid loss	E2	Parameter	Accounted for in the BRAGFLO treatment of brine flow	6.4.7.1	Appendix PAR, Parameters 1 and 3, Table PAR-43	
H23	Blowouts	E1, E2	Model	Accounted for in spallings and direct brine release models	6.4.7.1.1	Appendix CUTTINGS, Appendix A.2.4.1 Appendix MASS, Attachment 16-2	Appendix MASS, Attachment 16-2 is the description of BRAGFLO_DBR
H24	Drilling-induced geochemical changes	UP, M, E1, E2	Parameter	Accounted for by SECOPT2D in the Culebra	6.4.6.2	Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	
H30	Fluid injection-induced geochemical changes	UP, M, E1, E2	Parameter	Accounted for in SECOPT2D in the Culebra	6.4.6.2	Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	
H31	Natural borehole fluid flow	E1, E2	Model	Accounted for in BRAGFLO treatment of long-term releases through boreholes	6.4.7.2 6.4.12.7 6.4.13	Appendix BRAGFLO, Section 4.8	
H32	Waste-induced borehole flow	E1, E2	Model	Accounted for in BRAGFLO treatment of long-term releases through boreholes	6.4.7 6.4.2.1	Appendix BRAGFLO, Section 4.8	

FEP No.	FEP Name	*Scenario	FEP In-corporation	FEP Treatment	CCA cross-references	Parameter or Model	Comments
H36	Borehole-induced geochemical changes	UP, M, E1, E2	Parameter	Accounted for in SECOPT2D in the Culebra	6.4.6.2	Appendix PAR, Parameters 47 and 52 to 57, Table PAR-39	
H37	Changes in groundwater flow due to mining	UP, M, E1, E2	Parameter	Changes in groundwater flow due to mining outside the controlled area are accounted for in all scenarios by modifying the Culebra transmissivity fields used by SECOFL2D. Changes in groundwater flow due to future mining inside the controlled area are accounted for in disturbed performance scenarios by modifying the Culebra transmissivity fields used by SECOFL2D	6.4.6.2.3 6.4.12.8 6.4.13.8	Appendix PAR, Parameter 34	
H57	Loss of records	M, E1, E2	Parameter	Accounted for in estimates of the probability of inadvertent human intrusion	6.3 6.4.7 6.4.12.1	Appendix PAR, Table PAR-53	