ATTACHMENT VIII

3DEC PROGRAM MODIFICATION AND MODEL OPTIMIZATION FOR ROCKFALL ANALYSIS

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3DEC PROGRAM MODIFICATION AND MODEL OPTIMIZATION FOR ROCKFALL ANALYSIS

VIII.1 INTRODUCTION

Although 3DEC is fully capable for dynamic rockfall calculations, program modifications and optimization of the computer model are required in order to solve complex rockfall problems within a reasonable time frame. The complexity of the problem includes:

- Incorporate field fracture geometries with relatively short trace length
- Subject to post-closure ground motion time histories
- Subject to thermal stress induced from emplaced waste
- Conduct a large number of analyses to obtain a statistically meaningful rockfall frequency and size distribution.

VIII.2 3DEC PROGRAM MODIFICATION

Modifications of the 3DEC program for rockfall analyses include: (1) free-field boundaries, (2) partial density scaling for dynamic analysis, and (3) variable mechanical properties within a contact. A detailed description of the implementation and verification of these enhancements is provided by Lemos and Damjanac (2002). This attachment provides a brief description of these modifications and their relevance to rockfall analyses.

VIII.2.1 Free-Field Boundaries

The free-field boundaries ensure that plane waves propagating upward suffer no distortion at the boundary because the free-field grid supplies conditions that are identical to those in an infinite model. In order to apply a free-field boundary in 3DEC, the model must be oriented such that the base is horizontal and its normal is in the direction of the y-axis, and the sides are vertical and their normals are in the direction of either the x- or z-axis.

The free-field model consists of four plane free-field grids on the side boundaries of the model and four column free-field grids at the corners. The four corner free-field columns act as free-field boundaries for the plane free-field grids. The plane free-field grids are two-dimensional models that assume infinite extension in the direction normal to the plane. The column free-field grids are one-dimensional models that assume infinite extension in both horizontal directions. Both the plane and column grids consist of standard 3DEC zones, which have gridpoints constrained in such a way to achieve the infinite extension assumption. The zoning of free-field blocks is similar to the model side faces. The side free-field blocks have two gridpoints across the thickness that are linked to move together. The corner free-field meshes have four gridpoints at each elevation, also linked to move together.

VIII.2.2 Partial Density Scaling for Dynamic Analysis

Density scaling is a technique used in 3DEC in quasi-static calculations that substantially improves the efficiency of obtaining solutions. For the case of complex jointing models, zones with edge lengths much smaller than the average zone edge length are created during the automatic meshing procedure. These zones require very small timesteps for numerical stability of the explicit algorithm. The critical time step is proportional to the smallest zone edge length. This makes the dynamic solution extremely time consuming. Density scaling only for those very small zones (a couple of orders of magnitude smaller than the average zone size) for dynamic analysis eliminates the very small timesteps. The accuracy of the solution is preserved by keeping the change of the system inertia negligible. This scheme of partial density scaling is implemented in 3DEC in such a way that the user controls the amount of scaling to be introduced.

VIII.2.3 Variable Mechanical Properties within a Contact

A contact between two blocks in 3DEC is subdivided into a number of sub-contacts if the blocks involved in the contact are deformable. The sub-contacts are determined based on discretization of the block faces which create the contact. Discretization of contact into sub-contacts allows representation of variation of contact forces and deformation in the plane. In earlier versions of 3DEC, mechanical properties (e.g., normal and shear stiffness, shear strength) of sub-contacts were assigned based on material properties of the contact they belong to. A modification of the code allows assignment of material properties to the sub-contacts independent of the material properties of the contact (to which sub-contact belongs to). This capability allows the program to model the finite trace length fractures from FracMan.

VIII.3 3DEC MODEL OPTIMIZATION

Model optimization involves two aspects: reducing the model size and increasing the timestep. 3DEC is based on a dynamic (time domain) algorithm that solves the equations of motion of the block system by an explicit finite difference method. A timestep must be chosen that is smaller than some critical timestep but is reasonable for solution time.

VIII.3.1 Reducing the Model Size

The following methods are used to reduce the model size:

1. Joints are generated within a limited domain as a representative volume around the drift. The representative volume extends one diameter at the side and two diameters on the top of the opening as shown in Figure 40 in Section 6.3.1.1. A sensitivity study of the size of the representative volume to rockfall prediction is presented in Section 6.3.1.6.4.

2. Only blocks intersected by circular joints are cut during joint generation. Joints are sorted based on their trace length in a descending order. An algorithm is placed in block cutting process to hide all blocks that are not intersected by the joint considered.

3. Blocks that have face-face contact and their contact properties are completely solid are joined. That is, several blocks are merged to one if their contacts are all solid. Blocks that have partial cracks between them are not joined. This approach allows for an analysis of the potential for crack extension.

VIII.3.2 Increasing the Timestep

3DEC is based on a dynamic (time domain) algorithm that solves the equations of motion of the block system by an explicit finite difference method. The solution scheme used for the distinct element method is conditionally stable if the selected limiting timestep satisfies both the stability criterion for calculation of internal block deformation as well as that for inter-block relative displacement. Even though explicit calculations execute very rapidly per timestep, some way of increasing the timestep is desirable in order to reduce computer time.

The following methods are used to increase the timestep:

1. Calculation of the timesteps is a function of the minimum length (zone edge length) and stiffness (Itasca 2002, 3DEC Manual). Cutting blocks with random joints results in very small block edge lengths. Blocks with a small volume (i.e., less than $0.01 m^3$) are deleted in the model to eliminate part of the blocks with small zone edge lengths. However, blocks of large volume may contain one or two small edges. An algorithm was developed that alters the geometry of these blocks and removes small edges less than 10-cm in length. The blocks were first detected and their geometry is stored in a data structure before they were deleted. New blocks are constructed within the bounds of the original blocks. In most cases, two close vertices are contracted into a single vertex. Faces that have both vertices lose one vertex. If the face already has only three vertices, then the entire face is deleted. On faces which have only one of two vertices, a new face with co-planarity of vertices is created. The flow chart for the algorithm is shown in Figure VIII.1.

2. The method of partial density scaling was adopted for dynamic analysis. Partial density scaling was implemented for dynamic analysis in 3DEC as described in Section VIII.2.2. A timestep of 3×10^{-5} seconds is set for the analysis. This results in an increase of system mass ranging from 1 to 4 percent. The amount of increase is consistent with the verification problem provided by Lemos and Damjanac (2002). The accuracy of the solution is therefore preserved by keeping the change of the system inertia negligible.

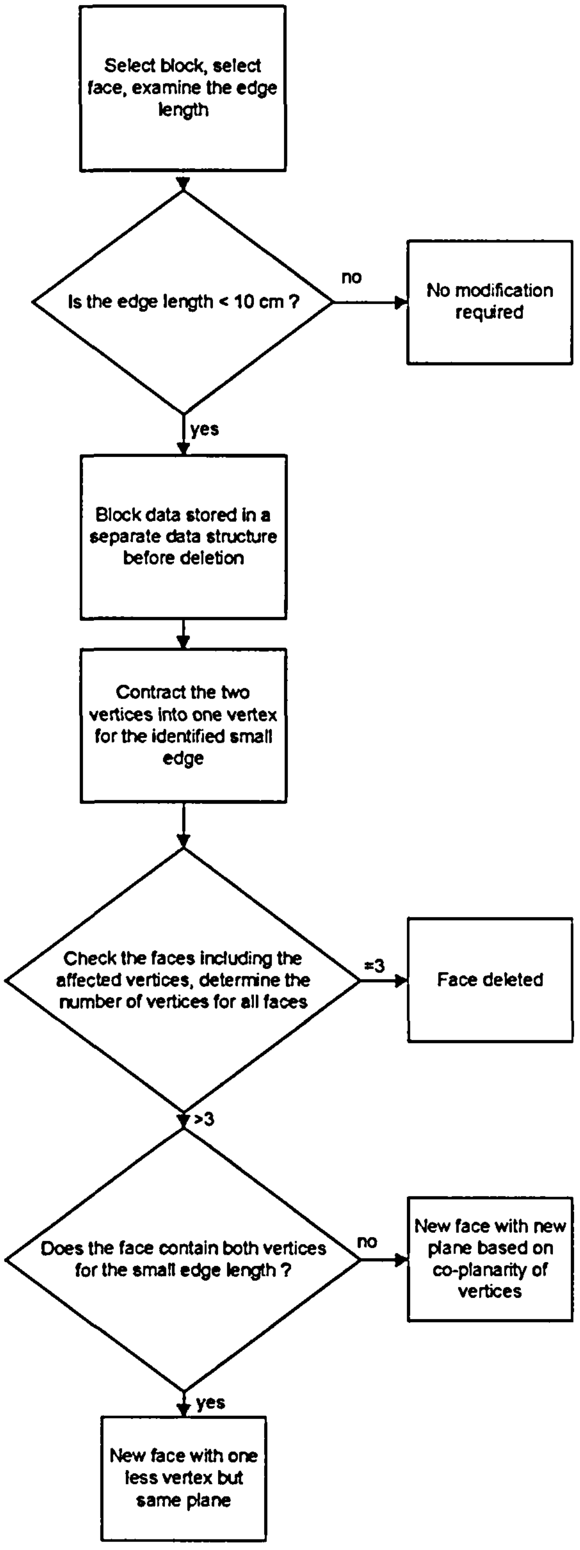

Figure VIII.1. Flow Chart for Treating the Small Edge Length Block

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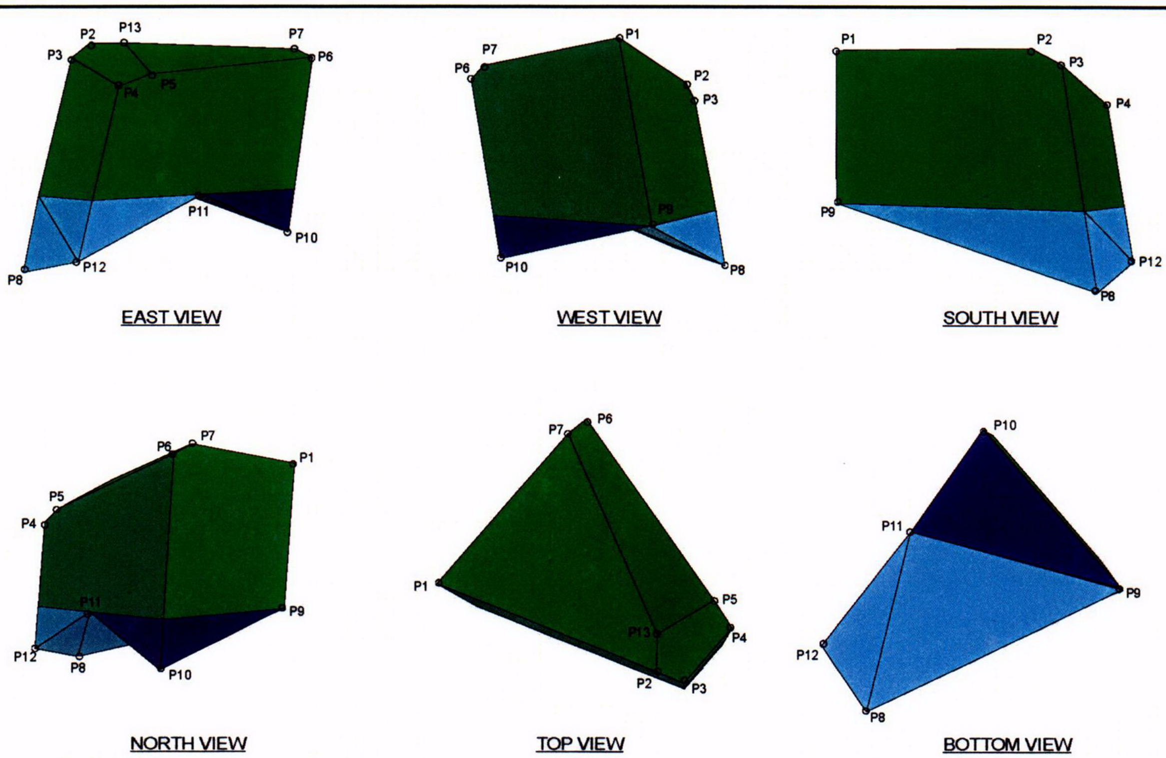
ATTACHMENT IX
BLOCK SIZE GEOMETRY

ATTACHMENT IX

BLOCK SIZE GEOMETRY

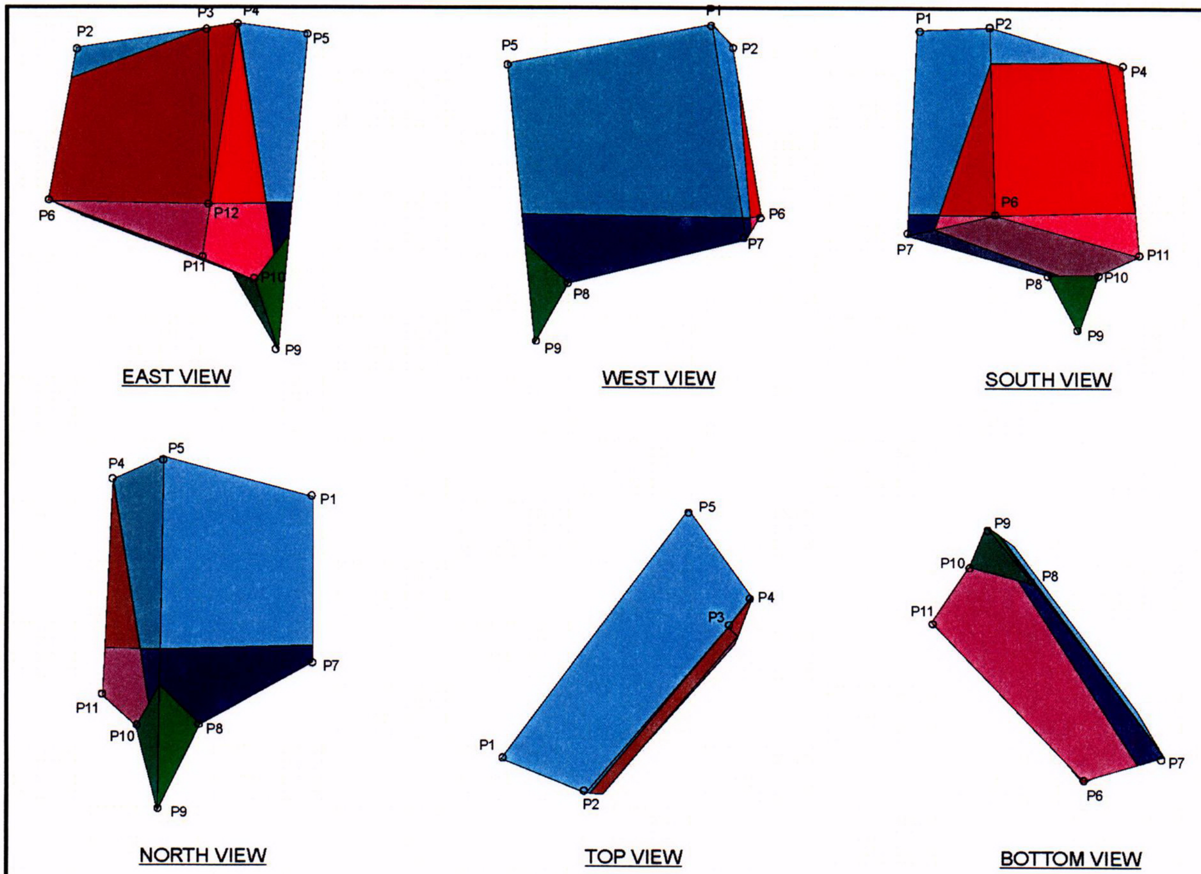
The predicted rock blocks impacting the drip shield have many different sizes and shapes. Since the block geometry information is mainly used for drip shield impact calculations, the geometry of large blocks is provided in this attachment. A total of 9 blocks with volume greater than 2.5 m^3 (6 metric tons) was selected. The block geometric information for each individual block is presented in Figures IX-1 to IX-9 respectively. Six different views are provided for each block with the corner point coordinates tabulated in each figure.



Block ID	#1		
Simulation	Case 58 for both 1×10^{-6} and 1×10^{-7} events		
Block Size (tonnes)	21.4		
Corner Point ID	X	Y	Z
P1	-5.34E+00	4.61E+00	-1.10E+00
P2	-3.02E+00	4.49E+00	-2.04E+00
P3	-2.71E+00	4.28E+00	-2.20E+00
P4	-2.10E+00	3.90E+00	-1.61E+00
P5	-2.33E+00	4.06E+00	-1.29E+00
P6	-3.78E+00	4.43E+00	6.85E-01
P7	-3.97E+00	4.57E+00	4.96E-01
P8	-2.41E+00	1.95E+00	-2.67E+00
P9	-5.26E+00	2.75E+00	-1.42E+00
P10	-3.63E+00	2.22E+00	3.56E-01
P11	-2.79E+00	2.75E+00	-7.48E-01
P12	-1.89E+00	2.15E+00	-2.00E+00
P13	-3.02E+00	4.49E+00	-1.64E+00

Figure IX-1. Block Geometry Information for Block #1

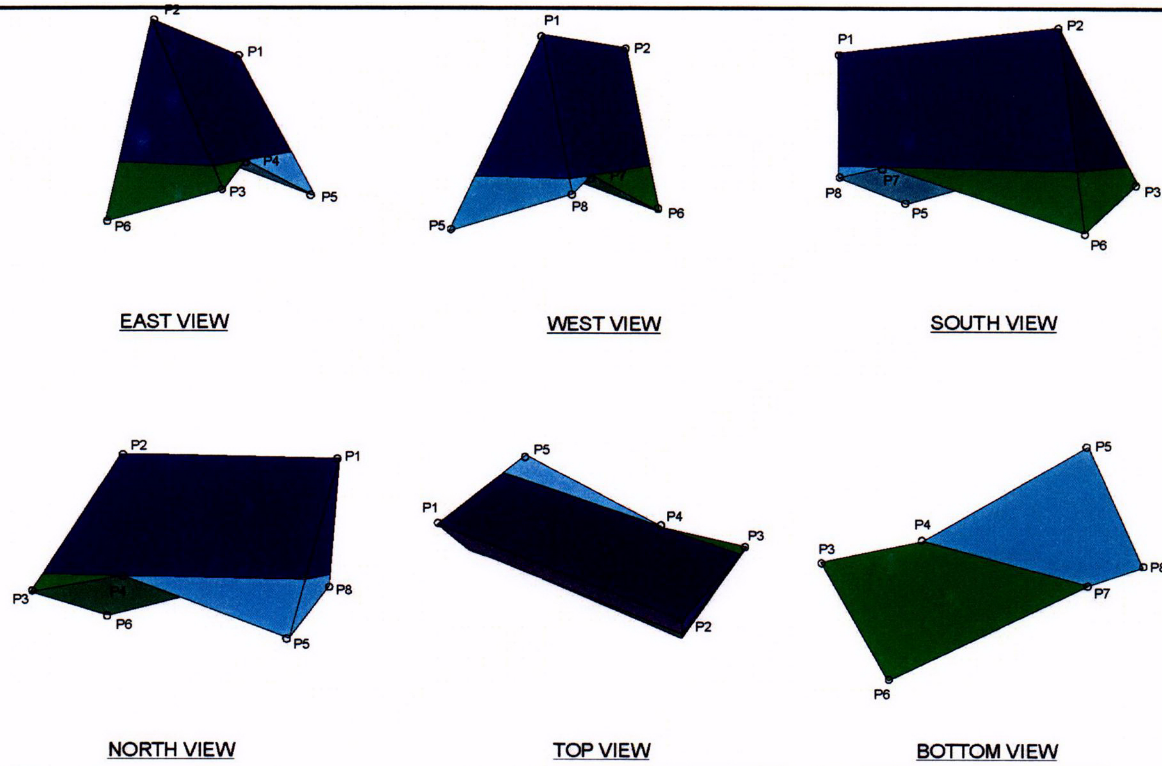
C121



Block ID	#2		
Simulation	Case 58 for both 1×10^{-6} and 1×10^{-7} events		
Block Size (tonnes)	14.5		
Corner Point ID	X	Y	Z
P1	-6.12E+00	4.66E+00	-7.84E-01
P2	-5.34E+00	4.61E+00	-1.10E+00
P3	-4.02E+00	4.57E+00	4.34E-01
P4	-3.80E+00	4.56E+00	7.25E-01
P5	-4.39E+00	4.60E+00	1.53E+00
P6	-5.27E+00	2.75E+00	-1.41E+00
P7	-6.16E+00	2.53E+00	-1.12E+00
P8	-4.72E+00	1.94E+00	7.47E-01
P9	-4.31E+00	1.14E+00	1.20E+00
P10	-4.07E+00	1.94E+00	9.23E-01
P11	-3.63E+00	2.22E+00	3.55E-01
P12	-3.67E+00	2.75E+00	4.35E-01

Figure IX-2. Block Geometry Information for Block #2

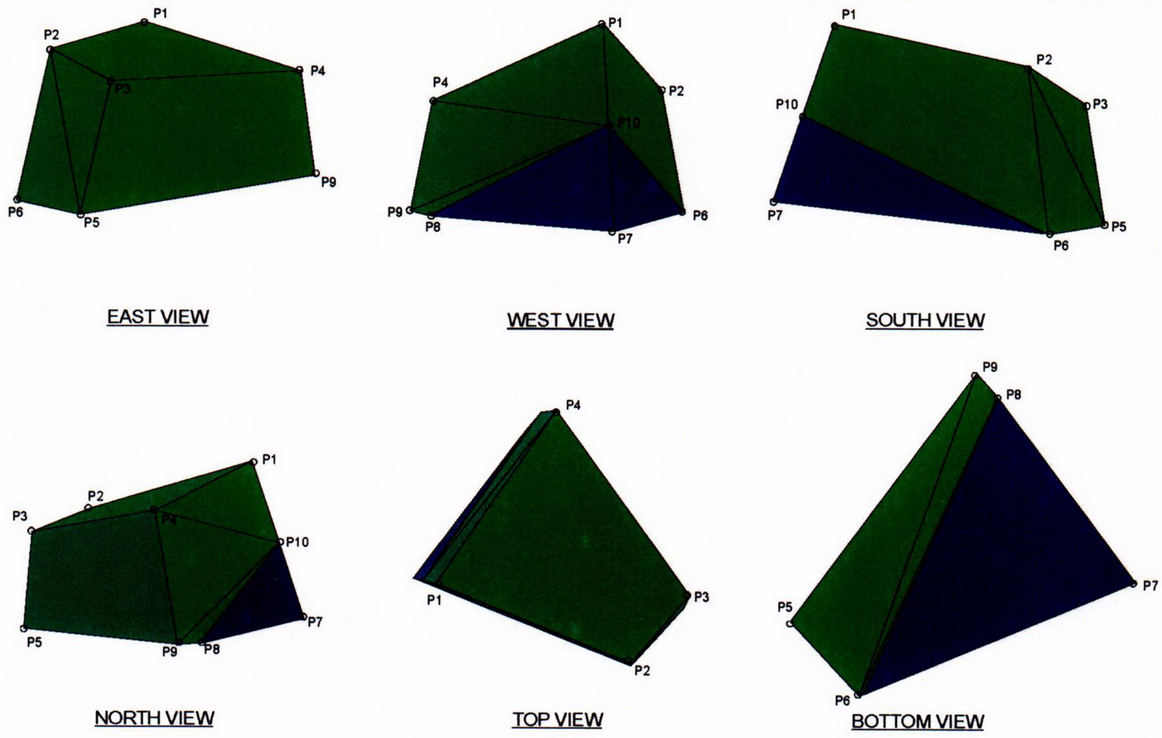
C122



Block ID	#3		
Simulation	Case 78 for 1×10^{-7} event		
Block Size (tonnes)	11.5		
Corner Point ID	X	Y	Z
P1	-1.01E+01	4.31E+00	-1.94E+00
P2	-7.10E+00	4.51E+00	-3.09E+00
P3	-5.95E+00	2.50E+00	-2.21E+00
P4	-7.21E+00	2.75E+00	-1.93E+00
P5	-9.24E+00	2.08E+00	-8.03E-01
P6	-6.85E+00	2.04E+00	-3.62E+00
P7	-9.34E+00	2.75E+00	-2.50E+00
P8	-1.00E+01	2.58E+00	-2.27E+00

Figure IX-3. Block Geometry Information for Block #3

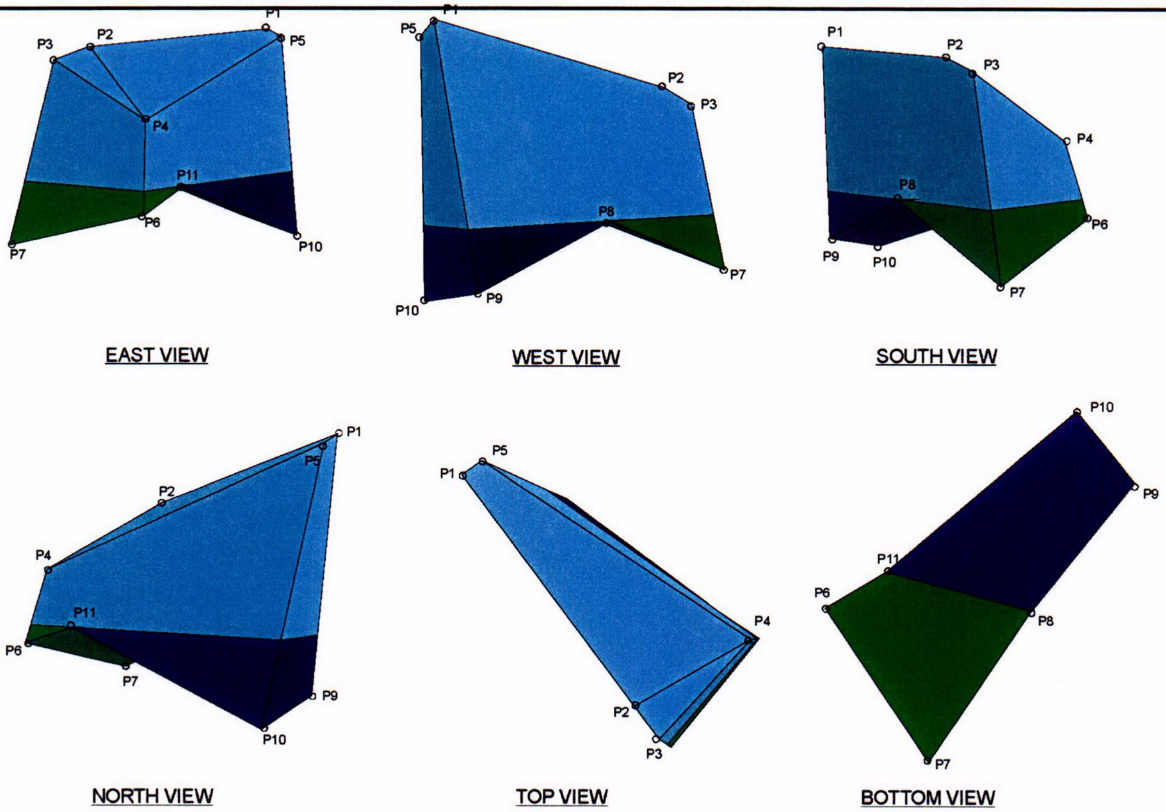
C123



Block ID	#4		
Simulation	Case 58 for 1×10^{-7} event		
Block Size (tonnes)	11.1		
Corner Point ID	X	Y	Z
P1	-4.65E+00	6.28E+00	-1.10E+00
P2	-2.90E+00	5.82E+00	-1.87E+00
P3	-2.29E+00	5.52E+00	-1.26E+00
P4	-3.61E+00	5.66E+00	5.30E-01
P5	-2.17E+00	4.45E+00	-1.49E+00
P6	-2.76E+00	4.47E+00	-2.14E+00
P7	-5.21E+00	4.61E+00	-1.15E+00
P8	-3.97E+00	4.57E+00	4.89E-01
P9	-3.79E+00	4.59E+00	7.09E-01

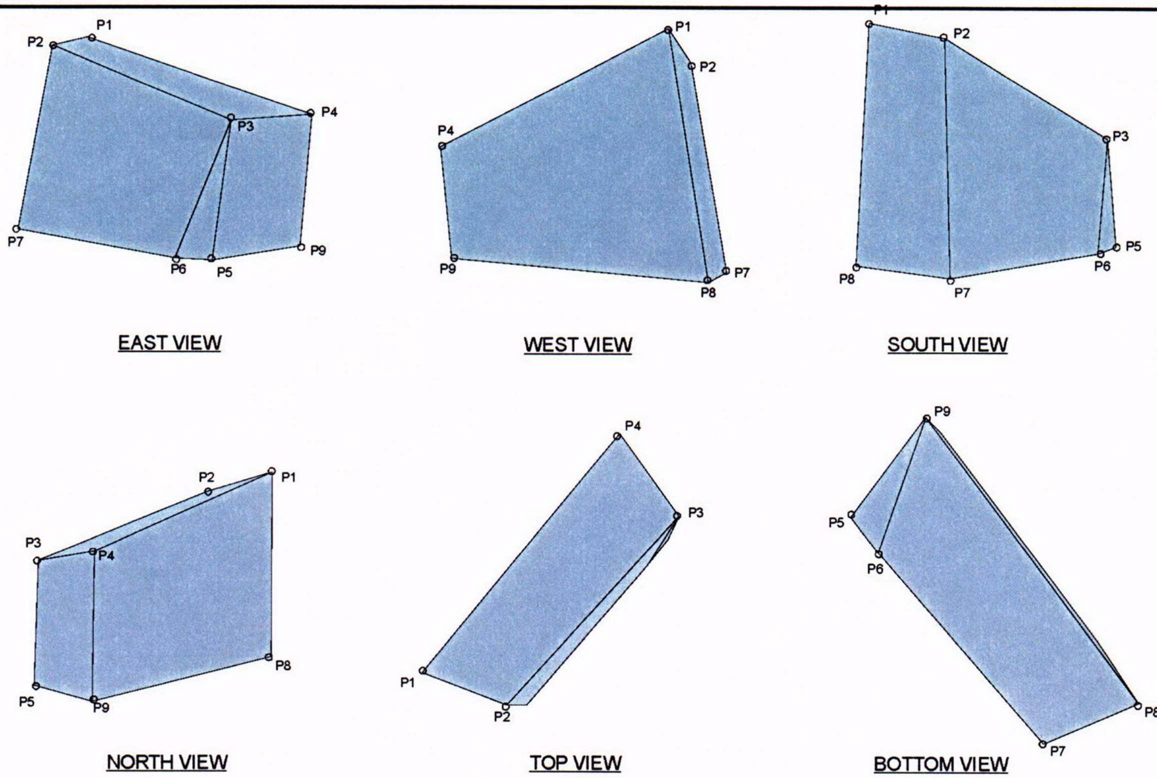
Figure IX-4. Block Geometry Information for Block #4

C124



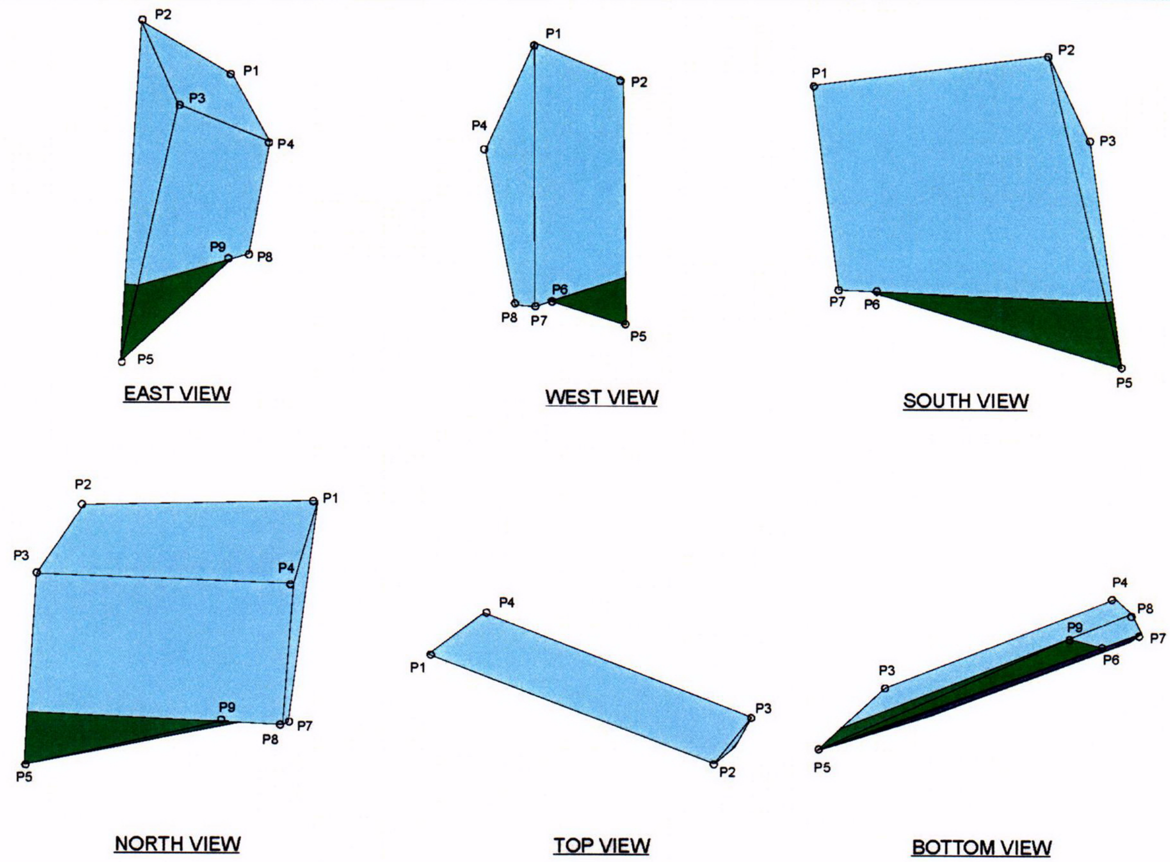
Block ID	#5		
Simulation	Case 58 for both 1×10^{-6} and 1×10^{-7} events		
Block Size (tonnes)	9.0		
Corner Point ID	X	Y	Z
P1	-3.78E+00	4.43E+00	6.85E-01
P2	-2.33E+00	4.06E+00	-1.29E+00
P3	-2.10E+00	3.90E+00	-1.61E+00
P4	-1.16E+00	3.32E+00	-7.10E-01
P5	-3.63E+00	4.32E+00	8.31E-01
P6	-9.36E-01	2.56E+00	-7.18E-01
P7	-1.89E+00	2.15E+00	-2.00E+00
P8	-2.79E+00	2.75E+00	-7.48E-01
P9	-3.63E+00	2.22E+00	3.56E-01
P10	-3.12E+00	2.05E+00	9.17E-01
P11	-1.46E+00	2.75E+00	-3.90E-01

Figure IX-5. Block Geometry Information for Block #5



Block ID	#6		
Simulation	Cases 35 and 58 for 1×10^{-7} event		
Block Size (tonnes)	8.0		
Corner Point ID	X	Y	Z
P1	-2.74E-01	4.85E+00	-1.27E+00
P2	3.86E-01	4.68E+00	-1.56E+00
P3	1.94E+00	3.89E+00	7.29E-02
P4	1.38E+00	3.95E+00	8.38E-01
P5	2.00E+00	2.79E+00	-8.05E-02
P6	1.78E+00	2.77E+00	-3.66E-01
P7	4.58E-01	2.81E+00	-1.90E+00
P8	-3.16E-01	2.86E+00	-1.58E+00
P9	1.41E+00	2.80E+00	7.30E-01

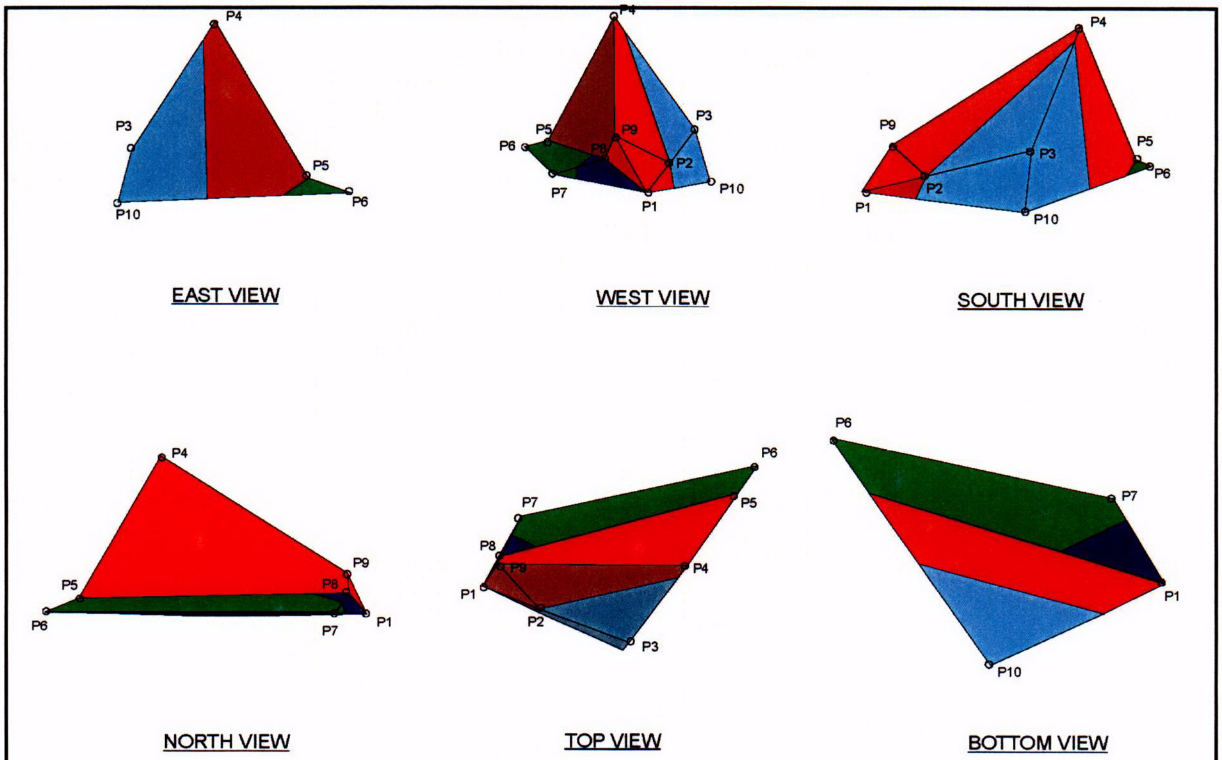
Figure IX-6. Block Geometry Information for Block #6



Block ID	#7		
Simulation	Case 78 for 1×10^{-7} event		
Block Size (tonnes)	7.0		
Corner Point ID	X	Y	Z
P1	-1.05E+01	5.30E+00	-2.45E+00
P2	-7.65E+00	5.45E+00	-3.51E+00
P3	-7.10E+00	4.51E+00	-3.09E+00
P4	-1.01E+01	4.31E+00	-1.94E+00
P5	-6.86E+00	2.04E+00	-3.62E+00
P6	-9.70E+00	2.75E+00	-2.60E+00
P7	-1.01E+01	2.75E+00	-2.44E+00
P8	-1.00E+01	2.75E+00	-2.24E+00
P9	-9.34E+00	2.75E+00	-2.50E+00

Figure IX-7. Block Geometry Information for Block #7

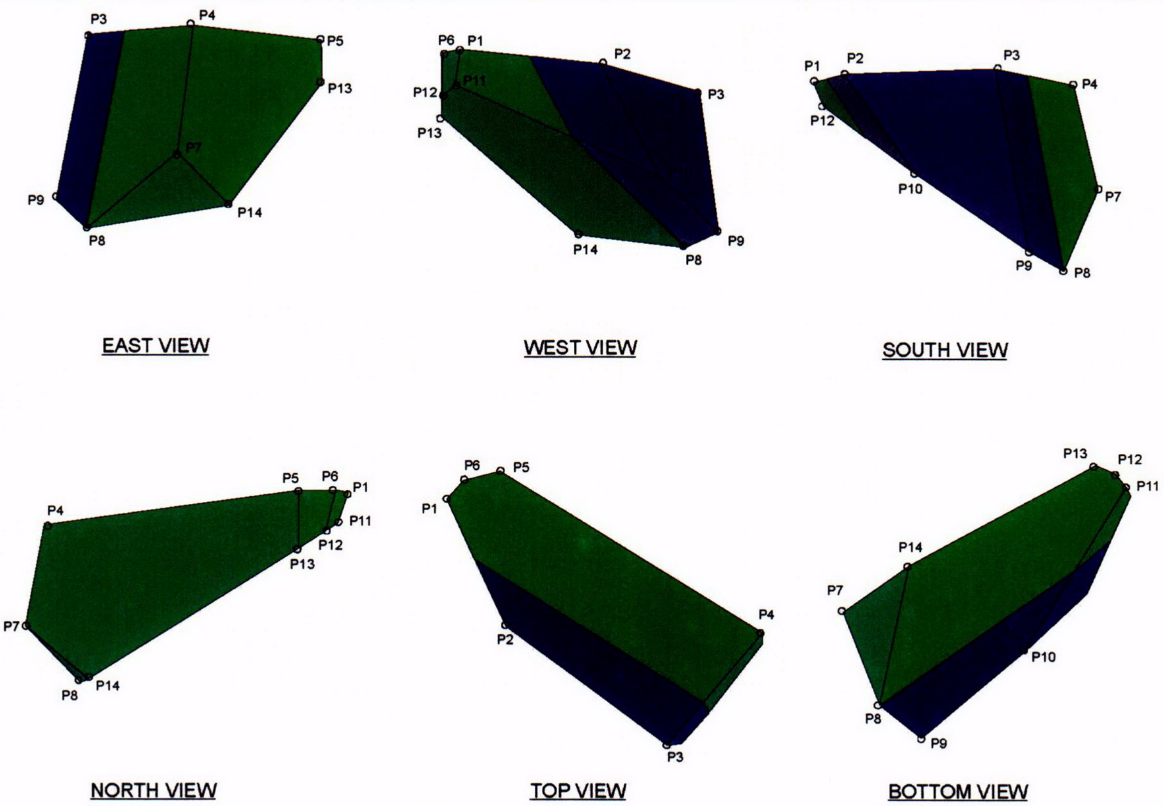
C127



Block ID	#8		
Simulation	Case 80 for both $1{\times}10^{-6}$ and $1{\times}10^{-7}$ events		
Block Size (tonnes)	6.4		
Corner Point ID	X	Y	Z
P1	4.87E+00	-2.25E+00	-1.03E+00
P2	5.66E+00	-2.04E+00	-1.33E+00
P3	6.85E+00	-1.72E+00	-1.74E+00
P4	7.46E+00	-2.63E-01	-7.36E-01
P5	8.28E+00	-1.94E+00	2.06E-01
P6	8.56E+00	-2.06E+00	5.79E-01
P7	5.41E+00	-2.13E+00	-9.42E-02
P8	5.17E+00	-1.94E+00	-6.29E-01
P9	5.17E+00	-1.71E+00	-7.28E-01
P10	6.77E+00	-2.37E+00	-1.92E+00

Figure IX-8. Block Geometry Information for Block #8

C128



Block ID	#9		
Simulation	Case 58 for both 1×10^{-6} and 1×10^{-7} events		
Block Size (tonnes)	6.3		
Corner Point ID	X	Y	Z
P1	-2.65E+00	4.52E+00	2.02E+00
P2	-2.19E+00	4.48E+00	9.91E-01
P3	-8.77E-01	4.41E+00	1.73E-02
P4	-9.21E-02	4.38E+00	9.38E-01
P5	-2.23E+00	4.50E+00	2.25E+00
P6	-2.52E+00	4.52E+00	2.17E+00
P7	1.03E-01	3.42E+00	8.24E-01
P8	-3.26E-01	2.80E+00	9.09E-02
P9	-6.39E-01	3.00E+00	-2.10E-01
P10	-1.51E+00	3.57E+00	4.59E-01
P11	-2.56E+00	4.27E+00	2.07E+00
P12	-2.44E+00	4.20E+00	2.19E+00
P13	-2.22E+00	4.06E+00	2.25E+00
P14	-5.38E-01	2.96E+00	1.22E+00

Figure IX-9. Block Geometry Information for Block #9

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ATTACHMENT X

RANDOM SELECTION OF 3DEC MODELING REGION IN A 100-M CUBE FRACTURE NETWORK GENERATED BY FRACMAN

ATTACHMENT X

RANDOM SELECTION OF 3DEC MODELING REGION IN A 100-M CUBE FRACTURE NETWORK GENERATED BY FRACMAN

A random selection of the 3DEC modeling region within a 100-m FracMan fracture network cube was conducted using the random number generation function provided in Microsoft Excel's spreadsheet analysis tools. Each 3DEC modeling region was uniquely determined by choosing the centroid of the modeling block. Random number generator with a uniform distribution in the range of -32.5 to 32.5 was used to generate the x-, y-, and z-coordinate. The range was selected so that the selected region is free of edge effects. The Microsoft Excel inputs for random number generation are shown in Figure X-1.

Table X-1 lists the 105 selected centroid locations. The centroids are projected to the X-Y, X-Z, and Y-Z planes as shown in Figures X-2 to X-4.

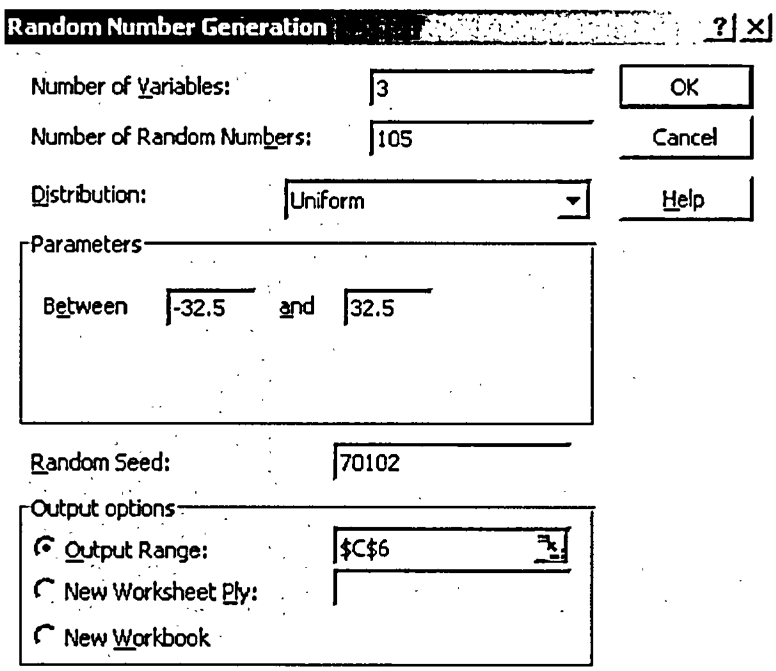

Figure X-1. Microsoft Excel Inputs for Random Number Generation

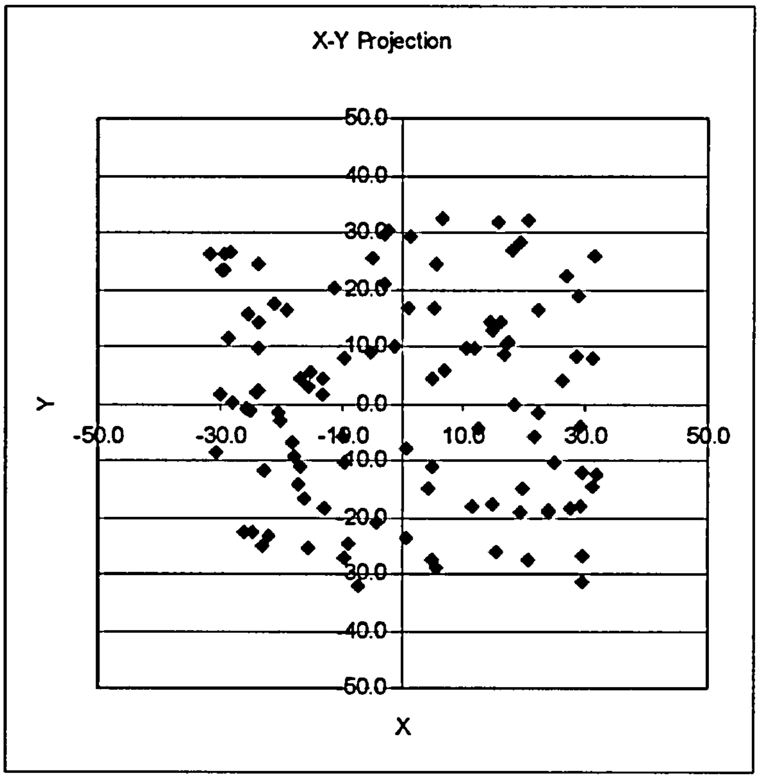

Figure X-2. Centroid Locations Projected to X-Y Plane

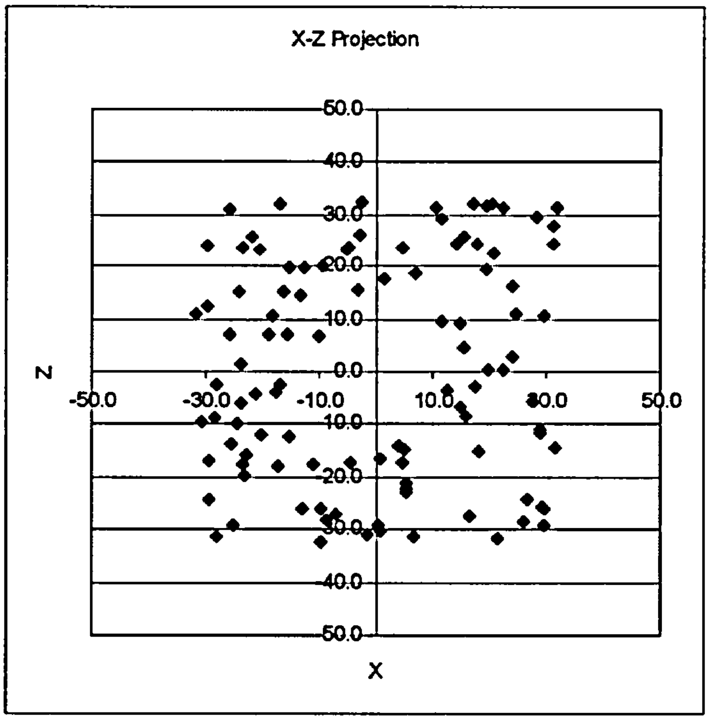

Figure X-3. Centroid Locations Projected to X-Z Plane

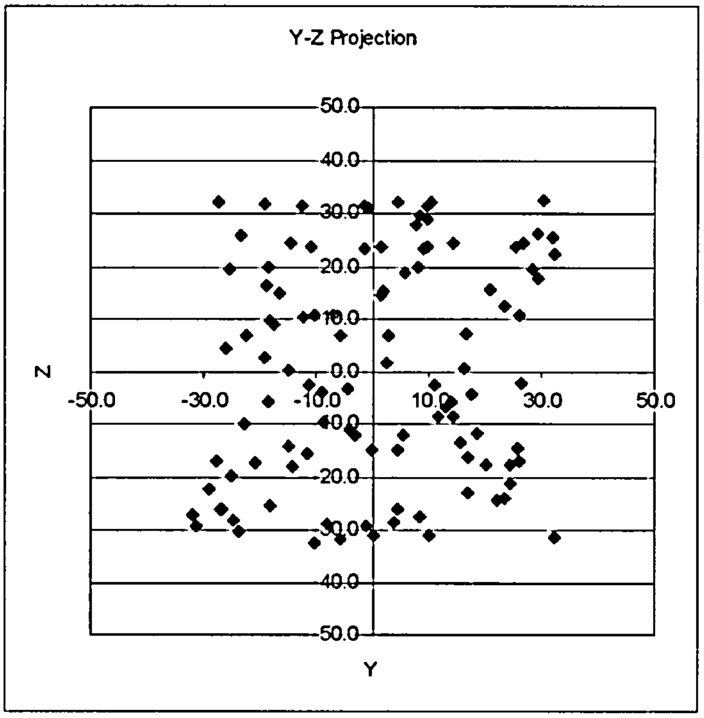

Figure X-4. Centroid Locations Projected to Y-Z Plane

Table X-1. Listing of Fracture Model Region Centroid Coordinates

Model Region	Centroid of Fracture Model Region		
	Xc	Yc	Zc
1	-2.8	29.5	26.0
2	-23.7	2.4	1.5
3	29.5	-26.7	-26.1
4	-16.7	4.5	32.2
5	28.5	8.3	29.6
6	-4.4	-20.8	-17.4
7	-20.2	-3.1	-12.1
8	-23.6	24.4	-17.7
9	-7.2	-32.0	-27.0
10	22.4	16.2	0.4
11	-17.2	-14.2	-18.1
12	-9.7	-27.1	-26.0
13	-21.1	17.5	-4.2
14	24.9	-10.4	10.8
15	19.5	28.3	19.4
16	-15.3	5.5	-12.3
17	-28.1	0.3	-31.2
18	10.6	9.8	31.5
19	-2.3	30.2	32.4
20	14.8	-17.7	9.0

Table X-1. Listing of Fracture Model Region Centroid Coordinates (Continued)

Model Region	Centroid of Fracture Model Region		
	Xc	Yc	Zc
21	-15.6	2.9	6.9
22	-25.3	15.5	-13.6
23	-16.8	-11.2	-2.6
24	18.3	0.0	-15.0
25	17.1	10.3	32.0
26	31.9	-12.6	31.3
27	27.6	-18.6	-5.8
28	21.6	-5.8	-31.9
29	-23.6	14.0	-5.9
30	6.6	32.3	-31.4
31	-3.1	20.7	15.4
32	-11.1	20.0	-17.7
33	-29.4	26.2	-16.9
34	-1.4	10.0	-31.0
35	-31.5	26.1	10.7
36	4.8	-11.1	23.7
37	6.9	5.7	18.8
38	29.6	-31.4	-29.3
39	-25.1	-1.1	-29.3
40	16.0	14.2	-8.6
41	29.2	-4.1	-11.0
42	26.8	22.2	-24.3
43	-13.3	1.5	14.4
44	14.4	14.2	24.3
45	-29.2	23.4	-24.2
46	5.5	24.4	-21.1
47	18.0	26.9	24.4
48	19.8	-14.9	0.3
49	-18.1	-6.9	10.6
50	14.9	12.9	-6.8
51	11.7	9.5	29.1
52	29.3	-18.2	-25.5
53	-15.3	-25.5	19.6
54	-29.5	23.5	12.3
55	-25.6	-1.0	30.9
56	4.3	-15.1	-14.1
57	16.7	8.5	-27.5
58	-22.7	-11.6	-15.7
59	15.7	31.8	25.6
60	0.6	-8.0	-29.1
61	-4.8	25.4	23.7
62	31.2	7.7	27.9

Table X-1. Listing of Fracture Model Region Centroid Coordinates (Continued)

Model Region	Centroid of Fracture Model Region		
	Xc	Yc	Zc
63	-16.1	-16.7	15.0
64	-9.6	-10.4	-32.4
65	-25.9	-22.5	6.9
66	29.0	18.6	-11.7
67	-23.0	-25.1	-19.7
68	1.0	16.8	-16.4
69	-20.6	-1.4	23.4
70	12.7	-4.4	-3.4
71	-9.8	-5.8	6.8
72	-8.8	-24.7	-28.2
73	-24.6	-22.7	-9.9
74	20.7	32.2	22.4
75	-19.0	16.4	7.1
76	23.9	-19.0	2.8
77	24.1	-18.8	16.3
78	-9.4	7.9	20.0
79	-24.1	1.9	15.2
80	26.2	3.9	-28.7
81	17.5	10.8	-2.7
82	-5.2	8.9	23.2
83	5.3	16.8	-23.1
84	19.4	-19.3	31.9
85	22.4	-1.6	31.4
86	20.6	-27.4	32.1
87	11.6	-18.2	9.5
88	-17.6	-9.2	-4.0
89	31.6	25.8	-14.4
90	31.2	-14.7	24.5
91	-28.5	11.6	-8.8
92	-30.6	-8.7	-9.7
93	29.7	-12.2	10.5
94	-28.2	26.5	-2.4
95	-13.0	4.3	-26.2
96	-29.8	1.6	23.9
97	15.5	-26.1	4.6
98	4.9	4.3	-14.7
99	1.4	29.3	17.8
100	4.8	-27.6	-17.1
101	-23.6	9.7	23.7
102	-12.7	-18.5	19.9
103	0.8	-23.8	-30.4
104	5.5	-29.0	-22.3
105	-22.0	-23.3	25.8

ATTACHMENT XI

LISTING OF IMPACT INFORMATION PREDICTED FROM 3DEC ANALYSES

ATTACHMENT XI

LISTING OF IMPACT INFORMATION PREDICTED FROM 3DEC ANALYSES

A listing of direct outputs from 3DEC, including block impact information, is provided in Tables XI-1, XI-2, and XI-3 for 1×10^{-6}, 1×10^{-7}, and 5×10^{-4} ground motion levels, respectively. Also, Table XI-4 provides block impact information for the static case. The direct outputs include block volume, x, y and z components of the impact velocity, and the x-, y- and z-coordinate of the impact location based on the drip shield local coordinate system (note that the definition of the drip shield local coordinate system is provided in Section 6.3.1.2.3). The impact velocity is the relative velocity against the drip shield. Additional information was generated based on the 3DEC direct outputs: block mass, velocity magnitude, impact angle, impact momentum, and impact energy. Block mass was calculated from block volume times saturated bulk density (2.41 g/cc). The magnitude of velocity is simply the square root of the square sum of the three velocity components. Impact angle (defined in Section 6.3.1.2.3) is obtained using the Microsoft Excel functions IF and ATAN2 with the following formula:

IF(ATAN2(z,y)*180/3.14<0, 360+ATAN2(z,y)*180/3.14, ATAN2(z,y)*180/3.14) (Eq. XI-1)

where the z and y are the impact location coordinates in the z- and y-axis, respectively.

This formula ensures the calculated impact angle is within 0° to 360°. The impact momentum and impact energy are calculated based on the following equations:

Impact momentum = block mass x velocity (Eq. XI-2)

Impact energy = 0.5 x block mass x $(\text{velocity})^2$. (Eq. XI-3)

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
1	15	1.99E-02	6.80E-01	-2.72E+00	-1.99E+00	-1.91E+00	-5.49E-01	1.27E+00	0.05	3.44	337	165	284
2	15	1.96E-02	-2.45E-02	1.16E+00	2.64E+00	5.45E+00	-9.09E-01	-1.27E+00	0.05	2.88	216	136	196
3	15	1.28E-01	9.62E-01	-1.59E+00	-1.73E+00	-7.65E-01	-8.36E-03	1.27E+00	0.31	2.54	360	783	995
4	17	1.01E-02	-3.06E+00	-4.14E+00	-2.02E-01	3.62E+00	1.44E+00	-3.51E-01	0.02	5.15	104	126	324
5	18	1.95E-02	-2.53E-01	-9.94E-01	2.23E+00	-5.74E+00	-4.02E-01	-1.23E+00	0.05	2.45	198	115	141
6	20	1.15E-02	-5.01E-01	-1.93E+00	1.96E+00	-5.11E+00	1.38E+00	-1.24E+00	0.03	2.79	132	78	108
7	20	9.10E-02	-7.93E-01	-2.39E+00	9.10E-01	-6.22E+00	1.44E+00	-1.01E+00	0.22	2.68	125	588	789
8	20	1.37E+00	-9.20E-01	-3.75E+00	8.24E-02	-6.07E+00	1.44E+00	-1.27E+00	3.31	3.86	131	12788	24712
9	21	3.82E-01	2.80E-01	4.77E-01	-1.16E+00	-8.97E+00	-9.97E-01	1.27E+00	0.92	1.29	322	1188	764
10	23	3.58E-01	-5.41E-01	1.60E-01	5.61E-01	9.29E+00	-1.44E+00	-1.27E+00	0.86	0.80	229	688	274
11	23	1.89E-01	8.53E-01	-9.35E-01	9.04E-01	-1.25E+00	3.19E-02	-1.27E+00	0.46	1.56	179	711	553
12	23	5.66E-01	-2.20E-01	7.62E-02	-1.04E-02	-1.09E+00	-1.44E+00	1.27E+00	1.37	0.23	311	318	37
13	23	1.72E-01	-1.16E+00	-1.67E-01	9.24E-02	1.09E+01	-1.06E+00	-1.91E-01	0.41	1.18	260	489	288
14	23	1.76E-02	-1.91E+00	-9.52E-01	1.01E+00	9.71E+00	-6.38E-01	-1.27E+00	0.04	2.36	207	100	118
15	24	6.00E-02	-7.04E-01	-2.16E+00	-1.92E+00	9.91E+00	1.44E+00	5.40E-01	0.14	2.97	70	431	641
16	25	1.81E-01	2.06E-01	-2.09E+00	2.83E-02	3.85E+00	1.44E+00	-1.26E+00	0.44	2.10	131	915	961
17	25	1.68E-02	-2.96E-01	-3.96E+00	1.62E+00	3.94E+00	9.34E-01	-1.27E+00	0.04	4.29	144	173	372
18	27	1.85E+00	2.85E-01	-2.73E+00	8.10E-01	9.32E-01	1.44E+00	-1.27E+00	4.45	2.86	131	12757	18267
19	28	2.91E-02	-2.23E+00	-3.11E+00	-2.37E+00	-7.97E+00	1.43E+00	1.26E+00	0.07	4.50	49	316	711
20	31	3.23E-02	-4.33E-01	-2.28E+00	-1.69E+00	4.64E-01	1.44E+00	-4.70E-01	0.08	2.87	108	223	321
21	31	7.49E-02	2.61E-01	-3.59E+00	-1.17E+00	3.43E+00	1.43E+00	1.27E+00	0.18	3.78	49	683	1292
22	31	2.33E-02	-3.10E+00	-2.30E+00	-1.92E+00	1.55E+00	1.44E+00	4.40E-01	0.06	4.31	73	243	523
23	31	1.90E-02	2.55E-01	-2.04E+00	1.72E-02	2.69E+00	1.43E+00	8.93E-01	0.05	2.05	58	94	97
24	31	5.25E-01	9.85E-01	-4.89E+00	-4.98E-02	-8.04E+00	1.44E+00	1.26E+00	1.27	4.99	49	6321	15774

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
25	32	1.52E-01	-2.36E-01	-6.27E+00	-1.12E-01	4.34E+00	1.44E+00	-3.84E-01	0.37	6.27	105	2304	7225
26	32	2.85E-02	4.07E-01	-4.77E+00	9.91E-01	5.31E+00	1.44E+00	8.12E-01	0.07	4.89	61	336	822
27	32	9.34E-02	-3.08E-01	-6.35E+00	-5.15E-01	5.39E+00	1.44E+00	5.90E-01	0.23	6.38	68	1437	4582
28	32	2.46E-02	-8.22E-01	-3.15E+00	3.24E-01	3.51E+00	1.44E+00	-7.86E-01	0.06	3.27	119	194	317
29	32	1.63E-02	4.25E-01	-1.80E+00	-4.32E-04	5.34E+00	1.44E+00	-8.81E-01	0.04	1.85	122	73	67
30	32	1.66E-01	7.55E-01	-4.52E+00	-9.30E-01	4.13E+00	1.44E+00	-8.22E-01	0.40	4.67	120	1872	4376
31	32	2.99E-02	-8.22E-01	-2.50E+00	2.06E+00	-2.50E+00	1.43E+00	-1.20E+00	0.07	3.34	130	241	402
32	32	1.68E-02	-1.50E+00	-1.12E+00	-3.08E-01	3.62E+00	1.44E+00	-6.07E-01	0.04	1.89	113	77	72
33	32	4.49E-01	-5.67E-01	-6.43E+00	-2.39E-01	4.90E+00	1.44E+00	-5.33E-01	1.08	6.46	110	7001	22618
34	32	1.29E-01	-5.19E-01	-3.95E+00	-6.86E-01	4.78E+00	1.44E+00	-9.80E-01	0.31	4.04	124	1256	2541
35	33	1.41E-01	-2.55E+00	5.46E-01	3.15E+00	2.39E+00	-1.10E+00	-1.26E+00	0.34	4.10	221	1390	2846
36	33	7.08E-02	8.46E-01	-4.29E+00	-2.37E+00	-2.46E+00	1.34E+00	1.22E+00	0.17	4.98	48	850	2117
37	33	2.43E-02	-2.57E+00	3.17E+00	3.75E+00	2.04E+00	5.02E-01	-1.27E+00	0.06	5.54	158	325	900
38	33	6.02E-02	5.68E-01	-1.49E+00	2.16E+00	1.76E+00	1.44E+00	-7.57E-01	0.15	2.68	118	390	523
39	35	3.14E-01	-8.74E-01	-4.58E+00	1.88E+00	6.01E+00	9.73E-01	-1.27E+00	0.76	5.03	143	3812	9585
40	35	1.50E-01	6.21E-01	-6.98E-01	-2.47E-01	3.11E+00	1.44E+00	-8.00E-01	0.36	0.97	119	349	169
41	35	9.46E-02	-2.12E-01	-2.98E+00	2.13E+00	5.29E+00	1.06E+00	-1.27E+00	0.23	3.67	140	837	1535
42	35	6.14E-02	-9.65E-01	-4.26E+00	9.82E-01	3.23E+00	1.44E+00	-9.20E-01	0.15	4.47	123	663	1482
43	35	5.08E-02	-8.64E-01	1.21E+00	2.25E+00	4.66E+00	-2.51E-01	-1.27E+00	0.12	2.69	191	330	444
44	35	1.22E-02	7.99E-01	-3.38E+00	2.94E+00	4.25E+00	1.44E+00	3.13E-01	0.03	4.55	78	134	305
45	35	1.43E-01	-1.08E-01	-3.64E+00	1.01E+00	1.72E+00	1.44E+00	2.94E-01	0.34	3.78	79	1299	2455
46	35	1.55E+00	-3.75E-01	2.36E-01	1.38E+00	4.98E+00	7.57E-01	-1.27E+00	3.75	1.45	149	5445	3957
47	35	1.16E-01	-4.54E-01	-2.91E+00	2.56E+00	6.86E+00	1.44E+00	-1.27E+00	0.28	3.90	131	1091	2126
48	35	2.83E-01	-1.30E+00	-3.08E-01	3.69E+00	1.70E+00	1.44E+00	6.33E-01	0.68	3.92	66	2678	5251

Table XI-1. Impact Information for $1x10^{-6}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
49	35	8.72E-02	4.14E-01	-4.44E+00	-1.30E-01	3.56E+00	1.44E+00	8.15E-01	0.21	4.47	61	939	2097
50	35	1.87E-02	-2.72E-03	-4.47E+00	1.11E+00	3.40E+00	1.44E+00	1.08E+00	0.05	4.60	53	207	477
51	35	1.30E-02	-4.35E-01	-3.86E+00	-1.33E+00	4.01E+00	1.41E+00	-1.26E+00	0.03	4.10	132	128	263
52	35	9.86E-02	-3.38E-01	-5.39E+00	2.01E+00	5.48E+00	1.44E+00	-3.20E-01	0.24	5.77	103	1372	3956
53	35	3.12E-01	-1.20E+00	1.92E-01	4.16E-01	5.32E+00	1.44E+00	2.46E-01	0.75	1.29	80	968	622
54	35	2.40E-01	-8.70E-01	-2.98E+00	5.75E+00	3.20E+00	1.44E+00	4.46E-01	0.58	6.53	73	3774	12321
55	35	8.14E-01	-1.83E+00	-4.11E+00	2.43E+00	4.06E+00	1.38E+00	-1.26E+00	1.96	5.12	133	10043	25694
56	35	3.14E-01	-3.31E-01	-2.59E-01	6.92E-01	5.77E+00	1.41E+00	-1.13E+00	0.76	0.81	129	612	248
57	35	1.24E-01	1.12E+00	-2.80E+00	2.33E+00	3.38E+00	1.44E+00	-4.14E-01	0.30	3.81	106	1137	2164
58	35	2.07E-02	1.07E+00	-3.61E+00	1.78E+00	5.00E+00	1.44E+00	-7.67E-01	0.05	4.16	118	208	433
59	35	9.73E-01	-2.18E-01	-4.63E+00	-1.51E-01	2.66E+00	1.44E+00	8.11E-02	2.35	4.64	87	10891	25265
60	35	7.23E-02	-2.34E+00	-2.92E+00	6.79E-01	3.01E+00	1.44E+00	-8.06E-01	0.17	3.80	119	663	1261
61	35	1.08E-02	1.11E+00	-5.07E+00	1.02E+00	4.03E+00	1.44E+00	-1.26E+00	0.03	5.29	131	137	364
62	35	8.78E-01	-8.96E-01	-1.35E+00	1.43E+00	5.29E+00	-1.29E+00	-1.27E+00	2.12	2.16	225	4573	4941
63	35	9.24E-02	3.10E-01	-3.09E+00	3.48E+00	6.39E+00	1.44E+00	-1.08E+00	0.22	4.66	127	1039	2423
64	35	8.36E-01	1.06E+00	-4.56E+00	-1.71E+00	7.16E+00	1.44E+00	-1.27E+00	2.02	4.98	131	10043	25009
65	35	5.52E-01	-1.37E-01	-1.11E+00	3.28E+00	4.74E+00	7.85E-01	-1.27E+00	1.33	3.46	148	4613	7990
66	35	1.29E-02	2.68E+00	1.46E+00	3.62E+00	8.56E+00	-7.94E-01	-1.27E+00	0.03	4.73	212	147	349
67	35	5.05E-01	-7.66E-01	-4.15E+00	1.32E+00	3.10E+00	1.44E+00	-1.49E-01	1.22	4.42	96	5388	11907
68	35	9.17E-01	-2.93E-01	-9.62E-01	7.64E-01	3.96E+00	1.44E+00	-6.27E-01	2.21	1.26	114	2793	1765
69	35	1.05E-01	9.94E-01	-2.48E+00	1.31E+00	5.42E+00	1.39E+00	-1.25E+00	0.25	2.98	132	757	1127
70	35	2.98E-01	-2.76E+00	-2.00E+00	8.96E-01	4.18E+00	1.41E+00	-1.20E+00	0.72	3.53	130	2536	4474
71	35	1.71E-01	-2.08E+00	-3.84E+00	1.22E+00	5.37E+00	1.44E+00	-4.10E-01	0.41	4.53	106	1865	4226
72	35	3.13E-02	-3.75E-01	-1.45E+00	7.03E-01	5.31E+00	1.44E+00	-4.75E-01	0.08	1.65	108	125	103

Table XI-1. Impact Information for $1x10^{-6}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
73	36	3.44E-01	1.11E-01	1.32E-01	-1.43E-01	2.59E+00	-1.44E+00	1.27E+00	0.83	0.22	311	186	21
74	36	1.92E-02	7.93E-01	1.52E+00	6.95E-01	7.22E-01	-1.19E+00	-1.27E+00	0.05	1.85	223	86	79
75	36	1.56E-02	2.14E-01	9.23E-01	-3.73E-01	5.08E+00	-1.38E+00	9.46E-01	0.04	1.02	304	38	20
76	36	6.82E-02	5.12E-01	2.02E+00	3.93E-01	5.29E+00	-1.43E+00	7.00E-01	0.16	2.12	296	348	369
77	36	1.48E-01	-1.80E-01	5.14E-01	-5.05E-01	3.99E+00	-1.44E+00	1.27E+00	0.36	0.74	311	265	98
78	36	1.42E-02	9.17E-01	-2.36E+00	-1.08E+00	1.58E+00	1.43E+00	-1.26E+00	0.03	2.76	131	94	130
79	36	2.27E-02	9.22E-01	-4.14E+00	-2.29E+00	-3.10E-01	1.34E+00	1.12E+00	0.05	4.83	50	265	639
80	36	1.58E-02	6.77E-01	-4.33E+00	9.98E-01	3.49E+00	1.44E+00	-5.91E-01	0.04	4.49	112	171	385
81	36	1.52E-02	1.64E-01	5.71E-01	6.47E-01	8.27E-01	-1.44E+00	-1.51E-02	0.04	0.88	269	32	14
82	36	1.83E-01	-1.58E-01	1.42E+00	-2.52E-01	4.04E+00	-1.44E+00	1.27E+00	0.44	1.45	311	643	467
83	36	5.99E-02	-3.99E-01	-1.30E+00	1.43E-01	1.43E+00	1.44E+00	-1.11E+00	0.14	1.36	128	197	134
84	37	5.68E-02	-1.84E+00	-1.07E+00	2.51E+00	-6.90E+00	1.21E+00	-1.27E+00	0.14	3.29	136	450	740
85	37	7.24E-02	-4.09E+00	2.09E+00	1.17E+00	-6.26E+00	-2.35E-01	-1.27E+00	0.17	4.74	190	828	1961
86	37	1.72E-01	-1.36E+00	-2.15E+00	2.25E+00	-4.57E+00	8.10E-01	-1.27E+00	0.42	3.40	147	1410	2396
87	37	1.88E-02	-1.03E-01	-4.05E-01	1.92E+00	-6.12E+00	1.00E+00	-1.27E+00	0.05	1.97	142	89	88
88	37	9.63E-02	6.59E-01	7.62E-01	4.81E-01	-7.70E+00	-9.88E-01	-1.27E+00	0.23	1.12	218	259	145
89	37	1.63E-01	-1.52E+00	-2.05E+00	1.14E+00	-6.77E+00	6.76E-01	-1.27E+00	0.39	2.80	152	1098	1535
90	39	6.12E-02	1.33E+00	-3.09E+00	-9.55E-01	-8.60E+00	1.40E+00	-1.24E+00	0.15	3.49	132	516	902
91	42	2.85E-01	-8.68E-01	-5.32E+00	1.36E+00	5.36E+00	1.33E+00	-1.21E+00	0.69	5.56	132	3829	10654
92	42	1.55E-02	-6.69E-01	3.66E+00	1.60E+00	5.78E+00	7.11E-01	-1.27E+00	0.04	4.05	151	151	307
93	43	7.01E-02	1.13E+00	-2.32E+00	9.35E-01	-7.71E+00	1.44E+00	2.60E-01	0.17	2.75	80	465	638
94	43	1.42E-01	-3.34E-01	-8.78E-01	-2.06E+00	-6.93E+00	-9.20E-01	1.27E+00	0.34	2.27	324	777	880
95	43	5.56E-01	1.37E+00	3.02E-01	-1.03E+00	-2.93E+00	-7.27E-01	1.27E+00	1.34	1.74	330	2332	2030
96	43	2.44E+00	1.03E+00	1.77E-02	-1.74E+00	-6.29E+00	-6.11E-01	1.27E+00	5.88	2.02	334	11899	12036

Table XI-1. Impact Information for $1x10^{-6}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg-m/sec)	Impact Energy (J)
97	43	2.70E-01	-1.99E-01	5.35E-01	-6.34E-01	-5.22E+00	5.28E-01	1.27E+00	0.65	0.85	23	555	237
98	44	1.04E-01	-1.91E+00	-2.44E+00	-1.65E+00	-4.23E+00	1.44E+00	5.16E-01	0.25	3.51	70	876	1538
99	44	1.62E-02	-4.06E-02	-2.25E+00	-4.34E+00	-7.09E+00	-7.88E-01	1.27E+00	0.04	4.89	328	192	469
100	44	6.22E-02	-4.15E-02	-4.55E+00	-9.57E-02	-3.67E+00	1.42E+00	1.26E+00	0.15	4.55	48	683	1556
101	45	2.46E-01	-1.93E+00	-2.93E+00	6.83E-01	4.34E-01	1.44E+00	1.01E+00	0.59	3.57	55	2123	3790
102	45	1.14E-02	-1.58E+00	-2.27E+00	1.33E-01	-6.04E-01	1.44E+00	-1.27E+00	0.03	2.77	131	76	105
103	45	3.02E-02	-1.37E+00	-4.33E+00	-1.92E+00	3.60E-01	1.44E+00	3.64E-01	0.07	4.93	76	359	885
104	45	2.95E-02	1.35E+00	-2.23E+00	-2.69E-01	2.12E-01	1.41E+00	-1.24E+00	0.07	2.62	132	186	244
105	45	9.52E-02	-6.29E-01	-3.63E+00	4.91E-01	2.67E+00	1.44E+00	-8.12E-01	0.23	3.72	119	854	1587
106	45	1.05E-01	-2.47E-01	-2.31E+00	-2.51E+00	1.22E+00	1.44E+00	-3.07E-01	0.25	3.42	102	864	1478
107	45	1.63E-02	-1.23E+00	-3.48E+00	1.91E+00	-9.10E-01	1.44E+00	1.06E+00	0.04	4.15	54	163	339
108	45	1.13E+00	-1.75E+00	-3.37E+00	-8.46E-01	-4.14E-02	1.44E+00	1.27E+00	2.71	3.89	49	10555	20525
109	45	5.56E-01	-1.50E+00	-3.97E+00	-1.41E+00	6.79E-01	1.44E+00	3.25E-01	1.34	4.47	77	5990	13386
110	45	4.98E-01	1.42E+00	-3.68E+00	-1.94E-01	2.65E+00	1.44E+00	1.42E-01	1.20	3.95	84	4743	9374
111	45	2.75E-02	-6.41E-01	-1.64E+00	-2.64E-01	1.19E-01	1.42E+00	-1.24E+00	0.07	1.78	131	118	105
112	45	3.95E-01	-1.71E+00	-1.40E+00	-1.26E-01	3.32E-02	1.44E+00	-7.56E-01	0.95	2.21	118	2104	2325
113	45	5.09E-02	-4.06E-01	-3.33E+00	7.58E-01	-6.75E-01	1.44E+00	-8.00E-01	0.12	3.44	119	422	726
114	45	1.51E-01	-1.28E+00	-5.98E+00	6.36E-01	-1.49E+00	1.44E+00	8.02E-01	0.36	6.15	61	2243	6893
115	45	2.65E-02	2.75E+00	-3.80E+00	1.16E+00	-2.52E-01	1.43E+00	-1.10E+00	0.06	4.83	128	308	744
116	45	6.88E-02	-1.37E-01	-3.28E+00	-1.59E+00	-2.44E-01	1.26E+00	-1.24E+00	0.17	3.64	135	604	1101
117	45	2.38E-02	1.05E+00	-1.70E+00	8.88E-01	-2.52E-01	1.44E+00	-8.77E-01	0.06	2.18	121	125	137
118	45	4.94E-01	-1.96E+00	-3.70E+00	-1.04E+00	-1.48E-01	1.34E+00	1.22E+00	1.19	4.31	48	5141	11089
119	45	1.49E-02	-1.55E+00	-5.65E+00	1.94E+00	-6.01E-01	1.44E+00	-5.89E-01	0.04	6.17	112	222	685
120	45	1.86E-01	-7.93E-01	-4.99E+00	9.72E-01	-1.21E+00	1.44E+00	4.94E-01	0.45	5.15	71	2312	5949

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
121	45	1.01E-02	1.44E+00	-1.57E+00	-1.02E+00	1.11E-01	1.43E+00	-1.17E+00	0.02	2.36	129	57	68
122	45	7.52E-02	-9.34E-01	-4.78E+00	-1.49E+00	1.31E+00	1.44E+00	-1.79E-01	0.18	5.09	97	924	2353
123	45	2.10E-02	-2.35E+00	-1.89E+00	-4.75E-01	5.83E-01	1.44E+00	-1.33E-02	0.05	3.05	91	154	235
124	45	1.32E-01	-3.73E-01	-1.90E+00	2.96E-01	-3.56E-02	1.44E+00	-1.26E+00	0.32	1.96	131	624	611
125	45	2.49E-02	1.81E+00	-2.76E+00	5.16E-01	2.01E+00	1.44E+00	-2.04E-01	0.06	3.34	98	201	336
126	45	1.12E-02	1.41E-01	-4.46E+00	7.02E-01	1.08E+00	1.44E+00	-3.08E-01	0.03	4.51	102	122	275
127	45	1.01E-02	1.74E+00	4.51E-01	1.12E+00	2.64E-01	1.44E+00	-6.24E-01	0.02	2.11	113	52	55
128	45	3.07E-02	1.89E+00	-3.84E+00	8.02E-01	7.81E-01	1.44E+00	-7.03E-01	0.07	4.35	116	322	702
129	45	8.49E-02	6.67E-01	-3.42E+00	9.63E-01	-4.63E-02	1.44E+00	-4.18E-01	0.20	3.61	106	740	1337
130	45	5.64E-01	-1.33E+00	-5.14E+00	-7.68E-01	-9.69E-01	1.44E+00	1.27E+00	1.36	5.37	49	7304	19603
131	45	3.22E-01	-1.60E+00	-5.40E+00	-1.10E+00	-3.45E-01	1.44E+00	1.27E+00	0.78	5.74	49	4464	12816
132	45	3.67E-02	-7.42E-02	-1.26E+00	5.30E-01	6.25E-01	1.44E+00	-5.26E-01	0.09	1.37	110	121	82
133	45	7.40E-02	-2.48E+00	-3.29E+00	-4.05E+00	1.61E+00	1.44E+00	5.63E-01	0.18	5.78	69	1030	2976
134	45	3.34E-02	-6.43E-01	-3.89E+00	2.67E-01	8.19E-01	1.44E+00	-5.07E-01	0.08	3.95	109	318	629
135	45	1.80E+00	-1.92E-01	-1.80E+00	1.48E-01	1.44E+00	1.40E+00	-1.26E+00	4.35	1.82	132	7908	7191
136	46	4.29E-02	-3.44E+00	-4.54E+00	7.87E-01	6.84E+00	1.44E+00	6.00E-01	0.10	5.75	67	596	1713
137	47	3.19E-02	-2.95E-02	-7.47E+00	1.48E-01	-5.25E+00	1.41E+00	1.26E+00	0.08	7.47	48	574	2146
138	47	4.82E-02	3.65E-01	-6.69E+00	-1.48E-01	-4.70E+00	1.44E+00	8.45E-01	0.12	6.70	60	780	2612
139	48	2.68E-01	-3.84E-01	7.17E-01	3.03E+00	4.25E+00	5.67E-02	-1.27E+00	0.65	3.14	178	2025	3175
140	49	2.78E-01	7.67E-06	-2.22E+00	1.79E+00	5.39E+00	-6.88E-01	-1.27E+00	0.67	2.85	208	1911	2724
141	49	2.78E-01	-7.10E-01	4.48E-01	-4.16E-01	6.94E+00	-1.41E+00	-1.25E+00	0.67	0.94	228	629	295
142	49	1.63E-01	6.92E-01	-2.09E+00	9.40E-01	-3.51E+00	-1.43E+00	-1.24E+00	0.39	2.39	229	941	1124
143	50	3.15E-01	5.00E-01	-3.44E+00	-1.72E+00	-8.99E+00	1.44E+00	3.56E-01	0.76	3.88	76	2941	5699
144	51	1.05E-02	-3.44E-01	-1.33E+00	2.36E+00	5.31E+00	-1.09E+00	-1.27E+00	0.03	2.73	221	69	94

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
145	51	1.03E+00	-4.07E-01	-1.52E+00	-1.57E-01	7.62E+00	1.44E+00	-1.27E+00	2.47	1.58	131	3906	3084
146	51	2.79E-02	-5.79E-02	-7.65E-01	-2.28E-01	8.31E+00	1.44E+00	-6.33E-01	0.07	0.80	114	54	22
147	52	5.62E-01	4.20E-01	-4.94E-01	-1.33E-01	-4.34E+00	1.44E+00	-1.27E+00	1.36	0.66	131	897	297
148	52	1.85E-02	-3.62E-01	-2.97E+00	-1.71E-01	-2.89E+00	1.44E+00	6.02E-01	0.04	3.00	67	134	200
149	54	6.18E-02	-1.18E+00	-3.47E+00	-8.51E-01	-1.08E+01	1.34E+00	1.03E+00	0.15	3.77	52	562	1058
150	54	3.04E-02	-7.52E-01	-2.92E+00	1.52E+00	-9.00E+00	7.10E-01	-1.27E+00	0.07	3.38	151	248	419
151	54	6.47E-02	-9.25E-01	-4.01E+00	-2.12E+00	-1.02E+01	7.22E-01	1.27E+00	0.16	4.63	30	722	1673
152	55	1.63E-02	-2.28E+00	-4.42E+00	6.77E-01	8.16E-01	1.44E+00	1.03E+00	0.04	5.02	55	197	493
153	55	2.04E+00	-4.91E-01	-2.45E+00	4.41E-01	2.90E+00	1.44E+00	-7.88E-01	4.92	2.53	119	12465	15793
154	55	8.87E-02	3.45E+00	-4.25E+00	1.28E+00	4.94E+00	1.44E+00	1.27E+00	0.21	5.62	49	1202	3376
155	55	2.32E+00	8.44E-01	-4.77E+00	-3.23E-01	1.09E+00	1.44E+00	9.96E-01	5.61	4.85	55	27194	65957
156	55	1.08E+00	7.78E-01	-3.49E+00	-1.56E-01	9.04E-01	1.44E+00	1.27E+00	2.59	3.58	49	9282	16600
157	55	2.88E-01	-4.52E-01	9.02E-01	1.88E+00	7.34E+00	-9.40E-01	-1.27E+00	0.70	2.14	217	1485	1585
158	55	1.11E-01	2.07E+00	9.85E-02	1.98E+00	7.82E+00	1.03E-01	-1.27E+00	0.27	2.86	175	767	1099
159	55	1.05E-01	-1.47E+00	-1.76E+00	1.70E-01	2.19E+00	1.44E+00	-5.28E-02	0.25	2.30	92	582	670
160	55	1.06E-01	-2.28E+00	-5.85E+00	1.35E+00	1.95E+00	1.44E+00	-5.16E-01	0.25	6.42	110	1637	5254
161	55	1.58E+00	-1.08E-01	-4.83E+00	-6.34E-01	4.17E-01	1.44E+00	1.27E+00	3.82	4.87	49	18611	45345
162	55	3.79E-01	6.72E-01	-3.22E+00	-5.58E-01	2.48E+00	1.44E+00	1.27E+00	0.91	3.34	49	3049	5091
163	55	7.58E-02	-2.63E+00	-3.51E+00	1.33E+00	1.21E+00	1.43E+00	-1.26E+00	0.18	4.59	132	838	1921
164	55	3.13E-01	-2.86E-01	-9.68E-01	1.77E-01	2.66E+00	1.44E+00	1.07E+00	0.75	1.02	53	773	396
165	55	4.64E-02	6.49E-01	-1.21E+00	-8.09E-02	2.17E+00	1.44E+00	1.03E+00	0.11	1.38	54	154	106
166	55	2.00E+00	-3.54E-02	-1.75E+00	1.59E-01	1.15E+00	1.44E+00	-1.27E+00	4.83	1.76	131	8492	7470
167	55	3.50E-01	-1.26E+00	-3.68E+00	1.27E+00	3.54E+00	1.44E+00	-1.04E-01	0.84	4.09	94	3449	7055
168	55	5.20E-02	6.74E-01	-5.60E-01	3.23E-01	2.53E+00	1.44E+00	-7.27E-01	0.13	0.93	117	117	55

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
169	55	1.20E+00	-2.19E-01	-3.51E+00	1.56E+00	6.15E+00	1.44E+00	-1.27E+00	2.89	3.85	131	11131	21409
170	55	3.45E-01	5.15E-02	-1.53E+00	2.27E+00	6.30E+00	1.44E+00	-1.26E+00	0.83	2.74	131	2278	3123
171	55	3.72E-01	-2.36E+00	-3.01E+00	1.48E+00	7.64E+00	1.34E+00	-1.24E+00	0.90	4.10	133	3679	7541
172	55	1.19E-01	1.82E+00	-1.76E+00	2.32E+00	7.66E+00	1.34E+00	-1.11E+00	0.29	3.43	130	983	1686
173	58	7.43E-02	7.07E-01	-1.18E-01	1.30E+00	-6.96E+00	-1.43E+00	-1.15E+00	0.18	1.49	231	266	198
174	58	1.43E-01	9.08E-01	-3.41E+00	-1.77E+00	-1.86E+00	1.44E+00	-1.08E+00	0.34	3.94	127	1355	2672
175	58	9.69E-02	1.07E+00	-3.69E+00	-1.38E+00	-1.60E+00	1.44E+00	-1.06E+00	0.23	4.08	126	955	1948
176	58	8.35E-01	1.16E+00	-5.50E+00	8.71E-01	-6.29E-01	1.44E+00	-3.22E-02	2.01	5.69	91	11471	32652
177	58	1.72E-01	-9.01E-02	-3.53E+00	3.05E-01	-2.89E+00	1.44E+00	-7.45E-02	0.41	3.54	93	1465	2594
178	58	6.13E-01	2.12E+00	-4.97E+00	1.13E+00	-1.95E+00	1.39E+00	1.23E+00	1.48	5.52	48	8159	22506
179	58	2.27E-02	9.03E-01	-1.69E+00	-1.60E+00	2.83E-02	1.34E+00	1.26E+00	0.05	2.49	47	136	170
180	58	6.19E-01	-6.14E-01	-1.92E+00	-1.02E+00	-2.08E+00	1.44E+00	-1.08E+00	1.49	2.26	127	3375	3812
181	58	4.67E-01	2.02E+00	-3.21E+00	8.36E-01	-4.54E-01	1.44E+00	2.90E-01	1.13	3.89	79	4385	8527
182	58	1.21E-01	-5.66E-01	-5.36E+00	-5.40E-01	-2.77E+00	1.44E+00	8.86E-01	0.29	5.41	58	1585	4288
183	58	3.71E+00	-9.99E-01	-2.23E+00	-4.19E-01	-2.18E+00	1.24E+00	1.19E+00	8.95	2.48	46	22171	27458
184	58	3.41E-01	5.99E-01	-4.82E+00	-4.11E-02	-1.31E+00	1.44E+00	5.89E-01	0.82	4.86	68	3989	9683
185	58	4.28E-02	7.63E-01	-5.78E+00	-2.55E-02	-5.70E-01	1.40E+00	1.26E+00	0.10	5.83	48	603	1758
186	58	1.06E+00	-7.38E-01	-4.36E+00	5.54E-01	-3.05E+00	1.36E+00	1.23E+00	2.55	4.45	48	11354	25278
187	58	1.04E-02	1.06E+00	1.65E-01	-4.56E-01	-8.04E+00	-1.44E+00	1.27E+00	0.02	1.17	311	29	17
188	58	2.38E-01	4.67E-01	-3.95E+00	8.03E-02	-1.70E+00	1.44E+00	-5.90E-01	0.57	3.98	112	2281	4538
189	58	1.15E-01	7.40E-01	-7.39E+00	1.41E+00	-8.13E-01	1.44E+00	-5.54E-01	0.28	7.56	111	2103	7948
190	58	1.44E+00	2.10E+00	-1.86E+00	1.62E+00	-3.19E+00	1.44E+00	-1.27E+00	3.48	3.23	131	11242	18182
191	58	6.02E+00	2.92E-02	-4.69E+00	6.56E-01	-4.94E+00	1.44E+00	-1.27E+00	14.53	4.74	131	68840	163083
192	58	2.36E+00	-7.35E-02	1.20E-01	1.12E+00	-3.39E+00	1.44E+00	-1.27E+00	5.68	1.13	131	6403	3608

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
193	58	3.19E-02	-4.11E+00	-1.97E+00	-1.24E+00	-1.00E+00	1.39E+00	8.46E-01	0.08	4.73	59	364	861
194	58	9.65E-01	1.21E+00	-5.07E+00	1.97E+00	-2.48E+00	1.44E+00	1.88E-01	2.33	5.57	83	12969	36127
195	58	6.35E-02	1.83E+00	-1.38E+00	1.78E+00	-8.60E-01	1.44E+00	-4.00E-01	0.15	2.90	106	444	645
196	58	1.99E-01	-1.73E+00	-4.53E+00	1.73E+00	-1.52E+00	1.44E+00	-1.26E+00	0.48	5.15	131	2473	6362
197	58	1.12E-01	1.06E+00	-2.50E+00	1.89E+00	-1.70E+00	1.44E+00	8.31E-02	0.27	3.31	87	894	1479
198	58	1.07E+00	-1.09E+00	-2.07E+00	1.73E+00	-1.18E+00	1.43E+00	-1.13E+00	2.58	2.91	128	7502	10910
199	58	1.19E+00	-6.92E-02	-3.36E+00	-2.34E+00	-3.46E+00	1.44E+00	-9.07E-01	2.87	4.09	122	11753	24052
200	58	2.76E-02	3.64E-01	-7.27E-01	-1.04E+00	-4.10E+00	1.38E+00	8.37E-01	0.07	1.32	59	88	58
201	58	2.45E-01	3.97E-01	-3.15E+00	-4.02E-01	-7.10E-01	1.44E+00	4.40E-01	0.59	3.20	73	1888	3020
202	58	4.73E-01	-9.65E-01	-4.75E+00	1.29E+00	-7.84E-01	1.41E+00	-1.27E+00	1.14	5.02	132	5733	14395
203	58	1.07E+00	1.64E+00	-3.14E+00	1.12E+00	2.10E-01	1.44E+00	-6.99E-01	2.58	3.71	116	9589	17809
204	58	2.59E+00	-4.30E-01	-1.33E+00	-1.51E-02	-4.80E-02	1.44E+00	7.16E-02	6.26	1.40	87	8761	6135
205	58	1.21E-01	-8.09E-02	-5.51E+00	-1.19E+00	3.59E-01	1.44E+00	-1.08E+00	0.29	5.63	127	1645	4633
206	58	7.35E-01	-6.96E-01	-3.03E+00	2.25E+00	-1.05E+00	1.44E+00	1.05E+00	1.77	3.84	54	6806	13064
207	58	2.26E+00	5.23E-02	-3.54E+00	1.16E+00	-2.65E+00	1.44E+00	-1.27E+00	5.45	3.72	131	20310	37816
208	58	1.42E+00	1.14E+00	-3.15E+00	1.34E+00	-2.94E+00	1.44E+00	9.77E-01	3.42	3.61	56	12340	22246
209	58	1.28E-01	-2.60E+00	-1.22E+00	-9.54E-01	-3.60E+00	1.44E+00	2.79E-01	0.31	3.03	79	931	1408
210	58	8.88E+00	-1.14E+00	-1.77E+00	4.00E-01	-2.54E+00	1.42E+00	1.25E+00	21.42	2.14	49	45899	49184
211	58	1.37E-02	1.76E+00	-4.70E+00	-6.98E-01	3.12E-01	1.44E+00	1.03E-01	0.03	5.07	86	167	424
212	58	8.36E-01	2.24E+00	-2.68E+00	3.71E-01	-4.71E-01	1.44E+00	7.63E-01	2.02	3.51	62	7080	12427
213	58	7.15E-01	7.28E-01	-2.30E+00	-2.65E-01	-2.11E-01	1.44E+00	1.85E-02	1.72	2.43	89	4188	5089
214	58	9.14E-02	-1.12E+00	-3.79E+00	1.29E-01	-3.61E-01	1.44E+00	-6.38E-01	0.22	3.96	114	873	1728
215	58	1.31E-02	1.31E+00	-5.87E+00	-9.52E-01	-8.43E-01	1.44E+00	1.03E+00	0.03	6.09	55	193	587
216	58	5.03E-01	1.38E+00	-4.66E+00	-2.09E-01	-1.23E+00	1.38E+00	-1.26E+00	1.21	4.87	132	5913	14395

Table XI-1. Impact Information for $1x10^{-6}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
217	59	1.60E-02	-2.52E-01	-4.11E+00	-1.90E+00	-1.00E+01	1.44E+00	-1.08E+00	0.04	4.54	127	175	397
218	59	2.83E-02	-8.40E-02	-8.66E-01	-4.51E-01	-4.70E+00	1.44E+00	-2.30E-01	0.07	0.98	99	67	33
219	59	2.79E-02	-3.66E-01	-2.42E+00	-7.30E-02	-9.32E+00	1.44E+00	-8.38E-01	0.07	2.45	120	165	202
220	59	1.71E-02	1.97E+00	-7.58E-01	2.05E+00	-8.00E+00	-3.61E-01	-1.27E+00	0.04	2.94	196	121	178
221	60	2.89E-02	-9.20E-01	6.76E-02	2.88E+00	-3.88E-01	-9.49E-01	-1.27E+00	0.07	3.02	217	211	319
222	60	1.84E-01	-3.11E-01	7.19E-01	5.05E-01	-9.23E-01	-1.44E+00	-1.27E+00	0.44	0.93	229	413	192
223	64	2.38E-02	-1.72E+00	-4.80E+00	-4.97E-01	-8.79E+00	1.44E+00	2.67E-01	0.06	5.13	80	294	754
224	64	1.23E-02	-5.73E-01	-1.62E+00	4.84E+00	-8.41E+00	-2.04E-01	-1.27E+00	0.03	5.13	189	153	392
225	64	4.98E-02	-1.83E+00	-1.70E+00	1.32E+00	-8.75E+00	-9.66E-01	-1.27E+00	0.12	2.82	217	339	478
226	64	9.18E-01	1.26E+00	-6.10E+00	-1.14E+00	-7.49E+00	1.44E+00	-1.27E+00	2.21	6.33	131	14021	44404
227	64	6.42E-02	-1.34E+00	-5.17E+00	-5.41E-01	-8.25E+00	1.27E+00	-1.20E+00	0.15	5.36	134	830	2226
228	66	2.69E-02	-1.26E+00	6.56E-01	-1.52E+00	-2.25E+00	-1.42E+00	1.26E+00	0.06	2.08	311	135	140
229	66	1.39E-01	-3.63E-01	-1.04E-01	-1.18E+00	-4.61E-01	-6.58E-01	1.27E+00	0.34	1.24	333	417	259
230	66	1.05E-01	7.89E-04	-1.37E-02	1.03E-02	-8.82E-01	1.34E+00	1.09E+00	0.25	0.02	51	4	0
231	66	7.53E-01	-7.26E-01	1.51E-01	-6.56E-01	-2.06E+00	-1.44E+00	1.27E+00	1.82	0.99	311	1797	890
232	66	2.68E-02	2.11E+00	-8.28E-01	-3.19E+00	-9.03E+00	6.98E-01	1.27E+00	0.06	3.92	29	253	496
233	67	2.01E-02	-1.09E+00	4.94E-02	7.97E-01	9.02E+00	-9.02E-01	-1.27E+00	0.05	1.35	215	65	44
234	68	5.65E-02	8.84E-01	1.05E+00	-1.69E+00	4.97E+00	-1.95E-01	1.27E+00	0.14	2.18	351	297	323
235	68	1.26E-02	3.11E+00	4.27E-01	-3.16E+00	4.62E+00	8.29E-01	1.27E+00	0.03	4.46	33	135	301
236	68	2.86E-02	-1.62E-01	2.52E-01	-8.43E-03	4.81E+00	-1.41E+00	1.26E+00	0.07	0.30	312	21	3
237	68	4.26E-02	1.88E+00	-2.04E+00	-1.79E+00	4.35E+00	6.84E-01	1.27E+00	0.10	3.31	28	340	562
238	68	3.06E-02	1.23E+00	-1.39E+00	-1.79E+00	4.18E+00	1.11E+00	1.27E+00	0.07	2.58	41	190	245
239	69	6.07E-02	-1.04E+00	-7.15E+00	-1.16E+00	-1.22E+00	1.44E+00	7.84E-02	0.15	7.32	87	1071	3921
240	69	4.26E-01	5.88E-01	-5.01E+00	-4.52E-01	2.10E+00	1.43E+00	1.27E+00	1.03	5.06	49	5206	13176

Table XI-1. Impact Information for 1×10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
241	69	2.07E+00	-5.00E-01	-2.80E+00	4.92E-01	-5.30E+00	1.44E+00	-1.26E+00	5.00	2.89	131	14467	20915
242	69	1.76E-01	-1.27E+00	-4.11E+00	1.99E+00	-3.85E+00	1.42E+00	1.26E+00	0.42	4.74	48	2009	4762
243	70	1.84E-02	-1.19E-01	-3.83E+00	-2.55E-01	-1.90E+00	1.44E+00	1.11E+00	0.04	3.84	53	170	327
244	71	4.31E-02	-4.68E-01	-6.13E+00	-1.19E+00	1.44E-01	1.18E-01	1.27E+00	0.10	6.26	5	651	2038
245	71	2.88E-02	1.15E+00	1.75E-01	4.18E-02	-3.96E-01	-1.34E+00	1.15E+00	0.07	1.16	311	81	47
246	72	1.73E-01	4.27E-01	-3.89E-01	1.15E+00	-6.12E+00	7.67E-01	-1.27E+00	0.42	1.28	149	536	344
247	72	2.35E-02	-4.56E-01	-6.60E-01	6.62E-01	-5.66E+00	-1.44E+00	-1.26E+00	0.06	1.04	229	59	31
248	72	2.92E-02	2.85E-02	4.99E-01	7.76E-01	-3.84E-01	-1.44E+00	-6.81E-01	0.07	0.92	245	65	30
249	72	2.72E-01	-1.63E-01	4.75E-01	9.55E-02	-6.31E+00	-1.44E+00	-1.27E+00	0.66	0.51	229	335	86
250	72	1.49E-01	-6.73E-02	2.23E-01	-5.73E-02	3.74E-01	-1.44E+00	1.27E+00	0.36	0.24	311	86	10
251	72	1.06E-02	8.98E-01	-2.21E+00	-2.92E+00	-9.52E+00	1.11E-01	1.27E+00	0.03	3.77	5	96	181
252	73	1.33E-01	-3.74E-01	-5.87E+00	1.68E+00	7.57E+00	1.32E+00	-1.26E+00	0.32	6.12	134	1958	5989
253	75	6.85E-02	-4.92E-01	-1.12E+00	-1.75E+00	-4.48E+00	-4.53E-01	1.27E+00	0.17	2.14	340	353	378
254	75	3.98E-02	1.90E-02	-2.09E+00	2.67E-01	-7.14E+00	1.43E+00	-1.10E+00	0.10	2.11	128	203	214
255	75	3.50E-01	-7.51E-01	-4.08E+00	-6.69E-01	-7.37E+00	1.38E+00	-1.18E+00	0.84	4.20	131	3545	7444
256	75	4.40E-02	-3.50E-01	-3.11E+00	-4.63E-02	-8.32E+00	1.44E+00	-9.10E-01	0.11	3.13	122	332	518
257	76	1.73E-02	1.28E+00	-1.43E+00	8.03E-01	4.72E-01	-2.98E-02	-1.27E+00	0.04	2.08	181	87	90
258	77	6.67E-02	-1.47E+00	-9.03E-01	-2.50E+00	-6.36E-01	5.66E-01	1.27E+00	0.16	3.04	24	488	742
259	77	1.26E-02	1.34E-01	-3.31E+00	-2.27E+00	-9.10E+00	1.34E+00	1.26E+00	0.03	4.02	47	122	246
260	77	2.89E-02	-3.45E-01	-4.00E+00	-1.52E+00	-8.13E+00	9.67E-01	1.27E+00	0.07	4.29	37	299	641
261	77	6.66E-02	7.79E-01	-2.16E+00	-1.20E+00	-7.93E+00	1.06E+00	1.27E+00	0.16	2.59	40	416	540
262	77	1.85E-02	-1.15E+00	-4.16E+00	-1.13E+00	-9.25E+00	1.43E+00	1.22E+00	0.04	4.46	49	199	445
263	77	2.08E-01	1.02E+00	-3.82E+00	1.71E+00	4.08E+00	1.54E-01	-1.27E+00	0.50	4.31	173	2158	4649
264	78	2.17E-01	4.76E-01	1.06E+00	-4.33E+00	3.61E+00	1.65E-01	1.27E+00	0.52	4.48	7	2350	5264

Table XI-1. Impact Information for 1x10^{-6} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
265	80	7.40E-02	-3.00E-01	1.98E+00	-7.73E-01	6.12E+00	-1.20E-01	1.27E+00	0.18	2.15	355	383	411
266	80	1.52E-01	8.64E-01	-4.61E+00	6.32E-01	5.31E+00	1.44E+00	-4.88E-01	0.37	4.73	109	1733	4097
267	80	4.71E-02	-7.46E-01	-2.02E-01	-3.83E-01	3.31E+00	-1.29E+00	1.27E+00	0.11	0.86	314	98	42
268	80	6.48E-02	-7.94E-01	-2.05E+00	-7.66E-01	1.08E+01	1.36E+00	-2.74E-01	0.16	2.32	101	363	422
269	80	2.64E+00	-1.68E+00	3.68E-01	-1.07E+00	5.28E+00	-1.32E+00	1.27E+00	6.38	2.03	314	12931	13113
270	80	6.38E-02	3.44E-01	3.69E-01	-4.61E-02	3.73E+00	-1.33E+00	1.27E+00	0.15	0.51	314	78	20
271	81	3.23E-02	1.04E+00	2.31E+00	-5.23E+00	-7.68E+00	1.02E+00	1.27E+00	0.08	5.81	39	453	1315
272	81	2.73E-02	-1.02E-01	-4.59E+00	-1.24E+00	-7.75E+00	8.32E-01	1.27E+00	0.07	4.75	33	313	743
273	83	1.14E-02	-2.35E+00	-2.68E+00	6.20E-01	9.05E+00	1.35E+00	-1.08E+00	0.03	3.62	129	99	180
274	84	3.23E-01	6.17E-02	3.48E-01	-3.63E-01	8.63E+00	-1.44E+00	1.27E+00	0.78	0.51	311	395	100
275	85	1.06E-02	-7.84E-01	-3.15E+00	1.47E+00	-5.34E+00	-8.47E-01	-1.27E+00	0.03	3.56	214	91	162
276	85	3.58E-02	4.48E-01	-2.99E+00	1.66E+00	-5.15E+00	-8.95E-01	-1.27E+00	0.09	3.45	215	298	513
277	85	1.39E+00	2.36E-01	-1.13E+00	2.71E-01	6.73E+00	1.34E+00	-1.23E+00	3.35	1.18	133	3958	2339
278	85	1.83E-01	3.39E-01	-5.38E+00	7.36E-01	-6.15E+00	1.38E+00	-9.41E-01	0.44	5.44	124	2395	6512
279	85	1.44E-01	-2.77E-01	-4.65E+00	-1.15E-01	-6.39E+00	1.43E+00	-1.26E+00	0.35	4.66	131	1622	3781
280	88	1.86E-02	-5.76E-01	-4.88E-01	-2.46E+00	2.96E+00	2.93E-01	1.27E+00	0.04	2.58	13	115	149
281	88	1.56E-02	7.98E-01	-4.55E-01	1.33E+00	-8.33E+00	1.59E-01	-1.27E+00	0.04	1.62	173	61	49

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg-m/sec)	Impact Energy (J)
1	EC58	7.43E-02	-1.37E+00	1.65E+00	1.25E+00	-6.96E+00	-1.34E+00	-1.17E+00	0.18	2.49	229	445	553
2	EC58	1.12E+00	3.09E+00	-5.49E+00	-8.13E-01	-3.01E+00	1.43E+00	-1.07E+00	2.70	6.35	127	17155	54492
3	EC58	7.75E-01	-5.73E-01	-5.97E+00	1.22E+00	-3.45E+00	1.44E+00	6.17E-01	1.87	6.12	67	11438	35002
4	EC58	1.43E-01	4.69E+00	-5.63E+00	-2.24E+00	-5.98E-01	1.44E+00	-7.54E-01	0.34	7.67	118	2635	10098
5	EC58	9.69E-02	4.33E+00	7.52E+00	9.87E+00	-3.70E-01	3.49E-01	-1.27E+00	0.23	13.15	165	3073	20200
6	EC58	8.35E-01	1.29E+00	-3.46E+00	-9.76E-01	-9.60E-01	1.44E+00	3.27E-02	2.01	3.82	89	7696	14699
7	EC58	6.13E-01	3.31E+00	-8.04E+00	5.86E-01	-4.33E+00	1.44E+00	-1.72E-01	1.48	8.71	97	12888	56151
8	EC58	2.27E-02	-2.43E+00	2.33E-01	-6.23E-01	-2.07E+00	-8.92E-02	1.27E+00	0.05	2.52	356	138	174
9	EC58	6.19E-01	2.12E+00	-3.52E+00	-7.31E-01	5.54E-01	1.44E+00	-6.51E-03	1.49	4.18	90	6239	13030
10	EC58	4.67E-01	1.53E+00	-4.26E+00	-3.41E+00	-1.20E-01	1.44E+00	3.19E-01	1.13	5.66	78	6384	18071
11	EC58	1.21E-01	2.46E-01	-8.16E-01	-3.61E+00	-5.15E+00	1.44E+00	1.21E+00	0.29	3.71	50	1087	2017
12	EC58	3.71E+00	-1.59E+00	-4.94E+00	1.63E+00	-2.03E+00	1.34E+00	1.24E+00	8.95	5.44	47	48697	132457
13	EC58	3.41E-01	2.07E+00	-2.37E+00	-2.65E+00	-2.80E+00	1.44E+00	7.37E-01	0.82	4.11	63	3377	6943
14	EC58	4.28E-02	3.30E+00	-5.03E+00	-3.50E-01	8.25E-01	1.44E+00	2.72E-01	0.10	6.03	79	623	1876
15	EC58	1.04E-02	-5.82E-01	2.45E-01	-7.02E-01	-7.79E+00	-1.43E+00	1.26E+00	0.02	0.94	311	24	11
16	EC58	3.32E+00	-4.94E-01	-3.09E+00	1.15E+00	-4.02E+00	1.44E+00	-6.42E-01	8.01	3.33	114	26698	44514
17	EC58	1.15E-01	5.77E-01	-6.08E+00	7.80E-01	-4.91E-01	1.44E+00	-3.55E-01	0.28	6.15	104	1713	5271
18	EC58	1.44E+00	-1.42E+00	-2.77E+00	2.32E+00	-4.27E+00	1.34E+00	-1.27E+00	3.48	3.88	133	13496	26203
19	EC58	6.02E+00	5.56E-02	-2.93E+00	3.24E-01	-3.49E+00	1.44E+00	-1.27E+00	14.53	2.95	131	42807	63061
20	EC58	2.36E+00	-2.06E+00	-4.55E+00	1.88E+00	-4.04E+00	1.44E+00	-1.26E+00	5.68	5.34	131	30329	80944
21	EC58	3.19E-02	2.42E-02	-5.50E+00	5.51E-01	5.44E-02	1.39E+00	1.24E+00	0.08	5.53	48	426	1176
22	EC58	4.17E-02	3.10E+00	-8.81E+00	1.92E+00	-6.46E-01	1.44E+00	5.91E-01	0.10	9.54	68	959	4570
23	EC58	9.65E-01	1.15E+00	-5.01E+00	7.69E-01	-4.22E+00	1.44E+00	-1.10E+00	2.33	5.20	127	12097	31431
24	EC58	6.35E-02	5.06E+00	-4.15E+00	5.43E+00	5.40E-01	1.44E+00	7.16E-01	0.15	8.51	64	1302	5539

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
25	EC58	1.99E-01	-4.88E+00	-5.58E+00	1.51E+00	-1.19E+00	1.44E+00	-1.17E+00	0.48	7.56	129	3635	13745
26	EC58	1.12E-01	7.59E+00	-7.04E+00	2.52E+00	2.09E-01	1.44E+00	1.80E-01	0.27	10.65	83	2875	15312
27	EC58	1.07E+00	-1.17E+00	-5.85E+00	3.21E+00	-1.40E+00	1.29E+00	-1.21E+00	2.58	6.78	133	17476	59204
28	EC58	1.19E+00	-1.66E+00	-8.77E+00	1.29E+00	-2.90E+00	1.44E+00	7.32E-01	2.87	9.02	63	25892	116734
29	EC58	2.76E-02	4.33E+00	-8.29E+00	2.56E+00	-5.39E+00	1.44E+00	-8.53E-01	0.07	9.69	121	646	3131
30	EC58	2.45E-01	-4.50E-01	4.97E-03	-5.50E-01	-5.51E-01	1.44E+00	-1.99E-01	0.59	0.71	98	419	149
31	EC58	4.73E-01	5.68E+00	-4.94E+00	3.50E+00	1.33E-01	1.44E+00	-9.55E-01	1.14	8.30	124	9480	39363
32	EC58	1.07E+00	1.62E+00	-2.78E+00	-3.24E-01	3.63E-01	1.44E+00	-6.96E-01	2.58	3.23	116	8350	13505
33	EC58	2.59E+00	1.80E+00	-1.40E+00	2.55E+00	-4.47E-01	1.44E+00	6.52E-01	6.26	3.42	66	21400	36606
34	EC58	1.21E-01	6.49E+00	-5.15E+00	-1.04E+00	2.57E+00	1.44E+00	-5.91E-01	0.29	8.35	112	2437	10177
35	EC58	7.35E-01	6.61E+00	-8.68E+00	1.16E+00	-4.89E-01	1.33E+00	-1.25E+00	1.77	10.97	133	19447	106654
36	EC58	2.26E+00	-2.25E+00	-2.58E+00	2.45E+00	-2.90E+00	1.44E+00	-1.26E+00	5.45	4.21	131	22975	48390
37	EC58	1.42E+00	2.63E+00	-2.44E+00	1.40E+00	-1.89E+00	1.44E+00	-8.48E-01	3.42	3.85	120	13188	25406
38	EC58	4.59E+00	-1.27E-01	-2.05E+00	7.65E-01	-3.98E+00	1.43E+00	-1.19E+00	11.07	2.19	130	24279	26623
39	EC58	1.28E-01	2.80E+00	-6.90E+00	3.41E+00	-4.08E+00	1.40E+00	1.26E+00	0.31	8.19	48	2519	10315
40	EC58	8.88E+00	-1.59E-02	-1.56E+00	9.13E-01	-2.70E+00	1.43E+00	1.26E+00	21.42	1.81	49	38728	35016
41	EC58	1.37E-02	1.22E+01	-5.25E+00	-1.98E+00	7.39E-01	1.43E+00	1.04E+00	0.03	13.41	54	443	2967
42	EC58	8.36E-01	4.21E+00	-8.35E+00	-1.16E+00	-1.42E+00	1.38E+00	2.59E-01	2.02	9.42	79	19002	89530
43	EC58	7.15E-01	3.73E-01	-1.24E+00	1.95E+00	-7.94E-01	1.44E+00	-8.09E-01	1.72	2.34	119	4027	4705
44	EC58	9.14E-02	6.60E+00	-3.88E+00	4.76E+00	1.64E+00	1.44E+00	-6.87E-01	0.22	9.01	116	1987	8956
45	EC58	1.31E-02	-2.43E-01	-4.75E+00	-1.34E+00	4.39E-01	1.44E+00	7.34E-01	0.03	4.94	63	156	387
46	EC58	5.03E-01	6.20E+00	-7.59E+00	8.97E-01	-1.38E+00	1.44E+00	-1.18E+00	1.21	9.84	129	11950	58801
47	EC55	1.63E-02	2.35E+00	-5.84E+00	1.47E-01	2.13E+00	1.44E+00	2.79E-03	0.04	6.30	90	247	777
48	EC55	1.04E-01	3.03E+00	-6.78E+00	3.19E+00	7.61E+00	8.89E-01	-1.27E+00	0.25	8.08	145	2033	8216

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg-m/sec)	Impact Energy (J)
49	EC55	1.96E-01	-1.01E+00	-2.52E+00	2.33E+00	6.80E+00	8.37E-01	-1.27E+00	0.47	3.58	147	1694	3033
50	EC55	2.04E+00	-1.40E+00	-3.09E+00	1.97E+00	3.11E+00	1.44E+00	-3.61E-01	4.92	3.93	104	19310	37901
51	EC55	8.87E-02	-5.36E-01	-6.57E+00	1.34E+00	4.66E+00	1.44E+00	-4.35E-01	0.21	6.72	107	1438	4833
52	EC55	2.32E+00	2.32E-01	-5.88E+00	-5.38E-01	1.88E+00	1.44E+00	4.78E-01	5.61	5.91	72	33144	97976
53	EC55	1.08E+00	1.48E+00	-3.74E+00	7.02E-01	1.01E+00	1.37E+00	1.03E+00	2.59	4.09	53	10601	21656
54	EC55	3.82E-01	-1.20E+00	-2.53E+00	-1.80E+00	6.32E-01	1.41E+00	1.22E+00	0.92	3.33	49	3067	5110
55	EC55	2.88E-01	-1.46E+00	-1.26E-01	4.75E+00	7.21E+00	1.44E+00	-1.26E+00	0.70	4.97	131	3456	8587
56	EC55	2.44E-02	-2.76E+00	-3.42E+00	1.76E+00	2.75E+00	-1.11E+00	-1.27E+00	0.06	4.73	221	279	659
57	EC55	5.80E-02	-1.33E+00	4.98E+00	1.80E+00	7.26E+00	-9.41E-02	-1.27E+00	0.14	5.46	184	763	2085
58	EC55	1.11E-01	-1.22E+00	-2.41E+00	2.13E-01	7.28E+00	-8.09E-01	-1.27E+00	0.27	2.71	213	725	982
59	EC55	1.05E-01	2.61E+00	-2.14E+00	1.92E+00	2.68E+00	1.44E+00	-2.32E-01	0.25	3.88	99	980	1903
60	EC55	1.06E-01	1.50E-01	-9.68E+00	1.18E+00	2.86E+00	1.44E+00	-4.80E-01	0.25	9.75	108	2487	12129
61	EC55	1.58E+00	-3.97E+00	-6.14E+00	5.41E-01	9.89E-01	1.44E+00	1.27E+00	3.82	7.33	49	28012	102719
62	EC55	3.79E-01	-8.48E-01	-6.74E+00	3.18E-01	1.52E+00	1.44E+00	1.27E+00	0.91	6.80	49	6209	21108
63	EC55	7.58E-02	1.09E+00	-4.38E+00	6.02E-01	3.03E+00	1.44E+00	6.78E-01	0.18	4.56	65	832	1896
64	EC55	3.13E-01	-5.70E-01	-1.58E+00	3.45E-01	1.66E+00	1.44E+00	6.37E-01	0.75	1.72	66	1295	1111
65	EC55	2.00E+00	-1.34E+00	-6.37E-01	3.22E+00	8.09E-01	1.42E+00	-1.17E+00	4.83	3.55	129	17124	30374
66	EC55	3.50E-01	-3.38E+00	-5.26E+00	6.29E-01	3.06E+00	1.44E+00	-3.37E-01	0.84	6.29	103	5300	16659
67	EC55	8.14E-02	-3.61E-01	-2.50E+00	2.22E+00	3.15E-01	1.15E+00	-1.27E+00	0.20	3.37	138	661	1114
68	EC55	1.11E+00	-1.55E+00	-2.32E+00	2.12E+00	-1.78E-01	1.32E+00	-1.27E+00	2.69	3.50	134	9404	16457
69	EC55	1.20E+00	-1.37E-01	-3.32E+00	1.95E+00	6.17E+00	1.44E+00	-1.26E+00	2.89	3.85	131	11153	21496
70	EC55	3.45E-01	-4.49E-01	-2.14E+00	2.14E+00	6.32E+00	1.44E+00	-1.27E+00	0.83	3.06	131	2545	3896
71	EC55	3.72E-01	-5.75E+00	-2.43E-01	8.82E+00	7.22E+00	1.44E+00	-1.27E+00	0.90	10.53	131	9451	49753
72	EC55	1.19E-01	-1.58E+00	-3.03E+00	3.14E+00	7.27E+00	6.35E-01	-1.27E+00	0.29	4.64	153	1331	3091

Table XI-2. Impact Information for $1x10^{-7}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
73	EC35	3.14E-01	-1.88E+00	-4.82E+00	3.75E+00	4.27E+00	1.25E+00	-1.27E+00	0.76	6.39	135	4847	15498
74	EC35	1.50E-01	-1.09E+00	-3.98E+00	5.56E+00	3.31E+00	1.44E+00	7.38E-02	0.36	6.92	87	2504	8668
75	EC35	9.46E-02	-1.86E+00	-3.39E-01	3.09E+00	5.10E+00	1.44E+00	-1.26E+00	0.23	3.62	131	826	1496
76	EC35	6.14E-02	2.89E+00	-6.16E+00	-2.59E+00	4.46E+00	1.42E+00	-1.25E+00	0.15	7.28	131	1078	3923
77	EC35	5.08E-02	-3.27E-01	-1.75E+00	4.80E+00	5.61E+00	-5.31E-01	-1.27E+00	0.12	5.12	203	627	1606
78	EC35	1.22E-02	1.51E+00	-2.31E+00	-5.44E+00	2.60E+00	1.44E+00	1.26E+00	0.03	6.10	49	180	548
79	EC35	1.55E+00	1.32E-01	-5.33E-01	3.60E+00	4.92E+00	9.84E-01	-1.27E+00	3.75	3.64	142	13642	24837
80	EC35	1.16E-01	-3.95E+00	-9.05E+00	1.62E+00	6.92E+00	1.44E+00	-1.27E+00	0.28	10.01	131	2801	14014
81	EC35	2.83E-01	-7.25E-01	-4.91E+00	5.30E+00	3.21E+00	1.44E+00	2.11E-01	0.68	7.26	82	4958	17999
82	EC35	8.72E-02	-5.18E+00	-5.04E+00	-1.28E+00	2.08E+00	1.44E+00	-4.40E-01	0.21	7.34	107	1544	5664
83	EC35	1.87E-02	4.13E-01	-5.87E+00	2.98E+00	6.12E+00	1.44E+00	1.11E+00	0.05	6.59	52	297	978
84	EC35	1.30E-02	2.80E-01	-5.29E+00	5.95E+00	4.57E+00	1.44E+00	-9.26E-01	0.03	7.97	123	250	994
85	EC35	9.86E-02	-6.30E+00	-7.18E+00	1.83E+00	5.39E+00	1.44E+00	-1.53E-01	0.24	9.72	96	2313	11247
86	EC35	3.12E-01	7.26E-01	-3.15E-02	8.15E-01	5.02E+00	1.44E+00	4.90E-01	0.75	1.09	71	822	449
87	EC35	2.40E-01	-2.57E-01	-6.76E+00	1.84E+00	4.32E+00	1.44E+00	-3.29E-01	0.58	7.01	103	4053	14213
88	EC35	3.32E+00	4.96E-01	-2.34E+00	-1.18E-01	2.05E+00	1.44E+00	4.69E-01	8.01	2.39	72	19165	22938
89	EC35	8.14E-01	-1.28E+00	-1.79E+00	4.92E+00	4.30E+00	1.28E+00	-1.13E+00	1.96	5.39	132	10576	28494
90	EC35	9.54E-01	2.12E-01	-3.67E+00	1.82E-01	1.14E+00	1.44E+00	1.27E+00	2.30	3.68	49	8478	15615
91	EC35	3.14E-01	-1.98E+00	-1.46E+00	2.10E+00	5.09E+00	8.16E-01	-1.27E+00	0.76	3.23	147	2445	3952
92	EC35	1.24E-01	5.51E+00	-3.88E+00	1.13E+00	4.59E+00	1.41E+00	1.24E+00	0.30	6.83	49	2039	6966
93	EC35	2.07E-02	7.69E-01	-3.20E+00	3.47E+00	6.03E+00	1.43E+00	-1.24E+00	0.05	4.79	131	239	572
94	EC35	9.58E-02	8.64E-01	-1.40E+00	-1.10E-02	2.81E+00	1.44E+00	9.68E-01	0.23	1.65	56	380	313
95	EC35	9.73E-01	1.50E+00	-5.24E+00	-1.64E+00	2.77E+00	1.44E+00	-3.04E-01	2.35	5.69	102	13353	37979
96	EC35	7.23E-02	-5.40E+00	-4.34E+00	1.17E-01	1.77E+00	1.44E+00	-1.00E+00	0.17	6.93	125	1207	4179

Table XI-2. Impact Information for 1×10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
97	EC35	1.08E-02	1.21E+00	-2.82E+00	1.64E+00	2.62E+00	1.44E+00	-3.24E-02	0.03	3.48	91	90	157
98	EC35	8.78E-01	-5.18E-01	-3.29E+00	2.15E+00	5.37E+00	-1.18E+00	-1.27E+00	2.12	3.96	223	8391	16632
99	EC35	9.24E-02	-1.28E+00	-4.39E+00	2.75E+00	5.97E+00	1.34E+00	-1.27E+00	0.22	5.34	133	1189	3172
100	EC35	8.36E-01	9.97E-01	-3.05E+00	1.88E+00	6.83E+00	1.43E+00	-9.92E-01	2.02	3.72	125	7498	13939
101	EC35	5.52E-01	-1.35E+00	-2.55E+00	4.93E+00	4.72E+00	9.74E-01	-1.27E+00	1.33	5.71	143	7609	21739
102	EC35	1.29E-02	1.36E+00	-4.29E+00	7.78E+00	6.19E+00	1.44E+00	-1.16E+00	0.03	8.99	129	280	1257
103	EC35	5.05E-01	1.60E+00	-2.31E+00	-3.97E+00	2.10E+00	1.44E+00	4.21E-01	1.22	4.86	74	5926	14407
104	EC35	9.17E-01	-3.32E-01	-2.04E+00	5.84E-01	3.54E+00	1.44E+00	-1.27E+00	2.21	2.14	131	4742	5086
105	EC35	1.05E-01	2.62E+00	-6.53E+00	4.04E+00	7.31E+00	1.44E+00	-1.23E-01	0.25	8.12	95	2061	8364
106	EC35	2.98E-01	9.43E-02	-4.07E+00	-3.66E-04	3.71E+00	1.44E+00	-9.26E-01	0.72	4.07	123	2927	5957
107	EC35	1.71E-01	3.04E+00	-4.24E+00	2.40E-01	6.30E+00	1.44E+00	6.59E-01	0.41	5.22	65	2148	5610
108	EC35	3.13E-02	-2.13E+00	-1.57E+00	1.03E+00	3.78E+00	1.44E+00	-2.21E-01	0.08	2.84	99	215	305
109	EC35	6.97E-01	-1.01E-01	-3.78E+00	-1.87E+00	5.52E+00	1.44E+00	9.60E-01	1.68	4.22	56	7095	14971
110	EC45	2.46E-01	6.04E+00	-5.46E+00	2.48E+00	2.32E+00	1.33E+00	1.24E+00	0.59	8.52	47	5063	21562
111	EC45	1.14E-02	5.63E+00	-3.02E+00	1.79E+00	3.13E+00	1.44E+00	-4.93E-01	0.03	6.64	109	183	607
112	EC45	3.02E-02	-1.02E+00	-4.56E+00	-1.46E+00	5.33E-01	1.44E+00	5.27E-01	0.07	4.89	70	356	871
113	EC45	2.95E-02	1.25E+00	-2.92E+00	-1.39E-01	2.78E-01	1.44E+00	-7.57E-01	0.07	3.18	118	226	359
114	EC45	9.52E-02	-5.85E-01	-4.23E+00	5.81E-01	2.79E+00	1.34E+00	-8.83E-01	0.23	4.31	123	990	2135
115	EC45	1.05E-01	4.23E+00	-2.20E+00	2.49E+00	6.71E-01	1.44E+00	3.27E-01	0.25	5.38	77	1358	3652
116	EC45	1.63E-02	3.92E+00	-3.41E+00	4.56E-01	2.43E+00	1.44E+00	6.95E-01	0.04	5.21	64	205	534
117	EC45	1.13E+00	-4.03E-01	-4.21E+00	-2.95E-01	6.48E-01	1.38E+00	1.24E+00	2.71	4.23	48	11493	24335
118	EC45	5.56E-01	-7.78E-01	-3.98E+00	-1.03E+00	8.23E-01	1.44E+00	5.15E-01	1.34	4.19	70	5610	11741
119	EC45	4.98E-01	1.76E+00	-2.76E+00	-3.10E-01	3.48E+00	1.44E+00	-3.48E-01	1.20	3.29	104	3951	6504
120	EC45	3.95E-01	1.38E+00	-2.25E+00	1.39E-01	5.19E-01	1.44E+00	-1.73E-01	0.95	2.65	97	2518	3331

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
121	EC45	5.09E-02	-4.89E-01	-4.85E+00	-3.56E-01	-6.62E-01	1.44E+00	-1.01E+00	0.12	4.89	125	601	1470
122	EC45	1.51E-01	-7.01E-01	-5.69E+00	2.70E-01	-1.38E+00	1.44E+00	6.29E-01	0.36	5.74	66	2094	6007
123	EC45	2.65E-02	-1.28E+00	-3.86E+00	4.94E+00	-2.05E+00	1.44E+00	-1.09E+00	0.06	6.39	127	409	1307
124	EC45	6.88E-02	-4.69E-01	-4.24E+00	-3.12E-01	-9.17E-02	1.37E+00	-1.19E+00	0.17	4.28	131	710	1517
125	EC45	2.38E-02	-2.24E+00	-1.90E+00	-1.29E+00	1.10E+00	1.44E+00	2.79E-01	0.06	3.21	79	184	295
126	EC45	4.94E-01	-5.42E-01	-4.41E+00	-9.15E-01	-1.10E-01	1.34E+00	1.26E+00	1.19	4.54	47	5408	12268
127	EC45	1.49E-02	4.62E+00	-2.90E+00	7.25E+00	2.64E+00	4.82E-01	-1.27E+00	0.04	9.07	159	326	1477
128	EC45	1.86E-01	1.31E-01	-5.88E+00	-2.82E-02	-1.06E+00	1.44E+00	3.42E-01	0.45	5.88	77	2639	7756
129	EC45	1.01E-02	-3.72E+00	1.66E+00	9.19E-01	1.53E+00	1.44E+00	-1.16E+00	0.02	4.18	129	101	212
130	EC45	7.52E-02	-3.10E-01	-4.55E+00	-1.37E+00	1.37E+00	1.44E+00	-9.73E-02	0.18	4.76	94	864	2059
131	EC45	2.10E-02	-5.61E+00	-1.84E+00	-3.52E-01	-2.96E+00	1.44E+00	-5.71E-01	0.05	5.91	112	299	884
132	EC45	1.99E-02	4.58E-01	-2.63E+00	-3.21E-01	-3.50E-01	1.44E+00	-6.61E-01	0.05	2.68	115	129	173
133	EC45	1.12E-02	-1.02E+00	1.97E-01	1.31E-01	5.32E-02	1.43E+00	-1.25E+00	0.03	1.05	131	28	15
134	EC45	1.01E-02	-4.19E-01	-2.89E+00	2.32E+00	9.00E-01	1.44E+00	7.06E-01	0.02	3.73	64	91	170
135	EC45	3.07E-02	-3.60E+00	8.69E-01	1.26E+00	-2.49E+00	-3.32E-01	-1.27E+00	0.07	3.91	195	289	566
136	EC45	8.49E-02	2.45E-01	-3.56E+00	-7.30E-01	5.67E-01	1.44E+00	7.33E-01	0.20	3.64	63	745	1357
137	EC45	5.64E-01	-1.28E+00	-4.89E+00	-8.12E-01	-9.88E-01	1.44E+00	1.27E+00	1.36	5.12	49	6963	17812
138	EC45	3.22E-01	-1.22E+00	-5.01E+00	-9.80E-01	-4.13E-01	1.44E+00	1.27E+00	0.78	5.25	49	4083	10724
139	EC45	3.67E-02	-4.11E-01	-4.04E-01	2.80E-01	8.15E-01	1.44E+00	-7.01E-01	0.09	0.64	116	57	18
140	EC45	7.40E-02	5.22E-01	-5.40E+00	1.74E+00	1.50E+00	1.44E+00	2.54E-01	0.18	5.69	80	1016	2891
141	EC45	3.34E-02	-3.97E-01	-3.84E+00	-8.48E-01	1.23E+00	1.44E+00	1.71E-01	0.08	3.95	83	318	629
142	EC45	1.80E+00	-5.64E-01	-5.35E+00	-4.81E-01	9.88E-01	1.44E+00	-1.27E+00	4.35	5.40	131	23492	63469
143	EC43	7.01E-02	-7.59E-01	-5.22E+00	-7.79E-01	-8.44E+00	1.44E+00	7.15E-01	0.17	5.33	64	902	2406
144	EC43	1.42E-01	2.64E+00	-1.28E+00	-1.29E+00	-7.14E+00	-1.24E-01	1.27E+00	0.34	3.21	354	1100	1766

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
145	EC43	5.56E-01	4.46E-01	-2.59E+00	-1.65E+00	-2.86E+00	-9.37E-01	1.27E+00	1.34	3.10	323	4160	6457
146	EC43	2.44E+00	1.22E+00	4.81E-01	-2.98E+00	-3.04E+00	-7.84E-01	1.27E+00	5.88	3.25	328	19146	31159
147	EC43	2.70E-01	2.14E+00	3.18E+00	-4.41E+00	-5.58E+00	1.17E+00	1.27E+00	0.65	5.84	43	3799	11090
148	EC43	1.58E+00	2.24E+00	3.23E+00	-3.11E+00	-6.68E+00	1.64E-02	1.27E+00	3.82	5.01	1	19131	47968
149	EC80	7.40E-02	1.82E+00	-9.39E-01	-4.55E+00	5.89E+00	-2.02E-01	1.27E+00	0.18	4.99	351	890	2220
150	EC80	1.52E-01	-1.85E+00	-5.20E+00	-3.73E-01	4.93E+00	1.44E+00	4.48E-01	0.37	5.53	73	2027	5608
151	EC80	4.71E-02	-1.11E+00	1.19E+00	-2.05E+00	3.35E+00	-1.22E+00	1.27E+00	0.11	2.62	316	297	389
152	EC80	6.48E-02	-1.14E+00	-1.70E+00	2.36E+00	1.04E+01	1.44E+00	-4.74E-01	0.16	3.13	108	488	763
153	EC80	2.64E+00	-2.37E+00	-3.22E-01	-3.47E+00	5.17E+00	-1.26E+00	1.27E+00	6.38	4.22	315	26876	56649
154	EC80	6.38E-02	6.88E-01	1.42E+00	-1.29E+00	3.71E+00	-1.34E+00	1.26E+00	0.15	2.04	313	314	319
155	EC69	6.07E-02	-7.94E-01	-6.73E+00	-6.18E-01	-1.26E+00	1.44E+00	2.74E-01	0.15	6.80	79	995	3386
156	EC69	4.26E-01	1.16E+00	-4.70E+00	-3.89E-01	1.93E+00	1.42E+00	1.26E+00	1.03	4.86	48	4998	12142
157	EC69	2.07E+00	-5.28E-01	-3.97E+00	-1.24E-01	-5.40E+00	1.44E+00	-1.27E+00	5.00	4.01	131	20059	40208
158	EC69	1.76E-01	7.24E-01	-2.34E+00	9.99E-01	-4.25E+00	1.44E+00	1.00E+00	0.42	2.65	55	1123	1487
159	EC27	6.33E-02	-2.20E+00	-5.81E+00	1.23E+00	-4.37E-01	4.76E-01	-1.24E+00	0.15	6.34	159	968	3066
160	EC27	1.87E+00	-3.75E+00	-3.29E+00	4.00E+00	1.48E+00	1.44E+00	-1.26E+00	4.51	6.39	131	28852	92241
161	EC27	6.81E-01	-1.62E+00	-1.50E+00	-8.34E-01	1.08E+00	1.43E+00	-1.27E+00	1.64	2.36	132	3882	4585
162	EC27	1.85E+00	1.20E+00	-3.66E+00	1.76E+00	9.33E-01	1.44E+00	-1.27E+00	4.45	4.23	131	18859	39925
163	EC27	2.12E+00	-1.15E-01	-6.24E+00	1.60E-01	9.88E-01	1.44E+00	-1.27E+00	5.11	6.25	131	31911	99686
164	EC27	3.10E-01	-2.42E+00	-1.63E+00	8.77E-01	6.39E-01	1.44E+00	-6.32E-01	0.75	3.04	114	2271	3453
165	EC85	2.14E-01	-2.26E+00	-4.30E+00	1.58E+00	2.48E+00	4.53E-01	-1.27E+00	0.52	5.11	160	2641	6746
166	EC85	1.06E-02	3.45E+00	-2.24E+00	3.61E+00	-4.55E+00	1.37E+00	-1.17E+00	0.03	5.48	130	140	383
167	EC85	3.58E-02	2.93E-01	1.59E+00	1.76E+00	-5.78E+00	-7.04E-01	-1.27E+00	0.09	2.39	209	206	246
168	EC85	1.39E+00	-5.51E-01	2.06E-01	4.39E+00	6.41E+00	1.44E+00	-1.26E+00	3.35	4.43	131	14840	32877

Table XI-2. Impact Information for $1x10^{-7}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
169	EC85	1.03E-02	-6.34E-01	-3.74E+00	5.23E-01	-2.58E-01	3.45E-01	-1.27E+00	0.02	3.82	165	95	181
170	EC85	8.84E-02	1.57E+00	-2.28E+00	3.83E-01	-2.02E-01	1.44E+00	5.05E-01	0.21	2.80	71	597	836
171	EC85	9.73E-02	-2.92E+00	-3.17E+00	4.69E+00	-1.85E+00	1.44E+00	-1.27E+00	0.23	6.37	131	1495	4762
172	EC85	8.06E-01	-1.03E-01	-1.74E+00	1.02E+00	2.33E+00	1.44E+00	-1.27E+00	1.94	2.02	131	3923	3960
173	EC85	3.01E-01	1.33E+00	-1.52E+00	3.12E-01	3.23E+00	1.44E+00	-4.68E-01	0.73	2.04	108	1480	1508
174	EC85	6.31E-02	-1.96E-01	-2.56E+00	5.88E-01	2.22E+00	1.44E+00	8.34E-01	0.15	2.64	60	401	529
175	EC20	1.15E-02	-2.81E+00	-1.31E+00	2.63E+00	-5.87E+00	1.34E+00	-1.15E+00	0.03	4.07	131	113	230
176	EC20	9.10E-02	-5.84E-01	-1.75E+00	-8.70E-01	-6.30E+00	1.44E+00	-1.00E+00	0.22	2.04	125	449	458
177	EC20	1.37E+00	1.68E-01	-2.75E+00	-1.78E+00	-5.14E+00	1.44E+00	-1.26E+00	3.31	3.28	131	10857	17812
178	EC23	1.61E-02	-4.44E+00	2.02E+00	2.27E+00	-2.61E+00	-9.85E-01	-1.27E+00	0.04	5.38	218	209	562
179	EC23	2.95E-01	4.16E-01	2.57E-01	1.20E+00	1.23E+00	-1.02E+00	-1.27E+00	0.71	1.30	219	923	600
180	EC23	3.58E-01	5.97E-02	3.99E-01	3.32E-01	1.05E+01	-1.44E+00	-1.27E+00	0.86	0.52	229	451	118
181	EC23	2.36E-01	-2.99E-01	1.07E-01	3.28E-01	-9.88E-01	-1.44E+00	-1.27E+00	0.57	0.46	229	260	59
182	EC23	1.89E-01	-4.33E+00	2.35E+00	4.33E+00	-1.28E+00	-8.55E-01	-1.27E+00	0.46	6.56	214	2997	9831
183	EC23	5.66E-01	-4.25E-02	4.94E-02	3.15E-02	-1.58E+00	-1.44E+00	1.27E+00	1.37	0.07	311	99	4
184	EC23	1.76E-02	-5.64E+00	3.83E-01	7.75E+00	1.03E+01	-1.06E+00	-1.27E+00	0.04	9.59	220	407	1950
185	EC32	1.85E-01	2.87E+00	-3.60E+00	1.66E-01	-4.13E+00	1.34E+00	-9.19E-01	0.45	4.61	124	2059	4743
186	EC32	1.37E-01	-4.29E+00	-2.97E+00	7.95E-01	3.84E+00	1.44E+00	-8.17E-02	0.33	5.28	93	1750	4619
187	EC32	1.52E-01	-2.34E+00	-2.58E+00	1.02E+00	4.00E+00	1.44E+00	-3.17E-01	0.37	3.63	102	1333	2418
188	EC32	1.03E-02	2.94E+00	-1.63E+00	3.07E+00	-1.03E+00	-6.79E-01	-1.27E+00	0.02	4.55	208	113	258
189	EC32	1.73E-02	-7.88E-01	-1.29E+00	2.14E+00	5.73E+00	1.44E+00	-7.57E-01	0.04	2.62	118	109	143
190	EC32	4.44E-02	1.59E+00	-5.30E+00	1.06E+00	6.80E+00	1.44E+00	-1.26E+00	0.11	5.63	131	603	1699
191	EC32	1.96E-01	-4.92E-01	-7.06E+00	-1.34E-01	6.37E+00	1.40E+00	-1.26E+00	0.47	7.08	132	3341	11825
192	EC32	2.62E-01	-1.50E+00	-6.08E+00	7.73E-01	3.97E+00	1.44E+00	2.72E-01	0.63	6.31	79	3983	12575

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg-m/sec)	Impact Energy (J)
193	EC32	4.09E-02	-2.29E+00	-5.59E+00	3.62E+00	7.15E+00	4.26E-01	-1.27E+00	0.10	7.04	161	695	2446
194	EC32	7.71E-01	4.16E-01	-2.27E+00	-2.76E+00	4.50E+00	1.44E+00	-1.12E-01	1.86	3.60	94	6691	12043
195	EC32	9.34E-02	9.23E-01	-5.69E+00	4.55E-01	5.62E+00	1.44E+00	5.25E-01	0.23	5.79	70	1303	3770
196	EC32	2.46E-02	1.68E+00	-4.17E+00	-2.71E+00	4.87E+00	9.22E-01	1.27E+00	0.06	5.25	36	311	817
197	EC32	3.15E-02	3.31E-01	-2.94E+00	-1.33E-01	6.02E+00	1.44E+00	-1.11E+00	0.08	2.96	128	225	332
198	EC32	8.36E-02	-1.40E+00	-6.89E+00	2.24E+00	-1.57E+00	7.33E-02	-1.27E+00	0.20	7.38	177	1487	5483
199	EC32	1.66E-01	-5.86E+00	-2.33E+00	-1.26E+00	3.75E+00	1.44E+00	-1.08E+00	0.40	6.43	127	2576	8284
200	EC32	2.99E-02	1.81E-01	-2.79E+00	2.40E+00	-1.73E+00	1.44E+00	-1.26E+00	0.07	3.69	131	266	490
201	EC32	1.68E-02	3.64E+00	-3.72E+00	-9.69E-03	6.36E+00	1.44E+00	-1.26E+00	0.04	5.20	131	210	547
202	EC32	1.19E-01	-2.96E+00	-3.26E+00	8.85E-01	4.17E+00	1.44E+00	-2.88E-02	0.29	4.49	91	1294	2907
203	EC32	1.96E-01	-3.17E+00	-2.09E+00	2.04E+00	4.74E+00	1.44E+00	1.27E+00	0.47	4.31	49	2037	4393
204	EC32	3.14E-02	-4.61E+00	-1.70E+00	-3.19E+00	1.81E+00	1.44E+00	-3.88E-01	0.08	5.86	105	444	1301
205	EC32	4.49E-01	-7.97E-01	-1.90E+00	-3.77E-02	5.02E+00	1.44E+00	-5.12E-01	1.08	2.06	110	2229	2293
206	EC32	1.29E-01	6.65E-01	-3.34E+00	6.09E-01	4.28E+00	1.44E+00	-9.17E-01	0.31	3.46	122	1075	1859
207	EC64	3.07E-01	-8.05E-01	1.08E+00	-1.44E+00	9.10E+00	-5.59E-01	1.27E+00	0.74	1.97	336	1460	1439
208	EC64	2.38E-02	-1.68E-01	-5.23E+00	5.44E-01	-7.96E+00	1.44E+00	3.93E-01	0.06	5.26	75	301	792
209	EC64	1.23E-02	9.59E-02	-4.32E+00	1.02E+00	-8.21E+00	9.61E-01	-1.27E+00	0.03	4.44	143	132	293
210	EC64	4.98E-02	-5.43E-01	-4.41E+00	6.09E-01	-8.48E+00	1.34E+00	-1.25E+00	0.12	4.49	133	538	1208
211	EC64	9.18E-01	-5.52E-02	-4.59E+00	5.95E-01	-7.40E+00	1.44E+00	-1.27E+00	2.21	4.63	131	10238	23675
212	EC64	6.42E-02	-2.51E-01	-3.08E-01	7.97E-01	-7.92E+00	1.44E+00	-1.27E+00	0.15	0.89	131	138	61
213	EC51	1.05E-02	4.84E+00	-1.28E+00	3.91E+00	4.73E+00	7.94E-01	-1.27E+00	0.03	6.36	148	161	510
214	EC66	2.69E-02	-2.84E-01	2.38E-01	-1.13E-01	-2.17E+00	-1.38E+00	1.25E+00	0.06	0.39	312	25	5
215	EC66	2.20E-02	-3.00E+00	7.50E+00	1.78E+00	-7.40E+00	-1.30E+00	1.16E+00	0.05	8.27	312	439	1813
216	EC66	6.00E-01	3.68E+00	-4.05E+00	1.89E+00	-4.83E+00	1.30E+00	-9.85E-01	1.45	5.79	127	8376	24235

Table XI-2. Impact Information for 1×10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
217	EC66	1.39E-01	-4.36E-01	5.17E+00	-7.39E+00	-1.22E+00	-2.45E-01	1.27E+00	0.34	9.03	349	3031	13683
218	EC66	3.64E-01	-2.42E-01	-5.07E-01	-2.39E+00	-2.62E+00	-1.04E+00	1.27E+00	0.88	2.45	321	2156	2646
219	EC66	7.53E-01	-2.50E-01	1.02E+00	-3.86E-01	-2.05E+00	-1.40E+00	1.27E+00	1.82	1.12	312	2033	1139
220	EC66	2.68E-02	-2.06E+00	5.42E+00	-8.12E+00	-8.19E+00	1.07E+00	1.26E+00	0.06	9.98	40	645	3219
221	EC66	3.49E-02	8.27E-01	7.34E+00	-4.63E+00	-8.88E+00	-6.02E-01	1.27E+00	0.08	8.72	335	735	3204
222	EC66	1.06E-02	-1.60E-02	1.35E+00	-9.01E+00	-8.72E+00	-1.87E-01	1.27E+00	0.03	9.11	352	232	1058
223	EC66	2.05E-02	7.99E-01	-5.02E+00	-3.37E+00	-8.92E+00	2.30E-01	1.27E+00	0.05	6.10	10	301	918
224	EC66	3.21E-01	7.89E-02	-8.46E+00	-1.56E+00	-1.02E+01	1.40E+00	1.27E+00	0.77	8.60	48	6656	28634
225	EC36	3.44E-01	1.57E-01	1.15E-01	-4.91E-01	3.31E+00	-1.44E+00	1.27E+00	0.83	0.53	311	439	116
226	EC36	1.92E-02	3.01E-01	-2.57E+00	3.35E+00	9.12E-01	1.11E+00	-1.27E+00	0.05	4.23	139	196	415
227	EC36	1.56E-02	2.98E-01	5.52E-01	4.76E-02	5.04E+00	-1.37E+00	9.43E-01	0.04	0.63	305	24	7
228	EC36	6.82E-02	-2.00E-01	9.38E-01	-1.42E+00	5.01E+00	-1.39E+00	8.17E-01	0.16	1.71	300	282	241
229	EC36	7.40E-02	1.03E+00	-4.90E+00	1.22E+00	3.16E+00	1.44E+00	-4.33E-01	0.18	5.16	107	920	2372
230	EC36	1.48E-01	2.00E-02	1.80E-01	-7.55E-01	3.29E+00	-1.44E+00	1.27E+00	0.36	0.78	311	278	108
231	EC36	1.42E-02	3.96E+00	-2.45E+00	5.53E+00	5.68E-01	1.23E+00	-1.25E+00	0.03	7.23	135	247	892
232	EC36	1.26E-01	1.38E-02	-1.44E+00	2.14E+00	1.08E+00	1.43E+00	-1.27E+00	0.30	2.58	132	784	1010
233	EC36	2.27E-02	-1.24E+00	-4.47E+00	-4.01E+00	3.87E-02	1.43E+00	1.26E+00	0.05	6.13	49	336	1030
234	EC36	1.58E-02	4.39E+00	5.82E-01	7.18E+00	2.38E+00	2.31E-01	-1.27E+00	0.04	8.43	170	322	1357
235	EC36	7.14E-02	4.72E+00	2.76E+00	5.18E+00	2.94E+00	-2.52E-01	-1.27E+00	0.17	7.53	191	1297	4886
236	EC36	1.52E-02	7.83E-01	1.12E+00	6.55E-02	1.68E+00	-1.44E+00	-2.51E-01	0.04	1.37	260	50	34
237	EC36	9.64E-02	1.16E+00	9.90E-01	3.05E+00	3.32E+00	-1.44E+00	-1.27E+00	0.23	3.41	229	792	1351
238	EC36	1.74E-01	-2.77E-01	3.16E-01	5.86E-01	3.69E+00	-1.44E+00	-1.27E+00	0.42	0.72	229	302	109
239	EC36	1.83E-01	-8.75E-01	1.39E+00	-3.98E-01	4.04E+00	-1.44E+00	1.27E+00	0.44	1.69	311	748	633
240	EC36	1.73E-01	-9.95E-01	-2.29E+00	2.09E+00	2.94E+00	1.43E+00	-1.24E+00	0.42	3.25	131	1359	2210

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
241	EC36	7.83E-02	-1.42E-02	-3.65E+00	2.83E+00	2.07E+00	1.44E+00	-6.59E-01	0.19	4.62	115	873	2017
242	EC49	2.78E-01	1.00E+00	-1.81E-02	1.25E+00	5.76E+00	-1.00E+00	-1.27E+00	0.67	1.60	218	1072	857
243	EC49	2.78E-01	-4.91E-01	4.23E-01	-1.23E+00	7.00E+00	-1.42E+00	-1.25E+00	0.67	1.39	228	932	648
244	EC49	1.63E-01	-1.83E+00	5.31E-01	1.40E+00	-3.34E+00	8.67E-01	-1.27E+00	0.39	2.36	146	930	1098
245	EC31	3.23E-02	1.92E+00	-3.44E+00	1.18E+00	1.02E+00	1.40E+00	4.43E-01	0.08	4.11	72	320	657
246	EC31	7.49E-02	4.43E+00	-6.49E+00	2.43E+00	1.73E+00	1.39E+00	1.27E+00	0.18	8.23	48	1486	6116
247	EC31	2.33E-02	1.82E-01	-2.25E+00	-7.77E-01	3.02E+00	1.40E+00	1.16E+00	0.06	2.38	50	134	160
248	EC31	1.90E-02	-4.75E-01	-2.00E+00	-1.47E+00	2.81E+00	-6.39E-01	1.24E+00	0.05	2.53	333	116	146
249	EC31	5.25E-01	9.42E-01	-3.14E+00	7.94E-01	-8.43E+00	1.40E+00	1.27E+00	1.27	3.37	48	4266	7186
250	EC72	1.73E-01	7.69E-02	-1.67E-02	4.31E-01	-5.96E+00	6.65E-01	-1.27E+00	0.42	0.44	152	183	40
251	EC72	2.16E-01	6.71E-01	1.61E+00	2.96E+00	-5.77E+00	-7.59E-01	-1.27E+00	0.52	3.44	211	1795	3087
252	EC72	2.92E-02	-3.48E-01	1.27E+00	1.88E+00	-3.92E-03	-1.40E+00	2.08E-01	0.07	2.30	278	162	186
253	EC72	2.72E-01	3.84E-02	9.07E-01	-1.35E-01	-5.48E+00	-1.39E+00	-1.26E+00	0.66	0.92	228	602	276
254	EC72	1.49E-01	3.54E-01	1.22E-01	2.11E-01	3.80E-01	-1.40E+00	1.27E+00	0.36	0.43	312	154	33
255	EC72	1.06E-02	-2.96E-01	-5.25E-01	-3.34E-01	-8.78E+00	-7.64E-01	1.27E+00	0.03	0.69	329	18	6
256	EC52	6.44E-02	-1.32E+00	-2.07E+00	-5.68E-01	-7.35E+00	1.34E+00	-1.22E+00	0.16	2.52	132	392	494
257	EC52	5.62E-01	1.41E+00	-1.38E-01	4.85E+00	-4.92E+00	1.41E+00	-1.19E+00	1.36	5.05	130	6848	17289
258	EC52	1.85E-02	2.23E+00	-1.35E+01	1.84E+00	-2.78E+00	1.44E+00	3.80E-01	0.04	13.84	75	618	4274
259	EC52	1.36E+00	-1.81E-02	-1.88E+00	3.87E-01	-4.71E+00	1.44E+00	-1.27E+00	3.28	1.92	131	6290	6026
260	EC52	1.32E-02	1.14E+00	-2.47E+00	-5.24E-01	-1.62E+00	1.43E+00	-9.69E-01	0.03	2.77	124	88	122
261	EC37	5.68E-02	-5.67E-01	-9.75E-01	7.65E+00	-5.87E+00	3.42E-01	-1.27E+00	0.14	7.73	165	1058	4090
262	EC37	7.24E-02	-9.34E-01	1.98E+00	4.83E+00	-6.07E+00	1.84E-02	-1.27E+00	0.17	5.30	179	927	2457
263	EC37	1.72E-01	-2.47E+00	-9.71E-01	2.35E+00	-4.27E+00	9.22E-02	-1.27E+00	0.42	3.54	176	1471	2606
264	EC37	1.88E-02	-6.07E+00	4.00E-01	9.20E+00	-6.91E+00	1.08E+00	-1.27E+00	0.05	11.03	140	501	2762

Table XI-2. Impact Information for $1x10^{-7}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
265	EC37	2.65E-02	7.37E-01	2.47E-02	-4.10E+00	1.33E+00	1.40E+00	2.17E-01	0.06	4.17	81	267	556
266	EC37	9.63E-02	1.61E+00	2.69E-01	2.36E+00	-4.81E+00	2.12E-01	-1.27E+00	0.23	2.86	171	666	954
267	EC37	1.63E-01	1.59E+00	-1.94E+00	6.28E-01	-6.11E+00	8.07E-01	-1.27E+00	0.39	2.58	148	1014	1311
268	EC75	6.85E-02	-2.60E-01	1.00E+00	-1.59E+00	-4.39E+00	-5.68E-01	1.27E+00	0.17	1.90	336	313	297
269	EC75	3.98E-02	6.79E-01	-9.13E-01	6.85E-02	-7.11E+00	1.37E+00	-1.21E+00	0.10	1.14	132	109	62
270	EC75	3.50E-01	-5.42E-02	-3.23E+00	1.24E+00	-6.97E+00	1.40E+00	-9.79E-01	0.84	3.46	125	2917	5040
271	EC75	4.40E-02	-2.03E-01	-3.63E+00	1.02E-01	-8.24E+00	1.40E+00	-7.32E-01	0.11	3.64	118	386	703
272	EC77	6.67E-02	-6.37E+00	-3.88E+00	-3.41E+00	-1.25E+00	4.26E-01	1.27E+00	0.16	8.20	19	1319	5410
273	EC77	1.26E-02	-8.99E-01	-4.53E+00	-1.30E+00	-9.32E+00	1.30E+00	1.24E+00	0.03	4.80	46	146	350
274	EC77	2.89E-02	3.31E+00	-2.72E+00	-2.27E+00	-7.74E+00	6.14E-02	1.27E+00	0.07	4.85	3	338	818
275	EC77	6.66E-02	-1.69E+00	-1.62E+00	-3.36E+00	-8.05E+00	-4.78E-01	1.27E+00	0.16	4.09	339	658	1346
276	EC77	1.85E-02	-4.42E-01	-4.12E+00	8.20E-02	-9.54E+00	1.40E+00	1.26E+00	0.04	4.14	48	185	383
277	EC77	2.08E-01	4.22E+00	-1.33E+00	4.96E+00	4.43E+00	1.30E+00	-9.81E-01	0.50	6.65	127	3330	11069
278	EC77	1.14E-02	1.27E+00	-1.44E+00	1.17E-01	-9.71E-01	1.40E+00	8.94E-01	0.03	1.92	57	53	51
279	EC21	3.82E-01	-8.70E-01	4.98E-01	-3.16E+00	-9.10E+00	-7.06E-01	1.27E+00	0.92	3.32	331	3060	5076
280	EC84	3.23E-01	8.39E-02	1.40E+00	-1.14E-01	9.93E+00	-1.40E+00	1.27E+00	0.78	1.41	312	1097	772
281	EC50	1.60E+00	4.15E-01	1.85E+00	-1.72E-01	7.29E+00	-1.40E+00	1.27E+00	3.85	1.90	312	7312	6946
282	EC50	3.15E-01	1.20E+00	-8.44E+00	-5.39E+00	-8.21E+00	1.28E+00	1.23E+00	0.76	10.08	46	7650	38571
283	EC33	1.41E-01	7.07E-01	-3.66E+00	2.38E+00	2.35E+00	-6.29E-02	-1.27E+00	0.34	4.42	183	1500	3316
284	EC33	7.08E-02	1.86E+00	-2.65E+00	-9.64E-01	-3.32E+00	1.40E+00	1.27E+00	0.17	3.38	48	577	974
285	EC33	2.43E-02	2.74E+00	-2.91E+00	4.73E+00	4.16E+00	1.40E+00	1.62E-02	0.06	6.19	89	363	1122
286	EC33	6.02E-02	1.65E+00	-1.03E+00	3.21E+00	1.43E+00	1.40E+00	-1.48E-01	0.15	3.75	96	545	1023
287	EC33	3.84E-01	-1.25E+00	-2.83E+00	-1.06E-01	-9.05E-01	1.40E+00	-1.25E+00	0.93	3.10	132	2871	4448
288	EC33	6.91E-01	9.15E-01	-1.00E+00	3.81E-01	5.31E+00	1.39E+00	1.26E+00	1.67	1.41	48	2348	1654

Table XI-2. Impact Information for $1x10^{-7}$ Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
289	EC33	7.31E-01	-1.75E+00	-3.19E+00	-1.10E+00	-8.42E-02	1.40E+00	9.54E-01	1.76	3.80	56	6692	12705
290	EC48	1.93E-02	-1.74E+00	-9.52E-02	1.03E+00	2.70E+00	-2.32E-01	-1.27E+00	0.05	2.02	190	94	95
291	EC48	1.57E-01	4.10E+00	-6.92E+00	-5.93E-02	3.89E+00	1.32E+00	-1.12E+00	0.38	8.04	130	3050	12267
292	EC48	2.68E-01	-2.65E-01	-2.61E+00	2.45E+00	2.51E+00	6.15E-01	-1.27E+00	0.65	3.59	154	2317	4155
293	EC48	2.01E-01	-4.71E-01	-1.52E+00	3.32E-01	5.12E+00	1.40E+00	-1.27E+00	0.49	1.62	132	788	638
294	EC78	4.77E+00	-2.52E-02	-7.77E+00	2.95E-01	-9.22E+00	1.40E+00	-1.27E+00	11.50	7.78	132	89502	348174
295	EC78	2.14E-02	1.86E+00	3.71E+00	-4.22E+00	4.39E+00	1.29E-01	1.27E+00	0.05	5.92	6	306	904
296	EC78	3.62E-02	-9.16E-01	-1.25E+00	-5.74E+00	2.95E+00	-7.15E-01	1.27E+00	0.09	5.95	331	520	1545
297	EC78	6.44E-02	5.53E-01	-1.47E+00	-4.30E+00	3.47E+00	1.20E+00	1.25E+00	0.16	4.58	44	711	1628
298	EC78	2.92E+00	3.07E-01	-5.63E-01	-6.37E-01	-8.72E+00	1.24E+00	1.08E+00	7.04	0.90	49	6369	2879
299	EC78	3.01E-01	3.26E+00	-1.41E+00	-4.65E+00	5.33E+00	1.40E+00	1.27E+00	0.73	5.85	48	4242	12407
300	EC78	2.17E-01	-1.08E+00	3.98E-02	-6.34E+00	3.58E+00	7.80E-01	1.27E+00	0.52	6.43	32	3371	10835
301	EC78	5.36E-02	1.57E-01	-1.13E+00	-5.23E+00	3.74E+00	1.40E+00	-3.11E-01	0.13	5.36	103	693	1856
302	EC60	1.84E-01	5.38E-01	1.01E+00	-1.59E-01	-9.88E-01	-1.40E+00	-1.27E+00	0.44	1.16	228	512	297
303	EC25	2.37E-02	9.00E-01	-4.73E+00	3.61E-01	4.03E+00	1.40E+00	4.34E-01	0.06	4.83	73	276	667
304	EC25	1.81E-01	-1.22E+00	-5.88E+00	2.22E-02	4.14E+00	1.40E+00	-8.75E-01	0.44	6.01	122	2619	7869
305	EC25	1.08E-02	-1.04E+00	-2.46E+00	1.19E+01	6.83E+00	7.36E-01	-1.27E+00	0.03	12.23	150	318	1944
306	EC25	1.68E-02	-7.79E+00	1.38E+01	3.69E-01	3.94E+00	6.76E-01	-1.27E+00	0.04	15.82	152	639	5056
307	EC44	1.04E-01	4.47E+00	-4.44E+00	8.01E-01	-4.04E+00	1.39E+00	1.20E+00	0.25	6.35	49	1585	5034
308	EC44	1.62E-02	4.07E+00	-7.88E+00	-5.99E+00	-6.02E+00	-2.37E-01	1.27E+00	0.04	10.71	349	419	2244
309	EC44	6.22E-02	5.22E-01	-9.42E+00	-6.10E-01	-3.85E+00	1.40E+00	1.07E+00	0.15	9.45	53	1418	6703
310	EC44	3.37E-02	-2.09E+00	6.89E+00	-1.42E+00	-4.00E+00	-1.54E-01	1.27E+00	0.08	7.34	353	597	2193
311	EC44	3.09E-02	-2.06E-01	-1.54E+01	6.41E+00	-4.89E+00	3.52E-01	-1.27E+00	0.07	16.68	165	1243	10371
312	EC44	2.06E-01	-3.33E+00	-3.88E+00	-4.70E+00	-1.76E+00	1.40E+00	4.05E-01	0.50	6.95	74	3453	11998

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
313	EC44	1.31E-01	5.54E-01	-8.98E+00	6.04E-01	5.90E+00	1.26E+00	-1.21E+00	0.32	9.02	134	2844	12826
314	EC68	5.65E-02	8.56E+00	2.71E+00	-2.39E+00	3.47E+00	1.38E+00	1.23E+00	0.14	9.29	48	1266	5879
315	EC68	1.26E-02	5.78E-01	-4.96E+00	-2.31E+00	4.26E+00	1.40E+00	-6.15E-01	0.03	5.51	114	167	459
316	EC68	4.88E-02	1.22E+00	-4.40E+00	-3.45E-01	9.28E+00	1.40E+00	7.67E-01	0.12	4.58	61	539	1236
317	EC68	1.02E-02	5.00E-02	2.94E+00	-1.57E+00	1.05E+01	2.54E-01	1.26E+00	0.02	3.33	11	82	136
318	EC68	1.89E-02	5.77E+00	3.15E+00	-2.08E+00	8.37E+00	1.05E+00	1.27E+00	0.05	6.90	40	314	1085
319	EC68	2.86E-02	9.43E-01	8.86E-01	-5.61E-01	4.35E+00	-1.30E+00	9.45E-01	0.07	1.41	306	97	69
320	EC68	1.24E-02	-1.20E+00	2.69E+00	-2.25E-01	1.17E+00	-1.40E+00	-9.74E-01	0.03	2.95	235	88	130
321	EC68	4.26E-02	2.19E+00	-3.61E+00	-2.38E+00	8.74E+00	1.40E+00	6.52E-01	0.10	4.85	65	498	1207
322	EC68	3.06E-02	1.07E+00	-1.68E+00	-1.36E+00	3.66E+00	-5.55E-01	1.27E+00	0.07	2.41	336	178	215
323	EC15	1.99E-02	4.71E-01	-6.02E+00	-1.14E+00	-1.70E+00	1.44E+00	1.26E+00	0.05	6.15	49	295	907
324	EC15	1.96E-02	-2.67E+00	-4.07E+00	2.05E+00	6.14E+00	-2.65E-01	-1.27E+00	0.05	5.28	192	249	657
325	EC15	1.28E-01	-5.39E-01	-7.15E+00	-1.44E+00	-5.11E-01	1.34E+00	1.22E+00	0.31	7.31	48	2255	8244
326	EC54	6.18E-02	2.73E+00	-4.56E-01	-2.09E+00	-1.09E+01	1.39E+00	-9.87E-02	0.15	3.46	94	516	894
327	EC54	3.04E-02	2.66E+00	-2.39E+00	8.46E+00	-8.90E+00	1.11E+00	-1.27E+00	0.07	9.18	139	673	3092
328	EC54	6.47E-02	-3.82E-02	-2.46E+00	-3.34E+00	-9.46E+00	-6.42E-01	1.27E+00	0.16	4.14	333	646	1339
329	EC54	3.26E-02	8.42E-01	6.82E-01	7.14E+00	-9.99E+00	-3.13E-01	-1.27E+00	0.08	7.22	194	568	2051
330	EC73	3.59E-02	-4.90E+00	-9.92E+00	2.39E+00	8.78E+00	-5.40E-01	-1.27E+00	0.09	11.31	203	979	5538
331	EC73	1.33E-01	-4.69E+00	-7.98E+00	2.19E+00	7.79E+00	6.01E-01	-1.27E+00	0.32	9.51	155	3043	14465
332	EC59	4.61E-01	-6.42E-01	-3.64E+00	1.37E-01	-5.48E+00	1.29E+00	1.21E+00	1.11	3.70	47	4112	7602
333	EC59	1.77E-02	-8.64E-01	1.10E+00	7.56E-01	-7.91E+00	-1.35E+00	-1.24E+00	0.04	1.59	227	68	54
334	EC59	1.60E-02	-7.70E-01	-6.18E+00	6.73E-01	-9.32E+00	1.40E+00	-6.19E-01	0.04	6.27	114	242	757
335	EC59	4.20E-01	-2.39E-01	-5.09E+00	-7.98E-01	-6.02E+00	1.40E+00	7.26E-01	1.01	5.16	63	5229	13495
336	EC59	2.79E-02	5.43E-02	-4.36E+00	-1.34E+00	-8.89E+00	1.38E+00	-1.06E+00	0.07	4.56	127	307	699

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
337	EC59	1.71E-02	-1.18E+00	-3.55E+00	1.43E+00	-8.58E+00	1.39E+00	-1.26E+00	0.04	4.00	132	165	330
338	EC47	3.19E-02	-3.66E-01	-8.76E+00	-6.07E-01	-4.98E+00	1.40E+00	1.27E+00	0.08	8.79	48	676	2970
339	EC47	1.48E-02	4.02E+00	-1.56E-01	4.46E+00	-1.24E+00	-7.12E-02	-1.27E+00	0.04	6.01	183	215	645
340	EC47	1.04E-02	-3.94E-01	-1.05E+00	2.77E+00	-2.90E+00	-3.08E-01	-1.27E+00	0.03	2.99	194	75	112
341	EC47	2.02E-02	5.21E-01	-2.01E+00	2.41E+00	-3.19E+00	-2.35E-01	-1.27E+00	0.05	3.18	190	155	246
342	EC47	4.82E-02	-9.57E-02	-7.75E+00	-6.78E-01	-4.94E+00	1.37E+00	1.26E+00	0.12	7.78	47	905	3522
343	EC71	4.31E-02	2.63E+00	-1.63E+00	-1.13E+00	5.42E-01	4.15E-01	1.27E+00	0.10	3.30	18	343	564
344	EC71	2.88E-02	-4.16E+00	-6.18E-01	-9.13E+00	-1.76E-01	-2.92E-01	1.26E+00	0.07	10.06	347	698	3511
345	EC71	3.89E-01	7.53E-01	2.36E+00	-7.57E+00	9.39E+00	-7.29E-01	1.27E+00	0.94	7.97	330	7469	29759
346	EC39	6.12E-02	-2.93E-02	-3.70E-01	1.45E+00	-8.02E+00	1.40E+00	1.22E-01	0.15	1.50	85	221	166
347	EC39	4.22E-02	5.31E-02	-1.64E+00	-3.24E-01	1.06E+01	1.40E+00	8.82E-01	0.10	1.67	58	170	142
348	EC24	4.14E-02	1.59E-01	2.64E+00	3.58E-01	2.35E+00	-1.40E+00	3.19E-01	0.10	2.67	283	267	356
349	EC24	6.00E-02	-6.42E+00	-1.52E+01	6.55E+00	1.09E+01	1.13E+00	-5.58E-01	0.14	17.74	116	2568	22783
350	EC81	3.23E-02	1.11E+00	1.76E+00	-2.64E+00	-6.86E+00	1.30E+00	1.11E+00	0.08	3.36	49	262	440
351	EC81	2.73E-02	7.67E-01	1.56E+00	-5.27E+00	-7.88E+00	2.03E-01	1.27E+00	0.07	5.54	9	365	1013
352	EC46	4.29E-02	-5.40E+00	-4.22E+00	-1.62E-01	6.23E+00	1.40E+00	-4.66E-01	0.10	6.86	108	710	2435
353	EC88	1.86E-02	2.60E+00	-9.89E-01	-2.18E+00	3.54E+00	2.60E-01	1.27E+00	0.04	3.53	12	158	279
354	EC88	1.49E-01	2.48E+00	-1.50E+00	-4.89E+00	-2.98E+00	-1.15E+00	1.27E+00	0.36	5.68	318	2040	5795
355	EC28	2.91E-02	5.94E-01	-4.49E+00	-1.16E+00	-8.11E+00	-8.45E-01	1.27E+00	0.07	4.67	326	328	766
356	EC28	5.21E-02	-2.39E+00	-2.33E-01	-2.39E+00	-9.06E+00	-6.85E-01	1.27E+00	0.13	3.39	332	426	722
357	EC67	3.08E-02	3.12E+00	-8.95E+00	-1.75E+00	1.08E+01	1.37E+00	-5.37E-02	0.07	9.64	92	716	3453
358	EC67	1.27E-01	-9.80E-01	-8.42E+00	2.46E+00	9.09E+00	1.40E+00	1.96E-01	0.31	8.83	82	2705	11938
359	EC67	2.01E-02	-1.47E+00	-4.42E+00	-7.64E-01	7.95E+00	1.40E+00	-5.27E-01	0.05	4.72	111	228	539
360	EC18	1.95E-02	7.04E-01	-1.43E+00	1.74E+00	-6.62E+00	-7.68E-01	-1.27E+00	0.05	2.36	211	111	131

Table XI-2. Impact Information for 1x10^{-7} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
361	EC70	1.84E-02	7.85E-01	-3.35E+00	6.86E-01	-1.90E+00	1.39E+00	1.26E+00	0.04	3.51	48	156	273
362	EC76	6.03E-02	-1.45E+00	-2.31E+00	-3.54E+00	-1.06E+01	-7.20E-02	1.27E+00	0.15	4.47	357	650	1454
363	EC76	1.73E-02	8.96E-01	-1.73E+00	2.13E+00	-1.36E+00	7.92E-02	-1.27E+00	0.04	2.89	177	120	174
364	EC83	1.14E-02	-2.34E+00	-4.68E+00	2.27E+00	8.52E+00	1.39E+00	-1.26E+00	0.03	5.71	132	157	448
365	EC17	1.01E-02	-1.44E+00	-5.75E+00	-4.27E-01	4.16E+00	1.40E+00	-7.86E-01	0.02	5.95	119	145	432
366	EC19	9.79E-02	6.25E-01	6.52E-01	-9.67E-01	9.91E+00	-2.63E-01	1.27E+00	0.24	1.32	348	312	207
367	EC29	3.46E-01	-2.93E+00	-1.07E+01	1.41E+00	-9.01E+00	1.40E+00	2.92E-01	0.83	11.22	78	9361	52521
368	EC40	1.44E-02	-1.70E+00	-2.18E+00	-6.47E-01	-1.98E-01	-5.68E-01	1.27E+00	0.03	2.84	336	98	140
369	EC42	2.85E-01	-8.42E-01	-5.76E+00	2.26E+00	5.86E+00	1.39E+00	-1.26E+00	0.69	6.24	132	4296	13409
370	EC42	1.55E-02	-5.92E+00	-6.50E-01	3.62E+00	3.46E+00	5.12E-01	-1.03E+00	0.04	6.96	154	260	907
371	EC42	5.09E-01	1.70E+00	-4.13E+00	1.62E+00	5.64E+00	1.40E+00	1.27E+00	1.23	4.75	48	5830	13844
372	EC42	2.06E+00	3.68E-01	-3.41E+00	-8.07E-01	4.53E+00	1.36E+00	-1.25E+00	4.96	3.53	133	17487	30832
373	EC62	2.23E+00	9.61E-01	-7.88E+00	2.87E+00	6.61E+00	1.40E+00	-1.27E+00	5.38	8.44	132	45388	191506
374	EC62	1.01E+00	-5.26E+00	3.77E+00	4.55E+00	-4.96E+00	-5.09E-01	-1.27E+00	2.43	7.91	202	19228	76087
375	EC63	1.40E-02	1.38E-01	9.92E-01	-3.63E+00	-8.29E+00	-4.87E-01	1.27E+00	0.03	3.76	339	127	240
376	EC65	2.87E-02	-5.39E-01	-4.18E+00	2.68E+00	8.94E+00	-1.11E+00	-1.27E+00	0.07	4.99	221	346	863
377	EC65	4.54E-02	-2.59E+00	-2.89E+00	9.39E-01	7.58E+00	-1.09E+00	-1.26E+00	0.11	4.00	221	438	876
378	EC65	2.54E-01	-3.14E+00	-5.00E+00	2.85E+00	8.73E+00	9.39E-01	-1.27E+00	0.61	6.55	144	4019	13168
379	EC87	1.72E-01	-1.88E-01	-5.78E+00	1.12E+00	-7.66E+00	1.38E+00	-1.26E+00	0.41	5.89	132	2444	7200
380	EC89	1.30E-02	-3.86E+00	-1.63E+00	-3.80E+00	5.25E+00	1.39E+00	1.27E+00	0.03	5.65	48	177	502

Table XI-3. Impact Information for 5x10^{-4} Probability of Exceedance Hazard

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate-X (m)	Impact Location Coordinate-Y (m)	Impact Location Coordinate-Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
1	1	1.99E-01	4.30E-02	-4.99E+00	7.14E-01	-1.14E+00	1.43E+00	-1.26E+00	0.48	5.05	131	2425	6118
2	1	1.07E+00	1.78E-01	-1.69E+00	3.06E-01	-9.14E-01	1.35E+00	-1.23E+00	2.58	1.73	132	4455	3847
3	1	2.45E-01	2.00E+00	-1.27E+00	1.71E+00	-1.11E-01	1.44E+00	-7.95E-01	0.59	2.92	119	1725	2520
4	2	9.74E-02	-3.87E-01	-3.19E+00	1.59E+00	6.61E+00	-3.09E-01	-1.27E+00	0.23	3.59	194	842	1510
5	2	1.20E+00	-5.41E-02	-3.12E+00	1.54E+00	6.21E+00	1.44E+00	-1.26E+00	2.89	3.48	131	10062	17494
6	2	3.45E-01	1.82E-01	-1.56E+00	2.26E+00	6.93E+00	1.44E+00	-1.26E+00	0.83	2.75	131	2288	3149
7	3	1.50E-01	-2.12E-01	-3.87E+00	6.46E-01	3.27E+00	1.44E+00	-4.23E-01	0.36	3.93	106	1421	2791
8	3	2.15E-02	-9.04E-01	2.25E-01	-3.25E+00	-2.09E+00	-3.71E-01	1.27E+00	0.05	3.38	344	175	296
9	3	1.36E-02	-1.08E-01	-2.52E+00	4.57E-02	4.74E+00	1.44E+00	-3.45E-02	0.03	2.52	91	83	104
10	3	1.37E-02	-6.85E-01	-2.83E+00	-1.83E-01	4.72E+00	1.43E+00	-1.25E+00	0.03	2.92	131	97	141
11	3	1.16E-01	3.57E-01	-3.86E+00	6.53E-01	5.89E+00	1.44E+00	-1.27E+00	0.28	3.93	131	1101	2164
12	3	8.72E-02	1.11E+00	-3.69E+00	7.37E-01	4.08E+00	1.30E+00	1.22E+00	0.21	3.92	47	826	1620
13	3	9.86E-02	1.22E+00	-6.68E-01	-2.45E-01	5.79E+00	1.44E+00	-9.80E-01	0.24	1.41	124	336	237
14	3	3.12E-01	-1.19E-01	-1.20E+00	4.82E-01	5.46E+00	1.44E+00	-1.07E+00	0.75	1.30	127	981	639
15	3	8.14E-01	-7.88E-01	2.84E-01	1.64E+00	2.89E+00	4.96E-01	-1.27E+00	1.96	1.84	159	3607	3315
16	3	7.23E-02	-2.09E-01	-2.66E+00	5.31E-01	3.22E+00	1.40E+00	-1.06E+00	0.17	2.72	127	474	644
17	3	8.36E-01	-2.39E-01	-1.80E+00	8.24E-01	7.11E+00	1.44E+00	-1.27E+00	2.02	2.00	131	4024	4014
18	3	2.63E-02	-2.40E-01	-5.94E-01	9.75E-01	4.98E+00	1.44E+00	-2.50E-01	0.06	1.17	100	74	43
19	3	2.98E-01	-4.17E-01	-1.20E+00	1.03E+00	4.13E+00	1.44E+00	-1.27E+00	0.72	1.64	131	1180	968
20	3	1.71E-01	-6.87E-01	-2.00E+00	1.09E-02	3.71E+00	1.44E+00	-1.27E+00	0.41	2.11	131	869	917
21	4	3.02E-02	3.28E-02	-1.17E+00	6.20E-01	5.52E-01	1.44E+00	5.25E-01	0.07	1.33	70	97	64
22	4	1.63E-02	1.65E-01	-2.43E+00	7.31E-02	4.60E-01	1.44E+00	-3.53E-01	0.04	2.44	104	96	117
23	4	4.98E-01	-1.07E-02	-1.93E+00	1.07E-01	1.74E+00	1.44E+00	-1.27E+00	1.20	1.93	131	2315	2233
24	4	2.65E-02	1.90E-01	-1.61E+00	1.31E+00	1.09E+00	1.44E+00	1.08E+00	0.06	2.08	53	133	139

Table XI-3. Impact Information for 5x10^{-4} Probability of Exceedance Hazard (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (kg·m/sec)	Impact Energy (J)
25	4	2.10E-02	3.95E-01	-2.25E+00	9.50E-01	7.97E-01	1.44E+00	2.43E-01	0.05	2.48	80	125	155
26	4	3.07E-02	-2.20E-01	-3.00E+00	1.81E-02	4.94E-01	1.44E+00	-6.41E-01	0.07	3.01	114	223	335
27	9	2.09E-02	6.35E-01	6.87E-01	5.90E-01	-1.40E+00	-1.20E+00	-1.27E+00	0.05	1.11	223	56	31
28	9	1.17E-02	-1.28E-01	7.77E-01	1.63E+00	-4.13E-01	-6.56E-01	-1.27E+00	0.03	1.81	207	51	47
29	14	1.02E-02	-2.26E-02	-1.16E+00	-1.55E-02	1.07E+01	1.44E+00	7.51E-01	0.02	1.16	63	28	16
30	15	2.68E-02	9.66E-02	-1.23E+00	-9.14E-01	-8.96E+00	-5.87E-01	1.27E+00	0.06	1.54	335	99	76
31	16	1.66E-02	-4.14E-01	-3.03E+00	4.00E-01	1.80E+00	-5.65E-01	-1.27E+00	0.04	3.09	204	124	191
32	16	2.68E-02	3.24E-01	-2.06E+00	5.96E-01	2.34E+00	-2.38E-02	-1.27E+00	0.06	2.16	181	140	151
33	16	1.48E-01	5.38E-02	-2.66E-02	-1.08E-02	3.29E+00	-1.44E+00	1.27E+00	0.36	0.06	311	22	1
34	16	1.52E-02	1.39E-01	-1.00E+00	6.02E-01	4.82E-01	-7.84E-01	-1.27E+00	0.04	1.18	212	43	25
35	18	1.32E-02	4.64E-01	2.78E-01	-4.51E-01	-9.03E-01	-1.01E-01	1.27E+00	0.03	0.70	355	22	8
36	19	1.49E-01	-5.18E-03	-4.54E-03	-1.50E-01	1.14E+00	-1.44E+00	1.27E+00	0.36	0.15	311	54	4
37	21	1.29E-02	-2.86E-01	-1.15E+00	1.18E+00	-6.42E+00	-9.84E-01	-1.27E+00	0.03	1.67	218	52	44

Table XI-4. Impact Information for Static Case

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (Kg·m/sec)	Impact Energy (J)
1	2	3.31E-02	-2.51E-01	-3.45E+00	1.61E-01	3.34E+00	1.44E+00	-2.64E-01	0.08	3.47	100	277	479
2	3	5.86E-02	-1.29E-01	-5.12E+00	5.08E-01	4.72E+00	1.44E+00	-1.05E-01	0.14	5.14	94	727	1871
3	3	1.05E-01	-2.99E-01	-3.93E+00	4.03E-02	6.14E+00	1.44E+00	-4.22E-01	0.25	3.94	106	998	1965
4	3	1.68E-02	8.45E-01	-2.46E+00	8.89E-01	4.05E+00	1.44E+00	2.75E-01	0.04	2.75	79	112	154
5	3	4.24E-02	-3.10E+00	-1.51E+00	-3.07E-01	3.26E+00	1.44E+00	-6.31E-01	0.10	3.47	114	355	615
6	3	1.59E-02	-9.55E-05	-5.20E+00	3.48E-04	3.74E+00	1.22E+00	1.02E+00	0.04	5.20	50	199	519
7	3	2.23E-01	-1.10E+00	-3.68E+00	-7.17E-01	4.68E+00	1.41E+00	-1.26E+00	0.54	3.91	132	2107	4119
8	3	2.56E-01	-1.18E-01	-5.45E+00	1.61E-01	5.39E+00	1.44E+00	-1.27E+00	0.62	5.46	131	3374	9204
9	3	9.03E-02	5.27E-01	-2.91E+00	2.03E+00	2.44E+00	1.44E+00	5.87E-01	0.22	3.58	68	780	1398
10	3	2.55E-01	1.21E-01	-4.13E+00	3.83E-01	3.09E+00	1.44E+00	-1.02E+00	0.61	4.15	125	2549	5287
11	4	2.95E-02	4.65E-01	-2.84E+00	-4.63E-01	2.59E-01	1.44E+00	-1.11E+00	0.07	2.92	128	208	303
12	4	9.52E-02	-1.98E-01	-3.67E+00	1.68E-01	2.61E+00	1.39E+00	-1.18E+00	0.23	3.68	131	846	1557
13	4	5.09E-02	-1.09E-01	-3.84E+00	-1.74E-02	-1.76E-01	1.44E+00	-6.99E-01	0.12	3.84	116	471	904
14	4	2.38E-02	2.79E-01	-2.62E+00	3.92E-01	1.16E-01	1.44E+00	-6.91E-01	0.06	2.66	116	153	204
15	4	1.49E-02	2.68E+00	-3.16E+00	1.65E+00	1.02E+00	1.44E+00	1.07E+00	0.04	4.46	53	160	358
16	4	1.01E-02	2.01E-01	-2.53E+00	1.40E-01	2.56E-01	1.44E+00	-8.25E-01	0.02	2.54	120	62	79
17	4	1.01E-02	6.47E-02	-2.76E+00	-1.16E-01	2.50E-01	1.44E+00	-9.01E-01	0.02	2.77	122	68	94
18	7	6.07E-02	3.05E-01	-5.18E+00	6.84E-01	-1.26E+00	1.44E+00	8.65E-02	0.15	5.23	87	765	2001
19	7	4.74E-01	5.93E-04	-5.34E+00	-3.14E-03	-2.22E+00	1.23E+00	-1.18E+00	1.14	5.34	134	6103	16292
20	10	8.35E-02	3.41E-01	-1.09E+00	-1.36E+00	5.62E-02	-1.35E+00	1.13E+00	0.20	1.78	310	358	318
21	10	1.82E-02	1.15E-05	-4.75E+00	1.03E-04	-2.44E+00	1.44E+00	1.04E+00	0.04	4.75	54	209	496
22	12	1.50E-02	3.80E-01	-1.36E+00	-3.63E-01	4.92E+00	1.44E+00	-1.10E+00	0.04	1.46	127	53	39
23	12	2.78E-02	1.93E-01	-4.10E+00	-3.90E-01	2.45E+00	1.44E+00	6.86E-02	0.07	4.12	87	277	570
24	12	3.09E-02	-9.30E-02	-3.70E+00	-4.36E-02	4.66E+00	1.44E+00	-8.85E-01	0.07	3.70	122	275	510

Table XI-4. Impact Information for Static Case (Continued)

Block Number	3DEC Simulation Number	Block Volume (m^3)	Impact Velocity – X component (m/sec)	Impact Velocity – Y component (m/sec)	Impact Velocity – Z component (m/sec)	Impact Location Coordinate–X (m)	Impact Location Coordinate–Y (m)	Impact Location Coordinate–Z (m)	Mass (tonnes)	Velocity (m/s)	Impact Angle (deg)	Impact Momentum (Kg·m/sec)	Impact Energy (J)
25	12	3.39E-02	3.98E-02	-4.15E+00	-3.46E-02	4.75E+00	1.44E+00	-2.98E-01	0.08	4.15	102	339	704
26	14	5.90E-01	-5.67E-01	-3.98E+00	1.90E+00	-4.50E+00	5.46E-01	-1.27E+00	1.42	4.44	157	6329	14065
27	15	4.96E-02	-2.45E+00	1.37E+00	-7.45E-01	-9.66E+00	-1.69E-01	1.27E+00	0.12	2.91	352	348	506
28	15	1.96E-01	6.01E-01	-2.57E+00	-1.47E+00	-8.65E+00	1.34E+00	1.25E+00	0.47	3.02	47	1428	2158
29	16	1.56E-01	1.14E+00	-9.23E-01	1.29E+00	3.89E+00	-6.27E-01	-1.27E+00	0.38	1.95	206	734	717
30	16	1.78E-01	1.37E-01	-3.97E+00	1.31E-01	2.48E+00	6.13E-01	-1.27E+00	0.43	3.97	154	1701	3379
31	16	1.94E-02	1.22E-03	-2.80E+00	2.61E-02	2.20E+00	1.44E+00	-1.26E+00	0.05	2.80	131	131	183
32	16	3.15E-02	1.63E-01	-5.37E+00	1.80E-01	2.85E+00	6.52E-01	-1.27E+00	0.08	5.37	153	409	1098
33	16	1.32E-01	1.05E-03	-1.33E+00	1.55E+00	1.57E+00	-1.06E+00	-1.27E+00	0.32	2.04	220	649	661
34	16	1.62E-02	4.18E-02	-3.11E+00	1.80E-01	2.56E+00	1.44E+00	-1.26E+00	0.04	3.12	131	121	189
35	18	1.43E-02	-7.68E-02	-3.21E+00	-9.46E-02	2.31E+00	1.44E+00	9.17E-01	0.03	3.21	58	110	177
36	19	5.75E-02	-9.52E-02	-1.70E+00	2.06E+00	-5.75E+00	-5.51E-01	-1.27E+00	0.14	2.67	203	371	495
37	20	5.90E-02	-4.16E-05	-5.39E+00	4.70E-05	-4.07E+00	1.40E+00	-1.27E+00	0.14	5.39	132	767	2066
38	20	7.15E-02	-3.48E-01	-1.15E+00	-1.89E-01	-4.91E+00	1.40E+00	-4.01E-01	0.17	1.21	106	209	127
39	22	3.98E-02	5.47E-01	-8.52E-01	-5.92E-01	-7.29E+00	1.27E+00	-1.27E+00	0.10	1.17	135	113	66
40	22	4.40E-02	-6.81E-02	-3.33E+00	1.48E-01	-8.13E+00	1.44E+00	-7.14E-01	0.11	3.33	116	354	590
41	23	1.26E-02	8.06E-01	-3.27E+00	-9.97E-01	-8.83E+00	1.44E+00	1.27E+00	0.03	3.51	49	107	187
42	23	2.89E-02	4.15E-01	-1.33E+00	4.62E-01	-8.46E+00	-1.25E+00	1.27E+00	0.07	1.46	315	102	75
43	23	6.66E-02	9.64E-01	-2.32E+00	-8.81E-01	-8.07E+00	1.23E+00	1.27E+00	0.16	2.66	44	427	568
44	23	1.85E-02	-7.42E-02	-3.98E+00	-2.05E-01	-9.08E+00	-5.19E-02	1.27E+00	0.04	3.98	358	178	354
45	25	1.46E-01	-3.12E-01	-4.36E+00	-3.72E-01	5.46E+00	1.44E+00	8.33E-01	0.35	4.38	60	1542	3381

ATTACHMENT XII
CONVERSION OF FRACMAN FRACTURE OUTPUT TO 3DEC INPUT

ATTACHMENT XII

CONVERSION OF FRACMAN FRACTURE OUTPUT TO 3DEC INPUT

The coordinate systems used for FracMan and 3DEC are shown in Figure XII-1. The FracMan system is a right-hand system with North pointing to the negative x-axis, whereas the 3DEC system uses a left-hand system with North parallel to the z-axis. The conversion is accomplished by using the following equations:

$$x_{3DEC} = y_{FracMan} \quad \text{(Eq. XII-1)}$$

$$z_{3DEC} = -x_{FracMan} \quad \text{(Eq. XII-2)}$$

$$y_{3DEC} = z_{FracMan} \quad \text{(Eq. XII-3)}$$

This conversion was done in the Microsoft Excel spreadsheet files *Tptpmn- Fracman Generated Fracture Data.xls* and *Tptpll- Fracman Generated Fracture Data.xls* (Attachment I). The x-, y-, and z-coordinates in worksheet "3DEC coord" were obtained based on the original coordinate values in worksheet "Fracman output" and Equations XII-1 to XII-3. The dip, dip direction, and radius inputs in 3DEC were a direct copy from FracMan outputs. Additional worksheets which sort the fracture data listing based on the descending order for radius are included in *Tptpmn- Fracman Generated Fracture Data.xls* and *Tptpll- Fracman Generated Fracture Data.xls*. This sorted fracture data is used for 3DEC model optimization as described in Attachment VIII.

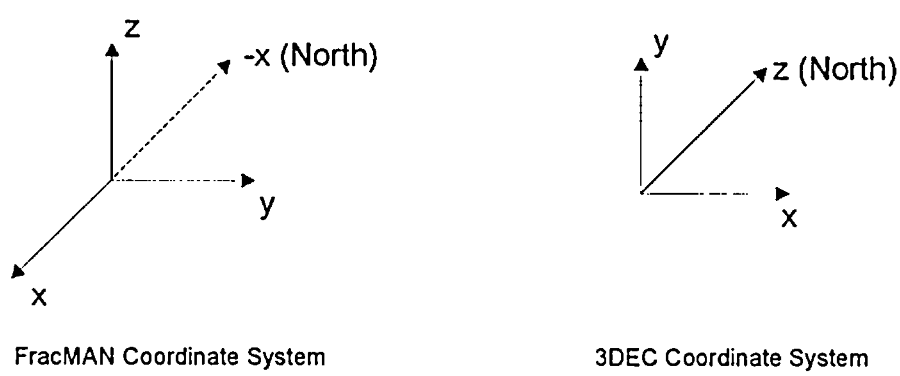

Figure XII-1. Coordinate System Adopted in FracMan and 3DEC

ATTACHMENT XIII

GFM2000 INPUT AND OUTPUT FILES FOR STRATIGRAPHIC UNIT THICKNESS DATA AND CROSS-SECTIONS

ATTACHMENT XIII

GFM2000 INPUT AND OUTPUT FILES FOR STRATIGRAPHIC UNIT THICKNESS DATA AND CROSS-SECTIONS

XIII.1 INTRODUCTION

Stratigraphic unit thickness and cross-sections for the thermal-mechanical calculation were extracted from DTN: MO0012MWDGFM02.002. The extracted stratigraphic unit thickness was used in calculating mean rock properties for the thermal-mechanical units, while the cross-sections were utilized to create three-dimensional mesh used in the thermal-mechanical calculation. The detailed calculation, data, and mesh description are presented in Attachments III and V.

The extraction of the unit thickness and cross-sections was conducted on the geologic data from the TDMS (DTN: MO0012MWDGFM02.002), using EarthVision V.5.1 software (see Section 3). The EarthVision V.5.1 software was qualified for 3-dimensional geologic modeling and was used within its range of validation. The stratigraphic unit thickness was extracted at the location of WE 170693 m and NS 232674 m that was approximately center of the repository (Attachment III, Figure III-3), while the three cross-sections were extracted at the locations of NS 231637 m, NS 234075 m, and NS 235904 m (Attachment III, Figure III-3).

All the input and output files from the EarthVision software for the extraction of the unit thickness and the cross-section are presented in the following sections.

XIII.2 EARTHVISON INPUT AND OUTPUT FILES

The input files (*central.dat*, *hope_01.sh*, and *combine.sh*) and output file (*alldata_01_2.dat*) for the extraction of the unit thickness at the location of WE 170693 m and NS 232674 m are available in the TDMS (DTN: MO0306MWDDDMIO.001).

The input files for the extraction of the three cross-sections at the locations of NS 231637 m (S3), NS 234075 m (S7), and NS 235904 m (S10) are also available in the TDMS (DTN: MO0306MWDDDMIO.001). The resulting cross-sections (output files *s3.dxf*, *s7.dxf*, and *s10.dxf*) are shown in Figures XIII-1 to XIII-3.

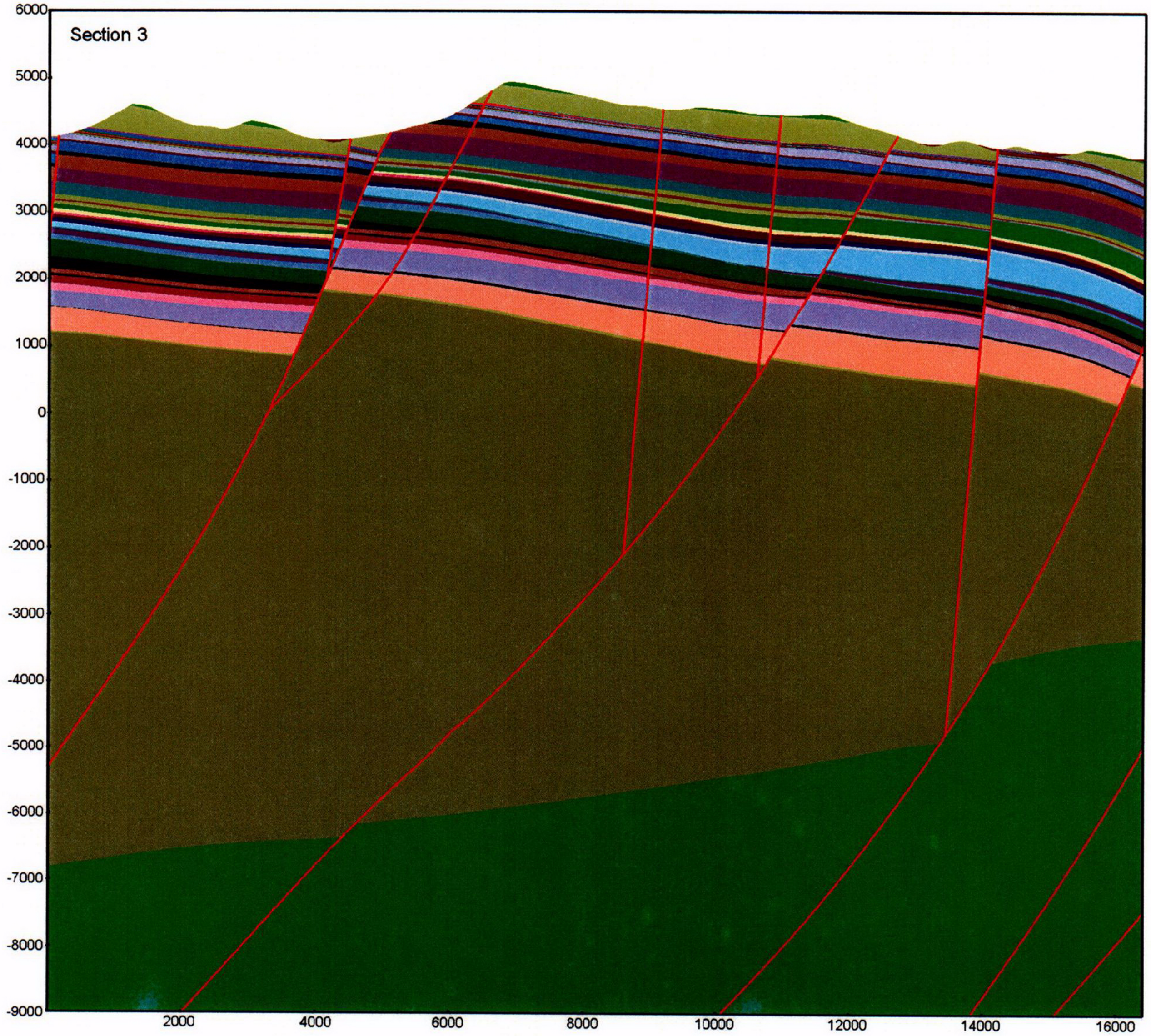

Figure XIII-1. Cross-Section Extracted at the Location of S3 (NS 231637 m), Using the EarthVision Software

C130

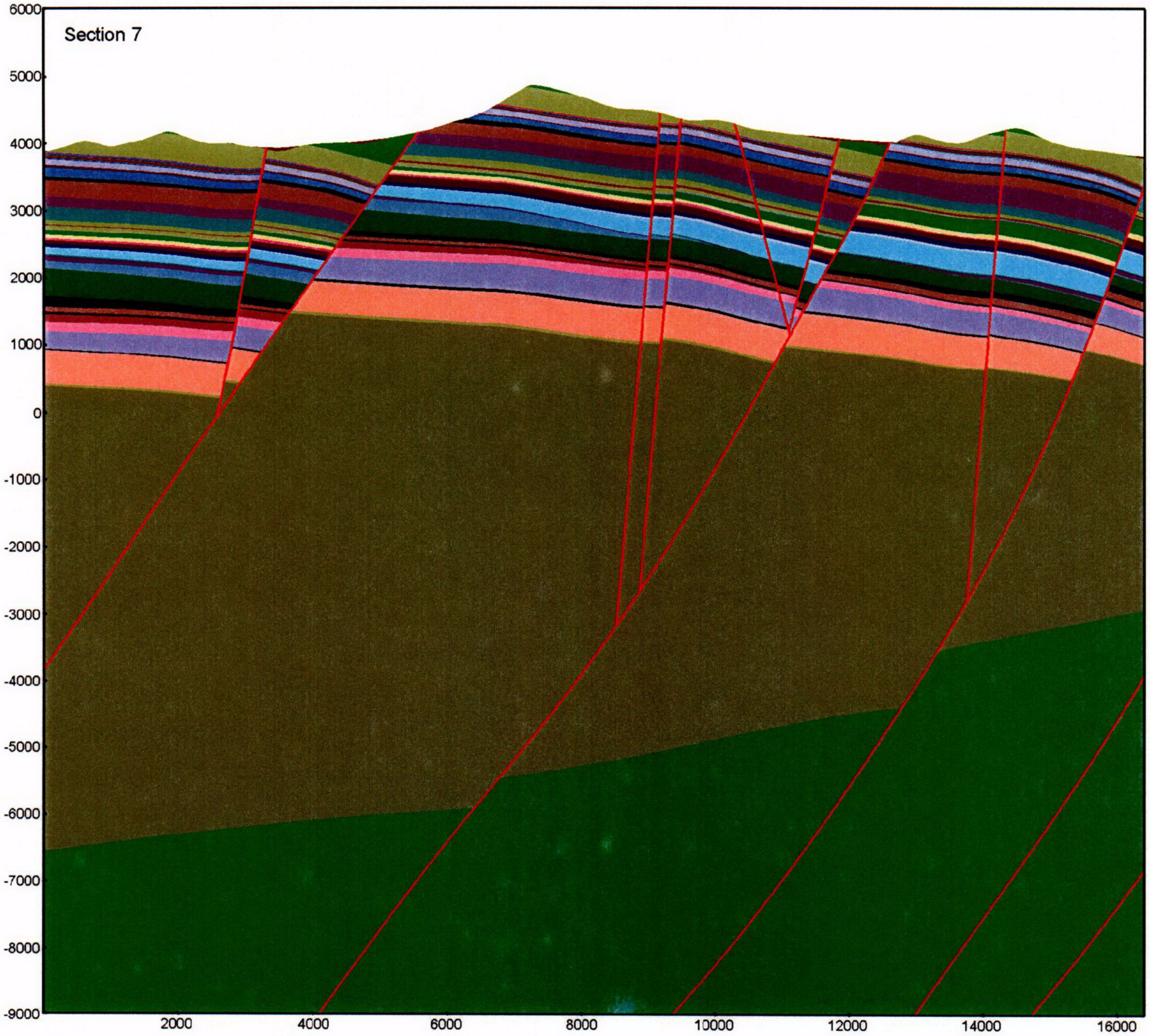

Figure XIII-2. Cross-Section Extracted at the Location of S7 (NS 234075 m), Using the EarthVision Software

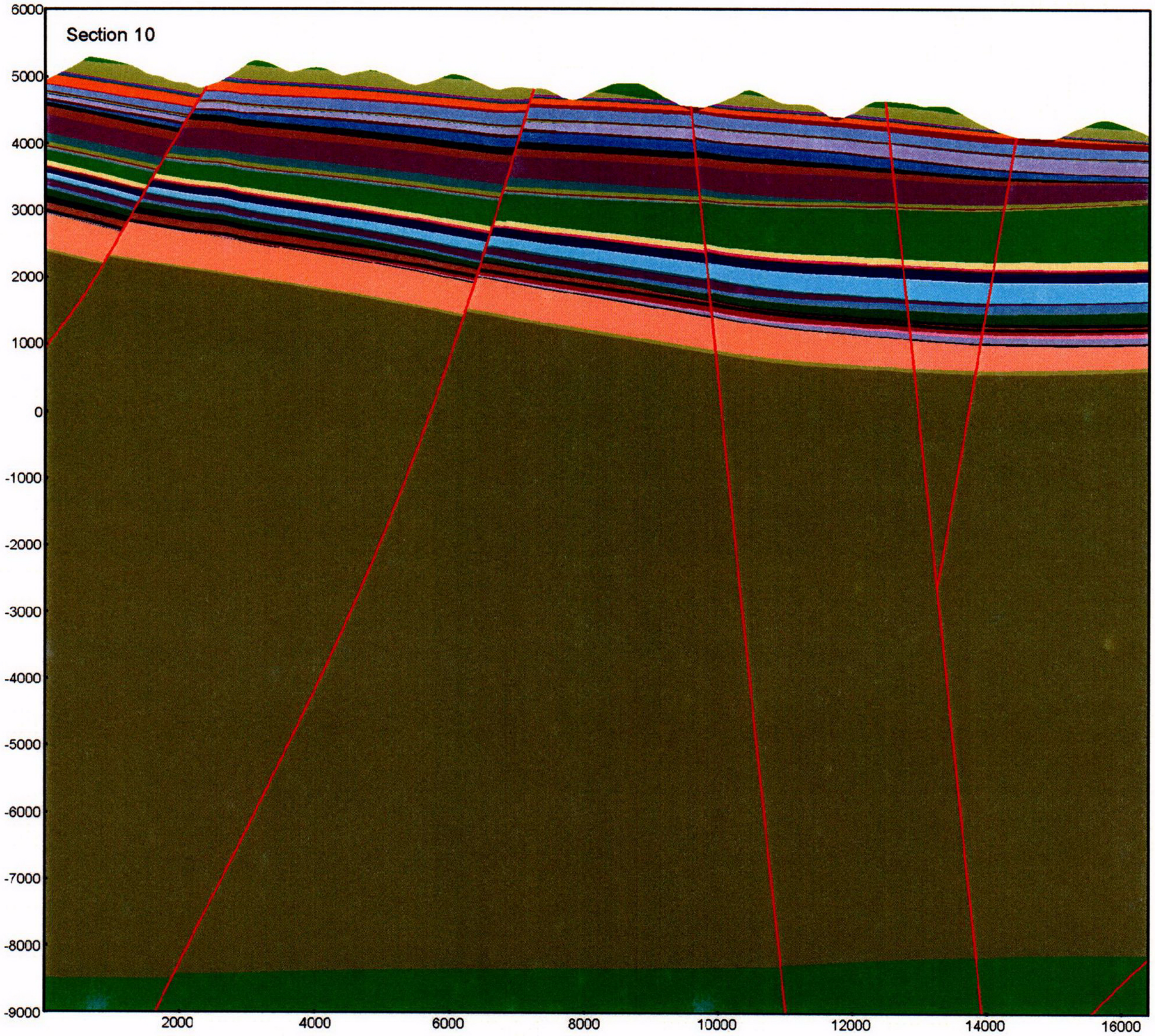

Figure XIII-3. Cross-Section Extracted at the Location of S10 (NS 235904 m), Using the EarthVision Software

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ATTACHMENT XIV

MODEL VALIDATION REVIEW - 3DEC MODELING OF SEISMIC GROUND MOTION-INDUCED ROCKFALL

ATTACHMENT XIV

MODEL VALIDATION REVIEW - 3DEC MODELING OF SEISMIC GROUND MOTION-INDUCED ROCKFALL

An outside expert technical review was conducted as a means of validating the 3DEC model for representation of nonlithophysal rock (see Section 7.10.4). Dr. John Tinucci of the PanTechnica Corporation in Minneapolis, Minnesota, was contracted for this purpose. Dr. Tinucci is a Professional Engineer and has a Ph.D. from the University of California, Berkeley, where his thesis research was in the area of analysis of the stability of blocky rock masses, and, in particular, in the development of key-block methods for tunnel stability assessment. He has extensive experience in the use of the 3DEC program for surface and underground stability assessment. Particularly valuable experience for the present application is his use of 3DEC to model dynamic stability of deep underground mine openings. Dr. Tinucci's review report is provided in this attachment.

The following errata are provided for Dr. Tinucci's report:

- Page 1/20: The report was submitted to the "Engineered Barrier System Department."
- Page 8/20: In Table 1, "Small Joints" are discussed on Page 11.
- Page 8/20: In Table 1, "Sub-horizontal Joint Spacing" is discussed on Page 12.
- Page 8/20: In Table 1, "Joint Strength Degradation" is discussed on Page 13.
- Page 9/20: In Table 1, "Fractured Rock Boundaries" are discussed on Page 14.
- Page 9/20: In Table 1, "Fractures in Floor" are discussed on Page 14.
- Page 9/20: In Table 1, "Event Orientation" is discussed on Page 15.
- Page 9/20: In Table 1, "Removing Unstable Blocks" is discussed on Page 15.
- Page 9/20: In Table 1, "Support System" is discussed on Page 17.
- Page 11/20: In the "Ground Motion" discussion, the three probable events are the 1 in 20,000 year event, the 1 in 1 million year event, and the 1 in 10 million year event.

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MODEL VALIDATION REVIEW

3DEC MODELING OF SEISMIC GROUND MOTION-INDUCED ROCKFALL

Submitted to

Engineers Barrier Group
Bechtel/SAIC

Review by

John P. Tinucci, PE, PhD
PanTechnica Corporation

Introduction

The 3DEC program is currently being used for simulation of mechanical response of the Middle Non-Lithophysal unit to seismic shaking induced by seismic ground motions. The objective of this modeling is to provide estimates of the size, shape and number of rocks that may be dislodged and fall into the emplacement drifts as a function of the level of the estimated ground motions. The ground motions (for various annual exceedence probability levels) are supplied by others within the project. This review is to be used as a portion of the validation requirements for model analysis given in procedure AP-SIII.10Q

Review Criteria - The documentation regarding the use of the 3DEC program for representing rockfall work has been reviewed using the following criteria:

1. Is this information presented accurately using applicable methods, assumptions, and recognized techniques?
2. Does existing model documentation provide adequate confidence required by the model's relative importance to the potential performance of the repository system to support model validation for its intended purpose and stated limitations?

Associated Documentation for Review – The following documents have been provided for review. It is understood that several of these documents are work-in-progress whose final content will be different upon submittal.

1. 3DEC V2.01 software qualification reports and Itasca 3DEC V2.01 addendum.
2. PowerPoint presentations of rockfall analyses.
3. Geology of the ECRB Cross Drift – Exploratory Studies Facility, Yucca Mountain Project, Yucca Mountain, Nevada, Mongano, et al, 1999.

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4. Fracture Geometry Analysis for the Stratigraphic Units of the Repository Host Horizon, G. Neider-Westerman, 2000.
5. Draft of preliminary work (draft report to date, Excel Spreadsheets for results summary, input files).
6. An Application of Rock Mass Characterization and Rock Joint Empirical Models at Yucca Mountain, To Assist in the Disposal Tunnel Design Studies, N. Barton, 2002.

Modeling Objectives – The original *Drift Degradation Analysis* documentation for these analyses was reviewed by NRC in 2001. The NRC identified four items related to rockfall analysis that must be resolved to close the Repository Design and Thermal-Mechanical Effects key technical issue. The four items, in annotated form, are:

- Provide clarification for how reduction in cohesion adequately accounts for thermal effects.
- Analyze small trace-length fracture data from the ESF and ECRB to assess their effect on block development.
- Provide basis for effective maximum rock size including consideration of the effect of variation of the joint dip angle.
- 1) Revise DRKBA analyses using appropriate joints strengths accounting for their long-term degradation. 2) Analyze block sizes based on joint trace length data supplemented by available small joint trace length data. 3) Verify DRKBA analyses using (a) thermal and seismic boundary conditions, (b) fracture patterns simulations, (c) thermal and mechanical properties for rock blocks and joints, (d) long-term degradation of joint strength, and (e) site-specific ground motion.

The 3DEC analyses are intended to address several of these items and this review includes comments on the applicable portions. The stated objectives of the drift degradation analysis, in annotated form are to:

- model jointing around the drifts,
- provide a statistical description of block sizes around the drifts,
- estimate changes in drift profile resulting from deterioration of the drifts, and
- provide an estimate of the time required for significant drift deterioration to occur.

Site Visit – On January 28 -30, 2003, a site visit was made to both the Bechtel/SAIC facilities and ESF facilities. Time spent at the Bechtel/SAIC facilities was to review the input data, model setup and analysis results which had been performed to date. Engineers Mark Board, Ming Lin, Dwayne Kicker and Rob Lung were involved in discussions. Part of one day involved an underground tour of the ESF facilities. The purpose of this trip

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was to examine actual rock conditions for which the 3DEC analyses were to represent. Both ESF and ECRB drifts were examined in the Lithophysal and Non-Lithophysal zones.

General Observations on Modeling Approach

The conceptual model that is used for these analyses is that a finite volume of rock containing the emplacement drift starts in an unsupported, equilibrium condition. Then a seismic event is applied to the model and blocks are shaken loose falling on the drip shield. Simulated fractures are used to compute blocks formed by their intersection and the rockmass is descretized in the numerical model. The program 3DEC is used to solve the system of equations. 3DEC uses a distinct element method to solve for the interaction between blocks. An explicit finite difference solution scheme is use to solve the equations of motion and deformability of the rock.

Conceptual Model Components – There are three key components of this conceptual model that have been included to represent realistic conditions. First the represented rock contains simulated fractures to capture the discontinuum behavior of the expected blocky rockmass. Second, the fractures have been generated using statistical data from mapped fractures, which produce realistic trace maps similar to traces mapped by the geologists underground. Finally, the in situ conditions of gravitational stresses, excavation-induced stresses and thermally-induced stresses have been included to represent static loading conditions, plus a stress wave is propagated through the model to represent dynamic loading conditions. These essential components define a model that is appropriate for the described purposes.

Representation Accuracy – As with any modeling analysis, the model is an accurate representation of actual expected rock behavior only when it represents conditions that lie within the known limitations. The mathematical tools employed (FRACMAN and 3DEC) are known to have limitations. However, upon review of the model, it does not appear that the conceptual model lies beyond the applicable mathematical representations of underground conditions and rock behavior. What has been implemented in these analyses is consistent with state-of-the-art numerical modeling techniques in the geomechanics industry.

Judging the accuracy of the model is very difficult because of the lack of measured data. The mathematical model only generally represents the underlying conceptual model. That is – there are no real underground drifts oriented the same as what was modeled to compare static results to. The fractures were only simulated since there is no way to map joints until the excavations are made. Rock and joint properties were only estimated from a few laboratory tests. No data has ever been recorded for ground motions for such low probability seismic event. However, the overall modeling approach that has been adopted has been used by other to show that it produces results that adequately represent expected

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conditions with sufficient accuracy required to estimate the four objectives of the analysis: effects of jointing, statistical representation of block sizes, changes in drift profile, and time required for drift deterioration to occur. We may never know how accurate the model results are, however, we do know that the approach adopted has been known to produce reasonably accurate results for analyses for which accuracy is known.

The analyses have done a reasonable job of quantifying where accuracy is required when additional, more accurate, analyses are preformed. The sensitivity study has identified that joint strength (especially dilation and cohesion), and joint frequency and orientation are critical parameters for predicting unstable block volumes. By identifying the sources of uncertainties and impacts of uncertainties on model output, the authors of this study are able to defend their current estimates and are knowledgeable about improving the model to reduce the uncertainties. More importantly, this study provides a basis for collecting additional field and laboratory data for resolving an important NRC key technical issue.

Mathematical Model Confidence – Due to the complexity of the analysis, the process used to establish confidence that the mathematical model produces reasonable results was broken down in parts. First the inputs, or initial conditions, were checked prior to simulating the seismic event. The volume of unstable blocks under 'static' conditions was examined for reasonableness. Since the analysis did not examine actual ESF or ECRB drift block geometries, it was not possible to compare the model results to unstable blocks observed underground. The next confidence check of the model was to pass a simple undamped wave to the model, applied at the bottom of the model. The output response at the top of the model was examined for reasonableness. This confirmed that the model was capable of passing waves without energy loss at boundaries and internally to the model. The model was then checked for result reasonableness by applying sequentially larger seismic events. This confirmed that larger seismic loading produced larger volumes of unstable blocks. Finally the sensitivity study was used to confirm the parameters having the greatest influence on the results. This was done to demonstrate the reasonableness of the base case conditions.

Alternative Algorithms – The overall approach of using FRACMAN to generate fracture, and 3DEC to compute the block and solve the equations of motions is not the only approach available for assessing block stability. There are alternative algorithms of simulating fractures, but none are known to so robustly address stochastic simulation, plus FRACMAN is the most widely used fracture simulation program in the petroleum, mining and nuclear waste industries. An alternative approach to simulating fractures was examined through the DRKBA rockfall analyses performed prior to this work. The simulation algorithm is not considered as robust as that implemented by FRACMAN. Similarly there are alternative block stability analysis methods available besides using the 3DEC program. The DRKBA program was used which makes use of limit equilibrium solution to stability. It is considered not as accurate as 3DEC since in situ stress, thermal stress, and seismic loading are not explicitly represented. An alternative numerical approach to 3DEC program is the 3-D DDA program. 3-D DDA is a distinct element method that solves the equations of motion and can account for in situ stress, thermal stress and seismic loading. Its limitation, as currently implemented is that blocks are simply deformable and the program has not been 'qualified' for use in the quality assurance aspects of nuclear waste program. Therefore, the overall approach to solving the mathematical models (i.e., FRACMAN and 3DEC combination) is the best that the geomechanics industry has to offer. The 3DEC program has been through the process of being 'qualified' for use from the quality assurance point of view.

Input Data Reasonableness – There are two classes of information used to develop the mathematical models: input data for assigning values to parameters and professional judgment for assembling the model. Great effort has been focused on using representative laboratory and field data to assign to parameters. A table in the report has been developed which identifies the source of inputs and how the magnitudes were determined. The only data that is unsubstantiated is the low probability seismic events (i.e., 1e-6, 1). In the absence of historic data, it is my opinion that these motions are too large and it needs to be demonstrated that the ground can geologically store and release such energy.

Model Abstractions – There is no doubt that some of the professional judgments used to develop the model have influence on the results. These judgments are treated differently because they are not a statement that is taken to be true in the absence of confirming data, as an assumption would do. Rather, these judgments are made to simplify the mathematical model, and thus are abstractions. There are trade-offs between accuracy and simplifications in order to compute results. The central constraint on these analyses is that the numerical model required to accurately represent the conceptual model can be excessively large and computationally intensive. Significant effort has been placed on reducing the mathematical model to a manageable size while having minimal impact on the accuracy of results. Judgments were necessary to optimize the number of blocks, the number of finite different zones, the boundary distance from the tunnel, constitutive behavior of intact rock and joints, time-step for dynamic loading, etc. The professional judgments used to simplify the model to a manageable size are logical and not inconsistent with what is commonly practiced in modeling underground tunnels in blocky ground conditions. Several of the simplifications can be argued as to their impact on results accuracy. However, their impact is minimal compared to the impact of the assumptions, especially in regards to the assumed seismic ground motions.

Intended Use of Results – It is understood that the output data is intended to be used for two general purposes: to estimate the force magnitude and location of blocks impacting the drip shield, and the profile of the degraded drift. These results could only represent 'typical best estimates' given that none of the real drifts currently exist and the fractures have not been mapped. Collectively, the assumptions and simplifications serve to provide results that are thought to be conservative; that is – one would expect that fewer blocks than are predicted by the model results would become unstable and fall when subjected to these conditions. However, these results are not considered to be 'upper bound' estimates because even more conservative assumptions and simplifications could be made and yet they would not be considered unreasonable. For example, it would have been reasonable to use 2-D UDEC models to provide estimates of unstable blocks. Therefore, the modeling approach adopted is reasonable (and rather novel) when compared to the intended use of the results.

Appropriate Confidence Level - Criteria for ensuring the appropriate level of confidence in the model results has been obtained is governed by two sets of criteria: appropriateness of the seismic events and appropriateness of the drift degradation analysis.

As mentioned before, I have serious concerns about the applicability of the low probability seismic records (i.e., $1e^{-6}$ and $1e^{-7}$ probability events) supplied as input to appropriately represent the expected ground motion. It has not been shown that such motions are sustainable by the geology, although the mathematical modeling techniques used to estimate the motion are consistent with common practice. Those techniques have not been shown to be applicable to low probability events. Other aspects of the seismic portion of the analysis (i.e., motion application, free field boundaries, event duration, etc.) appear to be appropriate. In order not to bias the results to an extreme type of seismic event, 17 real records were scaled to 3 expected magnitudes (i.e., 15 events implemented in combinations of various fracture realizations for a total of 105 simulations). This approach to examining various scenarios is appropriate given the lack of information on extremely infrequent historic seismic events.

Confidence in the other parts of the model related to simulating ground conditions (i.e., fracture simulation, application of various stress conditions, model discretization, removal of fallen blocks, etc.) are adequate given the intended use of the results. The criterion that data uncertainty be characterized and propagated through the model abstraction appears to be adequately addressed by the sensitivity studies. The need for the model to be compared to known conditions also appears to be adequately addressed by the fracture map comparisons, the pre-event conditions comparisons, and 3DEC results comparisons to DRKBA results. It is important to note that confidence in the model is based only on visual examination of expected conditions since no measurements or recordings were made as part of this analysis.

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Specific Observations on Model Assumptions and Abstractions

Given the above general discussion on the adequacy of the overall model results, there are aspects of the analysis that deserve specific comments. The purpose of this section is to address specific assumptions and abstractions that were necessary to assemble the conceptual and mathematical models.

Table 1 is a summary of each modeling issue. The table includes a summary of what aspect of that issue is important and the approach that was adopted in the analysis. Also tabulated is a summary of whether the approach is reasonable and any recommendations for changes or other issues that need to be considered.

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Table 1 – Summary Model Assumption and Abstraction Issues

Issue	Aspect	Approach	Approach Reasonableness	Recommendation.	Page Discussed
Joint Cohesion	Assumption – Magnitude of values	Mean minus 1 std dev, Zero in sensitivity	Reasonable, sensitivity will likely over-predict unstable blocks	Values should depend on other joint strength parameters.	10
Joint Friction	Assumption – Peak vs. Residual values	Mean peak, residual in sensitivity	Slightly conservative/slightly conservative	See above.	10
Joint Dilation	Assumption – not coupled w/ Friction	Zero, mean in sensitivity	Base case of zero combined with peak friction values is not reasonable	See above.	10
Joint Stiffness	Assumption – low normal & shear magnitudes	Similar normal & shear stiffness	Low values but acceptable since magnitude has minor impact on results		10
Intact Blocks Behavior	Abstraction – No rockmass failure	All elastic except 'glued' joints with high strength	Reasonable since inelastic blocks would not change results		11
Ground Motion	Assumption – extreme probabilities	Extrapolate using standard methods	$1e^{-6}$ and $1e^{-7}$ events appear unreasonably large, not completely rational	Reexamine the magnitude of input ground motions	11
Simulated Fracture Volume	Abstraction – Single realization in large volume	Random tunnel location within volume for different realizations	Reasonable given the limited of mapped data		11
Small Joints	Abstraction – small joints pulled from analysis database	Less than 1m length not included in statistics	Reasonable since they have low probability of forming blocks.		12
Non-Concave Blocks	Abstraction – Cutting non-joint area	Convex-blocks glued & given intact strength	Reasonable given that intact strength is much greater than joint strengths.		12
Fracture Size	Abstraction – Realness of simulation	Simulation based on area of joints per unit volume instead of length & spacing	Reasonable since samples from simulation compared well to maps.		12
Terezaghi Correction	Abstraction – Correct for joints sub-parallel to tunnel	Neglect correction	Reasonable given data collected from variable tunnel orientations & large tunnel size compared to joint spacing.		12
Sub-horizontal. Joint Spacing	Abstraction – Localized variations	Include all data to determine average	Locally not very conservative, but quite reasonable on overall repository scale.	Compute blocks on local spacing (~0.5m) to see block volume change – dynamic runs not necessary.	13
damping	Abstraction – natural damping of rock mass	None, 5% in sensitivity study	Reasonable given real value is not known and jointing provides some motion damping	Include a couple sensitivity runs	13
Bridge Failure	Abstraction – Bridge is only inelastic portion of block	Joints used intact rock strengths	Reasonable given rock strength is much greater than induced stress field	Check sub-contacts for several cases for failure along bridge and then re-assess need for using finer discretization.	13
Joint Strength Degradation	Assumption – Previous seismic loading of joint system	No degradation, residual friction. in sensitivity study	Unknown influence, but reasonable approach given sensitivity analysis is lower bound condition.		14
Similar	Abstraction –	None globally,	Collectively the approach is	Include references for other	14

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Analysis Approach	Acceptableness of approach	portions have been performed before	novel, but various parts are common to that done by others and thus overall approach is reasonable.	known studies that employ similar approaches.	14
Fractured Rock Boundaries	Abstraction – Sufficient Block Volume	Identify blocks along tunnel surface 25m, 35, & 45m in sensitivity study	Unknown impact, but issue with low probability seismic events, which are already suspect.	Run one case with a much larger fractured volume including floor	15
Fractures in Floor	Abstraction – Tunnel Deformability	Neglect blocks in floor	Reasonable given size of model and interest focused on falling rocks.	See above.	15
In Situ Stress	Assumption – Lithostatic stress field	Mean values, high stress ratio in sensitivity study	Reasonable, little impact on results since stresses would need to be much lower.		15
Event Duration	Abstraction – Length of shaking motion	5%/95% energy cut off by time	Reasonable, little impact on results since significant energy would need to be excluded.		15
Event Orientation	Abstraction – Compare to least stable block forces	Flip H_1 & H_2 along X&Y axes in sensitivity	Reasonable, little impact since horizontal components are similar in magnitude.		16
Removing Unstable blocks	Abstraction – Bulking stabilizes chain blocks	Deleted on contact, left in contact with drip shield in sensitivity study	Over predicts volume of unstable blocks, but provides a broader simulation of rockfall on drip shield		16
Comparison to Real Blocks	Abstraction – Observable validation	No comparisons made	Unknown impact since no real seismic response data exists	Should qualitatively compare blocks formed with those formed from simulated fractures.	16
DRKBA Analyses	Abstraction – Comparison to another approach	Of minor importance since analysis had major limitations	Stability part does not provide reliable comparison because no stress & no motion	De-emphasize DRKBA results in final report	16
Pore Pressures	Abstraction – Strength reduction during shaking	Neglect	Reasonable since not saturated		17
Thermal Stresses	Abstraction – Additional forces on blocks	Decoupled thermal and mechanical	Reasonable since boundary conditions for cooling are unknown		17
Reflecting Boundaries	Abstraction – Wave interference due to close boundaries	Implemented free-field non-reflecting boundaries	Reasonable		17
Support System	Abstraction – Effectiveness for additional support	Neglected	Reasonable since nobody knows how effective they will be in long-term		18

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Joint Cohesion – The approach adopted for joint cohesive strength was to use the mean value minus one standard deviation from laboratory data. It is not clear for these calculations how much of the cohesion can be relied on in the long-term. For most dam stability analyses (USACOE & USBR) the designers would assume no long-term cohesion. However, during trip underground the joints were observed to be very tight, with the only observable open joints at the springline, most likely associated with tunnel excavation disturbance. Overall, this approach to cohesion is reasonable and yet not overly conservative. It is recommended that joint cohesion be considered in conjunction with the other joint strength parameters, per Barton's recommendation. See Table 1.

Joint Friction – Friction angle values have been taken as mean peak total friction for the base calculations (while assuming dilation is zero). Residual friction values were used in the sensitivity studies. The combinations of cohesion, friction and dilation for estimating rock strength should all be inter-connected and not be treated as independent cases. The base case (i.e., fri. = peak fri. & dil. = 0) is not logical since laboratory tests did not show zero dilation when peak friction is attained. The case with residual friction and no dilation makes physical sense as a state that could exist after disturbance has occurred. It is recommended that joint friction be considered in conjunction with the other joint strength parameters. See Table 1.

Joint Dilation – Dilation angles other than zero were run in the sensitivity study. Results suggest dilation has a large influence on the stability of blocks. The laboratory values used for dilation are probably on the low side given the tightness of joints observed during the underground visit. Dilation plays an important role in these analyses partly because of the presence of low apex angle blocks formed by the intersection of the high angle joints. That is, the dominant joints intersect to form large sliver-shaped blocks whose apex angle is between 10° - 20°. Removable blocks require roughness (or dilation) angle if less than ½ the apex angle – in the range of 5° - 10° in order to be removable. This range is close to values reported for the laboratory tests. Therefore, by assuming dilation angle of zero would conservatively predict the number of removable blocks as well as a lower composite joint strength. It is recommended that joint dilation be considered in conjunction with the other joint strength parameters. See Table 1.

Joint Stiffness – Joint stiffness were taken as mean values from laboratory data. Shear stiffness normally is expected to be less than normal stiffness, by about 1-2 orders of magnitude. However, joint normal and shear stiffness were the same value in the analysis, which were 6 orders of magnitude less than the stiffness of the intact blocks. Their magnitude seems low given the tightness of joints. The implication of this is that most of the deformation around the tunnel will be taken up by the joint system. When combined with the low cohesion and medium friction angles used for joint strengths, much of the block deformation will be in the form of joint slip. Stiffer joints would mean more of the deformation would be from joint slip instead of compression. The approach adopted to assign joint stiffness is not expected to have significant influence on the number of unstable blocks. Thus, the approach to adopting joint stiffness is reasonable and yet not overly conservative. See Table 1.

Intact Blocks Behavior – Elastic blocks have been assumed in this analysis. This implies that the intact rock in infinitely strong. Sidewall fractures near springline in the tunnel were observed in the lower non-lithophysal unit during the underground visit. However, beyond a distance of about ½ m the rock showed minimal observable damage, even in the jointing. The strength of the non-lithophysal rocks is estimated at about 70 MPa, yet the maximum stresses around the tunnel are about 21 MPa (i.e., 3 times σ_1). During dynamic loading some localized sidewall spalling could be expected. By ignoring the energy loss associated with minor spalling more energy is transmitted to the joint system. This might slightly over estimate the number of unstable blocks. This approach to intact rock strength is quite reasonable, but might result in conservative results (i.e. too large unstable block volumes). It is recommended that a sensitivity case be run with inelastic blocks to see if the low probability seismic events produce stress spikes sufficient to local sidewall spalling. See Table 1.

Ground Motion – Ground motion input data represents three probable events: the 1 in 10,000 year event, the 1 in 1 million year event and the 1 in 10 million year event. Peak motions are reasonable for the $5e^{-4}$ event (PPV = 19 cm/s, PPA = 0.19 g). However, they appear high for the other 2 events ($1e^{-6}$: PPV = 2.44 m/s, PPA = 10.46 g and $1e^{-7}$: PPV = 5.35 m/s, PPA = 16.28 g). If such ground motions had been experienced underground, there is expected to be geologic evidence of damage, especially in the weaker lithophysal zone. Yet nothing has been reported by site geologists. When these large ground motions are input to the 3DEC model, the results indicate that all removable blocks become unstable. The results appear excessively conservative. See Table 1.

Simulated Fracture Volume – Simulated joints have been used to generate the jointing geometry that the blocks are computed from. Statistical parameters from scanline mapping data were computed and input to FRACMAN program to simulate a single realization of the 3-D joint system. The volume of rocks simulated was a 100 m x 100 m x 100 m cube oriented parallel the emplacement drifts (00/073 as X axis,). A 25m x 25m x 25m of rock surrounding the tunnel was then randomly located within the cube. The 3DEC model was "cut" depending on the relative location of joints within the volume. Given the lack of real data in the emplacement drifts (as they are unmined to date) this is a very reasonable approach to estimate the jointing that might be there when the tunnels are excavated. See Table 1.

Small Joints – It is understood that statistics were computed (length, spacing, dip, dip direction, termination, etc.) with only mapped joints longer than 1m. Ignoring small joints will have minimal impact on the stability results because 1) it can be shown that small joints have a low probability of intersecting to form blocks and 2) such small blocks have a high probability of being "nested" in larger removable blocks. Thus, the approach to neglecting short joints in the FRACMAN simulation is reasonable and does not produce overly conservative results. In fact the inclusion of such short joints is expected to produce a large number of "isolated" joints whose impact would be to soften the overall rockmass, likely reducing the number of unstable blocks for a given ground motion. This could be verified by making a sensitivity run but is not necessarily recommended at this time given the purpose of the analyses. See Table 1.

Non-concave Blocks – 3DEC is limited to using non-concave blocks. When fractures are input they must "cut" completely through a given block. The approach adopted was to overcome this limitation by "gluing" joints back together for the portion of the joint beyond the radius of the simulated joint. Complex FISH functions were written to allow this on a block by block basis. Although this approach is quite clever, it is recommended that these functions be carefully checked for errors due to their complexity. This approach has been used by others in programs like UDEC; however, I am not aware of it being used in 3-D. Although "gluing" cut blocks using intact rock properties is a common practice in 3DEC analyses, this application of "gluing partially cut" blocks in novel. This approach is a very reasonable and is capable of producing realistic block geometries and fractured rockmass geometries. See Table 1.

Fracture Size – Fracture size is handled in FRACMAN by using trace length and spacing data to compute a statistical area of fractures required in the given volume of rock. The simulation generates a fracture radius and location for a given set while checking the area-to-volume ratio. Each set is simulated separately and then superimposed to compute truncations. The reasonableness of this approach is checked by generating unrolled simulated fracture maps of fractures as they intersect the tunnel walls. These maps were compared to actual unrolled fracture maps recorded underground. The FRACMAN results produce reasonable maps that look realistic when compared to recorded unrolled maps. See Table 1.

Terezaghi Correction – The FRACMAN analysis has made no adjustments in the data for fractures oriented sub-parallel to the tunnel. It is common for fractures mapped in smaller diameter openings, such as boreholes, to be biased in the number of fractures recorded sub-parallel to the opening. A Terezaghi correction would normally be applied to the data to correct for this. In the case of the ESF, there is a sub-horizontal joint set sub-parallel to the plunge of the tunnel. However, the project geologists that did the mapping felt that due to a) the large diameter of the tunnel when compared to the observed spacing of the sub-horizontal set and b) the mapped tunnels traversed a range of orientations, it is not likely that a significant number of sub-horizontal fractures were not accounted for in the overall database of joints. Thus, the approach of not applying a Terezaghi correction to the sub-horizontal joint set data is reasonable. See Table 1.

Sub-horizontal Joint Spacing – The spacing of sub-horizontal jointing was observed to vary along the length of the tunnel in the non-lithophysal zone. In some locations it appeared to be on the order of ½ m spacing (longer joints) while in other areas it was in excess of 4m spacing (shorter joints). Results from the joint statistics report an average spacing of 4.2 m. It is likely that the statistics "smear" the spacing to this larger value. It is this sub-horizontal plane that typically forms the release plane on blocks formed by the intersection on the other 3 joint sets. By not directly accounting for the ½m spacing long sub-horizontal joints, only very large blocks become removable. It is these large blocks where de-stressing around the tunnel has little impact on their stability. Had this closer spacing been used, more blocks nearer the tunnel surface would have been formed and thus a larger unstable volume predicted in certain areas of the tunnel. The approach adopted is reasonable on the scale of the repository, but might under predict unstable blocks locally. It is recommended that other FRACMAN simulations be performed to check the effect on the distribution of removable blocks. It is probably not necessary to perform additional dynamic analyses unless block size distributions are vastly different. See Table 1.

Damping – All of the dynamic analyses have been performed with a motion damping coefficient of zero. This implies that the only damping in the system is the energy loss due to interaction between blocks brought about by the open/close shaking of joints. It is common practice to use some minor amount of damping (2% - 5%) to account for natural damping of the rock mass. The impact of not damping the motion is expected to be more high-frequency energy being available at block boundaries and more "vibration" of the joints. This would lead to more joint slip and, thus, more unstable blocks. To neglect damping is reasonable and yet not overly conservative. It is recommended that a couple sensitivity runs be made to verify how conservative this assumption is. See Table 1.

Bridge Failure – The way blocks are formed in the model required that the joint extend beyond the simulated radius, but the "non-real" area of the joint was "glued" back using intact rock strengths (see item Non-Concave Blocks above). This glued area simulates an intact "bridge" of rock. When combined with the elastic blocks, any differential motion across the "isolated" joint will result in significant stress concentrations in the "glued" portion nearest the joint. Since the intact rock strength was used for simulate the gluing, this is the only place in the model where the intact rock could fail. Given a) the large strength difference between the joints and the intact rock, b) the rapid load change of the applied seismic event, and c) no applied damping in the system, there could be artificially high stresses generated at the glued contacts nearest the joint contacts. It is not known what percent of the reported unstable blocks had originally glued joints that had broken during the seismic event. The percentage of "unstable blocks with partially glued faces" might be sensitive to the number of sub-contacts along the glued joints. If this is the case, the reported volume of unstable blocks could be over estimated for a modeling discretization reasons. It is recommended that the unstable blocks from a few runs be checked to see if a large portion of their face area were from glued sub-contacts. If this is true, a sensitivity run should be made with a more finely descretized grid. See Table 1.

Joint Strength Degradation – The strength of joints were held constant for all seismic events. However, blocks exposed to low probability events will also have experienced

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higher probability events. This repetitive loading will result in shaking damage to the joint system (e.g. on average for every 10^{-7} event the rock will have experienced 10 of the 10^{-6} events). This shaking damage should manifest itself as a reduction in strength. This behavior was not simulated in the base case analysis. The sensitivity study includes a case with residual joint strengths, which would represent a lower bound condition for this behavior. It is unlikely that accounting for this behavior would improve the reliability of the results since no laboratory data is available to estimate the magnitude of joint strength degradation. Thus, the approach adopted of examining results from residual strength runs is reasonable. See Table 1.

Similar Analysis Approach – The entire analysis approach adopted for this study is thought to be unique. The reviewer knows of no other complete set of analyses that have been published in the literature that approach the magnitude or complexity of this study. However, others have adopted aspects of the analyses. For example, the use of FRACMAN to simulate a volume of fractures based on line mapping data has been documented. The same is true of the use of 3DEC to simulate seismic ground motion. The novel portions of the model development (i.e., gluing blocks in non-joint regions, selectively cutting blocks to minimize the numbers of blocks, etc.) is not unique and has been documented. However, it is their automation via FISH functions that has not been published else where to the reviewer's knowledge. Rockfall analyses of waste repository drifts have been studied in the Finish waste program, although the approach was to analyze block stability using static loading and limit equilibrium solutions. Dynamic analyses of rockfall conditions have been performed for South African deep-mining rockburst problems. Given the uniqueness of these analysis requirements, it is the reviewer's opinion, sufficient aspects of the adopted modeling techniques have been documented by other researchers that the overall approach to estimating seismic rockfall volumes is reasonable. All other known similar analyses would be sufficiently more conservative than those presented here. It is recommended that the final report contain references to known published analyses. See Table 1.

Fractured Rockmass Boundaries – A 25m x 25m x 25m volume of rock was used to compute discrete blocks in 3DEC, even though 100m x 100m x 100m was simulated in FRACMAN. The sensitivity of results to this volume has been examined by computing blocks in 35m x 35m x 35m volume and 45m x 45m x 45m volume. Results indicate less unstable blocks at 35m and more at 45m. The reason for this is not explained. The reason for using the original 25m was to keep the computations to a manageable size. In the reviewers opinion the sensitivity study does not address whether the 25m volume is adequate. It is recommended that one large block model (60m x 60m x 60m of fractured rocks) with the tunnel centered in the volume be computed with fine zone discretization. This model would simulate blocks more than 10 tunnel diameters extending beyond the major zone of excavation-induced stress region. See Table 1.

Fractures in Floor – The model did not simulate any blocks in the floor of the tunnel, yet fractures are known to exist there. The reason was that the analysis focuses on gravitational rockfall after being dislodged. The impact of neglecting fractures in the floor is less deformability of the tunnel and more motion-energy is likely transmitted to the joint system. This approach allows a reduction in the computational size of the model. The approach is reasonable, yet would produce a larger volume of unstable blocks than had the floor been represented as fractured. It is recommended one large block model be computed that includes fractures in the floor (see Fractured Rockmass Boundaries). See Table 1.

In Situ Stress – Pre-excavation in situ stresses used in the analyses were taken from mean measurement values. A sensitivity run was made with a higher stress ratio ($\tau_h : \tau_v$). Given the small expected variations in the stress field, there is little influence on the results. In situ stress is considered a minor variable in the analyses and thus the approach adopted is reasonable. See Table 1.

Event Duration – The decision was made to truncate the duration of the seismic record due to excessive computational time required to complete the analysis. The approach was to compute the applied energy over time and cut the record duration so that the first 5% and last 5% of the energy was neglected. This is a common practice in numerical modeling of seismic events in such high strength materials because only small changes occur in the model with late-time motion. This would not be the case if pore pressure dissipation was thought to be an issue for block stability. An alternative approach that is used in similar analyses is to perform frequency filtering where high frequencies are filtered since they contain little energy. This was not necessary for these analyses for two reasons: a) the critical time-step is governed by the minimum block and zone sizes capable of transmitting the wave motion, and b) automatic inertial mass scaling was implemented into 3DEC. Additionally, the peak energy is applied early in the record so loose blocks will have had sufficient time to fall, and thus the length of the event is expected to have little impact on the final rockfall volume results. This approach to shorting the record duration is reasonable. See Table 1.

Event Orientation – Ground motion was applied to the model parallel the model boundaries with υ_v vertically in Z axis, υ_{H1} horizontally in X axis and υ_{H2} horizontally in Y axis. In the sensitivity study H_1 and H_2 motion components were reversed. This method does not necessarily produce the worst case motion on individual blocks. However, the combination of forces critical for block stability will be different for each block since each block is comprised of joints of different orientations. Given the near random shape of blocks (and thus their critical force vector orientation) and the fact that H_1 and H_2 components are of similar magnitude, the net impact on the predicted volume of unstable blocks is expected to be minimal. Therefore the approach of performing a sensitivity computation where the H_1 and H_2 components are reversed is reasonable. See Table 1.

Removing Unstable Blocks – The base case analysis adopted the approach of removing blocks from the analysis after they had made contact with the simulated drip shield. This

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was done to estimate potential impact of subsequently unstable blocks that might hit the drip shield. In actuality, large blocks would likely stay in contact with the drip shield preventing other blocks from impacting it. For large collapse zones, large blocks might even prevent other blocks from falling. The other blocks would loosen but not have space to fall freely. In the sensitivity analysis a case was run where no unstable blocks were deleted in order to check this approach. The approach of removing the blocks by deleting them after they contact the drip shield is reasonable. See Table 1.

<u>Comparison to Real Blocks</u> – All of the analyses were performed with block geometries determined from the FRACMAN-simulated joint volume. No real blocks in the underground tunnels were analyzed. Although the actual geometry is not known because they extend back into the Rockmass, fewer modeling assumptions are required to generate the blocks (i.e. their location, orientation and tunnel trace length are known). Such an analysis would provide a comparison between the volume of unstable simulated-blocks and the volume of unstable real-blocks. Comparisons of unstable blocks from real and simulated fracture sections are not expected to be the same; however, the ratio of stable to unstable volume of blocks should be similar. It is recommended for purposes of model calibration that 3DEC blocks be generated from the FRACMAN volume for comparison to specific sections of tunnel. If the block volumes are similar then there will be more confidence in the approach used to simulate blocks for emplacement drift orientations. There would be no need at this time to compute the seismic response unless the block volumes were vastly different. See Table 1.

<u>DRKBA Analyses</u> – The original rockfall study was comprised exclusively of results from DRKBA limit equilibrium analyses. Those analyses were limited by the following assumptions:

- In situ stresses were neglected.
- The seismic motion was represented by changing joint cohesive strengths.
- Thermal stresses were neglected.
- Fracture simulation was based on joint length and spacing only along tunnel surface and assumed infinite into the Rockmass.
- Small trace length data was included producing significantly more volume of small blocks

The first 3 of these are considered major limitations (the 2^{nd} is considered not completely rational as it applies to resisting forces instead of driving forces). Although there are these limitations, the analyses results provide an alternative approach to the 3DEC numerical model results. It is recommended that the DRKBA results discussion in the original report on be moved to an attachment and they be de-emphasized. See Table 1.

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Pore Pressures –Pore pressure in the rockmass generated as a result of the seismic shaking were neglected in these analyses. This is reasonable since the rock mass is only partly saturated and the build up of pore pressures is unlikely. See Table 1.

Thermal Stresses – Thermal strains induced by the waste heating the drifts will generally serve to increase the stresses on the blocks. As the repository cools over time, these stresses will dissipate. The cooling impact on the local joint system is unknown as joints may either stay closed in compression or open due to tension. Either way, this effect is expected to extend only locally around the peripheral of the drift where the radial stresses are low. Larger blocks would remain clamped by the thermal stresses. The approach adopted in the analysis was to decouple the thermal calculations from the mechanical calculations. This is reasonable since the rock is treated as elastic and all the strains (including thermally induced) are fully recoverable. The only irrecoverable deformations occur as joints slip. Thermal calculations were sequenced by computing: thermal equilibrium, static mechanical equilibrium, and then dynamic loading. This approach is reasonable because it allows the blocks to come to static equilibrium prior to seismic loading. See Table 1.

Non-reflecting Boundaries – One of the problems in modeling seismic events is that the applied wave reaches the boundary of the model and is reflected back into the area of interest before the complete wave has passed through the area of interest. This would result in an amplification of the motion. The 3DEC program was modified specifically for these analyses to include non-reflecting boundaries. This prevents reflected motion from propagating back through the grid. It is reasonable that an equivalent dynamic stress was applied to the base of the model propagating upwards to simulate the seismic event. Vertical free-field boundaries were applied consisting of a row of zones that simulate non-reflecting boundaries. This approach is common for dynamic analyses. See Table 1.

Support System – No ground support was included in the model. Although support is expected to be installed in the drifts, it is reasonable to assume that they will not contribute significant support in the long-term. See Table 1.

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Conclusions

The modeling effort represented by this work is some of the most extensive rockfall analyses in blocky rockmass known to be performed to date. The mathematical model makes use of several novel techniques for representing fractures and then creating a blocky rockmass.

The simulation work done with FRACMAN is theoretically sound and produces a realistic fracture pattern similar to trace maps recorded by the geologists. Although local fracturing (i.e., lengths, spacing, orientation relative to the drift, etc.) might be different than average values computed from the entire database, the simulated fractures appear very reasonable. Even the technique of simulating one set of fractures in a large volume and then sampling from random locations within the volume to create the 3DEC block model is a rational approach,

The combination of joint strength properties (i.e., cohesion, friction angle and dilation angle) for the base case has not been considered collectively. Rather, as independent parameters they represent conditions that do not make sense (i.e., peak friction and no dilation).

Joint stiffness values are low but, since their magnitude has minor impact on results, the approach is acceptable. In agreeing with Dr. Barton (Introduction: Reference #6, above), the normal stiffness should be stiffer than the shear stiffness, although I am not sure I agree with Dr Barton on the orders of magnitude.

The low probability seismic events (i.e., $1e^{-6}$ and $1e^{-7}$) appear unreasonably large as input ground motion. It should be demonstrated that the geology can store such energy before such events are used in analysis. No geologic evidence, to the reviewer's knowledge, has been presented which suggests that such large events have occurred in the geologic past. There is no doubt that this is the single most influential parameter in the analysis due to the large range of acceleration and velocity variations.

The manner in which sub-horizontal fracture spacing was treated results in predications not very conservative on a local level where average spacing of long fractures is significantly less. However, on an overall repository scale the approach is reasonable because there are other local areas where the sub-horizontal fracture spacing is significantly more than average. This is another reason that the study results apply overall conditions and not locally.

The DRKBA stability analysis performed for the original rockfall study does not provide reliable comparison to these analyses because no stress was included nor was ground motion properly represented. However since there are not many other discontinuum block analyses techniques that can be use to compare the FRACMAN/3DEC analyses to, a

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summary of the DRKBA results should be left in the report because they are of comparison value.

Finally, it is important to note that the analyses presented in this study have been well conceived. Given the complexity of mathematical models and the limited data available, the team has developed an analysis procedure which is state-of-the-art. They have combined techniques in a way that provides realistic estimates of rockfall volumes and impact on the drip shield. Undoubtedly, as more data become available this approach can be refined to provide more accurate estimates. I do not believe it is worthwhile spending the effort to provide more accurate estimates at this time since data uncertainty is still large.

Recommendations

There are several techniques that can be used to improve the accuracy of these analyses with the current uncertainty in data. The following recommendations should be considered as part of the work scope for producing a final document for this work. The recommendations are in order of decreasing importance.

1. As mentioned throughout this review the large seismic events are suspect. It is recommended that the input motions be reexamined. Although review of the seismology work was not part of this review scope, more convincing arguments need to be presented which demonstrates that the geology can actually store this energy and sustain such motion.

2. The base case values for joint strength parameters should be examined through a sensitivity study to be consistent with each of cohesion, fraction angle and dilation angle.

3. Due to the complexity of the FISH functions within 3DEC model, it is highly recommended that all the functions be independently checked by another engineer to ensure accuracy. This might include more detailed comments/documentation of those functions.

4. A sensitivity case should be included where a block system is compute on local spacing (~0.5m) of sub-horizontal joints to see block volume change. It would not be necessary to perform the dynamic runs. This will provide a feel for variations in the unstable block volumes.

5. The documentation of these analyses should include references for other known studies that employ similar approaches to solving this type problem. This will significantly boost the reader's confidence that the adopted approach has been published elsewhere.

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6. A sensitivity case should be included were several damping values are used to estimate the uncertainty in neglecting damping in the model.

7. Unstable blocks should be checked for sub-contacts to have been broken along the "bridge" portion of the block. The results should then be reassessed to see if a sensitivity case is needed with finer discretization provides the same results.

8. A sensitivity case should be developed that uses a much larger fractured volume which includes the floor. This will provide confidence that block stability is not biased by the limited number of blocks simulated in the model.

9. To provide confidence that the simulated fracture set provides stability results similar to that obtained from real mapped fractures, a sensitivity case should be run using specific jointing mapped in the ESF or ECRB drifts. This will qualitatively compare the volume of blocks formed with those formed from simulated fractures and provide confidence that the analyses are not excessively conservative in predicting unstable blocks.

10. The final documentation should de-emphasize DRKBA results by moving them to an attachment and provide a succinct summary of their results.

I hope that BSC finds this 3DEC modeling review to be beneficial. If you have questions on the findings I can be reached at 952-368-3079 or jtinucci@pantechnica.com.

Respectfully submitted

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