APPENDIX F
PHYSICAL AND CHEMICAL PROPERTIES OF THE WASTE/BACKFILL COMPOSITE

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PHYSICAL AND CHEMICAL PROPERTIES OF THE WASTE/BACKFILL COMPOSITE

1.0 INTRODUCTION

Quantitative estimates of physical and chemical properties for the combination of waste forms and backfill, when present, are required for the Design Analysis Model (DAM) to determine the relative effectiveness of each engineered alternative. In this section, the term "properties" refers to the physical and chemical properties of a homogeneous "composite" material consisting of the various waste forms (solid organics, solid inorganics, and sludges) and backfill material when present. The properties of a particular Engineered Alternative (EA) are in most cases unique to that alternative; in some cases, similarities occur from one alternative to another. Properties of the composite such as density, porosity, hydraulic conductivity, and effective waste volume, are quantified as a function of compaction stress level and are used in the DAM to predict the long-term performance of the disposal system under undisturbed conditions as well as human intrusion events.

The following sections briefly list the properties developed (Section 1.2), discuss the assumptions made in developing properties for the baseline case and for each of the EAs (Section 1.3), sources of data (Section 1.4), and finally, the quantification of the properties (Section 1.5 and 1.6).

Some of the important properties are coupled; an example is hydraulic conductivity and permeability. Assuming a fixed value for permeability, a mathematical relationship exists to determine hydraulic conductivity. Density and porosity are similarly related.

2.0 COMPOSITE PHYSICAL AND CHEMICAL PROPERTIES

The development of physical and chemical properties for each alternative assumes the waste composite to be a homogeneous mixture. Five physical and chemical properties of the composite as a function of time or stress, are required as input to the DAM.

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

These properties are discussed in more detail in Section 1.6.

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3.0 WASTE FORM DISTRIBUTION

The effectiveness of each of the various EAs is evaluated relative to the baseline case. The baseline case is defined as waste treated to the Waste Isolation Pilot Plant (WIPP) Waste Acceptance Criteria (WAC) that is emplaced in the current panel design with no backfill. "As received" waste composition is assumed to comply with the Butcher (1989) classification of the waste destined for the WIPP, which can be generalized into the three major waste form categories.

The three major waste forms comprise the majority of the stored and projected contact handled transuranic (CH-TRU) waste inventories. On a volumetric basis, the proportions of the three major waste forms for the baseline case are assumed [based on the WIPP Transuranic Waste Baseline Inventory Report (WTWBIR) (DOE, 1995d)] to be:

- 44.5 Percent Solid Organics
  Comprised of:
    - Combustible waste
    - Filter waste
    - Heterogeneous waste
    - Solidified organic waste

- 23.0 Percent Solid Inorganics
  Comprised of:
    - Inorganic non-metal waste
    - Lead/Cadmium metal waste
    - Uncategorized metal waste
    - Graphite waste
    - Salt waste
    - Soil waste

- 32.5 Percent Sludges
  Comprised of:
    - Solidified Inorganic waste

These proportions were developed from the inventory descriptions in the WTWBIR (DOE, 1995d) by grouping waste types with similar physical properties. This proportional distribution for the baseline case is maintained for comparison of each alternative studied, ensuring no calculational bias. Specifying this ratio reduces the number of sensitivity runs necessary to establish the relative effectiveness of the EAs. In addition to the proportional distribution of waste forms, the initial volume of waste contained in a disposal room is assumed constant. Based on the overall capacity of the WIPP repository and the planned room and panel layout, the WIPP underground is assumed to have eight panels for TRU waste and sufficient capacity within the main access drifts to equal two additional panel volumes. Each panel consists of seven waste rooms and two panel access drifts which have a capacity equal to 5.54 additional waste room volumes. Therefore, each panel has 12.54 equivalent waste room volumes. Each "room equivalent" is assumed to contain 6,421 55-gallon drums (or equivalent) of CH-TRU waste.

The initial conditions for the baseline case waste distribution parameters are listed in Table F-1. These values, along with the density of each component as a function of stress (from creep closure), are used in computing the composite physical and chemical properties.

4.0 DATA DEVELOPMENT FOR ENGINEERED ALTERNATIVES

The EAs investigated here are made up of components which include waste treatment methodologies, various backfill material options, and waste emplacement configurations. The following subsections present the data for each of the components used for the computation of the properties for the waste composite. The raw data necessary for computation of waste composite properties were obtained from the previous Engineered Alternative Task Force Report (DOE, 1991), the WTWBIR (DOE, 1995d), and Butcher, et al. (1991).

4.1 Waste Treatments

Waste treatment components of the EAs involve the modification of the physical properties of the waste. Treatment of the CH-TRU waste may also lead to a change in total waste volume to be handled and emplaced in the WIPP underground. Details of the five waste treatment processes, that are components of the EAs investigated in this report, are presented below. The waste treatment processes are supercompaction, shredding, low-force compaction, plasma melting, enhanced cementation of sludges, and adding clay. The effects of each waste treatment process on the physical properties of the composite is also presented.

4.1.1 Supercompaction

The supercompaction process is modeled after the Supercompaction and Repackaging Facility (SARF) which is in operation at the Rocky Flats Environmental Technology Site (RFETS) (DOE 1995c). Only solid organic and solid inorganic wastes are suitable for supercompaction (sludges are excluded).

In preparation for supercompaction, waste is first emptied into a glovebox where it is sorted to remove items which cannot be supercompacted. Items suitable for supercompaction are then compacted into a 132-liter (35-gallon) drum using a low-force (30 metric ton) compactor. The compacted 132-liter (35-gallon) drums are then transferred to the supercompactor. The supercompactor applies a high force (1,500 to 2,000 metric tons) to the 132-liter (35-gallon) drum, called a "puck", to compact the waste material into a smaller volume. The compacted pucks are then transferred to a 208-liter (55-gallon) drum for final packaging to WIPP WAC requirements. On average, 4 pucks can be packaged into each 208-liter (55-gallon) drum. The volume reduction ratio for supercompaction is assumed to be 2.9 : 1. A slight increase in waste mass occurs due to the additional packaging (the 132-liter drums), resulting in a mass increase factor of 1.1. The final waste density is assumed to be 1679 kg/m^3 (104.8 lb/ft^3), compared to an initial density of approximately 534 kg/m^3 (33.3 lb/ft^3). Supercompacted waste materials exhibit the following:

- Lower effective hydraulic conductivity
- Lower total volume of CH-TRU waste.

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TABLE F-1

WASTE QUANTITIES FOR THE BASELINE CASE

Waste Form	Total Mass[1] (kg)	Total Volume[1] (m^3)	Initial Density[1] (kg/m^3)	Drums per Room Equivalent[2]
Solid Organics	47,234,933	74,339	635	2,857
Solid Inorganics	13,007,073	38,396	339	1,477
Sludges	30,921,720	54,389	569	2,087
Total	91,163,726	167,124		6,421

[1]Total mass, total volume, and initial density are from Appendix O.
[2]The number of drums is computed from the distribution of the waste forms and the total number of drums per room.

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4.1.2 Shredding

The shredding process is modeled after commercially available equipment that has been successfully used for low-level waste and TRU waste (Moghissi et al., 1986; Owens, 1995). Only solid organic and solid inorganic wastes are suitable for shredding.

The shredding procedure assumed for alternative evaluations consists of making multiple passes through multiple shredders such that no individual waste item has a dimension greater than 4 inches. Waste material is the primary target of the shredding operation, although a fraction of the waste containers (boxes and drums) may also require this processing technique. Shredding some of the waste containers and repackaging them results in a small mass increase factor of 1.1. Shredded waste materials and containers exhibit the following:

- Improved compaction capability
- Lower effective hydraulic conductivity (especially after compaction)
- Improved strength.

4.1.3 Low-Force Compaction

Low-force compaction consists of compacting waste (typically shredded waste) into a 208-liter (55-gallon) drum using a low-force (30 metric ton) compactor. This process is repeated, adding more waste to the drum and compacting it, until the drum is full. The volume reduction ratio for compaction, in conjunction with shredding the waste first, is assumed to be 1.3 : 1. Low-force compacted waste materials exhibit the following:

- Lower effective hydraulic conductivity
- Lower total volume of CH-TRU waste.

4.1.4 Plasma Processing

The plasma melting treatment system is modeled after the Plasma Arc Centrifugal Treatment (PACT) system. The PACT was developed by Retech, Inc., and is currently being implemented by Lockheed Martin Environmental Systems and Technologies, Co. as part of the Pit 9 Comprehensive Demonstration (LESAT, 1995) at the Idaho National Engineering Laboratory. Plasma processing may be performed to all waste types (solid organics, solid inorganics, and sludges). To achieve optimum operations, it is desirable to process sludges, solid organic, and solid inorganic wastes simultaneously (Nielsen, 1995).

The plasma processing is accomplished with the use of a transferred arc plasma torch operating in an oxygen-rich environment. The operation of the torch in this environment will bring the waste to a molten state, destroy any organic materials, and oxidize or immobilize any heavy metals. The molten slag will then be poured into 208-liter (55-gallon) drums and allowed to cool. The slag is assumed to have varying amounts of entrained air in the form of bubbles. Due to weight limitations for transportation of 55-gallon drums, the drums may not be filled completely, leaving a void space above the slag. Upon cooling, the final molten slag becomes a non-leachable "glass". Plasma melting results in a volume reduction ratio of approximately 3 : 1 (Nielsen, 1995). Final waste form is assumed to have a bulk density of 1,610 kg/m^3 (100.5 lb/ft^3) (including the entrained air and void space in the drum) compared to an initial average bulk density of 534 kg/m^3 (33.3 lb/ft^3). Plasma melted waste materials and containers exhibit the following:

- Significantly lower effective hydraulic conductivity
- Destruction of organic materials which reduces the gas generation potential
- Oxidation or immobilization of heavy metals.
- Increased strength of composite.

4.1.5 Add Clay

Non-swelling clay (granular or pelletized illite or kaolinite) will be added to the waste to reduce the void spaces in the final waste form. The clay is mixed with the waste and placed into 208-liter (55-gallon) drums. It is assumed that the clay will fill 80% of the initial void volume in the waste package. It is also assumed that there will be no net change to the waste volume (i.e., treatment of one drum of waste results in one drum of treated waste). The final density of the waste is assumed to be 78.5 lb/ft^3 compared to an initial average density of 33.3 lb/ft^3. The mass increase factor due to the addition of the clay is 2.35. The density of the clay pellets added to the waste is assumed to be approximately 1,040 kg/m^3 (65 lb/ft^3) based on information from clay suppliers. Waste materials with clay added exhibit the following:

- Lower effective hydraulic conductivity
- Lower initial void volume.

4.2 Backfills

Backfills as components of the EAs involve the emplacement of earthen or cementitious materials between and around the CH-TRU waste containers. Backfills do not affect the physical properties of the waste but do have an effect on the properties of the waste composite. By both, volume and mass, backfill will typically account for a large proportion of the waste/backfill composite material. The five backfill components presented as part of these EAs are a sand and clay mixture, a salt aggregate based grout, a cementitious grout, a crushed salt and calcium oxide mixture, and a 100% clay based backfill. Details of the five backfills and their physical properties are presented below.

4.2.1 Sand and Clay Mixture Backfill

A backfill consisting of a mixture of medium grained sand and granulated clay is placed around the waste stack and between the drums filling the void space within the rooms. The backfill is 70% sand and 30% clay by volume. The clay is commercially available granulated or pelletized kaolinite or illite having a bulk density of approximately 1,040 kg/m^3 (65 lb/ft^3). Because of the inefficiencies associated with pneumatically placing a dry fine to medium grained material, a filling efficiency of 50% is assumed.

The sand plus clay backfill is placed to a height of approximately 0.6 m (2 ft) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 0.5 m). The total volume of backfill material for the entire underground is approximately 103,500 m^3 (3,655,000 ft^3) filling an available backfill void volume of 207,000 m^3 (7,310,000 ft^3) at a 50% filling efficiency. This translates to 827 m^3 (29,200 ft^3) of backfill material per room equivalent into an available backfill void volume of 1,654 m^3 (58,400 ft^3). The initial density of the sand plus clay backfill is 1,590 kg/m^3 (99.2 lb/ft^3) at a porosity of 40%. The density and porosity change as the load on the backfill increases due to creep closure to a final density of 1,855 kg/m^3 (115.8 lb/ft^3) and a porosity of 30% at 2,200 psi stress. The hydraulic conductivity of the sand plus clay backfill is expected to range from 6 x 10^{-7} m/second (s) at 0 psi stress to 9 x 10^{-9} m/s at 2,200 psi stress.

The sand plus clay backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite initial void
- Reduces the initial void volume of the room.

4.2.2 Salt Aggregate Grout Backfill

A cementitious based grout backfill using crushed salt as the aggregate and simulated WIPP brine as the added water (Gulick and Wakeley, 1989), is pumped around the waste stack and between the drums filling the void space within the rooms. Some inefficiencies will occur in placing the grout backfill so a filling efficiency of 80% is assumed.

The grout backfill is placed to a height of 0.6 m (1.89 ft) above the top of the waste stack (SNL/NM, 1991) and will fill the space between the waste drums and the room walls (approximately 0.5 m). The total volume of backfill material for the entire underground is approximately 166,000 m^3 (5,862,000 ft^3) filling an available backfill void volume of 207,000 m^3 (7,310,000 ft^3) at an 80% filling efficiency. This translates to 1,323 m^3 (46,720 ft^3) of grout material per room-equivalent into an available backfill void volume of 1,654 m^3 (58,400 ft^3). The initial density of the salt aggregate grout backfill is 1,884 kg/m^3 (117.6 lb/ft^3) at a porosity of 31.3%. Because of the grout's inherent strength, the density and porosity will not change as the load on the backfill increases due to creep closure. The hydraulic conductivity of the salt aggregate grout backfill is assumed to be constant over all expected stresses at 1.3 x 10^{-12} m/s.

The high salt content will allow the grout to maintain plastic properties under the constant lithostatic load. This will ensure that the grout will not chemically degrade or fracture during the 10,000-year period of performance.

The salt aggregate grout backfill:

- reduces the hydraulic conductivity of the backfill/waste composite
- is chemically compatible with the WIPP brine and surrounding salt.

4.2.3 Cementitious Grout Backfill

A cementitious grout backfill using ordinary Portland cement, sand aggregate, and fresh water, is pumped around the waste stack and between the drums filling the void space within the rooms. As with the salt aggregate grout backfill, some inefficiencies will occur in placing the grout backfill so a filling efficiency of 80% is assumed.

The cementitious grout backfill, as with the other backfills, is placed to a height of approximately 0.6 m (2 ft) above the top of the waste stack (SNL/NM, 1991), between the waste drums, and along the room walls. The material properties, including density, porosity, and hydraulic conductivity, of the cementitious grout backfill are assumed to be the same as that of the salt aggregate grout backfill.

The cementitious grout backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite.
- Increases the strength of the backfill/waste composite
- Reduces the initial void volume
- Increases the pH of the brines in the repository environment which lowers the radionuclide solubility.

4.2.4 Crushed Salt and Calcium Oxide Mixture Backfill

A backfill consisting of commercially available granulated CaO (quick lime) and crushed salt aggregate is pneumatically placed around the waste stack and between the drums filling the void space within the rooms. The mixture consists of less than 10% CaO and 90% crushed salt aggregate. Because of the inefficiencies associated with pneumatically placing a dry material, a filling efficiency of 50% is assumed.

The crushed salt and CaO backfill, as with the other backfills, is placed to a height approximately 0.6 m (2 ft) above the top of the waste stack (SNL, 1991), between the waste drums, and along the room walls. The total volume and the volume per room of the crushed salt plus CaO backfill are assumed to be the same as for the sand plus clay backfill presented above. Since the mixture is predominantly crushed salt, the properties of a crushed salt aggregate backfill are assumed. The initial density of the crushed salt backfill is 1,193 kg/m^3 (74.4 lb/ft^3) at a porosity of 44.8%. The final density and porosity at 2,200 psi stress is assumed to be 1,960 kg/m^3 (122.3 lb/ft^3) and 9.3%, respectively. The hydraulic conductivity of the CaO and crushed salt backfill is assumed to range from approximately 7×10^{-2} m/s at 0 psi stress to approximately 1×10^{-11} m/s at 2,200 psi stress.

The crushed salt plus CaO backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite
- Increases the pH of the brines in the repository environment which lowers the radionuclide solubility
- Is chemically compatible with the WIPP underground environment.

4.2.5 Clay Based Backfill

A backfill consisting of commercially available granular or pelletized kaolinite or illite clay (DOE, 1995a) is place pneumatically around the waste stack and between the drums at a filling efficiency of 50%. The initial density of the emplaced clay backfill is approximately 1,000 kg/m^3 (62.4 lb/ft^3) at a porosity of 62.5%. After consolidation at a stress of 2,200 psi due to creep closure, the clay backfill will reach a final density of 1,610 kg/m^3 (100.5 lb/ft^3) at a porosity of

39.7%. The hydraulic conductivity of the clay based backfill is assumed to range from 1×10^{-10} m/s at 0 psi stress to 2×10^{-13} m/s at 2,200 psi stress.

The clay based backfill will perform as follows:

- Reduces the hydraulic conductivity of the backfill/waste composite
- Reduces the initial void volume.

4.3 Emplacement Configurations

Two emplacement configurations are considered as components to the EAs. The differences between the two configurations are the room height and the number of drums of waste per layer within a waste emplacement room. The configurations are presented below.

4.3.1 Baseline in 13 x 33 x 300 ft Rooms

The baseline configuration assumes a waste emplacement room (or room equivalent) to be 13 ft high by 33 ft wide by 300 ft long, with waste containers stacked up to three layers high for a maximum of 6,421 drums per room equivalent. Because it is assumed that the overall radionuclide inventory within a panel cannot be greater than the inventory in the baseline engineered alternative, some of the EAs will have less than 6,421 drums of treated waste per room, resulting in waste containers being stacked less than 3 high. This configuration is still considered the baseline emplacement configuration since the room dimensions and available volume do not change.

4.3.2 Monolayer in 6 x 33 x 300 ft Rooms

The monolayer emplacement configuration assumes waste containers are emplaced in a single layer in a room that is 33 ft wide by 300 ft long but only 6 ft high. Only 2,000 drums are placed in the single layer for this configuration. This emplacement configuration is only used in the 77-series of EAs.

5.0 PHYSICAL/CHEMICAL PROPERTY CALCULATION METHODOLOGY

Initial calculations supply input values for a spreadsheet designed to compute physical/chemical properties of the waste/backfill composite on a per-room or panel basis. Therefore, generating the effective properties resulting from a given combination of engineered alternative components is reduced to specifying the basic input values for that EAs in the spreadsheet. Data files are then generated in the spreadsheet. The default values in the spreadsheet are those corresponding to the baseline case.

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Spreadsheet input parameters are listed below:

- The distribution of waste components in an average room. This distribution is dependent on the number of drums of each waste form component (solid organics, solid inorganics, and sludges) present.

- The average weight per drum of each waste form.

- Volume reduction factors, which are unique to the particular engineered alternative, and to the unprocessed waste form. They allow computation of the equivalent drum count, which is the number of unprocessed drums required to produce a processed drum of waste for the particular engineered alternative. The number of processed drums per room equivalent for each of the EAs is presented in Table F-2.

- The average height of the waste stack. Because it is assumed that the overall radionuclide inventory within a panel cannot be greater than the inventory in the baseline case, some of the EAs will have less than 6,421 drums of treated waste per room, resulting in waste containers being stacked less than 3 high. The average height of the waste stack is determined by multiplying the height of the waste stack for the baseline case (2.676 m) by the fraction of the number of drums per room equivalent for the engineered alternative relative to the baseline case (6,421 drums per room equivalent).

- The total volume of backfill (if present), volume of backfill within the waste stack, and void volume within the waste stack. The void volume within the waste stack is an estimation of the void space within the waste stack resulting from inefficiency in the backfilling process. The void volume is used to estimate an initial waste stack density. The total volume of backfill is utilized in the computation of waste/backfill composite density. The volume of backfill within the waste stack is used in the computation of hydraulic conductivity of the waste/backfill composite.

- The density variations of each waste or backfill component as a function of closure stress, from 0 psi (0 MPa) to lithostatic pressure (approximately 2,200 psi [15 MPa]) in 200 psi (1.35 MPa) increments. The waste or backfill component density values are used in the computation of waste/backfill composite density, porosity, and hydraulic conductivity of the room contents.

The effects of an EA on the waste/backfill composite properties are calculated with a computer spreadsheet. To compute physical and chemical properties of an EA, only those input values which deviate from the baseline case need to be modified in the spreadsheet. The remaining input variables are therefore unaltered from the baseline case. Some EAs require no computation of various properties (eg., cement based grout backfill is considered incompressible and therefore has a constant density and hydraulic conductivity). The hydraulic conductivity of a cement grout backfill would be considered a fixed input value for all closure stress levels. This spreadsheet computational methodology is used to evaluate the properties of each EA.

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DRUMS PER ROOM EQUIVALENT FOR EACH ENGINEERED ALTERNATIVE

Engineered Alternative	Number of Drums per Room Equivalent
Baseline Case	6,421
Alternative 1, Supercompact Solid Organics and Solid Inorganics	3,604
Alternative 6, Shred and Compact Solid Organics and Solid Inorganics	5,381
Alternative 10, Plasma Processing	2,120
Alternative 33, Sand Plus Clay Backfill	6,421
Alternative 35a, Salt Aggregate Grout Backfill	6,421
Alternative 35b, Cementitious Grout Backfill	6,421
Alternative 77a, Supercompact, Monolayer of 2000 Drums, Salt Aggregate Grout Backfill	2,000[1]
Alternative 77b, Supercompact, Monolayer of 2000 Drums, Clay Based Backfill	2,000[1]
Alternative 77c, Supercompact, Monolayer of 2000 Drums, Sand Plus Clay Backfill	2,000[1]
Alternative 77d, Supercompact, Monolayer of 2000 Drums, Crushed Salt Plus CaO Backfill	2,000[1]
Alternative 83, Crushed Salt Plus CaO Backfill	6,421
Alternative 94a, Enhanced Cementation, Shred and Add Clay, No Backfill	6,421[2]
Alternative 94b, Enhanced Cementation, Shred and Add Clay, Sand Plus Clay Backfill	6,421[2]
Alternative 94c, Enhanced Cementation, Shred and Add Clay, Cementitious Grout Backfill	6,421[2]
Alternative 94d, Enhanced Cementation, Shred and Add Clay, Salt Aggregate Grout Backfill	6,421[2]
Alternative 94e, Enhanced Cementation, Shred and Add Clay, Clay Based Backfill	6,421[2]
Alternative 94f, Enhanced Cementation, Shred and Add Clay, Crushed Salt Plus CaO Backfill	6,421[2]
Alternative 111, Clay Based Backfill	6,421

[1]2,000 drums per room defined by alternative. This alternative does not provide adequate space for all of the CH-TRU waste and leaves approximately 200,170 drums of waste outside of the WIPP.
[2]The enhanced cementation process increases the total waste volume above the WIPP capacity volume. Approximately 130,600 drums of CH-TRU waste are left outside of the WIPP.

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6.0 QUANTIFICATION OF PHYSICAL AND CHEMICAL PROPERTIES

The physical and chemical properties used in the DAM are evaluated over the range of closure stress expected in the repository. The properties of primary importance are as follows

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

The waste composite in the WIPP repository is assumed to contain up to four components. These components consist of the backfill material and the three major categories of waste (solid organics, solid inorganics, and sludges) which may be treated in some manner. The physical and chemical properties of each component will be dependent on the particular engineered alternative being considered. The methodologies and assumptions used to characterize these properties are detailed in the following sections.

Although material compressibility is not a DAM input property, it is a useful parameter upon which to base simplifying assumptions. Material compressibility is used to estimate the effects of creep closure on the physical properties of the waste composite. Waste and backfill materials in the WIPP repository will be subjected to triaxial compressive forces. Compressibility of these materials will affect all physical properties. The extent to which different materials consolidate is largely dependent on the strength of the bulk material. Treated wastes such as enhanced cemented sludges or vitrified glass have compressive strengths in excess of lithostatic pressure of 2,200 psi (14.8 MPa), and are assumed to be incompressible under the stresses expected in the repository.

It is important to note that effects of time on the physical properties of the waste composite are not considered in this analysis. Long-term (10,000 years) effects such as fatigue and degradation are not well quantified and are therefore considered inappropriate for these generalized calculations. Therefore, the density, porosity, and hydraulic conductivity of portland cement based materials used as backfill or sludge solidification are assumed to remain constant during the 10,000 year operating life of the WIPP.

6.1 Density

Density of the waste/backfill composite at any given stress level can be computed from the density of the individual components at that same stress level. The mass of each waste component is obtained from the mass distribution of the three major waste forms defined by Butcher, et al. (1991). The quantity of backfill is estimated from repository room design specifications from SNL/NM's performance assessment modeling (SNL/NM, 1991). Total mass for each alternative is assumed constant over the 10,000-year period for the computation of waste/backfill composite densities. This assumption simplifies the density calculations. It is understood that waste/backfill composite mass fluxes resulting from gas production/dissipation, and brine transport will vary the waste/backfill composite mass (e.g., by chemical degradation, physical erosion, and subsequent mass transfer into and out of the waste stack), though the extent to which these processes will occur is not well defined. Initial component volumes are known from the baseline design criteria, thus initial waste/backfill composite density is readily quantified.

The waste/backfill composite density resulting from EA evaluations may or may not increase during the consolidation process. For the baseline case, waste component densities as a function of stress level were obtained from Butcher et al. (1991). The methodology of computing density of a multicomponent system is outlined in Butcher et al. (1991). This method utilizes component densities (or mass and volume) to compute waste/backfill composite density. Implicit in the calculation is the assumption that the components act independently.

The formulation can be summarized as follows; the volume occupied by component i at some stress level x is:

$$V_i(x) = \frac{M_i}{D_i(x)} \qquad (3.6\text{-}1)$$

where,

$V_i(x)$ = *volume of component "i" at stress level x*
M_i = *mass of component "i"*
$D_i(x)$ = *density of component "i" at stress level x.*

The total waste/backfill composite volume at stress level x is the sum of the component volumes:

$$TV(x) = \sum_{i=1}^{n} V_i(x) \qquad (3.6\text{-}2)$$

where,

TV(x) = total waste/backfill composite volume at stress level x.

The total waste/backfill composite mass is the sum of the "n" component masses, or:

$$TM = \sum_{i=1}^{n} M_i \qquad (3.6\text{-}3)$$

where,

TM = the total waste/backfill composite mass.

Therefore, the waste/backfill composite density at stress level x can be computed as follows:

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$$RD(x) = \frac{TM}{TV(x)} = \sum_{i=1}^{n} \frac{TM}{(M_i/D_i(x))} \quad (3.6\text{-}4)$$

where,

RD(x) = density of waste/backfill composite at stress level x.

Equation 1.6-4 can be simplified by introducing a component weight fraction, W_i:

$$W_i = \frac{M_i}{TM} \quad (3.6\text{-}5)$$

After dividing the numerator and denominator of equation 3.6.4 by TM, the expression for the waste/backfill composite density becomes:

$$RD(x) = \sum_{i=1}^{n} \frac{1.0}{(W_i/D_i(x))} \quad (3.6\text{-}6)$$

In summary, waste/backfill composite density was computed at a given stress level by:

- Using densities as a function of stress level and weights for each component
- Utilizing the experimental densities of individual components such as metal, glass, sorbents and combustibles (all under pressure) as reported by Butcher et al. (1991)
- Using component mass proportions.

Table F-3 contains waste/backfill composite densities as a function of stress for each of the EAs analyzed using the DAM.

6.2 Porosity

Porosity is a measure of void space existing in a material and is defined as the ratio of void volume to total volume of the material. Within the repository, the waste/backfill composite porosity is dependent on waste characteristics, backfill materials (if present), efficiency of waste packaging, efficiency of backfill emplacement, and the extent to which these materials compact during the consolidation process. Computation of waste/backfill composite porosity (assuming constant mass) can be made on either a volume or density basis (Butcher, 1989), for example:

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TABLE F-3

COMPOSITE DENSITIES FOR ENGINEERED ALTERNATIVES
(pounds/cubic inch)

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	0.0107	0.0203	0.0136	0.0315	0.0325	0.0427	0.0427	0.0555	0.0324	0.0447	0.0364	0.0266
0	0.0197	0.0375	0.0251	0.0581	0.0378	0.0452	0.0452	0.0582	0.0366	0.0505	0.0411	0.0309
200	0.0437	0.0699	0.0605	0.0953	0.0534	0.0610	0.0610	0.0685	0.0474	0.0609	0.0605	0.0517
400	0.0549	0.0822	0.0822	0.1042	0.0580	0.0649	0.0649	0.0706	0.0525	0.0638	0.0657	0.0583
600	0.0618	0.0839	0.0839	0.1095	0.0606	0.0667	0.0667	0.0709	0.0553	0.0649	0.0678	0.0621
800	0.0672	0.0854	0.0854	0.1142	0.0625	0.0679	0.0679	0.0711	0.0576	0.0658	0.0697	0.0652
1000	0.0716	0.0864	0.0863	0.1175	0.0642	0.0688	0.0688	0.0712	0.0597	0.0667	0.0709	0.0674
1200	0.0754	0.0872	0.0872	0.1204	0.0657	0.0695	0.0695	0.0713	0.0614	0.0676	0.0721	0.0694
1400	0.0787	0.0879	0.0879	0.1229	0.0670	0.0701	0.0701	0.0714	0.0628	0.0684	0.0731	0.0711
1600	0.0818	0.0885	0.0885	0.1250	0.0683	0.0705	0.0705	0.0715	0.0638	0.0693	0.0739	0.0725
1800	0.0845	0.0890	0.0890	0.1270	0.0696	0.0709	0.0709	0.0716	0.0651	0.0701	0.0745	0.0737
2000	0.0870	0.0895	0.0895	0.1289	0.0707	0.0713	0.0713	0.0717	0.0658	0.0709	0.0754	0.0750
2200	0.0895	0.0900	0.0900	0.1308	0.0719	0.0716	0.0716	0.0717	0.0666	0.0717	0.0759	0.0761
Solid	0.1158	0.1171	0.1171	0.1469	0.1004	0.1021	0.1021	0.1023	0.1030	0.1004	0.0873	0.0875

TABLE F-3 (Continued)

COMPOSITE DENSITIES FOR ENGINEERED ALTERNATIVES
(pounds/cubic inch)

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	0.0107	0.0146	0.0357	0.0458	0.0458	0.0269	0.0298	0.0237
0	0.0197	0.0269	0.0415	0.0486	0.0486	0.0313	0.0347	0.0276
200	0.0437	0.0352	0.0477	0.0547	0.0547	0.0378	0.0456	0.0414
400	0.0549	0.0384	0.0500	0.0566	0.0566	0.0412	0.0489	0.0473
600	0.0618	0.0402	0.0515	0.0576	0.0576	0.0435	0.0510	0.0512
800	0.0672	0.0415	0.0526	0.0583	0.0583	0.0452	0.0526	0.0543
1000	0.0716	0.0425	0.0536	0.0588	0.0588	0.0468	0.0537	0.0571
1200	0.0754	0.0433	0.0544	0.0592	0.0592	0.0481	0.0547	0.0594
1400	0.0787	0.0439	0.0552	0.0595	0.0595	0.0491	0.0556	0.0613
1600	0.0818	0.0445	0.0559	0.0598	0.0598	0.0499	0.0563	0.0629
1800	0.0845	0.0450	0.0567	0.0600	0.0600	0.0508	0.0569	0.0646
2000	0.0870	0.0454	0.0573	0.0602	0.0602	0.0513	0.0575	0.0657
2200	0.0895	0.0457	0.0579	0.0604	0.0604	0.0519	0.0580	0.0669
Solid	0.1158	0.1181	0.1022	0.1034	0.1034	0.1051	0.0905	0.1029

On volume basis:

$$Porosity = \frac{(V_{total} - V_{solid})}{V_{total}} \qquad (3.6\text{-}7)$$

On density basis:

$$Porosity = 1 - \frac{(composite\ density)}{(composite\ solid\ density)} \qquad (3.6\text{-}8)$$

where,

V_{total} is the total volume ($V_{solid} + V_{void}$) of the room components at some stress level, and V_{solid} is the total solid volume of all room components. Therefore, the quantity ($V_{total} - V_{solid}$) represents V_{void}, the room void volume including the waste/backfill composite void volume minus the volume of the overlying air gap. Due to greater availability of density data for components, waste/backfill composite porosity is computed on a density basis. Table F-4 presents the waste/backfill composite porosities as a function of stress for each of the EAs analyzed using the DAM.

6.3 Hydraulic Conductivity

Hydraulic conductivity is a measure of the permeability of a porous media. It is dependent on the properties of the media as well as the fluid. The hydraulic conductivity of the waste/backfill composite in an average WIPP repository room is dependent on the waste components, backfill material (if present), and the brine present. In multicomponent systems, an effective hydraulic conductivity can be estimated by averaging the individual component hydraulic conductivities comprising the system. The following three different averaging techniques exist:

- Arithmetic mean - applies to flow through a parallel configuration of components
- Harmonic mean - applies to flow through a series configuration of components
- Geometric mean - applies to flow through a randomly distributed configuration of components.

In practice, the effective hydraulic conductivity of randomly distributed components is estimated by using the geometric mean of components. The geometric mean is preferred over arithmetic and harmonic means (parallel and series flow configurations, respectively), because it results in a better representation of randomly distributed components (Scheidegger, 1974).

In the baseline case, hydraulic conductivity of solid inorganic and solid organic waste is assumed to vary with porosity and is estimated from a modified version of the Kozeny-Carmen equation (Bear, 1972). Components such as grout or glass are assumed incompressible under repository conditions (compressive strengths greater than lithostatic pressure) and thus have constant hydraulic conductivities.

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TABLE F-4

COMPOSITE POROSITIES FOR ENGINEERED ALTERNATIVES

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	0.908	0.826	0.884	0.785	0.677	0.582	0.582	0.457	0.686	0.686	0.583	0.696
0	0.830	0.680	0.786	0.604	0.623	0.557	0.557	0.431	0.645	0.645	0.529	0.646
200	0.623	0.403	0.484	0.351	0.468	0.402	0.402	0.331	0.540	0.540	0.308	0.409
400	0.526	0.298	0.298	0.291	0.423	0.364	0.364	0.310	0.490	0.490	0.248	0.335
600	0.466	0.284	0.284	0.255	0.397	0.347	0.347	0.307	0.463	0.463	0.223	0.290
800	0.419	0.271	0.271	0.223	0.378	0.335	0.335	0.305	0.441	0.441	0.202	0.256
1000	0.382	0.263	0.263	0.200	0.361	0.326	0.326	0.304	0.420	0.420	0.188	0.230
1200	0.349	0.255	0.255	0.180	0.346	0.319	0.319	0.302	0.403	0.403	0.175	0.208
1400	0.320	0.250	0.250	0.163	0.333	0.314	0.314	0.302	0.390	0.390	0.163	0.188
1600	0.294	0.244	0.244	0.149	0.320	0.309	0.309	0.301	0.380	0.380	0.154	0.172
1800	0.270	0.240	0.240	0.135	0.307	0.305	0.305	0.300	0.367	0.367	0.146	0.158
2000	0.248	0.235	0.235	0.123	0.296	0.301	0.301	0.299	0.361	0.361	0.137	0.143
2200	0.227	0.231	0.231	0.110	0.284	0.298	0.298	0.299	0.353	0.353	0.130	0.131

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TABLE F-4 (Continued)

COMPOSITE POROSITIES FOR ENGINEERED ALTERNATIVES

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	0.908	0.876	0.651	0.557	0.557	0.744	0.671	0.770
0	0.830	0.772	0.594	0.530	0.530	0.702	0.617	0.732
200	0.623	0.702	0.533	0.471	0.471	0.640	0.496	0.597
400	0.526	0.675	0.510	0.452	0.452	0.608	0.459	0.540
600	0.466	0.659	0.496	0.443	0.443	0.586	0.436	0.502
800	0.419	0.649	0.486	0.436	0.436	0.570	0.419	0.472
1000	0.382	0.640	0.476	0.431	0.431	0.555	0.406	0.445
1200	0.349	0.634	0.467	0.428	0.428	0.543	0.395	0.422
1400	0.320	0.628	0.460	0.424	0.424	0.533	0.386	0.404
1600	0.294	0.623	0.453	0.422	0.422	0.525	0.378	0.389
1800	0.270	0.619	0.446	0.420	0.420	0.517	0.371	0.372
2000	0.248	0.616	0.440	0.418	0.418	0.512	0.365	0.361
2200	0.227	0.613	0.433	0.416	0.416	0.506	0.359	0.350

The components considered in the averaging process are the three primary waste forms and the backfill material within the waste stack. Backfill contained in the volume above the waste stack is not considered because this region is a physical extension of the host rock.

The values of hydraulic conductivity for each component are estimated on the basis of available data in literature. Components with large void space which compact under compressive stresses will typically have hydraulic conductivities that vary with the degree of compaction. This variability can be estimated or computed from the porosity. For example, the hydraulic conductivity of a crushed salt and CaO mixture is assumed to be a function of porosity and is estimated as a function of compaction with a bi-linear system of equations developed by Case and Kelsall (1987). Once the hydraulic conductivity of each component has been estimated, the effective hydraulic conductivity for the composite can be computed. The governing equation employing the geometric mean for averaging hydraulic conductivities is (Scheidegger, 1974):

$$\ln(K_{eff}) = \sum_{i=1}^{n} (F_i \ln(K_i)) \,. \tag{3.6-9}$$

where,

K_{eff} = effective waste/backfill composite hydraulic conductivity at stress level x
F_i = volume fraction of component i at stress level x
K_i = hydraulic conductivity of component i at stress level x.

The component volume fraction and the hydraulic conductivity may be functions of stress level or the state of compaction. The component volume fraction is computed as the component volume divided by the waste/backfill composite volume at a particular stress level:

$$F_i(x) = \frac{V_i(x)}{TV(x)} \tag{3.6-10}$$

where,

$F_i(x)$ = volume fraction of component i at stress level x
$V_i(x)$ = volume of component i at stress level x (including the void space within the waste/backfill composite)
$TV(x)$ = volume of waste/backfill composite at stress level x.

The component and waste/backfill composite volumes are obtained from estimated values of component masses and densities:

$$V_i(x) = \frac{M_i}{D_i(x)} \tag{3.6-11}$$

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$$TV(x) = \sum_{i=1}^{n} V_i(x) \qquad (3.6\text{-}12)$$

where,

$$M_i = \textit{mass of commmponent "i"}$$
$$D_i(x) = \textit{density of component "i" at stress level x.}$$

The procedure allows computation of an effective hydraulic conductivity for the average contents of a WIPP repository room at various stress levels. Table F-5 contains the hydraulic conductivities for each of the EAs analyzed using the DAM.

6.4 Gas Generation Potential

Gas generation potential is defined as the maximum amount of gas that can be generated under ideal conditions. Two potentials are defined: hydrogen generation form anoxic corrosion, and "biogas" generation from microbial degradation of organics.

The potential for hydrogen is based on the total mass of corrodible metal (metallic waste and container material) present in a panel. In most cases there is insufficient brine available to corrode all of the metal so that the total potential is never reached. It is still important however to define a potential so that the model does not predict the generation of more hydrogen than is physically possible.

The potential for "biogas" gas generation by microbial degradation of organic material is based on the total mass of degradable organics in a panel. The process of microbial gas generation stops when this potential is reached. The plasma treatment alternative is assumed to destroy all degradable organics so that the potential for this option is zero.

6.5 Effective Waste Volume

The effective waste volume is used to determine the radionuclide content in drill cuttings removed from the repository during human intrusion events. The effective waste volume is the volume of the waste/backfill composite minus the volume of the backfill along the sides of the waste stack. The term "drill cuttings" refers to the waste/backfill composite which would be brought to the surface with circulating drilling fluid during an inadvertent human intrusion event. The effective waste volume evaluation requires determination of the waste/backfill composite density as a function of stress, as per Equation (3.6.6). These calculations differ from each other only in that the waste/backfill composite density calculation neglects backfill on the sides of the waste stack. If penetration through the backfill on the sides of the waste stack occurs, the waste stack is assumed to remain intact and the cuttings are assumed not to contain any radionuclides. The backfill above the waste stack is considered because it would be mixed with extracted waste in the event the waste stack is breached by drilling activities.

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TABLE F-5

COMPOSITE HYDRAULIC CONDUCTIVITY FOR ENGINEERED ALTERNATIVES

(meters/second)

Stress (psi)	Baseline	Alt. 1	Alt. 6	Alt. 10	Alt. 33	Alt. 35a	Alt. 35b	Alt. 77a	Alt. 77b	Alt. 77c	Alt. 77d	Alt. 83
0	7.39×10^{-04}	1.14×10^{-04}	3.74×10^{-04}	7.35×10^{-16}	6.48×10^{-05}	8.49×10^{-07}	8.49×10^{-07}	1.22×10^{-07}	2.57×10^{-06}	1.20×10^{-05}	6.44×10^{-04}	2.18×10^{-03}
200	6.10×10^{-05}	6.38×10^{-06}	1.44×10^{-05}	7.35×10^{-18}	2.59×10^{-06}	5.43×10^{-09}	5.43×10^{-09}	1.90×10^{-09}	4.57×10^{-08}	6.83×10^{-07}	9.34×10^{-06}	4.09×10^{-05}
400	2.11×10^{-05}	1.89×10^{-06}	1.89×10^{-08}	7.35×10^{-16}	9.30×10^{-07}	1.29×10^{-09}	1.29×10^{-09}	6.06×10^{-10}	1.02×10^{-08}	2.73×10^{-07}	2.22×10^{-08}	9.84×10^{-06}
600	1.11×10^{-05}	1.55×10^{-06}	1.55×10^{-08}	7.35×10^{-16}	5.33×10^{-07}	6.26×10^{-10}	6.26×10^{-10}	5.18×10^{-10}	7.32×10^{-09}	2.32×10^{-07}	1.22×10^{-06}	3.82×10^{-06}
800	6.51×10^{-06}	1.27×10^{-06}	1.27×10^{-06}	7.35×10^{-16}	3.48×10^{-07}	3.76×10^{-10}	3.76×10^{-10}	4.49×10^{-10}	5.59×10^{-09}	1.98×10^{-07}	7.21×10^{-07}	1.70×10^{-06}
1000	4.21×10^{-06}	1.11×10^{-06}	1.11×10^{-08}	7.35×10^{-16}	2.49×10^{-07}	2.58×10^{-10}	2.58×10^{-10}	4.07×10^{-10}	4.64×10^{-09}	1.75×10^{-07}	4.98×10^{-07}	9.19×10^{-07}
1200	2.82×10^{-08}	9.67×10^{-07}	9.66×10^{-07}	7.35×10^{-16}	1.85×10^{-07}	1.88×10^{-10}	1.88×10^{-10}	3.72×10^{-10}	4.04×10^{-09}	1.56×10^{-07}	3.58×10^{-07}	5.26×10^{-07}
1400	1.96×10^{-06}	8.59×10^{-07}	8.59×10^{-07}	7.35×10^{-16}	1.42×10^{-07}	1.45×10^{-10}	1.45×10^{-10}	3.45×10^{-10}	3.64×10^{-09}	1.40×10^{-07}	2.35×10^{-07}	2.71×10^{-07}
1600	1.38×10^{-08}	7.64×10^{-07}	7.64×10^{-07}	7.35×10^{-16}	1.10×10^{-07}	1.15×10^{-10}	1.15×10^{-10}	3.22×10^{-10}	3.27×10^{-09}	1.26×10^{-07}	1.11×10^{-07}	9.14×10^{-08}
1800	9.79×10^{-07}	6.80×10^{-07}	6.80×10^{-07}	7.35×10^{-16}	8.67×10^{-08}	9.34×10^{-11}	9.34×10^{-11}	3.00×10^{-10}	2.98×10^{-09}	1.13×10^{-07}	5.58×10^{-08}	3.33×10^{-08}
2000	7.02×10^{-07}	6.06×10^{-07}	6.06×10^{-07}	7.35×10^{-16}	6.88×10^{-08}	7.74×10^{-11}	7.74×10^{-11}	2.81×10^{-10}	2.76×10^{-09}	1.01×10^{-07}	2.32×10^{-08}	9.36×10^{-09}
2200	4.93×10^{-07}	5.35×10^{-07}	5.34×10^{-07}	7.35×10^{-16}	5.43×10^{-08}	6.42×10^{-11}	6.42×10^{-11}	2.63×10^{-10}	2.54×10^{-09}	9.05×10^{-08}	1.25×10^{-08}	3.62×10^{-09}

TABLE F-5 (Continued)

COMPOSITE HYDRAULIC CONDUCTIVITY FOR ENGINEERED ALTERNATIVES

(meters/second)

Stress (psi)	Baseline	Alt. 94a	Alt. 94b	Alt. 94c	Alt. 94d	Alt. 94e	Alt. 94f	Alt. 111
0	$7.39x10^{-04}$	$3.59x10^{-06}$	$1.13x10^{-06}$	$2.48x10^{-08}$	$2.48x10^{-08}$	$2.90x10^{-07}$	$3.79x10^{-05}$	$1.66x10^{-05}$
200	$6.10x10^{-05}$	$3.85x10^{-07}$	$1.77x10^{-07}$	$2.57x10^{-09}$	$2.57x10^{-09}$	$2.56x10^{-08}$	$9.77x10^{-07}$	$1.81x10^{-07}$
400	$2.11x10^{-05}$	$1.72x10^{-07}$	$9.42x10^{-08}$	$1.23x10^{-09}$	$1.23x10^{-09}$	$9.85x10^{-09}$	$3.43x10^{-07}$	$3.30x10^{-08}$
600	$1.11x10^{-05}$	$1.09x10^{-07}$	$6.58x10^{-08}$	$8.33x10^{-10}$	$8.33x10^{-10}$	$5.79x10^{-09}$	$1.78x10^{-07}$	$1.27x10^{-08}$
800	$6.51x10^{-06}$	$7.94x10^{-08}$	$5.10x10^{-08}$	$6.40x10^{-10}$	$6.40x10^{-10}$	$4.02x10^{-09}$	$1.07x10^{-07}$	$6.21x10^{-09}$
1000	$4.21x10^{-06}$	$6.18x10^{-08}$	$4.15x10^{-08}$	$5.22x10^{-10}$	$5.22x10^{-10}$	$3.03x10^{-09}$	$7.31x10^{-08}$	$3.56x10^{-09}$
1200	$2.82x10^{-06}$	$5.06x10^{-08}$	$3.49x10^{-08}$	$4.45x10^{-10}$	$4.45x10^{-10}$	$2.46x10^{-09}$	$5.30x10^{-08}$	$2.26x10^{-09}$
1400	$1.96x10^{-06}$	$4.27x10^{-08}$	$3.00x10^{-08}$	$3.90x10^{-10}$	$3.90x10^{-10}$	$2.08x10^{-09}$	$3.67x10^{-08}$	$1.54x10^{-09}$
1600	$1.38x10^{-06}$	$3.71x10^{-08}$	$2.64x10^{-08}$	$3.50x10^{-10}$	$3.50x10^{-10}$	$1.81x10^{-09}$	$2.06x10^{-08}$	$1.08x10^{-09}$
1800	$9.79x10^{-07}$	$3.25x10^{-08}$	$2.33x10^{-08}$	$3.16x10^{-10}$	$3.16x10^{-10}$	$1.59x10^{-09}$	$1.21x10^{-08}$	$7.84x10^{-10}$
2000	$7.02x10^{-07}$	$2.92x10^{-08}$	$2.09x10^{-08}$	$2.92x10^{-10}$	$2.92x10^{-10}$	$1.45x10^{-09}$	$6.37x10^{-09}$	$5.93x10^{-10}$
2200	$4.93x10^{-07}$	$2.63x10^{-08}$	$1.88x10^{-08}$	$2.71x10^{-10}$	$2.71x10^{-10}$	$1.33x10^{-09}$	$4.05x10^{-09}$	$4.47x10^{-10}$

7.0 SUMMARY

Input variables required by the DAM include the physical and chemical properties of the repository contents following waste and backfill emplacement in the WIPP. The contents are assumed to be a homogeneous waste/backfill composite. This composite consists the four following components:

- Solid organics
- Solid inorganics
- Sludges
- Backfill material (if present).

The properties required by the DAM for evaluation of the effectiveness of EAs include the following:

- Density
- Porosity
- Hydraulic conductivity
- Gas generation potential
- Effective waste volume.

Density of the waste-backfill composite is computed by assigning weights to the individual component densities as illustrated with Equation (3.6.6). The porosity of the composite is a function of the composite density. An estimate of the hydraulic conductivity of the waste/backfill composite is the geometric mean of the component hydraulic conductivities. Gas generation (microbial and corrosion) potentials are computed from the equivalent number of unprocessed drums emplaced in a room, taking into account the effect of waste treatment on components. With the exception of total gas generation potential, the physical properties vary with pressure resulting from creep closure. Properties for the three major waste forms and the backfill materials are obtained from available literature, applicable relationships or equations, and information from Appendix O. Using the above evaluation process, physical properties of the waste/backfill composite in an average WIPP repository room are computed for use as input to the DAM.