SOCIETAL RISKS ARISING FROM MOD(UK)'s EXPLOSIVES STORAGE FACILITIES

BY

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ESTC RISK ASSESSMENT STUDY

MOD(UK)

Paper prepared for
US DOD Explosives Safety Seminar
Las Vegas, NV, 20 - 22 August 96

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1996**	2. REPORT TYPE	3. DATES COVERED **00-00-1996 to 00-00-1996**

4. TITLE AND SUBTITLE **Societal Risks Arising from MOD(UK)'s Explosives Storage Facilities**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **MOD, Directorate of Defence Health and Safety,TL-RAST(ESTC),London SW1A 2HB**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM000767. Proceedings of the Twenty-Seventh DoD Explosives Safety Seminar Held in Las Vegas, NV on 22-26 August 1996. U.S. Government or Federal Rights License

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report "SAR"**	**15**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

INTRODUCTION

The Ministry of Defence in the United Kingdom (MOD(UK)), is well aware of the increasing demand for public accountability, and the need to explain its activities to interested parties (stakeholders). Comparison is required between hazardous activities performed by MOD(UK), and more familiar hazards elsewhere. Procedures are reasonably well developed for the estimation of risks to an individual, both for the workforce and members of the general public, but we are less content with arrangements for estimating and managing risks to exposed groups of people. This paper is intended to publish some recent work by MOD(UK) on societal risk from its explosives storage activities, and to comment on the various methods we have used to arrange risks in order of importance.

BACKGROUND

MOD(UK) has a well defined management procedure for the safe control of explosives storage and handling. This calls for the operator of a facility to identify people at risk and to satisfy him- (or her-) self that risks are both tolerable and as low as reasonably practicable. In many cases, this can be achieved by following prescriptive rules which have been shown (for example by benchmark tests) to ensure an acceptably safe condition. In other situations a site specific risk assessment is necessary.

We have previously published [1,2], details of the procedure we have developed for assessing risks from explosives storage activities. A management protocol has been developed which combines the advantages of prescriptive rules (for routine and low risk situations) with risk assessment procedures (more appropriate for higher risks). The authority and advice of senior management is an essential input to the procedure where local powers are likely to be exceeded. Safe working arrangements are based upon the estimation of risks to representative exposed individuals.

However, situations can arise when estimates of risks to individuals do not give adequate weight to a particular situation. For example, when large numbers of people are exposed to a low risk, each member of the group will bear a negligible individual risk - especially if the duration of any exposure is short. Nevertheless, if the very unlikely hazard was to occur while large numbers of people happened to be in the area, then the number of fatalities could be unacceptable. MOD(UK) is in the process of producing guidance to its line managers on the management and control of societal risk.

An essential input to the decision making process is the ability to arrange estimates of risk in order of importance. .

RANKING RISKS FROM EXPLOSIVES STORAGE ACTIVITIES

The most straightforward method is to rank estimates of risk to individuals from events at Potential Explosion Sites. An illustrative example is shown in Figure 1, involving three different groups of people at risk. Continuously exposed residents; the work force (who are exposed for an eight hour day, 200 day- year), and a worst case motorist (who passes through a hazardous area four times a day). Each group is located at a different position and so different consequences can be anticipated if an event occurs.

Illustration of Individual Risk

GROUP	EXPOSURE	EVENT FREQUENCY	FATALITY	RISK
Resident	1	1.0e-3	1.0e-2	1.0e-5
Worker	0.24	1.0e-3	1.0e-1	2.4e-5
Motorist	0.003	1.0e-3	5.0e-2	1.5e-7

COMMENTS

- Useful for Manager to reduce risks within category
- Potential equitable balance between categories (manager's view)

PROBLEMS

- High Hazard -Low exposure appears justified
- No indication of total numbers involved for contingency plans

Figure 1

The Individual Risk and a priority order can be generated from the event frequency and the appropriate estimate of consequence. This gives useful guidance for the risk reduction plans within category, and can also provide a basis for the manager to illustrate his selection of an appropriate balance between groups.

However, there is a pitfall when the individual at risk is not continuously exposed to the hazard. Managers might be tempted to reduce risk values by exposing a succession of different individuals for short times. Although each person's Individual Risk may be tolerable, the risk of a fatality within the group of workers should also be taken into account.

Other difficulties with Individual Risk methods are that they do not indicate the numbers of people involved, nor guide the development of contingency plans. Therefore

although individual risk estimates do provide guidance to risk managers the process does need careful thought to avoid missing important information.

<u>Expected Annual Fatalities</u> Risks to groups of people can be estimated from the average number of fatalities expected for a particular situation per year. The information required to estimate risk to groups of exposed persons is very similar to that needed for Individual Risk, but the way in which the data is handled differs somewhat. We need details of:-

The populated exposed sites and the numbers present.
The fraction of a year when present.
The likelihood of each foreseeable event.
The related fatality probability for a continuously exposed individual at each site.

Societal Risk Illustration

GROUP	RESIDENT	WORKFORCE	PASSENGERS
NUMBER THERE	10	100	400
PROB FATALITY	1.0e-2	1.0e-1	5.0e-2
EXPECTED FAT	0.1	10	20
EXPOSURE	1.0	0.24	1.0e-3
EVENT FREQ	1.0e-3	1.0e-3	1.0e-3
EVENT x EXPOSURE	1.0e-3	2.4e-4	1.0e-6
AVE EXPECTED FAT	1.0e-4	2.4e-3	2.0e-5
? PRIORITY	2	1	3

Figure 2

An example is shown at Figure 2. The problem is the same as used earlier for individual risk. This time, the number of people in each group is added to provide information on the expected number of fatalities within each exposed group (residents, workers, travellers) and the average number of fatalities per year overall. Uncertainties are considerable, but inputs are chosen to provide maximum estimates of risk. The main value of this procedure is that the average expected number of fatalities can provide comparisons of risks to groups - for related activities. It therefore has potential use as a performance (or in this case failure) indicator.

However, the low numbers produced for quite hazardous situations can suggest a lack of concern. Also management can still be accused of not identifying, or paying sufficient regard to particularly vulnerable members of society.

The procedure does, however, enable results for many sites to be combined to generate national figures. In the UK, we have not yet achieved this, but we have combined results for 17 of the largest MOD(UK) explosives storage facilities with the following results. A summary is shown at Figure 3, and the complete results are given in Tables 1 and 2.

Nationwide Results

Average Expected Fatalities from 17 Major Explosives Storage Sites in UK

Estimates of frequency of explosives accidents with between X and Y fatalities

X	400	100	50	20	10	5
Y	101	51	21	11	6	1
FREQUENCY	3.1e-4	1.0e-2	8.0e-3	2.6e-3	1.9e-2	1.1e-1

AVE EXPECTED FATALITIES FOR EACH RANGE (per year)

(X):	0.13	1.03	0.40	0.05	0.19	0.55
(Y):	0.03	0.51	0.16	0.03	0.09	0.11

OVERALL EXPECTED FATALITIES : MAX 2.9 MIN 0.9

Figure 3

Results for individual sites have been ranked in order of the expected number of fatalities for each foreseeable event. These were banded together to yield estimates of the frequency of events expected to cause between X and Y fatalities.

Thus the expected average number of fatalities from all the major facilities in UK, is estimated to lie between one and three people per year. It can be also seen that the highest foreseeable number of fatalities from a single event we have identified is 400.

<u>F- N Curves</u> Another useful technique involves the use of Complimentary Cumulative Frequency Distribution curves, popularly shortened for this application to Fatality -Number or F - N curves.

This procedure also makes use of an ordered list of frequency/fatality data pairs. The expected number of fatalities from each reasonably foreseeable accident is listed in decreasing order.
Event frequencies are largely independent of the number of fatalities, and an attempt to plot frequency against number of fatalities generates a scatter plot. However, by summing the frequencies of events which are expected to generate more than N fatalities, we can obtain a moderately smooth Cumulative frequency or F-N curve.

A detailed example is given in the appendix. The F - N curves for explosives events show a steep intercept with the fatality axis. This indicates that there is usually a finite number of fatalities from this type of accident. In a few cases, regulations have been drafted to define acceptable levels of risk on the basis of F-N graphs. Many of these concern ionising radiation, where there is often a relationship between event frequency and the expected numbers of fatalities through the size of release and the dose. In these cases a linear threshold for an F-N envelope may be appropriate

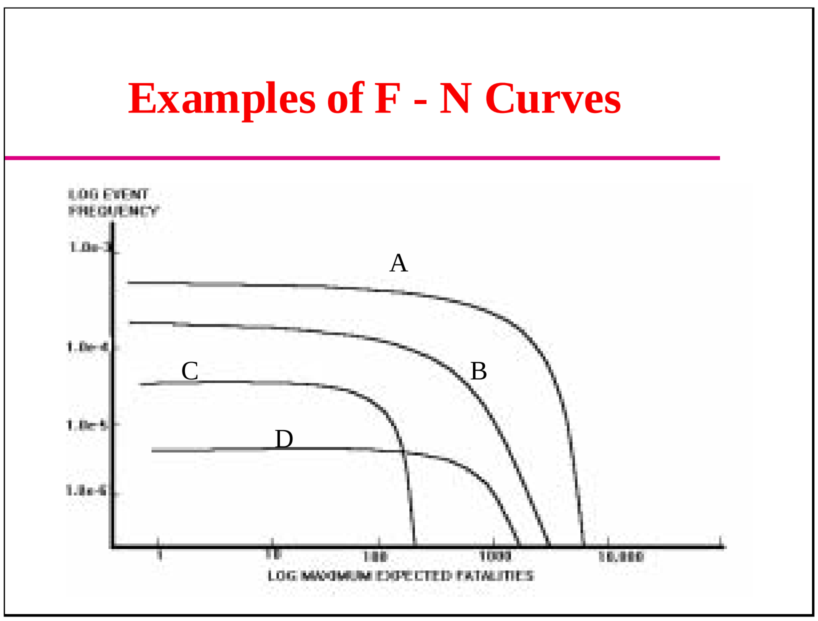

Figure 4

It is our view that in cases such as explosives safety management the use of regulations based upon linear F - N thresholds is unsound because only a small portion of the F - N Curve is controlled. However, F - N curves can be of considerable use to managers for guiding the selection of best solutions. (Figure 4). Obviously, curve (b) offers a clear advantage over curve (a). It is more difficult, however, to decide whether curve (c) or curve (d) presents the best improvement over curve (b).

In cases such as these, the manager needs to appreciate that the essential differences between the options are:-

high frequency low consequence
low frequency high consequence

and that different groups of people are probably involved. Managers can then make a visible and defensible choice of the best solution taking account of all stakeholders values.

F - N plots for the same sites referred to earlier are shown in Figure 5 . The figure also shows values of tolerable and broadly acceptable risk criteria which have been suggested by our Health and Safety Executive in the UK. The results indicate that estimates of maximum risk, lie well within the tolerable region. However, it is doubtful whether lowering the event frequency of accident scenarios which come closest to the threshold line would be seen as an acceptable means of reducing risk.

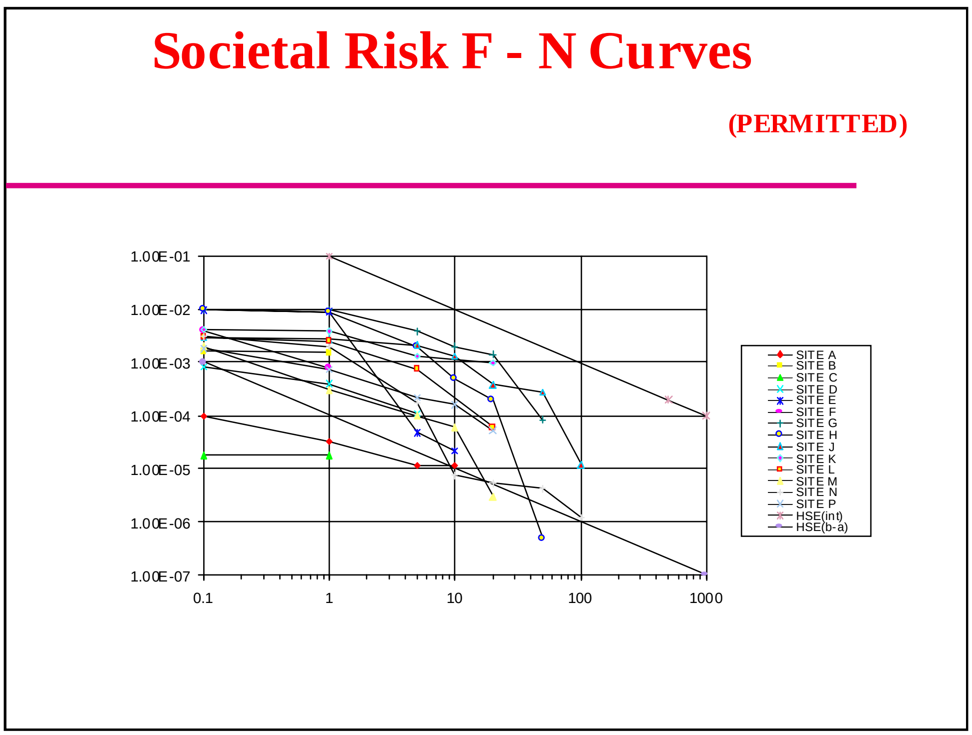

Figure 5

F - N curves are useful for illustrating different risk situations and the people affected by them. They can also help decision makers select the best solutions for their particular situation and resources. However, the general use of linear F - N thresholds as a basis for regulation is questionable.

CONCLUSIONS

No single risk assessment procedure meets our needs for a consistent and defensible control procedure.

Individual risk methods are the simplest and probably the best place to start. However, some apparently acceptable individual risk situations are difficult to defend in practice.

Contingency planning will need to take account of both the likelihood of foreseeable accidents and the number and nature of casualties.

Different groups of people will merit different levels of protection. Risk Assessments have to take account of the location and justifiable expectations of exposed groups at risk. Public perceptions of risk are always changing and a regular review of decisions on risk is necessary.

Management have difficult decisions to make, but RA can provide a defensible structure.

NEXT STEPS

It is obvious that the quality of decisions is limited by uncertainties in the data - and improvements need to be made. The need for solutions to specific problems will focus our efforts and support cases for resources.

We are particularly interested in comparing our approach with those used in other countries. The difficulties caused by centrally imposed prescriptive regulations are widely recognised, and alternative local control arrangements for safe working will have to be devised.

Although our experience has been obtained mainly through our need to manage risks from military explosives, we think that the principles we use are general. In addition to other H&S applications, we have found that environmental issues and also resource management decision can benefit from the same principles: Visibility, Defensibility, Consistency, Completeness.

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5 Figures
2 Tables
1 Appendix with 2 further figures and 3 tables

SOCIETAL RISK FROM F-N DATA

TABLE 1

SITE		ANNUAL FREQUENCY FOR ACCIDENTS WITH FATALITIES IN RANGE:					
	MAX	400	100	50	20	10	5
	MIN	101	51	21	11	6	1
01							6.7E-4
02				1.5E-4	3.5E-4	1.0E-3	2.3E-3
03				4.0E-4	6.0E-4	8.0E-4	5.0E-4
04						8.6E-8	1.4E-8
05				3.2E-5	3.3E-4	3.8E-4	1.5E-2
06				9.7E-4		3.3E-4	2.5E-3
07						9.6E-5	3.3E-2
08							1.0E-4
09						1.1E-4	2.9E-4
10					1.3E-4	5.3E-3	3.8E-2
11		1.2E-6	3.0E-6	1.1E-6	2.2E-6	1.6E-4	1.8E-3
12			1.0E-8	6.0E-5		7.4E-4	1.8E-3
13							7.9E-4
14				3.1E-5	2.0E-5	2.6E-5	9.0E-3
15		1.2E-5	2.6E-4	1.1E-4	9.2E-4	8.0E-4	6.0E-4
16				1.4E-3	6.0E-4	1.8E-3	5.8E-3
17		3.0E-4	9.7E-3	5.0E-3		8.0E-3	
SUM		3.1E-4	1.0E-2	8.0E-3	2.6E-3	1.9E-2	1.1E-1
		-------------- EXPECTED ANNUAL FATALITIES FOR EACH RANGE --------------					
	MAX	0.13	1.03	0.40	0.05	0.19	0.55
	MIN	0.031	0.51	0.16	0.03	0.09	0.11
		-------------- ANNUAL TOTAL EXPECTATION BETWEEN 2.3 AND 0.9 --------------					

TABLE 2

CUMULATIVE FREQUENCY(PER YEAR)OF ACCIDENTS WITH MORE THAN N DEATHS						
VALUE OF N	>100	>50	>20	>10	>5	>1
CUM FREQ (UK)	3.1E-4	1.1E-2	1.9E-2	2.1E-2	4.0E-2	1.5E-1

APPENDIX

ESTIMATION OF SOCIETAL RISK FOR AN EXPLOSIVES STORAGE FACILITY.

MOD(UK) has developed a method for estimating the risk of fatality at an exposed site (ES) from an accidental initiation at a licensed explosives building (also known as a potential explosion site or PES). Although this procedure is primarily intended to identify individuals at risk and the major contributors to such risks, the same information can be handled slightly differently to produce an F - N curve as a representation of societal risk.

The procedure is described below. For the purposes of this demonstration, it has been assumed that the consequences of each accidental initiation relate to instantaneous consumption of the maximum quantity of the most lethal store permitted in the building. The likelihood of initiation is set by the most vulnerable permitted store, and this is usually different from the consequence driver. This procedure produces a significant overestimate of the maximum risk. It is chosen here for demonstration purposes, to provide a data set without too many trivial inputs.

The facility under consideration has 72 licensed explosives buildings or open areas, including a road/rail interchange and 11 processing buildings. The remaining PES's house closed boxes of explosives stores which must be removed to a process area before opening. Nearby there is a public road and a railway line which carries limited passenger traffic.

For the demonstration, the normal output from the assessment of individual risk has been rearranged to provide information on societal risk. It can be assumed that all the people exposed to significant risk from the facility are present at one of the listed exposed sites. The probability of fatality at each exposed site (given that an initiation has occurred in a specified PES) can be multiplied by the number of people present at the ES to provide an estimate of the expected number of deaths. Repeating this process for all ES's provides an estimate for expected deaths for an event in the PES. Repeating the whole procedure for each PES generates the base information for an F - N plot. Table A1 shows for example, that the expected number of fatalities from an accident in ESH C9 amongst continuously exposed persons is five, and the likelihood of an initiation within the ESH is estimated as 1.76E-4 per year.

In addition to this we need to consider those who pass through the hazardous area, in a vehicle or by train. For instance, assuming that there are ten trains per day, and 400 passengers are on each train, and each train is in the danger area for 3 minutes, then the fraction of a year for which a train is exposed is 0.020; the likelihood of an accident occurring in ESH C9 while a train is present is 3.6E-6, and the expected number of fatalities is 95. A similar calculation can be achieved for a road use. Based on survey data there is only one car per hour in each direction, which, assuming a speed of only 30km/hr, exposes the passengers to the hazard for a total of 8 minutes. The number of occupants in each car is taken to be four.

A second table is constructed which combines the temporary risk data for all PES's with that from Table A1, and shows each event likelihood (frequency),f, for each credible event three different circumstances:

a. the presence of a train, (T)
b. the presence of a vehicle (V)
c. the absence of both train and vehicle. (N)

This data is ranked in order of the expected number of fatalities from each credible event in Table A3. Brief consideration of the raw data in Table A3 (which is plotted in fig A1) is sufficient to confirm that any plot of f against N is very sensitive to choice of bandwidth, frequently breaks up into random excursions. The procedure used by Farmer effectively circumvents this difficulty by converting the data to show the cumulative frequency (F) of accidents which are expected to generate N or more deaths. This has the effect of producing a complementary cumulative distribution function which decreases monotonically with N. Figure A2 refers.

FIG A1 ACCIDENT EVENT FREQUENCY

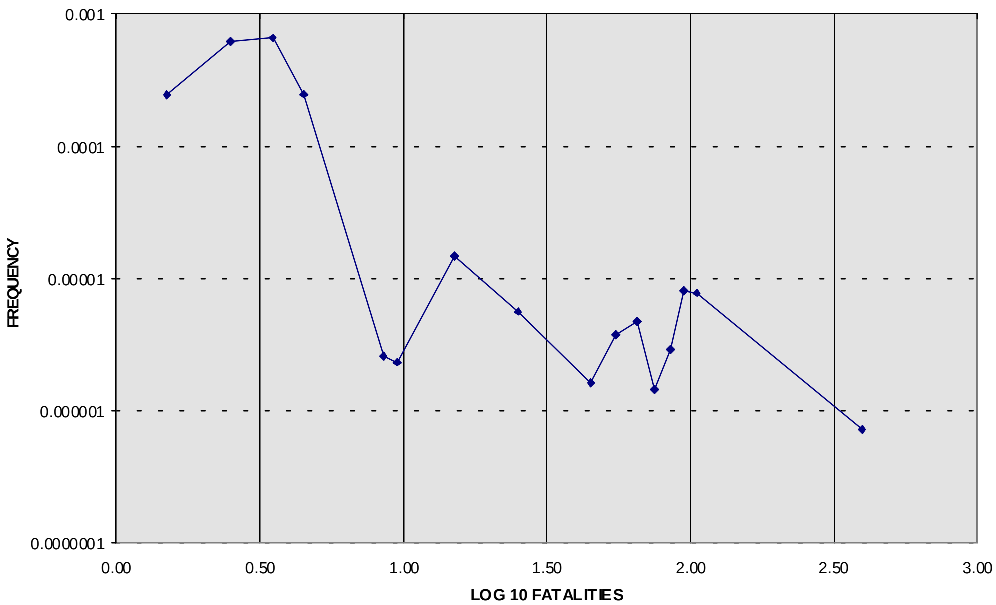

FIG A2 CUMULATIVE FREQUENCY

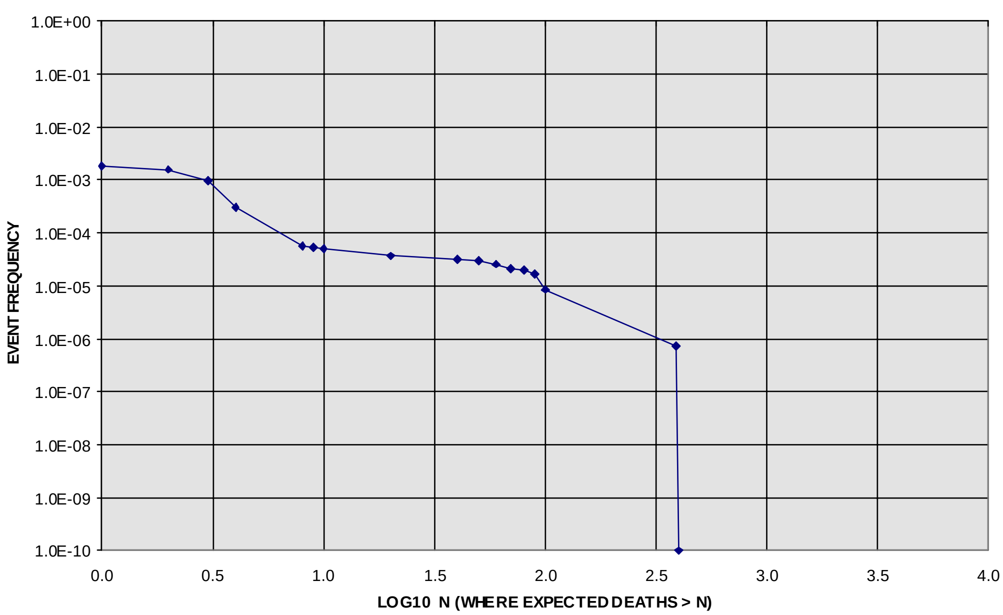

TABLE A1 - FATALITIES AT EACH EXPOSED SITE

PES		Explosion Frequency	Process Office	NESH	Main Office	Police Lodge	Private Residence	Bldg C8a	Bldg A14a	Unused ESH	All Fatalities
ESHA1	N	2.08e-04	1.27e-03	3.86e-06	2.78e-05	2.39e-05	2.70e-05	1.29e-03	0.00e+00	0.00e+00	2.64e-03
ESHA10	N	8.10e-05	9.02e-02	3.36e-02	1.93e-01	1.13e-01	7.47e-02	5.53e-01	1.82e-02	1.01e-02	1.09e+00
ESHA11	N	7.89e-05	2.14e-01	1.02e-01	5.50e-01	2.80e-01	1.91e-01	1.29e+00	9.67e-02	2.43e-02	2.74e+00
ESHA12	N	3.36e-05	2.95e-01	1.34e-01	7.07e-01	3.54e-01	1.92e-01	1.34e+00	2.40e-01	1.73e-02	3.27e+00
ESHA13	N	7.65e-05	4.38e-01	1.89e-01	8.78e-01	3.78e-01	1.61e-01	7.14e-01	5.52e-01	2.01e-02	3.33e+00
ESHA14	N	1.63e-05	4.29e-01	2.04e-01	7.90e-01	2.73e-01	1.03e-01	5.06e-01	1.35e+00	2.17e-02	3.68e+00
ESHA2	N	1.42e-05	9.26e-04	6.18e-06	4.04e-05	3.29e-05	4.73e-03	2.55e-03	4.76e-07	0.00e+00	8.29e-03
ESHA8	N	5.35e-05	9.44e-03	1.07e-04	4.30e-03	1.04e-02	8.90e-03	1.77e-04	4.77e-03	1.05e-03	3.91e-02
ESHA9	N	6.13e-05	5.13e-02	1.09e-02	1.02e-01	7.03e-02	4.71e-02	2.13e-01	1.30e-02	5.46e-03	5.12e-01
ESHB1	N	5.21e-05	2.49e-05	5.75e-06	5.44e-05	8.58e-03	3.61e-03	1.49e-03	0.00e+00	0.00e+00	1.38e-02
ESHB10	N	1.00e-04	3.97e-01	1.83e-01	8.80e-01	3.62e-01	1.55e-01	1.20e+00	4.25e-01	1.75e-02	3.62e+00
ESHB12	N	6.77e-05	1.87e-02	6.64e-03	2.17e-02	6.42e-03	5.87e-04	5.80e-02	5.15e-01	2.59e-04	6.27e-01
ESHB13	N	6.10e-05	2.01e-01	7.57e-02	2.32e-01	5.00e-02	9.52e-05	1.55e-01	2.16e+00	2.77e-02	2.90e+00
ESHB14	N	5.56e-05	9.30e-02	3.09e-02	6.86e-02	4.03e-05	7.14e-05	6.27e-02	2.16e+00	1.74e-02	2.43e+00
ESHB15	N	5.03e-05	4.80e-02	1.80e-02	1.63e-04	2.86e-05	4.76e-05	1.07e-01	5.72e-01	7.60e-03	7.53e-01
ESHB2	N	8.67e-06	2.86e-04	6.63e-05	1.03e-03	1.46e-04	2.23e-05	3.33e-05	0.00e+00	0.00e+00	1.59e-03
ESHB3	N	8.94e-06	1.18e-04	7.03e-05	1.09e-03	1.32e-04	9.66e-06	2.34e-04	0.00e+00	0.00e+00	1.65e-03
ESHB4	N	9.02e-06	8.19e-05	9.28e-04	1.43e-03	7.06e-05	3.88e-07	1.37e-03	0.00e+00	0.00e+00	3.88e-03
ESHB5	N	1.26e-05	6.75e-05	1.15e-03	5.30e-04	5.32e-06	1.74e-06	5.97e-02	4.24e-06	0.00e+00	6.14e-02
ESHB6	N	1.56e-05	7.69e-05	8.79e-04	2.08e-04	7.83e-06	4.25e-06	2.65e-01	1.73e-04	1.02e-06	2.66e-01
ESHB7	N	1.84e-05	1.23e-04	8.01e-04	2.05e-04	1.22e-05	7.96e-06	8.59e-01	1.33e-02	1.21e-05	8.73e-01
ESHB8	N	1.06e-04	2.33e-01	9.81e-02	5.14e-01	2.88e-01	1.91e-01	2.16e+00	1.48e-01	2.05e-02	3.65e+00
ESHB9	N	6.97e-05	3.02e-01	1.36e-01	7.04e-01	3.75e-01	1.83e-01	2.16e+00	2.00e-01	2.03e-02	4.08e+00
ESHC1	N	8.87e-06	8.96e-06	1.32e-05	1.19e-02	1.02e-03	1.69e-04	8.83e-04	0.00e+00	0.00e+00	1.40e-02
ESHC10	N	1.08e-04	4.63e-01	2.09e-01	9.66e-01	2.76e-01	1.07e-01	7.48e-01	4.83e-01	3.22e-02	3.28e+00
ESHC11	N	9.18e-05	5.09e-01	1.95e-01	5.63e-01	1.77e-01	4.34e-02	4.24e-01	5.63e-01	4.79e-02	2.52e+00
ESHC2	N	1.53e-05	1.41e-05	1.00e-05	1.55e-02	3.05e-03	5.29e-04	1.60e-03	0.00e+00	0.00e+00	2.07e-02
ESHC3	N	5.21e-05	2.01e-04	1.16e-04	5.54e-04	2.91e-02	7.41e-03	1.66e-02	0.00e+00	0.00e+00	5.40e-02
ESHC4	N	1.47e-05	1.28e-05	6.40e-05	1.74e-05	0.00e+00	0.00e+00	3.27e-06	0.00e+00	0.00e+00	9.74e-05
ESHC5	N	1.19e-05	3.23e-05	5.06e-04	4.81e-05	8.77e-07	0.00e+00	1.36e-03	0.00e+00	0.00e+00	1.95e-03
ESHC6	N	5.45e-05	2.49e-03	8.99e-04	3.55e-02	4.50e-02	3.64e-02	6.49e-02	1.74e-02	3.20e-03	2.06e-01
ESHC7	N	5.34e-05	2.46e-02	1.18e-02	1.33e-01	8.53e-02	5.08e-02	2.86e-01	1.29e-02	6.98e-03	6.11e-01
ESHC8	N	6.06e-05	6.57e-02	3.63e-02	2.18e-01	1.05e-01	7.50e-02	8.76e-01	1.04e-02	9.71e-03	1.40e+00
ESHC9	N	1.76e-04	4.02e-01	1.60e-01	7.93e-01	3.61e-01	1.43e-01	2.16e+00	2.95e-01	1.47e-02	4.33e+00
ESHD10	N	7.01e-05	2.95e-01	1.52e-01	6.62e-01	3.55e-01	1.70e-01	1.50e+00	1.48e-01	8.64e-03	3.29e+00
ESHD11	N	1.13e-04	4.07e-01	1.74e-01	7.76e-01	3.36e-01	1.44e-01	1.03e+00	2.40e-01	2.06e-02	3.13e+00
ESHD12	N	1.16e-04	4.20e-01	1.87e-01	8.16e-01	2.60e-01	9.82e-02	5.86e-01	3.44e-01	4.34e-02	2.76e+00
ESHD13	N	1.53e-04	4.58e-01	1.77e-01	4.98e-01	1.43e-01	3.12e-02	3.51e-01	3.95e-01	6.86e-02	2.12e+00
ESHD14	N	1.58e-04	2.27e-03	7.67e-05	3.60e-04	6.22e-05	1.12e-04	3.05e-01	4.51e-01	7.28e-02	8.31e-01
ESHD15	N	4.97e-05	3.94e-01	8.33e-02	1.42e-01	5.38e-05	9.52e-05	1.36e-01	1.80e-01	4.13e-01	1.35e+00
ESHD16	N	4.90e-05	3.52e-01	3.81e-02	8.63e-03	4.20e-05	7.48e-05	9.89e-02	9.38e-02	4.80e-01	1.07e+00
ESHD21	N	6.86e-05	2.40e-01	6.30e-02	1.13e-01	5.38e-05	9.52e-05	2.08e-01	7.31e-01	6.85e-02	1.42e+00
ESHD22	N	7.06e-05	1.29e-01	3.21e-02	3.98e-02	4.20e-05	7.48e-05	1.35e-01	7.14e-01	3.81e-02	1.09e+00
ESHD24	N	5.89e-05	2.19e-03	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.08e-02	3.11e-01	5.89e-03	3.70e-01
ESHD3	N	1.24e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00
ESHD4	N	1.66e-05	1.39e-02	7.13e-05	2.72e-05	3.80e-07	0.00e+00	1.07e-05	0.00e+00	0.00e+00	1.41e-02
ESHD6	N	8.55e-05	2.39e-03	5.10e-04	6.31e-05	1.55e-06	7.14e-07	1.51e-02	8.34e-07	0.00e+00	1.81e-02
ESHD7	N	6.01e-05	4.93e-03	4.57e-03	1.05e-01	7.28e-02	4.27e-02	6.81e-02	2.42e-02	6.16e-03	3.28e-01
ESHD8	N	5.78e-05	2.26e-02	2.27e-02	1.66e-01	8.33e-02	7.11e-02	3.53e-01	1.73e-02	8.17e-03	7.45e-01
ESHD9	N	5.77e-05	1.25e-01	9.52e-02	4.93e-01	2.87e-01	1.77e-01	7.74e-01	7.56e-02	1.40e-02	2.04e+00
ESHTS	N	4.02e-04	4.48e-02	1.18e-02	6.20e-02	4.54e-03	2.75e-03	2.30e-02	2.09e-02	1.03e-03	1.71e-01
PROD1	N	1.74e-05	5.59e-02	1.96e-04	7.93e-03	5.62e-03	3.09e-03	1.77e-03	1.33e-03	3.36e-04	7.62e-02
PROO3	N	1.99e-05	5.64e-05	2.83e-05	1.65e-04	1.45e-02	4.73e-03	1.86e-03	0.00e+00	0.00e+00	2.14e-02
PROO4	N	1.99e-05	8.28e-05	2.36e-05	1.89e-04	8.87e-03	2.93e-03	1.63e-03	0.00e+00	0.00e+00	1.37e-02
PROO7	N	1.70e-05	2.55e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	2.55e-04
PROO8	N	2.61e-05	2.19e-05	4.53e-04	1.65e-03	3.47e-04	1.04e-04	7.01e-04	4.20e-04	1.12e-04	3.81e-03
PROY4	N	1.70e-05	3.26e+00	4.71e-04	1.09e-04	0.00e+00	0.00e+00	5.37e-05	0.00e+00	0.00e+00	3.26e+00
PROY5	N	1.82e-05	3.29e+00	2.64e-04	4.59e-05	0.00e+00	0.00e+00	2.81e-05	0.00e+00	0.00e+00	3.29e+00
PROY6	N	1.35e-04	9.92e-05	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	9.92e-05
PROY7	N	2.72e-05	1.39e-05	3.46e-05	0.00e+00	0.00e+00	0.00e+00	2.69e-06	0.00e+00	0.00e+00	5.12e-05
PROY8	N	1.68e-05	5.07e-04	9.50e-07	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	5.08e-04
PROY9	N	1.35e-04	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00	0.00e+00

TABLE A2 - NORMAL, TRAIN AND VEHICLE SCENARIOS

PES		FREQ	FAT		FREQ	FAT		FREQ	FAT
ESHA1	N	2.08e-04	2.64e-03	T	4.33e-06	1.87e-02	V	2.70e-05	1.85e-05
ESHA10	N	8.10e-05	1.09e+00	T	1.68e-06	2.02e+01	V	1.05e-05	6.49e-02
ESHA11	N	7.89e-05	2.74e+00	T	1.64e-06	4.72e+01	V	1.03e-05	3.97e-01
ESHA12	N	3.36e-05	3.27e+00	T	6.99e-07	6.97e+01	V	4.37e-06	7.95e-01
ESHA13	N	7.65e-05	3.33e+00	T	1.59e-06	6.92e+01	V	9.95e-06	1.22e+00
ESHA14	N	1.63e-05	3.68e+00	T	3.39e-07	5.62e+01	V	2.12e-06	1.21e+00
ESHA2	N	1.42e-05	8.29e-03	T	2.95e-07	9.16e-03	V	1.85e-06	1.87e-05
ESHA8	N	5.35e-05	3.91e-02	T	1.11e-06	2.13e+00	V	6.96e-06	1.80e-04
ESHA9	N	6.13e-05	5.12e-01	T	1.28e-06	1.32e+01	V	7.97e-06	6.13e-02
ESHB1	N	5.21e-05	1.38e-02	T	1.08e-06	1.36e+00	V	6.77e-06	7.36e-05
ESHB10	N	1.00e-04	3.62e+00	T	2.08e-06	9.35e+01	V	1.30e-05	1.15e+00
ESHB12	N	6.77e-05	6.27e-01	T	1.41e-06	2.25e+00	V	8.80e-06	5.24e-02
ESHB13	N	6.10e-05	2.90e+00	T	1.27e-06	2.15e+01	V	7.93e-06	9.00e-01
ESHB14	N	5.56e-05	2.43e+00	T	1.16e-06	4.25e+00	V	7.23e-06	4.63e-01
ESHB15	N	5.03e-05	7.53e-01	T	1.05e-06	4.00e-07	V	6.54e-06	4.22e-01
ESHB2	N	8.67e-06	1.59e-03	T	1.80e-07	3.24e-03	V	1.13e-06	1.10e-03
ESHB3	N	8.94e-06	1.65e-03	T	1.86e-07	2.75e-04	V	1.16e-06	1.25e-03
ESHB4	N	9.02e-06	3.88e-03	T	1.88e-07	0.00e+00	V	1.17e-06	9.63e-03
ESHB5	N	1.26e-05	6.14e-02	T	2.62e-07	0.00e+00	V	1.64e-06	2.04e-02
ESHB6	N	1.56e-05	2.66e-01	T	3.24e-07	0.00e+00	V	2.03e-06	2.52e-02
ESHB7	N	1.84e-05	8.73e-01	T	3.83e-07	0.00e+00	V	2.39e-06	2.58e-02
ESHB8	N	1.06e-04	3.65e+00	T	2.20e-06	5.13e+01	V	1.38e-05	4.93e-01
ESHB9	N	6.97e-05	4.08e+00	T	1.45e-06	6.83e+01	V	9.06e-06	7.69e-01
ESHC1	N	8.87e-06	1.40e-02	T	1.84e-07	4.28e-03	V	1.15e-06	5.32e-03
ESHC10	N	1.08e-04	3.28e+00	T	2.25e-06	1.10e+02	V	1.40e-05	1.17e+00
ESHC11	N	9.18e-05	2.52e+00	T	1.91e-06	8.29e+01	V	1.19e-05	1.13e+00
ESHC2	N	1.53e-05	2.07e-02	T	3.18e-07	6.48e-03	V	1.99e-06	1.31e-02
ESHC3	N	5.21e-05	5.40e-02	T	1.08e-06	9.68e+00	V	6.77e-06	7.24e-02
ESHC4	N	1.47e-05	9.74e-05	T	3.06e-07	0.00e+00	V	1.91e-06	0.00e+00
ESHC5	N	1.19e-05	1.95e-03	T	2.48e-07	0.00e+00	V	1.55e-06	0.00e+00
ESHC6	N	5.45e-05	2.06e-01	T	1.13e-06	8.56e+00	V	7.09e-06	2.41e-02
ESHC7	N	5.34e-05	6.11e-01	T	1.11e-06	1.36e+01	V	6.94e-06	1.03e-01
ESHC8	N	6.06e-05	1.40e+00	T	1.26e-06	2.44e+01	V	7.88e-06	1.35e-01
ESHC9	N	1.76e-04	4.33e+00	T	3.66e-06	9.31e+01	V	2.29e-05	1.03e+00
ESHD10	N	7.01e-05	3.29e+00	T	1.46e-06	7.01e+01	V	9.11e-06	9.27e-01
ESHD11	N	1.13e-04	3.13e+00	T	2.35e-06	9.32e+01	V	1.47e-05	8.33e-01
ESHD12	N	1.16e-04	2.76e+00	T	2.41e-06	1.09e+02	V	1.51e-05	1.23e+00
ESHD13	N	1.53e-04	2.12e+00	T	3.18e-06	1.10e+02	V	1.99e-05	1.10e+00
ESHD14	N	1.58e-04	8.31e-01	T	3.29e-06	4.00e-07	V	2.05e-05	4.00e-03
ESHD15	N	4.97e-05	1.35e+00	T	1.03e-06	8.01e+01	V	6.46e-06	5.14e-01
ESHD16	N	4.90e-05	1.07e+00	T	1.02e-06	6.01e+01	V	6.37e-06	2.42e-01
ESHD21	N	6.86e-05	1.42e+00	T	1.43e-06	2.67e+01	V	8.92e-06	6.43e-01
ESHD22	N	7.06e-05	1.09e+00	T	1.47e-06	8.06e+00	V	9.18e-06	3.83e-01
ESHD24	N	5.89e-05	3.70e-01	T	1.23e-06	0.00e+00	V	7.66e-06	5.16e-02
ESHD3	N	1.24e-05	0.00e+00	T	2.58e-07	0.00e+00	V	1.61e-06	0.00e+00
ESHD4	N	1.66e-05	1.41e-02	T	3.45e-07	0.00e+00	V	2.16e-06	0.00e+00
ESHD6	N	8.55e-05	1.81e-02	T	1.78e-06	0.00e+00	V	1.11e-05	0.00e+00
ESHD7	N	6.01e-05	3.28e-01	T	1.25e-06	9.84e+00	V	7.81e-06	5.20e-02
ESHD8	N	5.78e-05	7.45e-01	T	1.20e-06	1.80e+01	V	7.51e-06	1.54e-01
ESHD9	N	5.77e-05	2.04e+00	T	1.20e-06	5.68e+01	V	7.50e-06	5.75e-01
ESHTS	N	4.02e-04	1.71e-01	T	8.36e-06	1.09e+01	V	5.23e-05	6.76e-04
PROD1	N	1.74e-05	7.62e-02	T	3.62e-07	4.40e+00	V	2.26e-06	8.96e-03
PROO3	N	1.99e-05	2.14e-02	T	4.14e-07	1.64e-02	V	2.59e-06	3.00e-02
PROO4	N	1.99e-05	1.37e-02	T	4.14e-07	1.41e-02	V	2.59e-06	2.94e-02
PROO7	N	1.70e-05	2.55e-04	T	3.54e-07	5.20e-05	V	2.21e-06	0.00e+00
PROO8	N	2.61e-05	3.81e-03	T	5.43e-07	2.68e-03	V	3.39e-06	1.37e-03
PROY4	N	1.70e-05	3.26e+00	T	3.54e-07	3.94e+02	V	2.21e-06	2.18e-07
PROY5	N	1.82e-05	3.29e+00	T	3.79e-07	3.99e+02	V	2.37e-06	0.00e+00
PROY6	N	1.35e-04	9.92e-05	T	2.81e-06	0.00e+00	V	1.76e-05	0.00e+00
PROY7	N	2.72e-05	5.12e-05	T	5.66e-07	1.44e-03	V	3.54e-06	0.00e+00
PROY8	N	1.68e-05	5.08e-04	T	3.49e-07	2.80e+00	V	2.18e-06	0.00e+00
PROY9	N	1.35e-04	0.00e+00	T	2.81e-06	1.04e+01	V	1.76e-05	0.00e+00

TABLE A3 - RANKED FATALITY DATA

PES		FREQ	FAT	PES		FREQ	FAT	PES		FREQ	FAT
PROY5	T	3.79e-07	3.99e+02	ESHA14	V	2.12e-06	1.21e+00	ESHB1	N	5.21e-05	1.38e-02
PROY4	T	3.54e-07	3.94e+02	ESHC10	V	1.40e-05	1.17e+00	PROO4	N	1.99e-05	1.37e-02
ESHD13	T	3.18e-06	1.10e+02	ESHB10	V	1.30e-05	1.15e+00	ESHC2	V	1.99e-06	1.31e-02
ESHC10	T	2.25e-06	1.10e+02	ESHC11	V	1.19e-05	1.13e+00	ESHB4	V	1.17e-06	9.63e-03
ESHD12	T	2.41e-06	1.09e+02	ESHD13	V	1.99e-05	1.10e+00	ESHA2	T	2.95e-07	9.16e-03
ESHB10	T	2.08e-06	9.35e+01	ESHD22	N	7.06e-05	1.09e+00	PROD1	V	2.26e-06	8.96e-03
ESHD11	T	2.35e-06	9.32e+01	ESHA10	N	8.10e-05	1.09e+00	ESHA2	N	1.42e-05	8.29e-03
ESHC9	T	3.66e-06	9.31e+01	ESHD16	N	4.90e-05	1.07e+00	ESHC2	T	3.18e-07	6.48e-03
ESHC11	T	1.91e-06	8.29e+01	ESHC9	V	2.29e-05	1.03e+00	ESHC1	V	1.15e-06	5.32e-03
ESHD15	T	1.03e-06	8.01e+01	ESHD10	V	9.11e-06	9.27e-01	ESHC1	T	1.84e-07	4.28e-03
ESHD10	T	1.46e-06	7.01e+01	ESHB13	V	7.93e-06	9.00e-01	ESHD14	V	2.05e-05	4.00e-03
ESHA12	T	6.99e-07	6.97e+01	ESHB7	N	1.84e-05	8.73e-01	ESHB4	N	9.02e-06	3.88e-03
ESHA13	T	1.59e-06	6.92e+01	ESHD11	V	1.47e-05	8.33e-01	PROO8	N	2.61e-05	3.81e-03
ESHB9	T	1.45e-06	6.83e+01	ESHD14	N	1.58e-04	8.31e-01	ESHB2	T	1.80e-07	3.24e-03
ESHD16	T	1.02e-06	6.01e+01	ESHA12	V	4.37e-06	7.95e-01	PROO8	T	5.43e-07	2.68e-03
ESHD9	T	1.20e-06	5.68e+01	ESHB9	V	9.06e-06	7.69e-01	ESHA1	N	2.08e-04	2.64e-03
ESHA14	T	3.39e-07	5.62e+01	ESHB15	N	5.03e-05	7.53e-01	ESHC5	N	1.19e-05	1.95e-03
ESHB8	T	2.20e-06	5.13e+01	ESHD8	N	5.78e-05	7.45e-01	ESHB3	N	8.94e-06	1.65e-03
ESHA11	T	1.64e-06	4.72e+01	ESHD21	V	8.92e-06	6.43e-01	ESHB2	N	8.67e-06	1.59e-03
ESHD21	T	1.43e-06	2.67e+01	ESHB12	N	6.77e-05	6.27e-01	PROY7	T	5.66e-07	1.44e-03
ESHC8	T	1.26e-06	2.44e+01	ESHC7	N	5.34e-05	6.11e-01	PROO8	V	3.39e-06	1.37e-03
ESHB13	T	1.27e-06	2.15e+01	ESHD9	V	7.50e-06	5.75e-01	ESHB3	V	1.16e-06	1.25e-03
ESHA10	T	1.68e-06	2.02e+01	ESHD15	V	6.46e-06	5.14e-01	ESHB2	V	1.13e-06	1.10e-03
ESHD8	T	1.20e-06	1.80e+01	ESHA9	N	6.13e-05	5.12e-01	ESHTS	V	5.23e-05	6.76e-04
ESHC7	T	1.11e-06	1.36e+01	ESHB8	V	1.38e-05	4.93e-01	PROY8	N	1.68e-05	5.08e-04
ESHA9	T	1.28e-06	1.32e+01	ESHB14	V	7.23e-06	4.63e-01	ESHB3	T	1.86e-07	2.75e-04
ESHTS	T	8.36e-06	1.09e+01	ESHB15	V	6.54e-06	4.22e-01	PROO7	N	1.70e-05	2.55e-04
PROY9	T	2.81e-06	1.04e+01	ESHA11	V	1.03e-05	3.97e-01	ESHA8	V	6.96e-06	1.80e-04
ESHD7	T	1.25e-06	9.84e+00	ESHD22	V	9.18e-06	3.83e-01	PROY6	N	1.35e-04	9.92e-05
ESHC3	T	1.08e-06	9.68e+00	ESHD24	N	5.89e-05	3.70e-01	ESHC4	N	1.47e-05	9.74e-05
ESHC6	T	1.13e-06	8.56e+00	ESHD7	N	6.01e-05	3.28e-01	ESHB1	V	6.77e-06	7.36e-05
ESHD22	T	1.47e-06	8.06e+00	ESHB6	N	1.56e-05	2.66e-01	PROO7	T	3.54e-07	5.20e-05
PROD1	T	3.62e-07	4.40e+00	ESHD16	V	6.37e-06	2.42e-01	PROY7	N	2.72e-05	5.12e-05
ESHC9	N	1.76e-04	4.33e+00	ESHC6	N	5.45e-05	2.06e-01	ESHA2	V	1.85e-06	1.87e-05
ESHB14	T	1.16e-06	4.25e+00	ESHTS	N	4.02e-04	1.71e-01	ESHA1	V	2.70e-05	1.85e-05
ESHB9	N	6.97e-05	4.08e+00	ESHD8	V	7.51e-06	1.54e-01	ESHB15	T	1.05e-06	4.00e-07
ESHA14	N	1.63e-05	3.68e+00	ESHC8	V	7.88e-06	1.35e-01	ESHD14	T	3.29e-06	4.00e-07
ESHB8	N	1.06e-04	3.65e+00	ESHC7	V	6.94e-06	1.03e-01	PROY4	V	2.21e-06	2.18e-07
ESHB10	N	1.00e-04	3.62e+00	PROD1	N	1.74e-05	7.62e-02	ESHC4	V	1.91e-06	0.00e+00
ESHA13	N	7.65e-05	3.33e+00	ESHC3	V	6.77e-06	7.24e-02	ESHC5	V	1.55e-06	0.00e+00
ESHD10	N	7.01e-05	3.29e+00	ESHA10	V	1.05e-05	6.49e-02	ESHD3	V	1.61e-06	0.00e+00
PROY5	N	1.82e-05	3.29e+00	ESHB5	N	1.26e-05	6.14e-02	ESHD4	V	2.16e-06	0.00e+00
ESHC10	N	1.08e-04	3.28e+00	ESHA9	V	7.97e-06	6.13e-02	ESHD6	V	1.11e-05	0.00e+00
ESHA12	N	3.36e-05	3.27e+00	ESHC3	N	5.21e-05	5.40e-02	PROO7	V	2.21e-06	0.00e+00
PROY4	N	1.70e-05	3.26e+00	ESHB12	V	8.80e-06	5.24e-02	PROY5	V	2.37e-06	0.00e+00
ESHD11	N	1.13e-04	3.13e+00	ESHD7	V	7.81e-06	5.20e-02	PROY6	V	1.76e-05	0.00e+00
ESHB13	N	6.10e-05	2.90e+00	ESHD24	V	7.66e-06	5.16e-02	PROY7	V	3.54e-06	0.00e+00
PROY8	T	3.49e-07	2.80e+00	ESHA8	N	5.35e-05	3.91e-02	PROY8	V	2.18e-06	0.00e+00
ESHD12	N	1.16e-04	2.76e+00	PROO3	V	2.59e-06	3.00e-02	PROY9	V	1.76e-05	0.00e+00
ESHA11	N	7.89e-05	2.74e+00	PROO4	V	2.59e-06	2.94e-02	ESHD3	N	1.24e-05	0.00e+00
ESHC11	N	9.18e-05	2.52e+00	ESHB7	V	2.39e-06	2.58e-02	PROY9	N	1.35e-04	0.00e+00
ESHB14	N	5.56e-05	2.43e+00	ESHB6	V	2.03e-06	2.52e-02	ESHB4	T	1.88e-07	0.00e+00
ESHB12	T	1.41e-06	2.25e+00	ESHC6	V	7.09e-06	2.41e-02	ESHB5	T	2.62e-07	0.00e+00
ESHA8	T	1.11e-06	2.13e+00	PROO3	N	1.99e-05	2.14e-02	ESHB6	T	3.24e-07	0.00e+00
ESHD13	N	1.53e-04	2.12e+00	ESHC2	N	1.53e-05	2.07e-02	ESHB7	T	3.83e-07	0.00e+00
ESHD9	N	5.77e-05	2.04e+00	ESHB5	V	1.64e-06	2.04e-02	ESHC4	T	3.06e-07	0.00e+00
ESHD21	N	6.86e-05	1.42e+00	ESHA1	T	4.33e-06	1.87e-02	ESHC5	T	2.48e-07	0.00e+00
ESHC8	N	6.06e-05	1.40e+00	ESHD6	N	8.55e-05	1.81e-02	ESHD24	T	1.23e-06	0.00e+00
ESHB1	T	1.08e-06	1.36e+00	PROO3	T	4.14e-07	1.64e-02	ESHD3	T	2.58e-07	0.00e+00
ESHD15	N	4.97e-05	1.35e+00	PROO4	T	4.14e-07	1.41e-02	ESHD4	T	3.45e-07	0.00e+00
ESHD12	V	1.51e-05	1.23e+00	ESHD4	N	1.66e-05	1.41e-02	ESHD6	T	1.78e-06	0.00e+00
ESHA13	V	9.95e-06	1.21e+00	ESHC1	N	8.87e-06	1.40e-02	PROY6	T	2.81e-06	0.00e+00

table ends