ENCLOSURE 2

BSC (Bechtel SAIC Company) 2004. Ash Fall Hazard for North Portal Operations Area Facilities. CAL-WHS-GS-000001 REV 00A. Las Vegas, Nevada: Bechtel SAIC Company. ACC: DOC.20041116.0001; DOC.20050815.0004.

BSC

Engineering Change Notice

Complete only applicable items.

1. QA: QA
2. Page 1 of 1

3. Document Identifier:	4. Rev.:	5. Title:	6. ECN:
CAL-WHS-GS-000001	00A	Ash Fall Hazard for North Portal Operations Area Facilities	001

7. Reason for Change:

Per LP-3.12Q-BSC Design Calculations and Analyses Section 5.1 [2] c,

> "The decision of the DEM, PCSA Manager, Criticality Manager, or PCA Manager to issue calculations or analyses with a "committed" status will be based on an experienced assessment of the likelihood that the results of the calculation or analysis will change, and the degree of impact those changes will have on designs that support the regulatory submittals or procurement activities, based on the design's bounding conservatism."

the status designation of *Ash Fall Hazard for North Portal Operations Area Facilities* (CAL-WHS-GS-000001) can be changed to "Committed" as the results are not expected to change in such a manner that will affect support of regulatory submittals.

8. Supersedes Change Document: ☐ Yes If, Yes, Change Doc.: ____ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes ☒ No	Results Impacted:	☐ Yes ☒ No
Assumptions Changed:	☐ Yes ☒ No	Design Impacted:	☐ Yes ☒ No

10. Description of Change: (Address any "Yes" answers)

Add a "Committed" option in Block 7 on the cover sheet and change the "Document Status Designation" from Preliminary to "Committed". Block 7 on the cover sheet should read as follows:

7. Document Status Designation			
☐ Preliminary	☒ Committed	☐ Final	☐ Cancelled

Note: An interdisciplinary review per LP-2.14Q-BSC is not required for this change to the document.

11. Originator: (Print/Sign/Date)
Jo A. Ziegler *[signature]* 8/11/05

Checker: (Print/Sign/Date)
Farzin Nouri *[signature]* 8/11/05

Approved: (Print/Sign/Date)
Michael K. Cline *[signature]* 8/11/05

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OCRWM	**DESIGN CALCULATION OR ANALYSIS COVER SHEET**	1. QA: QA 2. Page 1 of 50

3. System	4. Document Identifier
WHS	CAL-WHS-GS-000001 Rev. 00A

5. Title
Ash Fall Hazard for North Portal Operations Area Facilities

6. Group
Disruptive Events

7. Document Status Designation

☒ Preliminary ☐ Final ☐ Cancelled

8. Notes/Comments

R. Youngs was responsible for conceptual approach.
T. Nieman was responsible for calculational work.

Attachments	Total Number of Pages
Attachment A - CD-ROM of Computer Files	N/A
Attachment B –ASHPLUME Grid Dimensions	Included

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. QER (Print/Sign/Date)	16. Approved/Accepted (Print/Sign)	17. Date
00A	Initial Issue	48	48	Robert Youngs Tim Nieman [signature] 11/12/04 [signature] 11/12/04	William Imrie [signature] 11/12/04	Jerry Heaney Jerry Heaney 11/16/04	[signature] for McClure 11/16/04	11/16/04

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Ash Fall Hazard for North Portal Operations Area Facilities

1. PURPOSE

The Analysis Report *Characterize Framework for Igneous Activity at Yucca Mountain Nevada* (BSC 2004a [DIRS 169989]) describes the frequency of basaltic volcanism in the Yucca Mountain Region. The purpose of this design calculation (hereafter referred to as the "design calculation" to distinguish from the more general use of the term calculation) is to provide an estimate of the ash fall hazard at the North Portal Operations area due to potential basaltic volcanism. The ash fall hazard, expressed as probability of deposition areal density, was calculated using Analytica®. The resultant hazard curve (frequency versus areal density) will be used to guide building design to withstand potential ash fall from basaltic volcanism. This design calculation is applicable for that intended use only.

Inputs to this design calculation include ash deposition calculations (DTN: LA0409WS831812.001 [DIRS 171768]) generated by the ASHPLUME computer code. The ASHPLUME computer code implements the mathematical model of Suzuki (1983 [DIRS 100489]) for estimation of the areal density of tephra deposits on the surface of the earth following a volcanic eruption. The code, developed by Jarzemba et al. (1997 [DIRS 100987]), includes estimation of the areal density of spent fuel particles incorporated into tephra particles due to a volcanic event that intersects the repository. ASHPLUME is used as a component of the Total Systems Performance Assessment (TSPA) model to assess hazards from possible volcanic activity at the Yucca Mountain site. The ash deposition calculation was conducted using ASHPLUME_DLL_LA Version 2.0 [STN: 11117-2.0-00].

In addition to ASHPLUME generated data, the design calculation also requires an estimate of predominant wind azimuths that would carry the ash to the facilities under consideration, and estimates of the frequency of potential eruptions in the vicinity of the repository. Wind directions used in the design calculation are taken from *Atmospheric Dispersal and Deposition of Tephra from a Volcanic Eruption at Yucca Mountain, Nevada* (BSC 2004b [DIRS 170026]). Eruption frequencies are taken from *Characterize Framework for Igneous Activity at Yucca Mountain Nevada* (BSC 2004a [DIRS 169989]).

The point used to represent the North Portal Operations Area Facilities is the southwest corner of the Canister Handling Facility. The location of this point in UTM is documented in *YMP Site Operations–Maintenance–Field Engineering–Survey Section, Coordinate Transformation* (BSC 2004c [DIRS 171769]).

This design calculation was developed under the Office of Civilian Radioactive Waste Management procedure AP–3.12Q and other applicable procedures. Development of this calculation and the supporting activities have been determined to be subject to the Yucca Mountain Project's quality assurance program (DOE 2004b [DIRS 171539]) and applicable Project procedures and guiding documents.

2. METHOD

The annual frequency of exceeding a given areal ash fall density, $\nu^{A>n}(t)$, is computed for different values of n in order to create a hazard curve of ash fall areal density versus frequency. $\nu^{A>n}(t)$, is computed using the relationship:

$$\nu^{A>n}(t) = \iint_R \lambda(x,y,t) \cdot \int_w P(w) \cdot P^{A>n}(|w,x,y)\, dw\, dx\, dy \qquad \text{(Eq. 1)}$$

where

$\nu^{A>n}(t)$	= annual frequency of exceeding a given areal ash fall density, n,
A	= mass of ash per unit area at Northern Portal Operations Area Facilities in g/cm^2
$\lambda(x,y,t)$	= rate of volcanic events at location (x,y) for the current time t,
R	= region surrounding the proposed facilities, defined in terms of x and y, with x and y in km
$P(w)$	= probability of the wind blowing in direction w,
w	= wind direction, in degrees
$P^{A>n}(\|w,x,y)$	= conditional probability that the areal density of ash fall, A, at the facility associated with a volcanic event at point (x,y) and wind direction w exceeds the value n,

The actual calculation was performed on a 1-km × 1-km grid spacing using the numerical summation:

$$\nu^{A>n}(t) = \sum_{i=500}^{600} \sum_{j=4000}^{4150} \lambda(x_i,y_j,t) \cdot \sum_{k=0}^{360} P(w_k) \cdot P^{A>n}(|w_k,x_i,y_j)\, \Delta w\, \Delta x\, \Delta y \qquad \text{(Eq. 2)}$$

The results from this summation, repeated for selected values of n, are used to generate a hazard curve of ash fall areal density at the North Portal Operations Area Facilities. All of the data required to perform these calculations have been previously generated; the calculations simply perform a set of grid manipulations to ensure that the proper ash fall areal density data for a given volcano location and wind direction are extracted from the ASHPLUME outputs and used for the probability calculation.

In practice, the design calculation requires that for any given volcano location and wind direction, we determine which part, if any, of the simulated ash plumes will fall on the fixed facilities location. Because the ash plume data are generated with respect to a fixed wind direction, the calculation essentially entails pinning the origin of the ash plume data at a given potential volcano location, rotating the ash plume grid with the wind direction, and determining what part of the resulting ash plume grid intersects the facilities location. The general set of steps for completing the design calculation is as follows:

1. Ash areal density data have been generated by ASHPLUME in a set of 110 simulations (Pre-closure Ash Distribution Density, DTN: LA0409WS831812.001 [DIRS 171768]). However, the simulations have varying grid dimensions and grid spacing. This first step involves interpolating and/or extrapolating the ash areal density data from each of the realizations onto a common grid so that a full set of simulated ash areal densities are available for all grid points.

2. For each hypothetical volcano and possible wind direction, perform the necessary grid calculations to extract the proper distribution of ash fall areal densities from the ASHPLUME gridded data at the facilities location. Each volcano/wind direction combination will have a value from each of the ASHPLUME simulations. From these ash areal density distributions, calculate the probabilities of exceeding various ash areal densities for the given volcano and wind direction, and sum over the probabilities of the wind directions to determine the overall probabilities for exceeding the ash areal density for that volcano.

3. Repeat step 2 for each possible volcano location and wind direction, multiply the results by the estimated frequency of eruption at each location, and sum over all locations to get the overall hazard curve for the facilities.

There are three input data sets required for performing the calculations.

1. ASHPLUME results. Input data consist of 110 simulations of ash fall from a hypothetical volcano under different conditions (Pre-closure Ash Distribution Density, DTN: LA0409WS831812.001 [DIRS 171768]). All data are represented relative to the prevailing wind direction. Results are represented spatially on a grid, whose dimensions and grid cell spacing very dependent on the simulation. These ash areal density calculations were performed using ASHPLUME_DLL_LA Version 2.0 [STN: 11117-2.0-00] and GoldSim Version 8.02 [STN: 10344-SVR-8.02-00]. The ASHPLUME_DLL_LA Version 2.0 code was implemented within a GoldSim model file and all model parameters were input using the GoldSim graphical user interface. The ASHPLUME parameter values used to run the simulations are discussed in *Atmospheric Dispersal and Deposition of Tephra from a Volcanic Eruption at Yucca Mountain, Nevada*, MDL-MGR-GS-000002 Revolt (BSC 2004b [DIRS 170026]). Wind direction distributions are also discussed in that AMR. All input data for these ASHPLUME runs were taken from the following DTNs:

   ASHPLUME Parameters - DTN: LA0408GK831811.002 ([DIRS 171749])
   Wind Directions – DTN: MO0408SPADRWSD ([DIRS 171803])

   The GoldSim/ASHPLUME model was used to run 110 realizations of the Atmospheric Dispersal model with the results from each realization stored in separate files. The ASHPLUME output is contained in two files for each realization. One file contains ash areal densities on the full grid of receptor points for each realization. The other file contains areal densities only at locations on a local grid defined by the points (0.0, +0.5), (0.0, -0.5), (0.5, +0.5), (0.5, 0.0), and (0.5, -0.5). Note that all grid dimensions used throughout the calculations are expressed in km. A total of 220 files of ASHPLUME output are contained in the included .zip file.

2. Wind direction: Wind direction probabilities are taken from *Atmospheric Dispersal and Deposition of Tephra from a Volcanic Eruption at Yucca Mountain, Nevada* (BSC 2004b [DIRS 170026]). Probabilities are represented in 30-degree increments of azimuth, and are provided for each 1 km increment of altitude from 0 to 13 km. The wind direction probabilities are contained in DTN MO0408SPADRWSD.002 ([DIRS 171803]). Consistent with the use in TSPA, the wind direction distribution used in this design calculation for any given ASHPLUME simulation is the one that corresponds to the maximum column height of the plume. TSPA also uses a wind speed that corresponds to the maximum column height of the plume, however the effect of wind speed is included in the Ashplume code calculation of ash deposition and is not separately required or used in these calculations. Wind direction data are considered to be consistent across the area under consideration.

3. Volcano frequency: The frequency of volcanic events has been characterized for locations on a 100 x 150 km grid with 1 km grid spacing in *Characterize Framework for Igneous Activity at Yucca Mountain Nevada* (BSC 2004a [DIRS 169989]). This results in a total of 15,251 hypothetical volcanoes. The mean eruption frequencies at each of these points are contained in file CFRACSM.XY in DTN LA0009FP831811.001 ([DIRS 164712]).

All input files, output files, computer codes, and other supporting software were maintained and executed on a single dedicated PC secured by controlled access and password protection. Standard backup procedures were employed by the analyst to ensure data integrity.

3. ASSUMPTIONS

The underlying assumptions used in the ASHPLUME mathematical model and model runs are discussed in Suzuki (Suzuki 1983 [DIRS 100489]), Jarzemba *et al.* (Jarzemba 1997 [DIRS 100987]), and *Atmospheric Dispersal and Deposition of Tephra from a Volcanic Eruption at Yucca Mountain, Nevada* (BSC 2004b [DIRS 170026]). The underlying assumptions regarding the use of wind directions data are also discussed in that AMR. The underlying assumptions used in the volcano eruption frequency estimates are discussed in *Characterize Framework for Igneous Activity at Yucca Mountain Nevada* (BSC 2004a [DIRS 169989]). No additional data assumptions are required for this design calculation.

4. COMPUTER AND SOFTWARE MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE (QA) WORK

The ash areal density calculations used as input to this design calculation were performed using ASHPLUME_DLL_LA Version 2.0 [STN: 11117-2.0-00] and GoldSim Version 8.02

[STN: 0344-SVR-8.02-00] on the computer WSB-152320, running Windows 2000, and located in the TSPA computer lab in Las Vegas.

The validation test report for ASHPLUME is found in *Validation Test Report for: ASHPLUME_DLL_LA Version 2.0* (DOE 2003 [DIRS 166506]) and for GoldSim in *Software Validation Report for: GoldSim v8.02, Rev. No.: 00* (DOE 2004a [DIRS 169878]).

4.2 EXEMPT SOFTWARE

The following commercial off-the-shelf software are exempt software products in accordance with *Software Management* (LP-SI.11Q-BSC, Subsection 2).

Analytica® Version 3.0.1, a commercially available decision analysis modeling software package, was used to calculate all results for this design calculation. Analytica is appropriate because simple mathematical expressions and operations that are standard in Analytica were used to derive the results.

Microsoft® Excel 2002, a commercially available spreadsheet software package, was used to parse ASHPLUME input files prior to importing to Analytica, and to perform a complete set of duplicate calculations on a subset of data. Excel is appropriate because simple mathematical expressions and operations that are standard in Excel were used to derive the results.

All software used in this calculation was executed on an IBM ThinkPad T41 laptop computer running under the Microsoft Windows XP Professional 2002 Service Pack 1 operating system. The system is located at the offices of Geomatrix Consultants, Inc. in Oakland, California and is identified with the inventory number 00045-122-114-399.

5. CALCULATION

As described in Section 2, the numerical summation for performing the design calculation is:

$$\nu^{A>n}(t) = \sum_{i=500}^{600} \sum_{j=4000}^{4150} \lambda(x_i, y_j, t) \cdot \sum_{k=0}^{360} P(w_k) \cdot P^{A>n}(|w_k, x_i, y_j)\ \Delta w\ \Delta x\ \Delta y \qquad \text{(Eq. 2)}$$

5.1 OVERVIEW OF CALCULATION PROCEDURE

This section discusses the general procedure used to implement the design calculation. The steps involved for implementation in Analytica are explained in detail in section 5.2.

5.1.1 ASHPLUME Data on Common Grid

The ASHPLUME code determines the appropriate grid spacing and dimensionality as part of each simulation run; therefore the results of the 110 simulations do not exist on a common grid. Grid spacing varies from 1 km to 10 km, while the sizes of the grids range from 20 km to 200 km along a dimension. Attachment B shows the grid dimensions for each of the simulation runs.

This first step entails taking each of the simulation results and performing a set of interpolations, and in some cases, extrapolations, to put all of the data on a common grid. The maximum dimensions of the common grid are set to 100 km in both the x and y coordinates. The maximum distance from a potential volcano to the surface facilities is 93.5 km; the 100 km grid dimension therefore ensures that there is always an ASHPLUME data point for any potential volcano. The grid for interpolation therefore has dimensions of x = 0 to 100 km and y = -100 to 100 km, while the spacing is set to 0.5 km to provide an existing grid point for all ASHPLUME generated points. Note that the ASHPLUME data are symmetrical about the y axis, data points are not generated for negative x values to avoid duplication.

Also during this step, data are inspected for potential problems. Of the 110 ASHPLUME simulation runs, 13 were determined to have incorrect terminations because of not meeting a minimum ashfall criterion in the ASHPLUME code. These simulations were not used in the final results.

Interpolations and extrapolations are performed in ln-ln space. The method is relatively simple to implement in Analytica and Excel, and is considered to provide a reasonably good approximation for data that follow a power law curve.

Also within this step, data near the origin are treated with special consideration. ASHPLUME does not generate a value specifically at the origin due to the power law equations within its calculations. Also, because of the varying grids generated by ASHPLUME, the nearest data point to the origin is from 1 to 10 km away. Therefore, the second set of ASHPLUME runs was performed to generate data at 5 points surrounding the origin. The five points occur at x,y (km) coordinates (0, +0.5), (0.5, +0.5), (0.5, 0), (0.5, -0.5), and (0, -0.5).

To provide an ash areal density value at the origin itself, the nearest data value in the downwind direction (x = 0, y = +0.5) is used. That data point always represents the maximum areal density value generated by ASHPLUME. Nevertheless, the value is likely an under-estimation of the proper value that would be representative of the ash density at the origin. However, this conservative treatment is acceptable for this calculation, because the value at the origin is never used in the calculation. Because of how the grid points fall with respect to the facilities location, the closest hypothetical volcano to the facilities is approximately 0.5 km away. Since the ash areal density data are represented on a grid spacing of 0.5 km, there always exists a non-origin data point to be used for the nearest volcano to the facilities.

5.1.2 Grid Calculations

Determine the appropriate ASHPLUME grid point to extract for each potential volcano location and wind direction. For each of the 15,251 volcano points (100 x 150 km grid at 1 km spacing) and for each of 12 possible wind directions, calculations were done to determine the distance and direction to the facilities with respect to the wind direction. Those data were used to orient the ASHPLUME grid, and determine the ASHPLUME coordinates coinciding with the facilities location in order to extract the ash areal density values. For each potential volcano, this results in 1164 simulated ash areal densities (97 simulations x 12 wind directions).

This step essentially entails orienting the ASHPLUME gridded data on the volcano grid with respect to the volcano location and the wind direction, then determining the point on the oriented ASHPLUME grid that coincides with the facilities location. Figure 1 shows a schematic of what is involved for one of the volcano points and a wind direction of approximately 120 degrees. The desired outputs of this grid calculation are the x,y grid points, Ax and Ay, that provide the point to be extracted from the ASHPLUME simulations for a given volcano location and wind direction.

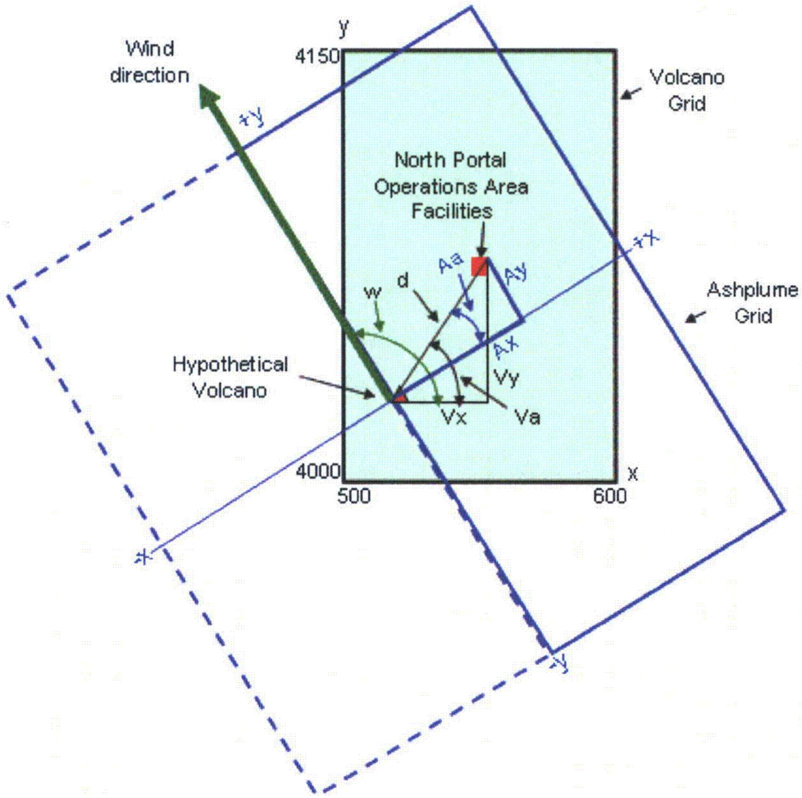


Figure 1. Schematic of Relationship Between Ashplume Grid and Volcano Grid

5.1.3 Overall Frequency Versus Density Curve

Calculate the probabilities of exceeding various ash densities for each potential volcano, multiply by the frequency of eruption, and sum over all potential volcanoes to determine the overall frequency versus density curve. Each potential volcano has 1164 simulated ash densities (97 simulations x 12 wind directions) with associated probabilities of occurrence; probabilities of exceeding a certain ash areal density were extracted from these distributions for each volcano prior to multiplying by the frequency of occurrence and summing.

5.2 DETAILS OF CALCULATION PROCEDURE

All calculations, with the exception of an initial data formatting step, were conducted in Analytica. Analytica is structured using influence diagrams that can be organized in a hierarchical sense to simplify the presentation of the design calculation. Figure 2 shows the overall flow of information in the design calculation at a high level.

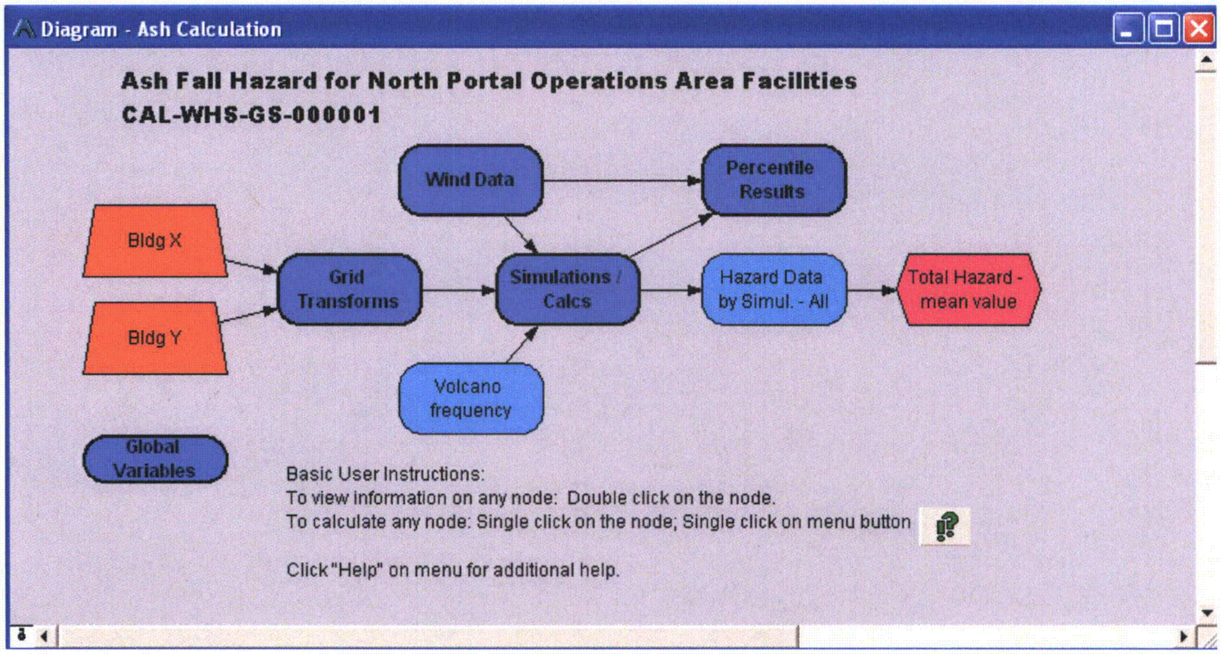


Figure 2. Diagram of Overall Calculation Flow in Analytica

Each node in this diagram holds data or performs a part of the design calculation. The nodes shown are:

"Bldg X" - the x location of the facilities under consideration with respect to the volcano grid.

"Bldg Y" – the y location of the facilities under consideration with respect to the volcano grid.

"Grid Transforms" – Module of nodes to perform the set of calculations to determine the x and y coordinates on the ASHPLUME data grids for values to be extracted for each combination of volcano location and wind direction. Most of the calculations discussed in section 5.1.2 above are conducted in this module.

"Simulations / Calcs" – Module of nodes to perform the hazard calculations for each of the 110 ASHPLUME simulation data sets. Most of the calculations discussed in sections 5.1.1 and 5.1.3 above are conducted in this module. First, interpolation and extrapolation of each of the ASHPLUME data sets are performed to place the data on the common grid. Then the grid transformation information (from the "Grid Transforms" module) is used to extract the appropriate ash areal density values for each simulation data set. Then calculations are performed to determine the hazard curves for each simulation in turn. Note that the final step of using all of the simulations to calculate the total hazard curve is done outside of this module.

"Wind Data" – Module of nodes with probabilities for the 12 wind directions at each of 13 plume altitudes in 1-km increments. The same set of wind probabilities (for a given plume simulation) is assumed for all potential volcano locations.

"Volcano frequency" – Eruption frequency data for each of the 15,251 potential volcano locations.

"Hazard Data by Simul. – All" – Table showing hazard data for each simulation, summed over wind direction.

"Percentile Results" – Module of nodes used to extract and display percentiles of hazard curve results.

"Total Hazard – mean value" – Overall mean value for the hazard curve.

5.2.1 ASHPLUME Data on Common Grid

The calculations for this step in Analytica occur inside the module – "Simulations / Calcs". To manage the size of the calculation in Analytica and to make it easier to follow the calculation steps, calculations were constructed and performed on each of the 110 provided ASHPLUME simulations separately. A module exists to perform the calculations for each of the simulations. These modules are shown in Figure 3 as the numbered nodes with the bold edges.

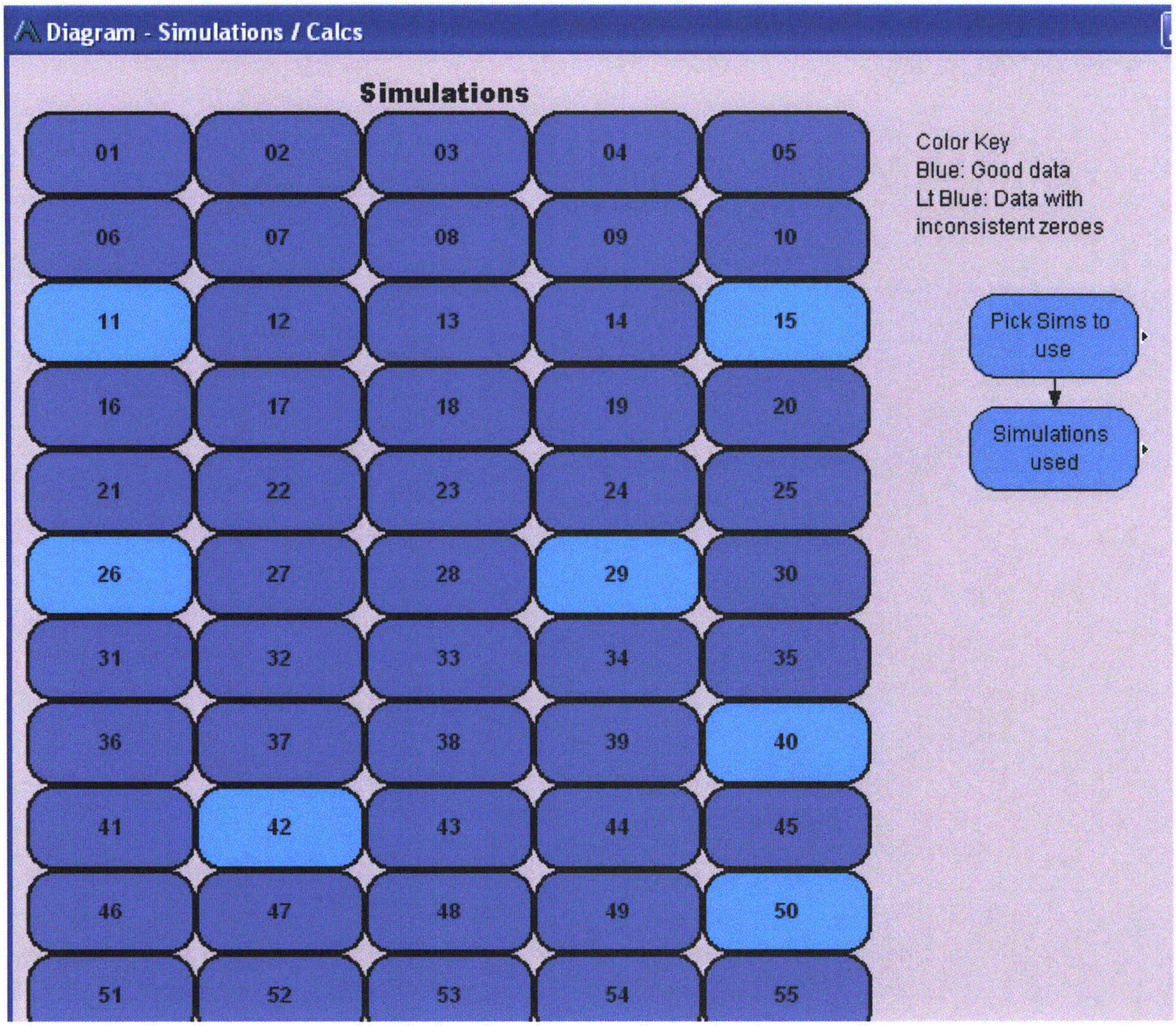


Figure 3. Diagram of "Simulations / Calcs" Module in Analytica

Calculations are performed inside each of the 110 simulation modules. Figure 4 shows the calculation flow for simulation 01 (inside the module labeled "01"). The remainder of this section will use simulation 01 to describe the sequence of calculation steps

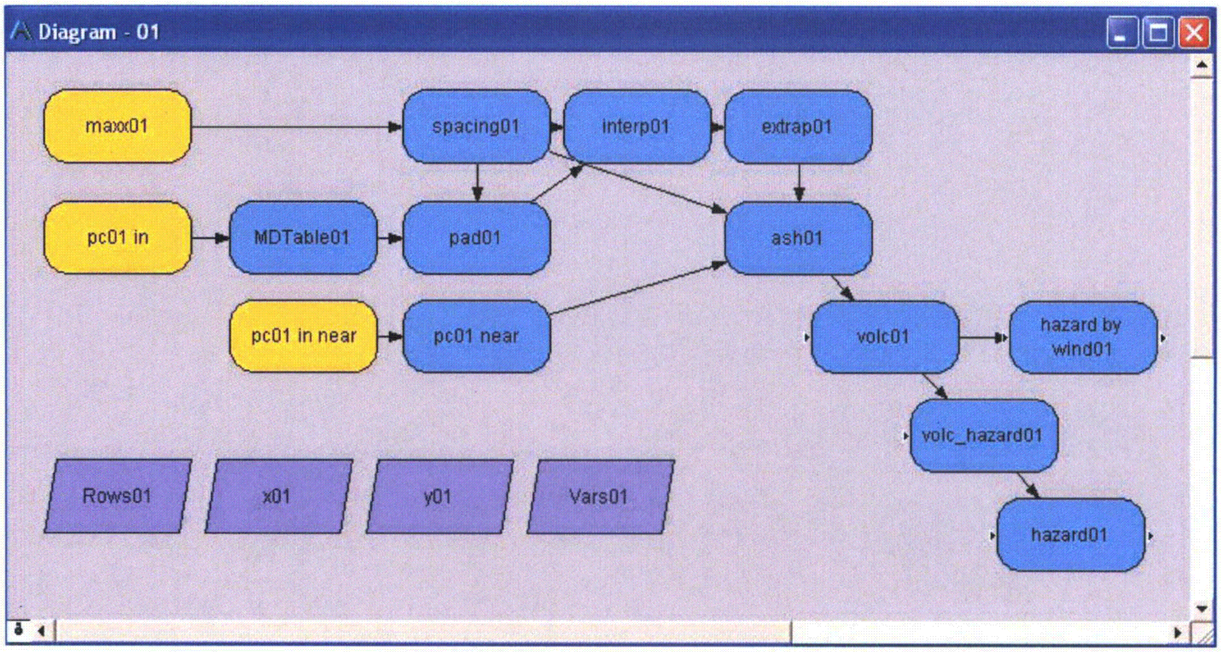


Figure 4. Diagram of Calculation Flow for Simulation 01 in Analytica

The steps involved are as follows:

a) Open the "PCa-1.out" file from ASHPLUME in Excel. Convert text data into column format. ASHPLUME .out files were processed in groups of 10. The 11 Excel files are included with the attached CD-ROM; file names are of the form "PCa-OUT31-40.xls".

b) Copy x, y, and xash data into Analytica. The maximum distance along the x-dimension is first entered into the node "maxx01". The results of this operation are not shown here. The nodes where the data are copied into Analytica are labeled "pcnn in", where nn ranges from 01 to 110. In Figure 4, data are copied into the node "pc01 in". Figure 5 shows the node information and partial results of this operation.

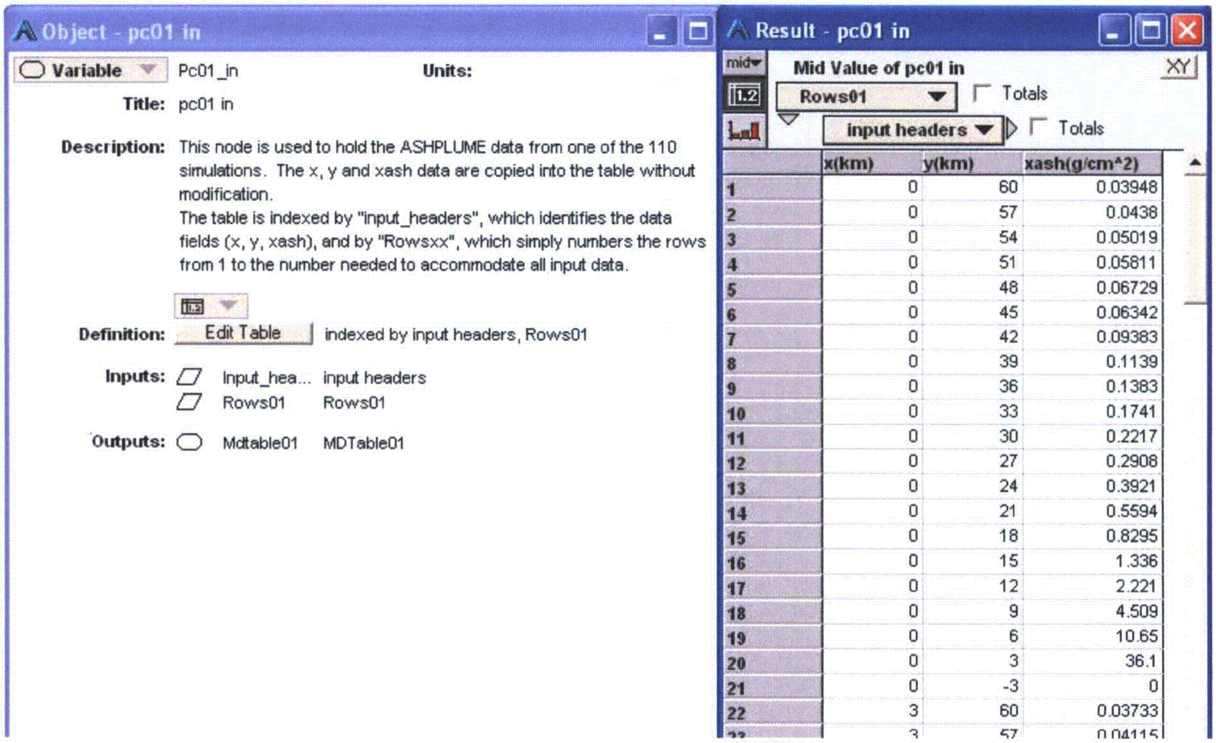


Figure 5. Information and Partial Results for the Node “pc01 in” in Analytica

c) Convert the flat file data into a 2-D grid, indexed in x and y by the original dimensions from the ASHPLUME runs. Figure 6 shows the node information and partial results of this operation.

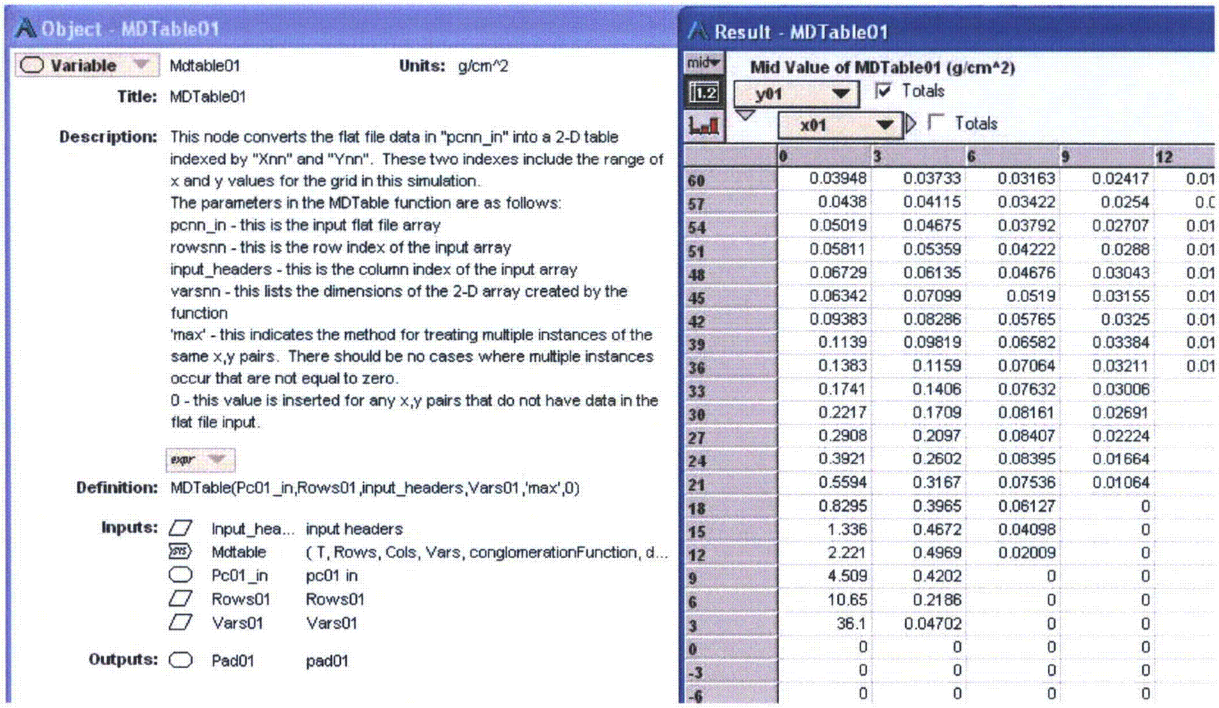


Figure 6. Information and Partial Results for the Node "MDTable01" in Analytica

d) Inspect the data for incomplete ASHPLUME data containing excess zero points. An example is shown in Figure 7 for simulation number 61. In this example, the data for x = +2 from y = +2 to y = +30 are inconsistent with the surrounding data. The data along x = +10 are also inconsistent. These inconsistencies are the result of the incorrect termination of some ASHPLUME calculation sweeps in the y-direction because of minimal ashfall. In these cases, one can either exclude the simulation, or attempt to fill in the data by interpolation and extrapolation. In order to maintain a consistent treatment of all simulations and to avoid the possibility of introducing additional uncertainty, any simulation that contains apparent incomplete data is excluded from the final calculations. The total number of simulations falling into this category is 13, or 12% of the total.

Result - MDTable61

Mid Value of MDTable61 (g/cm^2)

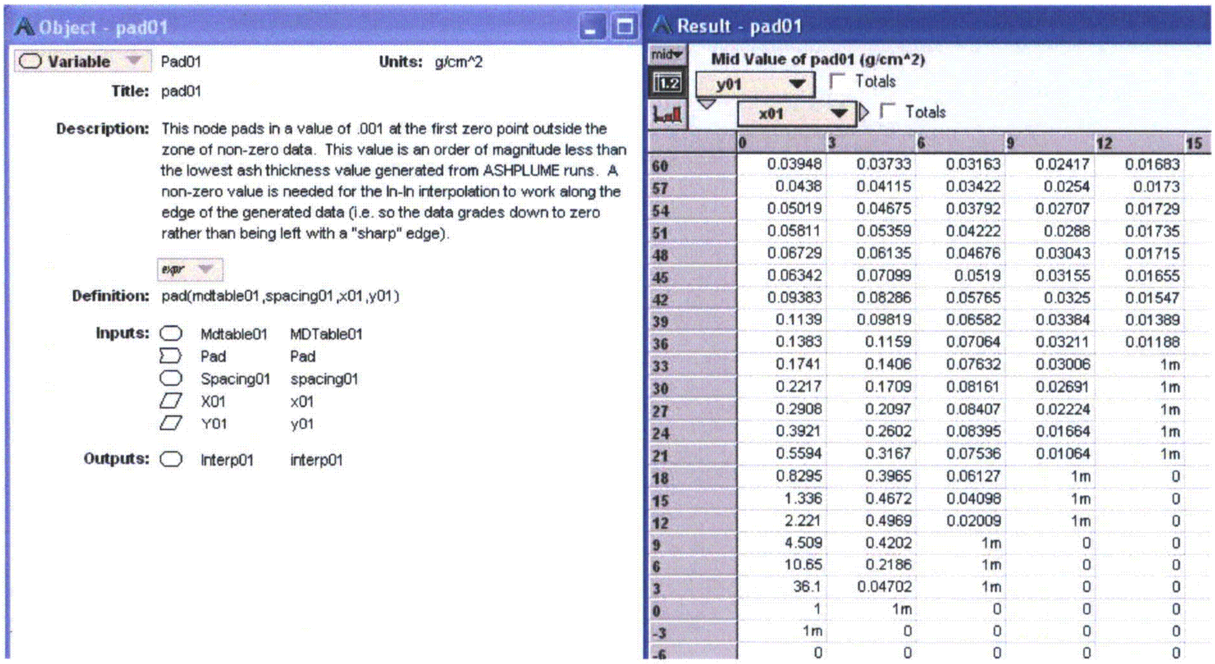
y61 ▼ Totals

x61 ▼ Totals

	0	2	4	6	8	10	12
40	0.0306	0.03	0.0283	0.0257	0.0226	0.0193	0.01
38	0.0344	0.0337	0.0316	0.0284	0.0246	0.0206	0.01
36	0.0391	0.0381	0.0354	0.0314	0.0268	0.022	0.01
34	0.0447	0.0434	0.0399	0.0349	0.0291	0.0234	0.01
32	0.0516	0.0499	0.0454	0.0389	0.0317	0.0248	0.01
30	0.0602	0	0.0519	0.0435	0.0344	0.0261	0.01
28	0.0712	0	0.0599	0.0488	0.0373	0.0272	0.01
26	0.0854	0	0.0697	0.0549	0.0403	0	0.01
24	0.104	0	0.0819	0.0618	0.043	0	0.01
22	0.13	0	0.0969	0.0693	0.0454	0	0.01
20	0.165	0	0.116	0.0772	0.0467	0	0.01
18	0.216	0	0.14	0.0854	0.0466	0	0.01
16	0.293	0	0.167	0.091	0.0446	0	0.01
14	0.414	0	0.2	0.0932	0.0392	0	
12	0.617	0	0.233	0.0884	0.0311	0	
10	0.983	0	0.255	0.0737	0.0212	0	
8	1.69	0	0.245	0.0501	0.0117	0	
6	3.27	0	0.178	0.0246	0	0	
4	7.54	0	0.0786	0	0	0	
2	24.5	0	0.0162	0	0	0	
0	0	0	0	0	0	0	

Figure 7. Partial Results for the Node "MDTable61" in Analytica

e) Pad values around the edge of non-zero data. The purpose of padded values is to provide a very small, but non-zero, set of values around the edge of the data so that the ensuing ln-ln interpolation will ramp from the last non-zero value down to near zero. Attempting to interpolate the last non-zero value with the next generated zero value will not work in ln-ln space since ln(0) is not defined. The pad value is set to 0.001. This is one order of magnitude less than the smallest value output by ASHPLUME (once ASHPLUME detects values less than 0.01 g/cm^2, it sets values equal to zero). Figure 8 shows the node information and partial results of this operation. Note that in the figure, the suffix "m" means 1/1000, so that the value "1m" is the equivalent for 0.001.



y01 \ x01	0	3	6	9	12
60	0.03948	0.03733	0.03163	0.02417	0.01683
57	0.0438	0.04115	0.03422	0.0254	0.0173
54	0.05019	0.04675	0.03792	0.02707	0.01729
51	0.05811	0.05359	0.04222	0.0288	0.01735
48	0.06729	0.06135	0.04676	0.03043	0.01715
45	0.06342	0.07099	0.0519	0.03155	0.01655
42	0.09383	0.08286	0.05765	0.0325	0.01547
39	0.1139	0.09819	0.06582	0.03384	0.01389
36	0.1383	0.1159	0.07064	0.03211	0.01188
33	0.1741	0.1406	0.07632	0.03006	1m
30	0.2217	0.1709	0.08161	0.02691	1m
27	0.2908	0.2097	0.08407	0.02224	1m
24	0.3921	0.2602	0.08395	0.01664	1m
21	0.5594	0.3167	0.07536	0.01064	1m
18	0.8295	0.3965	0.06127	1m	0
15	1.336	0.4672	0.04098	1m	0
12	2.221	0.4969	0.02009	1m	0
9	4.509	0.4202	1m	0	0
6	10.65	0.2186	1m	0	0
3	36.1	0.04702	1m	0	0
0	1	1m	0	0	0
-3	1m	0	0	0	0
-6	0	0	0	0	0

Figure 8. Information and Partial Results for the Node "pad01" in Analytica

f) Expand to the full grid dimensions and perform ln-ln interpolations to fill in data for new grid points that fall between existing data points. Interpolations are done first in the x-direction, then in the y-direction. The equation for the interpolation along x (or y) is:

$$xash_i = \exp\{\frac{\ln(dist_i) - \ln(dist_L)}{\ln(dist_H) - \ln(dist_L)} * [\ln(xash_H) - \ln(xash_L)] + \ln(xash_L)\}$$

where:

$xash_i$ = ash areal density value at the interpolated data point

$dist_i$ = distance from volcano to the new point

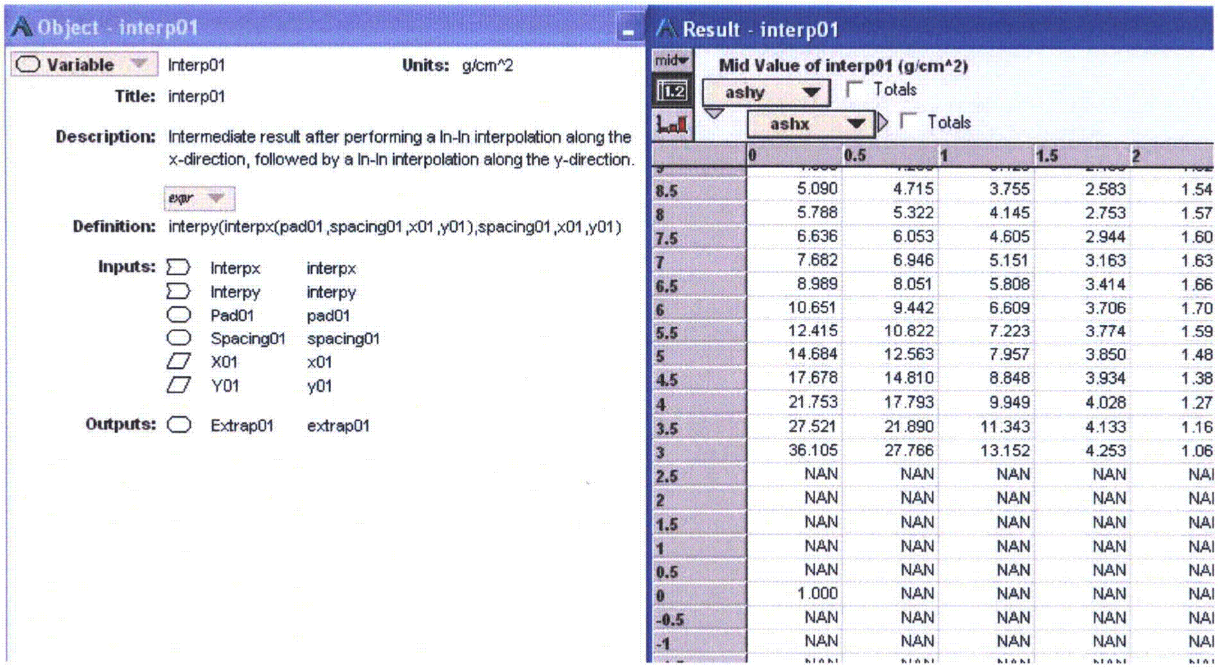
$dist_L$ = distance from volcano to the nearest data point in the negative x (or y) direction from the new point

$dist_H$ = distance from volcano to the nearest data point in the positive x (or y) direction from the new point

$xash_L$ = ash areal density value at the nearest data point in the negative x (or y) direction from the new point

$xash_H$ = ash areal density value at the nearest data point in the positive x (or y) direction from the new point

Figure 9 shows the node information and partial results of this operation. Note that the interpolation does not work for the data near the origin, resulting in values of NAN (not a number). The data near the origin are treated separately in a later step.



	0	0.5	1	1.5	2
8.5	5.090	4.715	3.755	2.583	1.54
8	5.788	5.322	4.145	2.753	1.57
7.5	6.636	6.053	4.605	2.944	1.60
7	7.682	6.946	5.151	3.163	1.63
6.5	8.989	8.051	5.808	3.414	1.66
6	10.651	9.442	6.609	3.706	1.70
5.5	12.415	10.822	7.223	3.774	1.59
5	14.684	12.563	7.957	3.850	1.48
4.5	17.678	14.810	8.848	3.934	1.38
4	21.753	17.793	9.949	4.028	1.27
3.5	27.521	21.890	11.343	4.133	1.16
3	36.105	27.766	13.152	4.253	1.06
2.5	NAN	NAN	NAN	NAN	NAI
2	NAN	NAN	NAN	NAN	NAI
1.5	NAN	NAN	NAN	NAN	NAI
1	NAN	NAN	NAN	NAN	NAI
0.5	NAN	NAN	NAN	NAN	NAI
0	1.000	NAN	NAN	NAN	NAI
-0.5	NAN	NAN	NAN	NAN	NAI
-1	NAN	NAN	NAN	NAN	NAI

Figure 9. Information and Partial Results for the Node "interp01" in Analytica

g) Perform ln-ln extrapolations to extend data for new grid points in the positive y (downwind) direction. In cases where the ASHPLUME grid does not extend to the full 100 km in the +y direction, the data often do not terminate at near-zero values. Therefore, to avoid an abrupt an unrealistic drop off to zero, the data are extrapolated out to 100 km using the last two non-zero values along +y. The equation for the extrapolation is:

$$xash_i = \exp\{\frac{\ln(dist_i) - \ln(dist_M)}{\ln(dist_M) - \ln(dist_{M-1})} * [\ln(xash_M) - \ln(xash_{M-1})] + \ln(xash_M)\}$$

where:

$xash_i$ = ash areal density value at the extrapolated data point

$dist_i$ = distance from volcano to the new point

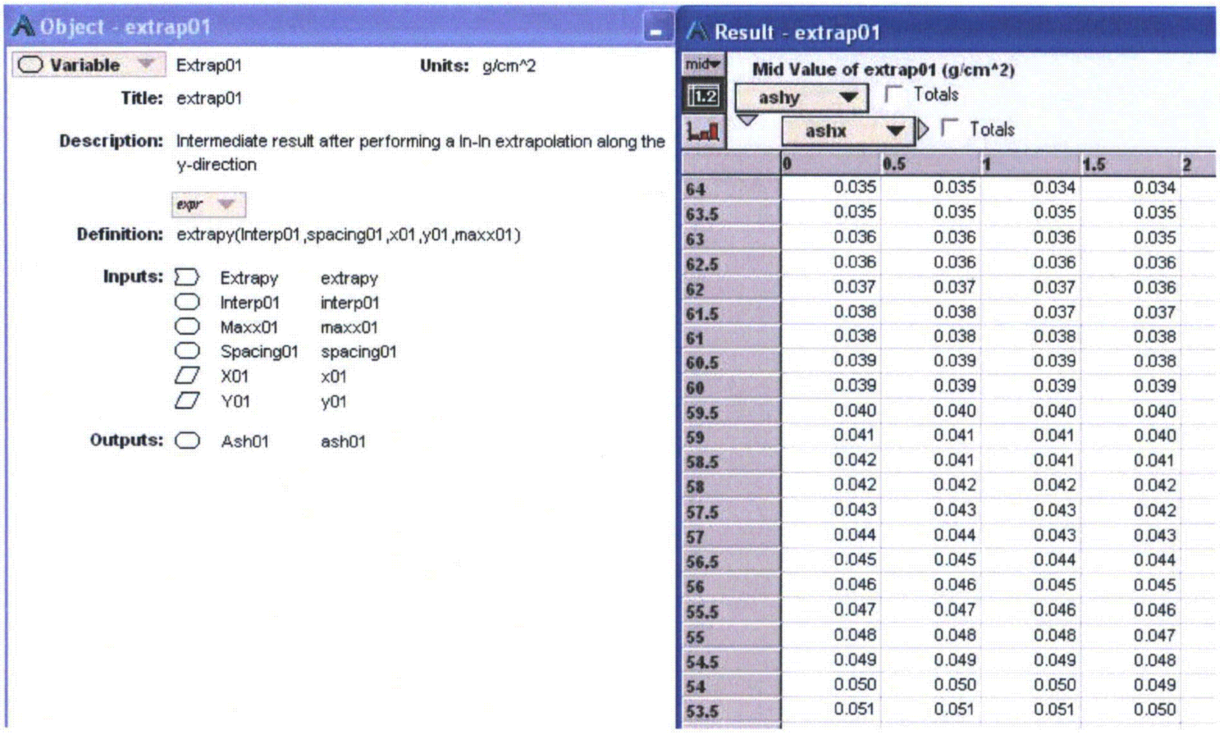
$dist_M$ = distance from volcano to the last valid (non-zero) data point in the positive y direction towards the new point

$dist_{M-1}$ = distance from volcano to the second to last valid (non-zero) data point in the positive y direction towards the new point

$xash_M$ = ash areal density value at the last valid (non-zero) data point in the positive y direction towards the new point

$xash_{M-1}$ = ash areal density value at the second to last valid (non-zero) data point in the positive y direction towards the new point

Figure 10 shows the node information and partial results of this operation.



ashy \ ashx	0	0.5	1	1.5
64	0.035	0.035	0.034	0.034
63.5	0.035	0.035	0.035	0.035
63	0.036	0.036	0.036	0.035
62.5	0.036	0.036	0.036	0.036
62	0.037	0.037	0.037	0.036
61.5	0.038	0.038	0.037	0.037
61	0.038	0.038	0.038	0.038
60.5	0.039	0.039	0.039	0.038
60	0.039	0.039	0.039	0.039
59.5	0.040	0.040	0.040	0.040
59	0.041	0.041	0.041	0.040
58.5	0.042	0.041	0.041	0.041
58	0.042	0.042	0.042	0.042
57.5	0.043	0.043	0.043	0.042
57	0.044	0.044	0.043	0.043
56.5	0.045	0.045	0.044	0.044
56	0.046	0.046	0.045	0.045
55.5	0.047	0.047	0.046	0.046
55	0.048	0.048	0.048	0.047
54.5	0.049	0.049	0.049	0.048
54	0.050	0.050	0.050	0.049
53.5	0.051	0.051	0.051	0.050

Figure 10. Information and Partial Results for the Node "extrap01" in Analytica

h) Address the near-origin data. First, copy x, y, and xash data from the file "PCb-1.out" into Analytica for the ASHPLUME generated points around the origin. The nodes where data are copied into Analytica are labeled "pcnn in near", where nn ranges from 01 to 110. Figure 11 shows the node information and results of this operation.

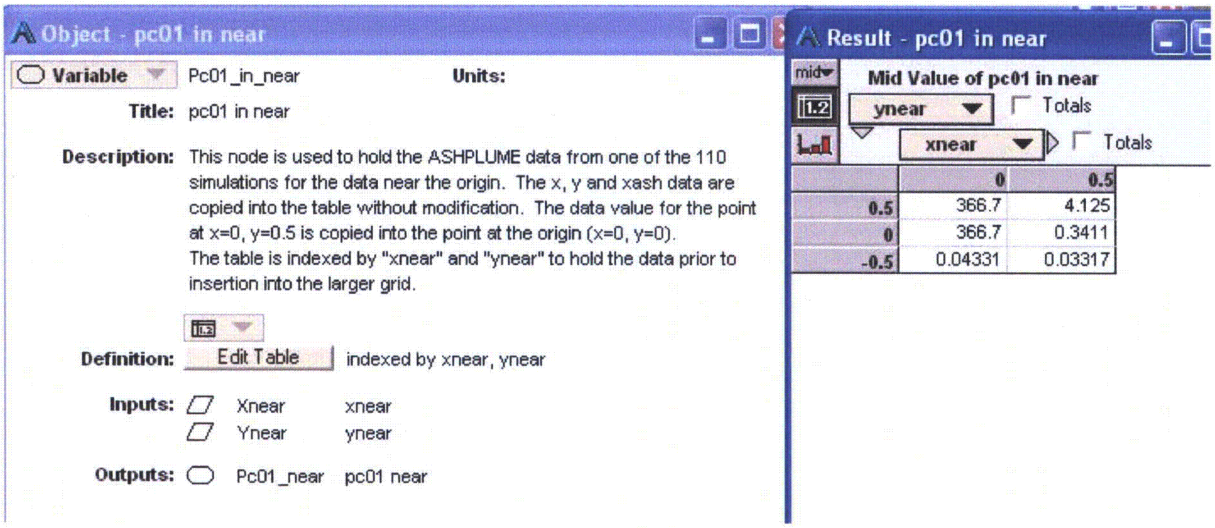


Figure 11. Information and Partial Results for the Node "pc01 in near" in Analytica

i) Expand this input grid to the full grid dimensions. Figure 12 shows the node information and partial results of this operation.

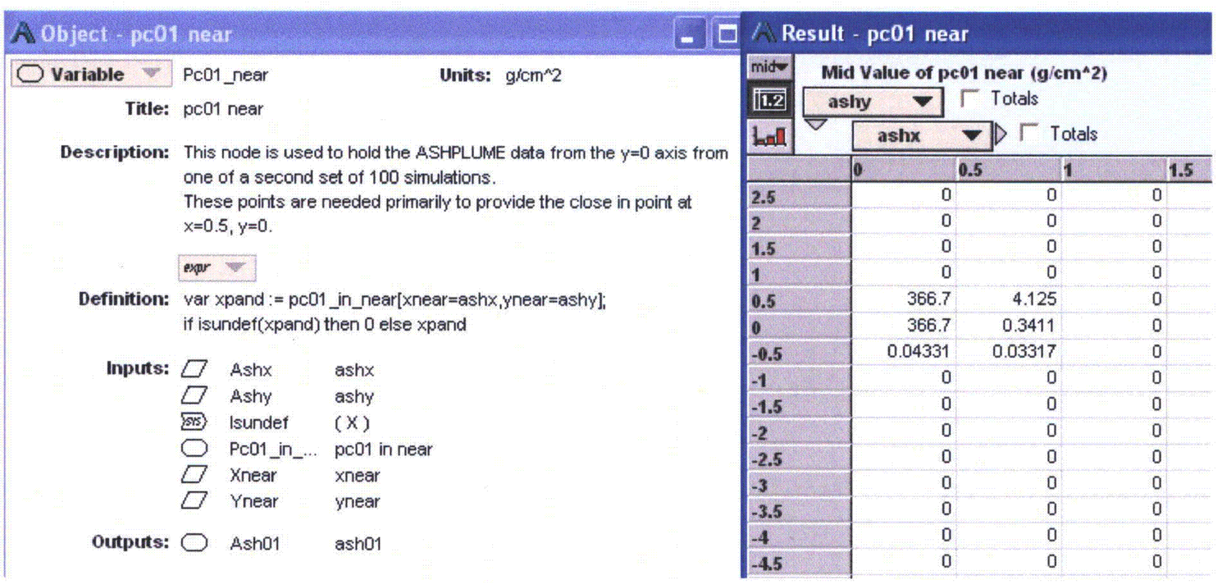
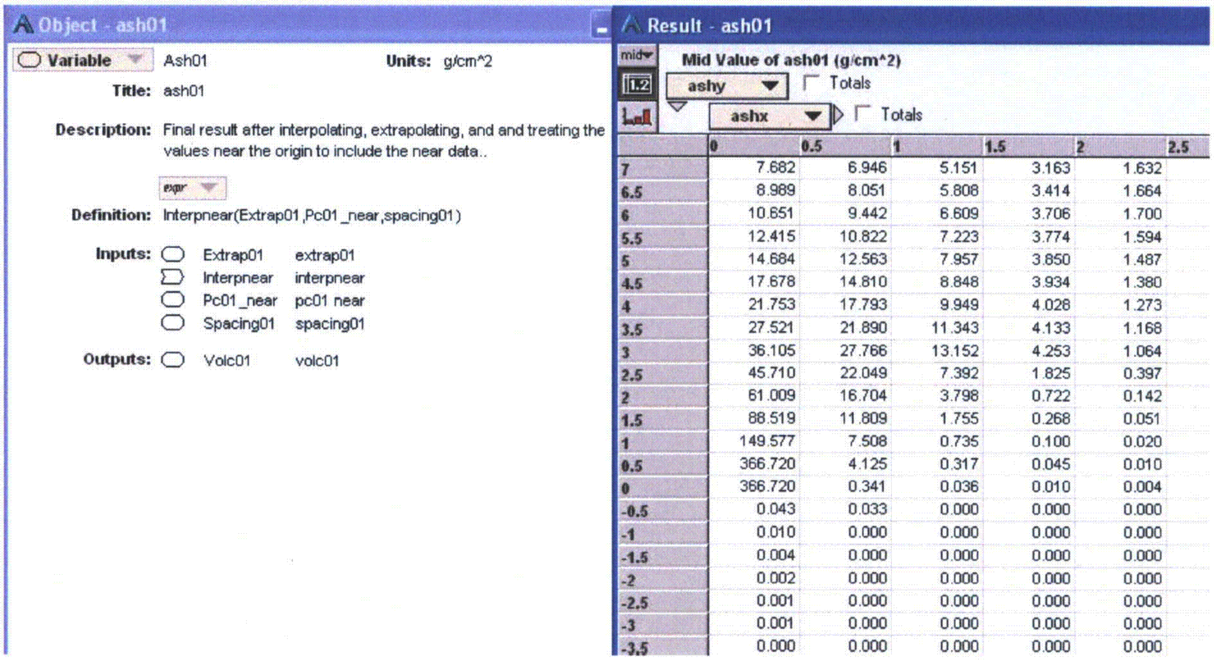


Figure 12. Information and Partial Results for the Node "pc01 near1" in Analytica

j) Insert the near-origin data into the previously interpolated and extrapolated data set, and re-interpolate from the near-origin data to the nearest points in original data that have ASHPLUME generated data. For example, if the grid spacing is 3.0 km, as is the case in simulation 01, the nearest set of ASHPLUME generated points in the each direction lies at x and y grid points equal to 3. The previous interpolation step (see step f above) would have already attempted to interpolate between points at the origin and nearby points. This step replaces those points with the new data points near the origin, and re-interpolates using those points and the nearest existing data points. Figure 13 shows the node information and partial results of this operation.



ashy \ ashx	0	0.5	1	1.5	2	2.5
7	7.682	6.946	5.151	3.163	1.632	
6.5	8.989	8.051	5.808	3.414	1.664	
6	10.651	9.442	6.609	3.706	1.700	
5.5	12.415	10.822	7.223	3.774	1.594	
5	14.684	12.563	7.957	3.850	1.487	
4.5	17.678	14.810	8.848	3.934	1.380	
4	21.753	17.793	9.949	4.028	1.273	
3.5	27.521	21.890	11.343	4.133	1.168	
3	36.105	27.766	13.152	4.253	1.064	
2.5	45.710	22.049	7.392	1.825	0.397	
2	61.009	16.704	3.798	0.722	0.142	
1.5	88.519	11.809	1.755	0.268	0.051	
1	149.577	7.508	0.735	0.100	0.020	
0.5	366.720	4.125	0.317	0.045	0.010	
0	366.720	0.341	0.036	0.010	0.004	
-0.5	0.043	0.033	0.000	0.000	0.000	
-1	0.010	0.000	0.000	0.000	0.000	
-1.5	0.004	0.000	0.000	0.000	0.000	
-2	0.002	0.000	0.000	0.000	0.000	
-2.5	0.001	0.000	0.000	0.000	0.000	
-3	0.001	0.000	0.000	0.000	0.000	
-3.5	0.000	0.000	0.000	0.000	0.000	

Figure 13. Information and Partial Results for the Node "Ash01" in Analytica

The results of this step provide the fully interpolated and extrapolated set of ASHPLUME data for the given simulation.

5.2.2 Grid Calculations

The steps for determining the appropriate ASHPLUME grid point to extract for each potential volcano location and wind direction occur inside the module – "Grid Transforms". Figure 14 shows the calculation flow.

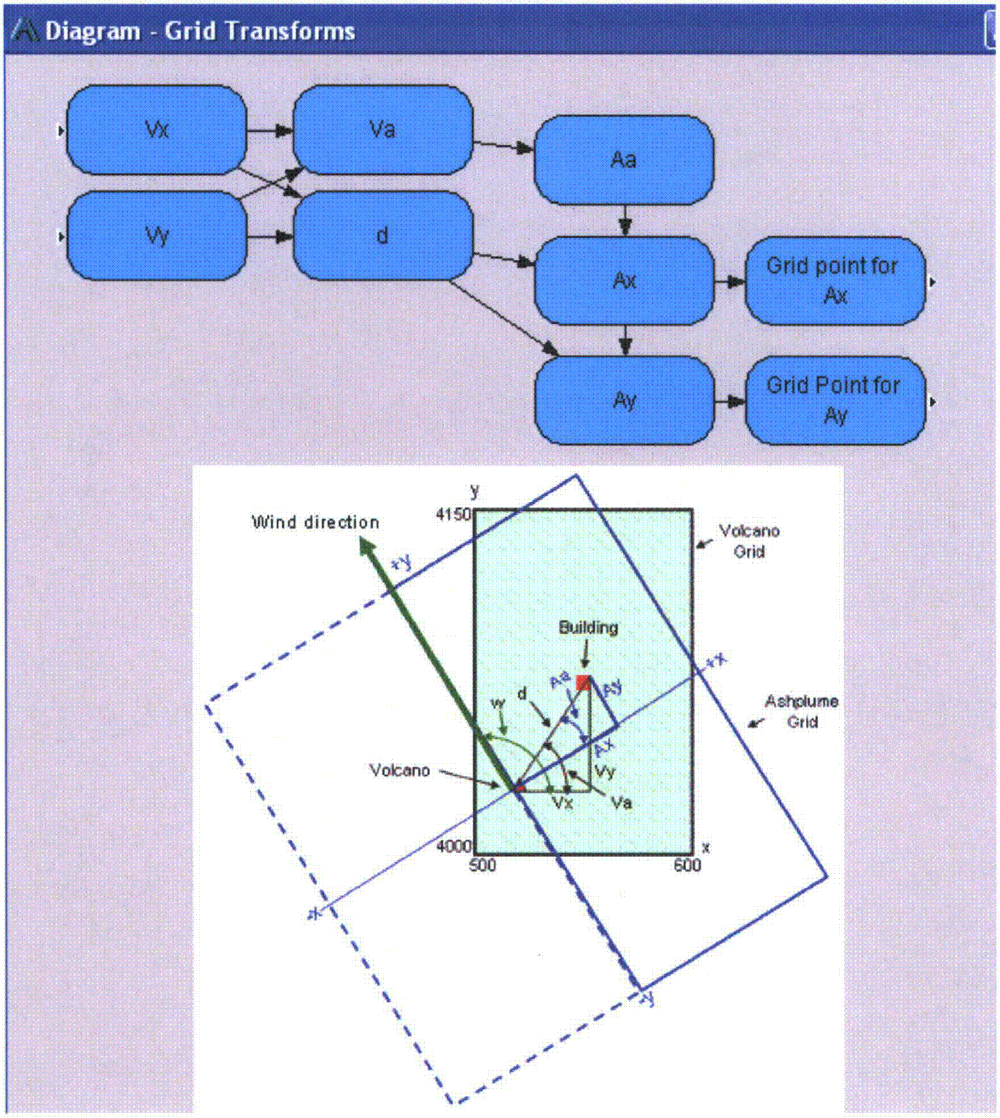


Figure 14. Diagram of Calculation Flow for "Grid Transforms" in Analytica

The steps involved are as follows:

a) For each volcano location, determine the distance along the x-axis and the distance along the y-axis to the facilities location, with respect to the grid of volcano points (Vx and Vy, respectively, in Figure 14). Figure 15 shows the node information and partial results of these operations.

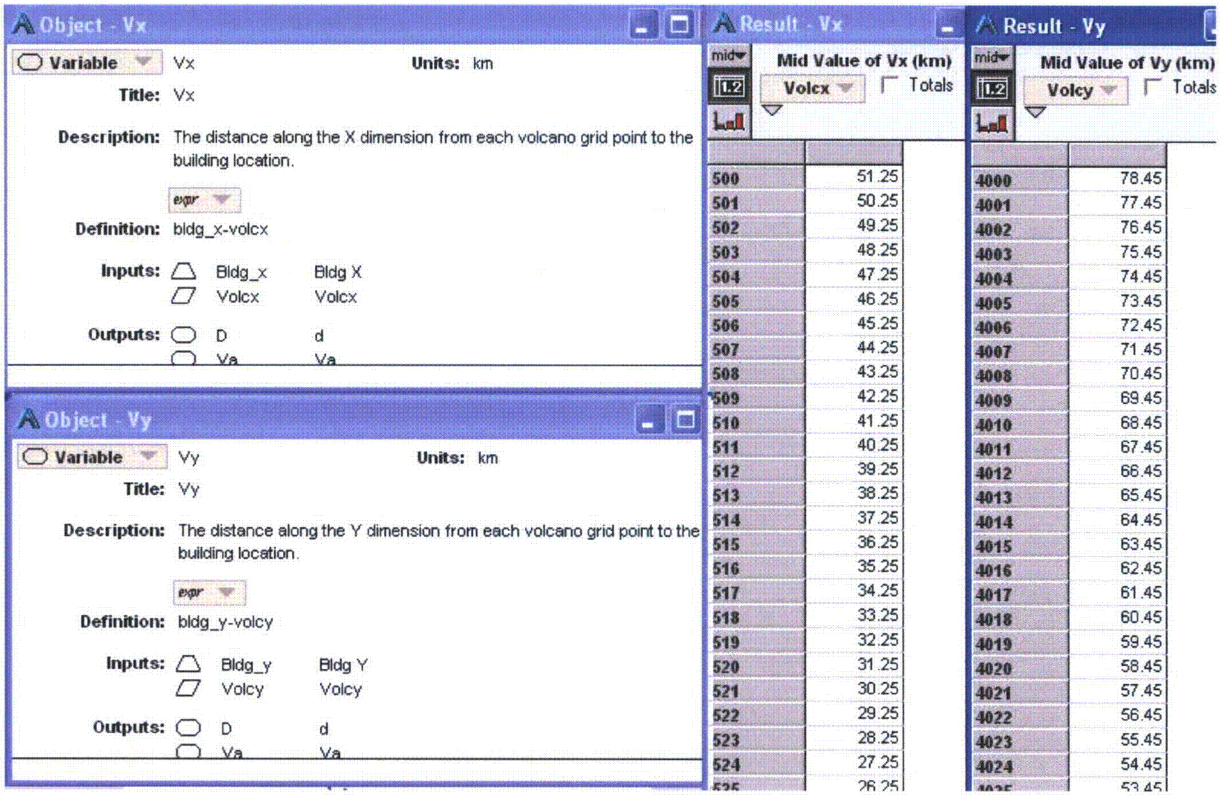
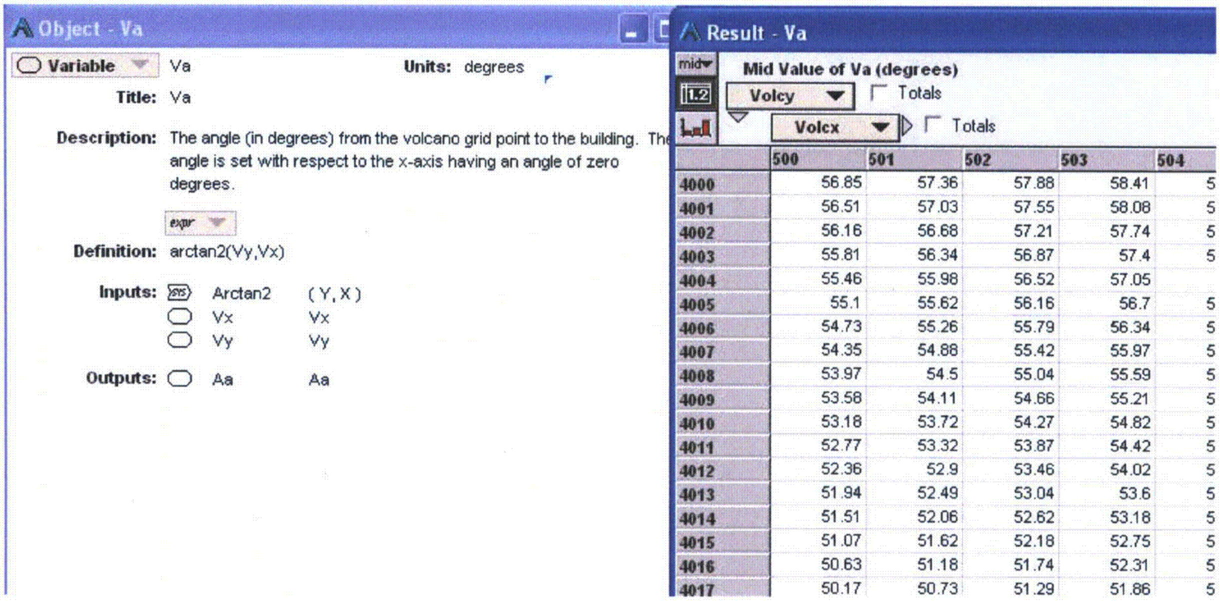


Figure 15. Information and Partial Results for the Nodes "Vx" and "Vy" in Analytica

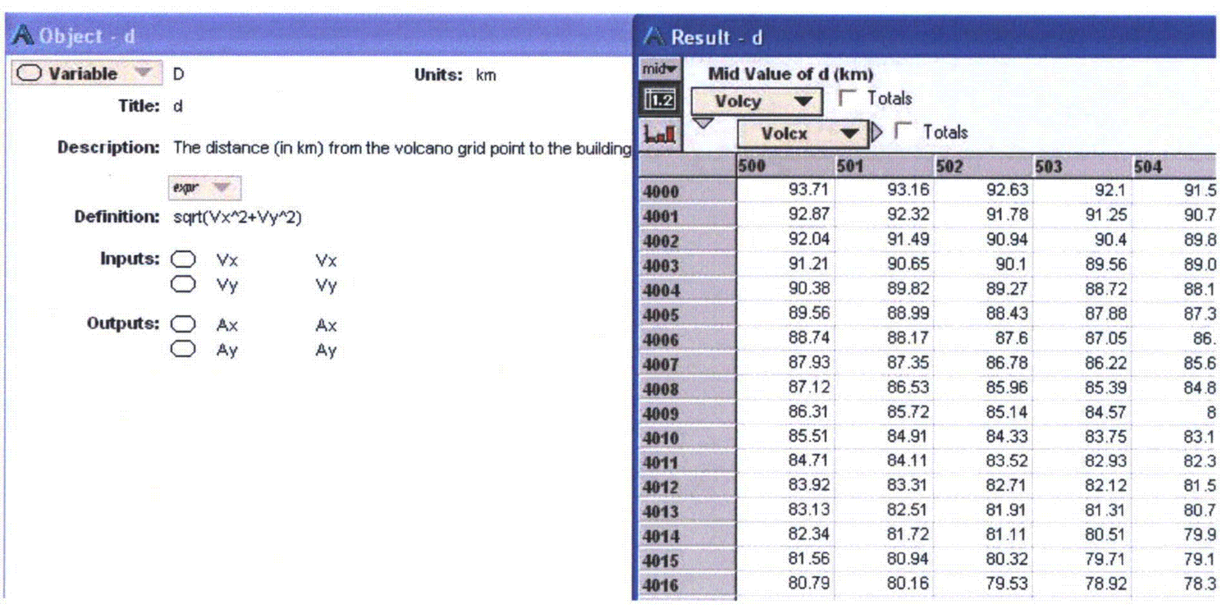
b) Calculate the angle from each volcano location to the facilities location, with respect to the grid of volcano points (Va, in Figure 14). Figure 16 shows the node information and partial results of this operation.



	500	501	502	503	504
4000	56.85	57.36	57.88	58.41	5
4001	56.51	57.03	57.55	58.08	5
4002	56.16	56.68	57.21	57.74	5
4003	55.81	56.34	56.87	57.4	5
4004	55.46	55.98	56.52	57.05	
4005	55.1	55.62	56.16	56.7	5
4006	54.73	55.26	55.79	56.34	5
4007	54.35	54.88	55.42	55.97	5
4008	53.97	54.5	55.04	55.59	5
4009	53.58	54.11	54.66	55.21	5
4010	53.18	53.72	54.27	54.82	5
4011	52.77	53.32	53.87	54.42	5
4012	52.36	52.9	53.46	54.02	5
4013	51.94	52.49	53.04	53.6	5
4014	51.51	52.06	52.62	53.18	5
4015	51.07	51.62	52.18	52.75	5
4016	50.63	51.18	51.74	52.31	5
4017	50.17	50.73	51.29	51.86	5

Figure 16. Information and Partial Results for the Node "Va" in Analytica

c) Calculate the distance from each volcano location to the facilities location, with respect to the grid of volcano points (d, in Figure 14). Figure 17 shows the node information and partial results of this operation.



	500	501	502	503	504
4000	93.71	93.16	92.63	92.1	91.5
4001	92.87	92.32	91.78	91.25	90.7
4002	92.04	91.49	90.94	90.4	89.8
4003	91.21	90.65	90.1	89.56	89.0
4004	90.38	89.82	89.27	88.72	88.1
4005	89.56	88.99	88.43	87.88	87.3
4006	88.74	88.17	87.6	87.05	86.
4007	87.93	87.35	86.78	86.22	85.6
4008	87.12	86.53	85.96	85.39	84.8
4009	86.31	85.72	85.14	84.57	8
4010	85.51	84.91	84.33	83.75	83.1
4011	84.71	84.11	83.52	82.93	82.3
4012	83.92	83.31	82.71	82.12	81.5
4013	83.13	82.51	81.91	81.31	80.7
4014	82.34	81.72	81.11	80.51	79.9
4015	81.56	80.94	80.32	79.71	79.1
4016	80.79	80.16	79.53	78.92	78.3

Figure 17. Information and Partial Results for the Node "d" in Analytica

d) For each volcano location and wind direction, calculate the angle from the volcano location to the facilities location, with respect to the oriented grid of ASHPLUME points (Aa, in Figure 14). Figure 18 shows the node information and partial results of this operation.

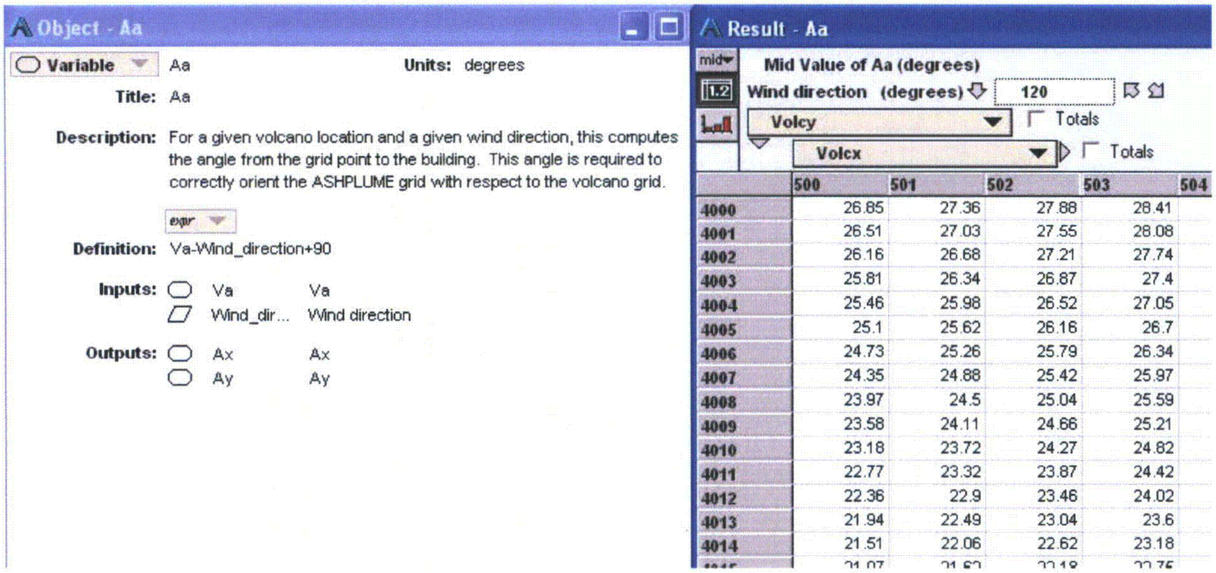


Figure 18. Information and Partial Results for the Node "Aa" in Analytica

e) For each volcano location and wind direction, determine the distance along the x-axis and the distance along the y-axis to the facilities location, with respect to the grid of ASHPLUME points (Ax and Ay, respectively, in Figure 14). Figures 19 and 20 show the node information and partial results of these operations.

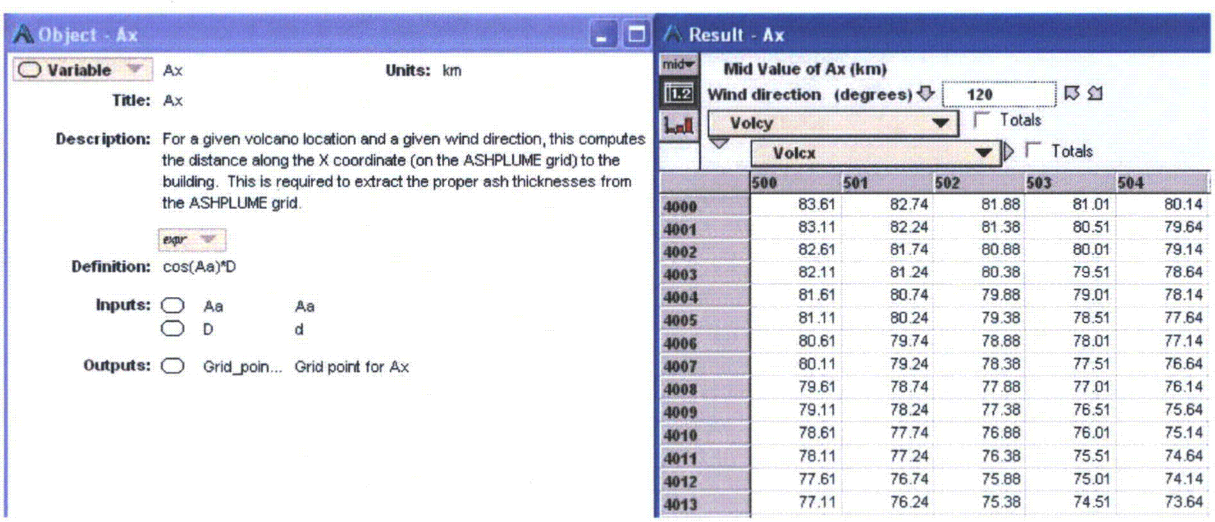
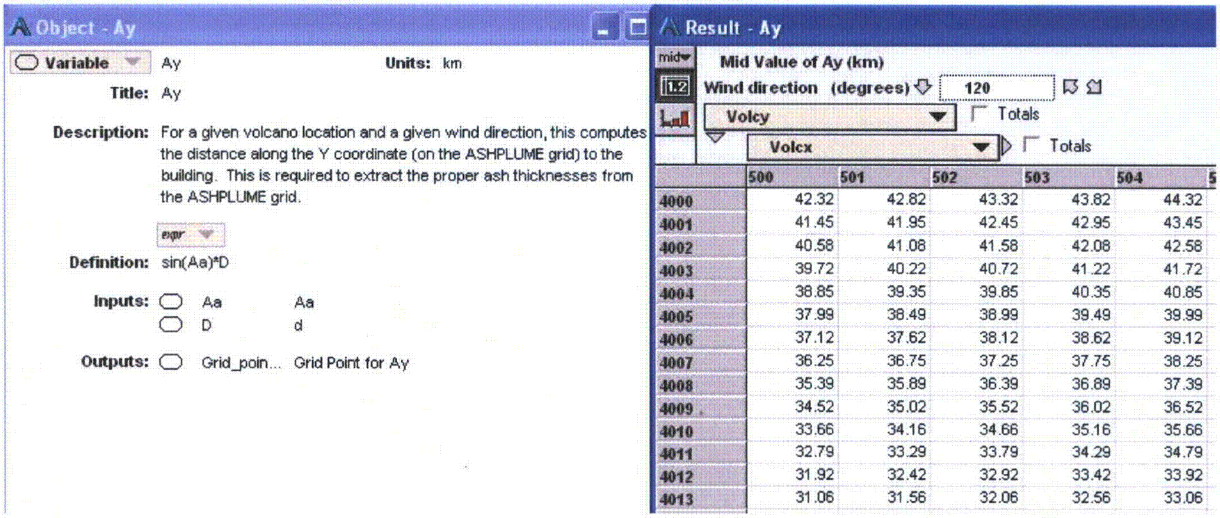


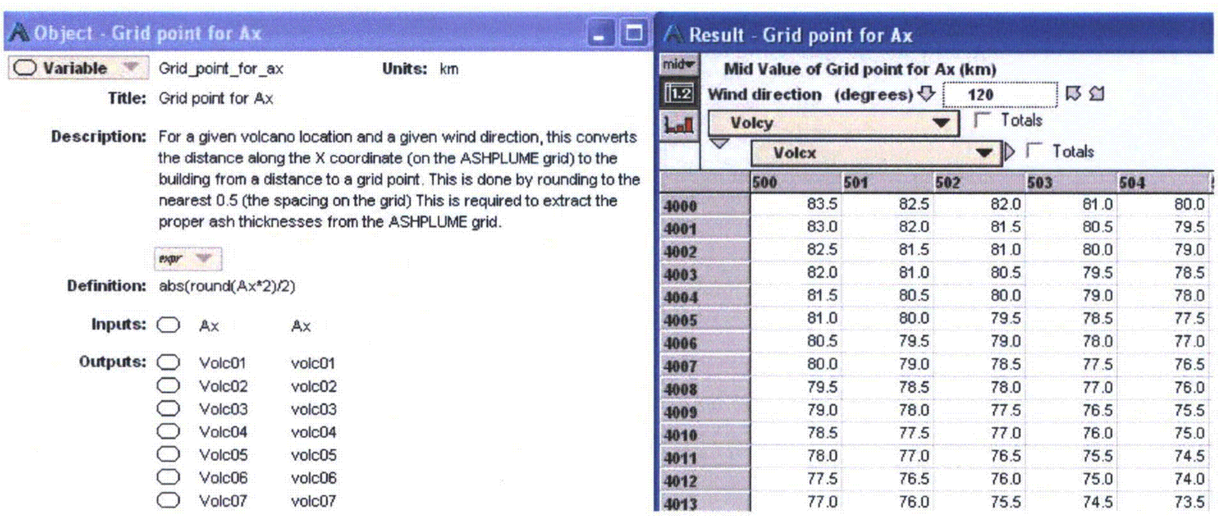
Figure 19. Information and Partial Results for the Node "Ax" in Analytica



	500	501	502	503	504	5
4000	42.32	42.82	43.32	43.82	44.32	
4001	41.45	41.95	42.45	42.95	43.45	
4002	40.58	41.08	41.58	42.08	42.58	
4003	39.72	40.22	40.72	41.22	41.72	
4004	38.85	39.35	39.85	40.35	40.85	
4005	37.99	38.49	38.99	39.49	39.99	
4006	37.12	37.62	38.12	38.62	39.12	
4007	36.25	36.75	37.25	37.75	38.25	
4008	35.39	35.89	36.39	36.89	37.39	
4009	34.52	35.02	35.52	36.02	36.52	
4010	33.66	34.16	34.66	35.16	35.66	
4011	32.79	33.29	33.79	34.29	34.79	
4012	31.92	32.42	32.92	33.42	33.92	
4013	31.06	31.56	32.06	32.56	33.06	

Figure 20. Information and Partial Results for the Node "Ay" in Analytica

f) For each volcano location and wind direction, determine the grid coordinates with respect to the ASHPLUME grid that correspond to the distances along x and y. This operation involves rounding off the x and y distances to the nearest 0.5. Figures 21 and 22 show the node information and partial results of these operations.



	500	501	502	503	504	5
4000	83.5	82.5	82.0	81.0	80.0	
4001	83.0	82.0	81.5	80.5	79.5	
4002	82.5	81.5	81.0	80.0	79.0	
4003	82.0	81.0	80.5	79.5	78.5	
4004	81.5	80.5	80.0	79.0	78.0	
4005	81.0	80.0	79.5	78.5	77.5	
4006	80.5	79.5	79.0	78.0	77.0	
4007	80.0	79.0	78.5	77.5	76.5	
4008	79.5	78.5	78.0	77.0	76.0	
4009	79.0	78.0	77.5	76.5	75.5	
4010	78.5	77.5	77.0	76.0	75.0	
4011	78.0	77.0	76.5	75.5	74.5	
4012	77.5	76.5	76.0	75.0	74.0	
4013	77.0	76.0	75.5	74.5	73.5	

Figure 21. Information and Partial Results for the Node "Grid point for Ax" in Analytica

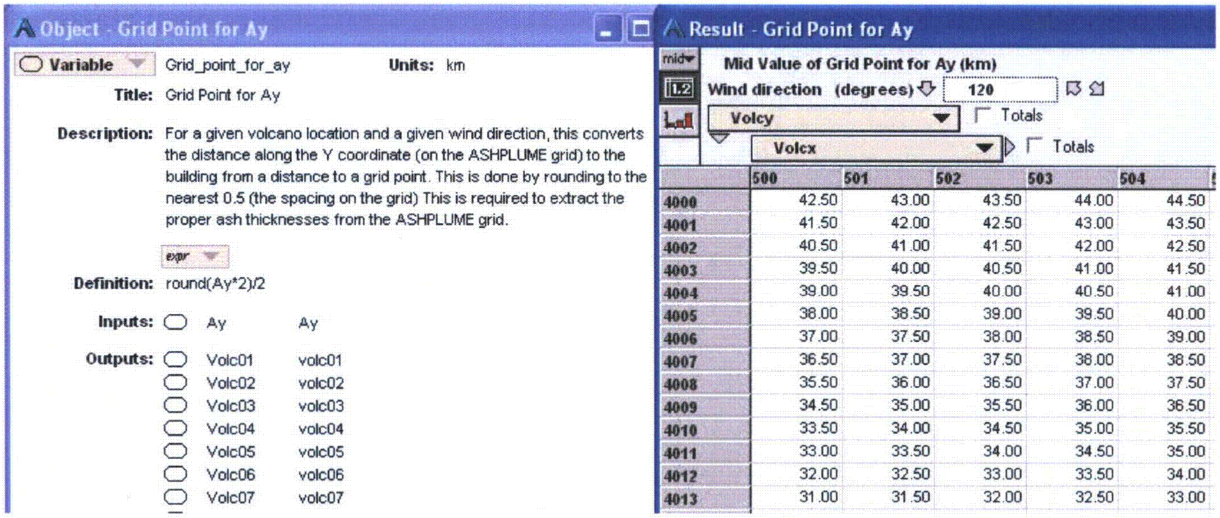


Figure 22. Information and Partial Results for the Node "Grid Point for Ay" in Analytica

The end result of this step is the set of coordinates (with respect to the ASHPLUME grid) for every volcano location and every wind direction needed to extract ASHPLUME values from the simulation data.

5.2.3 Overall Frequency Versus Ashfall Areal Density Curve

For each volcano location, extract the probabilistic ash areal densities that an eruption could contribute to the facilities. This entails extracting a density for each of the possible 12 wind directions from each of the 97 simulations used. Wind direction probabilities are provided in the *Atmospheric Dispersal and Deposition of Tephra from a Potential Volcanic Eruption at Yucca Mountain, Nevada* (BSC 2004b [DIRS 170026]) for each 1 km increment of altitude from 0 to 13 km. In keeping with the methodology used in TSPA, the wind direction probabilities used for a simulation are those that correspond to the highest elevation of the plume for the simulation.

Within each simulation, the ASHPLUME ashfall areal density data are extracted, the probability of exceeding a pre-defined set of areal densities is determined for each potential volcano location (incorporating the wind direction probabilities), and those probabilities of exceeding are combined with the eruption frequency estimates to get the overall hazard curve (frequency versus areal density) for that particular simulation. Finally, those data are combined for all simulations to get the overall hazard curve. The steps to perform these operations are as follows:

a) For each volcano location and wind direction, extract the ash areal density from the gridded ASHPLUME data. Figure 23 shows the node information and partial results of this operation (refer to Figure 4 to see where this (node "volc01") fits into the calculation flow).

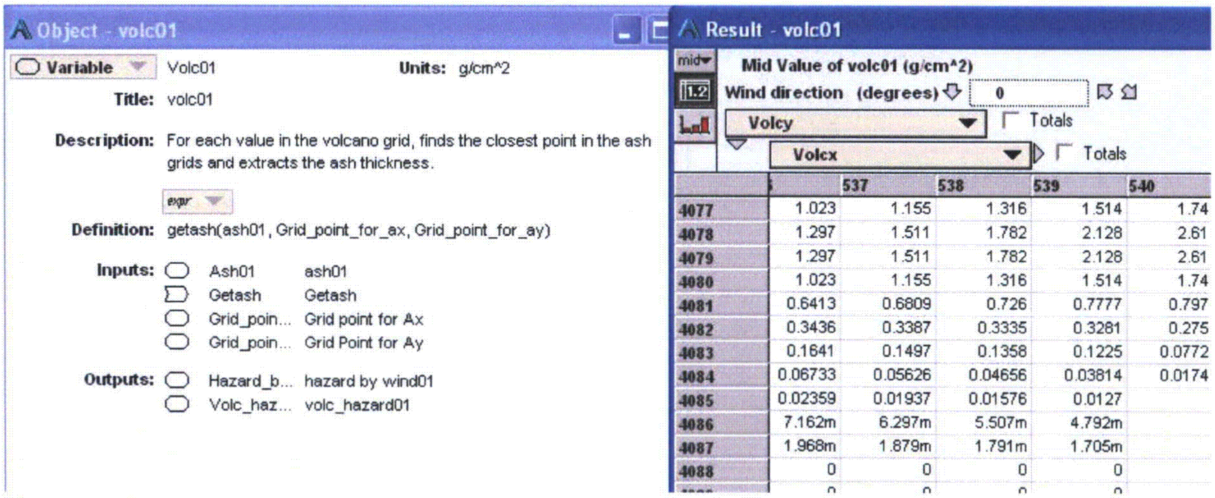


Figure 23. Information and Partial Results for the Node "volc01" in Analytica

b) For each potential volcano location, determine the likelihood of exceeding various ash areal densities. To do this, the densities associated with each wind direction are tested to see if they exceed the given density, then the probabilities associated with the wind directions where the areal density is exceeded are summed to get the overall probability of exceeding that areal density for the given volcano location. The wind probabilities used for a given simulation are dependent on the height of the modeled ash plume for the simulation, consistent with the modeling approach used for TSPA. For example, the ash plume in simulation 1 reaches a modeled column height of 7.8 km. Therefore, the wind direction probabilities from the increment '7-8' km are used for this simulation. Figure 24 shows the node information and partial results of this operation.

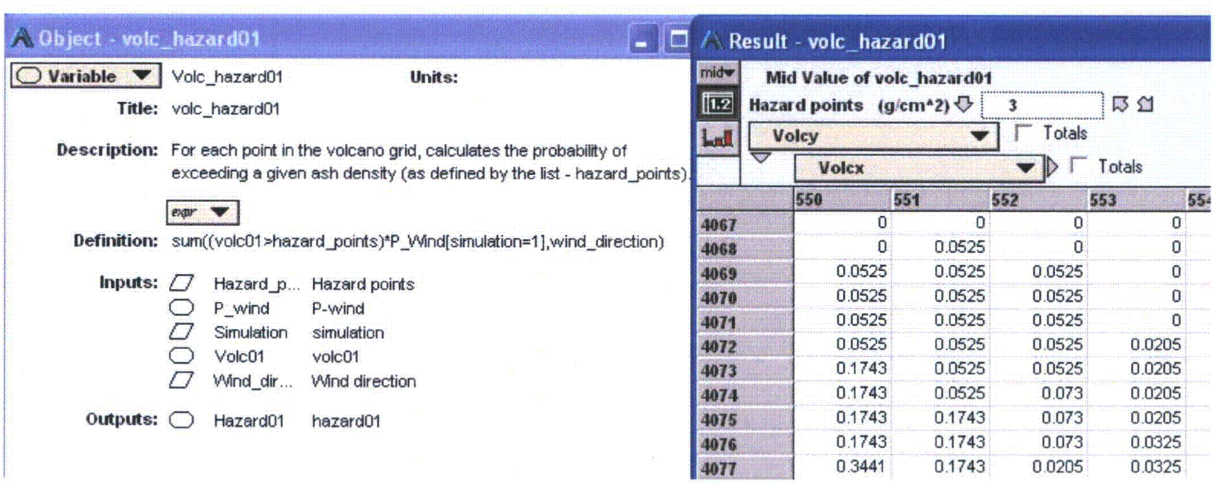


Figure 24. Information and Partial Results for the Node "volc_hazard01" in Analytica

c) Multiply each of the volcano hazard curves by the estimated eruption frequency, and sum over all volcano locations, to get the overall hazard curve estimate for this simulation. Figure 25 shows the node information and partial results of this operation.

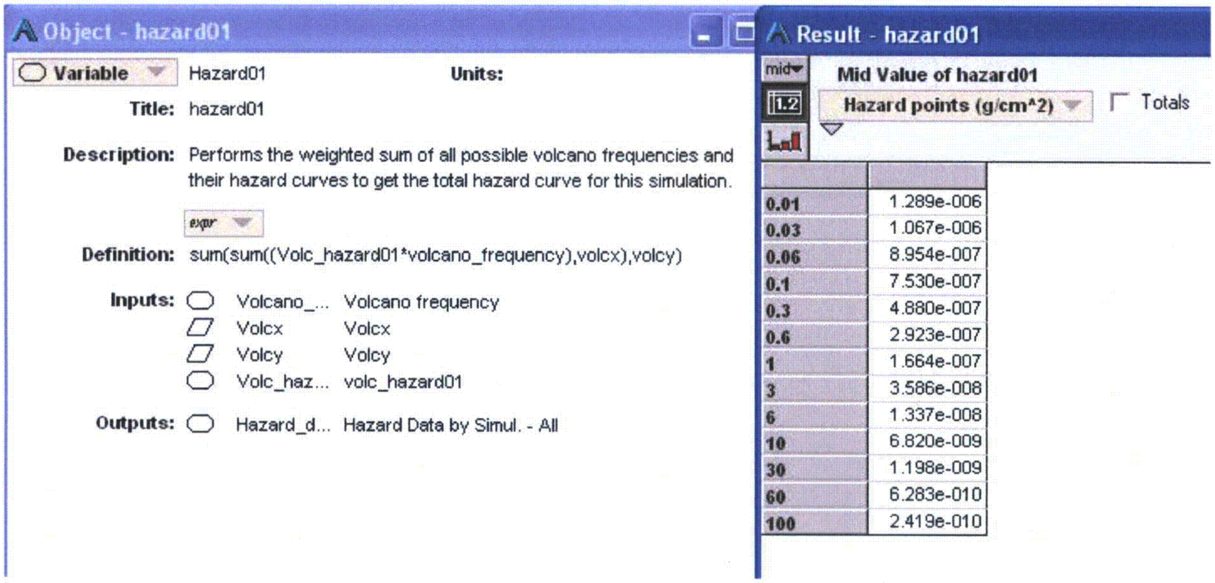


Figure 25. Information and Partial Results for the Node "hazard01" in Analytica

d) Collect the hazard curve data for all of the simulations in one table. Figure 26 shows the node information and partial results of this operation.

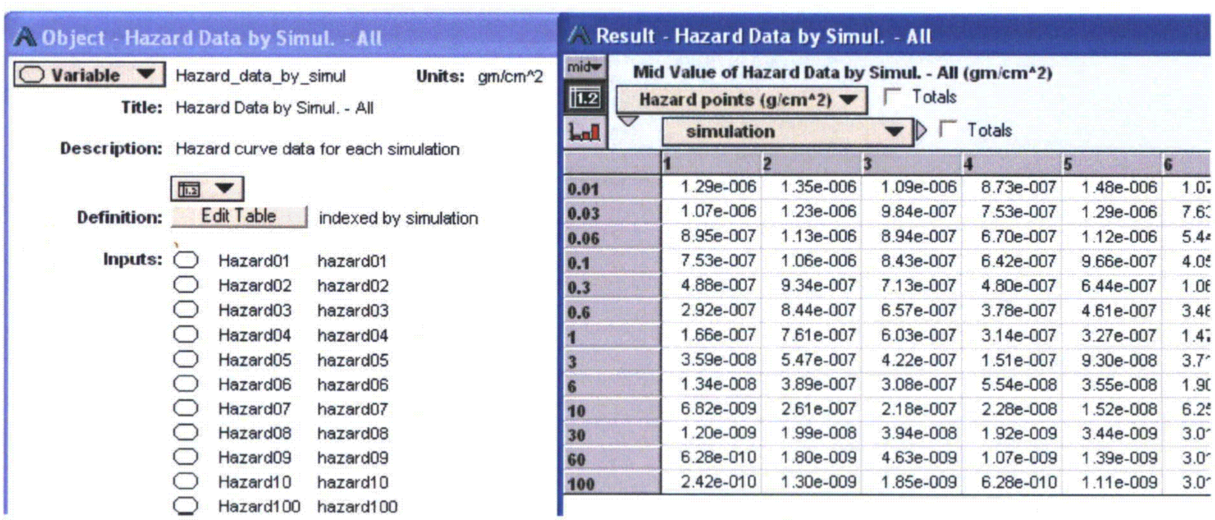
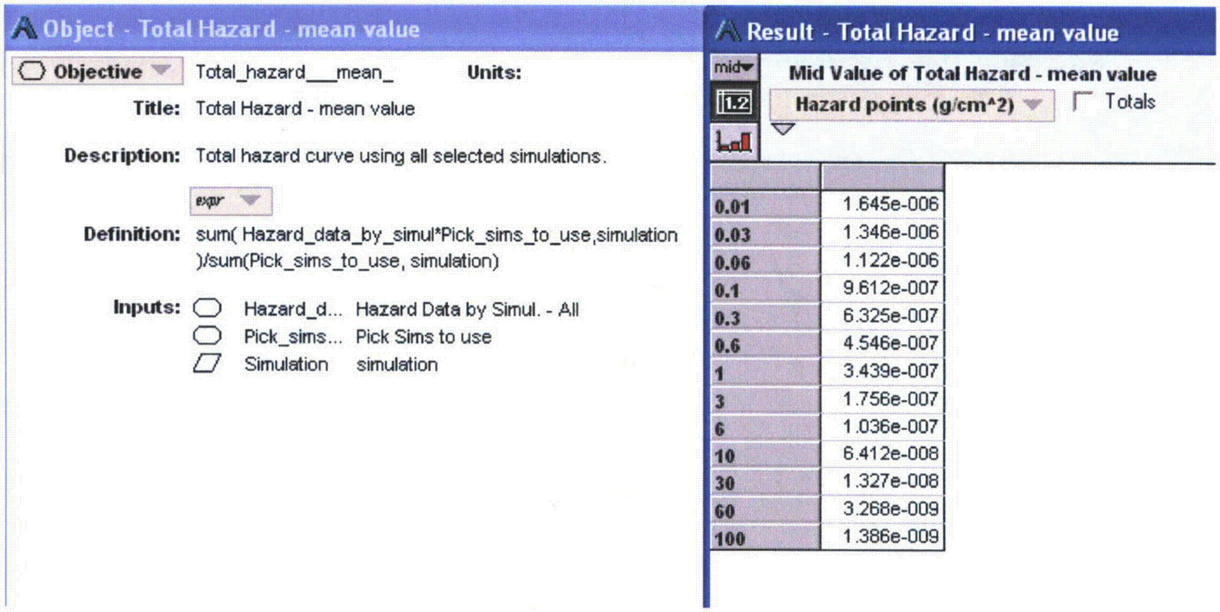


Figure 26. Information and Partial Results for the Node "Hazard Data by Simul - All" in Analytica

e) Average across all simulations used to get the expected (probability weighted) hazard curve. This result is one of the key outputs of this design calculation report; it provides the overall probability weighted hazard curve for the facilities in question. Figure 27 shows the node information and results of this operation.



Hazard points (g/cm^2)	
0.01	1.645e-006
0.03	1.346e-006
0.06	1.122e-006
0.1	9.612e-007
0.3	6.325e-007
0.6	4.546e-007
1	3.439e-007
3	1.756e-007
6	1.036e-007
10	6.412e-008
30	1.327e-008
60	3.268e-009
100	1.386e-009

Figure 27. Information and Partial Results for the Node "Total Hazard – Mean Value" in Analytica

f) Extract percentiles for each point on the total hazard curve. This is done in a series of nodes in the module "Percentile Results" (see Figure 28). First, the data are reduced to include only the 97 simulations used. Then those data are sorted from lowest frequency to highest frequency. Then the values at given percentiles are extracted.

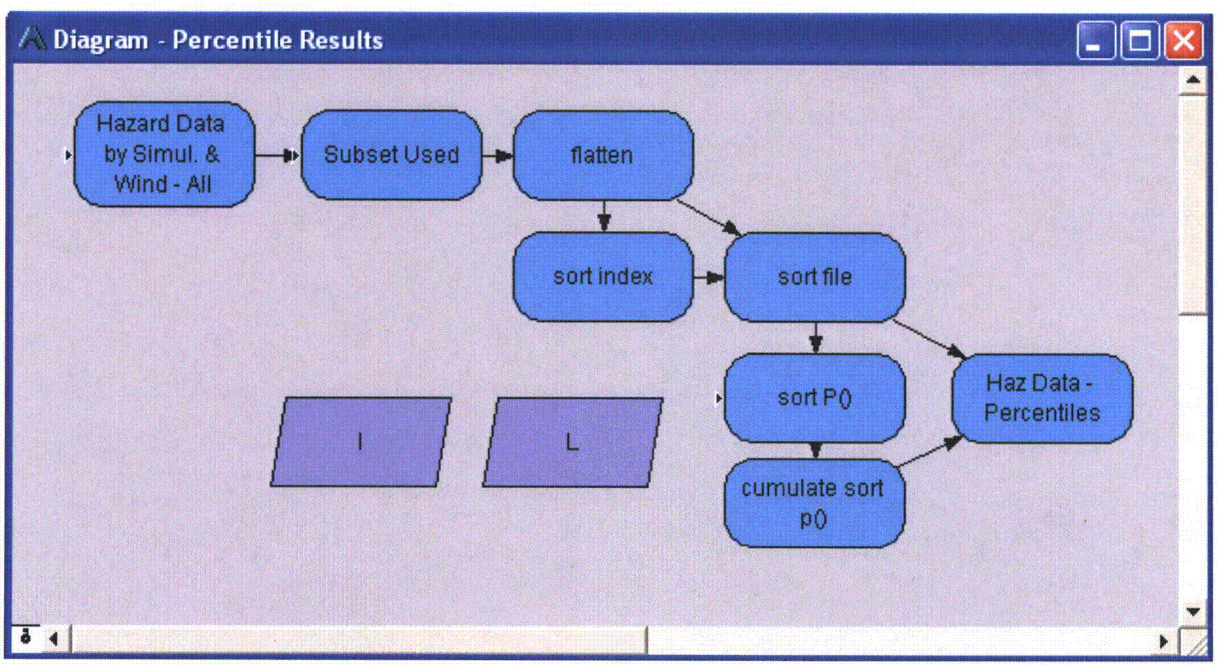
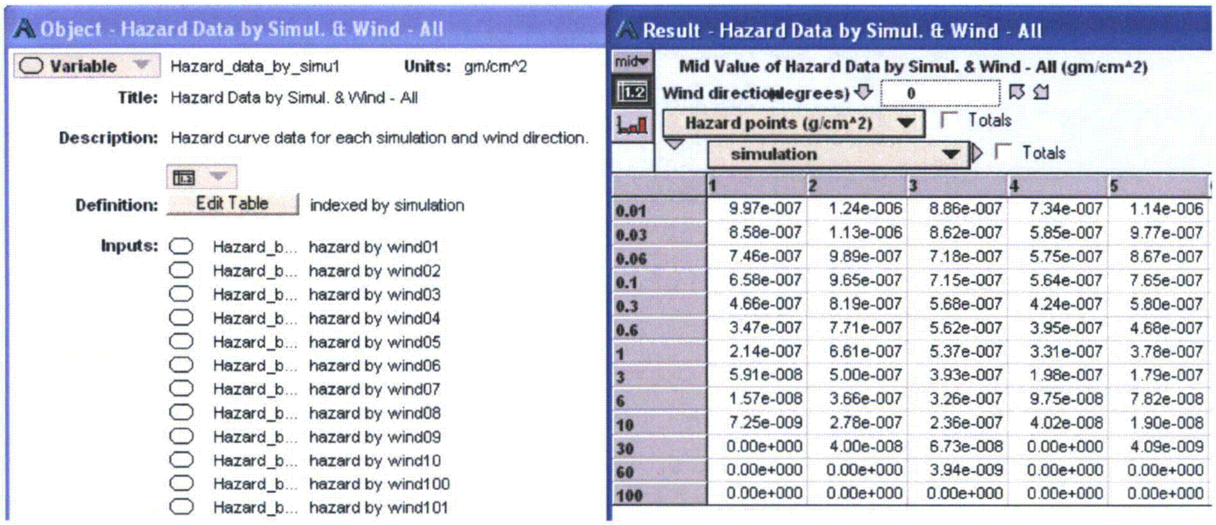


Figure 28. Diagram of Calculation Flow for "Percentile Results" in Analytica

g) Accumulate the hazard curve information for each simulation and wind direction into one table. Figure 29 shows the node information and partial results of this operation.



	1	2	3	4	5
0.01	9.97e-007	1.24e-006	8.86e-007	7.34e-007	1.14e-006
0.03	8.58e-007	1.13e-006	8.62e-007	5.85e-007	9.77e-007
0.06	7.46e-007	9.89e-007	7.18e-007	5.75e-007	8.67e-007
0.1	6.58e-007	9.65e-007	7.15e-007	5.64e-007	7.65e-007
0.3	4.66e-007	8.19e-007	5.68e-007	4.24e-007	5.80e-007
0.6	3.47e-007	7.71e-007	5.62e-007	3.95e-007	4.68e-007
1	2.14e-007	6.61e-007	5.37e-007	3.31e-007	3.78e-007
3	5.91e-008	5.00e-007	3.93e-007	1.98e-007	1.79e-007
6	1.57e-008	3.66e-007	3.26e-007	9.75e-008	7.82e-008
10	7.25e-009	2.78e-007	2.36e-007	4.02e-008	1.90e-008
30	0.00e+000	4.00e-008	6.73e-008	0.00e+000	4.09e-009
60	0.00e+000	0.00e+000	3.94e-009	0.00e+000	0.00e+000
100	0.00e+000	0.00e+000	0.00e+000	0.00e+000	0.00e+000

Figure 29. Information and Partial Results for the Node "Hazard Data by Simul & Wind - All" in Analytica

h) Select only the 97 simulations to be used. This is done in the node labeled "Subset Used". The figure and results for this step are not shown; the results are the same as the previous step (Figure 29) for the simulations that are included. Next, "flatten" this 3-dimensional table into a series of 2 dimensional lists for each hazard value. This step is required to be able to extract percentiles from the 1164 data points associated with each hazard value. The 1164 points (97 simulations x 12 wind directions) will subsequently be sorted and the associated probabilities of each of those points carried along so that the value corresponding to a given cumulative percentile can be extracted from the list. Figure 30 shows the node information and partial results of this operation. Note that in the syntax used in the figure, the suffix "u" is the equivalent of 10^{-6} and the suffix "n" is the equivalent of 10^{-9}.

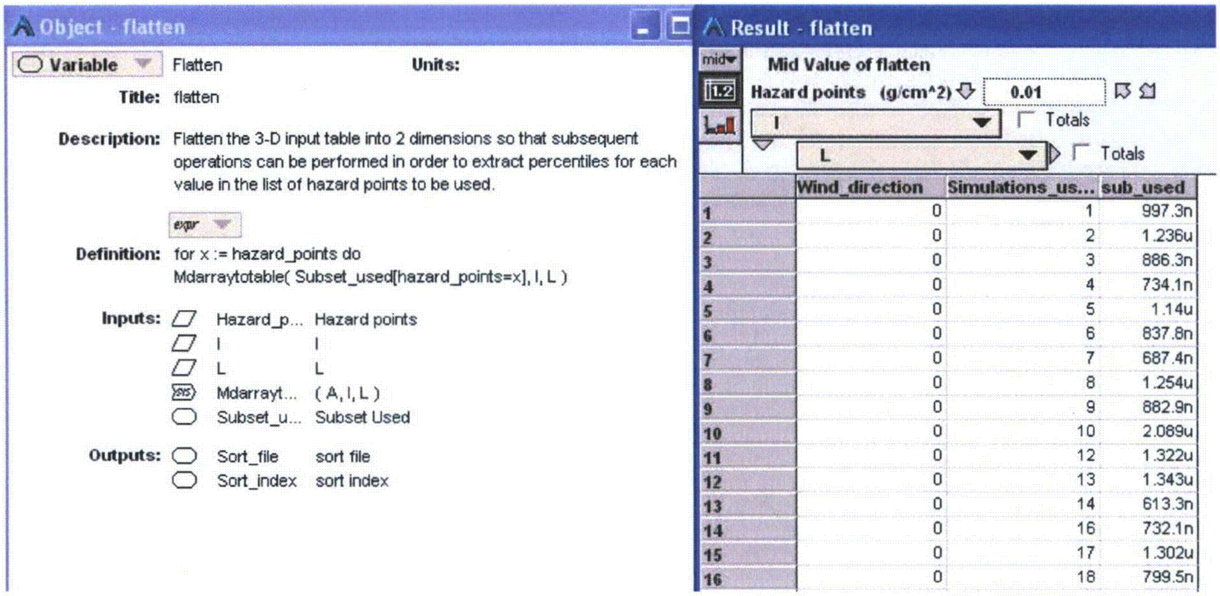


Figure 30. Information and Partial Results for the Node "flatten" in Analytica

i) Next, sort the file by frequency, from lowest to highest value. This is done in two steps. The node labeled "sort index" returns the original row numbers sorted from the lowest associated value to the highest, for each of the columns of data. We are only concerned with the sorted values for the frequency data. The output of this step is not shown here. Next, that information is used to generate the original data sorted by frequency. Figure 31 shows the node information and partial results of this operation; the column labeled "sub_used" contains the frequency data. Note that in the syntax used in the figure, the suffix "n" is the equivalent of 10^{-9}.

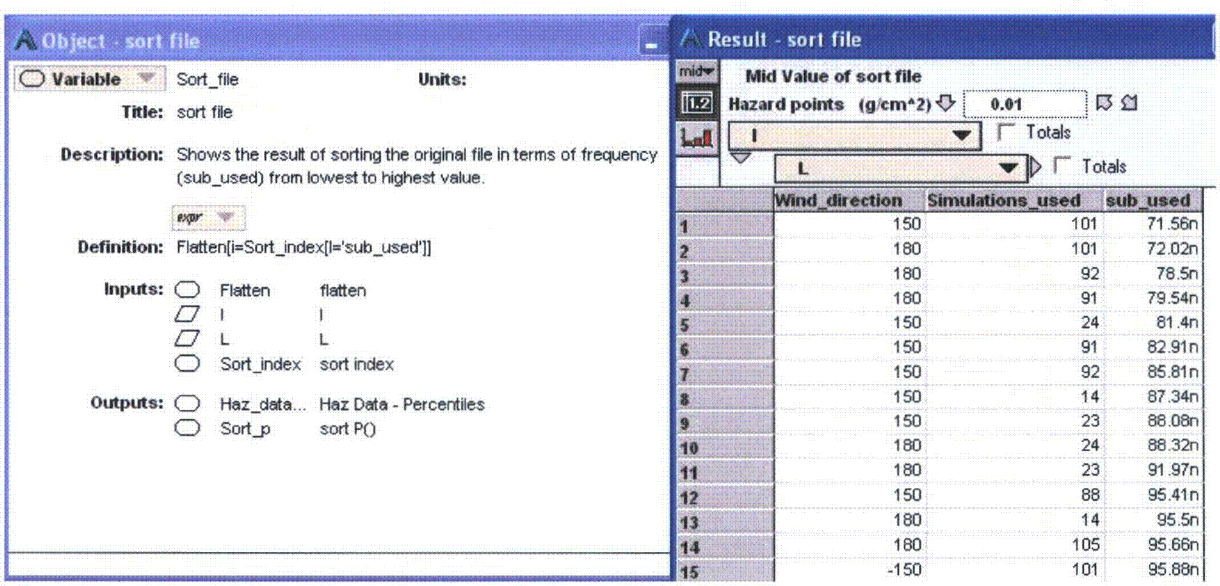


Figure 31. Information and Partial Results for the Node "sort file" in Analytica

j) Generate a list of overall probabilities of occurrence for each data point, sorted in the same order as the values in the "sort file" data set. For example, the value of 71.56n in row 1 (for hazard point 0.01) has a probability of occurrence of 0.00028. Figure 32 shows the node information and partial results of this operation.

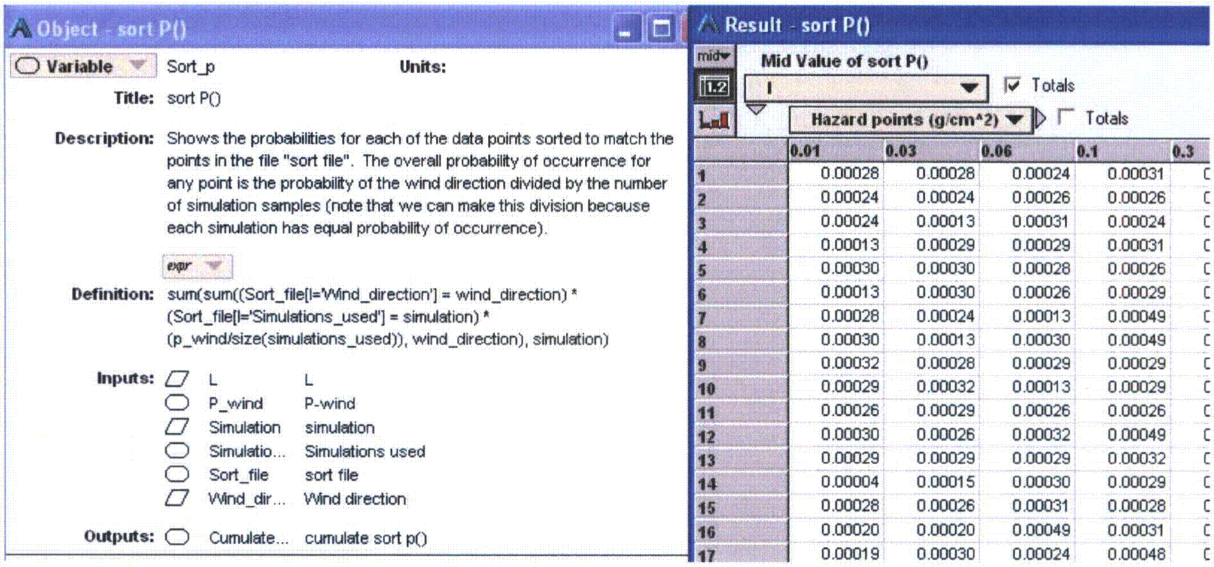


Figure 32. Information and Partial Results for the Node "sort P()" in Analytica

k) Now, we cumulate the probabilities of the sorted data sets so that we can extract any given percentile data point that we choose. Figure 33 shows the node information and partial results of this operation.

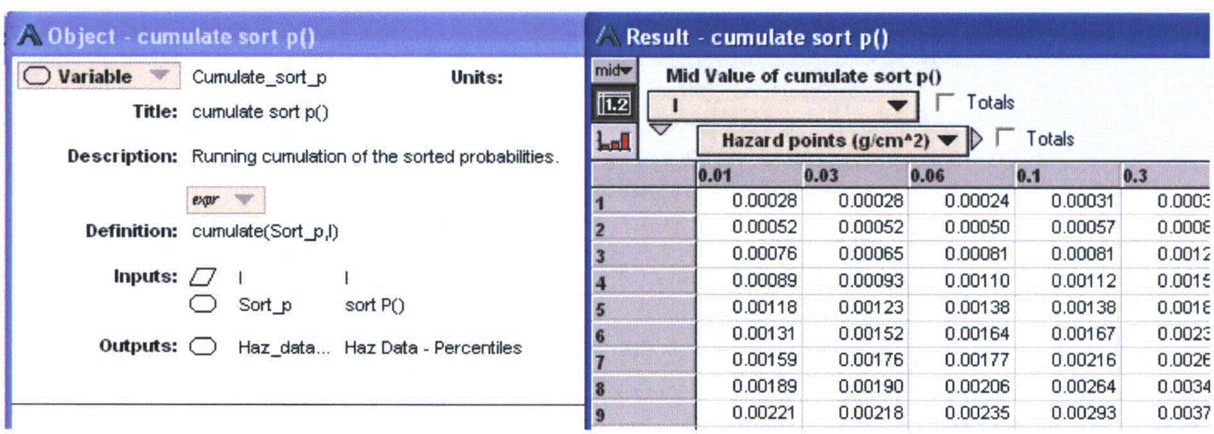
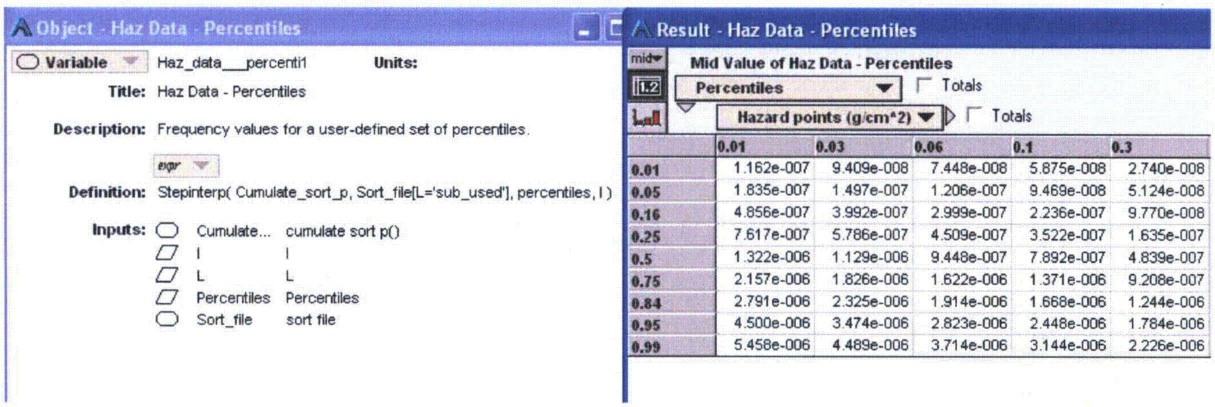


Figure 33. Information and Partial Results for the Node "Cumulate sort P()" in Analytica

l) Finally, extract the final set of desired percentile frequencies from the data. Figure 34 shows the node information and partial results of this operation.



	0.01	0.03	0.06	0.1	0.3
0.01	1.162e-007	9.409e-008	7.448e-008	5.875e-008	2.740e-008
0.05	1.835e-007	1.497e-007	1.206e-007	9.469e-008	5.124e-008
0.16	4.856e-007	3.992e-007	2.999e-007	2.236e-007	9.770e-008
0.25	7.617e-007	5.786e-007	4.509e-007	3.522e-007	1.635e-007
0.5	1.322e-006	1.129e-006	9.448e-007	7.892e-007	4.839e-007
0.75	2.157e-006	1.826e-006	1.622e-006	1.371e-006	9.208e-007
0.84	2.791e-006	2.325e-006	1.914e-006	1.668e-006	1.244e-006
0.95	4.500e-006	3.474e-006	2.823e-006	2.448e-006	1.784e-006
0.99	5.458e-006	4.489e-006	3.714e-006	3.144e-006	2.226e-006

Figure 34. Information and Partial Results for the Node "Haz Data - Percentiles" in Analytica

Along with the expected value hazard curve (Figure 27), this result is a primary output of this design calculation.

5.3 DUPLICATE CALCULATIONS IN MICROSOFT EXCEL

In order to corroborate the calculations in Analytica, a selected set of calculations were duplicated in Microsoft Excel. These calculations correspond to those done in Analytica for simulations 01, 02, and 80 and are carried out through step 3c described above (see Figure 25). The calculations can only be duplicated this far in Excel, since going farther would require calculation of all 97 used simulations. These three simulations were selected to represent different grid dimensions generated by the ASHPLUME runs. The maximum grid dimensions of the three runs are 60, 200 and 20 km, respectively. These correspond to grid spacings of 3, 10, and 1 km, respectively. The excel files for these duplicate calculations are included with this report (pc-1.xls, pc-2.xls, pc-80.xls, global.xls).

The following describes the calculation in Excel, using simulation 01 as the illustrative example (see attached files pc-1.xls and global.xls).

5.3.1 ASHPLUME Data on Common Grid

The steps involved for performing the calculation in Excel are as follows:

a. Open PCa-1.out file as excel workbook (see sheet "PC data" in pc-1.xls).

b. Convert column A by "text to columns" under the Data menu in Excel.

c. Pad data values to bottom of list to ensure that all possible values for x and y are represented. This requires creating dummy points for x coordinates that are not represented, and is needed to ensure that the PivotTable in the next step expands as needed.

d. Create PivotTable (in sheet "PivotTable") to convert x, y, xash data from the flat file in "PC data" to a 2-D table.

e. Copy pivot table data to appropriate cells in larger (201x401) grid, in a new sheet ("Full_grid"). Doing this requires use of Index and Match functions to perform lookup of existing data, and an IF and OR statement to place zeros at values outside of the given ASHPLUME grid. Copied data are shown in red text in the worksheet. The following general equation is used to transfer existing ASHPLUME data and put zeros outside the grid:

```
=IF(OR($A196>'PC data'!$E$9, $A196<'PC data'!$E$10, B$1>'PC data'!$E$8), 0,
INDEX(PivotTable!$A$4:$V$45, MATCH($A196, PivotTable!$A$4:$A$45,),
MATCH(B$1,PivotTable!$A$4:$V$4,)))
```

f. Pad values around the edge of non-zero data. The purpose of padded values is to provide a very small, but non-zero, set of values around the edge of the data so that the ensuing ln-ln interpolation will ramp from the last non-zero value down to near zero. Attempting to interpolate the last non-zero value with the next zero value will not work in ln-ln space since ln(0) is not defined. The pad value is set to 0.001 and the cells where padded values were inserted are shown by text in red italics.

g. Perform interpolations in ln-ln space to fill in data between existing data points. Note that the region around the origin will be handled separately (described below). Interpolations are performed in two steps, first in the x dimension, then in the y dimension. The equation for the x dimension is of the form:

```
=IF(OR(B196=0,H196=0), 0, EXP((LN(SQRT($A196^2+C$1^2))-
LN(SQRT($A196^2+B$1^2))) / (LN(SQRT($A196^2+H$1^2))-
LN(SQRT($A196^2+B$1^2))) * (LN(H196)-LN(B196))+LN(B196)))
```

The equation for the y dimension is of the form:

```
=IF(OR(B190=0,B196=0), 0, EXP((LN(SQRT($A195^2+B$1^2))-
LN(SQRT($A196^2+B$1^2))) / (LN(SQRT($A190^2+B$1^2))-
LN(SQRT($A196^2+B$1^2))) * (LN(B190)-LN(B196))+LN(B196)))
```

h. Copy values for the data points near the origin from the file PCb-1.out. Use the value from the point (x = 0, y = +0.5) for the origin. If any of the values are zero, use the value of 0.001 (consistent with the padding argument described above). These data points (six total) are shown in red.

i. Interpolate (in ln-ln space) along the x dimension from the three new data points at (0.5, +0.5), (0.5, 0), and (0.5, -0.5) to the nearest set of existing data points from the previous interpolation. For simulation 01, the nearest data points are at (3.0, +0.5), (3.0, 0), and (3.0, -0.5). The equation is of the form:

```
=IF(OR(C201=0,H201=0), 0, EXP((LN(SQRT($A201^2+D$1^2))-
LN(SQRT($A201^2+C$1^2))) / (LN(SQRT($A201^2+H$1^2))-
LN(SQRT($A201^2+C$1^2))) * (LN(H201)-LN(C201))+LN(C201)))
```

j. Interpolate (in ln-ln space) along the y dimension from the data just created along y = 0.5 and y = -0.5 to the nearest set of existing data points from the previous interpolations (from step g). The equation is of the form:

=IF(OR(D196=0,D201=0), 0, EXP((LN(SQRT($A200^2+D$1^2))-LN(SQRT($A201^2+D$1^2))) / (LN(SQRT($A196^2+D$1^2))-LN(SQRT($A201^2+D$1^2))) * (LN(D196)-LN(D201))+LN(D201)))

k. Perform ln-ln extrapolations to extend data for new grid points in the positive y (downwind) direction. In cases where the ASHPLUME grid does not extend to the full 100 km in the +y direction, the data do not terminate at near-zero values. Therefore, to avoid an abrupt and unrealistic drop off to zero, the data are extrapolated out to 100 km using the last two non-zero values along +y. These new points are shown by cells shaded in green. The equation for the extrapolation is:

=EXP((LN(SQRT($A81^2+B$1^2)) - LN(SQRT($A$82^2+B$1^2))) / (LN(SQRT($A82^2+B1^2)) - LN(SQRT($A$88^2+B$1^2))) * (LN(B$82)-LN(B$88))+LN(B$82))

l. Plot data in 3-D view to check results visually (see sheet "Chart").

5.3.2 Grid Calculations

a. For each volcano location, determine the distance along the x-axis and the distance along the y-axis to the facilities location, with respect to the grid of volcano points. In the sheet "Calc", the equations are of the form (example from cells C6 and D6):

=$B$2-A6, =$C$2-B6

b. Calculate the angle from each volcano location to the facilities location, with respect to the grid of volcano points. The equation is of the form (example from cell F6):

=ATAN2(C6,D6)

c. Calculate the distance from each volcano location to the facilities location. The equation is of the form (example from cell G6):

=SQRT(C6^2+D6^2)

d. For each of the 12 wind directions, perform the following calculations. Note that the wind direction probabilities are dependent on the column height of the plume, and are pulled in from the linked spreadsheet, global.xls.

e. Calculate the angular difference between the given wind direction and the direction to the facilities. The equation is of the form (from cell J6):

=$F6-K$3+RADIANS(90)

f. Using that angle and the distance to the facilities, convert to x and y distances (with respect to the ASHPLUME grid). The equations are of the form (example from cells H6 and I6):

```
=COS(J6)*G6, =SIN(J6)*G6
```

g. Round the x and y distances to the nearest 0.5 km to determine the x and y coordinates. The equations are of the form (example from cells K6 and L6):

```
=ABS(ROUND(H6*2,0)/2), =ROUND(I6*2,0)/2
```

5.3.3 Overall Frequency Versus Density Curve for the Simulation

a. Using the x, y coordinates, extract the ash density from the "Full-data" sheet. The equation is of the form (example from cell M6):

```
=IF(OR(K6>100, K6<0, ABS(L6-0.5)>100), 0,
INDEX(Full_grid!$A$1:$GT$402, MATCH(L6,Full_grid!$A$1:$A$402,),
MATCH(K6,Full_grid!$A$1:$GT$1,)))
```

b. Calculate the probability of exceeding different ash densities for each of the volcano locations, incorporating the wind direction probabilities. The equation is of the form (example from cell BG6):

```
=IF($M6>BG$5,$J$1,0) + IF($Q6>BG$5,$P$1,0) + IF($U6>BG$5,$T$1,0) +
IF($Y6>BG$5,$X$1,0) + IF($AC6>BG$5,$AB$1,0) +
IF($AG6>BG$5,$AF$1,0) + IF($AK6>BG$5,$AJ$1,0) +
IF($AO6>BG$5,$AN$1,0) + IF($AS6>BG$5,$AR$1,0) + IF($AW6>
BG$5,$AV$1,0) + IF($BA6>BG$5,$AZ$1,0) + IF($BE6>BG$5,$BD$1,0)
```

c. Calculate the overall frequency of exceeding different ash densities by multiplying the volcano frequencies by the hazard curves for each, then summing over all volcanoes. The equation is of the form (example from cell BG2):

```
=SUMPRODUCT(BG6:BG15256,$BP6:$BP15256)
```

Comparison of the results of the calculations performed in Analytica and Excel show equivalency in the two sets of results for the three simulations where calculations were completed in Excel. The calculations were conducted to provide corroboration in a separate calculation platform that the results in Analytica are behaving as expected.

6. RESULTS

The following table summarizes the results of the final full calculation. This table includes the results presented as the probability-weighted mean (see Figure 27) and in terms of percentiles (see Figure 34) of the frequency of exceeding various ash densities.

The outputs are reasonable compared to the inputs. The estimate of the thickness hazard at the North Portal Operations Area, as calculated in this document, is suitable to be used in the building design to withstand potential ash fall from basaltic volcanism.

Table 1. Summary Results of the Ash Areal Density Calculations

		Frequency of exceeding given ash density at building location									
			Percentile								
Ash density (g/cm^2)		**Mean**	**0.01**	**0.05**	**0.16**	**0.25**	**0.5**	**0.75**	**0.84**	**0.95**	**0.99**
	0.01	1.65E-06	1.16E-07	1.84E-07	4.86E-07	7.62E-07	1.32E-06	2.16E-06	2.79E-06	4.50E-06	5.46E-06
	0.03	1.35E-06	9.41E-08	1.50E-07	3.99E-07	5.79E-07	1.13E-06	1.83E-06	2.33E-06	3.47E-06	4.49E-06
	0.06	1.12E-06	7.45E-08	1.21E-07	3.00E-07	4.51E-07	9.45E-07	1.62E-06	1.91E-06	2.82E-06	3.71E-06
	0.1	9.61E-07	5.88E-08	9.47E-08	2.24E-07	3.52E-07	7.89E-07	1.37E-06	1.67E-06	2.45E-06	3.14E-06
	0.3	6.33E-07	2.74E-08	5.12E-08	9.77E-08	1.64E-07	4.84E-07	9.21E-07	1.24E-06	1.78E-06	2.23E-06
	0.6	4.55E-07	1.73E-08	3.01E-08	5.60E-08	8.26E-08	3.07E-07	6.75E-07	8.92E-07	1.41E-06	1.86E-06
	1	3.44E-07	1.13E-08	1.68E-08	3.49E-08	5.56E-08	1.74E-07	5.23E-07	6.91E-07	1.23E-06	1.70E-06
	3	1.76E-07	2.70E-09	5.73E-09	1.39E-08	1.84E-08	4.70E-08	2.03E-07	3.75E-07	8.51E-07	1.28E-06
	6	1.04E-07	1.36E-09	2.56E-09	6.25E-09	9.63E-09	2.14E-08	8.20E-08	1.79E-07	5.97E-07	8.55E-07
	10	6.41E-08	0.00E+00	1.36E-09	3.27E-09	5.16E-09	1.21E-08	3.63E-08	9.75E-08	3.53E-07	6.79E-07
	30	1.33E-08	0.00E+00	0.00E+00	6.81E-10	1.36E-09	3.03E-09	8.34E-09	1.42E-08	6.10E-08	1.65E-07
	60	3.27E-09	0.00E+00	0.00E+00	0.00E+00	6.54E-10	1.40E-09	2.48E-09	3.40E-09	7.30E-09	2.22E-08
	100	1.39E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.81E-10	1.48E-09	2.17E-09	3.38E-09	5.50E-09

The following hazard curve (Figure 35) shows the frequency of exceeding any given areal ash density in a graphical form. The data used here are the probability weighted mean values (the column labeled "Mean" in Table 1).

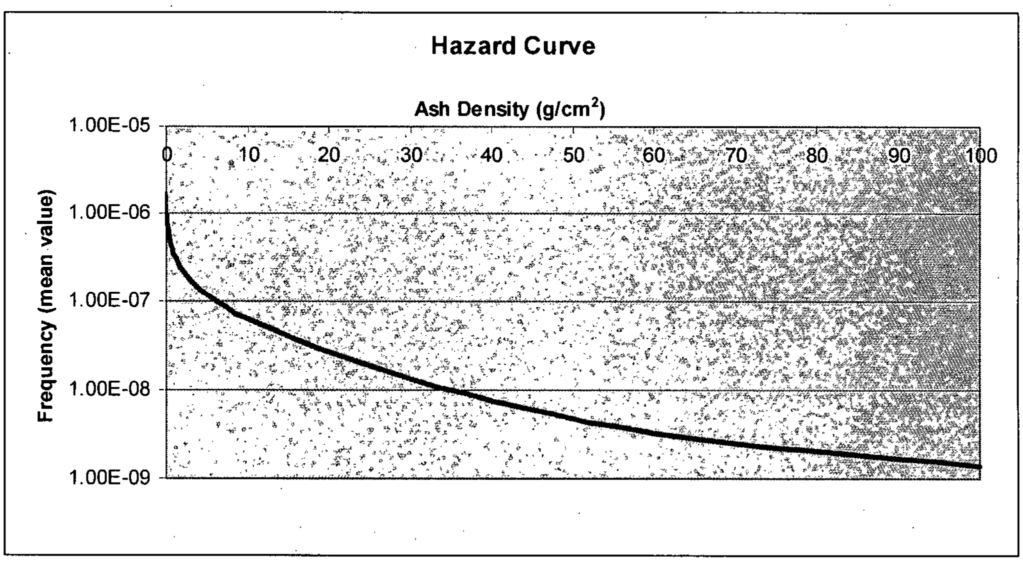


Figure 35. Hazard Curve (Frequency of Occurrence Versus Areal Ash Density) Using Expected Values

Of particular importance for design consideration are the frequency calculations corresponding to the ash areal density of 10 g/cm^2. Using a specific gravity of approximately 1 for ash, the current facilities' design load of 20 pounds/ft^2 corresponds to an ash areal density of 9.8 g/cm^2.

Figure 35 shows the frequency of exceeding an ash areal density of 10 g/cm^2 plotted against the probability of the frequency being less than that value.

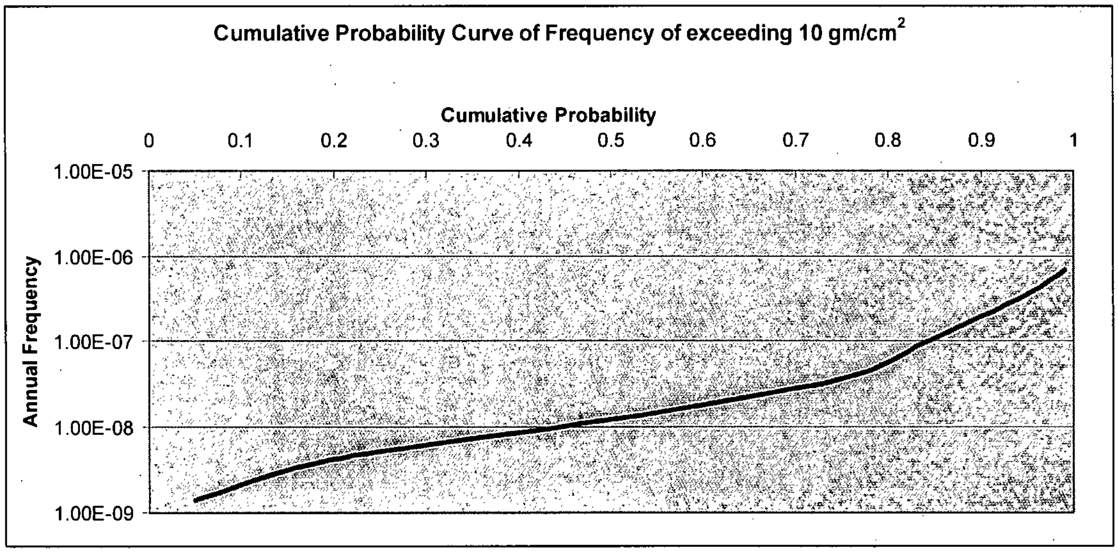


Figure 36. Frequency of exceeding ash areal density of 10 g/cm^2 (Cumulative Probability Curve)

The results indicate that the mean annual frequency of exceeding an ash areal density of 10 g/cm^2 is 6.4 x 10^{-8}. Because these results incorporate uncertainty, we can also look at the results from a more conservative standpoint, and conclude that there is a 99% probability that the mean annual frequency of exceeding a density of 10 g/cm^2 will not exceed 6.8 x 10^{-7}.

7. REFERENCES

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7.2 CODES, STANDARDS, REGULATIONS, AND PROCEDURES

AP-3.12Q, Rev. 2, ICN 2. Design Calculations and Analyses. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20030403.0003.

LP-SI.11Q-BSC, Rev. 0, ICN 1. *Software Management.* Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste Management. ACC: DOC.20040225.0007.

7.3 SOURCE DATA LISTED BY TRACKING NUMBER

LA0009FP831811.001. Compilation and Summaries of Data Supporting Computation of Volcanic Event Intersection Frequencies. Submittal date: 09/01/2000. 164712

LA0408GK831811.002. Input Parameter Values for the ASHPLUME_DLL_LA V 2.0 Model for TSPA-LA. Submittal date: 08/26/2004. 171749

LA0409WS831812.001. Pre-Closure Ash Distribution Data. Submittal date: 09/16/2004. 171768

MO0408SPADRWSD.002. Desert Rock Wind Speed and Wind Direction Analysis for Years 1978-2003. Submittal date: 08/19/2004. 171803

ATTACHMENT A–CD-ROM OF COMPUTER FILES

All computer files used for this calculation are contained on the attached CD-ROM. Table A-1 lists the files contained on the CD and provides file size, date, time, and a description of the purpose of the files.

Table A-1. Description of files on attached CD-ROM

Filename	Size (KB)	Date	Time	Description
PC_ash.ana	2,657	9/14/2004	8:33 am	Analytica model file used to perform calculations. File contains all input data, intermediate calculations, and results.
Setupana30.exe	12,924	9/14/2004	9:54 am	Set up file for installing free Player version of Analytica for running "pc_ash.ana" model calculation.
PCa-OUT1-10.xls	139	8/27/2004	1:52 pm	File to parse ASHPLUME files PCa-1.out through PCa-10.out prior to importing into Analytica
PCa-OUT11-20.xls	144	8/25/2004	12:55 pm	File to parse ASHPLUME files PCa-11.out through PCa-20.out prior to importing into Analytica
PCa-OUT21-30.xls	136	8/24/2004	12:21 pm	File to parse ASHPLUME files PCa-21.out through PCa-30.out prior to importing into Analytica
PCa-OUT31-40.xls	163	8/24/2004	1:44 pm	File to parse ASHPLUME files PCa-31.out through PCa-40.out prior to importing into Analytica
PCa-OUT41-50.xls	180	8/24/2004	2:46 pm	File to parse ASHPLUME files PCa-41.out through PCa-50.out prior to importing into Analytica
PCa-OUT51-60.xls	199	8/24/2004	2:58 pm	File to parse ASHPLUME files PCa-51.out through PCa-60.out prior to importing into Analytica
PCa-OUT61-70.xls	209	8/25/2004	7:56 am	File to parse ASHPLUME files PCa-61.out through PCa-70.out prior to importing into Analytica
PCa-OUT71-80.xls	274	8/25/2004	8:02 am	File to parse ASHPLUME files PCa-71.out through PCa-80.out prior to importing into Analytica
PCa-OUT81-90.xls	201	8/25/2004	8:06 am	File to parse ASHPLUME files PCa-81.out through PCa-90.out prior to importing into Analytica
PCa-OUT91-100.xls	223	8/25/2004	8:12 am	File to parse ASHPLUME files PCa-91.out through PCa-100.out prior to importing into Analytica
PCa-OUT101-110.xls	223	8/25/2004	8:16 am	File to parse ASHPLUME files PCa-101.out through PCa-110.out prior to importing into Analytica
pc-1.xls	65,718	9/14/2004	9:04 am	Duplicate complete calculation in Excel of hazard curve for ASHPLUME simulation 1
pc-2.xls	61,253	9/14/2004	8:53 am	Duplicate complete calculation in Excel of hazard curve for ASHPLUME simulation 2
pc-80.xls	58,838	9/14/2004	9:03 am	Duplicate complete calculation in Excel of hazard curve for ASHPLUME simulation 80
global.xls	19	8/27/2004	1:52 pm	Wind probability data for use in Excel calculations
CFRACSM.XY	552	4/16/2000	9:07 pm	Output file from DTN LA0009FP831811.001 containing volcano frequency data for grid points.
Ashplume_PreClose_8-23-04.zip	386	8/23/2004	11:21 am	Zip file containing the 220 output files of ASHPLUME runs

ATTACHMENT B–ASHPLUME GRID DIMENSIONS

Table B-1. Grid Dimensions of ASHPLUME Full-Grid Realizations

File	Spacing (km)	Min x (km)	Max x (km)	# points	Min y (km)	Max y (km)	# points
PCa-1.out	3	0	60	21	-60	60	41
PCa-2.out	10	0	200	21	-200	200	41
PCa-3.out	7	0	140	21	-140	140	41
PCa-4.out	5.5	0	110	21	-110	110	41
PCa-5.out	4.5	0	90	21	-90	90	41
PCa-6.out	2	0	40	21	-40	40	41
PCa-7.out	3.5	0	70	21	-70	70	41
PCa-8.out	2	0	40	21	-40	40	41
PCa-9.out	3	0	60	21	-60	60	41
PCa-10.out	4	0	80	21	-80	80	41
PCa-11.out	5	0	100	21	-100	100	41
PCa-12.out	10	0	200	21	-200	200	41
PCa-13.out	6.5	0	130	21	-130	130	41
PCa-14.out	3	0	60	21	-60	60	41
PCa-15.out	2	0	40	21	-40	40	41
PCa-16.out	6.5	0	130	21	-130	130	41
PCa-17.out	10	0	200	21	-200	200	41
PCa-18.out	2.5	0	50	21	-50	50	41
PCa-19.out	6	0	120	21	-120	120	41
PCa-20.out	8.5	0	170	21	-170	170	41
PCa-21.out	7	0	140	21	-140	140	41
PCa-22.out	4	0	80	21	-80	80	41
PCa-23.out	3.5	0	70	21	-70	70	41
PCa-24.out	3.5	0	70	21	-70	70	41
PCa-25.out	7	0	140	21	-140	140	41
PCa-26.out	4	0	80	21	-80	80	41
PCa-27.out	5.5	0	110	21	-110	110	41
PCa-28.out	5	0	100	21	-100	100	41
PCa-29.out	1.5	0	30	21	-30	30	41
PCa-30.out	2	0	40	21	-40	40	41
PCa-31.out	5	0	100	21	-100	100	41
PCa-32.out	4.5	0	90	21	-90	90	41
PCa-33.out	10	0	200	21	-200	200	41
PCa-34.out	7	0	140	21	-140	140	41
PCa-35.out	3	0	60	21	-60	60	41
PCa-36.out	6.5	0	130	21	-130	130	41
PCa-37.out	3.5	0	70	21	-70	70	41

Table B-1. Grid Dimensions of ASHPLUME Full-Grid Realizations (Continued)

File	Spacing (km)	Min x (km)	Max x (km)	# points	Min y (km)	Max y (km)	# points
PCa-38.out	3.5	0	70	21	-70	70	41
PCa-39.out	6	0	120	21	-120	120	41
PCa-40.out	2	0	40	21	-40	40	41
PCa-41.out	4	0	80	21	-80	80	41
PCa-42.out	2.5	0	50	21	-50	50	41
PCa-43.out	3.5	0	70	21	-70	70	41
PCa-44.out	3	0	60	21	-60	60	41
PCa-45.out	4	0	80	21	-80	80	41
PCa-46.out	10	0	200	21	-200	200	41
PCa-47.out	2.5	0	50	21	-50	50	41
PCa-48.out	2.5	0	50	21	-50	50	41
PCa-49.out	3	0	60	21	-60	60	41
PCa-50.out	7.5	0	150	21	-150	150	41
PCa-51.out	6	0	120	21	-120	120	41
PCa-52.out	4	0	80	21	-80	80	41
PCa-53.out	3.5	0	70	21	-70	70	41
PCa-54.out	1.5	0	30	21	-30	30	41
PCa-55.out	2	0	40	21	-40	40	41
PCa-56.out	4	0	80	21	-80	80	41
PCa-57.out	2.5	0	50	21	-50	50	41
PCa-58.out	2.5	0	50	21	-50	50	41
PCa-59.out	4	0	80	21	-80	80	41
PCa-60.out	4	0	80	21	-80	80	41
PCa-61.out	2	0	40	21	-40	40	41
PCa-62.out	6	0	120	21	-120	120	41
PCa-63.out	5	0	100	21	-100	100	41
PCa-64.out	2.5	0	50	21	-50	50	41
PCa-65.out	2	0	40	21	-40	40	41
PCa-66.out	5.5	0	110	21	-110	110	41
PCa-67.out	8.5	0	170	21	-170	170	41
PCa-68.out	9.5	0	190	21	-190	190	41
PCa-69.out	9.5	0	190	21	-190	190	41
PCa-70.out	2.5	0	50	21	-50	50	41
PCa-71.out	3	0	60	21	-60	60	41
PCa-72.out	2	0	40	21	-40	40	41
PCa-73.out	10	0	200	21	-200	200	41
PCa-74.out	10	0	200	21	-200	200	41
PCa-75.out	2.5	0	50	21	-50	50	41
PCa-76.out	3	0	60	21	-60	60	41
PCa-77.out	5	0	100	21	-100	100	41

Table B-1. Grid Dimensions of ASHPLUME Full-Grid Realizations (Continued)

File	Spacing (km)	Min x (km)	Max x (km)	# points	Min y (km)	Max y (km)	# points
PCa-78.out	9.5	0	190	21	-190	190	41
PCa-79.out	10	0	200	21	-200	200	41
PCa-80.out	1	0	20	21	-20	20	41
PCa-81.out	4.5	0	90	21	-90	90	41
PCa-82.out	5	0	100	21	-100	100	41
PCa-83.out	10	0	200	21	-200	200	41
PCa-84.out	3	0	60	21	-60	60	41
PCa-85.out	10	0	200	21	-200	200	41
PCa-86.out	4	0	80	21	-80	80	41
PCa-87.out	5.5	0	110	21	-110	110	41
PCa-88.out	4.5	0	90	21	-90	90	41
PCa-89.out	6	0	120	21	-120	120	41
PCa-90.out	6	0	120	21	-120	120	41
PCa-91.out	4	0	80	21	-80	80	41
PCa-92.out	5	0	100	21	-100	100	41
PCa-93.out	7	0	140	21	-140	140	41
PCa-94.out	5.5	0	110	21	-110	110	41
PCa-95.out	3	0	60	21	-60	60	41
PCa-96.out	3	0	60	21	-60	60	41
PCa-97.out	3	0	60	21	-60	60	41
PCa-98.out	2	0	40	21	-40	40	41
PCa-99.out	7.5	0	150	21	-150	150	41
PCa-100.out	3	0	60	21	-60	60	41
PCa-101.out	3.5	0	70	21	-70	70	42
PCa-102.out	2.5	0	50	21	-50	50	43
PCa-103.out	3	0	60	21	-60	60	44
PCa-104.out	6	0	120	21	-120	120	45
PCa-105.out	6.5	0	130	21	-130	130	46
PCa-106.out	2	0	40	21	-40	40	47
PCa-107.out	8	0	160	21	-160	160	48
PCa-108.out	2	0	40	21	-40	40	49
PCa-109.out	7.5	0	150	21	-150	150	50
PCa-110.out	2.5	0	50	21	-50	50	51

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