OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT
CALCULATION COVER SHEET

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	Print Name	Signature	Date
6. Originator	John McCord	[signature]	Nov 15, 2000
7. Checker	Michael Sauer	[signature]	Nov 15, 2000
8. Lead	Michael Sauer	[signature]	Nov 15, 2000

Remarks

Revision History

10. Revision No.	11. Description of Revision
REV01	REV01 is a complete revision of REV00. REV01 includes updating this calculation to account for revised thermal design considering "no-backfill design" change described by Technical Change Request: "Site Recommendation Design Baseline" (CRWMS M&O 2000g). In addition, this calculation revision includes: • new input probabilities calculated in CRWMS M&O 2000b for the length and orientation of dikes intersecting the repository footprint and for the number of eruptive centers within the repository footprint; • revised input information related to the probability distribution for number of dikes in a swarm (CRWMS M&O 2000a); • revised input information related to assumed minimum conduit diameter; • revised calculation approach related to Volcanic Eruption scenario to provide cumulative distribution functions for conduit diameter and number of conduits on a dike, and calculating maximum number of waste packages intersected per conduit diameter, • revised calculation approach for the Igneous Intrusion Groundwater Release scenario using relationships and calculations based on area; • revised calculation assumptions which address both a "with backfill" repository design (waste packages hit in Zone 1) and the "no backfill" design (waste packages hit in Zone 1 and Zone 2 combined) (CRWMS M&O 2000c); • revised input related to repository layout, waste package length, and waste package spacing (CRWMS M&O 2000h); • and miscellaneous editorial changes including eliminating discussion related to a drift azimuth angle of 108 degrees.

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Enclosure 2

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FIGURES

TABLES

ACRONYMS

CDF	Cumulative Distribution Function
CRWMS	Civilian Radioactive Waste Management System
DTN	Data Tracking Number
M&O	Management and Operation
MTU	Metric tonne uranium
PDF	Probability Distribution Function
PHVA	Probabilistic Volcanic Hazard Analysis
SR	Site Recommendation
TBV	To be Verified
TSPA	Total Systems Performance Assessment

1.0 PURPOSE

In broad terms, the purpose of this calculation is to support the analyses of the contribution of igneous activity to Yucca Mountain Repository Total System Performance Assessments. Igneous activity is a disruptive event that is included in the Total System Performance Assessment-Site Recommendation analyses. Two igneous-activity scenarios are analyzed here (Figure I-1). The Volcanic Eruption scenario is direct release of radioactive waste to the accessible environment because of a volcanic eruption. The Igneous Intrusion Groundwater Release scenario considers the *in situ* damage to waste packages that occurs if they are encapsulated or otherwise affected by magma as a result of an igneous intrusion. An igneous intrusion is defined as magmatic activity that does not reach the earth's surface. Magma that does reach the surface from igneous activity is an eruption (or extrusive activity).

The objective of the calculation is to develop a probabilistic measure of the number of waste packages that could be affected (either damaged or dispersed) by the two scenarios. For the Volcanic Eruption Scenario, the number of waste packages destroyed by a volcanic eruption is the calculated number of waste packages contained within an eruptive conduit of a specified diameter, given that a dike has intersected the drift, and that the conduit is located at a drift. For the Igneous Intrusion Groundwater Release Scenario the number of waste packages damaged by an igneous intrusion (dike) that intersects the repository, but does not result in an eruption reflects the calculated number of waste packages that have been damaged in-situ by magma.

On January 26, 2000 a design change was initiated to resolve certain thermal design issues. This design change will result in a greater ability of the waste packages to reject heat after closure of the repository, thereby maintaining the two thermal requirements. The first requirement is protective of the fuel cladding, and the second requires that a section of the rock pillar between drifts remain below the boiling temperature of water, providing a path for water drainage. This design change is described in CRWMS M&O 2000g, *Technical Change Request: "Site Recommendation Design Baseline"*. TCR: T2000-0133. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000503.0159. This current baseline is also specified in *Monitored Geologic Repository Project Description* (CRWMS M&O 2000j).

This design change requires changes to documents that utilized the previous design. Among the documents requiring changes is Revision 00 of this calculation (CRWMS M&O 2000i). Significant differences between the initial issue of this calculation (Revision 00) which addressed a repository design that included "backfill" and this revision which addresses a repository design with "no backfill" are described in Section 6.0 Results.

In addition to this design change REV01 includes:

- new input probabilities calculated in CRWMS M&O 2000b *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada*, ANL-MGR-GS-000001 REV00 ICN1 for the length and orientation of dikes intersecting the repository footprint and for the number of eruptive centers within the repository footprint;
- revised input information related to the probability distribution for number of dikes in a swarm (CRWMS M&O 2000e. *Input Transmittal Providing Recommendation on the*

Maximum Number of Dikes in a Swarm. 00318.T. Las Vegas, Nevada: CRWMS M&O. Submit to RPC);

- revised assumption information related to minimum conduit diameter;
- revised calculation approach for the Volcanic Eruption scenario;
- revised calculation approach for the Igneous Intrusion Groundwater Release scenario;
- revised input related to repository layout, waste package length, and waste package spacing (CRWMS M&O 2000h. *Site Recommendation Subsurface Layout.* ANL-SFS-MG-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. Submit to RPC URN-0220);
- miscellaneous editorial changes including changes made to accommodate the revised inputs and eliminating discussion related to a drift azimuth angle of 108 degrees; and
- a more detailed discussion on the use of EXCEL spreadsheet application.

The work is being performed according to procedure AP-3.12Q, Rev. 0/ICN 3, *Calculations.* The development plan for this work is documented in (CRWMS M&O 2000f). The QAP-2.0 evaluation for the activity is documented in (CRWMS M&O 1999).

2.0 METHOD

This calculation utilizes a conceptual model for an igneous intrusion that intersects the repository footprint (described below), simplifying assumptions related to the impact of igneous intrusions on waste packages (see Section 3), and input parameters from analysis/model reports (see Section 5). In this calculation, the inputs are sorted and used in hand calculations to determine the number of waste packages destroyed due to an igneous event that intrudes into the repository. The hand calculations are done using accepted EXCEL spreadsheet functions (see Section 4). Outputs from this calculation are discussed in Section 6.

The methods used to control the electronic management of data as required by AP-SV.1Q, *Control of the Electronic Management of Information*, were not specified in the Development Plan, *Number of Waste Packages Hit by Igneous Intrusion* (CRWMS M&O 2000f). With regard to the development of this calculation, the control of electronic management of data was evaluated in accordance with YAP-SV.1Q, *Control of the Electronic Management of Data*. The evaluation (CRWMS M&O2000k) determined that current work processes and procedures are adequate for the control of the electronic management of data for this activity. Though YAP-SV.1Q has been replaced by AP-SV.1Q, this evaluation remains in effect.

All key components related to the basic conceptual model used in this calculation are based on data and interpretations in the Probabilistic Volcanic Hazards Analysis (PVHA) report (CRWMS M&O 1996a) and the repository layout in, *Site Recommendation Subsurface Layout* (CRWMSM&O 2000h). Figure I-2 shows a schematic drawing of the repository layout. The PVHA report provides the framework for three analysis/model reports that provide probability distributions that are used as input for this calculation. These analysis/model reports include *Characterize Framework for Igneous Activity at Yucca Mountain, Nevada* (CRWMS M&O 2000b), *Dike Propagation Near Drifts*, (CRWMS M&O 2000c); and, *Characterize Eruptive*

Processes at Yucca Mountain, Nevada (CRWMS M&O 2000a). This calculation provides outputs to *Igneous Consequence Modeling for the TSPA-SR* (CRWMS M&O 2000e).

Basic elements of the conceptual model used in this calculation include:

- An igneous event occurs in the Yucca Mountain region. An event is defined as an ascending basaltic dike(s) that reaches the repository elevation and intersects the repository footprint. If the dike(s) continues to the surface, then a volcanic eruption occurs. If the dike does not continue to the surface, then the event is termed an igneous intrusion.

- The intrusion process assumed is that a vertical tabular dike propagates up to the level of a horizontal planar network of parallel, equally spaced repository drifts. Above the drifts, eruptive conduits may form somewhere along the dike. These conduits are circular in cross section and develop from the surface downward. At the surface, the conduit is referred to as a vent. For each eruptive vent there is assumed to be one and only one conduit. Conduits connect the earth's surface with dikes at repository level.

- A dike(s) is described by its length inside the repository footprint, its azimuth angle (orientation of the dike relative to the drifts), its width, the number of eruptive centers (or as used in this calculation "conduits") on the dike(s), the diameter of conduits, and the number of dikes in a swarm. CRWMS M&O 2000b (Section 6.5) provides information on dike length, azimuth angle, and number of conduits on a dike. CRWMS M&O 2000a (Section 6.1) and CRWMS M&O 2000e (entire) provides information on dike width, conduit diameter, and number of dikes in a swarm.

- The probability of occurrence for a dike intersecting the repository footprint was initially developed in the PVHA (see, for example CRWMS M&O 1996, Figure 4-32a). This probability has been updated because the repository shape and size are now different from that used in the PVHA elicitations. The new probabilities have been developed from the original PVHA interpretations and are provided in CRWMS M&O 2000b (Section 6.5).

- CRWMS M&O 2000b (Section 6.5.2.2, page 94) defines five alternative approaches for assessing the number of eruptive centers per volcanic event and the spatial distribution of eruptive centers along the length of a dike assuming that the presence of repository drifts has no impact on the likelihood of an eruptive conduit forming within the potential repository footprint. The weighting for these alternative assessments is provided and justified in CRWMS M&O 2000b (Section 6.5.2.2, page 96). The five alternative approaches for the number of eruptive centers (conduits) on a dike and their relative weighting include:

  1. **IUD-UC:** Independent, uniformly distributed conduit locations, with distribution for total number of conduits not correlated with dike length (weighting 0.05);

2. **IUD-C:** Independent, uniformly distributed conduit locations, with distribution for total number of conduits correlated with dike length; (e.g. lower probability for short dikes and higher probability for long dikes) (weighting 0.075) ;

3. **USRD-UC**: Uniformly spaced dike segments, random location of conduit within each segment, distribution for total number of conduits not correlated with dike length (weighting 0.15);

4. **USRD-C:** Uniformly spaced dike segments, random location of conduit within each segment, distribution for total number of conduits correlated with dike length (weighting 0.225); and

5. **USRD-FD**: Uniformly spaced dike segments, random location of conduit within each segment, distribution for total number of conduits based on an empirical distribution for average spacing of 2.5 km between eruptive centers (weighting 0.50).

In addition, CRWMS M&O 2000b (Section 6.5.2.2, page 97) evaluates a sixth alternative approach that considers that the proposed repository opening induces at least one eruptive center. CRWMS M&O 2000b (Section 6.5.3.2) provides probability results for all six approaches. The weightings are used to combine the calculation results and provide a composite conditional distribution for the number of eruptive centers. The results of all calculations are combined to provide a final composite conditional probability distribution for the number of eruptive centers on a dike within the repository footprint (CRWMS M&O 2000b, Table 12a).

- The repository layout (CRWMS M&O 2000h) provides information on the number of drifts that could be crossed by a dike with a given azimuth angle and length inside the repository. The intersection of the repository by a dike is described by simple linear and area relationships between vertical tabular dikes that intersect a horizontal planar network of parallel, equally spaced repository drifts.

- For the no-backfill design two zones are defined related to the assumed level of damage to waste packages. Zone 1 is that area of a drift(s) that is intersected by a dike(s). The waste packages in Zone 1 are assumed to be completely destroyed and all waste from these packages is immediately available for transport (see Section 3.6). Zone 2 is that drift area that contains the remaining waste packages in each drift that is intersected by a dike(s). The waste packages in Zone 2 are assumed to experience some damage that is less extensive than the damage to Zone 1 packages. A more detailed discussion of this conceptual model is provided in CRWMS M&O 2000c (Section 6.3.1, page 26 and 27). In addition, Zone 1 is the only area of a drift that would be impacted by a dike for a repository design that includes backfill.

- There are several styles of eruptions that have previously occurred in the Yucca Mountain region (CRWMS M&O 2000a, Section 6.2; CRWMS M&O 2000b, Section 6.3). A relatively violent eruption of long duration would have the greatest potential for interacting with relatively more waste packages and dispersing volcanic ash contaminated with radioactive waste over relatively large distances. Volcanologists characterize such highly dispersive eruptions as "violent strombolian" (CRWMS M&O 2000a, Section 6.5.1).

- Factors that are not considered because they are beyond the scope of this calculation include; fragmentation depth (the depth at which trapped gases exsolve from the liquid magma) of the ascending magma; eruption duration; magma chemical and physical properties; and the interaction of the dike with the repository drift network.

3.0 ASSUMPTIONS

This section identifies assumptions that are essential for this calculation. The discussion of each assumption includes four elements: (1) a statement of the assumption; (2) the rationale for the assumption; (3) a statement on the need for further confirmation, if any, of the assumption (i.e. the TBV status); and (4) a statement where the assumption is used in the calculation.

3.1 REPOSITORY CHARACTERISTICS

Assumption: This calculation uses a set of simplified repository characteristics for the 70,000 MTU Primary Block. Repository characteristics are documented in CRWMS M&O 2000h. Simplifying assumptions include: (1) assuming that each drift contains approximately 219 waste packages (average of total number of waste packages of 11,184 in 51 drifts); (2) assuming that the average drift length is 1,102.4 m (number of waste packages per drift multiplied by the sum of waste package length and waste package spacing); and (3) assuming that the repository is a rectangular area with a north-south length of 4,343.58 m and a east-west length of 1,048.44 m The east-west length is determined using the right-triangle formula with a drift azimuth angle of 72° and the calculated average drift length (see (2) above). The north-south length is then calculated by dividing 70,000 MTU Primary Block area specified in CRWMS M&O 2000h (Section 6.3.1) by the calculated east-west length.

Rationale: This assumption is a reasonable simplification made to facilitate the calculation.

Confirmation Status: No additional work is planned to verify this assumption. It is considered as a reasonable simplification.

Use within the Calculation: This assumption is used in Sections 5.3.

3.2 DIKE LENGTH, AZIMUTH ANGLE AND NUMBER OF ERUPTIVE CONDUITS ON A DIKE

Assumption: It is assumed that the simulation output file CCSM-PCB documented in CRWMS M&O 2000b and provided in DTN LA0009FP831811.004 is the most representative for igneous intrusive events in the Yucca Mountain region. File CCSM-PCB contains the composite conditional distributions for dike length, dike azimuth, and number of eruptive centers, appropriate for the mean frequency of intersection of both the primary block and the contingency block. While this calculation only considers the waste packages contained in the Primary Block, the CCSM-PCB output file was selected for use in this calculation because it is considered more conservative than the CCSM-PB output file.

Rationale: In CRWMS M&O 2000b six simulations files were reported reflecting the uncertainties inherent in the PVHA calculation and repository design. The six files are CCSM-PB.CMP, CC05-PB.CMP, CC95-PB.CMP, CCSM-PCB.CMP, CC05-PCB.CMP, and CC95-PCB.CMP. File CCSM-PB contains the composite conditional joint probability distributions for dike length, dike azimuth, and number of eruptive centers within the repository footprint, appropriate for the mean frequency of intersection of the primary repository block. Files CC05-PB and CC95-PB contain the conditional distributions for dike length, dike azimuth, and number of eruptive centers, appropriate for the 5^{th} and 95^{th}-percentile of the distribution for frequency of intersection, respectively. File CCSM-PCB contains the conditional distributions for dike length, dike azimuth, and number of eruptive centers, appropriate for the mean frequency of intersection of both the primary block and the contingency block. Files CC05-PCB and CC95-PCB contain the conditional distributions for dike length, dike azimuth, and number of eruptive centers, appropriate for the 5^{th} and 95^{th}-percentile of the distribution for frequency of intersection, respectively. Only the CCSM-PCB output file is used in this calculation because it is expected to bound the effects of possible design changes.

Confirmation Status: No additional work is planned to verify this assumption. All output data from this simulation are expected to bound the effects of possible design changes.

Use within the Calculation: The parameters associated with this are used in Sections 5.2 and 5.3.

3.3 DIKE WIDTH, NUMBER OF DIKES IN A SWARM, AND CONDUIT DIAMETER

Assumption: It is assumed that the probabilities for dike width, number of dikes in a swarm, and conduit diameter provided in CRWMS M&O 2000a are representative for igneous events in the Yucca Mountain region. It is further assumed that the maximum number of dikes in a swarm is 15 (CRWMS M&O 2000e), which is considered a reasonable and bounding representation.

Rationale: This assumption is considered to be reasonable and is based on the expert elicitations documented in the *Probabilistic Volcanic Hazards Analysis Report* (CRWMS M&O 1996), and the input transmittal providing a recommendation on the maximum number of dikes in a swarm (CRWMS M&O 2000e).

Confirmation Status: No additional work is planned to verify this assumption. These probabilities are considered to be bounding.

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2 and 5.3.

3.4 MINIMUM CONDUIT DIAMETER

Assumption: It is assumed that the minimum conduit diameter used for this calculation is 4.5 m.

Rationale: CRWMS M&O 2000a (Section 6.1) indicates that the minimum conduit diameter should be the same as the dike width selected for each realization. To simplify this calculation a single dike width of 4.5 m (approximate length of one waste package) is assumed to provide the minimum conduit diameter. This dike width correlates to the 95th percentile probability for dike width (CRWMS M&O 2000a, Section 6.1).

Confirmation Status: No additional work is planned to verify this assumption. This assumption is conservative.

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2.

3.5 DIKE INTERSECTION WITH THE REPOSITORY

Assumption: It is assumed that the point of intersection of a dike with the repository occurs at the widest part of the repository for every dike azimuth angle. A simple geometric model is used with a vertical tabular dike intersecting a horizontal planar network of parallel, equally spaced repository drifts.

Rationale: This assumption is conservative and maximizes the dike length inside the repository.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is conservative.

Use within the Calculation: The parameter associated with this assumption is used in Sections 5.2 and 5.3.

3.6 EFFECTIVE DIKE WIDTH FOR A REPOSITORY DESIGN THAT INCLUDES BACKFILL

Assumption: It is assumed that the effective width for an intersecting dike with a drift is the width of the dike plus 15 meters on each side of the dike. This is considered as the Zone 1 (CRWMS M&O 2000c, page 27) region. All waste packages within this zone are assumed to be destroyed and the waste in the packages immediately available for groundwater transport. This assumption results in an individual effective dike width of 30m + the width of the individual dike. This total effective dike width results in three waste packages on both sides of a dike to be included in the calculation for number of waste packages hit under the Igneous Intrusion Groundwater Release scenario in Zone 1.

Rationale: This value is within the range provided in CRWMS M&O 2000c (pages 25-26) and represents the only region of concern in a repository design that includes "backfill". This assumption is considered reasonable for a repository design that includes backfill.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is considered to be reasonable.

Use within the Calculation: The parameter associated with this assumption is used in Section 5.3.

3.7 IMPACT OF A DIKE INTERSECTING A DRIFT IN ZONE 1 AND ZONE 2 FOR A "NO BACKFILL" REPOSITORY DESIGN

Assumption: It is assumed that a dike intersecting a drift without backfill will fill the drift with magma and all packages within the drift will be impacted. It is assumed that all packages in Zone 1 (see Section 3.6 above) will be destroyed and the waste from these packages immediately available for groundwater transport. The remaining waste packages in the drift are within Zone 2 and are assumed to show variable degrees of damage (CRWMS M&O 2000c, pages 26-27). This calculation determines the number of waste packages in each zone.

Rationale: This assumption reflects the conceptual model for the interaction of a dike with a drift provided in CRWMS M&O 2000c. This assumption is considered reasonable for a repository design that does not includes backfill.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is considered to be reasonable.

Use within the Calculation: The parameter associated with this assumption is used in Section 5.3.

3.8 DIKE SWARMS

Assumption: All dikes in a swarm are assumed to have the same length and width.

Rationale: This assumption is a simplification.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is a reasonable simplification to facilitate the calculation.

Use within the Calculation: The parameter associated with this assumption is used in Section 5.3.

3.9 DIKE SPACING WHEN MULTIPLE DIKES INTERSECT A DRIFT

Assumption: When multiple dikes intersect a drift, it is assumed that the dike spacing is 30 meters.

Rationale: This assumption is a simplification. When coupled with Assumption 3.6, this assumption results in one combined dike with a total width equal to the sum of effective dike widths for each dike in the swarm.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is a reasonable simplification to facilitate the calculation.

Use within the Calculation: The parameter associated with this assumption is used in Section 5.3.

3.10 CONDUITS OCCURING WITHIN THE REPOSITORY FOOTPRINT INTERSECT AT LEAST ONE DRIFT

Assumption: When a conduit occurs within the repository footprint it is assumed that at least one drift is intersected.

Rationale: This assumption is a simplification that maximizes the potential for a conduit to intersect a drift.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is conservative in that it maximizes the potential for a conduit to intersect a drift.

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2.

3.11 WHEN A CONDUIT INTERSECTS A DRIFT(S)

Assumption: When one conduit with a diameter of less than 90 m intersects a drift, the conduit is assumed to be centered on the drift and all waste packages within the conduit diameter are assumed to be destroyed. When the diameter of one conduit is greater than 90 m, it is assumed to intersect two drifts. It is further assumed that when a conduit intersects two drifts, that conduit is centered on a pillar which maximizes the number of waste packages destroyed.

Rationale: This assumption is a simplification that maximizes the number of waste packages hit by a single conduit that intersects a drift(s).

Confirmation Status: Section 5.2 provides a discussion that supports this assumption. This assumption is conservative in that it maximizes the number of waste packages hit when one conduit intersects a drift(s).

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2.

3.12 WHEN MULTIPLE CONDUITS INTERSECT THE REPOSITORY

Assumption: When multiple conduits occur within the repository footprint, all conduits are assumed to have the same diameter.

Rationale: This assumption is a simplification that maximizes the number of waste packages hit by multiple conduits.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is conservative because it maximizes the number of waste packages hit when multiple conduits occur within the repository footprint.

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2.

3.13 WASTE PACKAGES DESTROYED WITHIN A CONDUIT

Assumption: It is assumed that only those waste packages located partially or entirely within the area of the eruptive conduit contribute to the radionuclide source term for the volcanic release scenario. The number of waste packages within an eruptive conduit is a function of conduit diameter, waste package length, and inter-package spacing.

Rationale: Although magma associated with an eruption may contact other packages along the drift, the magma moving with sufficient velocity to entrain waste in an eruption is assumed to be located only within the conduit.

Confirmation Status: No additional work is planned to verify this assumption. This assumption is considered reasonable.

Use within the Calculation: The parameters associated with this assumption are used in Sections 5.2.

4.0 USE OF COMPUTER SOFTWARE AND MODELS

This calculation is a hand calculation that uses built-in spreadsheet applications from the EXCEL -97 for Windows. Only EXCEL built-in functions (such as SUM, SIN, COS, ATAN, MIN, MAX, IF, CEILING, etc.) have been used in the calculation. These built-in functions are used in EXCEL workbooks to:

- Sort input data;
- Sample input data for use in equations 1 through 7;
- Facilitate the hand calculations specified in equations 1 through 7; and
- Develop probabilities and cumulative distribution functions (CDF's).

Sections 5.2 and 5.3 provide detailed discussions on the applications of all built-in EXCEL functions used in this calculation.

Attachment IV provides a description for the use of EXCEL functions in this calculation. This attachment is provided so that an independent reviewer of this calculation can easily check and verify the calculation results.

5.0 CALCULATION

The objective of this calculation is to develop a probabilistic measure for the number of waste packages affected (either damaged or dispersed) under the following two scenarios (Figure I-3):

Volcanic Eruption Scenario: Number of waste packages contained within an eruptive conduit of a specified diameter, given that a dike has intersected the drift, and that the conduit is located at a drift, Igneous Intrusion Groundwater Release Scenario: Number of waste packages in the drifts that have been contacted by magma, given that a dike has intersected the drifts.

The probability of occurrence for the Volcanic Eruption Scenario (P [conduit occurs at a drift on a dike inside the repository]) can be expressed in terms of its component probabilities as:

P [one conduit coincides with a drift] • (a)
P [conduit occurs anywhere inside the repository on a dike of length L, azimuth α] • (b)
P [dike with parameters (L,α) occurs in repository] • (c)
P [dike intersects repository footprint]. (d)

Component probabilities (b), (c), and (d) are provided in CRWMS M&O 2000b (Sections 6.5.3.1 and 6.5.3.2). The dike length–azimuth (L,α) data file represents the possible outcomes and their corresponding probabilities for a simulation of a dike intrusion event into the repository area. The conditional probability of this event is 1.0. Any individual (L,α) pair is only a component of the total conditional probability. To evaluate the event, the component probabilities are summed over all (L,α) pairs to give the probability that a conduit occurs at a drift. In this calculation component probability (a) is assumed to be 1.0 (see Section 3.10).

The probability of occurrence for the Igneous Intrusion Groundwater Release scenario (P [dike crosses n drifts]) can be expressed in terms of its component probabilities as:

P [dike with parameters (L,α) occurs in repository] • (c)
P [dike intersects repository footprint]. (d)

The component probabilities are summed over all (L,α) pairs to give the probability that a dike has intersected a drift. In the following sections, the component probabilities are described in more detail.

5.1 INPUT SOURCES

Table II-1 summarizes all inputs used for this calculation.

CCSM-PCB.CMP: The CCSM-PCB output file of conditional probabilities (CRWMS M&O 2000b, Section 7.1 and DTN LA0009FP831811.004) is used as input to this calculation for dike length, azimuth angle, and number of eruptive centers (conduits) on a dike. The probabilities in this output file are conditional on the occurrence of intersections of the repository by a dike. The output file consists of 3888 points in a parameter space for dike length and azimuth angle. The data exhaustively cover all angles from 0° (north) to 175° in 5 increments (south-southeast) and lengths from 0 km to 5.35 km in 0.05 km increments. At each length-azimuth point, the simulation has stochastically calculated the probability of occurrence. Details of this analysis are discussed in CRWMS M&O 2000b (Section 6.5), but in essence the simulation assumes an origin for the igneous event and a dike with a given length and direction extending away from the origin. Points of origin have been used throughout the region around the repository based on the PVHA experts' interpretations. This input information is used in the calculations for the number of waste packages hit for both the Volcanic Eruption scenario (Section 5.2) and the Igneous Intrusion Groundwater Release scenario (Section 5.3).

Marginal Conditional Distribution for Number of Eruptive Centers (Conduits) on a Dike: CRWMS M&O 2000b, Section 6.5.2, Table 12a provides the final composite conditional probability distribution for number of eruptive centers on a dike for the primary + contingency block mean hazard. This distribution is used as input to this calculation for the determining the cumulative distribution function for number of eruptive centers on a dike.

Repository Design Input Information: The 70,000 MTU repository design input information provided in Table II-1 includes drift orientation, drift spacing, drift diameters, Primary Block area, number of waste packages, waste package length, and waste package spacing have been taken from CRWMS M&O 2000h. The sections from this technical report which identify the individual input information are specified in Table II-1. This input information is used in the calculations for the number of waste packages hit for both the Volcanic Eruption scenario (Section 5.2) and the Igneous Intrusion Groundwater Release scenario (Section 5.3). Figure I-2 shows a representation of the layout of the 70,000 MTU Primary Block.

Dike Width, Number of Dikes in a Swarm, and Conduit Diameter Input Information: Probabilities for dike width, number of dikes in a swarm, and eruptive conduit diameter are taken from CRWMS M&O 2000a (Section 6.1). In addition, a recommendation from the originator of this analysis/model report to truncate the PDF for number of dikes in a swarm at 15 is provided in a design input transmittal (CRWMS M&O 2000e). Each of these probabilities are transformed into CDFs. The CDF for conduit diameter is used in the calculations for the number of waste packages hit for the Volcanic Eruption scenario (Section 5.2). The CDFs for dike width and number of dikes in a swarm are used in the calculation for number of waste packages hit for the Igneous Intrusion Groundwater Release scenario (Section 5.3).

Dike Interaction with Repository Drifts: Magma that flows down drifts away from the dike can proceed until the materials in the drift obstruct it, or it solidifies. Waste packages that are so impacted by this laterally flowing magma can be destroyed, and thus can release radionuclides that may be later transported by groundwater. From CRWMS M&O 2000c (pages 26-27), magma is considered to flow approximately 15 m on either side of the dike through the drifts for a repository design that includes backfill (Zone 1 – see Section 3.6). For a repository design with "no backfill", the magma is assumed to fill the drift completely and destroy or damage all waste packages within that drift (Zone 1 + Zone 2 – see Section 3.6 and 3.7).

5.2 CALCULATIONS FOR DETERMINING NUMBER OF WASTE PACKAGES HIT UNDER THE VOLCANIC ERUPTION SCENARIO

The calculations accomplished for this scenario are done utilizing EXCEL workbook CAL-WIS-PA-000001_REV00_ICN1_Volc_anal_Sept-00.xls. The output from this calculation includes:

- CDF for conduit diameter;
- number of waste packages contained within an area circumscribed by a conduit diameter; and
- CDF for number of eruptive centers on a dike.

Calculating the CDF for conduit diameter: The distribution for conduit diameter is taken from CRWMS M&O 2000a (Section 6.1). This distribution is given as a log normal distribution with a minimum equal to dike width, a median value of 50 m and a maximum value of 150 m. For this calculation the minimum diameter is assumed to be 4.5 m (see section 3.4). This value for the minimum conduit diameter corresponds to the 95 percentile dike width (CRWMSM&O 2000a Section 6.1) and approximates the length of one waste package. This probability distribution conservatively defines the range of conduit diameters for a potential volcanic event at Yucca Mountain. Given this input, a full probability distribution function is generated in this calculation. Table II-2 provides the resulting probability and cumulative distributions for conduit diameter. Figure I-4 shows the probability distribution function (PDF) for eruptive conduit diameters.

Calculating the number of waste packages contained in an area circumscribed by a conduit diameter: Section 3.11 provides the assumption on the number of waste packages hit when one or two drifts are intersected by one conduit.

The calculation for the number of waste packages destroyed when the conduit is centered on a drift uses the waste-package length and inter-package spacing (see Table II-1) and the conduit diameter. To determine the whole and fractional packages contained within the conduit centered on a drift:

$$N_{pkgconduit} = \text{CEILING}\ [CD/(P_l+P_s)] \qquad \text{(Eq. 1)}$$

where *CEILING* is the EXCEL spreadsheet function that rounds up its arguments and CD is conduit diameter in meters. The number of packages is the quotient of conduit diameter divided by the sum of package length, P_l, and package spacing, P_s (see Table II-1 for information source)

.

When one conduit with a diameter of greater than 90 m occurs in the repository it will intersect two drifts , $N_{pkgconduit}$ is calculated assuming that the conduit is centered on a pillar. To determine the number of waste packages contained within a conduit that is centered on a pillar:

$$I_L = \text{SQRT}((CD/2)^2 - (DS/2)^2) \times 4 \qquad \text{(Eq. 2)}$$

where SQRT is the EXCEL spreadsheet square root function, DS is drift spacing in meters, and I_L is the intersection length along the center-line of the adjacent drifts.

$$N_{pkgconduit} = \text{CEILING}[\ I_L/\ (P_l+P_s)] \qquad \text{(Eq. 3)}$$

Equation 2 first solves for a the intersection length in one quadrant of the conduit using the length formula for a right triangle where the base of the triangle is the half-length of drift spacing (center-line to center-line spacing of 81 m) and the hypotenuse of the triangle is the radius of the conduit. Figure I-3c shows this relationship. To get the total intersection length, this result for one quadrant is multiplied by 4. Note that this calculation for $N_{pkconduit}$ does not consider additional packages that would be impacted at the periphery of a large conduit.

Table II-3 summarizes the number of packages intersected for the range of expected conduit diameters when the conduit is: (1) centered on a drift; and (2) when the conduit is centered on a pillar. The number of waste packages intersected by a conduit ranges from 1 for a conduit diameter of 4.5 m up to 51 for a conduit diameter of 150 m.

Review of this table indicates that the maximum number of packages intersected occurs when a conduit is centered on a drift up to a conduit diameter of about 90 m. For conduit diameters greater than 90 m, the maximum number of packages intersected occurs when the conduit is centered on a pillar.

Calculating the CDF for number of conduits on a dike: The distribution for number of conduits on a dike is taken from CRWMS M&O 2000b (Section 6.5.3.2, Table 12a) for the Primary + Contingency Block mean probabilities. For this calculation this distribution is given for:

- weighted average for the random location alternatives;
- re-normalized for the assumption that the repository induces at least one conduit; and
- the final composite conditional probability.

Table II-4 provides the final composite conditional probability distribution and cumulative distribution for number of conduits on a dike within the repository footprint.

5.3 CALCULATION OF THE NUMBER OF WASTE PACKAGES HIT UNDER THE IGNEOUS INTRUSION GROUNDWATER EVENT SCENARIO

The calculations accomplished for this scenario are done utilizing EXCEL workbook CAL-WIS-PA-000001_REV00_ICN1_EST_anal_Sept-00.xls. The output from this calculation includes:

- CDF for the number of waste packages hit in Zone 1; and
- CDFs for the number of drifts crossed by a dike (or dike swarm), and the total number of waste packages hit in Zone 1 and Zone 2 combined.

For the no-backfill design, the waste packages in Zone 1 are assumed to be destroyed and completely available for transport. The additional waste packages in Zone 2 are damaged to varying degrees. Determination of the degree of damage to these waste packages is beyond the scope of this calculation. This calculation only identifies the number of packages in Zone 1 that are destroyed and the number of combined number of waste packages hit in Zone 1 + Zone 2.

The number of waste packages hit by a dike in Zone 1 is calculated using Equation 4

$$N_{pkgsdike} = (dike_A) \times (drift_{\%A}) \times (wp_{\%}) \qquad \text{(Eq. 4)}$$

where, $dike_A$ is dike area (m^2) within the repository and equal to $D_L \times D_W$. D_L = dike length inside the repository (m), and D_W = dike width of a dike (or dike swarm) inside the repository (m). D_L is the dike length given as input in CCSM-PCB. D_W is calculated considering the CDFs for dike width (ranging from 0.5 to 8 m) and number of dikes in a swarm (1 to 15). In addition, the calculation of D_L includes Assumptions 3.6, 3.8, and 3.9.

$drift_{\%A}$ is the drift area percentage of the total Primary Block repository area and is given by d_A/R_A,

where $d_A = d_L \times d_W \times d_n$. d_L is average drift length [this parameter is assumed to be equal to the average number of waste packages per drift (219.29) times the combined length of the average waste package and waste package spacing (5.027 m). Therefore d_L = 1102.37 m.]. d_W is the width of a drift and equal to 5.5 m. d_n the total number of emplacement drifts in the Primary Block repository layout and is equal to 51. For these values d_A is equal to 309,215 m^2.

R_A is given in CRWMS M&O 2000h ANL-SFS-MG-000001 REV00 (page 80) and is equal to 4,553,982 m^2.

Therefore $drift_{\%A} = 0.0679$.

$wp_{\%}$ is the number of waste packages per drift area and is given by $wp_{\%}$ = 11,184/309,215 m^2 or 0.0362 waste packages per square meter of drift.

In addition to calculating the number of waste packages hit in Zone 1, the calculation also determines the number of drifts crossed by a dike (or swarm of dikes). There are two parts associated with determining the number of drifts crossed by a dike. The first part is determining the number of drifts crossed along the dike length,

The dike length along a line perpendicular to the drifts, D_n, is calculated from the relation

$$D_n = L_r \sin(\beta - \alpha), \qquad \text{(Eq. 5)}$$

where L_r is the length inside the repository considering repository dimensions and $(\beta-\alpha)$ is the angle between a dike with orientation from north of α, and a drift with the compass heading β. L_r is given by

$$L_r = R_{ew} / \sin\alpha \qquad \text{(Eq. 6)}$$

where R_{ew} is the calculated east-west length of the repository. In the spreadsheet application of this calculation, L_r is constrained to a maximum length between 4343.58 m (the simplified north south length of the repository) and 1048.44 m (the simplified east-west length of the repository). Figures I-3a and I-3b shows schematic diagrams for these relationships.

The number of drifts crossed by a dike (n_D) along the dike length is calculated by dividing D_n by the drift spacing (d_s) (see Table II-1).

$$n_D = D_n/d_s \qquad \text{(Eq. 7)}$$

The second part of determining the number of drifts crossed by a dike uses an area approach. This approach takes into account dike (or dike swarm) width. In this approach the total area of a dike (or dike swarm), $D_L \times D_W$, is compared to the area determined by multiplying the number of drifts crossed along a dike length (n_D) by the average area of a single drift (average drift length [1102.39 m] x drift width [5.5 m] = 6063.15 m^2).

If the total dike area is less than or equal to this product (n_D x 6063.15 m^2), then the number of drifts crossed is equal to n_D. If the total dike area within the repository is greater than this product then the number of drifts crossed is rounded up to account for the larger dike area.

Igneous Intrusion Groundwater Release Scenario Calculation Spreadsheets

The Igneous Intrusion Groundwater Release scenario calculation is done in Excel workbook CAL-WIS-PA-000001_REV00_ICN1_*EST_anal_Sept-00.xls*. This EXCEL workbook includes seven spreadsheets that document the entire calculation.

Spreadsheet No.1 - *CCSM-PCB.OUT* – This spreadsheet contains the first three columns from the output file data (3888 entries) of the simulation CCSM-PCB.CMP (CRWMS M&O Section 7.1).

Examples of output information used in this calculation are shown in Table II-5. The first column of the table gives the dike length (in km); the second column is azimuth angle (in degrees from north). The third column is the probability of occurrence of that length-azimuth pair in the simulation.

Spreadsheet No.2 – *No Zeros* - The simulation CCSM-PCB data included many length-azimuth pairs that were zero (i.e., the simulations produced no instances where a dike had those parameters). This spreadsheet uses the EXCEL sorting function to retain only the non-zero length–azimuth probabilities and reduces the file size to 1821 entries. In addition, the data have been sorted to make the azimuth the more slowly varying. Reordering the pairs allows the probabilities to be easily summed over all dike lengths for each azimuth angle.

Examples of output information used in this calculation are shown in Table II-6. The first column of the table gives the dike length (in km); the second column is azimuth angle (in degrees from north). The third column is the probability of occurrence of that length-azimuth pair in the simulation.

Spreadsheet No. 3 – PDFs – CDFs – This spreadsheet calculates the CDFs for the input probabilities for dike width, number of dikes in a swarm, and conduit diameter. The input probabilities are taken from CRWMS M&O 2000a (Section 6.1). In addition, information provided in CRWMS M&O 2000e provides guidance recommending truncating the number of dikes in a swarm to 15. For dike width, the probability is defined as a log normal distribution with a minimum of 0.5 m, a mean of 1.5 m, and a 95th percentile of 4.5 m. For number of dikes in a swarm, the probability is defined as a log normal distribution with a minimum of 1, a mean of 3, and a 95th percentile of 10 and truncated at a maximum number of 15.

The CDF for conduit diameter was generated following guidance provided in CRWMS M&O 2000a that defined the distribution for conduit diameter as being log-normal with a minimum value equal to the dike width, a median value of 50 meters, and a maximum value of 150 meters. The resulting CDF was developed in 5 meter steps to allow for adequate sampling resolution within the TSPA-SR model. The CDF for dike width was defined within CRWMS M&O 2000a as log-normal distribution with a minimum of 0.5 meters, a mean of 1.5 meters, and a 95th percentile of 4.5 meters. The resulting CDF conforms to this specification with a maximum value of 8.0 meters and was developed in 0.5 meter steps for adequate sampling resolution within TSPA-SR. The CDF for number of dikes in a swarm was defined in CRWMS M&O 2000a and additional guidance was provided in CRWMS M&O 2000e. The number of dikes in a swarm was defined as a log-normal distribution with a minimum of 1 dike, a mean of 3 dikes, a 95th percentile of 10 dikes, and a maximum value of 15 dikes. The resulting CDF conforms to this specification with a 95^{th} percentile of 10 dikes and was developed in "1 dike" steps for adequate sampling resolution within TSPA-SR.

Table II-7 and II-8 provide the PDFs and CDFs for dike width and number of dikes in a swarm. Figures I-5 and I-6 show plots of the PDFs for dike width and number of dikes in a swarm.

Spreadsheet No. 4 - *Inp-params-EST* - This spreadsheet summarizes the other input information and results of supporting hand calculations used in the calculation.

Table II-9(a) duplicates the upper portion of this spreadsheet and includes the following information:

- drift angle (see Table II-1 for information source);
- drift spacing (see Table II-1 for information source);
- drift diameter (see Table II-1 for information source);
- waste package length and waste package spacing (see Table II-1 for information source);
- the calculated azimuth range for parallel angle and the parallel angle (arctangent of the drift spacing divided by the drift length and is +/- 4.2 degrees);
- the Primary block area (see Table II-1 for information source);
- the calculated Primary block drift area (total drift length x drift diameter);
- the total number of waste packages in the Primary block (see Table II-1 for information source);
- the calculated percentage of drift area in the Primary block (drift area divided by total primary Block repository area);
- the calculated number of waste packages per drift area (total number of waste packages divided by drift area);
- the total number of drifts in the Primary block (see Table II-1 for information source);
- the calculated average number of waste packages per drift (total number of waste packages divided by total number of emplacement drifts);
- the calculated approximate north-south length of a simplified rectangular area encompassing the Primary block (total repository area divided by calculated east-west length);
- the calculated approximate east-west length of a simplified rectangular area encompassing the Primary block (cosine (90-72) times average drift length);

- the calculated average drift length (calculated average number of waste packages per drift times the sum of waste package length and waste package spacing); and
- the calculated average drift area (calculated average drift length times drift diameter).

Table II-9(b) provides CDF look-up tables for dike width and number of dikes in the swarm (see discussion for Spreadsheet No. 3).

Spreadsheet No. 5 - *Simulations-EST* - The next spreadsheet in the workbook, labeled *Simulations-EST*, samples from the CDF look-up tables in Spreadsheet No. 3 to calculate the numbers of waste packages hit by one or more dikes in Zone 1. Table II-10 provides a sample from this spreadsheet.

The number of waste packages in Zone 1 that can contribute to the enhanced source term are calculated from the simulations shown in Table II-10 (labeled *Simulations-EST*). This spreadsheet repeats the dike length, azimuth, and probability data from sheet *No-zeros*.

Column 4 uses Equation 6 to calculate the maximum dike length that can lie within repository boundaries based on the length and azimuth angle for every input dike length given in column 1.

Column 5 calculates the total dike area within the repository by multiplying column 4 values by the effective total width of a dike swarm (top of column 5). The total effective width of a dike is calculated by multiplying individual dike widths by number of dikes in a swarm. In addition, it is assumed magma will flow laterally along a drift away from the dike a distance of approximately 15 m (see Section 3.6) on either side of the dike. This assumption adds 30 meters to each calculated dike width. This calculation is accomplished in this spreadsheet multiple times to exhaustively consider each CDF value for dike width and number of dikes in swarm for each input value of dike length. The calculation uses the EXCEL CEILING function which rounds the calculated results up to the nearest whole number.

Column 6 calculates how much of the total dike area encompasses a drift(s). This calculation uses the values in column 5 and multiples these values by the percentage drift area of the repository (taken from Spreadsheet No. 3).

Column 7 calculates the number of waste packages hit in Zone 1 for the specified dike width and number of dikes in a swarm. This calculation uses the values in column 6 and multiples them by the number of waste packages per drift area (taken from spreadsheet 3). This value is limited by the maximum number of packages in the repository (11,184). Column 7 lists the number of packages per hit for every dike length–azimuth pair in the file. Because of the different probabilities of occurrence, these numbers of packages must be weighted by the corresponding probabilities (column 3). The weighted average number of packages hit is listed at the top of column 8 as Weighted Average Packages hit. It also uses the Excel CEILING function to round the results up.

Columns 9 through 12 calculates the number of drifts intersected by a dike. Columns 9 uses Eq. 5 to calculate the dike length perpendicular to drifts. Column 10 calculates the number of drifts crossed by the length of the dike by dividing column 9 by drift spacing (Eq.7). This calculation only considers the number of drifts crossed along the length of a dike.

For dikes with an effective dike width of greater than approximately 80 m (dike spacing), one or more lateral drifts may also be intersected. The calculation to determine if one or more lateral drifts are intersected compares the product of the number of drifts crossed along the dike length and the average drift area from Table II-9(a) to the calculated drift area intersected by the dike (column 11). If this product is greater than the value in column 11, then the number of dikes crossed is equal to the value in column 10. If this product is less than the value in column 11, then the number of drifts crossed is calculated by (1) subtracting the product of average drift area and the number of drifts crossed along a dike length from the calculated drift area intersected by a dike; (2) dividing this value by average drift area; and (3) then adding this number to the number of drifts crossed along a dike length. This calculation is done in column 12 and uses the EXCEL IF function to compare values and select which value to calculate. The EXCEL CEILING function to round the returned value up to the next whole number.

Spreadsheet No. 6 – Zone 1 - As indicated above, the full calculation is done multiple times to exhaustively sample all dike lengths for each azimuth angle and all effective dike widths for each value of dike width and number of dikes in a swarm. The calculation imposes a limit on the dike length equal to the maximum length of the repository shown as Approximate PB N/S length in Table II-9a. In practice this is done by first selecting a dike width and then calculating the number of waste packages hit for each dike length and each number of dikes in a swarm (see CDF for number of dikes in a swarm in Table II-8). This procedure is repeated for each dike width included in the CDF for dike widths shown in Table II-9(b).

All results from the iterative calculations done in spreadsheet No. 4 are compiled and organized into sixteen bins in this spreadsheet. The bins are based on the dike width and are organized in half meter increments, each of which includes the results for 1 through 15 dikes. Table II-11 is a sample from this spreadsheet showing this compilation and organization. This table includes three vertical tables. These tables organize and compile the calculation output showing (a) number of dikes with the associated PDF, (b) dike width with the associated PDF, and (c) number of packages hit with the associated PDF. In addition, Spreadsheet No. 5 sorts and orders the number of packages hit and calculates the CDF for the number of packages hit in Zone 1. Table III-4 shows this CDF which is plotted on Figure I-7.

Spreadsheet No. 7 – Zone 1 + Zone 2 - This spreadsheet is used to generate results for how many drifts are crossed for each dike length/azimuth angle pair. These results are then sorted and grouped into 52 bins (spanning 0-51 drifts crossed) to generate the CDF for number of drifts crossed by an igneous intrusion. The associated probabilities for each grouping is determined by summing the conditional probabilities for each dike length/azimuth angle pair for that grouping. Table II-12 shows a sample from this spreadsheet. This sample shows three vertical tables that compile and organize the information. The last of these tables is used to develop the CDF for number of drifts crossed.

The resulting CDF for the number of drifts crossed is used to calculate the number of packages hit in Zone 1 + Zone 2 combined. The repository contains 11,184 packages and 51 drifts (see Table II-1 for information source). This gives an average of approximately 219 packages per drift. Thus, each point in the CDF for the number of drifts crossed can be multiplied by 219 to generate a CDF for the number of packages damaged by an igneous dike. Table III-5 shows this CDF which is plotted on Figure I-8.

6.0 RESULTS

This document may be affected by technical product input information that requires confirmation. Any changes to the document that may occur as a result of completing the confirmation activities will be reflected in subsequent revisions. The status of the input information quality may be confirmed by review of the Document Input Reference System database.

Factors that are not considered because they are beyond the scope of this calculation include; fragmentation depth (the depth at which trapped gases exsolve from the liquid magma) of the ascending magma; eruption duration; magma chemical and physical properties; and the interaction of the dike with the repository drift network.

The output from this calculation includes: (1) EXCEL Workbook CAL-WIS-PA-000001 REV 00 ICN1 Volc_Anal_Sept-00.xls [DTN MO0010SPAVOL01.001]; (2) EXCEL Workbook CAL-WIS-PA-000001 REV00 ICN1 EST-Anal_Sept-00.xls [DTN MO0010SPAVOL01.001]; and (3) EXCEL workbook CAL-WIS-PA-000001 REV00 ICN01_ OUTPUT.xls [DTN MO0010SPAOUT01.002].

Note that these EXCEL file names were established during a period of document development when it was planned that document changes would be carried as an interim change notice (ICN). Subsequently it was decided that the changes required that this document be a revision (REV01). These output files are not affected by this change in document designation and are the valid output files for this document (CAL-WIS-PA-000001 REV01).

6.1 VOLCANIC ERUPTION SCENARIO

The calculation output for the number of waste packages intersected by a conduit(s) for the Volcanic Eruption scenario are provided in the EXCEL workbook CAL-WIS-PA-000001 REV00 ICN01_ OUTPUT.xls [DTN MO0010SPAOUT01.002]. This workbook includes the output from the calculations done using EXCEL workbook CAL-WIS-PA-000001 REV00 ICN1 Volc Anal_Sept-00.xls [DTN MO0010SPAVOL01.001] and includes:

- CDF for conduit diameter;
- number of waste packages contained within an area circumscribed by a conduit diameter; and
- CDFs for number of eruptive centers on a dike.

This output information is shown on Tables III-1, III-2, and III-3.

The number of waste packages hit per conduit will range from 1 for the minimum conduit diameter of 4.5 m to 51 for the maximum conduit diameter of 150 m. For the median conduit diameter of 50 m, 10 waste packages will be hit.

The number of conduits on a dike range from 0 to 13. The composite conditional probability that at least one conduit will occur on a dike within the repository footprint is 0.77.

From the conceptual perspective, the number of waste packages hit by a volcanic eruption is assumed to be limited to those waste packages circumscribed by a given conduit diameter. Therefore, the change in design from "with backfill" to "no backfill" has no impact on the methodology used to calculate the number of waste packages hit by a volcanic eruption. However, there are differences in the results presented in this document for the "no backfill" design compared to the results in REV00 of this calculation (CRWMS M&O 2000i) for the "backfill" design. These differences are due to:

- revised input probabilities for number of eruptive centers on a dike;
- revised maximum number of eruptive centers on a dike from five in CRWMS M&O 2000i to thirteen in this document;
- a revised CDF for conduit diameter that assumes a lower limit of 4.5 m (versus 15 m for CRWMS M&O 2000i); and
- a revised calculation approach used to determine the number of waste packages hit by a conduit that intersects two drifts.

The last three of these differences tend to marginally increase the total number of waste packages hit by a volcanic eruption.

6.2 IGNEOUS INTRUSION GROUNDWATER RELEASE SCENARIO

The results for the number of waste packages contacted by magma for the igneous intrusion groundwater release scenario are detailed in the EXCEL workbook CAL-WIS-PA-000001 REV00 ICN01_OUTPUT.xls [DTN MO0010SPAOUT01.002]. This workbook includes the output from the calculations done using EXCEL workbook CAL-WIS-PA-000001 REV00 ICN1 EST Anal_Sept-00.xls [DTN MO0010SPAVOL01.001] and includes:

- probability and cumulative distribution for dike width
- probability and cumulative distribution for number of dikes in a swarm
- CDF for number of waste packages hit in Zone 1; and
- CDF for number of waste packages hit in Zone 1 + Zone 2.

This output information is shown on Tables III-4 through III-7.

Table III-6 shows that the number of packages hit in Zone 1 range from 98 to 1,785. The 50th percentile value of the distribution for number of packages hit is about 200. Figure I-7 shows CDF for the number of packages hit in Zone 1.

Table III-7 shows that the number of packages hit in Zone 1 + Zone 2 combined range from 219 (all waste packages contained in one drift) to 11,184 (all waste packages contained in fifty-one drifts). The 50th percentile value of the distribution for number of packages hit is about 1,970. Figure I-8 shows CDF for the number of packages hit in Zone 1 + Zone 2 Combined.

The waste packages in Zone 1 are assumed to be destroyed and completely available for groundwater transport. The additional waste packages in Zone 2 are damaged to varying degrees. Determination of the degree of damage to these waste packages is beyond the scope of this calculation. This calculation only identifies the number of packages in Zone 1 that are destroyed and the number of combined number of waste packages hit in Zone 1 + Zone 2.

Note that probability that a dike intersects the repository footprint (probability (d) listed in Section 5.0) has not been incorporated. This probability must be applied in the TSPA model analysis.

The primary difference in the results presented in this document for the "no backfill" design compared to the results in REV00 (CRWMS M&O 2000i) for the "backfill" design is that this revised calculation determines the number of waste packages hit in Zone 1 and Zone 2 combined. CRWMS M&O 2000i addressed the number of waste packages hit in Zone 1 only. In addition, the results of this calculation include differences that reflect:

- revised input probabilities for dike length/azimuth angle pairs; and
- a revised calculation approach that uses relationships and calculations based on an area.

7.0 REFERENCES

7.1 DOCUMENTS CITED

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CRWMS M&O 2000k. Process Control Evaluation for Supplement V: "Performance Assessment Operations. (Reference QAP-2-0 Activity Evaluation Form. Conduct of Performance Assessment, November 9, 1999)". Las Vegas, Nevada: CRWMS M&O. ACC: MOL.20000128.0236.

7.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

AP-3.12Q Rev0/ICN3. *Calculations.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL. 20001026.0084.

YAP-SV.1Q Rev0/ICN1. *Control of the Electronic Management of Data.* Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL. 19991008.0209.

AP-SV1.Q Rev.0 ICN 2. *Control of the Electronic Management of Information.* Las Vegas, Nevada: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: MOL. 20000831.0065.

7.3 SOURCE DATA, LISTED BY DATA TRACKING NUMBER

LA0009FP831811.004. Data Summaries Supporting Computation of Volcanic Event Intersection Frequencies for the 70,000 MTU Repository Layout. Submittal date: 9/14/00.

7.4 OUTPUT DATA, LISTED BY DATA TRACKING NUMBER

MO0010SPAOUT01.002 CAL-WIS-PA-000001 REV00 ICN1 Output_Oct-00.xls. Date submitted: 10/17/00.

MO0010SPAVOL01.001 EXCEL Workbooks CAL-WIS-PA-000001 REV00 ICN1_Volc_Anal_Sept00.xls and CAL-WIS-PA-000001 REV00 ICN1_EST_anal_Sept00.xls. Date submitted: 10/17/00.

8.0 ATTACHMENTS

ATTACHMENT I FIGURES

ATTACHMENT II TABLES

ATTACHMENT III CAL-WIS-PA-000001 REV01 OUTPUT

ATTACHMENT IV EXPLANATION OF EXCEL-ASSISTED CALCULATIONS

ATTACHMENT I

FIGURES

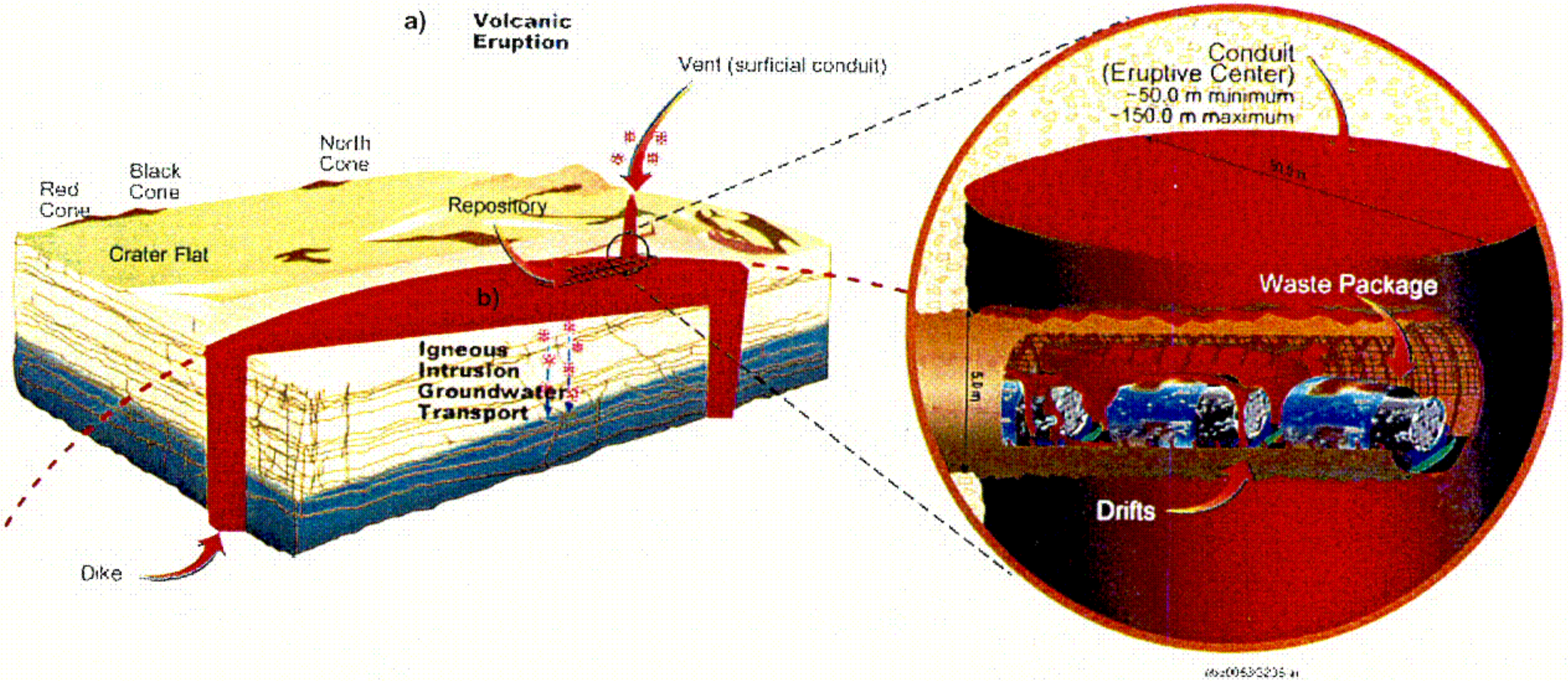


Figure I-1. Conceptual Figure of a) Volcanic Eruption and b) Igneous Intrusion Groundwater Transport Scenarios

C01

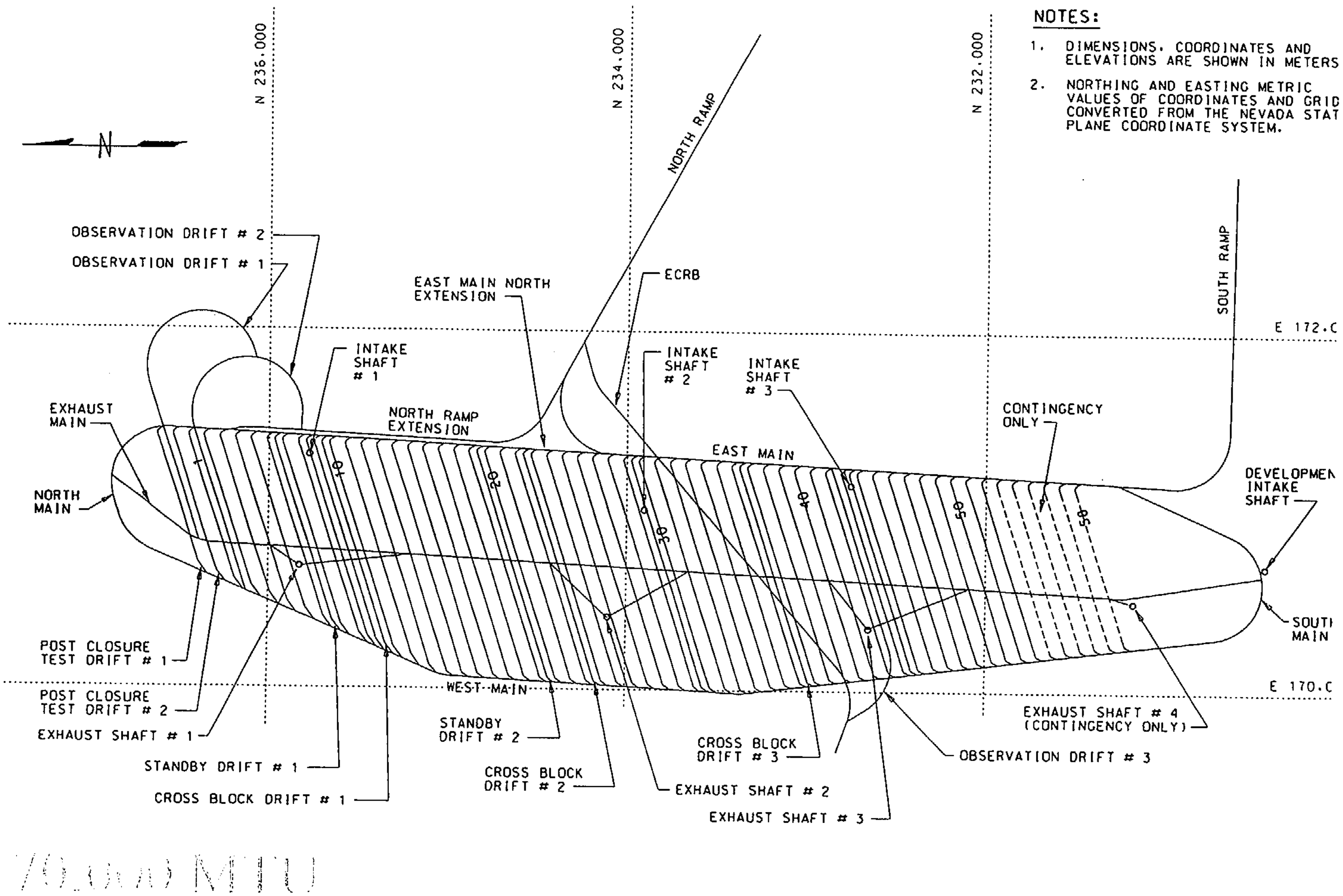
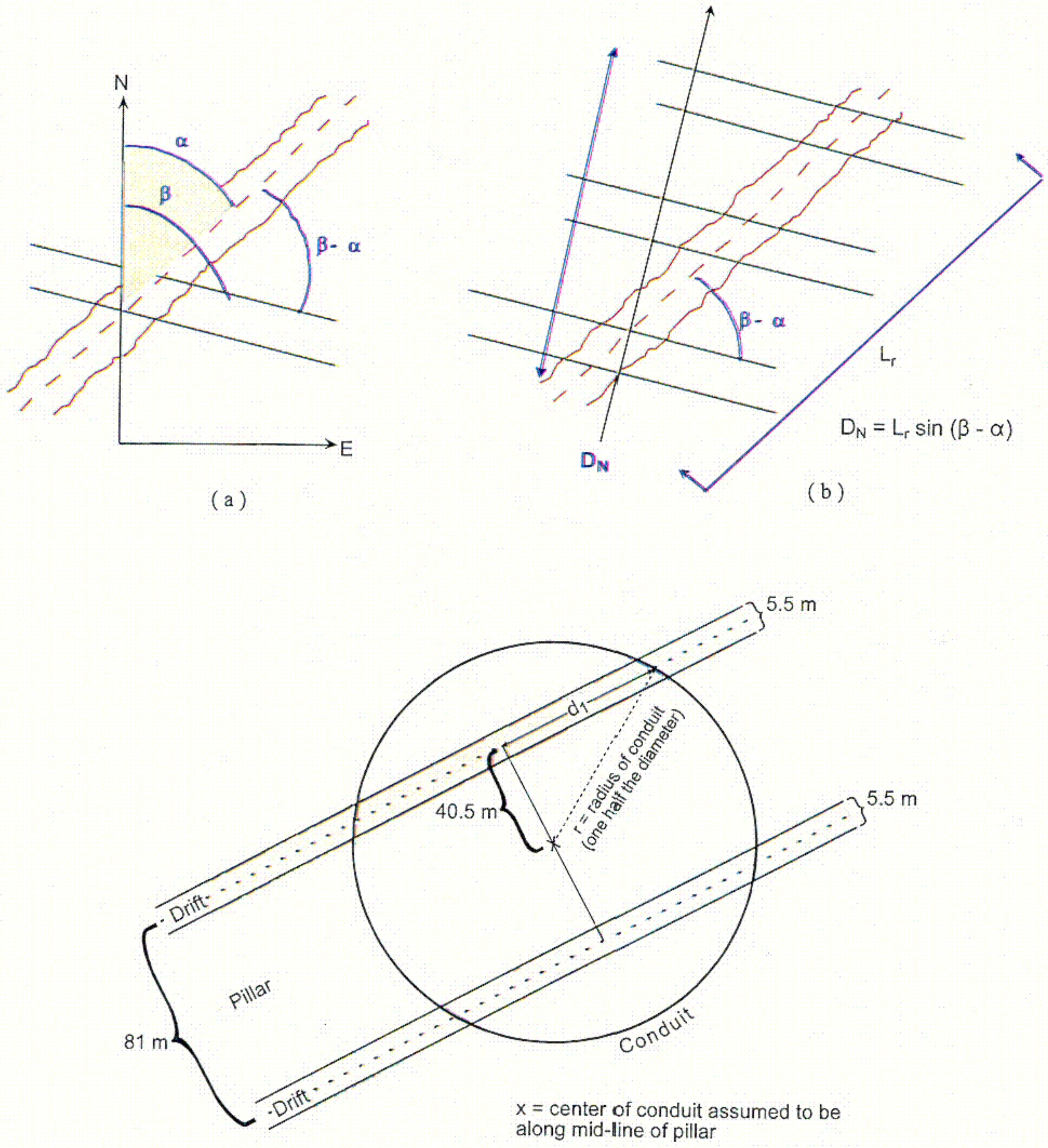


Figure I-2. Schematic of Repository Layout (after CRWMS M&O 2000h)



x = center of conduit assumed to be along mid-line of pillar

d_1 = conduit intersection length along drift for one quadrant of the conduit

$$d_1 = \sqrt{r^2 - (40.5)^2}$$

Total conduit intersection length along two drifts is equal to 4 x d_1

(c)

Figure I-3. Illustrations of Geometric Relationships between Dikes and Drifts (a and b), and a Conduit Centered on a Pillar and Adjacent Drifts (c)

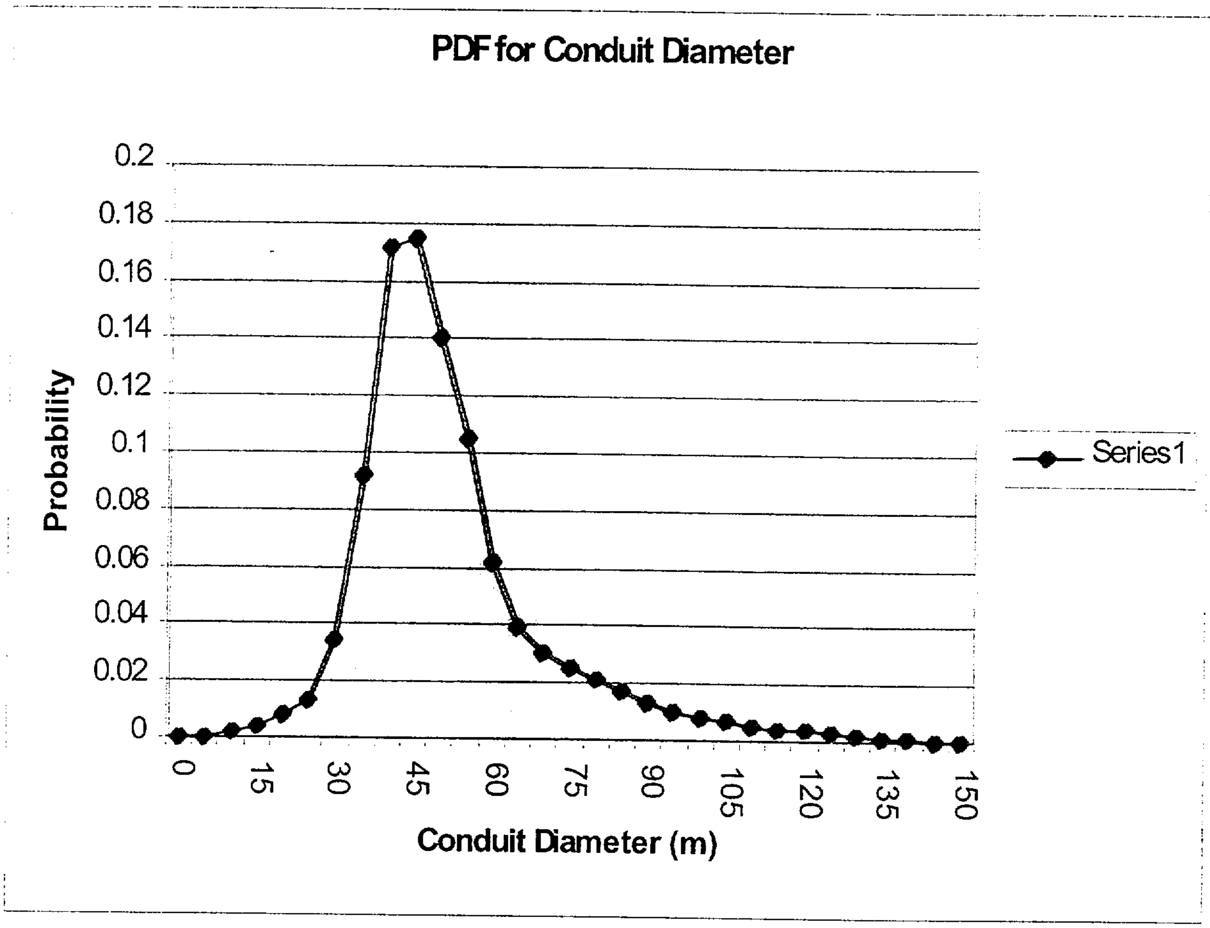


Figure I-4. PDF for Eruptive Conduit Diameter (after CRWMS M&O 2000a)

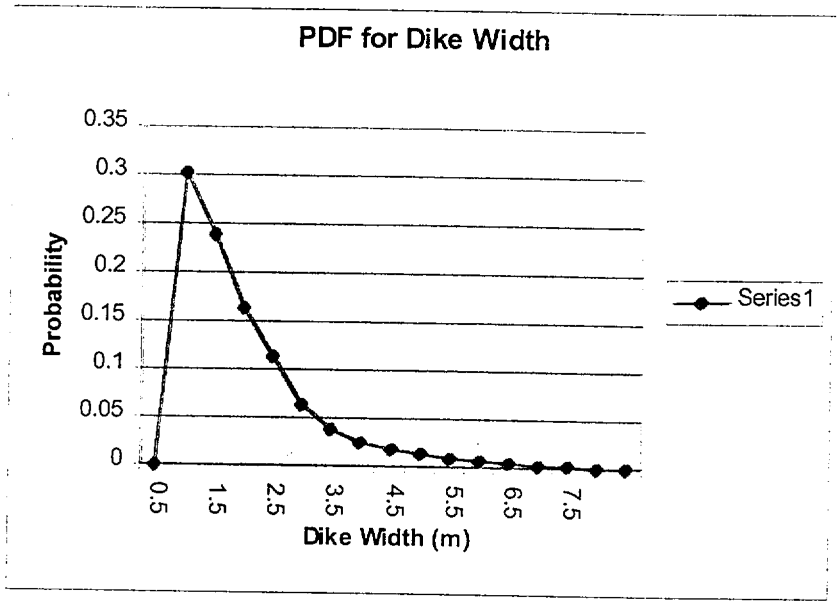


Figure I-5. PDF for Dike Width (after CRWMS M&O 2000ab)

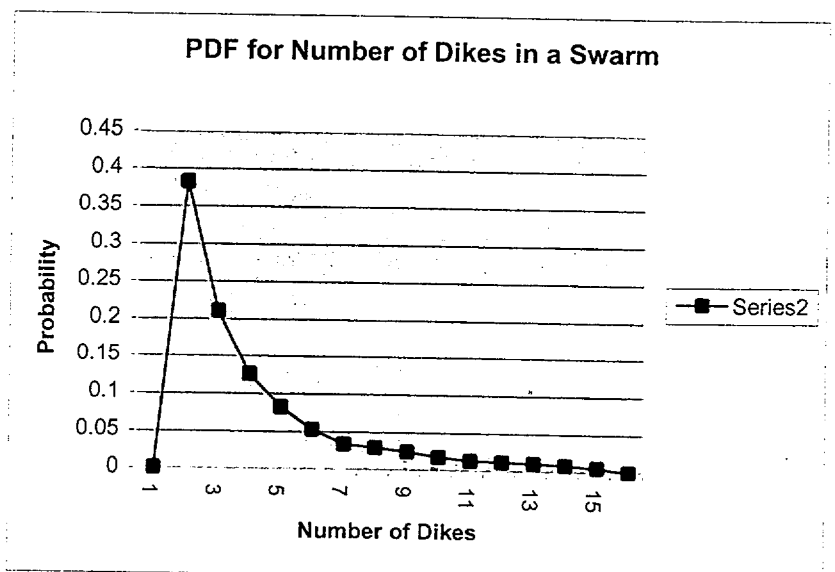


Figure I-6. PDF for Number of Dikes in Swarm (after CRWMS M&O 2000a)

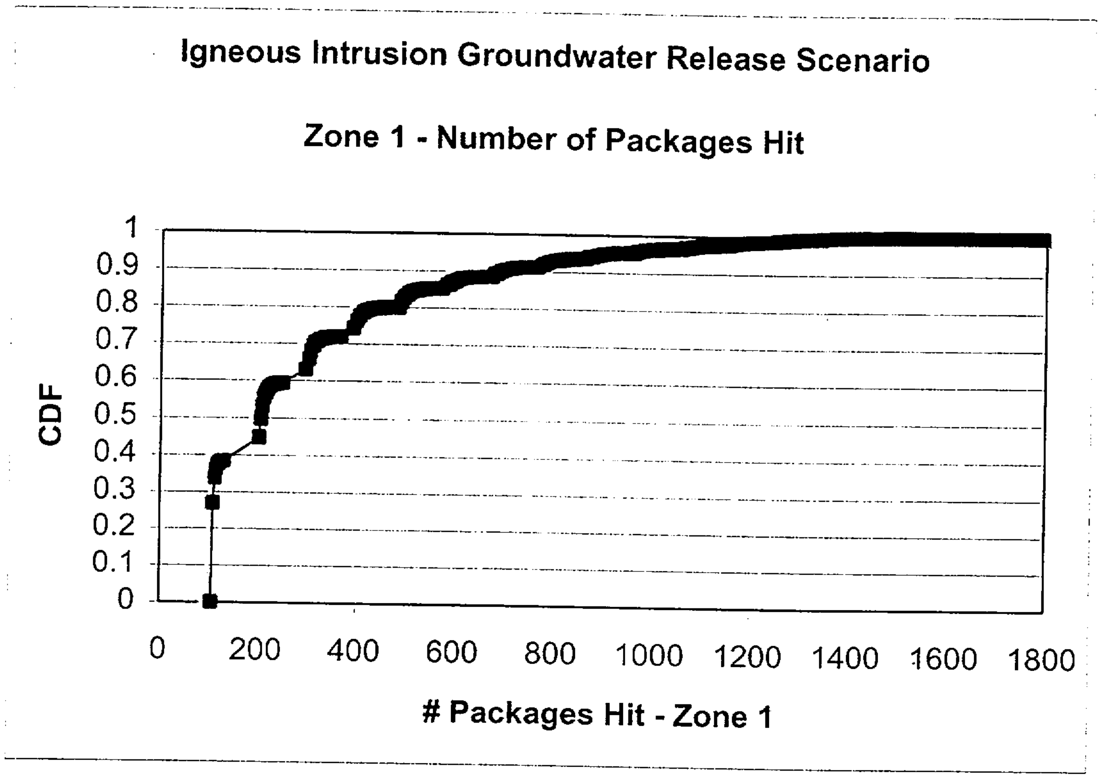


Figure I-7. CDF for Number of Packages Hit for Zone 1

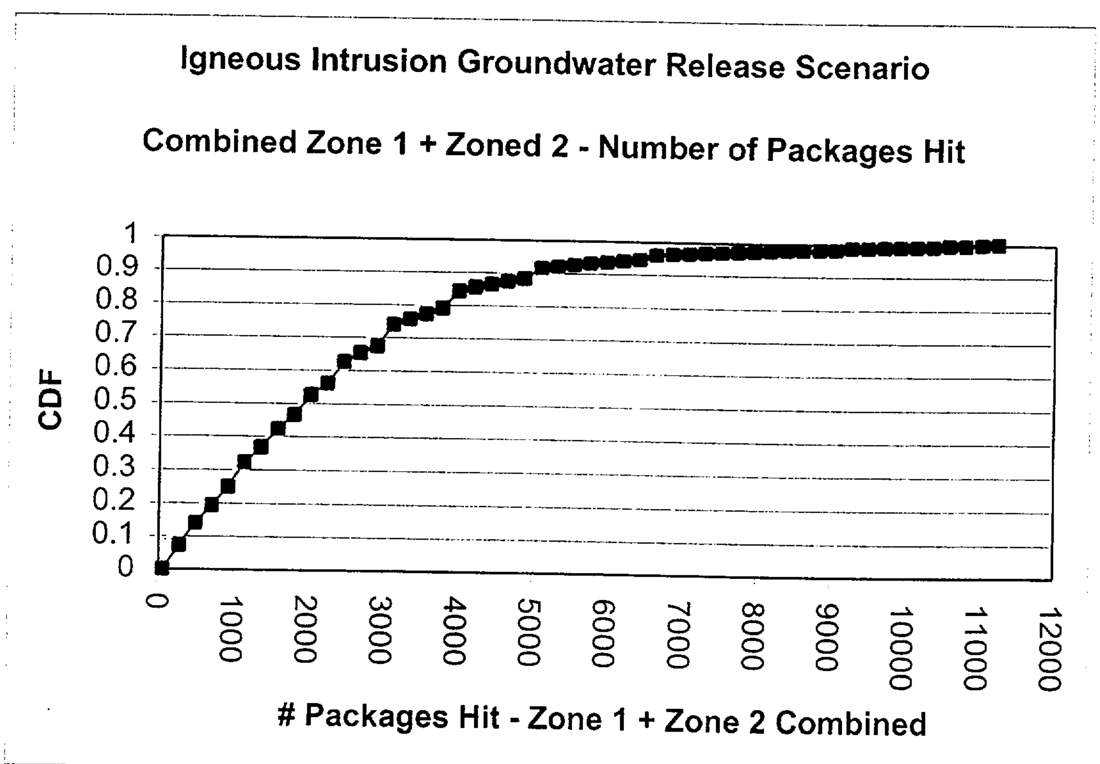


Figure I-8. CDF for Number of Packages Hit for Zone 1 + Zone 2 Combined

ATTACHMENT II

TABLES

Table II-1. Summary of Calculation Inputs

Input Information	Source for Input Information	Value
CCSM-PCB.CMP (output file containing conditional probabilities for dike length, dike azimuth angle, and number of eruptive centers (conduits) on a dike)	CRWMS M&O 2000b, Section 7.1. DTN LA0009FP831811.004.	Technical product output
Conditional Probabilities for number of eruptive centers (conduits) on a dike	CRWMS M&O 2000b, Section 6.5.3, Table 12a. DTN LA0009FP831811.004.	Technical product output
Drift orientation	CRWMS M&O 2000h, Section 6.2.1.2 (azimuth angle cited as 252°. In this calculation the equivalent azimuth angle of 72° is used).	72°
Drift spacing	CRWMS M&O 2000h, Section 6.2.1.2	81 m
Drift diameter	CRWMS M&O 2000h, Section 6.2.1.2	5.5 m
Total number of waste packages scheduled for emplacement in the 70,000 MTU Primary Block	CRWMS M&O 2000h, Section 6.3.1	11,184
Waste package average length	CRWMS M&O 2000h, Section 6.3.1, Table 28	4.927 m
Waste package spacing	CRWMS M&O 2000h, Section 6.3.1	0.1 m
70,000 MTU Primary Block area	CRWMS M&O 2000h, Section 6.3.1	1,125.3 acres (4,553,982 m^2)
Dike width	CRWMS M&O 2000a, Section 6.1, Section 7.	Log normal distribution with a minimum of 0.5 m, a mean of 1.5 m, and a 95th percentile of 4.5 m
Number of dikes in a swarm	CRWMS M&O 2000a, Section 6.1, Section 7.	Log normal distribution with a minimum of 1, a mean of 3, and a 95th percentile of 10 truncated at a maximum value of 15
Maximum number of dikes in a swarm	CRWMS M&O 2000e, entire	Basis for assumption (see Section 3.4)
Conduit diameter	CRWMS M&O 2000a, Section 6.1, Section 7.	Log normal distribution with a minimum equal to dike width (m), a median of 50 m, and a maximum of 150 m
Dike Interaction with repository drifts	CRWMS M&O 2000c, pages 26-27	Basis for assumptions (see Sections 3.6 and 3.7)

Table II-2. Conduit Diameter Probability Distribution and Cumulative Distribution

Conduit Diameter (m)	Probability Distribution	Cumulative Distribution
4.5	0.0004	0.0000
10	0.0018	0.0004
15	0.0044	0.0022
20	0.0079	0.0066
25	0.0132	0.0145
30	0.0346	0.0277
35	0.0919	0.0623
40	0.1720	0.1541
45	0.1747	0.3262
50	0.1405	0.5008
55	0.1054	0.6413
60	0.0615	0.7467
65	0.0395	0.8082
70	0.0299	0.8477
75	0.0250	0.8776
80	0.0211	0.9026
85	0.0176	0.9237
90	0.0136	0.9412
95	0.0105	0.9549
100	0.0079	0.9654
105	0.0066	0.9733
110	0.0054	0.9799
115	0.0044	0.9853
120	0.0036	0.9897
125	0.0026	0.9933
130	0.0018	0.9960
135	0.0011	0.9978
140	0.0007	0.9989
145	0.0004	0.9996
150	0.0000	1.0000

Probability Information:

Source: CRWMS M&O 2000a: Log normal distribution with a minimum diameter assumed to be 4.5 m (see Section 3.5), a median diameter of 50 m, and a maximum diameter of 150 m.

Table II-3. Comparison of the Number of Packages Intersected by a Conduit When Centered on a Drift and When Centered on a Pillar

Conduit Diameter (m)	Number of Packages Intersected when Conduit is Centered on a Drift	Number of Packages Intersected When a Conduit is Centered on a Pillar
4.5	1	0
15	3	0
25	5	0
35	7	0
45	9	0
55	11	0
65	13	0
75	15	0
85	17	11
95	19	20
105	21	27
115	23	33
125	25	38
135	27	43
145	20	48
150	30	51

Table II-4. Number of Conduits on a Dike Probability Distribution and Cumulative Distribution

Number of Conduits	Final Composite Conditional Probability Distribution	Cumulative Distribution
0	0.226000	0.000565
1	0.578500	0.226565
2	0.091000	0.805065
3	0.039250	0.896065
4	0.028750	0.935315
5	0.019000	0.964065
6	0.008500	0.983065
7	0.004050	0.991565
8	0.002100	0.995615
9	0.001015	0.997715
10	0.000650	0.998730
11	0.000450	0.999380
12	0.000165	0.999830
13	0.000005	0.999995

Probability Information:

Source: CRWMS M&O 2000b, Table 12a "Primary + Contingency Block mean final composite conditional probability.

Table II-5. Sample of CCSM-PCB Spreadsheet Showing Dike Length, Dike Azimuth Angle, and Dike Probability

Length (km)	Azimuth (°)	Dike Probability
0.50	0	2.13E-04
0.50	35	2.55E-03
0.50	70	1.03E-04
0.50	105	8.30E-06
0.50	140	7.41E-05
0.50	175	1.49E-04
1.00	0	2.05E-04
1.00	35	1.91E-03
1.00	70	2.82E-04
1.00	105	8.82E-06
1.00	140	6.52E-05
1.00	175	1.69E-04
2.00	0	1.52E-04
2.00	35	3.86E-03
2.00	70	0.00E+00
2.00	105	0.00E+00
2.00	140	0.00E+00
2.00	175	1.12E-04
4.00	0	4.22E-05
4.00	35	0.00E+00
4.00	70	0.00E+00
4.00	105	0.00E+00
4.00	140	0.00E+00
4.00	175	6.38E-05

Table II-6. Sample of the "No Zeros" Spreadsheet

Length (km)	Azimuth (o)	Dike probability
0.50	0	2.13E-04
1.00	0	2.05E-04
2.00	0	1.52E-04
4.00	0	4.22E-05
5.00	0	5.68E-04
0.50	35	2.55E-03
1.00	35	1.91E-03
2.00	35	3.86E-03
2.45	35	5.09E-03
0.50	70	1.03E-04
1.00	70	2.82E-04
1.40	70	8.72E-04
0.50	105	8.30E-06
1.00	105	8.82E-06
1.35	105	1.24E-05
0.50	140	7.41E-05
1.00	140	6.52E-05
1.90	140	1.85E-04
0.50	175	1.49E-04
1.00	175	1.69E-04
2.00	175	1.12E-04
4.00	175	6.38E-05
4.85	175	1.39E-04

Table II-7. Dike Width Probability Distribution and Cumulative Distribution

Dike Width (m)	Probability Distribution	Cumulative Distribution
0.5	0.301583	0.000000
1.0	0.238753	0.301583
1.5	0.163358	0.540337
2.0	0.113094	0.703694
2.5	0.062830	0.816788
3.0	0.037698	0.879618
3.5	0.025132	0.917316
4.0	0.017592	0.942448
4.5	0.013194	0.960040
5.0	0.009676	0.973234
5.5	0.006911	0.982910
6.0	0.004901	0.989822
6.5	0.002890	0.994722
7.0	0.001634	0.997612
7.5	0.000754	0.999246
8.0	0.000000	1.000000

Probability Information:

Source: CRWMS M&O 2000a. Log normal distribution with a minimum of 0.5 m, a mean of 1.5 m, and a 95th percentile width of 4.5 m.

Table II-8. Number of Dikes in a Swarm Probability Distribution and Cumulative Distribution

Number of Dikes	Probability Distribution	Cumulative Distribution
1	0.38220	0.00000
2	0.20940	0.38220
3	0.12540	0.59160
4	0.08150	0.71700
5	0.05240	0.79850
6	0.03280	0.85090
7	0.02860	0.88370
8	0.02380	0.91230
9	0.01690	0.93610
10	0.01270	0.95300
11	0.01130	0.96570
12	0.01000	0.97700
13	0.00800	0.98700
14	0.00500	0.99500
15	0.00000	1.00000

Probability Information:

Source: CRWMS M&O 2000a. Log normal distribution with a minimum of 1, a mean of 3 m, and a 95th percentile width of 10 m. CRWMS M&O 2000e provides guidance for truncating the distribution at 15 dikes.

Table II- 9(a) – Upper Portion of Spreadsheet "Input-Params-EST"

Drift angle (°):	72
Drift Spacing (m):	81
Drift diameter (m):	5.5
Package length (m):	4.927
Package spacing (m):	0.1

Azimuth range for Parallel angle (°)	67.79 to 76.20
Parallel angle (°)	4.20
Primary Block (PB) Area (m^2)	4553982
Drift Area (m^2)	309221
Number of waste packages	11184
Percentage Drift Area	0.0679
Packages per drift area (WP/m^2)	0.0362
Number of Drifts	51
Avg WP per Drift	219.29

Approximate PB N/S length (m)	4343.58
Approximate PB E/W Length (m)	1048.44
Calculated PB Average Drift Length (m)	1102.39
Average Drift Area (m^2)	6063.16

Table II- 9(b). Lower Portion of Spreadsheet "Input-Params-EST"

CDF	Dike Width
0.0000	0.5
0.3016	1.0
0.5403	1.5
0.7037	2.0
0.8168	2.5
0.8796	3.0
0.9173	3.5
0.9424	4.0
0.9600	4.5
0.9732	5.0
0.9829	5.5
0.9898	6.0
0.9947	6.5
0.9976	7.0
0.9992	7.5
1.0000	8.0

CDF	Number of Dikes
0.000	1
0.382	2
0.592	3
0.717	4
0.799	5
0.851	6
0.884	7
0.912	8
0.936	9
0.953	10
0.966	11
0.977	12
0.987	13
0.995	14
1.000	15

Table II-10. Sample of "Simulations-EST" Spreadsheet

		Dike Width (m)	Number of Dikes CDF			
		0.5	0.5			
		Dike Width (m)	Number of Dikes CDF	Effective Total width of Swarm (m)		Weighted Average Pkgs hit
		1	2	63		197
Length (km)	Azimuth (°)	Dike Probability	Max Length inside Repos (m)	Total dike area within the PB (m2)	Drift Area Intersected by Dike	Number of WP Hit
0.05	0	1.79E-04	50	3150	214	8
1.00	0	2.05E-04	1000	63000	4278	155
2.00	0	1.52E-04	2000	126000	8556	310
4.00	0	4.22E-05	4000	252000	17111	619
5.00	0	5.68E-04	4344	273646	18581	673
0.50	35	2.55E-03	500	31500	2139	78
1.00	35	1.91E-03	1000	63000	4278	155
2.00	35	3.86E-03	1828	115158	7819	283
2.45	35	5.09E-03	1828	115158	7819	283
0.50	70	1.03E-04	500	31500	2139	78
1.00	70	2.82E-04	1000	63000	4278	155
1.40	70	8.72E-04	1116	70291	4773	173
0.50	105	8.30E-06	500	31500	2139	78
1.00	105	8.82E-06	1000	63000	4278	155
1.35	105	1.24E-05	1085	68382	4643	168
0.50	140	7.41E-05	500	31500	2139	78
1.00	140	6.52E-05	1000	63000	4278	155
1.90	140	1.85E-04	1631	102758	6977	253
0.50	175	1.49E-04	500	31500	2139	78
1.00	175	1.69E-04	1000	63000	4278	155
2.00	175	1.12E-04	2000	126000	8556	310
4.00	175	6.38E-05	4000	252000	17111	619
4.85	175	1.39E-04	4344	273646	18581	673

Table II-10. Sample of "Simulations-EST" Spreadsheet (Continued)

Dike Length Perpendicular to Drifts (m)	Number of Drifts Intersected along Dike Length	Drift Area Intersected by Dike	Total Number of Drifts Intersected Per Drift Area
48	1	214	1
951	12	4278	12
1902	24	8556	24
3804	47	17111	47
4131	51	18581	51
301	4	2139	4
602	8	4278	8
1100	14	7819	14
1100	14	7819	14
17	1	2139	1
35	1	4278	1
39	1	4773	1
272	4	2139	4
545	7	4278	7
591	8	4643	8
464	6	2139	6
927	12	4278	12
1512	19	6977	19
487	7	2139	7
974	13	4278	13
1949	25	8556	25
3897	49	17111	49
4232	51	18581	51

Table II-11. Sample of "Zone 1" Spreadsheet

Number of Dikes		Dike Width		Number of Packages Hit		Weighted		Number of Packages Hit		GoldSim
Value	PDF	Value	PDF	PDF	Value	Packages	Value	PDF	CDF	CDF
1	0.38220	0.5	0.30158	0.11527	98	11.296	98	1.153E-01	0.1153	0.0000
2	0.20940	0.5	0.30158	0.06315	194	12.251	101	1.537E-01	0.2690	0.2690
3	0.12540	0.5	0.30158	0.03782	287	10.854	104	6.724E-02	0.3362	0.3362
4	0.08150	0.5	0.30158	0.02458	384	9.438	107	2.401E-02	0.3602	0.3602
5	0.05240	0.5	0.30158	0.01580	481	7.601	110	1.177E-02	0.3720	0.3720
6	0.03280	0.5	0.30158	0.00989	574	5.678	113	6.340E-03	0.3783	0.3783
7	0.02860	0.5	0.30158	0.00863	671	5.788	116	2.978E-03	0.3813	0.3813
8	0.02380	0.5	0.30158	0.00718	767	5.505	119	9.125E-04	0.3822	0.3822
9	0.01690	0.5	0.30158	0.00510	860	4.383	122	0.000E+00	0.3822	0.3822
10	0.01270	0.5	0.30158	0.00383	957	3.665	194	6.315E-02	0.4454	0.4454
11	0.01130	0.5	0.30158	0.00341	1054	3.592	197	4.999E-02	0.4953	0.4953
12	0.01000	0.5	0.30158	0.00302	1147	3.459	200	3.421E-02	0.5296	0.5296
13	0.00800	0.5	0.30158	0.00241	1243	2.999	203	2.368E-02	0.5532	0.5532
14	0.00500	0.5	0.30158	0.00151	1340	2.021	207	1.316E-02	0.5664	0.5664
15	0.00000	0.5	0.30158	0.00000	1433	0.000	210	7.894E-03	0.5743	0.5743
1	0.38220	1.0	0.23875	0.09125	101	9.216	213	5.263E-03	0.5795	0.5795
2	0.20940	1.0	0.23875	0.04999	197	9.849	216	3.684E-03	0.5832	0.5832
3	0.12540	1.0	0.23875	0.02994	294	8.802	219	2.763E-03	0.5860	0.5860
4	0.08150	1.0	0.23875	0.01946	390	7.589	222	2.026E-03	0.5880	0.5880
5	0.05240	1.0	0.23875	0.01251	487	6.093	225	1.447E-03	0.5895	0.5895
6	0.03280	1.0	0.23875	0.00783	583	4.566	228	1.026E-03	0.5905	0.5905
7	0.02860	1.0	0.23875	0.00683	683	4.664	231	6.052E-04	0.5911	0.5911
8	0.02380	1.0	0.23875	0.00568	779	4.427	235	3.421E-04	0.5914	0.5914
9	0.01690	1.0	0.23875	0.00403	876	3.535	238	1.579E-04	0.5916	0.5916
10	0.01270	1.0	0.23875	0.00303	972	2.947	241	0.000E+00	0.5916	0.5916
11	0.01130	1.0	0.23875	0.00270	1069	2.884	287	3.782E-02	0.6294	0.6294
12	0.01000	1.0	0.23875	0.00239	1165	2.781	294	2.994E-02	0.6594	0.6594
13	0.00800	1.0	0.23875	0.00191	1265	2.416	297	2.049E-02	0.6798	0.6798
14	0.00500	1.0	0.23875	0.00119	1362	1.626	303	1.418E-02	0.6940	0.6940

Table II-12. Sample of "Zone 1 + Zone 2" Spreadsheet

											Combined	
Number of Drifts Hit			Number of Drifts Hit			Number of Drifts Hit				GoldSim	Zone 1 + Zone 2	
Value	PDF		Value	PDF		Value	PDF	CDF		CDF	# Packages Hit	
0	0.0001753		0	0.0001753		0	0.0184686	0.0184686		0	0	
1	0.0001789		0	0.0002028		1	0.0531901	0.0716587		0.0716587	219	
2	0.0001866		0	0.0003791		2	0.0664306	0.1380894		0.1380894	439	
2	0.0001902		0	0.000824		3	0.054242	0.1923314		0.1923314	658	
3	0.0002025		0	0.0013393		4	0.0551428	0.2474741		0.2474741	877	
3	0.0001927		0	0.0021178		5	0.0748957	0.3223698		0.3223698	1096	
4	0.0002013		0	0.0026928		6	0.0448711	0.3672409		0.3672409	1316	
5	0.0002133		0	0.0024584		7	0.054636	0.4218768		0.4218768	1535	
5	0.0001997		0	0.0020093		8	0.042751	0.4646279		0.4646279	1754	
6	0.0001998		0	0.0026189		9	0.0595366	0.5241644		0.5241644	1974	
6	0.0002132		0	0.0009797		10	0.0347963	0.5589607		0.5589607	2193	
7	0.0002153		0	0.0006958		11	0.0658866	0.6248473		0.6248473	2412	
8	0.0002173		0	0.0003394		12	0.0276824	0.6525297		0.6525297	2632	
8	0.0002182		0	0.0001973		13	0.0204849	0.6730146		0.6730146	2851	
9	0.00021		0	0.0001317		14	0.0653535	0.7383681		0.7383681	3070	
9	0.0002005		0	7.056E-05		15	0.0170182	0.7553863		0.7553863	3289	
10	0.0002105		0	4.115E-05		16	0.0157742	0.7711605		0.7711605	3509	
10	0.0002153		0	3.474E-05		17	0.0187165	0.789877		0.789877	3728	
11	0.0002126		0	1.909E-05		18	0.0513604	0.8412374		0.8412374	3947	
12	0.0002232		0	1.474E-05		19	0.012857	0.8540944		0.8540944	4167	
12	0.0002047		0	1.097E-05		20	0.0094215	0.8635159		0.8635159	4386	
13	0.0002082		0	7.119E-06		21	0.0097118	0.8732277		0.8732277	4605	
13	0.0001967		0	6.274E-06		22	0.0080712	0.8812989		0.8812989	4824	
14	0.0002149		0	4.773E-06		23	0.033194	0.9144929		0.9144929	5044	
15	0.0001992		0	5.803E-06		24	0.0051794	0.9196723		0.9196723	5263	
15	0.0001919		0	7.342E-06		25	0.0053248	0.9249971		0.9249971	5482	

Table II-12. Sample of "Zone 1 + Zone 2" Spreadsheet (Continued)

											Combined
Number of Drifts Hit			Number of Drifts Hit			Number of Drifts Hit				GoldSim	Zone 1 + Zone 2
Value	PDF		Value	PDF		Value	PDF	CDF		CDF	# Packages Hit
16	0.0002031		0	1.985E-05		26	0.0055689	0.9305661		0.9305661	5702
16	0.0001917		0	2.665E-05		27	0.0044156	0.9349816		0.9349816	5921
17	0.0001791		0	6.978E-05		28	0.0041206	0.9391023		0.9391023	6140
18	0.0001841		0	0.0001351		29	0.0047421	0.9438444		0.9438444	6360
18	0.0001949		0	0.0001171		30	0.0149689	0.9588132		0.9588132	6579
19	0.0001762		0	0.0001463		31	0.00315	0.9619633		0.9619633	6798
19	0.0001829		0	0.000174		32	0.0024279	0.9643911		0.9643911	7017
20	0.0001707		0	0.0001379		33	0.0023754	0.9667665		0.9667665	7237
20	0.0001644		0	0.0001309		34	0.0020303	0.9687968		0.9687968	7456
21	0.0001727		0	0.0001271		35	0.0021042	0.970901		0.970901	7675
22	0.0001677		1	0.0001789		36	0.0019745	0.9728756		0.9728756	7895
22	0.0001646		1	0.0002237		37	0.0019217	0.9747973		0.9747973	8114
23	0.0001596		1	0.0004148		38	0.0021618	0.9769591		0.9769591	8333
23	0.0001637		1	0.0008684		39	0.0014971	0.9784562		0.9784562	8552
24	0.0001522		1	0.0013299		40	0.0015788	0.9800351		0.9800351	8772
25	0.0001542		1	0.0019596		41	0.0014308	0.9814658		0.9814658	8991
25	0.0001465		1	0.0023738		42	0.0049337	0.9863995		0.9863995	9210
26	0.000153		1	0.0024692		43	0.0007598	0.9871593		0.9871593	9430
26	0.0001424		1	0.0027893		44	0.0015589	0.9887183		0.9887183	9649
27	0.0001413		1	0.003518		45	0.0011742	0.9898924		0.9898924	9868
28	0.0001349		1	0.002499		46	0.0006708	0.9905632		0.9905632	10088
28	0.0001246		1	0.0039061		47	0.0007391	0.9913023		0.9913023	10307
29	0.0001305		1	0.0018959		48	0.003711	0.9950132		0.9950132	10526
29	0.0001358		1	0.003656		49	0.0003983	0.9954116		0.9954116	10745
30	0.0001161		1	0.0021009		50	0.0022824	0.997694		0.997694	10965
30	0.0001292		1	0.003488		51	0.0023062	1.0000001		1.0000001	11184

ATTACHMENT III

CAL-WIS-PA-000001 REV01 OUTPUT

III-1 CDF for Conduit Diameter

III-2 Maximum Number of Waste Packages Hit Per Conduit Diameter

III-3 CDF for Number of Conduits on a Dike

III-4 Dike Width Probability Distribution and Cumulative Distribution

III-5 Number of Dikes in a Swarm Probability Distribution and Cumulative Distribution

III-6 CDF for Number of Waste Packages Hit in Zone 1

III-7 CDF for Number of Waste Packages Hit in Zone 1 and Zone 2 Combined

Table III-1. CDF for Conduit Diameter.

Conduit Diameter (m)	CDF
4.5	0.0000
10	0.0004
15	0.0022
20	0.0066
25	0.0145
30	0.0277
35	0.0623
40	0.1541
45	0.3262
50	0.5008
55	0.6413
60	0.7467
65	0.8082
70	0.8477
75	0.8776
80	0.9026
85	0.9237
90	0.9412
95	0.9549
100	0.9654
105	0.9733
110	0.9799
115	0.9853
120	0.9897
125	0.9933
130	0.9960
135	0.9978
140	0.9989
145	0.9996
150	1.0000

Table III-2. Maximum Number of Waste Packages Hit Per Conduit Diameter

Conduit Diameter (m)	Number of WP Intersected when Conduit is Centered on a Drift	Number of WP Intersected When Conduit is Centered on a Pillar	Maximum Number of Waste Packages Hit Per Conduit Diameter
4.5	1	0	1
10	2	0	2
15	3	0	3
20	4	0	4
25	5	0	5
30	6	0	6
35	7	0	7
40	8	0	8
45	9	0	9
50	10	0	10
55	11	0	11
60	12	0	12
65	13	0	13
70	14	0	14
75	15	0	15
80	16	0	16
85	17	11	17
90	18	16	18
95	19	20	20
100	20	24	24
105	21	27	27
110	22	30	30
115	23	33	33
120	24	36	36
125	25	38	38
130	26	41	41
135	27	43	43
140	28	46	46
145	29	48	48
150	30	51	51

Table III-3. CDF for Number of Conduits on a Dike

Number of Conduits	Final Composite CDF
0	0.00
1	0.23
2	0.81
3	0.90
4	0.94
5	0.96
6	0.98
7	0.99
8	1.00
9	1.00
10	1.00
11	1.00
12	1.00
13	1.00

Probability Information:
Source: CRWMS M&O 2000b, Table 12a "Primary + Contingency Block mean final composite conditional probability.

Table III-4. Dike Width Probability Distribution and Cumulative Distribution

Dike Width (m)	Probability Distribution	Cumulative Distribution
0.5	0.301583	0.000000
1.0	0.238753	0.301583
1.5	0.163358	0.540337
2.0	0.113094	0.703694
2.5	0.062830	0.816788
3.0	0.037698	0.879618
3.5	0.025132	0.917316
4.0	0.017592	0.942448
4.5	0.013194	0.960040
5.0	0.009676	0.973234
5.5	0.006911	0.982910
6.0	0.004901	0.989822
6.5	0.002890	0.994722
7.0	0.001634	0.997612
7.5	0.000754	0.999246
8.0	0.000000	1.000000

Probability Information:

Source: CRWMS M&O 2000a. Log normal distribution with a minimum of 0.5 m, a mean of 1.5 m, and a 95th percentile width of 4.5 m.

Table III-5. Number of Dikes in a Swarm Probability Distribution and Cumulative Distribution

Number of Dikes	Probability Distribution	Cumulative Distribution
1	0.38220	0.00000
2	0.20940	0.38220
3	0.12540	0.59160
4	0.08150	0.71700
5	0.05240	0.79850
6	0.03280	0.85090
7	0.02860	0.88370
8	0.02380	0.91230
9	0.01690	0.93610
10	0.01270	0.95300
11	0.01130	0.96570
12	0.01000	0.97700
13	0.00800	0.98700
14	0.00500	0.99500
15	0.00000	1.00000

Probability Information:

Source: CRWMS M&O 2000a. Log normal distribution with a minimum of 1, a mean of 3 m, and a 95th percentile width of 10 m. CRWMS M&O 2000e provides guidance for truncating the distribution at 15 dikes.

Table III-6. CDF for Number of Waste Packages Hit in Zone 1

Number of Packages Hit	CDF
98	0.0000
101	0.2690
104	0.3362
107	0.3602
110	0.3720
113	0.3783
116	0.3813
119	0.3822
122	0.3822
194	0.4454
197	0.4953
200	0.5296
203	0.5532
207	0.5664
210	0.5743
213	0.5795
216	0.5832
219	0.5860
222	0.5880
225	0.5895
228	0.5905
231	0.5911
235	0.5914
238	0.5916
241	0.5916
287	0.6294
294	0.6594
297	0.6798
303	0.6940
306	0.7019
312	0.7066
316	0.7098
322	0.7120
325	0.7136
331	0.7149
334	0.7157
340	0.7163
344	0.7167
350	0.7169
353	0.7170
359	0.7170
384	0.7416

Table III-6. CDF for Number of Waste Packages Hit in Zone 1 (Continued)

Number of Packages Hit	CDF
390	0.7610
396	0.7744
403	0.7836
409	0.7887
415	0.7918
421	0.7938
428	0.7952
434	0.7963
440	0.7971
446	0.7977
452	0.7981
459	0.7983
465	0.7984
471	0.7985
477	0.7985
481	0.8143
487	0.8268
496	0.8354
502	0.8413
512	0.8446
518	0.8466
527	0.8479
533	0.8488
543	0.8495
549	0.8500
558	0.8504
565	0.8506
574	0.8607
580	0.8608
583	0.8686
590	0.8686
593	0.8740
596	0.8740
602	0.8777
611	0.8798
621	0.8810
630	0.8818
639	0.8824
649	0.8828
658	0.8831
667	0.8834
671	0.8920
677	0.8922
683	0.8990

Table III-6. CDF for Number of Waste Packages Hit in Zone 1 (Continued)

Number of Packages Hit	CDF
686	0.8991
692	0.9037
695	0.9038
705	0.9071
714	0.9089
726	0.9099
736	0.9107
748	0.9112
758	0.9115
767	0.9187
770	0.9190
779	0.9249
792	0.9289
801	0.9290
804	0.9317
814	0.9317
817	0.9332
823	0.9332
829	0.9341
835	0.9341
842	0.9347
854	0.9351
860	0.9402
867	0.9406
876	0.9446
879	0.9448
888	0.9476
891	0.9478
904	0.9498
916	0.9509
929	0.9509
932	0.9516
941	0.9516
944	0.9520
954	0.9520
957	0.9559
960	0.9562
972	0.9594
988	0.9616
1000	0.9618
1004	0.9632
1016	0.9633
1019	0.9641
1029	0.9641

Table III-6. CDF for Number of Waste Packages Hit in Zone 1 (Continued)

Number of Packages Hit	CDF
1035	0.9646
1044	0.9646
1050	0.9650
1054	0.9684
1057	0.9684
1066	0.9686
1069	0.9713
1072	0.9713
1081	0.9715
1088	0.9733
1097	0.9734
1103	0.9747
1113	0.9748
1122	0.9755
1128	0.9756
1138	0.9760
1144	0.9760
1147	0.9791
1156	0.9793
1159	0.9794
1165	0.9817
1172	0.9819
1175	0.9820
1184	0.9836
1190	0.9837
1203	0.9849
1206	0.9850
1222	0.9856
1225	0.9857
1240	0.9861
1243	0.9885
1259	0.9888
1265	0.9907
1275	0.9907
1278	0.9909
1284	0.9922
1287	0.9924
1293	0.9924
1296	0.9925
1306	0.9934
1309	0.9934
1315	0.9935
1324	0.9940
1334	0.9941

Table III-6. CDF for Number of Waste Packages Hit in Zone 1 (Continued)

Number of Packages Hit	CDF
1340	0.9956
1346	0.9959
1352	0.9959
1362	0.9971
1365	0.9973
1371	0.9974
1384	0.9982
1390	0.9982
1405	0.9989
1409	0.9989
1427	0.9993
1433	0.9993
1446	0.9993
1449	0.9995
1458	0.9995
1468	0.9995
1471	0.9997
1480	0.9997
1486	0.9997
1492	0.9998
1505	0.9998
1508	0.9998
1514	0.9999
1527	0.9999
1536	0.9999
1549	0.9999
1552	0.9999
1558	0.9999
1574	0.9999
1580	1.0000
1598	1.0000
1601	1.0000
1620	1.0000
1623	1.0000
1645	1.0000
1667	1.0000
1692	1.0000
1714	1.0000
1738	1.0000
1760	1.0000
1785	1.0000

Table III-7 – CDF for Number of Waste Packages Hit in Zone 1 and Zone 2 Combined

Number of Drifts Intersected	Number of Packages Hit	CDF
0	0	0.000000
1	219	0.071659
2	439	0.138089
3	658	0.192331
4	877	0.247474
5	1096	0.322370
6	1316	0.367241
7	1535	0.421877
8	1754	0.464628
9	1974	0.524164
10	2193	0.558961
11	2412	0.624847
12	2632	0.652530
13	2851	0.673015
14	3070	0.738368
15	3289	0.755386
16	3509	0.771160
17	3728	0.789877
18	3947	0.841237
19	4167	0.854094
20	4386	0.863516
21	4605	0.873228
22	4824	0.881299
23	5044	0.914493
24	5263	0.919672
25	5482	0.924997
26	5702	0.930566
27	5921	0.934982
28	6140	0.939102
29	6360	0.943844
30	6579	0.958813
31	6798	0.961963
32	7017	0.964391
33	7237	0.966767
34	7456	0.968797
35	7675	0.970901
36	7895	0.972876
37	8114	0.974797
38	8333	0.976959

Table III-7 – CDF for Number of Waste Packages Hit in Zone 1 and Zone 2 Combined (Continued)

Number of Drifts Intersected	Number of Packages Hit	CDF
39	8552	0.978456
40	8772	0.980035
41	8991	0.981466
42	9210	0.986400
43	9430	0.987159
44	9649	0.988718
45	9868	0.989892
46	10088	0.990563
47	10307	0.991302
48	10526	0.995013
49	10745	0.995412
50	10965	0.997694
51	11184	1.000000

ATTACHMENT IV

EXPLANATION OF EXCEL-ASSISTED CALCULATIONS

1. EXCEL WORKBOOK *CAL-WIS-PA-000001 REV00 ICN1 VOLC Anal_Sept-00.xls*

This workbook calculates the CDFs for conduit diameter and number of conduits on a dike. In addition, the maximum number of waste packages hit for the range of conduit diameters defined by the conduit diameter CDF is calculated.

Spreadsheet No. 1 – Conduit Diameter PDF and CDF

This spreadsheet utilizes the probability input from CRWMS M&O 2000a to develop the CDF for conduit diameter. This CDF is developed using **EXCEL** arithmetic functions. The probability input from CRWMS M&O 2000a defines the probability distribution for conduit diameter as a log-normal distribution with a minimum diameter equal to dike width, a median value of 50 m and a maximum value of 150 m. The resulting CDF was developed in 5 meter steps to allow for adequate sampling resolution within the TSPA-SR model.

1.2 Spreadsheet No. 2 – WP Hit Per Conduit Diameter

This spreadsheet uses **EXCEL arithmetic** functions to calculate the number of waste packages hit per conduit diameter for: (1) when the conduit is centered on a drift (Section 5.2 - Equation 1); and (2) when the conduit is centered on a pillar (Section 5.2 – Equation 3). The **EXCEL CEILING** function is used to round up calculation results to the nearest integer value. The **EXCEL MAX** function is used to selected the maximum value calculated using each equation.

1.3 Spreadsheet No. 3 – Number of Conduits on a Dike

This spreadsheet utilizes the probability input from CRWMS M&O 2000b (Table 12a) to develop the CDF for number of conduits on a dike. This CDF is developed using **EXCEL** arithmetic functions.

2. EXCEL Workbook *CAL-WIS-PA-000001 REV00 ICN1 EST Anal_Sept-00.xls*

This workbook calculates the number of waste packages hit for the range of dike widths and number of dikes in a swarm as defined by CDFs for each of these parameters. It also calculates the number of drifts crossed by a dike

2.1 Spreadsheet No. 1 – CCSM-PCB.CMP

This spreadsheet is comprised of the output data file CCSM-PCB.CMP (DTN. Pending). No EXCEL operations are performed on this spreadsheet

2.2 Spreadsheet No. 2 – No Zeros

This spreadsheet uses the **EXCEL sort** function to:(1) identify the dike-azimuth angle pairs that have zero probabilities: and (2) provide a spreadsheet which has the azimuth data as the more slowly varying. After identifying the length-azimuth pairs with zero probabilities, these pairs were deleted.

2.3 PDFs-CDFs

This spreadsheet utilizes the probability input from CRWMS M&O 2000a to develop the CDFs for dike width and number of dikes in a swarm. These CDFs are developed using **EXCEL arithmetic** functions. The probability input from CRWMS M&O 2000a defines the probability distribution for dike width as a log-normal distribution with a minimum width of 0.5 m, a mean value of 1.5 m and a 95th percentile of 4.5 m. The probability input from CRWMS M&O 2000a defines the probability distribution for number of dikes in a swarm as a log-normal distribution with a minimum of 1 dike, a mean of 3 dikes and a 95th percentile of 10 dikes truncated at a maximum of 15 dikes.

2.4 Spreadsheet No. 3 – Input-params-EST

This spreadsheet includes input information (see Table II-1 for information sources) and simple **EXCEL arithmetic** calculations (add, divide, multiply, and calculate the arctangent of an angle [ATAN].

2.5 Spreadsheet No. 4 – Simulations-EST

Dike Width CDF and Number of Dikes CDF are the labels for the manually selected CDF values used by the **EXCEL VLOOKUP** function (found under the **Dike Width (m)** and **Number of Dikes)** to sample the CDFs in spreadsheet No. 3. This calculation is sequentially done to exhaustively sample both CDFs.

Effective Total width of Swarm (m) uses the **EXCEL CEILING** function to round up the calculated width to the nearest integer value.

Max Length inside Repos (m) uses **EXCEL IF** and **MIN** functions to select how the value is calculated and limit the length to the maximum simplified repository dimensions.

The calculations done for **Total dike area within the PB (m^2)** and **Drift Area Intersected by Dike** and **Number of WP Hit** use simple **EXCEL arithmetic** functions to solve Equation 4 (Section 5.3). In addition, **Number of WP Hit** uses **EXCEL CEILING** and **MIN** functions to round up the calculated value and limit the number of waste packages hit to the total number planned for emplacement in the repository (11,184).

Weighted Average Pkgs hit uses the **EXCEL SUM and CEILING** functions to calculate the weighted average for the number of packages and round that value up to the nearest interval value.

Dike Length Perpendicular to Drifts (m) uses **EXCEL ABS and SIN** functions to solve Equation 5 (Section 5.3).

Number of Drifts Intersected along Dike Length Hit uses **EXCEL CEILING** and **MIN** functions to round up the calculated number of drifts crossed and limit the number of drifts to the total number of drifts in the repository (51).

Total Number of Drifts Intersected Per Drift Area uses the **EXCEL IF** function to determine if the dike width – dike length area combination intersects more drifts than the number of drifts calculated using Equation 7 (Section 5.3). If this is the case, then the number of drifts representative of the larger area is calculated and rounded up to the nearest integer value using the **EXCEL CEILING** function. This number of drifts representative of the larger area is then added to the number of drifts calculated using Equation 7 to arrive at the total number of drifts intersected by the dike.

2.6 Spreadsheet No. 5 – Zone 1

The results of all calculations for the number of packages hit done in spreadsheet No. 4 are manually compiled in the first three tables on this spreadsheet (**Number of Dikes, Dike Width,** and **Number of Packages Hit**. Simple **EXCEL** functions are then used to organize these values and calculate the CDF for number of waste packages hit in Zone 1.

2.7 Spreadsheet No. 6 – Zone 1 + Zone 2

The results of all calculations for the number of drifts hit done in spreadsheet No. 4 are manually compiled in the first table on this spreadsheet **(Number of Drifts Hit)**. Simple **EXCEL** functions are then used to organize these values and calculate the CDF for number of drifts hit in Zone 1 + Zone 2. The number of waste packages hit is also determined by multiplying the number of drifts hit by 219 (approximate average number of waste packages per drift).