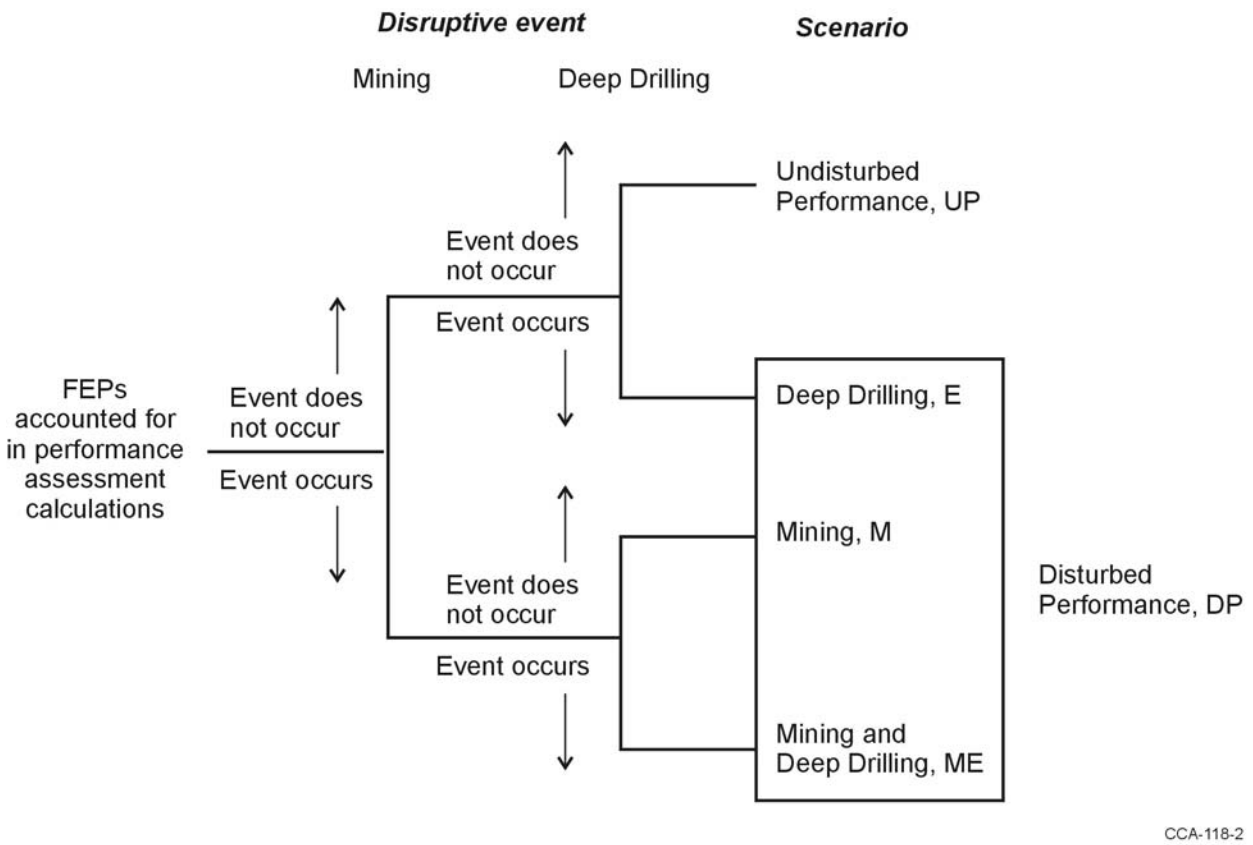

Figure ~~6-7~~*6-8*. Logic Diagram for Scenario Analysis

No potentially disruptive natural EPs are likely to occur during the regulatory time frame (Section 6.2.3 and Appendix ***PA*** ~~SCR~~, ***Attachment SCR*** ~~Section SCR.1~~). Therefore, all naturally occurring EPs retained for scenario construction are nondisruptive and are considered as part of ~~undisturbed performance~~***(UP)***. The only natural features and waste- and repository-induced FEPs retained after screening that are not included in the ~~undisturbed performance~~***(UP)*** scenario but are included in ~~disturbed performance~~***(DP)*** are those directly associated with the potential effects of future deep drilling within the controlled area. These drilling-related FEPs are discussed in Section 6.3.2. Potash mining outside the controlled area does not constitute a disruption of the disposal system by human intrusion and is included in the ~~undisturbed performance~~***(UP)*** scenario. In total, ***70*** ~~67~~ ~~undisturbed performance~~***(UP)*** FEPs ~~have been~~ ***were*** identified (Section 6.2.3). These FEPs have been assigned a screening designator ~~undisturbed performance~~***(UP)*** in tables in Section 6.2.3 and ~~Appendix SCR and~~ are listed separately in ***Table 6-8***~~Table 6-6~~. ***Table 6-8***~~Table 6-6~~ also contains references to text in Section 6.4 that describes the conceptual models***,*** ~~that~~ ***which*** account for the UP FEPs.

Among the most significant FEPs that will affect the ~~undisturbed performance~~***(UP)*** within the disposal system are excavation-induced fracturing, gas generation, salt creep, and MgO ~~backfill~~ in the disposal rooms.

- The ~~excavation of the~~ repository ***excavation*** and ~~the~~ consequent changes in the ***rock*** stress field ~~in the rock~~ surrounding the excavated opening will ~~result in the creation of~~

create a DRZ immediately adjacent to excavated openings. The DRZ will exhibit mechanical and hydrological properties different than those of the intact rock.

- Organic material in the waste may degrade because of microbial activity, and brine will corrode metals in the waste and waste containers, with concomitant generation of gases. Gas generation may result in pressures sufficient to both maintain or develop fractures and change the fluid flow pattern around the waste disposal region.

- At the repository depth, salt creep will tend to heal fractures and reduce the permeability of the DRZ and the crushed salt component of the long-term shaft seals to near that of the host rock salt.

- The MgO ~~backfill~~ ***engineered barrier*** emplaced in the disposal rooms will react with ~~carbon dioxide~~ CO_2 and maintain mildly alkaline conditions. Corrosion of metals in the waste and waste containers will maintain reducing conditions. These effects will ~~control~~ ***decrease*** radionuclide solubility.

Radionuclides can become mobile as a result of waste dissolution and colloid generation following brine flow into the disposal rooms. Colloids may be generated from the waste (humics, mineral fragments, and actinide intrinsic colloids) or from other sources (humics, mineral fragments, and microbes).

Conceptually, there are several pathways for radionuclide transport within the undisturbed disposal system that may result in releases to the accessible environment (Figure ~~6-8~~***6-9***). Contaminated brine may migrate away from the waste-disposal panels if pressure within the panels is elevated by ~~the generation of~~ gas ***generated*** from corrosion or microbial ***consumption*** ~~degradation~~. Radionuclide transport may occur laterally, through the anhydrite interbeds toward the subsurface boundary of the accessible environment in the Salado, or through access drifts or anhydrite interbeds ~~(primarily MB139)~~ to the base of the shafts. In the latter case, if the pressure gradient between the panels and overlying strata is sufficient, ~~then~~ contaminated brine may migrate up the shafts. As a result, radionuclides may be transported directly to the ground surface, or ~~they may be transported~~ laterally away from the shafts, through permeable strata such as the Culebra, toward the subsurface boundary of the accessible environment. These conceptual pathways are shown in Figure ~~6-8~~***6-9***.

The modeling system described in Section 6.4 includes potential radionuclide transport along other pathways, such as migration through Salado halite. However, the natural properties of the undisturbed system make radionuclide transport to the accessible environment via these other pathways unlikely.

6.3.2 Disturbed Performance

Assessments for compliance with 40 CFR § 191.13 need to consider the potential effects of future disruptive natural and human-initiated EPs on the performance of the disposal system. As discussed in Section 6.2.3, no potentially disruptive, natural EPs are considered ~~to be~~ sufficiently likely to require inclusion in analyses of either ~~undisturbed performance~~***(UP)*** or ~~disturbed performance~~***(DP)***. The only future human-initiated EPs retained after FEP screening are those

associated with mining and deep drilling (but not the subsequent use of a borehole) within the controlled area ~~at a time~~ when institutional controls cannot be assumed to eliminate the possibility of such activities (Sections 6.2.5.2 and 6.4.12.1). In total, 21 ~~disturbed performance~~***(DP)*** FEPs associated with future mining and deep drilling have been identified. These FEPs ~~have been~~ ***were*** assigned a screening designator ***"***DP***"*** in tables in Section 6.2 ~~and Appendix SCR~~ and are listed separately in ***Table 6-9***~~Table 6-7~~. ***Table 6-9***~~Table 6-7~~ also contains references to text in Section 6.4 that describes the conceptual models which account for the DP FEPs.

For ~~evaluation of~~ ***evaluating*** the consequences of ~~disturbed performance~~***(DP)***, the DOE has defined the mining scenario, M, the deep drilling scenario, E, and a mining and drilling scenario, ME. These scenarios are described in the following sections.

6.3.2.1 The Disturbed Performance Mining Scenario

The ~~disturbed performance~~***(DP)*** mining scenario, M, involves future mining within the controlled area.

Consistent with the criteria stated by the EPA in 40 CFR § 194.32 (b) for ~~performance assessment~~***PA*** calculations, the effects of potential future mining within the controlled area are limited to changes in hydraulic conductivity of the Culebra that result from subsidence (as described in Section 6.4.6.2.3.

Radionuclide transport may be affected in the M scenario if a head gradient between the waste-disposal panels and the Culebra causes brine contaminated with radionuclides to move from the waste-disposal panels to the base of the shafts and up ~~the shafts~~ to the Culebra. The changes in the Culebra transmissivity field may affect the rate and direction of radionuclide transport within the Culebra. Features of the M scenario are illustrated in Figure ~~6-9~~***6-10***.

The three disturbed performance FEPs labeled ***"***M***"*** in ***Table 6-9*** ~~Table 6-7~~ relate to the occurrence and effects of future mining. The modeling system used for the M scenario is similar to that developed for the UP scenario, but with a modified Culebra transmissivity field ~~within~~ ***in*** the controlled area to account for the ~~effects of~~ mining ***effects***.

6.3.2.2 The Disturbed Performance Deep Drilling Scenario

The ~~disturbed performance~~***DP*** deep drilling scenario, E, involves at least one deep drilling event that intersects the waste disposal region. The EPA provides criteria ~~concerning analysis of~~ ***for analyzing*** the consequences of future drilling events in PAs in 40 CFR § 194.33(c):

> Performance assessments shall document that in analyzing the consequences of drilling events, the Department assumed that:
>
> (1) Future drilling practices and technology will remain consistent with practices in the Delaware Basin at the time a compliance application is prepared. Such future drilling practices shall include, but shall not be limited to: the types and amounts of drilling fluids; borehole depths, diameters, and seals; and the fraction of such boreholes that are sealed by humans; and

Table *6-8* ~~6-6~~. Undisturbed Performance FEPs

UP FEPs	~~Chapter~~ *Section*
NATURAL FEPs	
Geological	
Stratigraphy	
Stratigraphy	6.4.2-
Structural effects	
Seismic activity	
Seismic activity	6.4.5.3-
Geochemical	
Dissolution	
Shallow dissolution	6.4.6.2-
Subsurface hydrological	
Groundwater characteristics	
Saturated groundwater flow	6.4.5 6.4.6-
Unsaturated groundwater flow	6.4.6-
Fracture flow	6.4.6.2-
Effects of preferential pathways	6.4.6.2-
Subsurface geochemical	
Groundwater geochemistry	
Groundwater geochemistry	6.4.3.4 6.4.6.2-
Geomorphological	
Physiography	
Physiography	6.4.2-
Surface hydrological	
Groundwater recharge and discharge	
Groundwater discharge	6.4.10.2-
Groundwater recharge	6.4.10.2-
Infiltration	6.4.10.2-
Changes in surface hydrology	
Changes in groundwater recharge and discharge	6.4.9
Climatic	
Climate	
Precipitation (for example, rainfall)	6.4.9-
Temperature	6.4.9-
Climate change	
Meteorological	
Climate change	6.4.9-

Table 6-8~~6-6~~. Undisturbed Performance FEPs — Continued

UP FEPs	~~Chapter~~ *Section*
WASTE- AND REPOSITORY-INDUCED FEPs	
Waste and repository characteristics	
Repository characteristics	
Disposal geometry	6.4.2.1-
Waste characteristics	
Waste inventory	6.4.3.3-
Container characteristics	
Container material inventory	6.4.3.3-
Seal characteristics	
Seal geometry	6.4.3-
Seal physical properties	6.4.4-
Backfill characteristics	
Backfill chemical composition	6.4.3.4-
Radiological	
Radioactive decay	
Radionuclide decay and ingrowth	6.4.5.4.2 6.4.12.4-
Geological and Mechanical	
Excavation-induced fracturing	
DRZ	6.4.5.3-
Excavation-induced changes in stress	6.4.3.1-
Rock creep	
Salt creep	6.4.3.1-
Changes in the stress field	6.4.3.1-
Roof falls	
Roof falls	6.4.5.3-
Effects of fluid pressure changes	
Disruption due to gas effects	6.4.5.2-
Pressurization	6.4.5.2-
Effects of explosions	
Gas explosions	6.4.5.3
Mechanical effects on material properties	
Consolidation of waste	6.4.3.1-
Consolidation of seals	6.4.4-
Mechanical degradation of seals	6.4.4-
Underground boreholes	6.4.5.3-
Subsurface hydrological and fluid dynamics	
Repository-induced flow	

Table *6-8*~~6-6~~. Undisturbed Performance FEPs — Continued

UP FEPs	~~Chapter~~ *Section*
Brine inflow	6.4.3.2-
Wicking	6.4.3.2-
Effects of gas generation	
Fluid flow due to gas production	6.4.3.2-
Geochemical and chemical	
Gas generation	
Microbial gas generation	
~~Degradation~~ *Consumption* of organic material*s*	6.4.3.3-
Effects of temperature on microbial gas generation	6.4.3.3-
Effects of biofilms on microbial gas generation	6.4.3.3-
Corrosion	
Gases from metal corrosion	6.4.3.3-
Chemical effects of corrosion	6.4.3.3-
Chemical speciation	
Speciation	6.4.3.4 6.4.3.5-
Precipitation and dissolution	
Dissolution of waste	6.4.3.5-
Sorption	
Actinide sorption	6.4.3.6 6.4.6.2.1-
Kinetics of sorption	6.4.6.2.1-
Changes in sorptive surfaces	6.4.6.2.1-
Reduction-oxidation chemistry	
Effect of metal corrosion	6.4.3.5-
Reduction-oxidation kinetics	6.4.3.5-
Organic complexation	
Organic complexation	***6.4.3.4***
Organic ligands	***6.4.3.4***
Humic and fulvic acids	6.4.3.6 6.4.6.2.2-
Chemical effects on material properties	
Chemical degradation of seals	6.4.4-
Microbial growth on concrete	6.4.4-
Contaminant transport mode	
Solute transport	

Table 6-8~~6-6~~. Undisturbed Performance FEPs — Continued

UP FEPs	~~Chapter~~ *Section*
Solute transport	6.4.5.4 6.4.6.2.1-
Colloid transport	
Colloid transport	6.4.6.2.2-
Colloid formation and stability	6.4.3.6-
Colloid filtration	6.4.6.2.2-
Colloid sorption	6.4.6.2.2-
Microbial transport	
Microbial transport	6.4.6.2.2-
Contaminant transport processes	
Advection	
Advection	6.4.5.4 6.4.6.2-
Diffusion	
Diffusion	6.4.5.4 6.4.6.2-
Matrix diffusion	6.4.6.2-
HUMAN-INITIATED EPs	
Geomorphological	
Surface disruptions	***6.4-***
Geological	
Excavation activities	
Potash mining outside controlled area	6.4.6.2.3 6.4.12.8 6.4.13.8-
Subsurface hydrological and geochemical	
Borehole fluid flow	
Drilling-induced flow	
Drilling induced geochemical changes	6.4.6.2-
Fluid injection	
Fluid injection-induced geochemical changes	6.4.6.2-
Flow through abandoned boreholes	
Borehole-induced geochemical changes	6.4.6.2-
Excavation-induced flow	
Changes in groundwater flow due to mining	6.4.6.2.3 6.4.12.8 6.4.13.8-

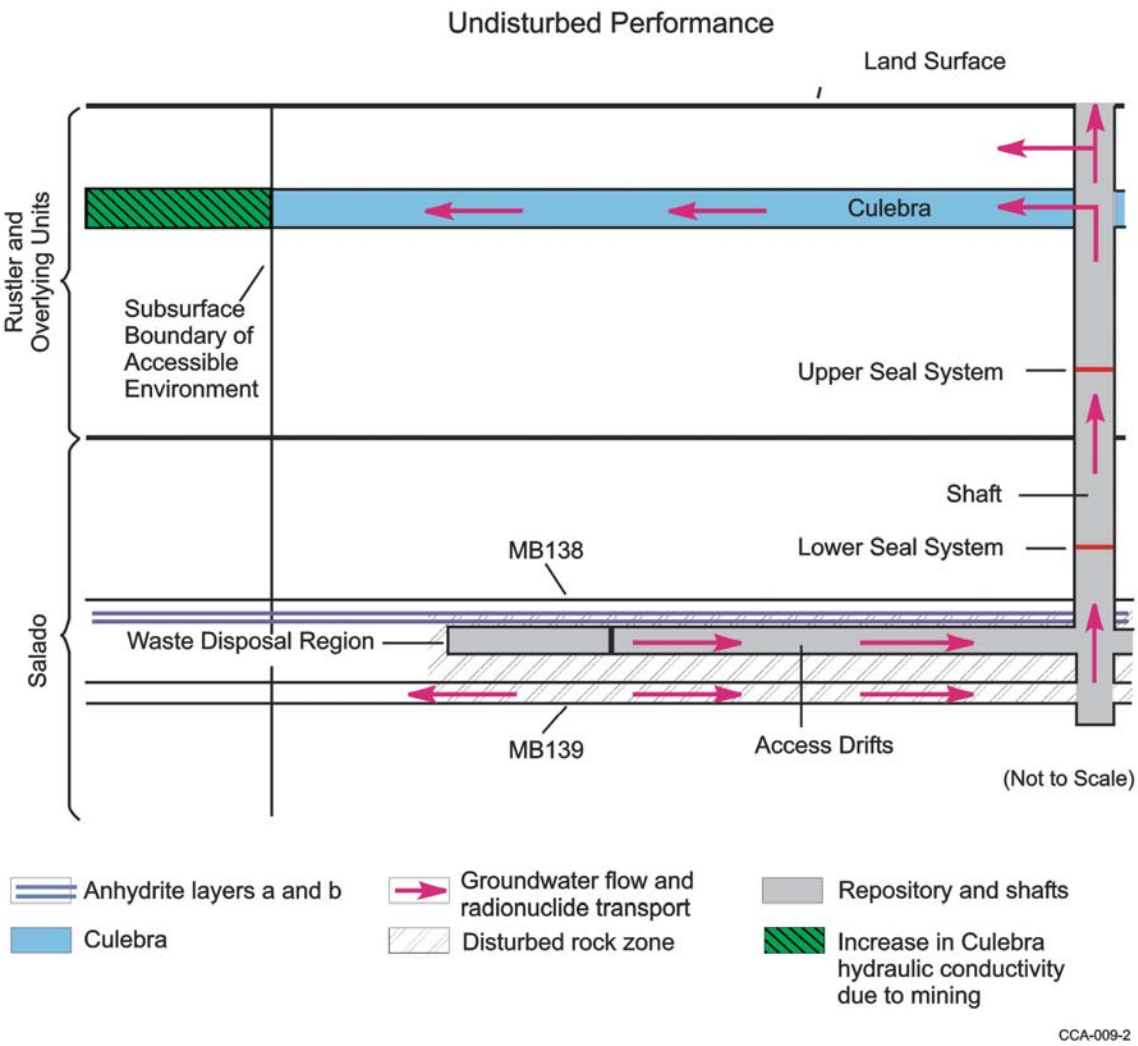

Figure ~~6-8~~*6-9*. Conceptual Release Pathways for the Undisturbed Performance Scenario

(2) Natural processes will degrade or otherwise affect the capability of boreholes to transmit fluids over the regulatory time frame.

Consistent with these criteria, there are several pathways for radionuclides to reach the accessible environment in the E scenario. ~~During the period b~~***B***efore any deep drilling intersects the waste, potential release pathways are identical to those in the ~~undisturbed performance~~***UP*** scenario.

If a borehole intersects the waste in the disposal rooms, releases to the accessible environment may occur as material entrained in the circulating drilling fluid is brought to the surface, as discussed ~~further~~ in Section 6.4.7.1. Particulate waste brought to the surface may include cuttings, cavings, and spallings. Cuttings are the materials cut by the drill bit as it passes through waste. Cavings are the materials eroded by the drilling fluid in the annulus around the drill bit. Spallings are the materials ~~that may be~~ forced into the circulating drilling fluid if there is

Table 6-9~~6-7~~. Disturbed Performance FEPs

(FEPs)	Scenario	~~Chapter~~ *Section*
ALL UP FEPs		
NATURAL FEPs		
Geological		
Stratigraphy		
Brine reservoirs	E1	6.4.8 6.4.12.6-
WASTE- AND REPOSITORY-INDUCED FEPs		
Waste and repository characteristics		
Waste characteristics		
Heterogeneity of waste forms	E1, E2	6.4.12.4
Contaminant transport mode		
Particulate transport		
Suspensions of particles	E1, E2	6.4.7.1-
Cuttings	E1, E2	6.4.7.1-
Cavings	E1, E2	6.4.7.1-
Spallings	E1, E2	6.4.7.1 6.4.13.7-
HUMAN-INITIATED EPs		
Geological		
Drilling		
Oil and gas exploration	E1, E2	6.4.7 6.4.12.2-
Potash exploration	E1, E2	6.4.7 6.4.12.2-
Oil and gas exploitation	E1, E2	6.4.7 6.4.12.2-
Other resources	E1, E2	6.4.7 6.4.12.2-
Enhanced oil and gas recovery	E1, E2	6.4.7 6.4.12.2-
Excavation activities		
Potash mining	M	6.4.6.2.3 6.4.12.8 6.4.13.8-
Subsurface hydrological and geochemical		
Borehole fluid flow		
Drilling-induced flow		
Drilling fluid flow	E1, E2	6.4.7.1-
Drilling fluid loss	E2	6.4.7.1.1-
Blowouts	E1, E2	6.4.7.1.1-

Table *6-9* ~~6-7~~. Disturbed Performance FEPs — Continued

(FEPs)	Scenario	~~Chapter~~ *Section*
Drilling-induced geochemical changes	E1, E2	6.4.6.2-
Flow through abandoned boreholes		
Natural borehole fluid flow	E1, E2	6.4.7.2 6.4.12.7 6.4.13
Waste-induced borehole flow	E1, E2	6.4.7.2 6.4.12.7 6.4.13-
Borehole-induced geochemical changes	E1, E2	6.4.6.2-
Excavation-induced flow		
Changes to groundwater flow due to mining	M	6.4.6.2.3 6.4.12.8 6.4.13.8-
Ecological		
Social and technological developments		
Loss of records	M, E1, E2	6.4.7 6.4.12.1-

Legend:
M Mining within the controlled area.
E1 Deep drilling that intersects the waste disposal region and a brine reservoir in the Castile.
E2 Deep drilling that intersects a waste disposal panel.

sufficient pressure in the waste disposal panels. During drilling, contaminated brine may flow up the borehole and reach the surface, depending on fluid pressure within the waste disposal panels.

When abandoned, the borehole is assumed to be plugged in a manner consistent with current practice in the Delaware Basin (see Section 6.4.7.2; ***and*** Appendix DEL, Sections DEL.5 and DEL.6; ***Appendix DATA, Section 2,*** and ***CCA*** Appendix ***PA, Attachment*** MASS, Section ~~MASS~~.16.3 ~~and MASS Attachment 16-1~~). An abandoned intrusion borehole with degraded casing and/or plugs may provide a pathway for fluid flow and contaminant transport from the intersected waste panel to the ground surface if the fluid pressure within the panel is sufficiently greater than hydrostatic. Additionally, if brine flows through the borehole to overlying units, such as the Culebra, it may carry dissolved and colloidal actinides that can be transported laterally to the accessible environment by natural groundwater flow in the overlying units.

Alternatively, the units intersected by an intrusion borehole may provide sources for brine flow to a waste panel during or after drilling. For example, in the northern Delaware Basin, the Castile, which underlies the Salado, contains isolated volumes of brine at fluid pressures greater than hydrostatic (as discussed in Section 2.2.1.2.2). The WIPP-12 penetration of one of these reservoirs provided data on one brine reservoir within the controlled area. The location and properties of brine reservoirs cannot be reliably predicted; thus, the possibility of a deep borehole penetrating both a waste panel and a brine reservoir is accounted for in consequence analysis of the WIPP, as discussed in Section 6.4.8. Such a borehole could provide a connection for brine

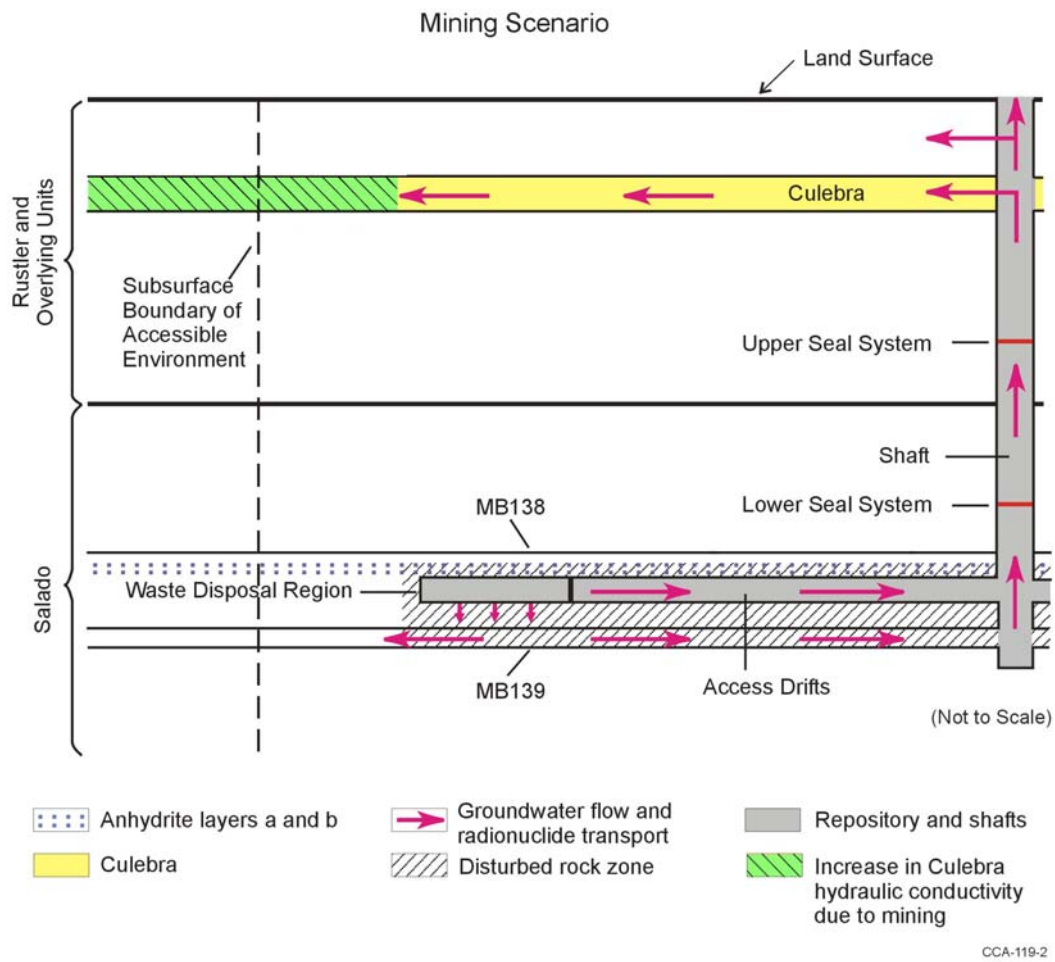

Figure ~~6-9~~*6-10*. Conceptual Release Pathways for the Disturbed Performance Mining Scenario

flow from the Castile to the waste panel, thus increasing fluid pressure and brine volume in the waste panel.

~~Also, a~~*A* borehole that is drilled through a disposal room pillar, but does not intersect waste, could ***also*** penetrate the brine reservoir underlying the waste disposal region. Such an event would, to some extent, depressurize the brine reservoir, and thus would affect the consequences of any subsequent ~~intersections of the~~ reservoir ***intersections***. ***The PA does not take credit for possible brine reservoir depressurization.*** ~~The possibility for boreholes that do not penetrate the waste to depressurize a brine reservoir underlying the waste disposal region is accounted for in the consequence analysis of the WIPP.~~

The DOE has distinguished two types of deep drilling events by whether or not the borehole intersects a Castile brine reservoir. A borehole that intersects a waste disposal panel and penetrates a Castile brine reservoir ~~has been~~ ***is*** designated an E1 event. The 18 ~~disturbed performance~~ ***DP*** FEPs labeled ***"***E1***"*** in ***Table 6-9***~~Table 6-7~~ relate to the occurrence and effects of

an E1 drilling event. A borehole that intersects a waste panel but does not penetrate a Castile brine reservoir ~~has been~~ ***is*** designated an E2 event. The 18 DP FEPs labeled ***"***E2***"*** in ***Table 6-9***~~Table 6-7~~ relate to the occurrence and effects of an ***"***E2***"*** drilling event.

In order to evaluate the consequences of future deep drilling, the DOE has divided the E scenario into three drilling subscenarios; E1, E2, and E1E2, distinguished by the number of E1 and E2 drilling events that are probabilistically assumed to occur in the regulatory time frame. These subscenarios are described in order of increasing complexity in the following sections.

6.3.2.2.1 The E2 Scenario

The E2 scenario is the simplest scenario for inadvertent human intrusion into a waste disposal panel. In this scenario, a panel is penetrated by a drill bit; cuttings, cavings, spallings, and brine flow releases may occur; and brine flow may occur in the borehole after it is plugged and abandoned. Sources for brine that may contribute to long-term flow up the abandoned borehole are the Salado or, under certain conditions, the units above the Salado. An E2 scenario may involve more than one E2 drilling event. Features of the E2 scenario are illustrated in Figure ~~6-10~~***6-11***. A modeling system has been developed to evaluate the consequences of an E2 scenario during which single or multiple E2 events occur.

6.3.2.2.2 The E1 Scenario

Any scenario with one inadvertent penetration of a waste panel that also penetrates a Castile brine reservoir is called E1. Features of this scenario are illustrated in Figure ~~6-11~~***6-12***.

Sources of brine in the E1 scenario are the brine reservoir, the Salado and, under certain conditions, the units above the Salado. However, the brine reservoir is conceptually the dominant source of brine in this scenario. The model configuration developed for the E1 scenario ~~is used to~~ evaluate***s*** the consequences of futures that have only one E1 event. ~~A future during which more than one E1 event occurs is described as an E1E2 scenario.~~

6.3.2.2.3 The E1E2 Scenario

The E1E2 scenario is defined as all futures ~~that have~~ ***with*** multiple penetrations of a waste panel of which at least one intrusion is an E1~~-type~~. One case of this scenario, with a single E1 event and a single E2 event penetrating the same panel, is illustrated in Figure ~~6-12~~***6-13***. However, the E1E2 scenario can include many possible combinations of intrusion times, locations, and types of event (E1 or E2). The sources of brine in this scenario are those listed for the E1 scenario, and multiple E1~~-type~~ sources may be present. The E1E2 scenario has a potential~~ly~~ flow path not present in the E1 or E2 scenarios: flow from an E1 borehole through the waste to another borehole. This flow path has the potential to (1) bring large quantities of brine in direct contact with waste and (2) provide a less restrictive path for this brine to flow to the units above the Salado (via multiple boreholes) compared to either the individual E1 or E2 scenarios. It is both the presence of brine reservoirs and the potential for flow through the waste to other boreholes that make this scenario different in terms of potential consequences from combinations of E2 boreholes. The extent to which flow occurs between boreholes, as estimated by modeling, determines whether combinations of E1 and E2 boreholes at specific locations in the repository should be treated as E1E2 scenarios or as independent E1 and E2 scenarios in the consequence

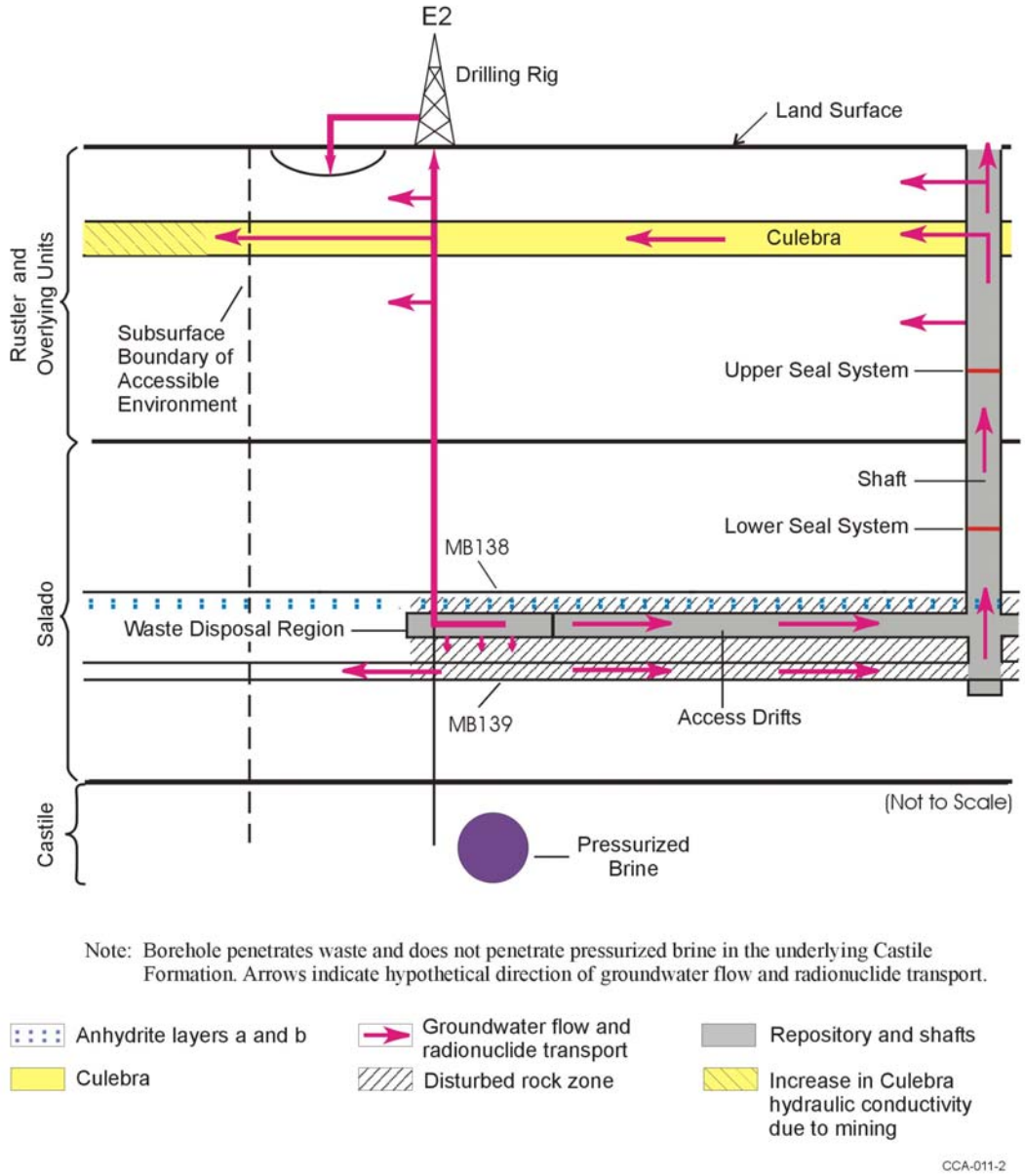

Figure ~~6-10~~*6-11*. Conceptual Release Pathways for the Disturbed Performance Deep Drilling E2 Scenario

analysis. ~~Because of the number of~~ ***The*** possible combinations of drilling events~~,~~ ***make*** the modeling configuration for the E1E2 scenario differ~~s~~ in significant ways from ~~the model configuration~~ ***that*** used ~~for evaluating~~ ***to evaluate*** E1 and E2 scenarios. This configuration is described in Section 6.4.13.5.

6.3.2.3 <u>The Disturbed Performance Mining and Deep Drilling Scenario</u>

Mining in the WIPP site (the M scenario) and deep drilling (the E scenario) may both occur in the future. The DOE calls a future in which both of these events occur the ME scenario. The

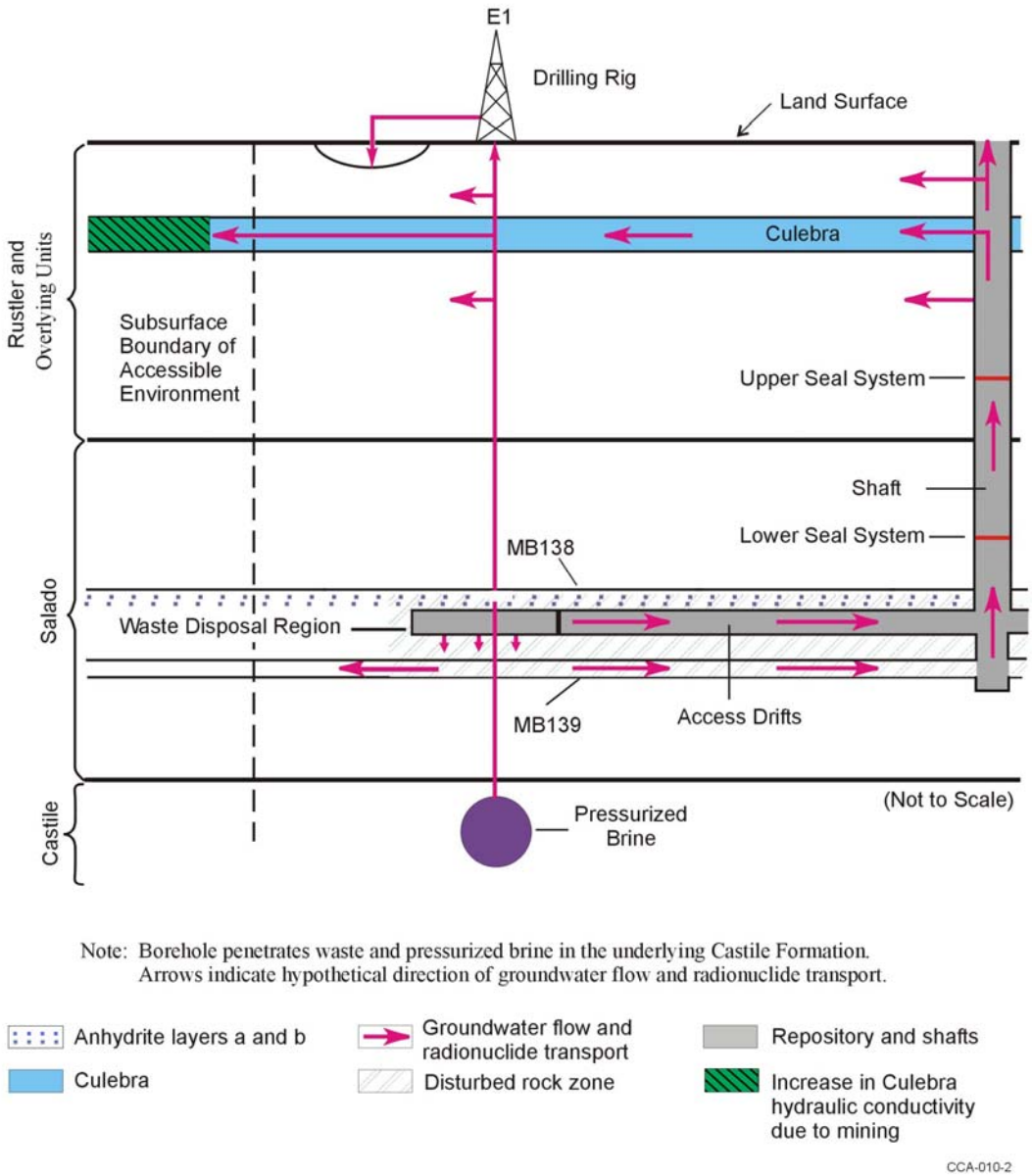

Figure ~~6-11~~*6-12*. Conceptual Release Pathways for the Disturbed Performance Deep Drilling Scenario E1

occurrence of both mining and deep drilling do not create processes ~~in addition to~~ ***beyond*** those already described separately for the M and E scenarios. For example, the occurrence of mining does not influence any of the interactions between deep boreholes and the repository or brine reservoirs. ~~As well, t~~T***Nor does t***he occurrence of drilling ~~does not~~ impact the effects of mining on Culebra hydrogeology~~, either~~. The difference between the M and E scenarios considered separately and the ME scenario is that the combination of borehole transport to the Culebra (E) and a transmissivity field impacted by mining (M) may result in more rapid transport of actinides to the accessible environment. For example, because the M scenario does not include drilling the only pathway for actinides to reach the Culebra is up the sealed shafts. For clarity in describing

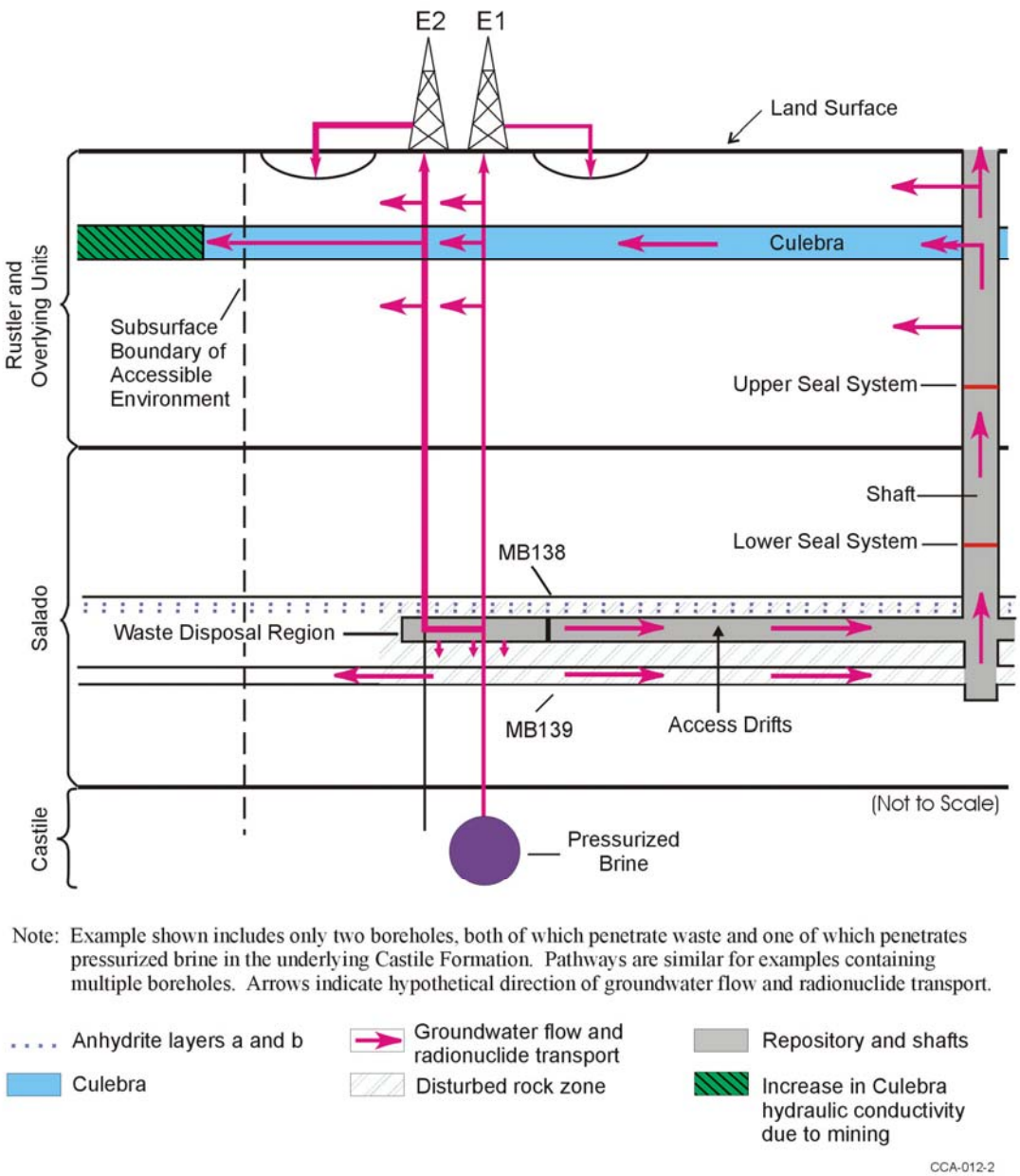

Figure ~~6-12~~*6-13.* Conceptual Release Pathways for the Disturbed Performance Deep Drilling Scenario E1E2

computational results, the ME scenario has been subdivided according to the types of deep drilling subscenarios into the ME1 scenario (M and E1), the ME2 scenario (M and E2), and the ME1E2 scenario (M and E1E2).

The system used ~~for~~ ***to*** model~~ing~~ flow and transport in the Culebra for the ME scenario is similar to that used for the E scenario. However, in the ME scenario, the Culebra transmissivity field is modified to account for ~~the effects of~~ mining within the controlled area.

6.3.3 Scenarios Retained for Consequence Analysis

The~~se~~ scenarios described in Sections 6.3.1 and 6.3.2 have been retained for consequence analysis to determine compliance with the Containment Requirements in 40 CFR § 191.13. The modeling systems used to evaluate the consequences of these ~~undisturbed performance~~***UP*** and ~~disturbed performance~~***DP*** scenarios are discussed in Section 6.4. For consequence analysis, the scenarios and subscenarios ~~described in this section~~ are further subdivided into scenarios, S_i. The S_i scenarios are distinguished by, for example, the time of occurrence of disruptive events. The S_i scenarios are generated, and their probabilities determined, by probabilistic sampling of selected processes and events (see Sections 6.1.5.2 and 6.4.12).

6.4 Calculation of Scenario Consequences

Scenario consequence, cS_i, is the third element of the ordered triples shown in Equation ***(6.***2***)*** in Section 6.1.1. ~~Estimation of~~ ***Estimating*** cS_i requires quantitative modeling. ~~Performance assessment~~***PA*** uses a linked system of individual computer codes. This section discusses the conceptual and computational models and some parameter values used to estimate the consequence of the scenarios described in Section 6.3. Additional discussion of conceptual models and modeling assumptions is provided in Appendix ***PA*** ~~MASS~~***, Section PA-2***. Additional descriptions of sampled parameter values are included in Appendix ***PA, Section 5.0 and Attachment*** PAR***.*** ~~(Parameters 1 to 57).~~

6.4.1 Types of Models

A single modeling system was used to represent the disposal system and calculate the CCDFs) presented in Section 6.5. The modeling system, however, can be conveniently described in terms of various submodels, with each describing a part of the overall system. This section ~~is organized to~~ provide***s***, for each submodel defined, an integrated, summary description of the conceptual model, mathematical model, numerical model, computational model, experimental data, and model parameters used. These terms are described below.

The models used in the WIPP ~~performance assessment~~***PA***, as in other complex analyses, exist at four different levels:

(1) **Conceptual models** are a set of qualitative assumptions ~~used to~~ ***that*** describe a system or subsystem for a given purpose. At a minimum, these assumptions concern the geometry and dimensionality of the system, initial and boundary conditions, time dependence, and the nature of the relevant physical and chemical processes. The assumptions should be consistent with one another and with existing information within the context of the given purpose.

(2) **Mathematical models** ~~are developed to~~ represent the processes at the site. The conceptual models provide the context within which these mathematical models must operate and define the processes they must characterize. The mathematical models are predictive in the sense that, once provided with the known or assumed properties of the system and possible perturbations to the system, they predict the response of the system. The processes represented by these mathematical models include fluid flow, mechanical

deformation, radionuclide transport in groundwater, and removal of waste through intruding boreholes.

(3) **Numerical models** are developed to ~~provide approximations of~~ ***approximate*** mathematical model solutions because most mathematical models do not have closed-form solutions.

(4) The complexity of the system requires ~~the use of~~ computer codes to solve the numerical models. The implementation of the numerical model in the computer code with specific initial and boundary conditions and parameter values is generally referred to as the **computational model**.

Data are descriptors of the physical system being considered, normally obtained by experiment or observation. Parameters are values necessary in mathematical, numerical, or computational models. The distinction between data and parameters can be subtle. Parameters are distinct from data, however, for three reasons. First, data may be evaluated, statistically or otherwise, to generate ~~for a~~ model parameters to account for uncertainty in data. Second, some parameters have no relation to the physical system, such as the parameters in a numerical model ~~specified~~ to determine when an iterative solution scheme has converged. Third, many model parameters are applied at a different scale than one ~~that can be~~ directly observed or measured in the physical system. The distinction between data and parameter values is described further in Appendix ***PA, Attachment*** PAR, where ~~the derivations of~~ distribution~~s~~ ***derivations*** for specific parameters are given. The interpretation and the scaling of experimental and field data are discussed in Appendix ***PA, Attachment*** PAR for individual and sampled parameters, as appropriate.

6.4.2 Model Geometries

Although the specific geometries used in ~~performance assessment~~***PA*** models are developed after the conceptual and mathematical models are defined, they are introduced here because they provide a useful framework for presenting the full discussion of the modeling system. ~~Performance assessment~~***PA*** represents the three-dimensional geometry of the disposal system (repository, shafts, and controlled area) using two primary two-dimensional simplifications. In the first ~~two-dimensional~~ geometry, processes that act on the entire disposal system occur within the repository and are simulated in the BRAGFLO (BRine And Gas FLOw) computer code using a geometry that approximates a north-south vertical cross section through the disposal system and some surrounding rock. This geometry ~~is used to~~ simulate***s*** processes in the disposal system, such as two-phase flow and movement of actinides, as well as processes acting only within the repository, such as creep closure of disposal rooms and gas generation. In the second ~~two-dimensional~~ geometry, groundwater flow and actinide transport in the Culebra, which provides a potential pathway for lateral transport of actinides to the accessible environment, are simulated in the ***MODFLOW-2000*** ~~SECOFL2D~~ and SECOTP2D computer codes using a two-dimensional horizontal geometry that treats the Culebra as a single layer. These two geometries are discussed in the following sections. ~~Additional geometries used to simulate system behavior during drilling intrusions are discussed in Sections 6.4.7 and 6.4.13.~~ ~~Performance assessment~~***PA*** codes and the flow of numerical information through the ~~performance assessment~~***PA*** are described in Section 6.4.11 and referenced appendices.