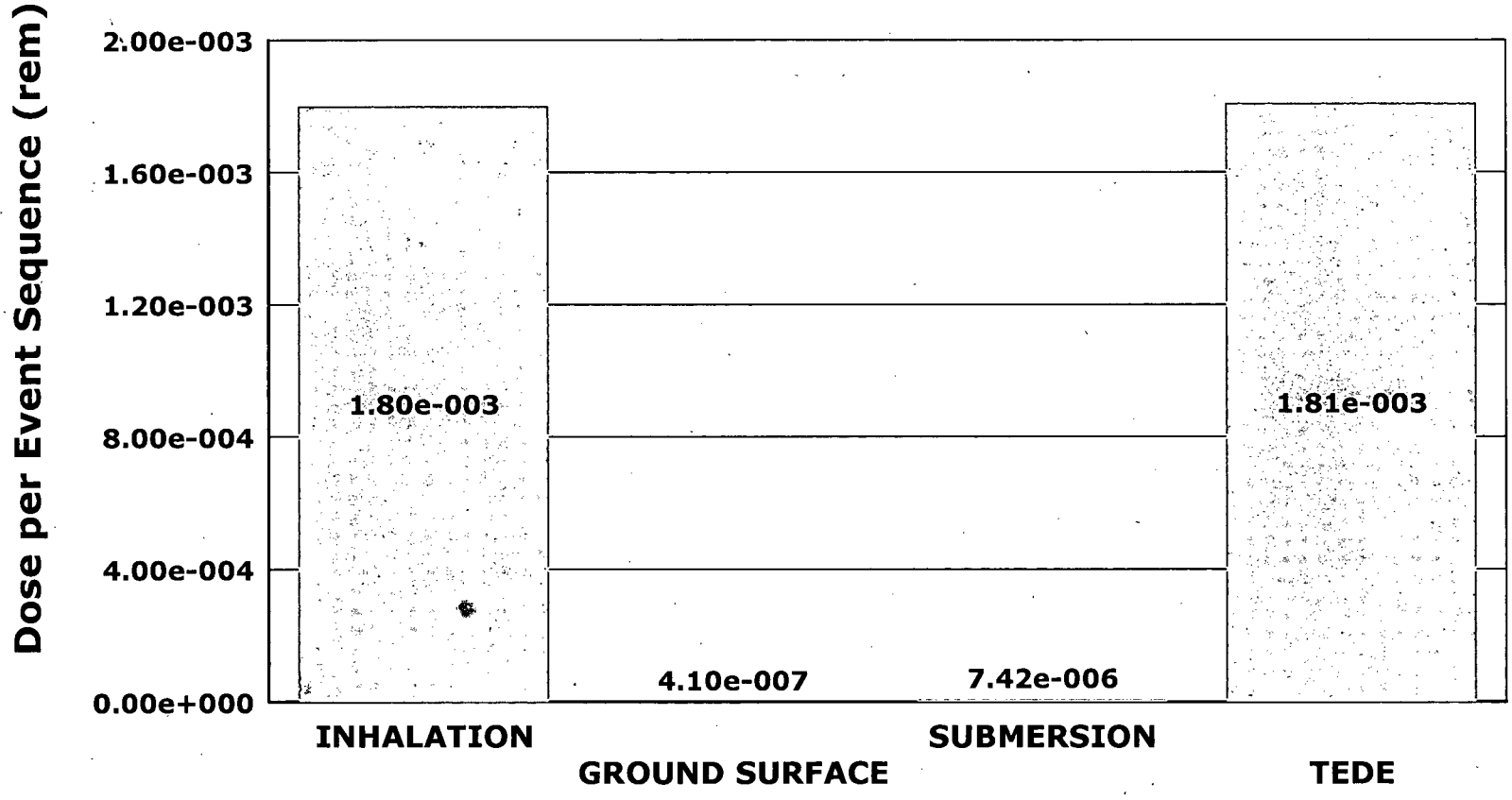
RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

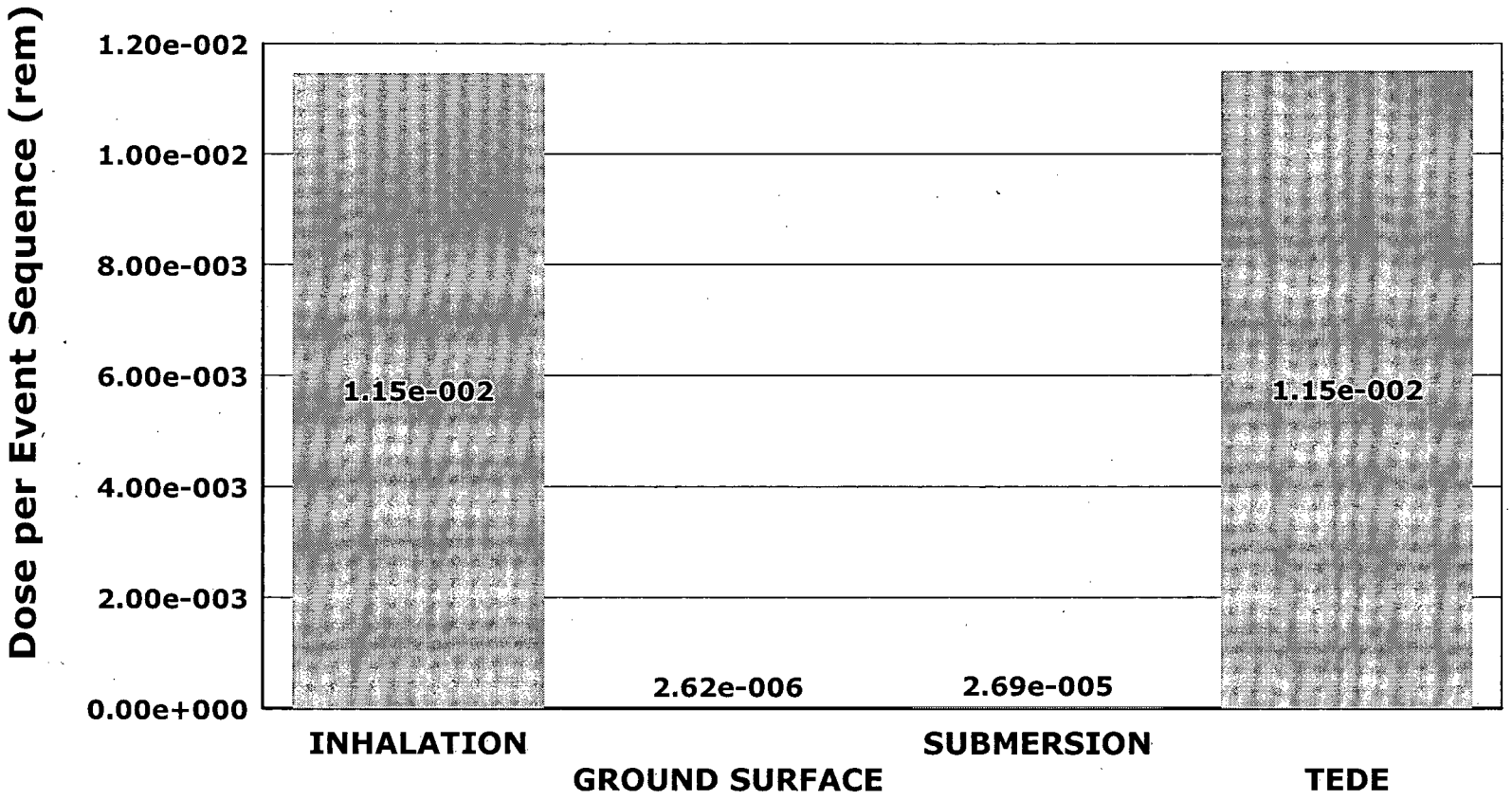
Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.80E-03	1.80E-03	1.80E-03	1.80E-03	1.80E-03	1.80E-03
GROUND SURFACE	4.10E-07	4.10E-07	4.10E-07	4.10E-07	4.10E-07	4.10E-07
SUBMERSION	7.42E-06	7.42E-06	7.42E-06	7.42E-06	7.42E-06	7.42E-06
TEDE	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03	1.81E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06
SUBMERSION	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

Fuel Selection / Assemblies Breached

Fuel Type	Burnup (MWd/MTU)	Enrichment (%)	Decay Time (Y)	Co-60 Crud Activity (Ci/Assembly)	Number of Assemblies Breached
User				0.64	1

Release Fraction by Group (User Specified)

HEPA Filtration Operative

Release in Air

Group ID	Group Name	Release Fraction	HEPA Mitigation	Radionuclides In Group
Group 1	H-3	3.00e-01	1.0	H-3
Group 2	Ruthenium	2.00E-05	0.0003	Ru-106
Group 3	Iodine	2.30E-03	1.0	I-129
Group 4	Cesium	2.00E-05	0.0003	Cs-134, Cs-135, Cs-137
Group 5	Noble gases	3.00E-01	1.0	Ar-39, Kr-85, Rn-219, Rn-220, Rn-222
Group 8	Co-60 Crud	1.50e-01	0.0003	Co-60 Crud
Group 9	Other particulates and fuel fines	2.00E-05	0.0003	All others
Group 6	Strontium	2.00E-05	0.0003	Sr-90

Bldg. Discharge, Probabilistic

Vapors and Noble Gases	Crud (Co-60)	Particulates
1.0	0.1	0.01

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

Source Term

Radionuclide	Group	Inventory (Ci/Assembly)	Bldg Discharge Fraction	HEPA Mitigation	Assemblies	Release Fraction	Released Activity (Ci)
H 3	1	1.14E+02	1.00e+00	1.00e+00	1	3.00e-01	3.42e+01
C 14	9	3.32E-01	1.00e-02	3.00e-04	1	2.00E-05	1.99e-11

CL 36	9	6.80E-03	1.00e-02	3.00e-04	1	2.00E-05	4.08e-13
AR 39	5	5.22E-05	1.00e+00	1.00e+00	1	3.00E-01	1.57e-05
FE 55	9	3.46E+00	1.00e-02	3.00e-04	1	2.00E-05	2.08e-10
NI 59	9	2.09E+00	1.00e-02	3.00e-04	1	2.00E-05	1.25e-10
CO 60	9	3.13E+02	1.00e-02	3.00e-04	1	2.00E-05	1.88e-08
CO 60 Crud	8	6.40e-01	1.00e-01	3.00e-04	1	1.50e-01	2.88e-06
NI 63	9	2.52E+02	1.00e-02	3.00e-04	1	2.00E-05	1.51e-08
SE 79	9	4.57E-02	1.00e-02	3.00e-04	1	2.00E-05	2.74e-12
KR 85	5	1.13E+03	1.00e+00	1.00e+00	1	3.00E-01	3.39e+02
SR 90	6	2.72E+04	1.00e-02	3.00e-04	1	2.00E-05	1.63e-06
Y 90	9	2.72E+04	1.00e-02	3.00e-04	1	2.00E-05	1.63e-06
MO 93	9	4.14E-02	1.00e-02	3.00e-04	1	2.00E-05	2.48e-12
NB 93M	9	1.30E+01	1.00e-02	3.00e-04	1	2.00E-05	7.80e-10
ZR 93	9	8.94E-01	1.00e-02	3.00e-04	1	2.00E-05	5.36e-11
NB 94	9	8.39E-01	1.00e-02	3.00e-04	1	2.00E-05	5.03e-11
TC 99	9	8.98E+00	1.00e-02	3.00e-04	1	2.00E-05	5.39e-10
RH106	9	1.23E-02	1.00e-02	3.00e-04	1	2.00E-05	7.38e-13
RU106	2	1.23E-02	1.00e-02	3.00e-04	1	2.00E-05	7.38e-13
PD107	9	8.41E-02	1.00e-02	3.00e-04	1	2.00E-05	5.05e-12
SN121M	9	1.59E+00	1.00e-02	3.00e-04	1	2.00E-05	9.54e-11
SB125	9	9.71E+00	1.00e-02	3.00e-04	1	2.00E-05	5.83e-10
TE125M	9	2.37E+00	1.00e-02	3.00e-04	1	2.00E-05	1.42e-10
SB126	9	5.39E-02	1.00e-02	3.00e-04	1	2.00E-05	3.23e-12
SB126M	9	3.85E-01	1.00e-02	3.00e-04	1	2.00E-05	2.31e-11
SN126	9	3.85E-01	1.00e-02	3.00e-04	1	2.00E-05	2.31e-11
I129	3	2.19E-02	1.00e+00	1.00e+00	1	2.30E-03	5.04e-05
CS134	4	2.52E+01	1.00e-02	3.00e-04	1	2.00E-05	1.51e-09
CS135	4	3.50E-01	1.00e-02	3.00e-04	1	2.00E-05	2.10e-11
BA137M	9	3.88E+04	1.00e-02	3.00e-04	1	2.00E-05	2.33e-06
CS137	4	4.11E+04	1.00e-02	3.00e-04	1	2.00E-05	2.47e-06
PM147	9	1.19E+02	1.00e-02	3.00e-04	1	2.00E-05	7.14e-09
SM147	9	0.00E+00	1.00e-02	3.00e-04	1	2.00E-05	0.00e+00
SM151	9	2.11E+02	1.00e-02	3.00e-04	1	2.00E-05	1.27e-08
EU152	9	1.31E+00	1.00e-02	3.00e-04	1	2.00E-05	7.86e-11
EU154	9	6.71E+02	1.00e-02	3.00e-04	1	2.00E-05	4.03e-08
EU155	9	5.15E+01	1.00e-02	3.00e-04	1	2.00E-05	3.09e-09

TL208	9	7.42E-03	1.00e-02	3.00e-04	1	2.00E-05	4.45e-13
BI212	9	2.06E-02	1.00e-02	3.00e-04	1	2.00E-05	1.24e-12
PB212	9	2.06E-02	1.00e-02	3.00e-04	1	2.00E-05	1.24e-12
PO216	9	2.06E-02	1.00e-02	3.00e-04	1	2.00E-05	1.24e-12
RN219	5	1.61E-05	1.00e+00	1.00e+00	1	3.00E-01	4.83e-06
RN220	5	2.06E-02	1.00e+00	1.00e+00	1	3.00E-01	6.18e-03
RN222	5	0.00E+00	1.00e+00	1.00e+00	1	3.00E-01	0.00e+00
RA224	9	2.06E-02	1.00e-02	3.00e-04	1	2.00E-05	1.24e-12
TH228	9	2.06E-02	1.00e-02	3.00e-04	1	2.00E-05	1.24e-12
TH231	9	0.00E+00	1.00e-02	3.00e-04	1	2.00E-05	0.00e+00
U232	9	2.04E-02	1.00e-02	3.00e-04	1	2.00E-05	1.22e-12
PA233	9	2.47E-01	1.00e-02	3.00e-04	1	2.00E-05	1.48e-11
PA234M	9	1.48E-01	1.00e-02	3.00e-04	1	2.00E-05	8.88e-12
TH234	9	1.48E-01	1.00e-02	3.00e-04	1	2.00E-05	8.88e-12

U234	9	6.77E-01	1.00e-02	3.00e-04	1	2.00E-05	4.06e-11
U235	9	7.37E-03	1.00e-02	3.00e-04	1	2.00E-05	4.42e-13
PU236	9	1.01E-03	1.00e-02	3.00e-04	1	2.00E-05	6.06e-14
U236	9	1.72E-01	1.00e-02	3.00e-04	1	2.00E-05	1.03e-11
NP237	9	2.47E-01	1.00e-02	3.00e-04	1	2.00E-05	1.48e-11
U237	9	5.90E-01	1.00e-02	3.00e-04	1	2.00E-05	3.54e-11
PU238	9	2.29E+03	1.00e-02	3.00e-04	1	2.00E-05	1.37e-07
U238	9	1.48E-01	1.00e-02	3.00e-04	1	2.00E-05	8.88e-12
NP239	9	2.20E+01	1.00e-02	3.00e-04	1	2.00E-05	1.32e-09
PU239	9	1.77E+02	1.00e-02	3.00e-04	1	2.00E-05	1.06e-08
PU240	9	3.18E+02	1.00e-02	3.00e-04	1	2.00E-05	1.91e-08
AM241	9	1.98E+03	1.00e-02	3.00e-04	1	2.00E-05	1.19e-07
PU241	9	2.46E+04	1.00e-02	3.00e-04	1	2.00E-05	1.48e-06
PU242	9	1.64E+00	1.00e-02	3.00e-04	1	2.00E-05	9.84e-11
AM243	9	2.20E+01	1.00e-02	3.00e-04	1	2.00E-05	1.32e-09
CM245	9	3.07E-01	1.00e-02	3.00e-04	1	2.00E-05	1.84e-11
CM246	9	1.04E-01	1.00e-02	3.00e-04	1	2.00E-05	6.24e-12

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

Meteorological Data

Parameter	Value	Max Value Default Value Min Value	Remarks
Average wind velocity (m/s)	0.9	NONE 4.3 0.0	
Stack release height (m)	35.0	NONE 40.0 0.0	
Mixing layer height (m)	1420.0	3000.0 1420.0 0.0	
Air density (g/m^3)	1.29e+03	NONE 1.29e+03 0.0	
Wet deposition scavenging coefficient (1/s)	0.0	NONE 0.0 0.0	
Plume depletion by dry deposition	1	1 1 0	
Deposition velocities to be entered	Yes	FIXED	

		Yes	
		FIXED	
Deposition velocities (m/s) Solids	0.001	NONE 0.001	
		0.0	
Deposition velocities (m/s) Halogens	0.01	NONE 0.01	
		0.0	
Deposition velocities (m/s) Noble gases	0.0	NONE 0.0	
		0.0	
Deposition velocities (m/s) Cesium	0.001	NONE 0.001	
		0.0	
Deposition velocities (m/s) Ruthenium	0.001	NONE 0.001	
		0.0	

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

Downwind distance (m)	50.0	NONE 11000.0	float - Site-specific approximation (U.S. Department of Energy, 1998c)
		100.0	
Linear constant in decay function (1/s)	1.0	NONE 1.0	
		0.0	
Exponential constant in decay function (1/s)	0.0	NONE 0.0	
		0.0	
Crosswind distances to be entered	No	FIXED No	
		FIXED	
Diffusion definition	2	FIXED 2	
		FIXED	
Type of sigma (standard deviation) set	1	3 1	
		1	
Building width (m)	0.0	NONE 0.0	
		0.0	
Building height (m)	0.0	NONE 0.0	
		0.0	
Weather class	6	8 6	integer - 6 relates to class F, the most-probable class (site-specific estimate)
		1	
Plume rise indicator	0	FIXED 0	

FIXED

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

Inhalation Dose

Parameter	Value	MaxValue Default Value Min Value	Remarks
Type of dose calculation	1	FIXED 1 FIXED	integer - International Commission on Radiological Protection-30 inhalation with user-specified parameters
Output control for dose	-2	FIXED -2 FIXED	
Dose unit	1	FIXED 1 FIXED	
Elements for calculation	0	FIXED 0 FIXED	
Organ choice	1	FIXED 1 FIXED	
For inhalation, breathing rate (m^3/s)	3.33e-04	NONE 3.33e-04 0.0	
Decay time for exponential decay function (s)	0.0	NONE 0.0 0.0	
Activity mean aerodynamic diameter (micrometer)	1.0	NONE 1.0 0.1	
Clearance classes	3	FIXED 3 FIXED	

PCSA Controlled Area Worker RSAC Input Report

Project: PCSAToolExOutWkr1

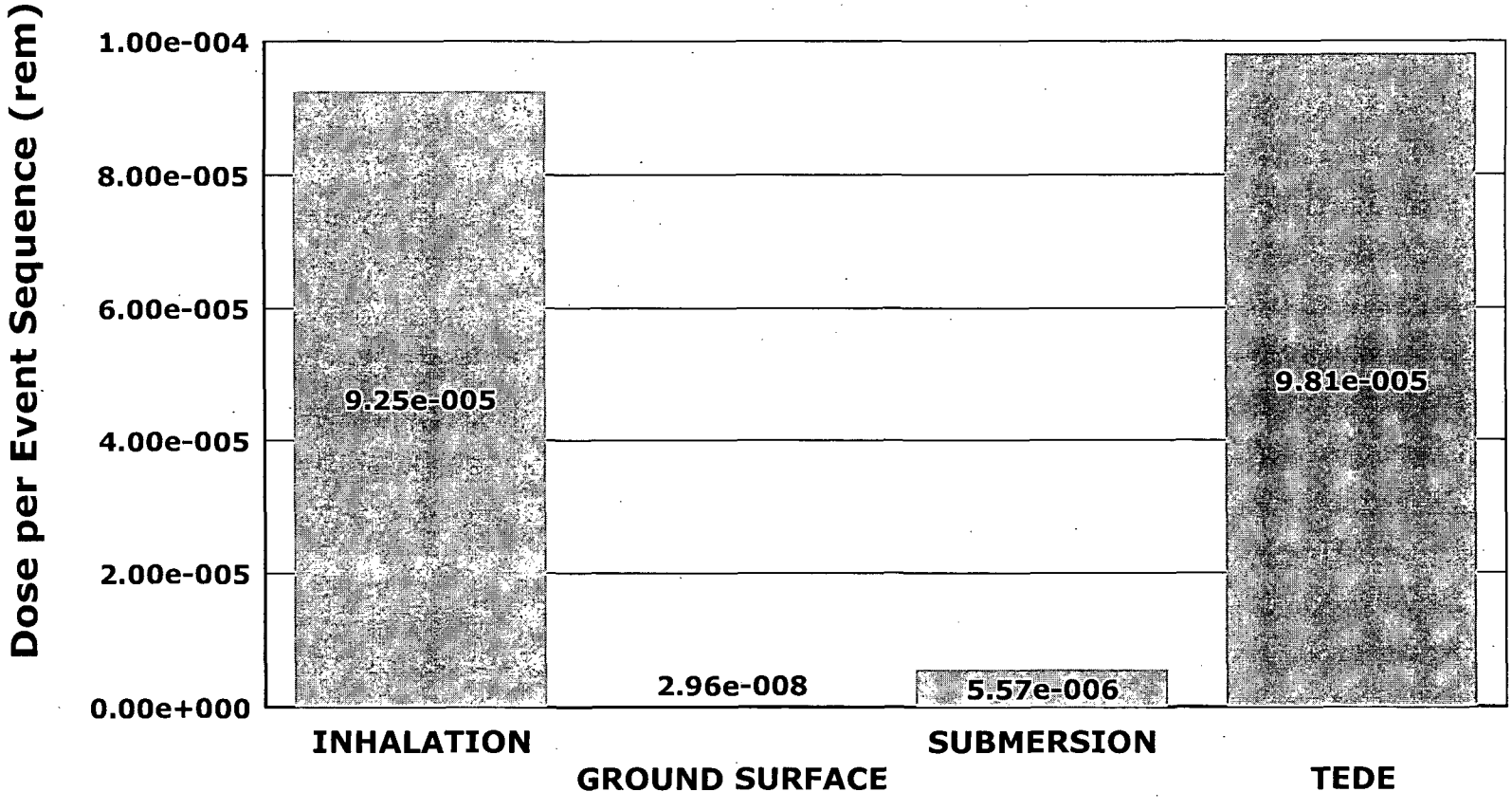
Submersion Dose

Parameter	Value	Max Value Default Value Min Value	Remarks
Gamma cloud model selection	0	FIXED 0 FIXED	integer - All calculations are made using a finite model
Decay time for exponential decay function (s)	0.0	NONE 0.0 0.0	float - RSAC default value for instantaneous release

Ground Surface Dose

Parameter	Value	Max Value Default Value Min Value	Remarks
Type of dose calculation	4	FIXED 4 FIXED	
Output control for dose	-2	FIXED -2 FIXED	
Dose unit	1	FIXED 1 FIXED	
Elements for calculation	0	FIXED 0 FIXED	
Organ choice	1	FIXED 1 FIXED	
Decay time for exponential decay function (s)	0.0	NONE 0.0 0.0	
TB - Ground surface exposure time (y)	0.22831	NONE 1.0 0.0	
Building shielding factor (dimensionless)	0.7	1.0 0.7 0.0	

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

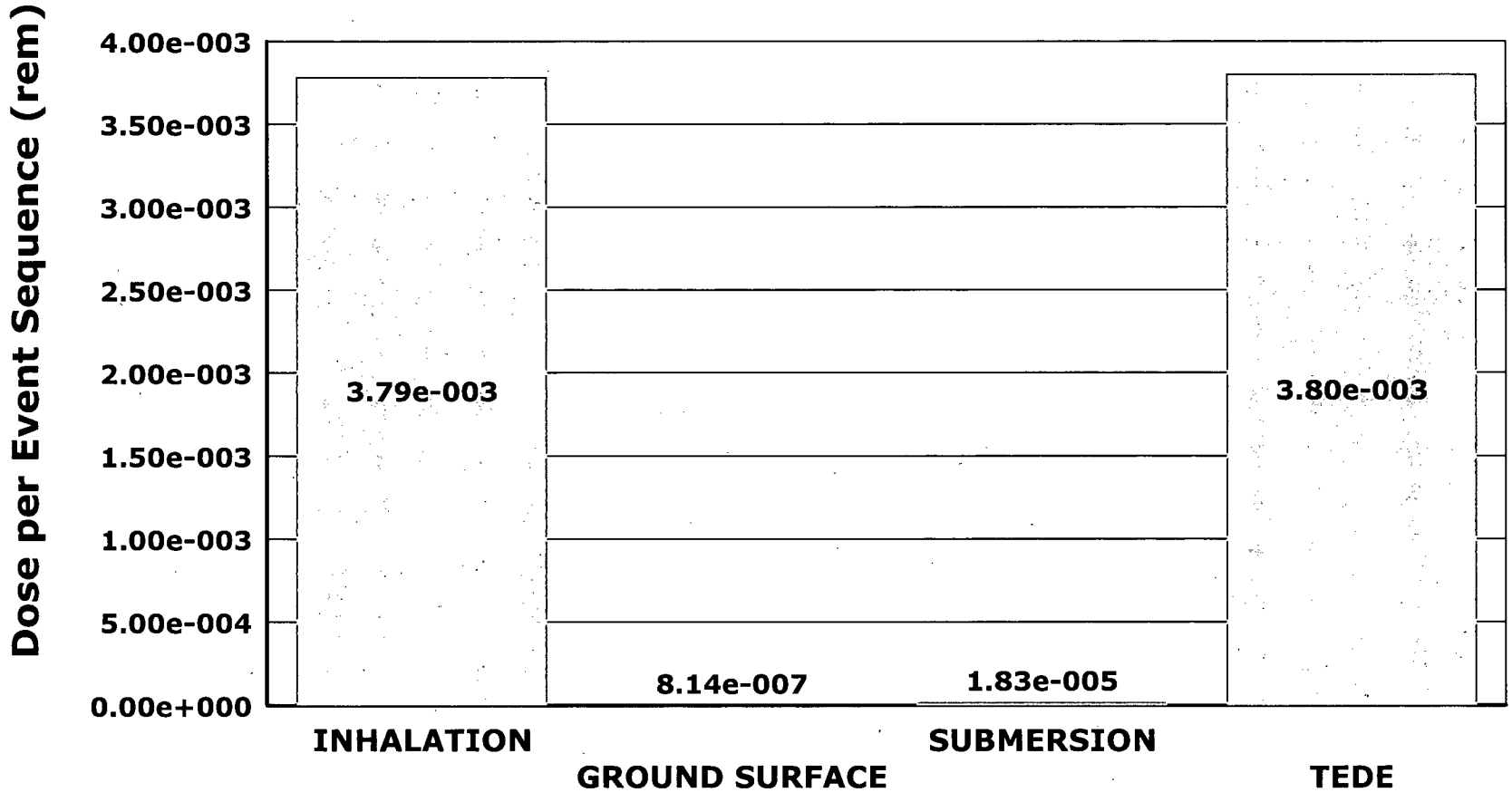
Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	9.25E-05	9.25E-05	9.25E-05	9.25E-05	9.25E-05	9.25E-05
GROUND SURFACE	2.96E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08	2.96E-08
SUBMERSION	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06
TEDE	9.81E-05	9.81E-05	9.81E-05	9.81E-05	9.81E-05	9.81E-05

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

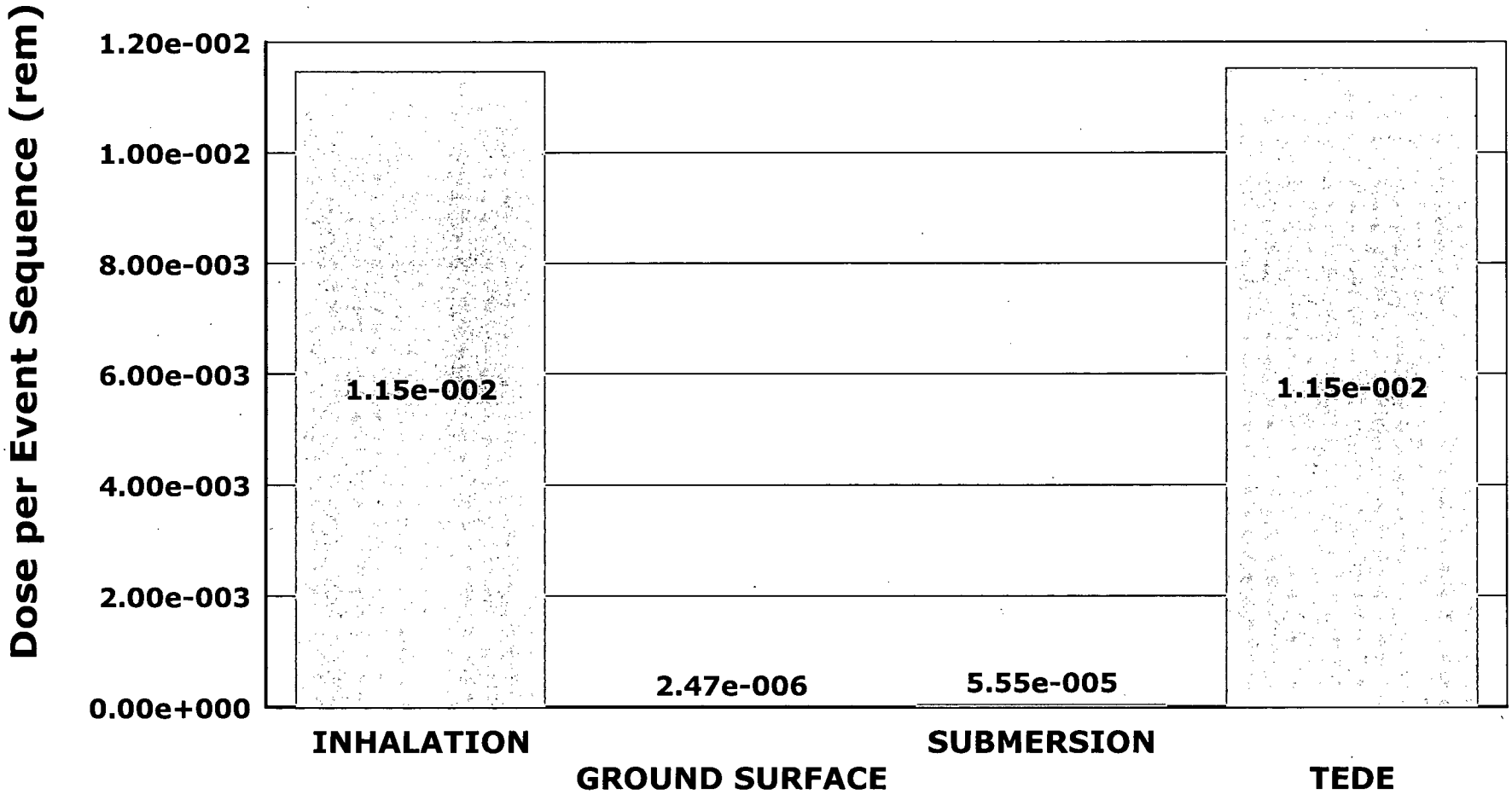
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03
GROUND SURFACE	8.14E-07	8.14E-07	8.14E-07	8.14E-07	8.14E-07	8.14E-07
SUBMERSION	1.83E-05	1.83E-05	1.83E-05	1.83E-05	1.83E-05	1.83E-05
TEDE	3.80E-03	3.80E-03	3.80E-03	3.80E-03	3.80E-03	3.80E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

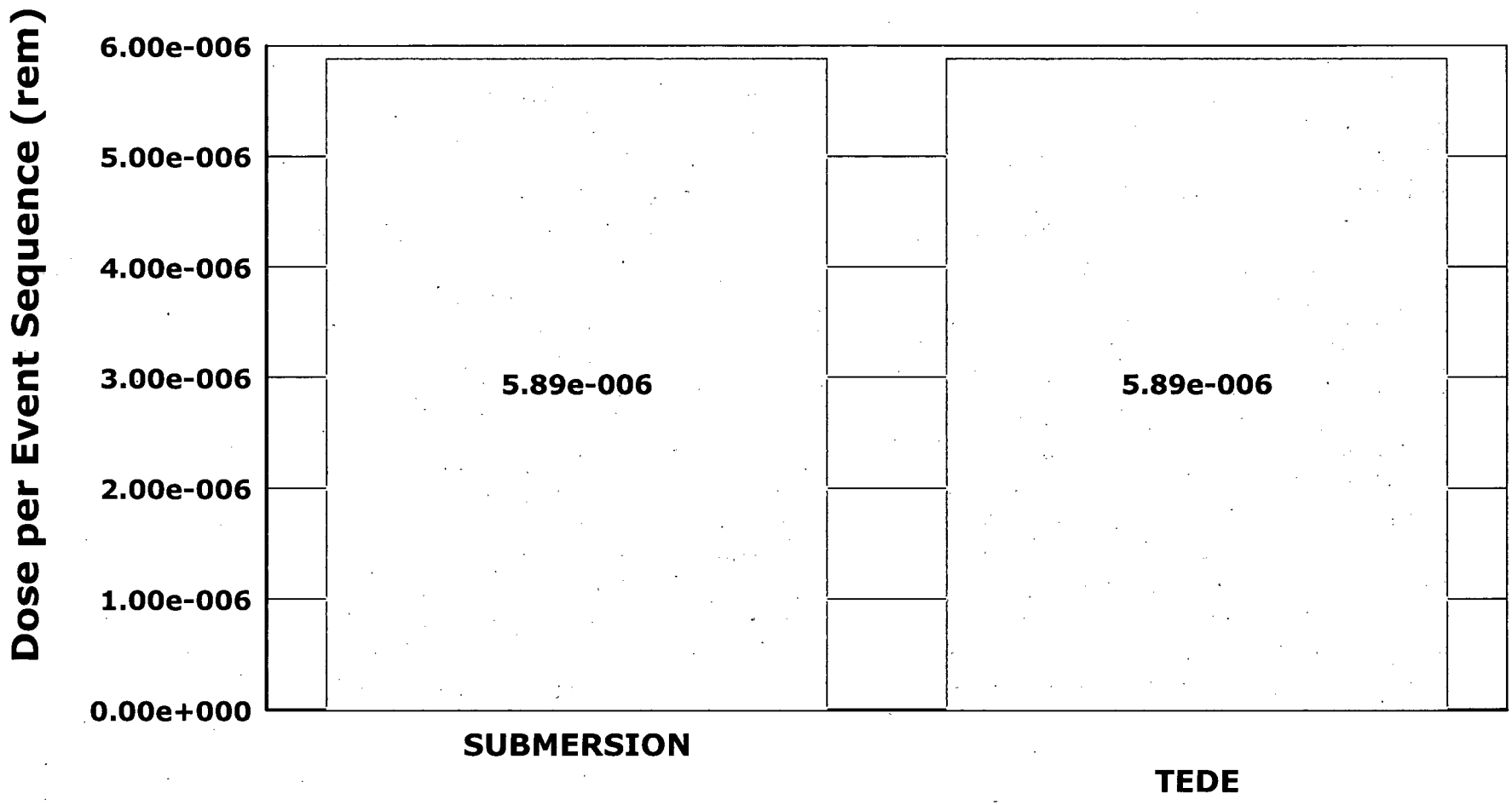
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06
SUBMERSION	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	13.00		

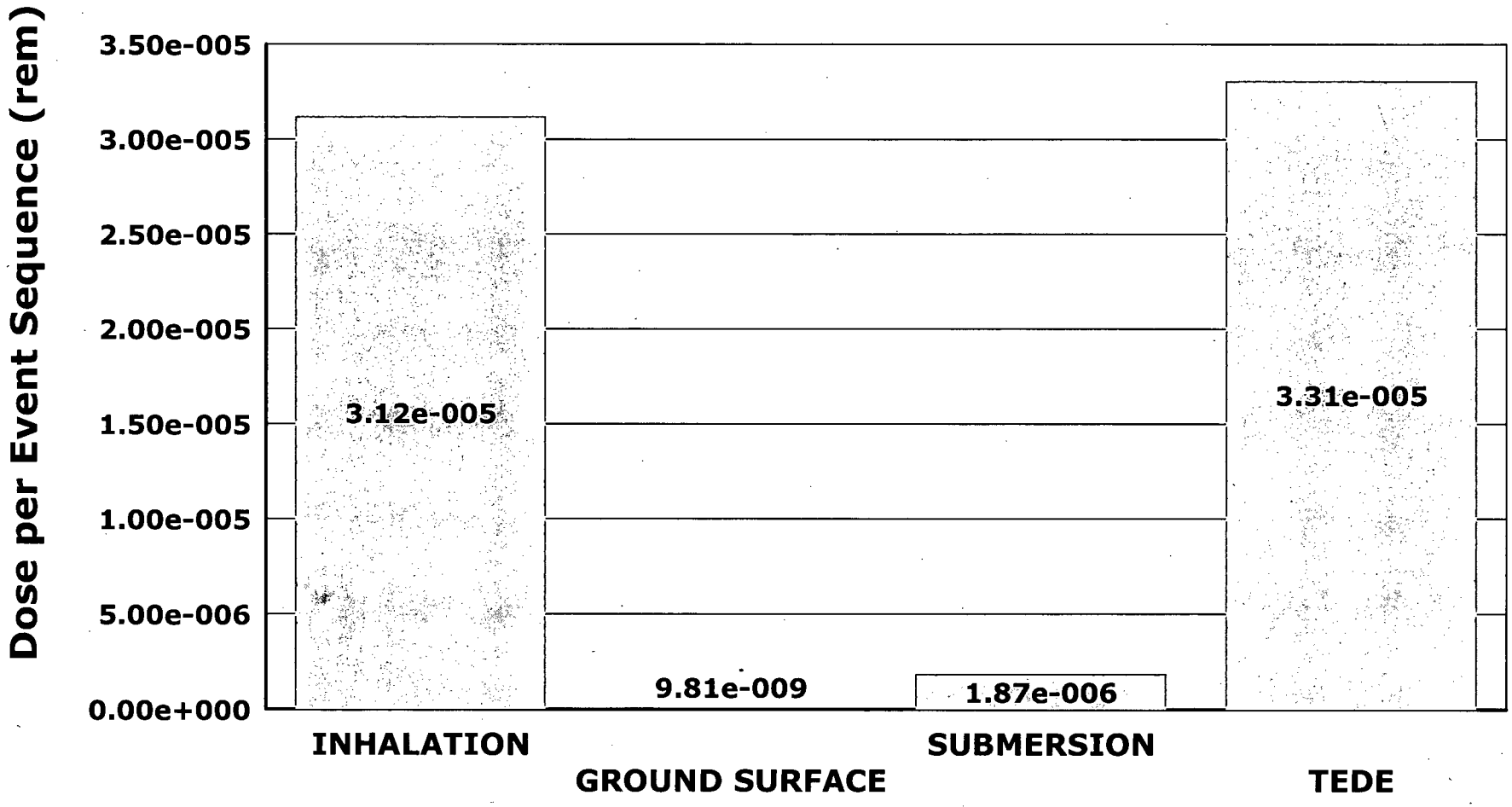
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
SUBMERSION	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06
TEDE	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06	5.89E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

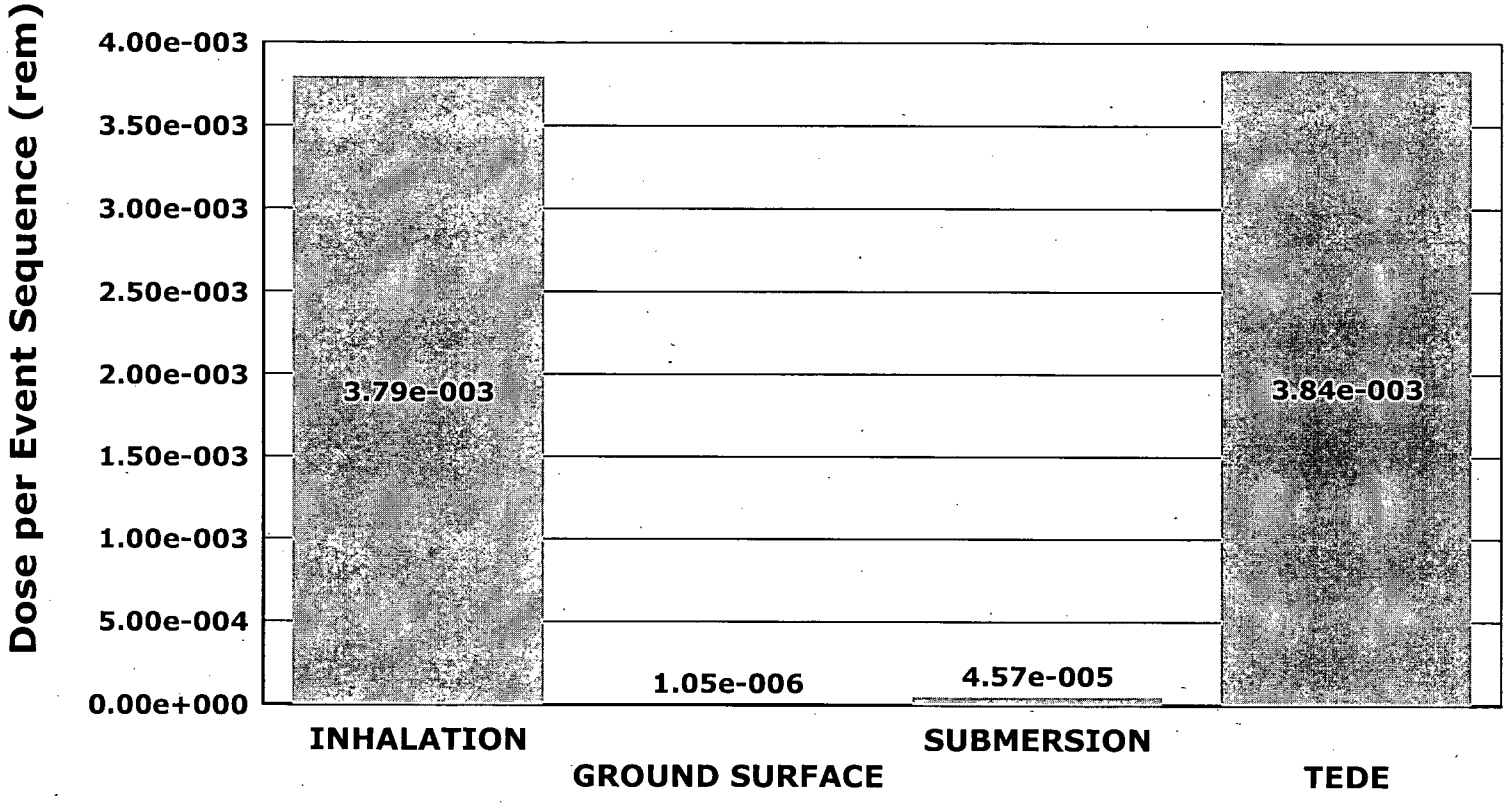
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.12E-05	3.12E-05	3.12E-05	3.12E-05	3.12E-05	3.12E-05
GROUND SURFACE	9.81E-09	9.81E-09	9.81E-09	9.81E-09	9.81E-09	9.81E-09
SUBMERSION	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06
TEDE	3.31E-05	3.31E-05	3.31E-05	3.31E-05	3.31E-05	3.31E-05

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

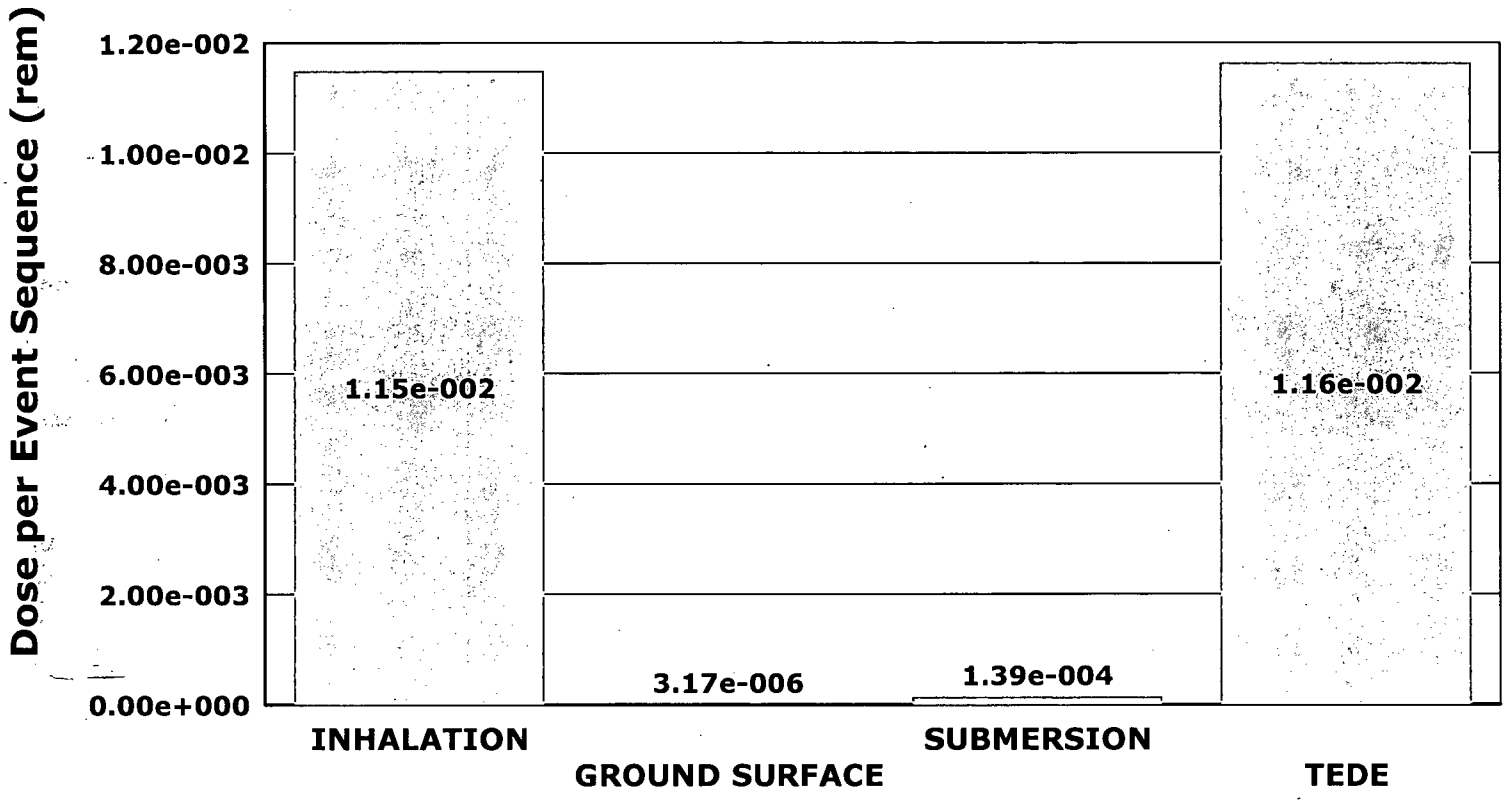
Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03
GROUND SURFACE	1.05E-06	1.05E-06	1.05E-06	1.05E-06	1.05E-06	1.05E-06
SUBMERSION	4.57E-05	4.57E-05	4.57E-05	4.57E-05	4.57E-05	4.57E-05
TEDE	3.84E-03	3.84E-03	3.84E-03	3.84E-03	3.84E-03	3.84E-03

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

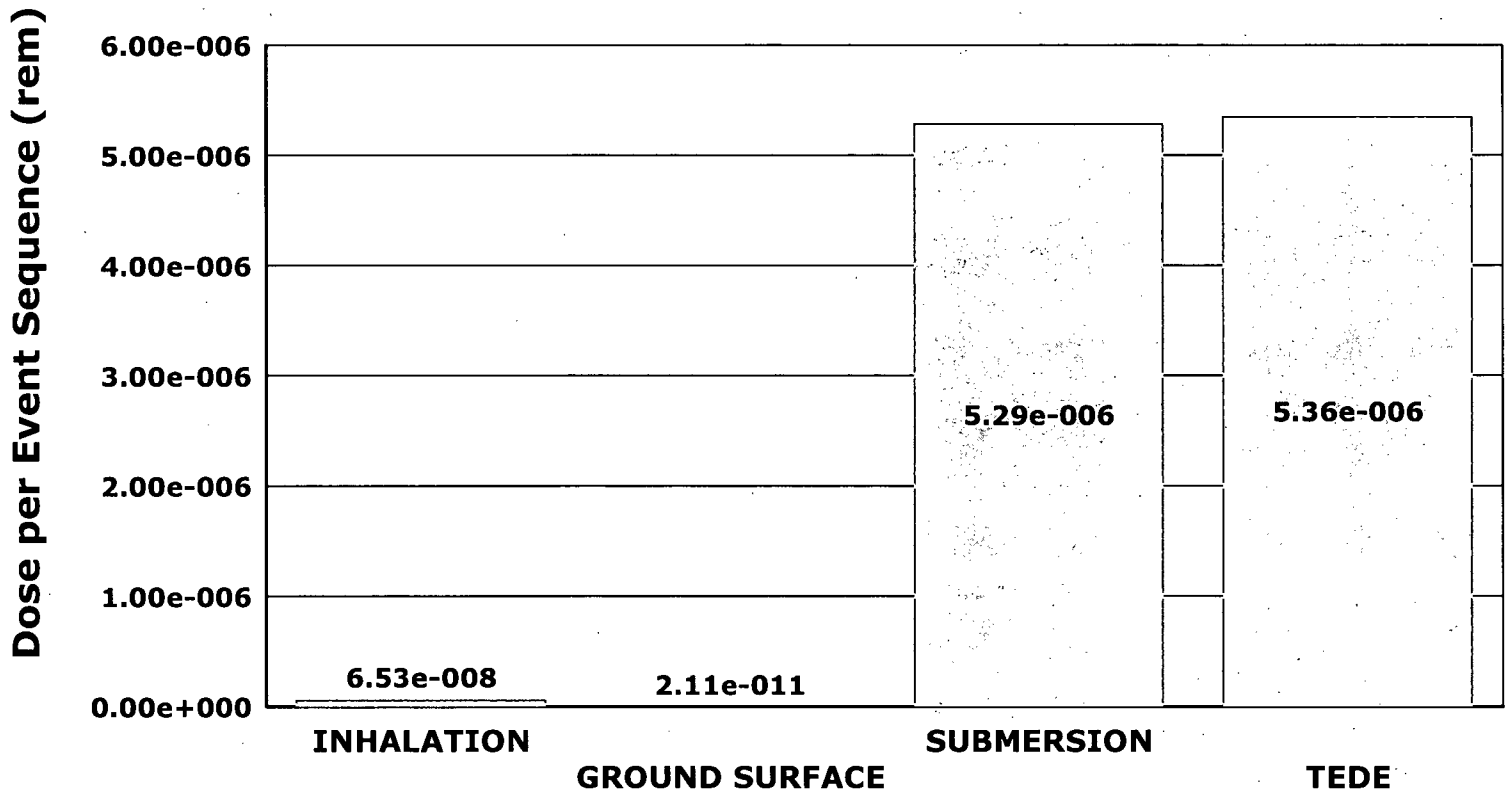
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06
SUBMERSION	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04
TEDE	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	13.00		

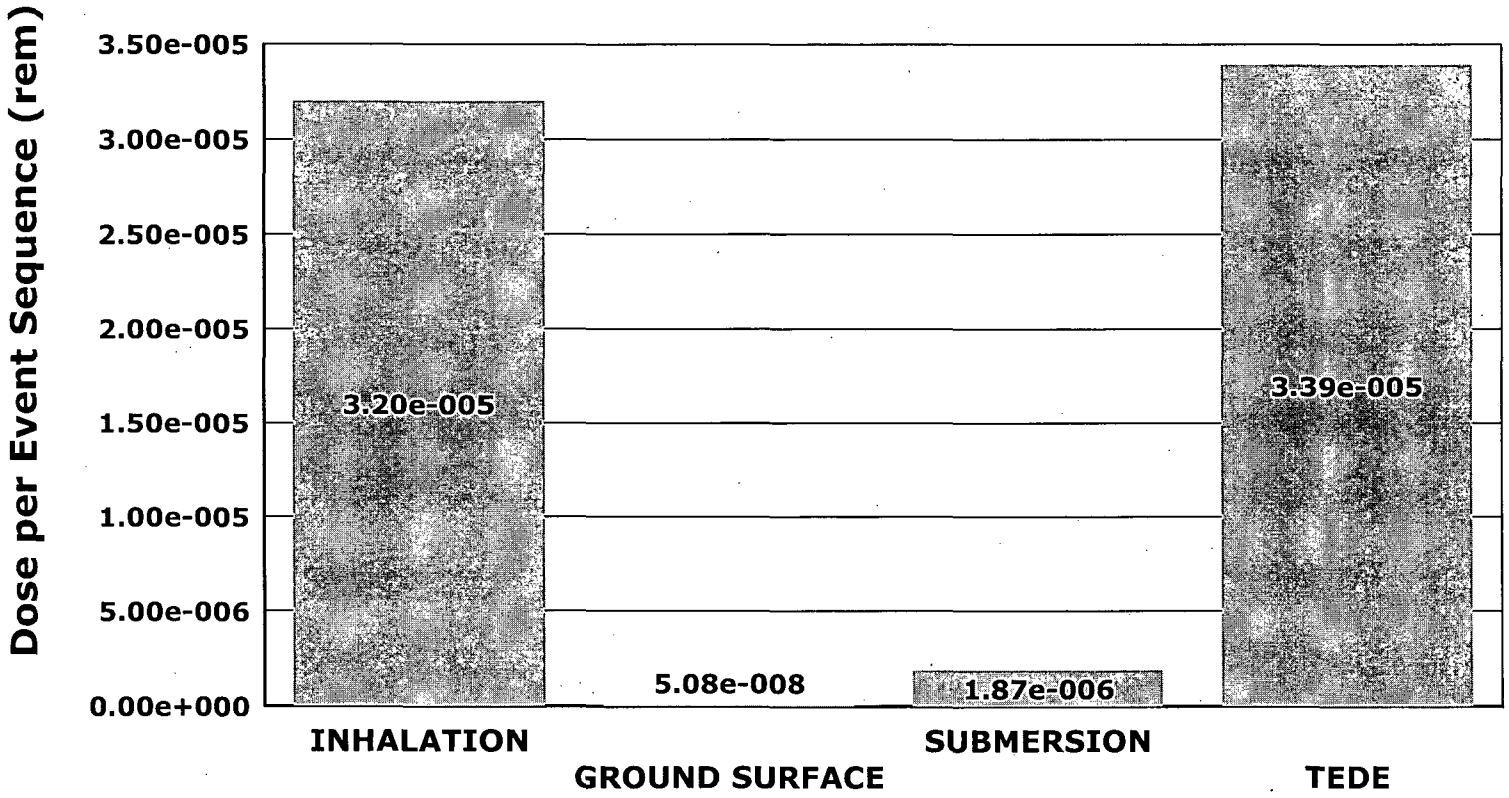
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	6.53E-08	6.53E-08	6.53E-08	6.53E-08	6.53E-08	6.53E-08
GROUND SURFACE	2.11E-11	2.11E-11	2.11E-11	2.11E-11	2.11E-11	2.11E-11
SUBMERSION	5.29E-06	5.29E-06	5.29E-06	5.29E-06	5.29E-06	5.29E-06
TEDE	5.36E-06	5.36E-06	5.36E-06	5.36E-06	5.36E-06	5.36E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

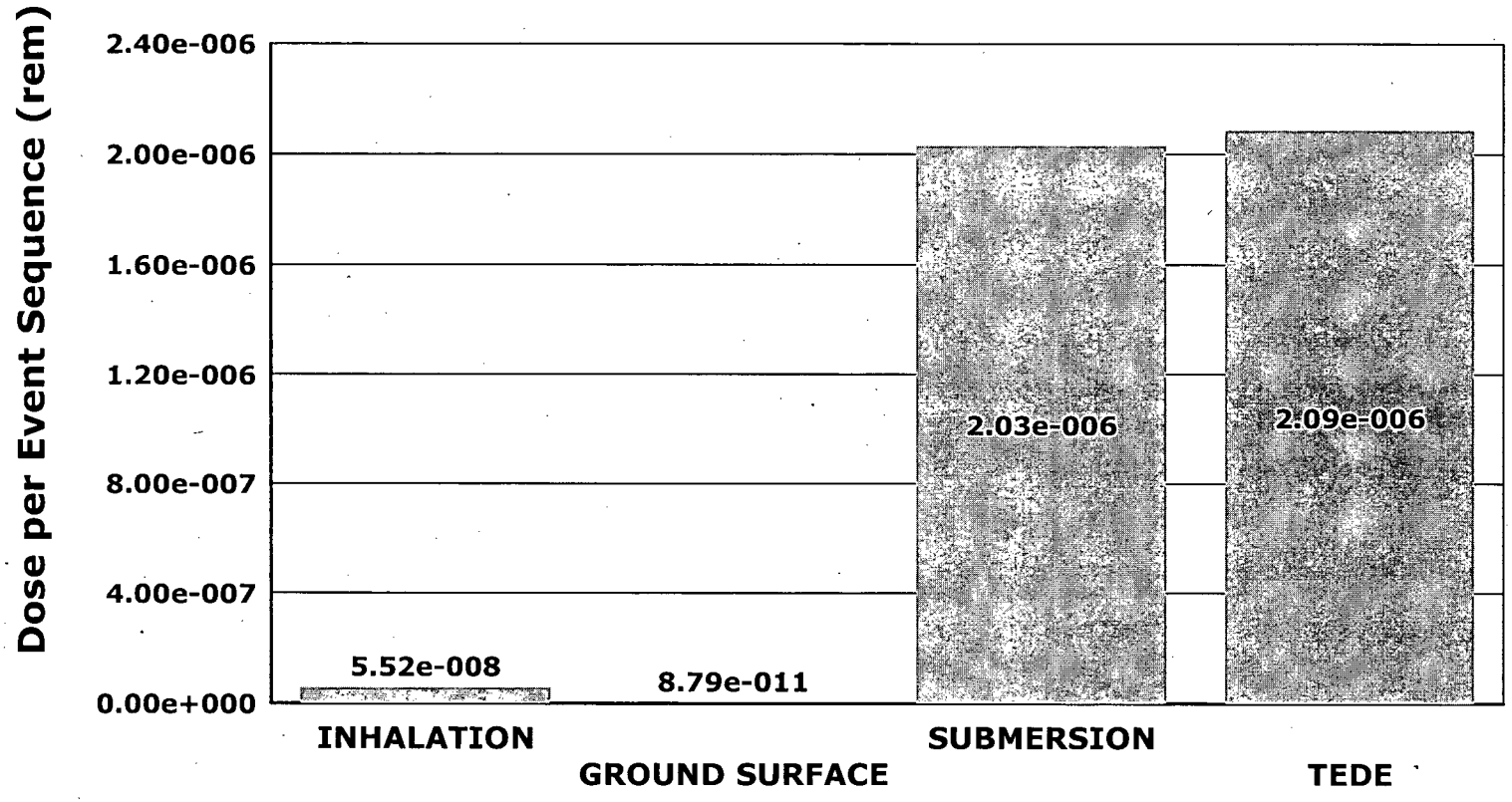
Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.20E-05	3.20E-05	3.20E-05	3.20E-05	3.20E-05	3.20E-05
GROUND SURFACE	5.08E-08	5.08E-08	5.08E-08	5.08E-08	5.08E-08	5.08E-08
SUBMERSION	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06
TEDE	3.39E-05	3.39E-05	3.39E-05	3.39E-05	3.39E-05	3.39E-05

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

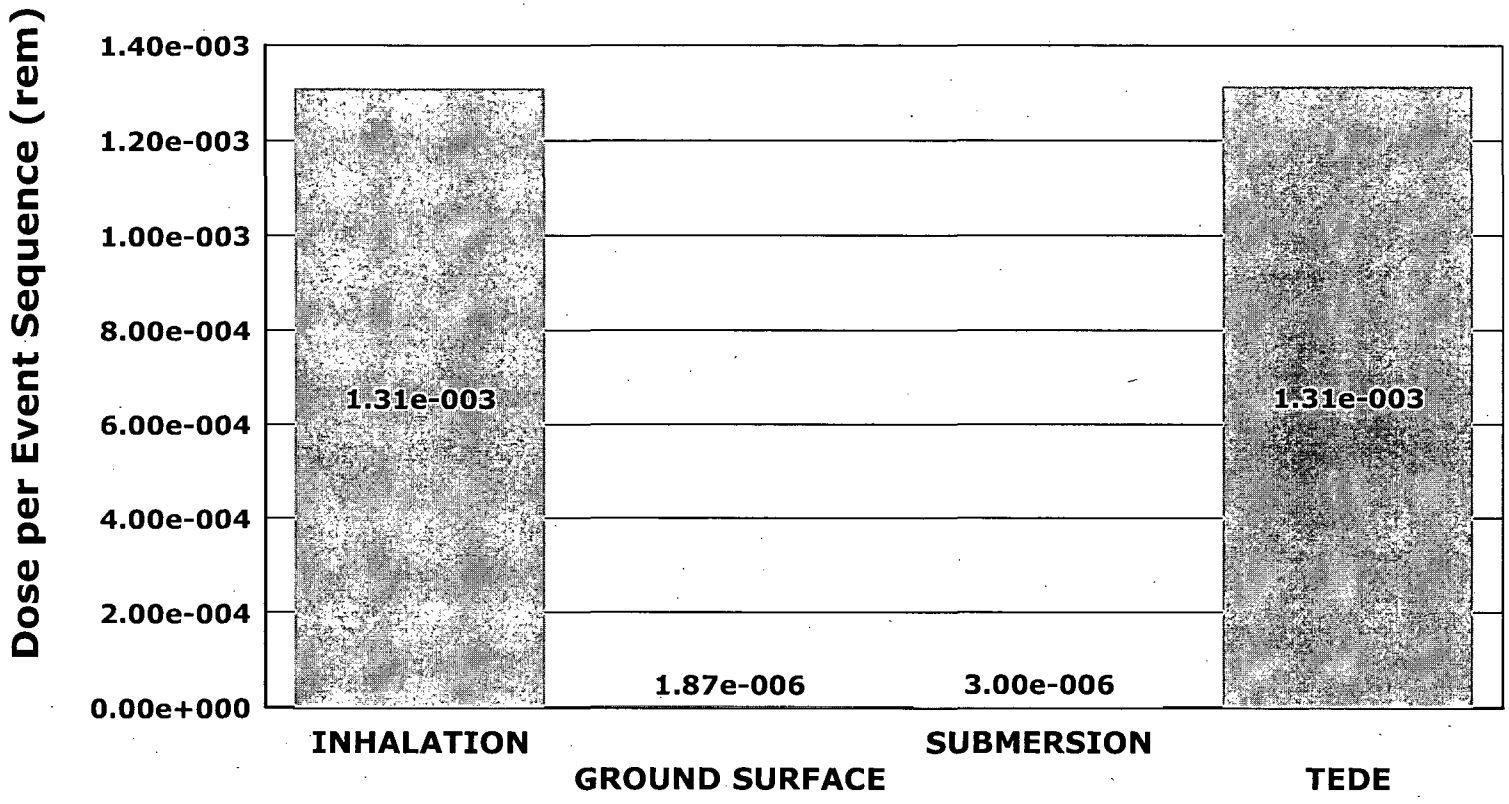
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	5.52E-08	5.52E-08	5.52E-08	5.52E-08	5.52E-08	5.52E-08
GROUND SURFACE	8.79E-11	8.79E-11	8.79E-11	8.79E-11	8.79E-11	8.79E-11
SUBMERSION	2.03E-06	2.03E-06	2.03E-06	2.03E-06	2.03E-06	2.03E-06
TEDE	2.09E-06	2.09E-06	2.09E-06	2.09E-06	2.09E-06	2.09E-06

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

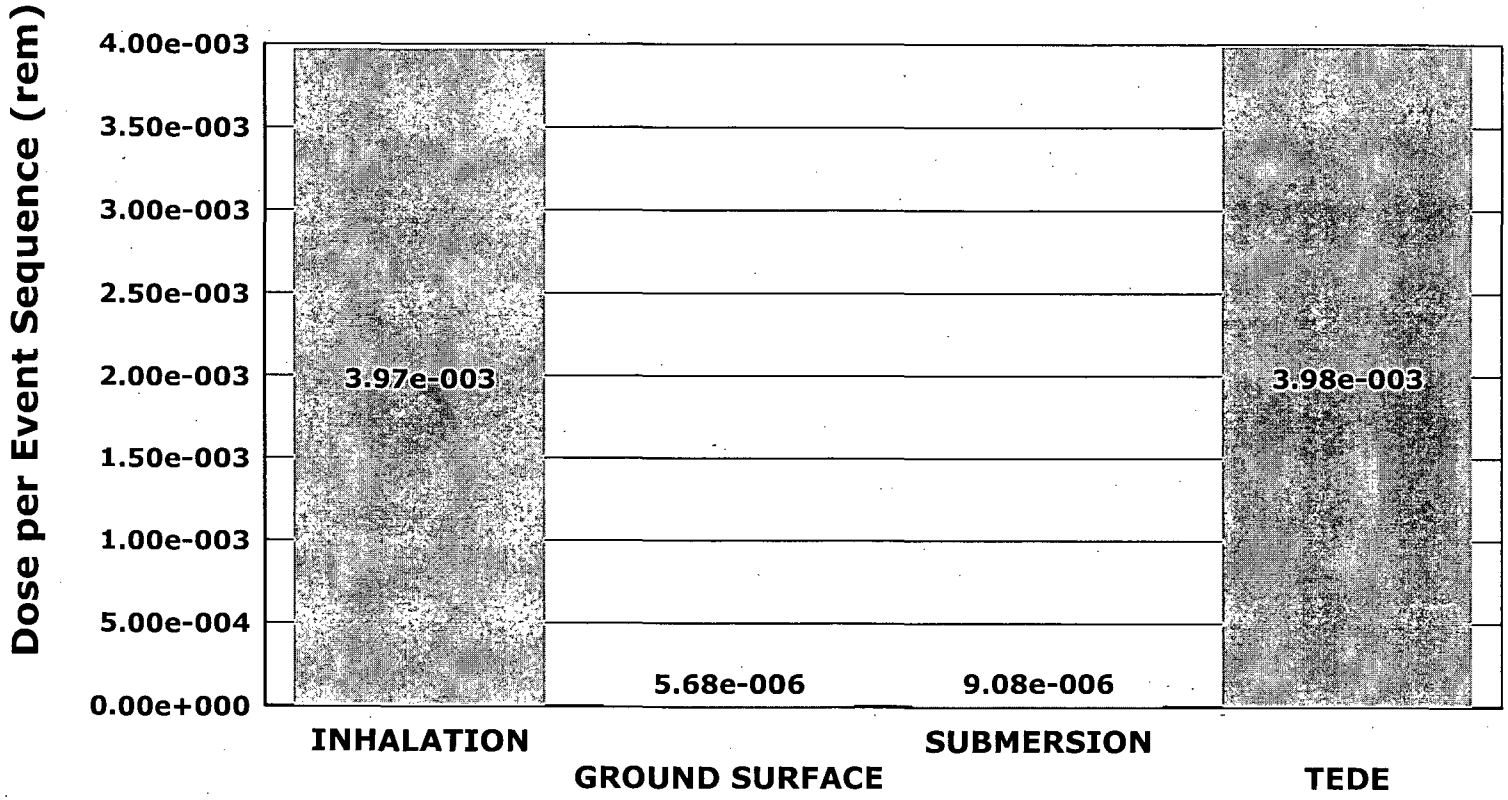
Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03
GROUND SURFACE	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06	1.87E-06
SUBMERSION	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06	3.00E-06
TEDE	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

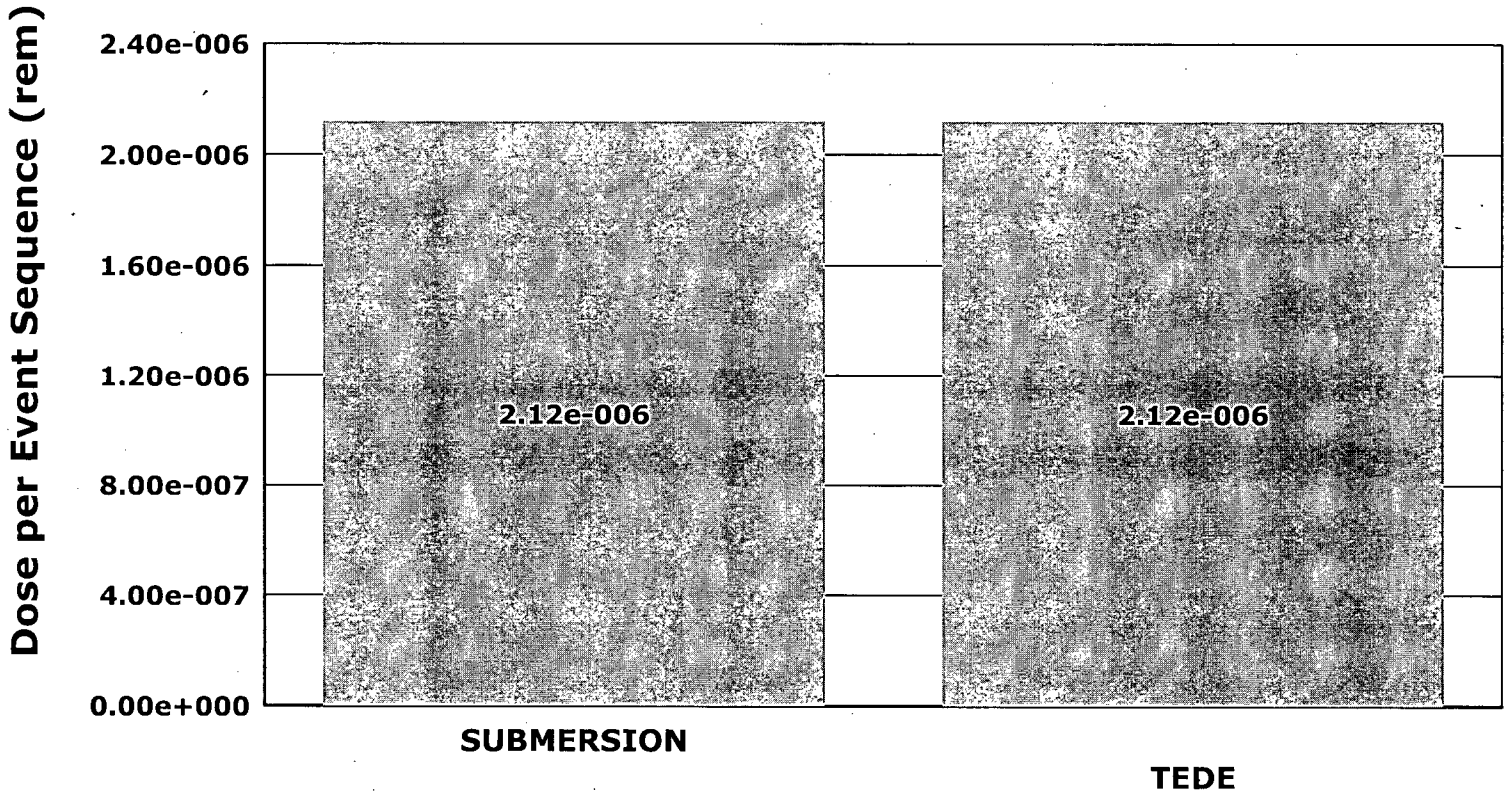
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06
SUBMERSION	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06
TEDE	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

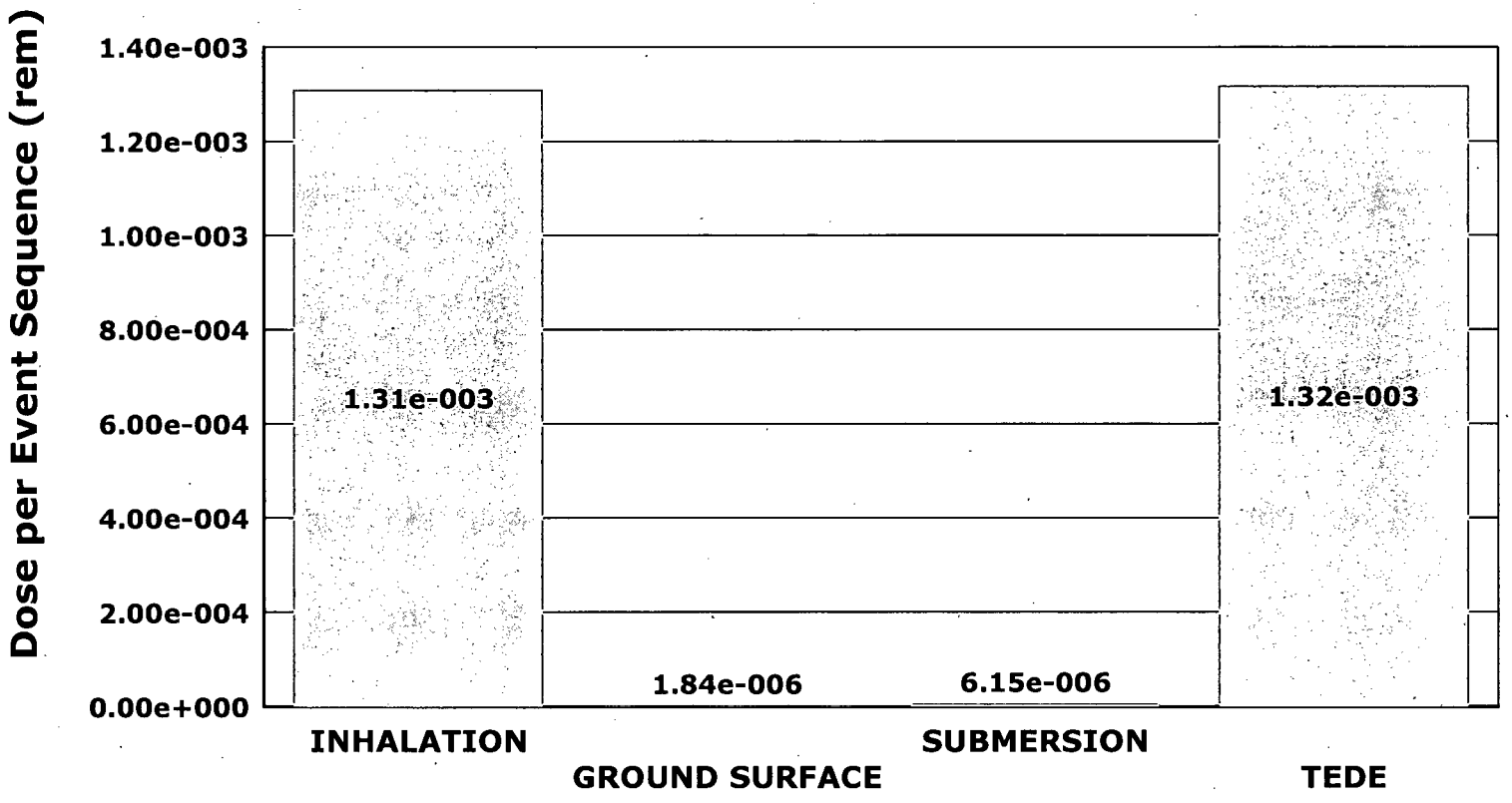
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
SUBMERSION	2.12E-06	2.12E-06	2.12E-06	2.12E-06	2.12E-06	2.12E-06
TEDE	2.12E-06	2.12E-06	2.12E-06	2.12E-06	2.12E-06	2.12E-06

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

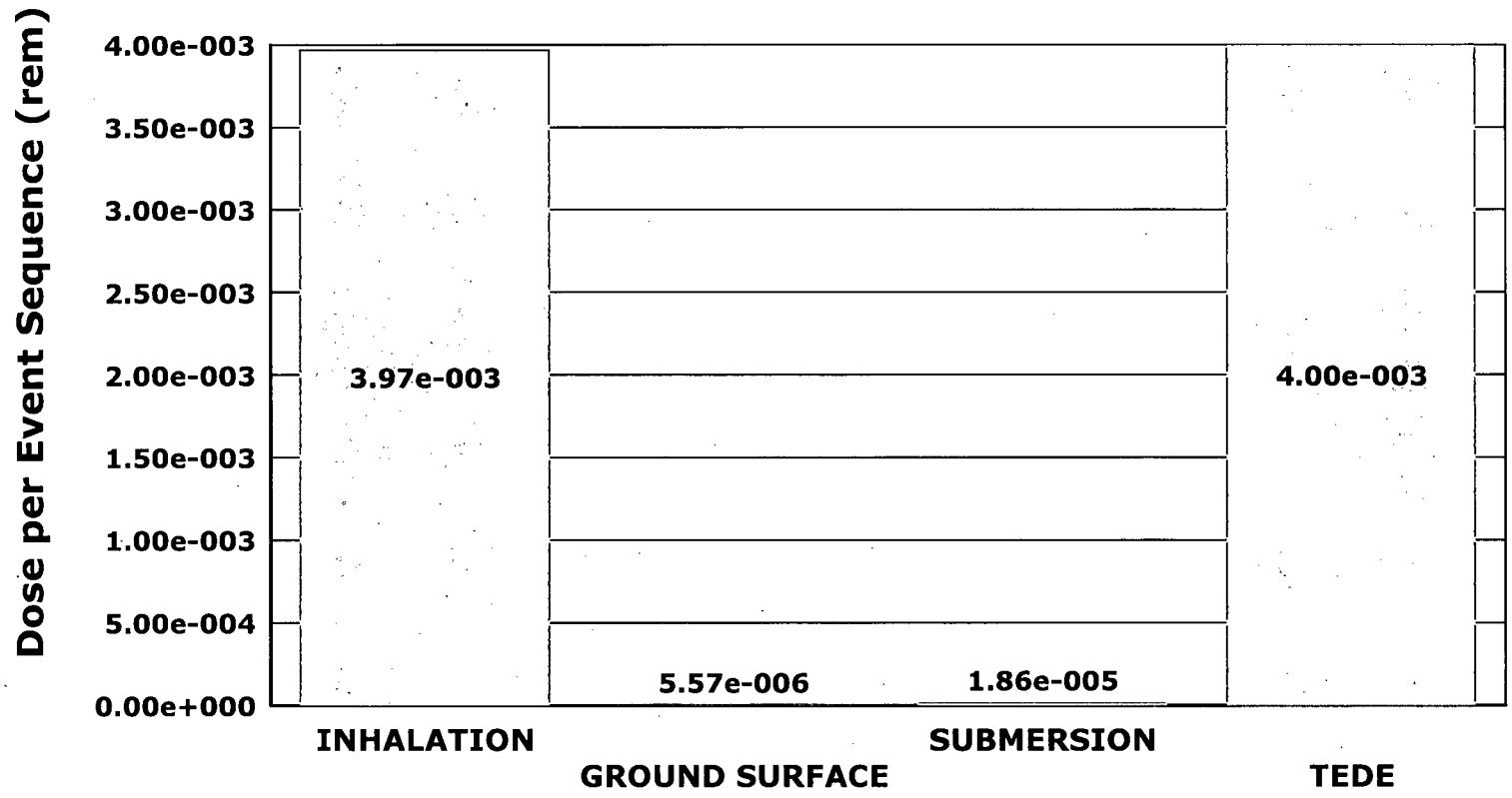
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03
GROUND SURFACE	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06	1.84E-06
SUBMERSION	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06	6.15E-06
TEDE	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03	1.32E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

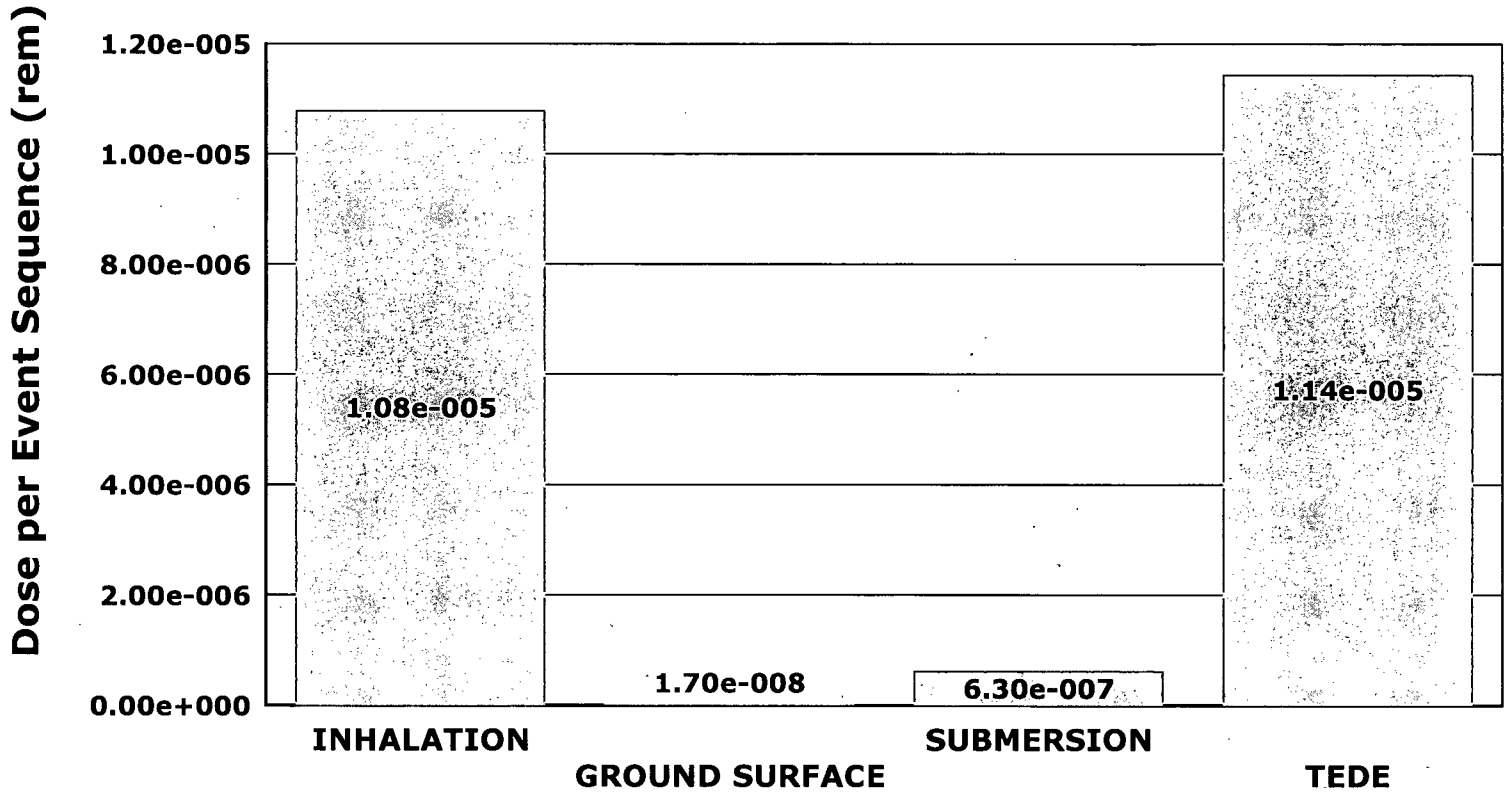
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06
SUBMERSION	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05
TEDE	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

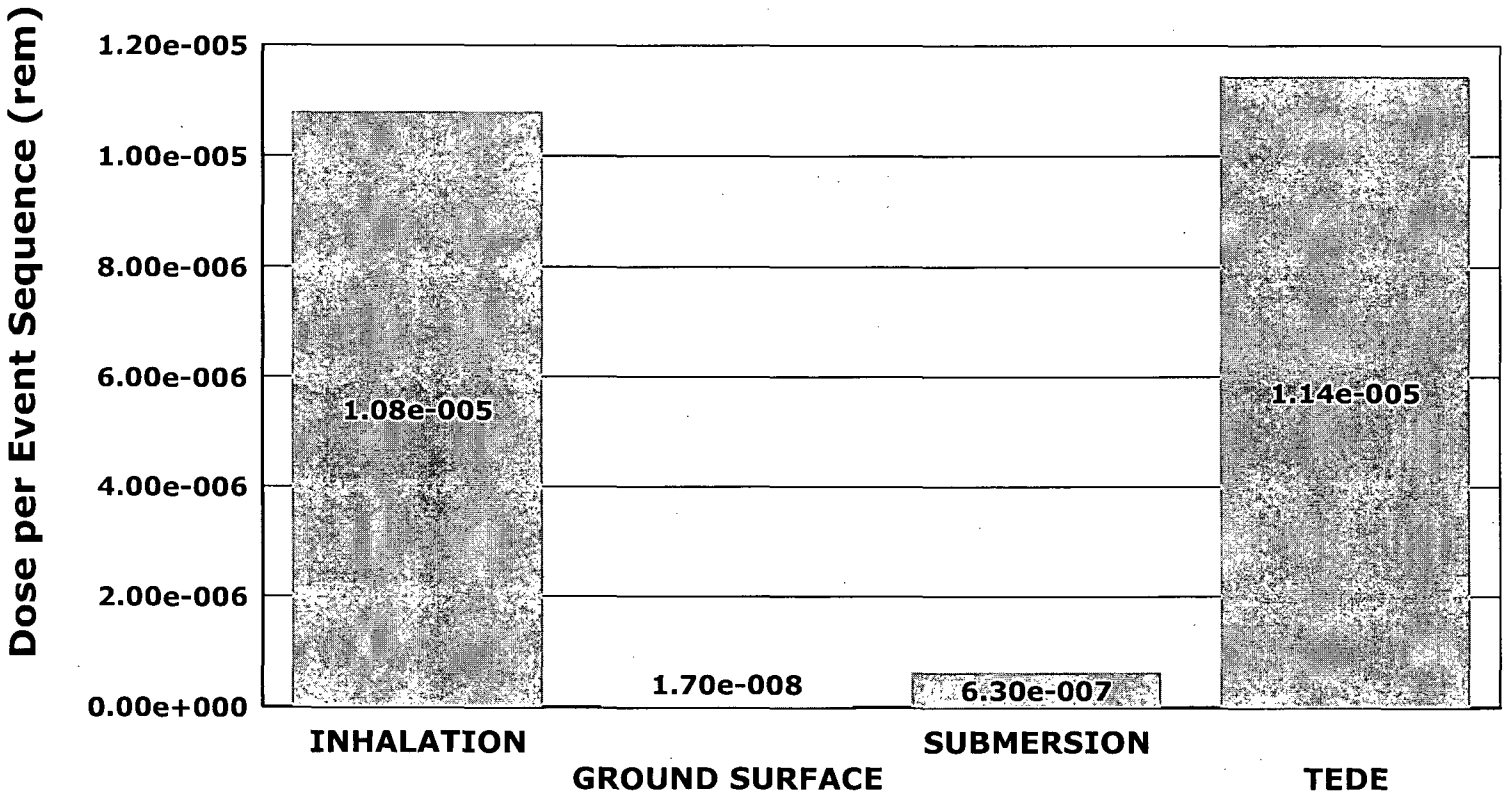
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05
GROUND SURFACE	1.70E-08	1.70E-08	1.70E-08	1.70E-08	1.70E-08	1.70E-08
SUBMERSION	6.30E-07	6.30E-07	6.30E-07	6.30E-07	6.30E-07	6.30E-07
TEDE	1.14E-05	1.14E-05	1.14E-05	1.14E-05	1.14E-05	1.14E-05

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

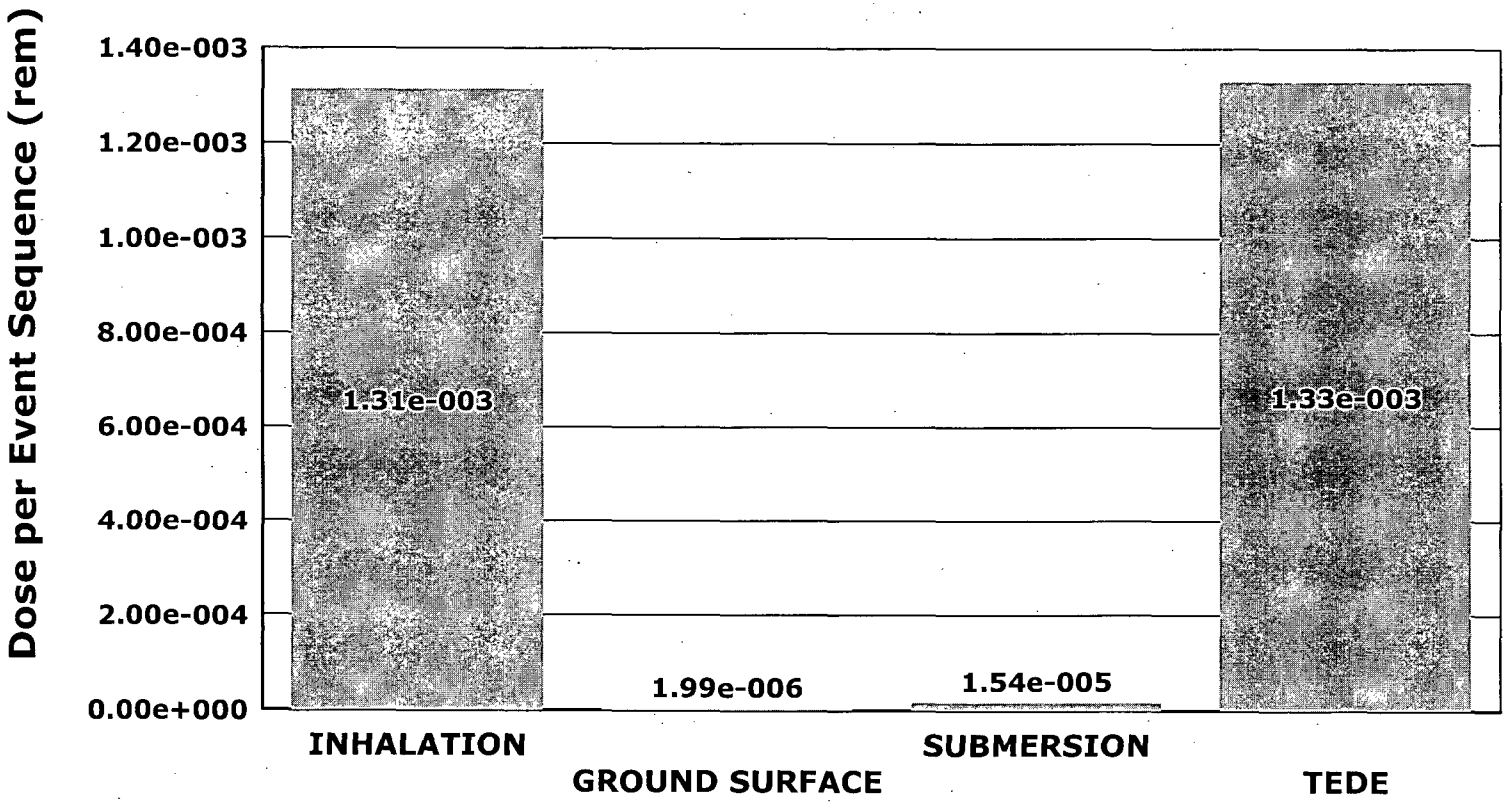
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05	1.08E-05
GROUND SURFACE	1.70E-08	1.70E-08	1.70E-08	1.70E-08	1.70E-08	1.70E-08
SUBMERSION	6.30E-07	6.30E-07	6.30E-07	6.30E-07	6.30E-07	6.30E-07
TEDE	1.14E-05	1.14E-05	1.14E-05	1.14E-05	1.14E-05	1.14E-05

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

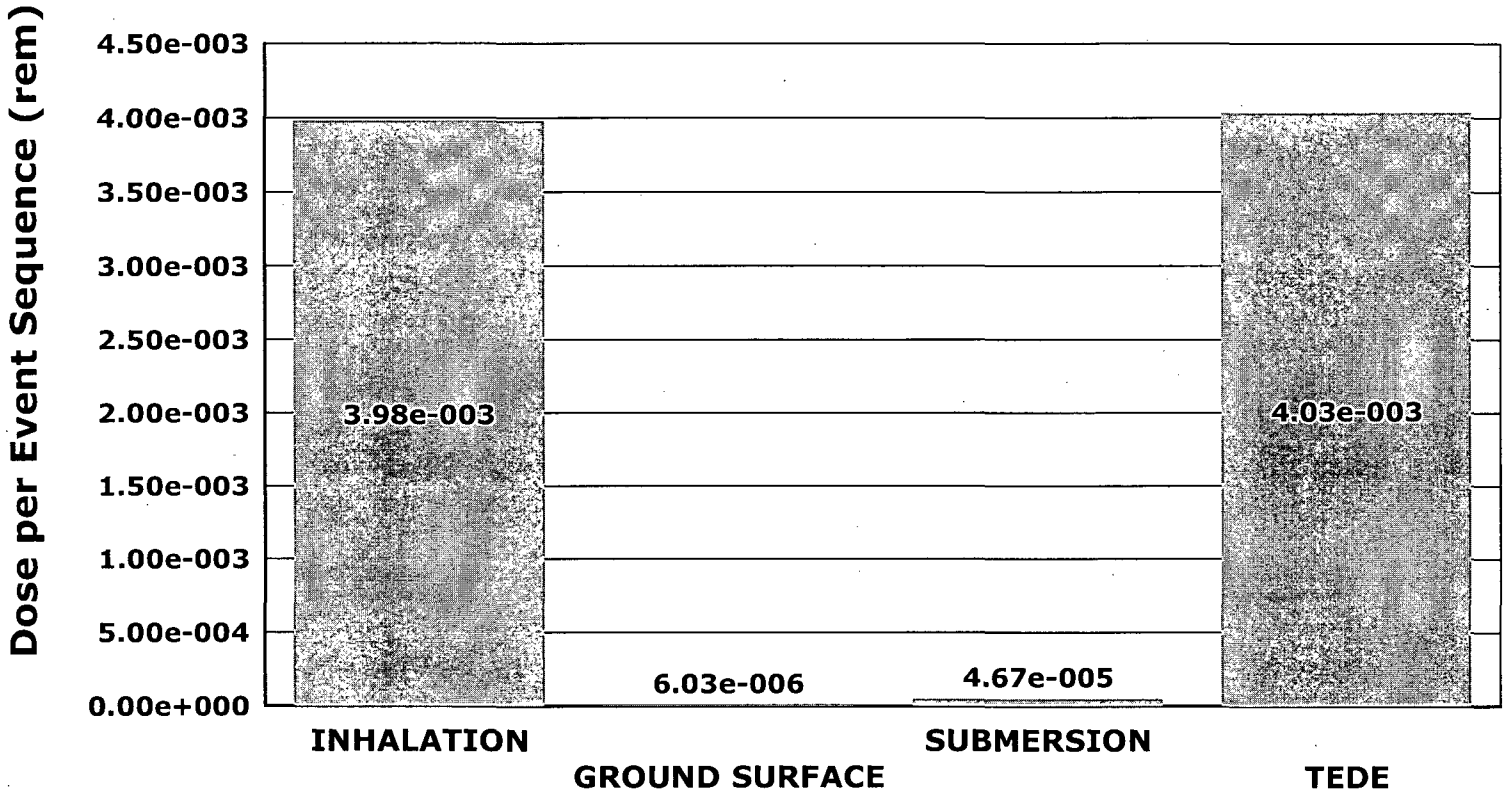
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03	1.31E-03
GROUND SURFACE	1.99E-06	1.99E-06	1.99E-06	1.99E-06	1.99E-06	1.99E-06
SUBMERSION	1.54E-05	1.54E-05	1.54E-05	1.54E-05	1.54E-05	1.54E-05
TEDE	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03	1.33E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

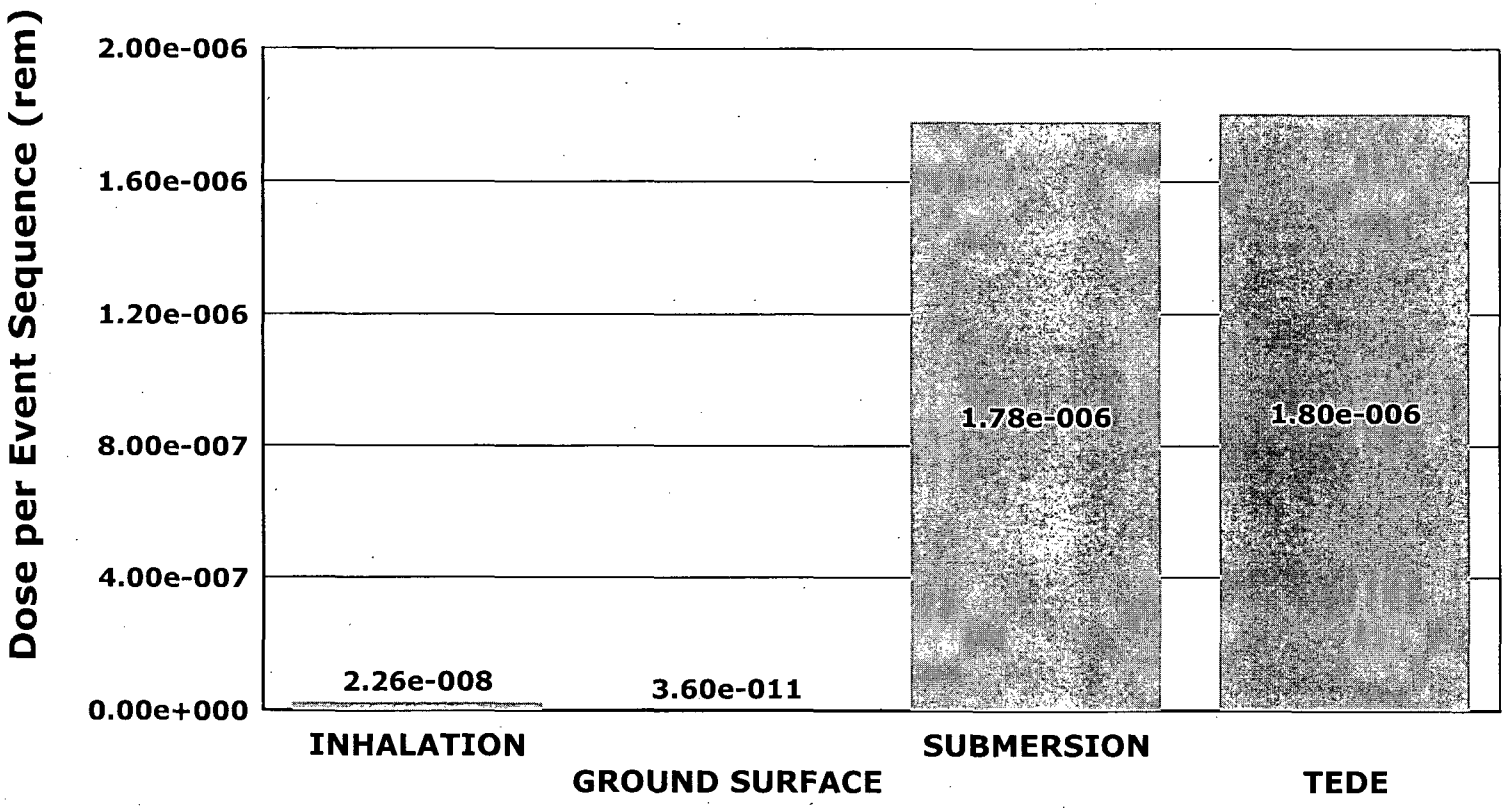
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03
GROUND SURFACE	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06
SUBMERSION	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05
TEDE	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

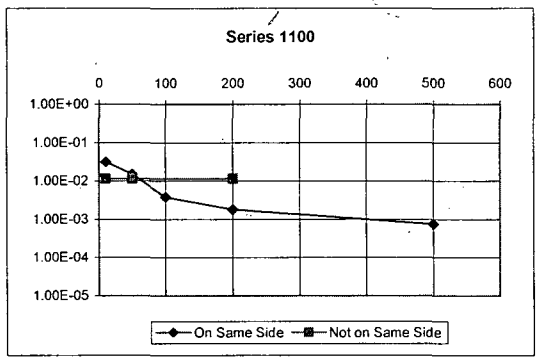
Input Parameters

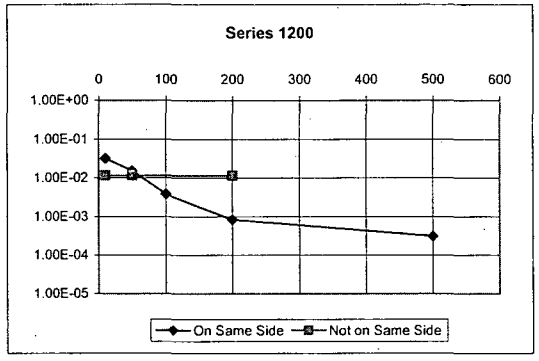
Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	13.00		

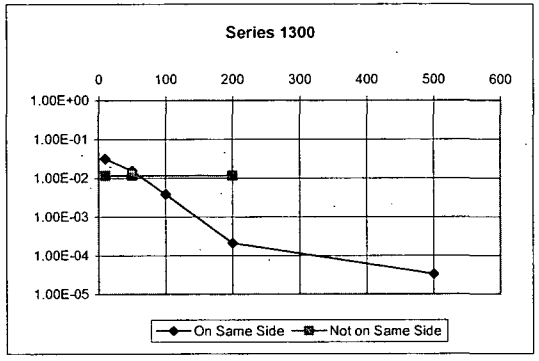
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	2.26E-08	2.26E-08	2.26E-08	2.26E-08	2.26E-08	2.26E-08
GROUND SURFACE	3.60E-11	3.60E-11	3.60E-11	3.60E-11	3.60E-11	3.60E-11
SUBMERSION	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
TEDE	1.80E-06	1.80E-06	1.80E-06	1.80E-06	1.80E-06	1.80E-06

Run Identifier	1101	1102	1103	1104	1105	1106	1107	1108
Pathway	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
INHALATION	3.14E-02	1.51E-02	3.78E-03	1.80E-03	7.34E-04	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	7.18E-06	3.46E-06	8.64E-07	4.10E-07	1.65E-07	2.62E-06	2.62E-06	2.62E-06
SUBMERSION	7.39E-05	3.55E-05	8.89E-06	7.42E-06	6.18E-06	2.69E-05	2.69E-05	2.69E-05
TEDE	3.15E-02	1.52E-02	3.79E-03	1.81E-03	7.41E-04	1.15E-02	1.15E-02	1.15E-02
Distance	10	50	100	200	500	10	50	200
Ratio of GS to TEDE	2.28E-04	2.28E-04	2.28E-04	2.27E-04	2.23E-04	2.28E-04	2.28E-04	2.28E-04

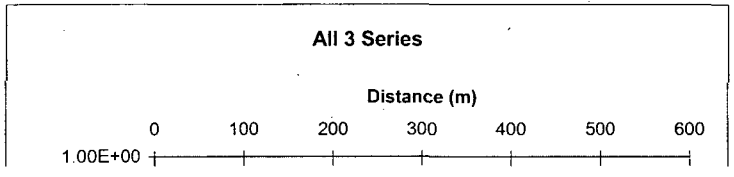


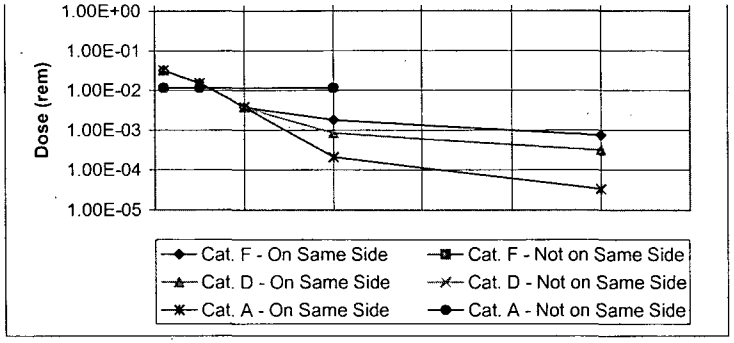




Run Identifier	1201	1202	1203	1204	1205	1206	1207	1208
Pathway	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
INHALATION	3.15E-02	1.51E-02	3.79E-03	8.33E-04	3.07E-04	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	6.76E-06	3.25E-06	8.14E-07	1.70E-07	5.72E-08	2.47E-06	2.47E-06	2.47E-06
SUBMERSION	1.52E-04	7.32E-05	1.83E-05	7.31E-06	5.05E-06	5.55E-05	5.55E-05	5.55E-05
TEDE	3.16E-02	1.52E-02	3.80E-03	8.40E-04	3.12E-04	1.15E-02	1.15E-02	1.15E-02
Distance	10	50	100	200	500	10	50	200
Ratio of GS to TEDE	2.14E-04	2.14E-04	2.14E-04	2.02E-04	1.83E-04	2.15E-04	2.15E-04	2.15E-04

Run Identifier	1301	1302	1303	1304	1305	1306	1307	1308
Pathway	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
INHALATION	3.15E-02	1.52E-02	3.79E-03	2.07E-04	3.16E-05	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	8.70E-06	4.19E-06	1.05E-06	5.62E-08	8.36E-09	3.17E-06	3.17E-06	3.17E-06
SUBMERSION	3.80E-04	1.83E-04	4.57E-05	5.01E-06	1.85E-06	1.39E-04	1.39E-04	1.39E-04
TEDE	3.19E-02	1.54E-02	3.84E-03	2.12E-04	3.34E-05	1.16E-02	1.16E-02	1.16E-02
Distance	10	50	100	200	500	10	50	200
Ratio of GS to TEDE	2.73E-04	2.72E-04	2.73E-04	2.65E-04	2.50E-04	2.73E-04	2.73E-04	2.73E-04




1.00E+00
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
Dose (rem)
Cat. F - On Same Side
Cat. F - Not on Same Side
Cat. D - On Same Side
Cat. D - Not on Same Side
Cat. A - On Same Side
Cat. A - Not on Same Side

DRAFT

Note on Dose Calculations for Downwind Workers

This is not intended to be a full explanation, but just an interim note to let you know where things are. Please consider it draft and for discussion.

Part 1. Modification.

First, as I mentioned verbally to some, there is an erroneous statement in the previous writeup. In Window 5, the distance from the source, x, does not need to be less than $2.5 \cdot H_B$. A closer reading of the literature indicates the following:
1. If the stack height, $H_S \geq 2.5 \cdot H_B$, then the released contaminant concentration downwind is unaffected by the building; just use the Gaussian plume with an elevated source (H_S).
2. If the stack height is lower, $H_S < 2.5 \cdot H_B$, then the flow over the building will entrain the contaminant and bring it down to ground level.
3. The contaminant brought to ground level will disperse beyond the building, but the disturbed flow field persists for an indefinite distance (or value of x); the literature indicates that the

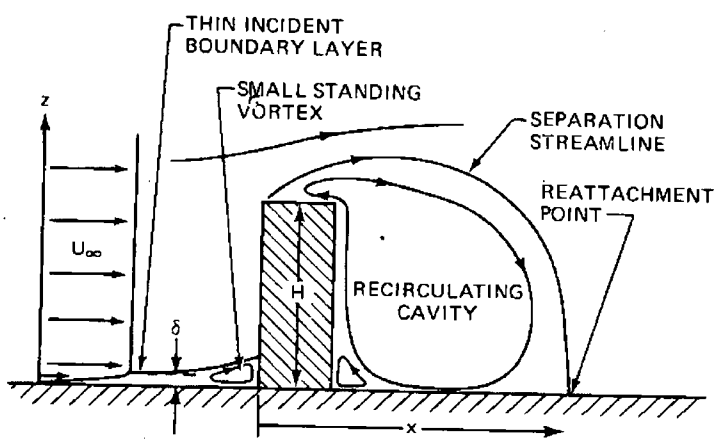


Fig. 7.7 Typical flow field near a strictly two-dimensional sharp-edged bluff body subjected to a nearly uniform incident flow where the depth of the incident boundary layer, δ, is much smaller than H. The concept that the cavity is bounded by the separation streamline should not be extrapolated to three-dimensional obstacles. (From J. C. R. Hunt, W. H. Snyder, and R. E. Lawson, Jr., Flow Structure and Turbulent Diffusion Around a Three-Dimensional Hill, in *Fluid Modeling Study on Effects of Stratification, Part I. Flow Structure*, Report EPA-600/4-78-041, U. S. Environmental Protection Agency, 1978.)

disturbed flow produces a zone that grows like a boundary layer as the flow moves downwind.

For Discussion

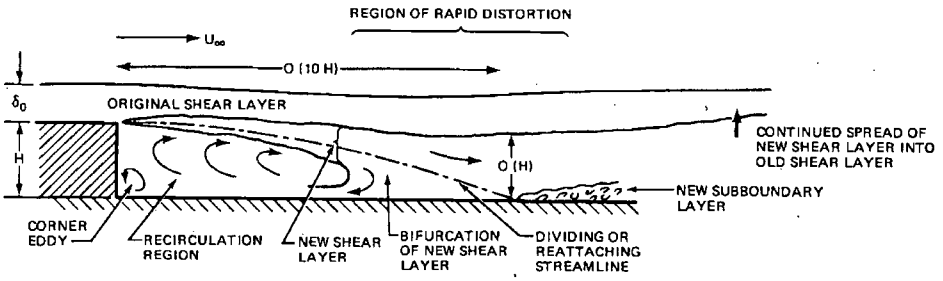


Fig. 7.9 Schematic of reattaching flow behind a two-dimensional step. [From P. Bradshaw and F. Y. F. Wong, The Reattachment and Relaxation of a Turbulent Shear Layer, *J. Fluid Mech.*, 52(Pt. 1): 113-135, Cambridge University Press, 1972.]

Consider the following diagrams taken from the text, "Atmospheric Science and Power Production", DOE/TIC-27601, ed. Daryl Randerson, 1984. Figure 7.7 clearly shows the "recirculating cavity" that is the conceptual basis for the "Cavity Zone". After the "reattachment point" will come the "Wake Zone". The second figure, Figure 7.9 shows how the "Wake Zone" continues to extend past the reattachment point for some distance, which may be very large. Elsewhere in the text, the author of this Chapter (R.P. Hosker, Jr.), points out that the actual behavior behind real three-dimensional obstacles may be different than these schematic drawings

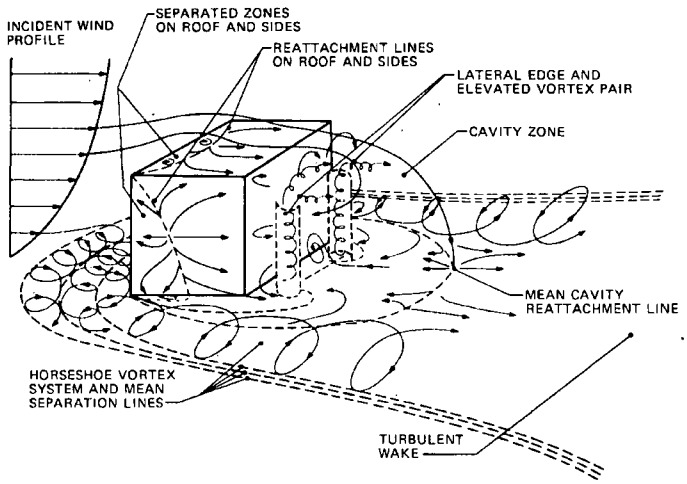


Fig. 7.15 Recent model of flow near a sharp-edged three-dimensional building in a deep boundary layer. [Based on H. G. C. Woo, J. A. Peterka, and J. E. Cermak, *Wind-Tunnel Measurements in the Wakes of Structures*, NASA Contractor Report NASA CR-2806, National Space and Aeronautics Administration, 1977; and on J. C. R. Hunt, W. H. Snyder, and R. E. Lawson, Jr., Flow Structure and Turbulent Diffusion Around a Three-Dimensional Hill, in *Fluid Modeling Study on Effects of Stratification, Part I. Flow Structure*, Report EPA-600/4-78-041, U. S. Environmental Protection Agency, 1978.]

for two-dimensional obstacles (these basic concepts were developed by wind tunnel studies). For a true, three-dimensional obstacle, the flow system in front of and behind the obstacle may be quite complex, as shown in Figure 7.15. For our problem an important consideration is: "The far wake of a three-dimensional ground-mounted body immersed in a deep incident boundary layer

is even more complex than that of a two-dimensional body because the presence of potentially persistent longitudinally oriented vortices generated by the body can strongly influence the flow far down wind."

Thus the upper limit on distance in the wake zone should be removed.

Part 2. Some Preliminary Calculations.

The following geometry was chosen for this problem, based on dimensions from DOE designs.

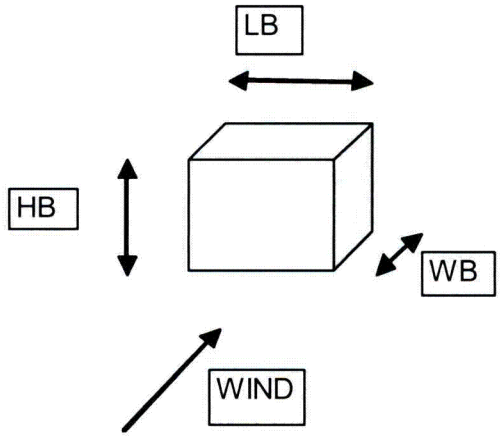


Figure 4. Geometry used for preliminary calculations.

The building has a length (LB) of 150 m, a depth (WB) of 135 m, and a height (HB) of 34m. The wind is assumed to blow in the direction of the building depth; therefore the frontal area of the building is: AB = LB*HB = 5100 m^2.

To explore the differences in the calculation approaches, two release heights for the contaminants, HS, will be assumed: (1) 34 m assumes a vent on the building roof and (2) 90 m assumes a high stack. Note that 2.5 HB = 85 m, so a 90 m release height avoids getting the flow near the building involved in contaminant dispersal. The breakout of cases, physically and computationally, under these assumptions then becomes:

1. For HS = 90m, the contaminant is in the Displacement Zone; therefor e use the standard Gaussian plume model with a source height of 90m.

2. For HS = 34 m, the building affects the concentration downwind; therefore use one of the other 4 calculational procedures. There are two distinct cases: (A) the receptor is on the building or (B) the receptor is not on the building.

For Discussion

2.A. The receptor is on the building and is either (i) very close to the stack or vent or (ii) a moderate distance from the stack or vent. Since we have assumed a vent size of approximately 16 inches square; an equivalent round vent will have a diameter of 0.459 m. For simplicity assume a round vent with a diameter of 0.5 m. The dividing distance between cases 2.A.i and 2.A.ii is $3 \cdot D = 1.5$ m.

2.B. The receptor is <u>not</u> on the building and is either (i) closer to the building in the Cavity Zone or (ii) further from the building in the Wake Zone. For decision purposes, the extent of the Cavity Zone (the dividing distance between cases 2.B.i and 2.B.ii) is taken to be $2.5 \cdot [AB]^{1/2} = 179$ m in this case.

Based on this configuration and assumptions, the doses estimated are shown in Figure 5.

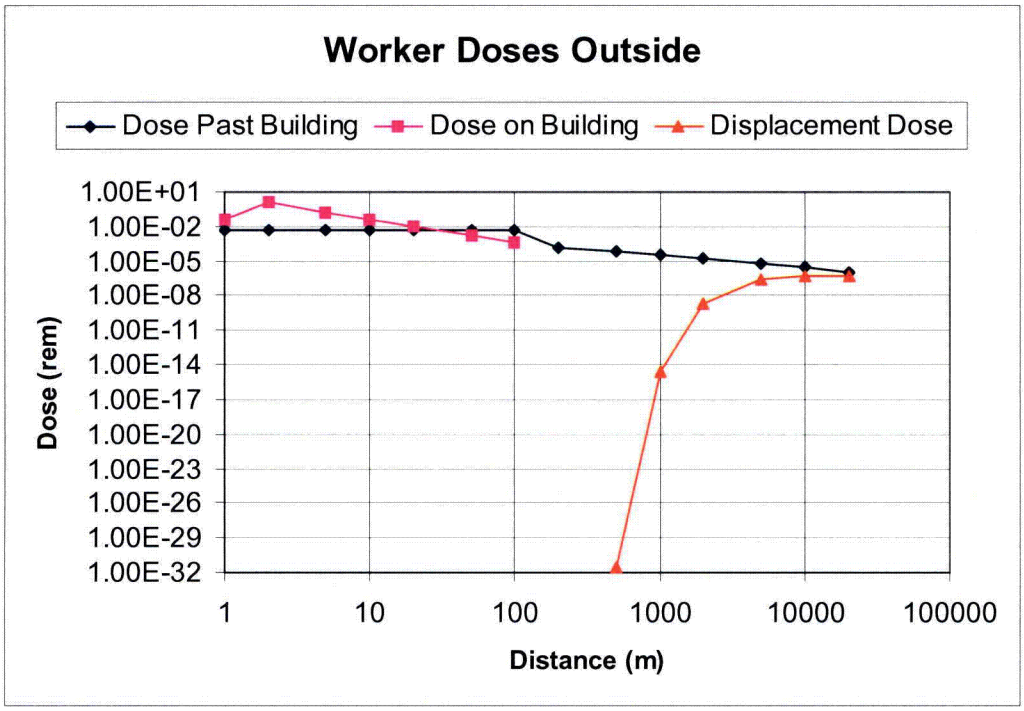


Figure 5. Plot of worker doses outside.

These dose estimates were obtained using runs of the RSAC code and modifying those results manually, based on the approach previously transmitted. There are several interesting observations that may be made about these results:

1. Note that both axes are logarithmic scales.
2. Doses were computed at the following values of x: 1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000, 10,000, 20,000 m. This takes the range from very close to the release

point to beyond the site boundary.

3. Corresponding to the regimes outlined above are: Case 1 - high stack, the curve is orange; Cases 2A - receptors are on the building, the curve is dark blue; Cases 2B - receptors are near the building, the curve is magenta.
4. Only one point on the curves plotted (1 m, 3.94E-02 rem) is based on the receptor being in close proximity to the vent. This is because only one point (x = 1m) was within the 1.5 m range for this case.
5. The calculation for the remainder of the receptors for Case 2A (on the building) was stopped when x > 135 m, which is the depth of the building. **Currently the suggested approach has no test for this condition; it should probably be added.**
6. Of the remaining doses for Case 2A (x = 2, 5, 10, 20, 50, 100 m), three are larger than the dose very close to the vent (2 m, 1.12E+00 rem; 5 m, 1.79E-01 rem; 10 m, 4.47E-02 rem). This does not make sense physically. Once the radionuclides are diluted to the concentration in the vent/stack, there is no compelling physical reason why the concentration should increase [one could argue that a vena contracta could form reducing the area through which the contaminated air flows, once it exits the vent/stack, but this is an unlikely condition for this configuration]. This condition of higher concentrations arises because the concentration "in the vent" is just the release rate divided by the vent flow, $\acute{R}/V$, while the concentration "near the vent" is the release rate divided by the air velocity multiplied by the square of the distance, $\acute{R}/U \cdot X^2$. For small distances, the concentration "near the vent" can be larger than the concentration "in the vent". **We should probably change the calculation so that the "near the vent" correction factor can be no greater than the "in the vent correction factor".**
7. If the receptor is not on the building and the stack is low, the dark blue curve results. Note that the dose estimate is a constant 0.879 rem in the Cavity Zone, which extends to 178.5 m ($2.5 \cdot [AB]^{1/2}$). If we assume the release is on the front edge of the building, then the building will extend to 135 m. Therefore this dose represents a receptor on the building or behind it, but not on the same side as the release. In this case, this dose is lower than the dose experienced by the person breathing stack air; however, it may be possible for the concentration computed to be higher (for example, for a very narrow building and low wind speed). **As with item 6, we should probably change the calculation so that the "Cavity Zone" correction factor can be no greater than the "in vent correction factor".**
8. Starting with 200 m and extending to 20,000 m the dark blue curve describes the dose in the wake zone. This dose falls off with distance. The basis for the concentration causing the dose is a ground-level release, so the concentration decreases because of increasing values of σ_y and σ_z as distance increases. In addition a correction is made for enhanced vertical mixing, by increasing the nominal value of σ_z based on the building characteristics. At larger distances, the impact of this correction becomes smaller.
9. For the case of the high (90 m) stack the orange curve is obtained. The estimated dose increases until a distance of 10,000 m is reached where the value is 6.07E-07 rem; although it is difficult to see in this graph, the dose at 20,000 m is smaller and equal to

5.31E-07 rem. Because the source is elevated, the concentration remains very low for this case until the plume "touches down"; this occurs approximately when $HS = 2\cdot\sigma_z(x)$ (at this value the value of the term $\exp\{-\frac{1}{2}(H/\sigma_z)^2\}$ is about 0.9, so the effects of the elevated source are small) . Note that $\sigma_z(x)$ has the values 4.82E+01m and 6.33E+01m respectively at x= 10,000m and 20,000m. Thus the computed maximum value of dose occurs just where we would expect it.

10. Note that the dose computed for the "Wake Zone" (dark blue curve) and the dose computed for the high stack (orange curve) converge at large values of x (10000 to 20000 m). This is to be expected, because at large distances two things happen: (1) the factor introduced into the wake zone calculation to account for enhanced mixing from building turbulence reduction, approaches a value of unity at large distances, because $\sigma_z^2(x) >> AB/\pi$; and (2) the influence of the elevation of the source becomes negligible for the displacement zone dose, because $HS << \sigma_z$.

11. It is instructive for this problem to estimate the plume rise assuming a vertical stack release. Plume rise due to momentum may be important, because the air exchange rate for the hot cell, which is used to compute the stack flow rate, is high (8 air changes per hour). One equation for plume rise due to the gas momentum in the stack is given by:

$$h_{pr} = (3\cdot D_S\cdot V_S)/U$$

Where,

h_{pr} is the plume rise due to the stack gas momentum
D_S is the diameter of the stack
Vs is the stack gas velocity
U is the wind velocity

For our case $h_{pr} = (3\cdot 0.5\text{ m}\cdot 57.69\text{ m/s})/3.0\text{ m/s} = 28.84\text{ m}$; since the height of the building is 34 m, this is a significant momentum plume rise. Of course, if the flow is distributed horizontally, there will not be any substantial plume rise (buoyancy is probably not significant, or if there is any, it may be negative, because the air from the facility is likely to be cool). Since we do not really know the design parameters, we can't tell whether DOE should get credit for a vertical release in which the plume rise lofts the contamination above the immediate vicinity of the release. By any measure, a stack velocity of close to 60 m/s seems extremely high.

Part 3. Derivation of Formulas.

The IAEA Safety Series 19 provides formulas for screening calculations for the case of air releases of radionuclides. These formulas, which are not generally valid, are intended to provide dose estimates in a particular context:

1. The provide conservative estimates of doses;
2. The doses estimated are intended to be used prior to licensing a facility and are prospective;
3. The releases are assumed to be approximately constant for long periods of time (several years of operation).

Although some of these limitations do not apply to prelicensing estimates of worker doses at the proposed Yucca Mountain Repository, the formulas are used as a starting point. The formulas are modified to account for some of the differences between their intended application and this application. In particular these formulas are used as a guide for how to treat the effects of the building on air dispersion. Some adjustments, for example to treat short term releases, rather than chronic releases, are necessary.

There are five separate formulas used to calculate the downwind concentration in the IAEA document corresponding to five different regimes. These different regimes are based on the physical configuration of the release, building, and receptors. For convenience, the flow chart describing these regimes is duplicated here (Figure 6). The formulas from IAEA corresponding to these different cases are:

1. <u>Displacement Zone</u>:

$$C_A = P_P F Q_i / U_A \qquad (2)$$

Where,

C_A is the ground level air concentration at the downwind distance x in sector direction P;
P_P is the fraction of the time during the year that the wind blows toward the receptor of interest in sector P;
F is the Gaussian diffusion factor appropriate for the height of release H and the downwind distance x considered (m^{-2});
Q_i is the annual average discharge rate for radionuclide i (Bq/s)
U_A is the geometric mean of the wind speed at the height of release representative of one year (m/s)

And

$$F = [12/(2\pi^3)^{1/2}]\cdot[1/x\sigma_z]\cdot\exp\{-\tfrac{1}{2}(H/\sigma_z)^2\} \qquad (3)$$

Where,

σ_z is the dispersion coefficient in the z direction
H is the release height.

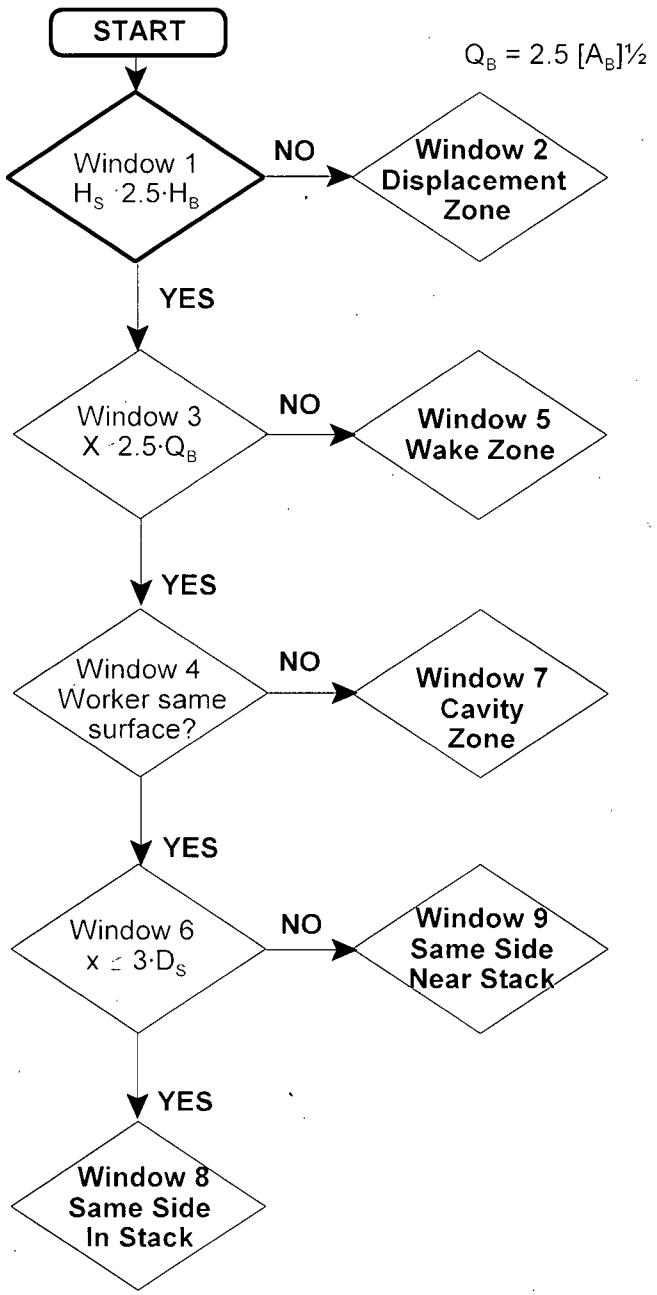


Figure 6. Flow chart for IAEA air dispersion calculations.

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This result is obtained from the standard Gaussian plume model by performing a sector average.

That is, if we take the standard Gaussian plume solution for a ground-level receptor:

$$C_G = [Q_i/U_A]\cdot[g_1 g_2/(2\pi\sigma_y\sigma_z)] \qquad (3\text{-A})$$

Where,

C_G is the concentration downwind based on the standard Gaussian plume model;
g_1 is the function describing y dependence and $= \exp\{-½\,(y/\sigma_y)^2\}$;
g_2 is the function depending on z, but for a ground level receptor reduces to:
$g_2 = 2\cdot\exp\{-½\,(H/\sigma_z)^2\}$
σ_y and σ_z are the dispersion coefficients for y and z respectively, which depend on x.

Note that equation (3-A) may be rewritten as:

$$C_G = [Q_i/U_A]\cdot[g_2/(2\pi\sigma_z)]\cdot[g_1/\sigma_y] = [Q_i/U_A]\cdot[g_2/(2\pi\sigma_z)]\cdot[\exp\{-½\,(y/\sigma_y)^2\}/\sigma_y] \qquad (3\text{-B})$$

Note that the last term in brackets is a function only of y; to perform part of the sector average process integrate this over y from $y = \pm\infty$. Since,

$$\int_0^\infty e^{-a^2x^2}\,dx = \frac{\sqrt{\pi}}{2a}$$

we can double the value for the integral for $y = \pm\infty$ and equation (3-B) becomes:

$$\text{integral } C_G = [Q_i/U_A]\cdot[g_2/(2\pi\sigma_z)]\cdot[(2\pi)^{½}] \qquad (3\text{-C})$$

If we assume that the wind blows toward a single sector which represents one of 12 compass points, then this integrated concentration is spread over a radial sector whose length is exactly:

$$L = r\theta = x\cdot(2\pi/12)$$

If we divide the result (3-C) by this length we get the sector average concentration, Č, (assumes that all the released mass is averaged over the radial length of the sector):

$$\check{C}_G = [Q_i/U_A]\cdot[g_2/(2\pi\sigma_z)]\cdot[(2\pi)^{½}]/\{x\cdot(2\pi/12)\} = [Q_i/U_A]\cdot[g_2/(x\sigma_z)]\cdot[12/(2\pi)^{3/2}]$$

and since $g_2 = 2\cdot\exp\{-½\,(H/\sigma_z)^2\}$, this becomes:

$$\check{C}_G = [12/(2\pi^3)^{½}]\cdot[Q_i/U_A]\cdot[\exp\{-½\,(H/\sigma_z)^2]\cdot[1/(x\sigma_z)] \qquad (3\text{-D})$$

This result is equivalent to equations (2) and (3) combined, except that it does not contain the factor, P_P. This demonstrates that the concentration calculated is just a probability weighted sector average concentration based on a standard Gaussian plume model.

To adapt this to our issue of acute releases and worker doses, we make two key assumptions:

1. We conservatively assume the wind is always blowing toward an exposed downwind worker; i.e., $P_P = 1$.
2. We should use the Gaussian plume model without modification for the sector average, because we are dealing with an acute, short-term accidental release, not a multi-year average.

This is the basis for assuming in the model writeup for Window 2: "Use the RSAC model with a receptor elevation equal to zero."

For Discussion

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2. For the case of the Wake Zone (Window 5) the suggested formula from the IAEA is:

$$C_A = P_P B Q_i / U_A \quad (4)$$

Where all terms are defined as before and

$$B = [12/(2\pi^3)^{1/2}]\cdot[1/x\Sigma_z] \quad (5)$$

and $$\Sigma_z = [\sigma_z^2 + A_B/\pi]^{1/2} \quad (6)$$

where,

A_B is the area of the building facing the wind flow (m^2).

In other words, this is just the sector average solution again, but the dispersion coefficient in the z direction is increased by a factor to account for the enhanced turbulence caused by the flow field downwind of the building (see Part 1flow diagrams). To adapt this to the worker dose conditions make the following assumptions:

1 We conservatively assume the wind is always blowing toward an exposed downwind worker; i.e., $P_P = 1$.

2 Assume that the dose at any location downwind is only a function of the concentration at that location. Since we should only calculate inhalation dose, air submersion dose and ground plane dose, this should be a very good approximation. Inhalation dose and submersion dose are only dependent on downwind concentration. Since this is a short-term release, the amount of deposited radionuclides should be small, so the ground plane dose should be negligible. Furthermore, if it were substantial, workers would be excluded from the contaminated area.

Based on this second assumption, we can use the RSAC code to calculate the dose at an appropriate distance, x, and then modify that dose to account for the increased mixing downwind of the building. First, we use a ground level release (source height, H_S, = 0); this is because the flow field behind the building is assumed to entrain the release, whatever its height, and bring it down to the ground surface. As before the receptor height is zero. Using a standard Gaussian plume solution and assuming the wind is blowing directly at the receptor (Assumption 1) we would get:

$$C_G = [Q_i/U_A]\cdot[1/(\pi\sigma_y\sigma_z)] \quad (3\text{-E})$$

since in equation (3-A) for the degenerate conditions we have assumed ($y = z = H_S = 0$), g_1 = 1and $g_2 = 2$. This is parallel to equation (4) if we remove the sector averaging, except that equation (4) uses a modified value for σ_z that reflects the enhanced mixing. We should be able to obtain this value from the dose calculated by RSAC by multiplying the RSAC result by the ratio:

$$F_W = \sigma_z/\Sigma_z$$

where σ_z is the standard Gaussian vertical dispersion coefficient and

Σ_z is the modified vertical dispersion coefficient calculated according to equation (6).

This reasoning gives rise to the instructions for Window 5.

3. All the Other Cases. For all the other cases, we employ the RSAC runs by noting the following :

1 The RSAC output provides a lot of information: doses, organ doses, chi/Q values (sometimes called dilution factors), and concentrations.

For Discussion

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2 chi/Q is the normalized concentration (normalized by the release rate Q). Therefore:

$$C = (chi/Q)\cdot Q$$

3 As before assume dose is proportional to concentration; i.e., assume:

$$D_I \propto C_I$$
$$D_R \propto C_R$$

where D is dose, C is concentration, R refers to an RSAC computation, and I refers to an IAEA computation.

4 Combining these we can write:

$$D_I/D_R = C_I/C_R$$

or $$D_I = D_R\cdot(C_I/C_R)$$

5 Combining this with point 2 we can then write:

$$D_I = D_R\cdot(C_I/[(chi/Q)\cdot Q])$$

This result can then be used to derive the remainder of the relationships we seek.

6 It does not matter what location we use to determine the RSAC dose; as a matter of convenience, use x=100m, which is the lower limit of the range used to gather data on the dispersion coefficients.

<u>For Window 7</u> the Cavity Zone, the relationship provided by the IAEA is:

$$C_A = P_P Q_i/(\pi U_A H_B K)$$

As before we set P_P=1, since this is a short-term release. K is taken to be 1 m and H_B is the smaller of the height or width of the building. Then the correction factor for the RSAC dose for the Cavity Zone is:

$$F_C = D_I/D_R = [Q_i/(\pi U_A H_B K)]/[(chi/Q)\cdot Q]) = 1/[\pi U_A H_B K(chi/Q)]$$

because the Q's essentially drop out.

<u>For Window 9</u> the Same Side Near Stack, the relationship provided by the IAEA is:

$$C_A = B_0 Q_i/U_A x^2$$

where in this case B_0 has a value of 30 and other variables are as before.

Then the correction factor for the RSAC dose for the Same Side Near Stack is:

$$F_S = D_I/D_R = (B_0 Q_i/U_A x^2/[(chi/Q)\cdot Q]) = B_0/[U_A x^2(chi/Q)]$$

Essentially the Q's drop out.

<u>For Window 8</u> the Same Side In Stack, the relationship provided by the IAEA is:

$$C_A = P_P Q_i/V \qquad (1)$$

where V is the volumetric air flow in the vent or stack and other variables are as before, including P_P=1.

Then the correction factor for the RSAC dose for the Same Side In Stack is:

$$F_V = D_I/D_R = (Q_i/V/[(chi/Q)\cdot Q]) = 1/[V\cdot(chi/Q)]$$

Essentially the Q's drop out.

For Discussion

		Nominal	
Wind Speed m/s	U	3	
Building Length (m)	LB	150	Assume the length is oriented perpendicular to the wind flow.
Building Width (m)	WB	135	Assume the width is oriented in the direction of wind flow.
Building Height (m)	HB	34	
Source Height (m)	HS	34	

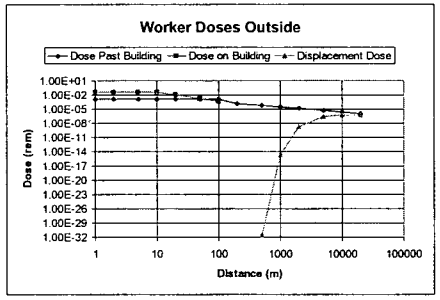
		in	cm	A (m2)	R2 (m)	R (m)	D (m)	nominal (m)	nominal area
duct size	w	16	40.64	0.165161	0.052572	0.229287	0.458573	0.5	0.19635

		room volun	building vo	air change	flow (m3/s)	nominal velocity	plume rise (m)
duct flow	V	5097.032	20388.13	8	11.32674	57.68661	28.8433

WB	150 m	
HB	34 m	85
AB	5100 m2	
QB	178.5357 m	

	Window	Minimum D	Maximum Distance
Same Side in Stack	8	0	1.5
Same Side near Stack	9	1.5	135
Cavity Zone	7	0	178.5357
Wake Zone	5	178.5357	∞
Displacement Zone			

Note: minimum value for Cavity Zone is indeterminate; however x is the downwind distance, so it can be zero, if the worker is not on the same side.
Note: The upper range of x is infinity; at large x, the effects of an elevated release and increased dispersion coefficient are negligible, so the concentration is the same as in the displacement zone.



RSAC Output HS=0 — HS=34 ON Building

	CEDE	chi/Q	X	X-3D		
				1	-0.5	In Stack ON Buildin FV
				2	0.5	Near Stack ON Buildin FS
				5	3.5	Near Stack ON Buildin FS
				10	8.5	Near Stack ON Buildin FS
				20	18.5	Near Stack ON Buildin FS
σz	CEDE	chi/Q		50	48.5	Near Stack ON Buildin FS
2.37E+00	4.98E-03	1.12E-02		100	98.5	Near Stack ON Buildin FS
4.01E+00	1.55E-03	3.46E-03		200	198.5	Near Stack OFF Buildi NA
7.92E+00	3.27E-04	7.34E-04		500	498.5	Near Stack OFF Buildi NA
1.29E+01	1.04E-04	2.33E-04		1000	998.5	Near Stack OFF Buildi NA
2.03E+01	3.45E-05	7.73E-05		2000	1998.5	Near Stack OFF Buildi NA
3.44E+01	8.79E-06	1.98E-05		5000	4998.5	Near Stack OFF Buildi NA
4.82E+01	3.40E-06	7.66E-06		10000	9998.5	Near Stack OFF Buildi NA
6.33E+01	1.43E-06	3.22E-06		20000	19998.5	Near Stack OFF Buildi NA

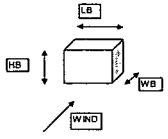
HS=34 OFF Building — HS≥2.5HB HS=90

Corr. Facto	Dose	QB-X	X≤QB	Corr. Facto	Dose	X	chi/Q	dose
7.92E+00	3.94E-02	177.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	1	
7.92E+00	3.94E-02	176.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	2	
7.92E+00	3.94E-02	173.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	5	
7.92E+00	3.94E-02	168.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	10	
2.24E+00	1.12E-02	158.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	20	
3.59E-01	1.79E-03	128.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	50	chi/Q dose
8.97E-02	4.47E-04	78.53571	Cavity Zon	2.80E-01	1.39E-03	Displacem	100	0.00E+00 0.00E+00
		-21.4643	Wake Zon	9.91E-02	1.54E-04	Displacem	200	0.00E+00 0.00E+00
		-321.464	Wake Zon	1.93E-01	6.31E-05	Displacem	500	6.51E-32 2.94E-32
		-821.464	Wake Zon	3.05E-01	3.17E-05	Displacem	1000	6.24E-15 2.83E-15
		-1821.46	Wake Zon	4.50E-01	1.55E-05	Displacem	2000	4.12E-09 1.87E-09
		-4821.46	Wake Zon	6.50E-01	5.71E-06	Displacem	5000	6.47E-07 2.94E-07
		-9821.46	Wake Zon	7.67E-01	2.61E-06	Displacem	10000	1.34E-06 6.07E-07
		-19821.5	Wake Zon	8.44E-01	1.21E-06	Displacem	20000	1.17E-06 5.31E-07

Previous Spreadsheet

Column N	Column O	Col T/π	Col U/π
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394
8.79E-01	4.38E-03	0.279882	0.001394

FV = 1/(V [chi/Q])
FS = 30/(UA x^2 [chi/Q])
FC = 1/(UA π HB K [chi/Q])
FW = σz / σzmod zmod = [(σz)2 + (AB/π)]½



Note the jump between FV and FS at the common point x=1.5 m

FV/chi/Q	1/V	8.83E-02
FS/chi/Q	30/UA^x^2	4.44E+00 Which in this case is a factor of about 50.

Note the jump between FC and FS at the end of the building, i.e. x=135 m

FS/chi/Q	30/UA^x^2	5.49E-04
FC/chi/Q	1/UA*HB*K	9.80E-03

ENHANCED DEPOSITION PARAMETERS
PARTICLE DIAMETER = 0.000E+00 (m) PARTICLE DENSITY = 0.000E+00 (g/cm3)

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/cu m)
1.000E+02	0.000E+00	4.011E+00	2.372E+00	1.115E-02
2.000E+02	0.000E+00	7.642E+00	4.011E+00	3.461E-03
5.000E+02	0.000E+00	1.826E+01	7.918E+00	7.337E-04
1.000E+03	0.000E+00	3.531E+01	1.290E+01	2.330E-04
2.000E+03	0.000E+00	6.764E+01	2.029E+01	7.732E-05
5.000E+03	0.000E+00	1.561E+02	3.442E+01	1.975E-05
1.000E+04	0.000E+00	2.876E+02	4.818E+01	7.657E-06
2.000E+04	0.000E+00	5.202E+02	6.333E+01	3.221E-06

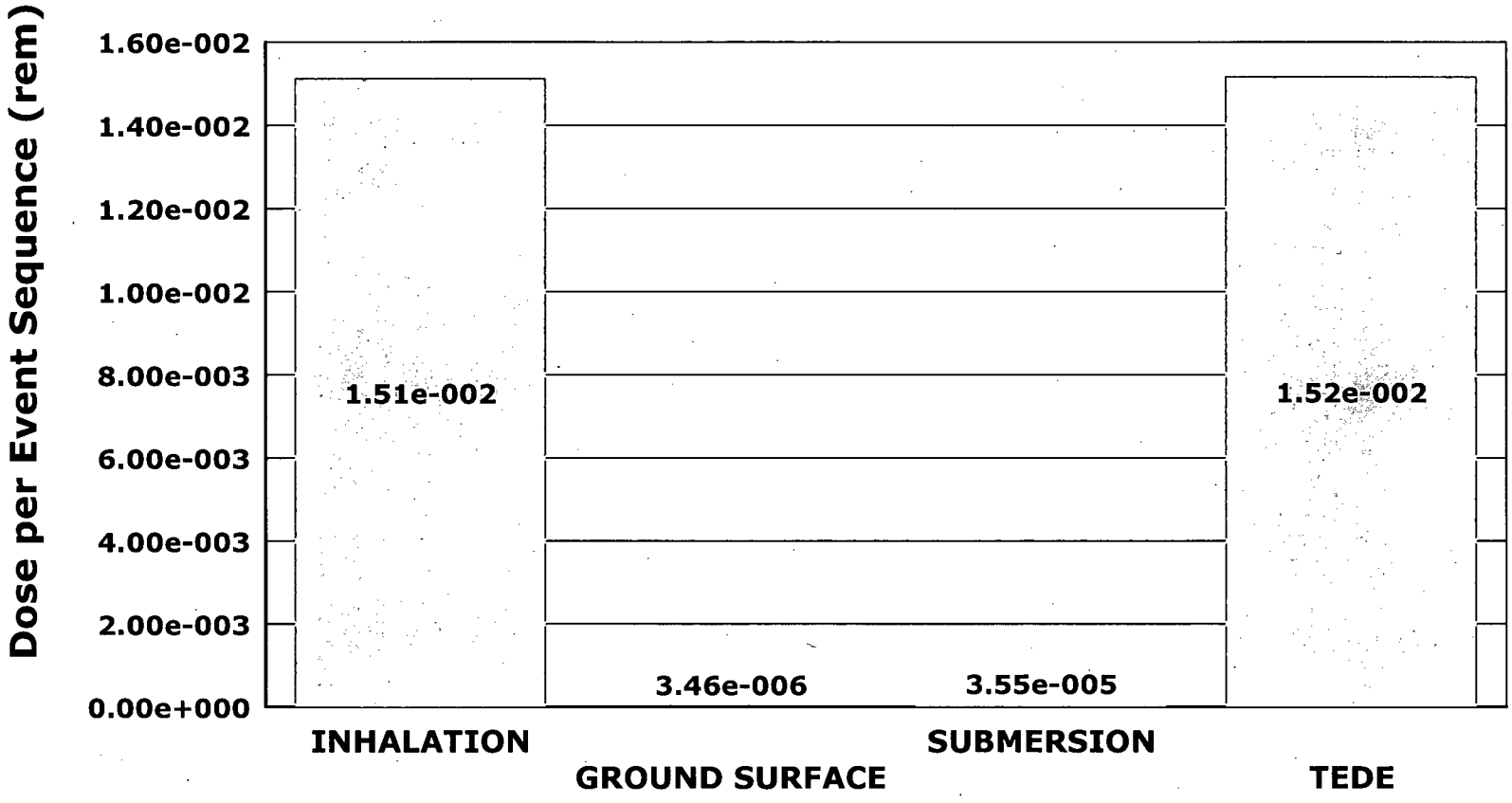
RADIOLOGICAL SAFETY ANALYSIS COMPUTER PROGRAM (RSAC-6)
(RSAC-6, REV 6.2, 03/11/02) SERIAL 1 DATE 20040720 TIME 17:13 PAGE 4
: Dose Calcs for inhalation, NOT ingestion, ground surface, & submersi

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/cu m)
1.000E+02	9.000E+01	4.011E+00	2.372E+00	0.000E+00
2.000E+02	9.000E+01	7.642E+00	4.011E+00	0.000E+00
5.000E+02	9.000E+01	1.826E+01	7.918E+00	6.509E-32
1.000E+03	9.000E+01	3.531E+01	1.290E+01	6.243E-15
2.000E+03	9.000E+01	6.764E+01	2.029E+01	4.121E-09
5.000E+03	9.000E+01	1.561E+02	3.442E+01	6.472E-07
1.000E+04	9.000E+01	2.876E+02	4.818E+01	1.338E-06
2.000E+04	9.000E+01	5.202E+02	6.333E+01	1.173E-06

*** FRACTION OF PLUME REMAINING AIRBORNE FOLLOWING DEPLETION BY DEPOSITION

24 0.00E+00 0.00E+00 2.94E-32 2.83E-15 1.87E-09 2.94E-07 6.07E-07 5.31E-07

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

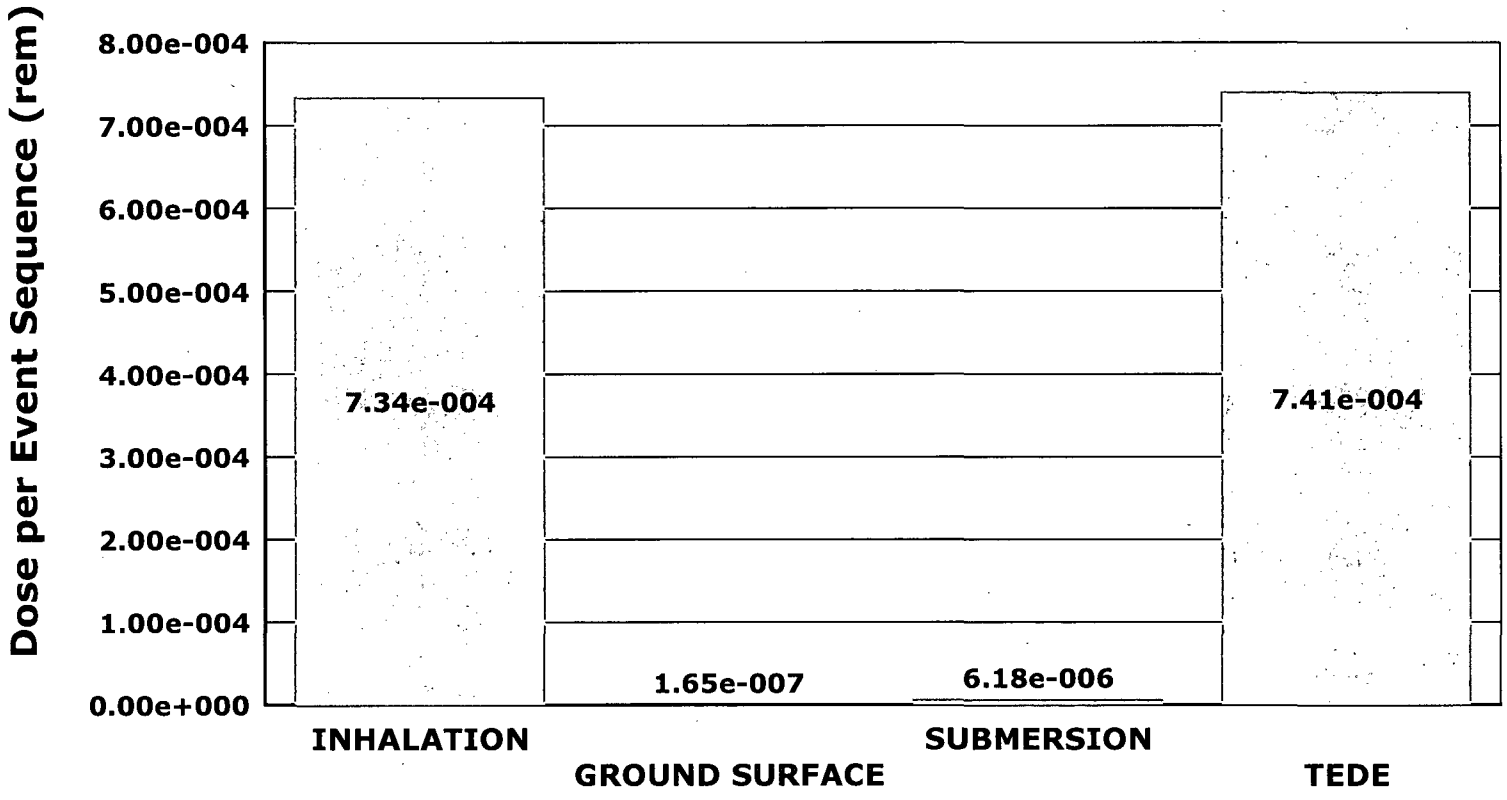
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02
GROUND SURFACE	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06	3.46E-06
SUBMERSION	3.55E-05	3.55E-05	3.55E-05	3.55E-05	3.55E-05	3.55E-05
TEDE	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

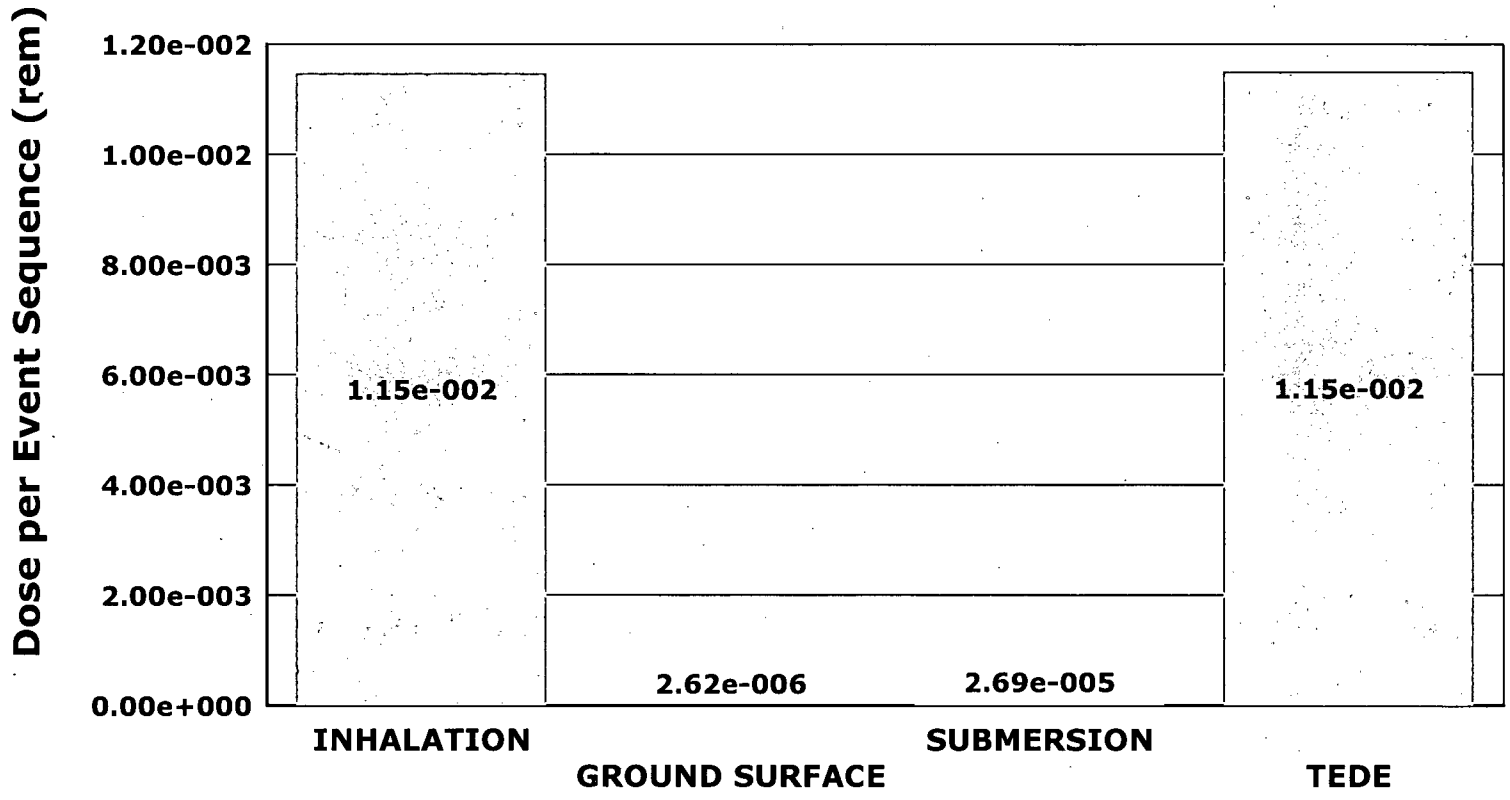
Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	*75.00*		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	7.34E-04	7.34E-04	7.34E-04	7.34E-04	7.34E-04	7.34E-04
GROUND SURFACE	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07	1.65E-07
SUBMERSION	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06	6.18E-06
TEDE	7.41E-04	7.41E-04	7.41E-04	7.41E-04	7.41E-04	7.41E-04

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

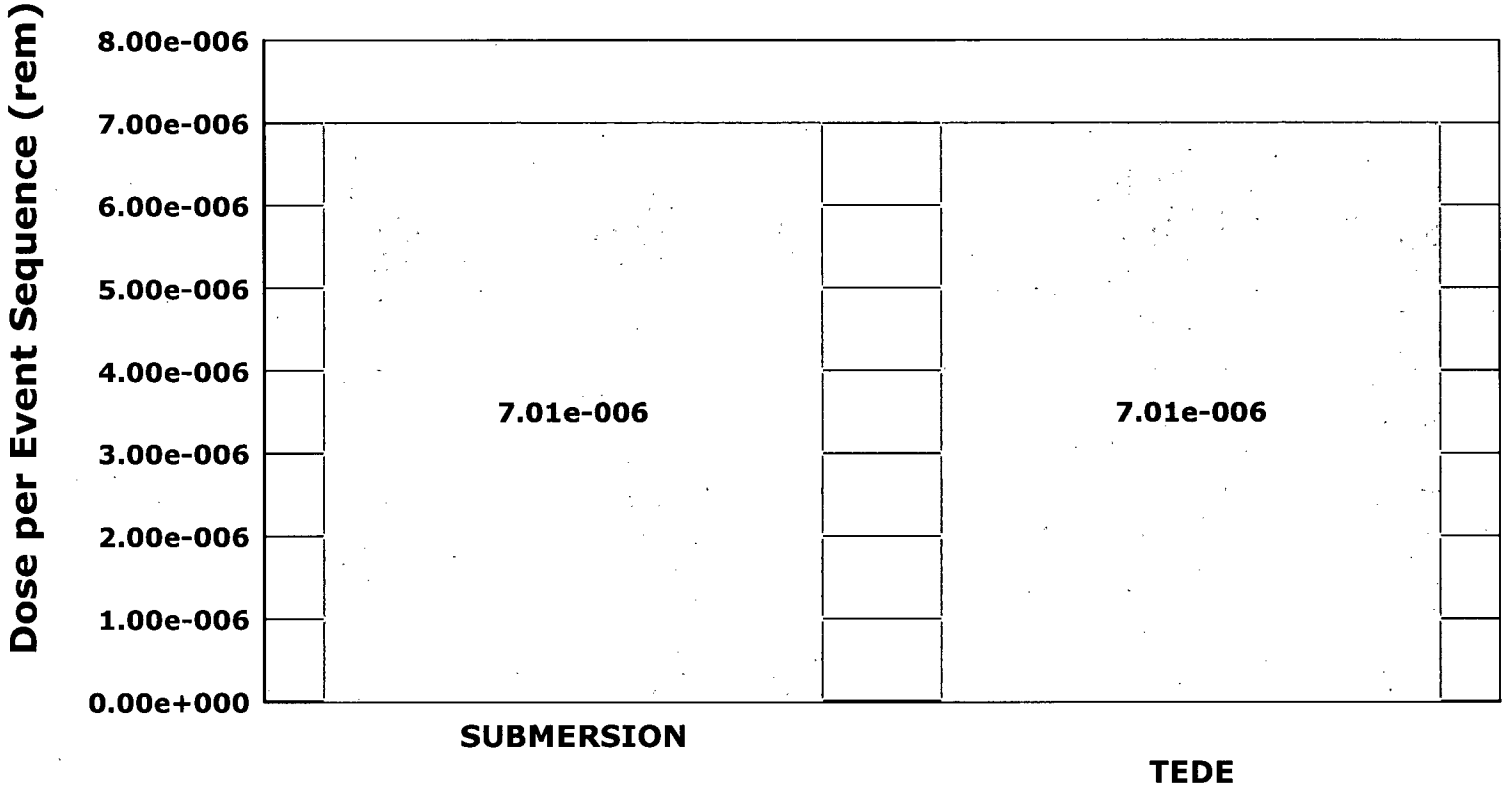
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06
SUBMERSION	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

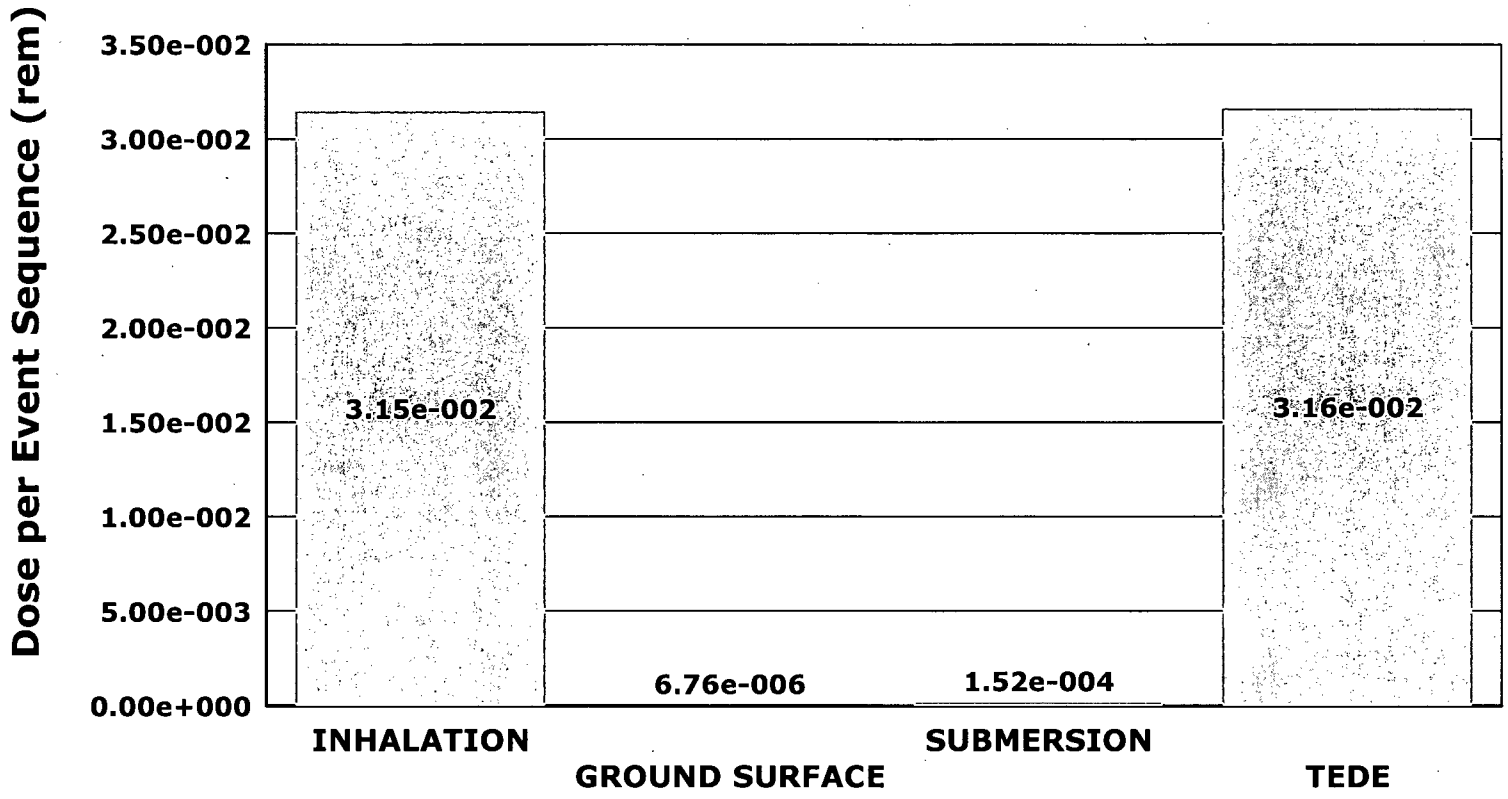
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
SUBMERSION	7.01E-06	7.01E-06	7.01E-06	7.01E-06	7.01E-06	7.01E-06
TEDE	7.01E-06	7.01E-06	7.01E-06	7.01E-06	7.01E-06	7.01E-06

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

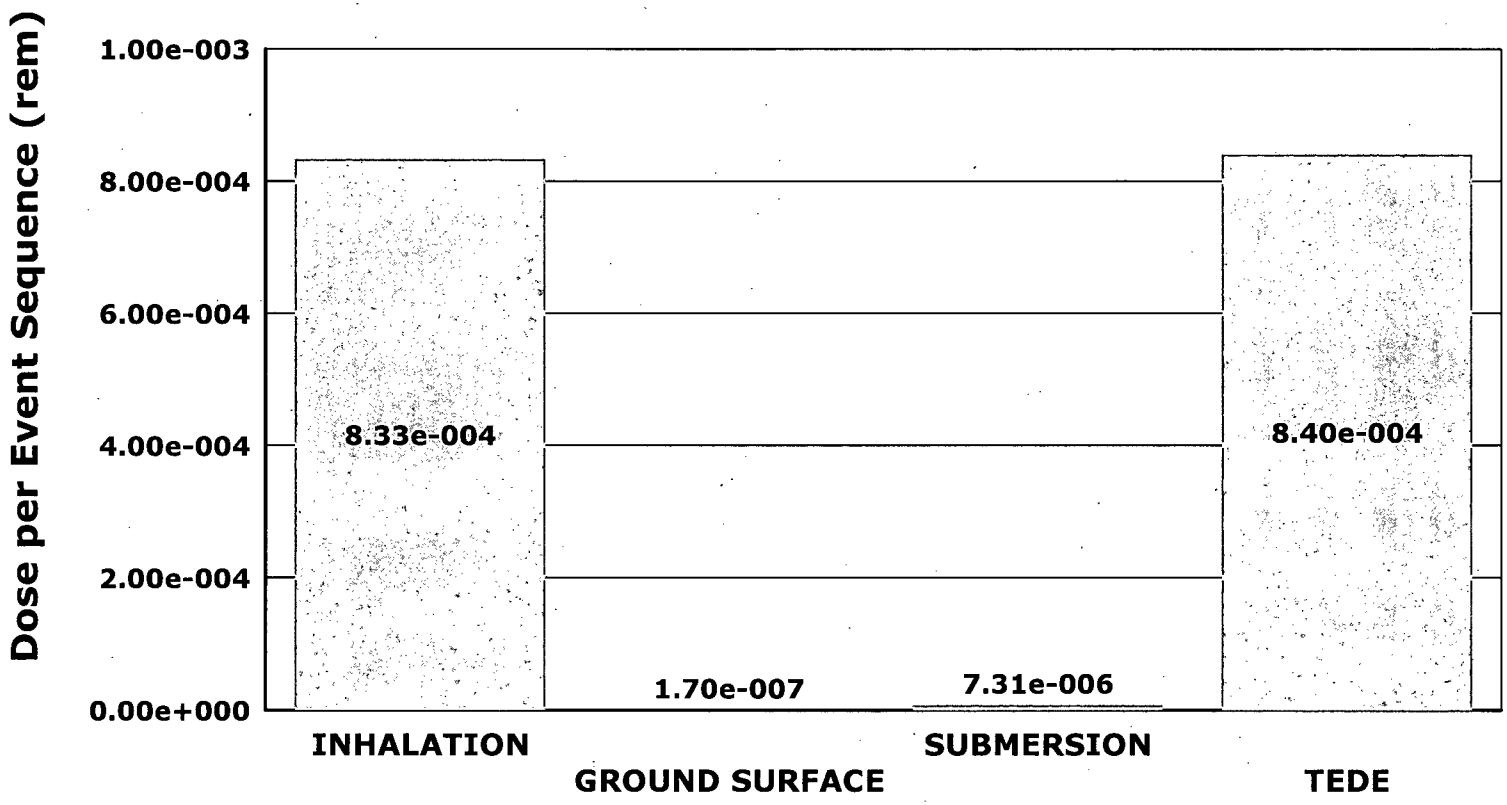
Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02
GROUND SURFACE	6.76E-06	6.76E-06	6.76E-06	6.76E-06	6.76E-06	6.76E-06
SUBMERSION	1.52E-04	1.52E-04	1.52E-04	1.52E-04	1.52E-04	1.52E-04
TEDE	3.16E-02	3.16E-02	3.16E-02	3.16E-02	3.16E-02	3.16E-02

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

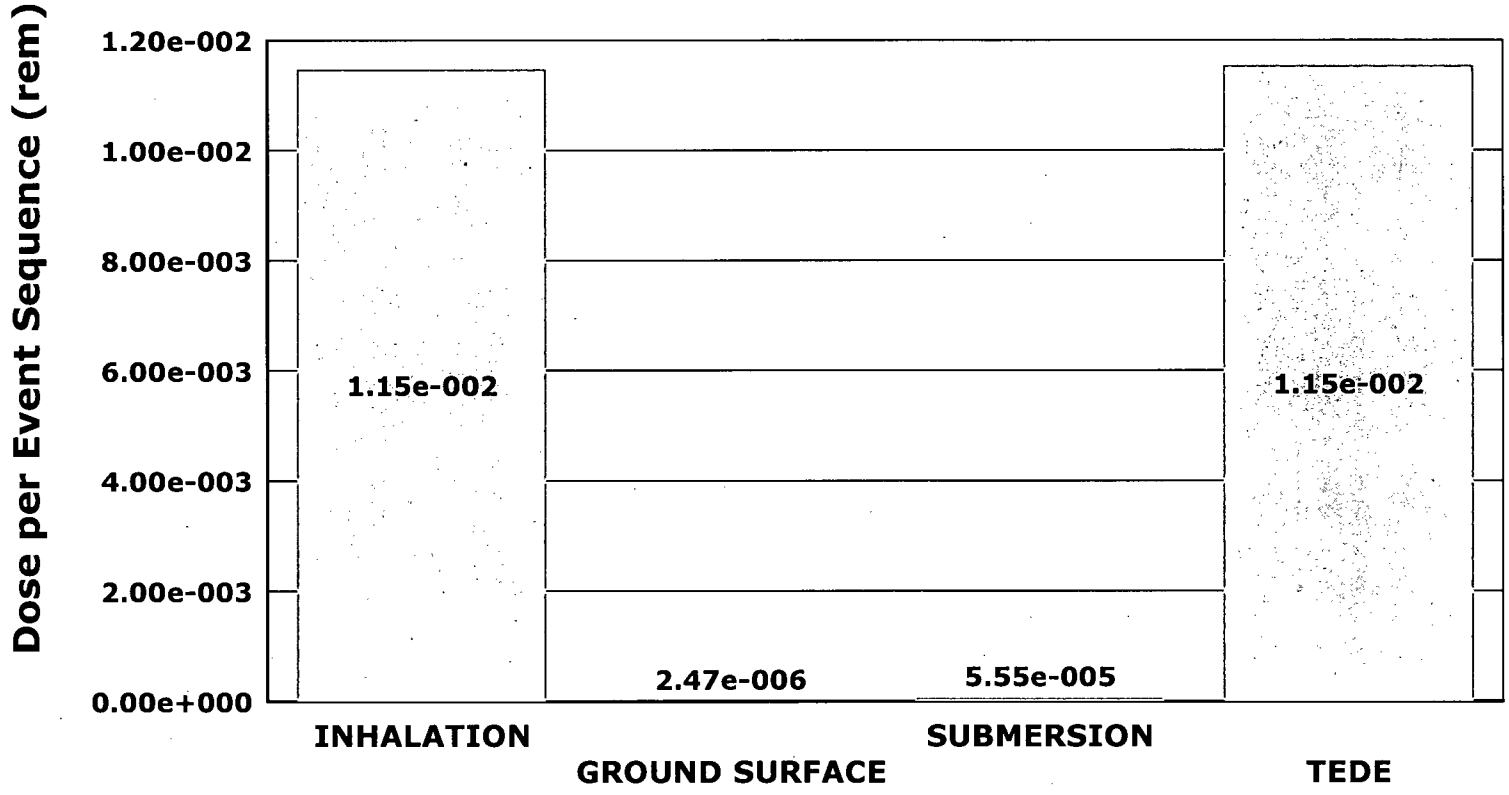
Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	8.33E-04	8.33E-04	8.33E-04	8.33E-04	8.33E-04	8.33E-04
GROUND SURFACE	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07	1.70E-07
SUBMERSION	7.31E-06	7.31E-06	7.31E-06	7.31E-06	7.31E-06	7.31E-06
TEDE	8.40E-04	8.40E-04	8.40E-04	8.40E-04	8.40E-04	8.40E-04

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

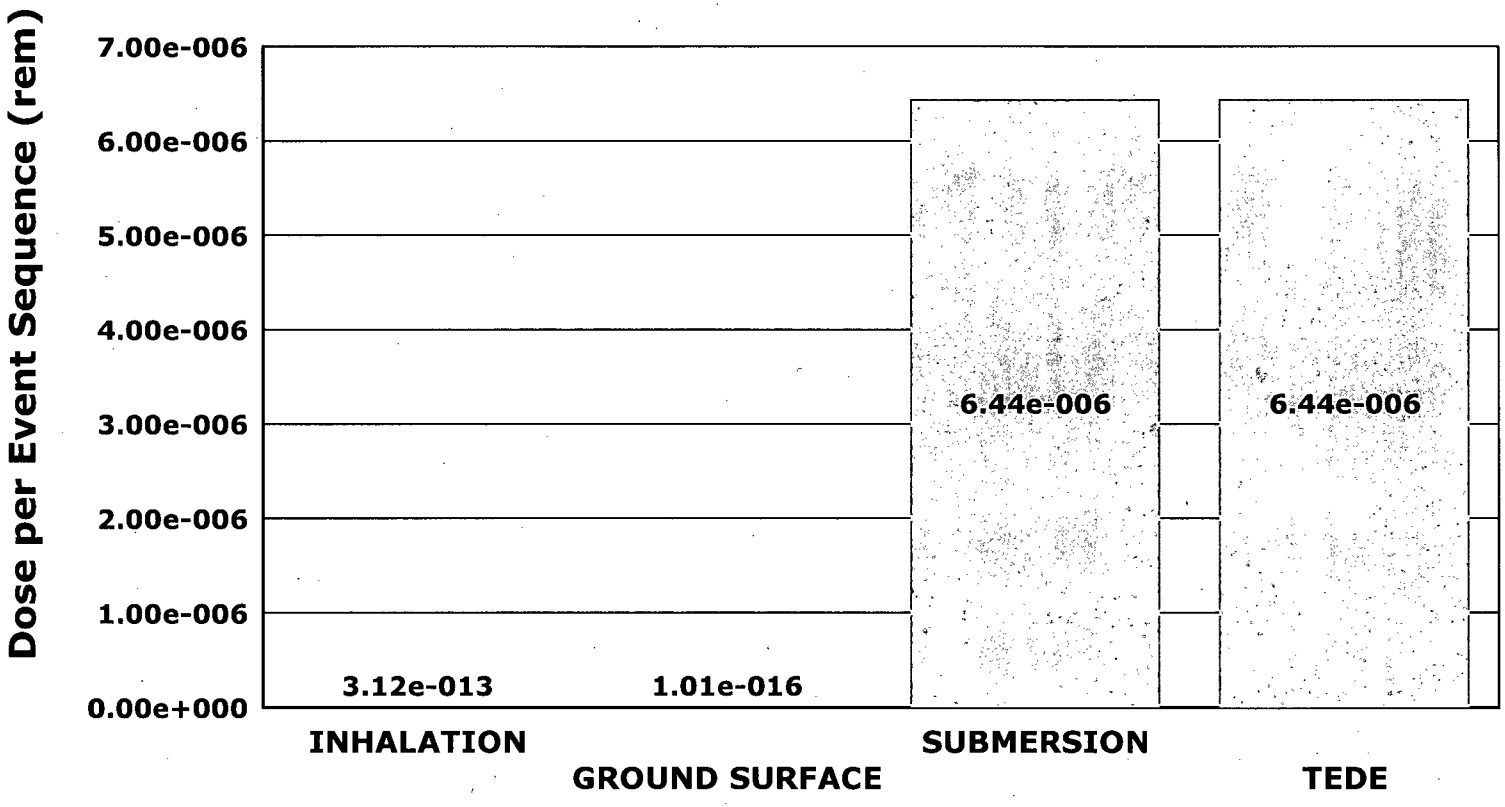
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06
SUBMERSION	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

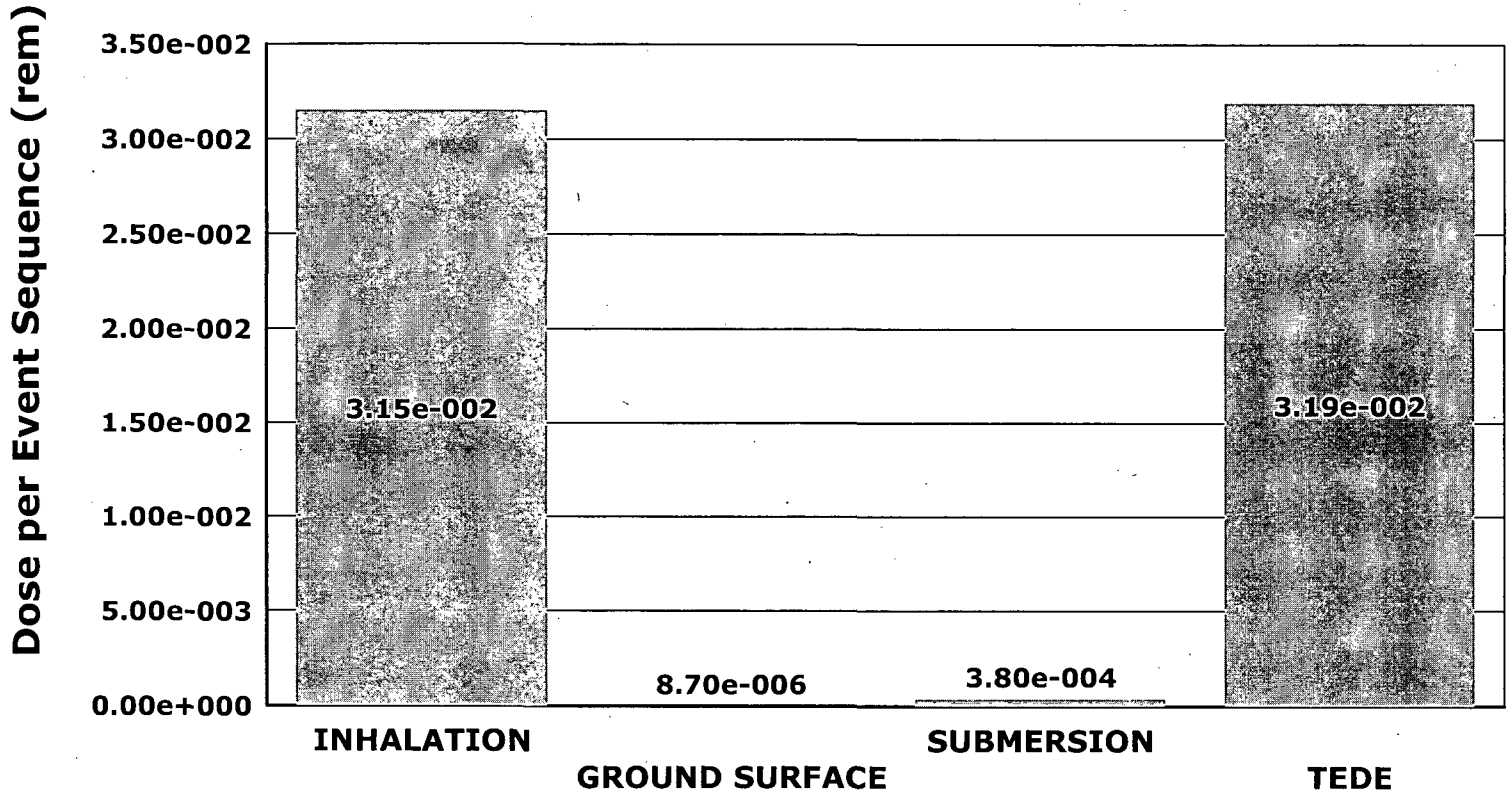
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.12E-13	3.12E-13	3.12E-13	3.12E-13	3.12E-13	3.12E-13
GROUND SURFACE	1.01E-16	1.01E-16	1.01E-16	1.01E-16	1.01E-16	1.01E-16
SUBMERSION	6.44E-06	6.44E-06	6.44E-06	6.44E-06	6.44E-06	6.44E-06
TEDE	6.44E-06	6.44E-06	6.44E-06	6.44E-06	6.44E-06	6.44E-06

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

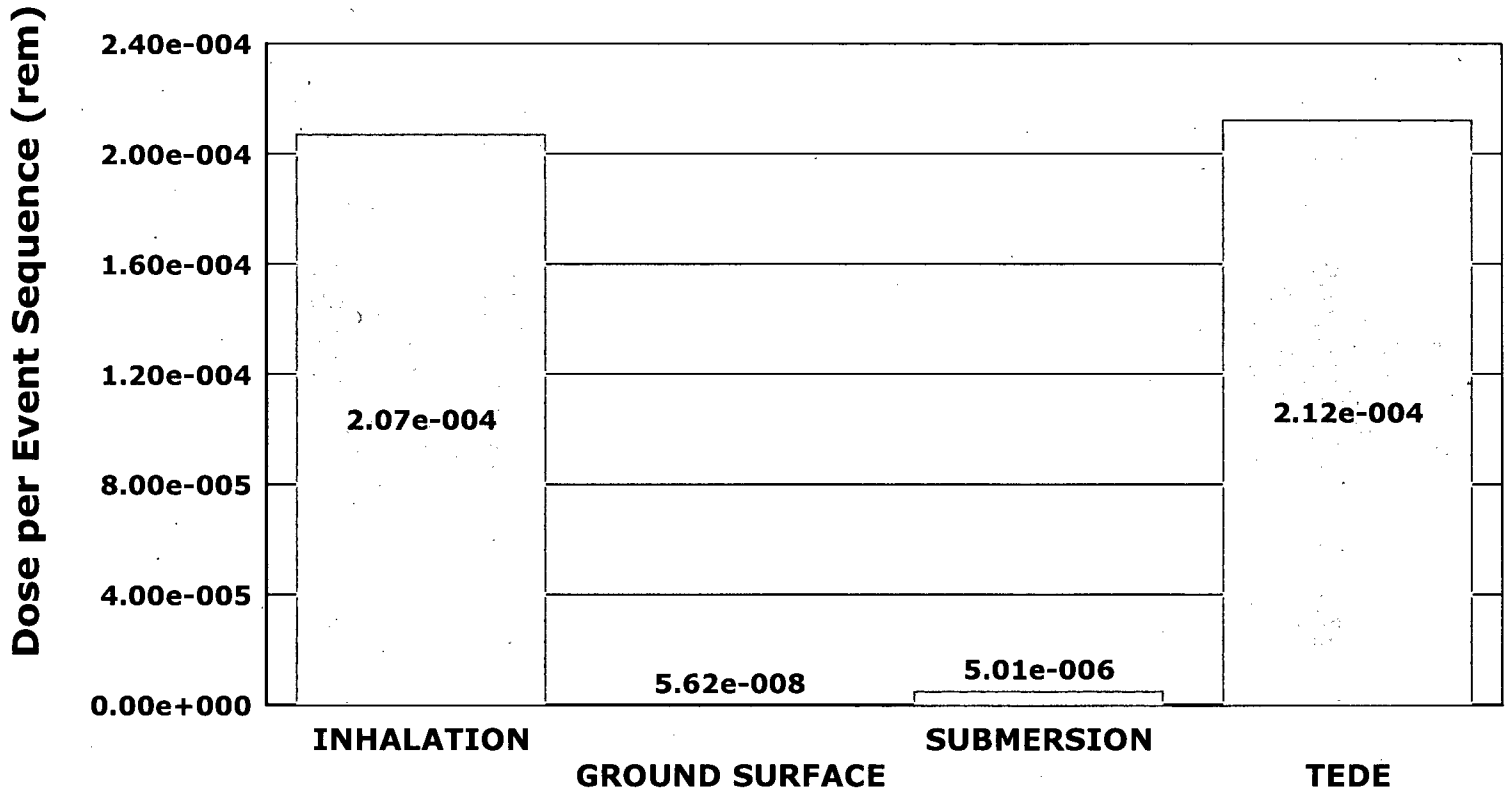
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02
GROUND SURFACE	8.70E-06	8.70E-06	8.70E-06	8.70E-06	8.70E-06	8.70E-06
SUBMERSION	3.80E-04	3.80E-04	3.80E-04	3.80E-04	3.80E-04	3.80E-04
TEDE	3.19E-02	3.19E-02	3.19E-02	3.19E-02	3.19E-02	3.19E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

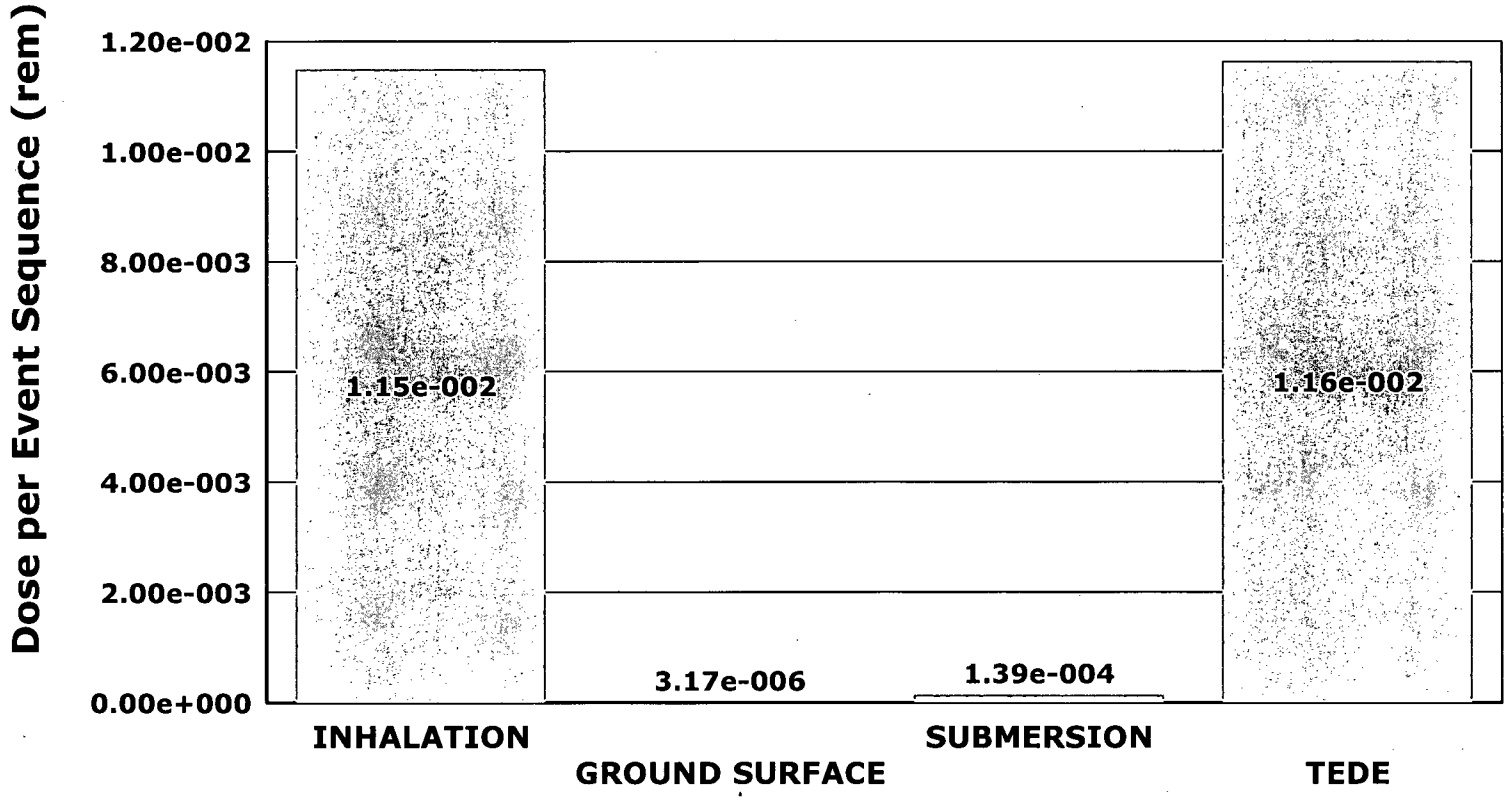
Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04	2.07E-04
GROUND SURFACE	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08	5.62E-08
SUBMERSION	5.01E-06	5.01E-06	5.01E-06	5.01E-06	5.01E-06	5.01E-06
TEDE	2.12E-04	2.12E-04	2.12E-04	2.12E-04	2.12E-04	2.12E-04

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

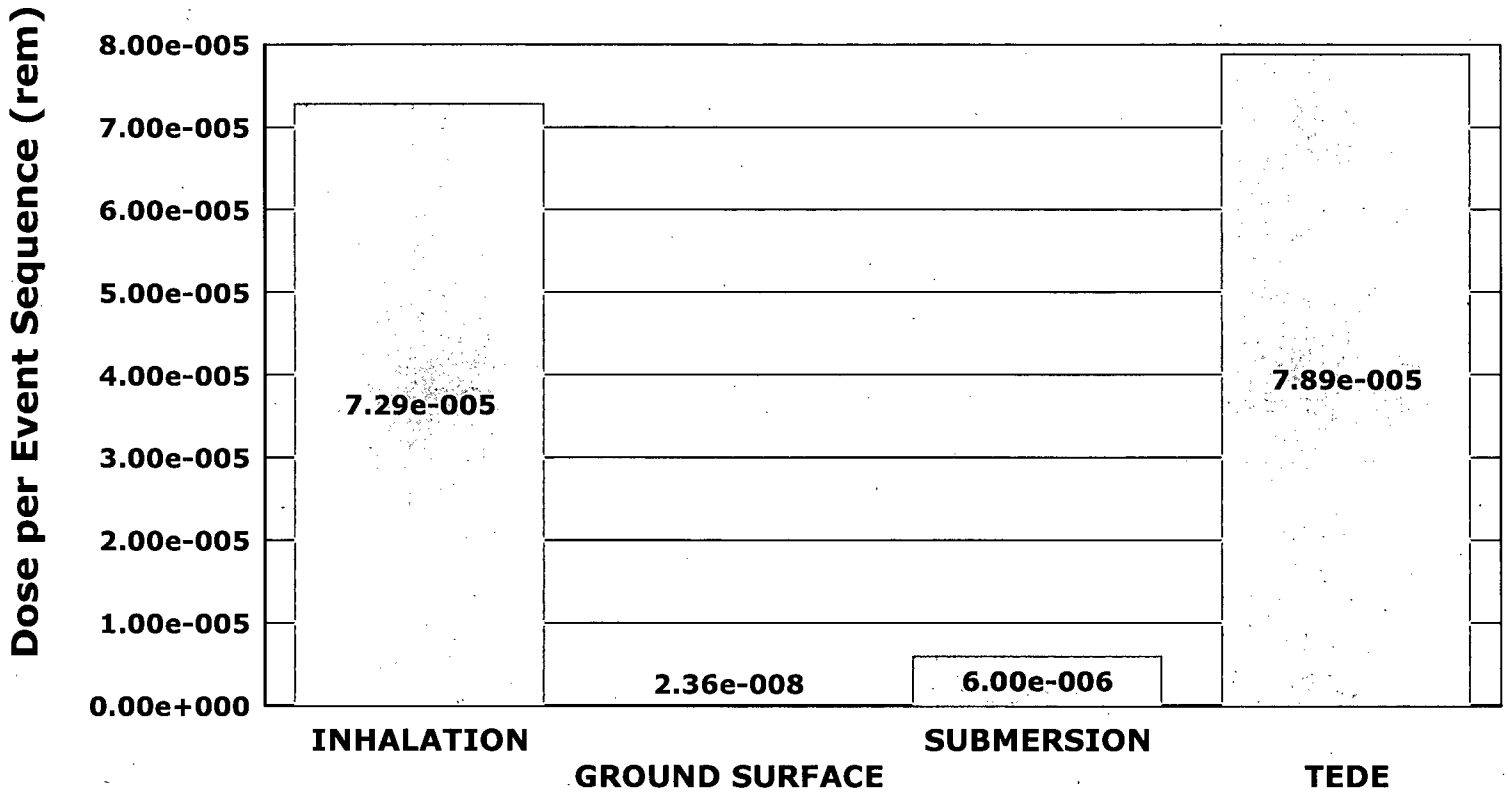
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06
SUBMERSION	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04
TEDE	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

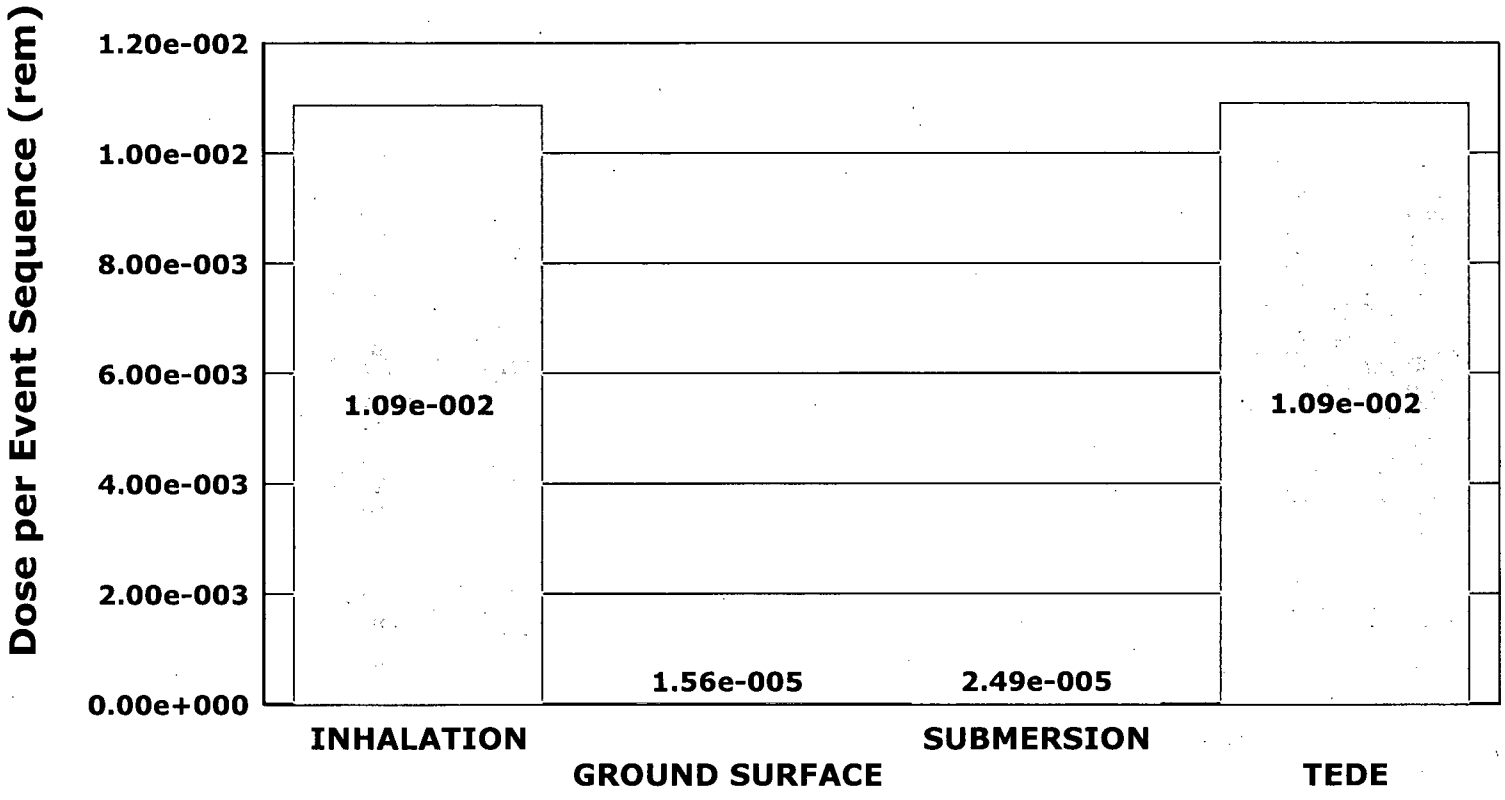
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05	7.29E-05
GROUND SURFACE	2.36E-08	2.36E-08	2.36E-08	2.36E-08	2.36E-08	2.36E-08
SUBMERSION	6.00E-06	6.00E-06	6.00E-06	6.00E-06	6.00E-06	6.00E-06
TEDE	7.89E-05	7.89E-05	7.89E-05	7.89E-05	7.89E-05	7.89E-05

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

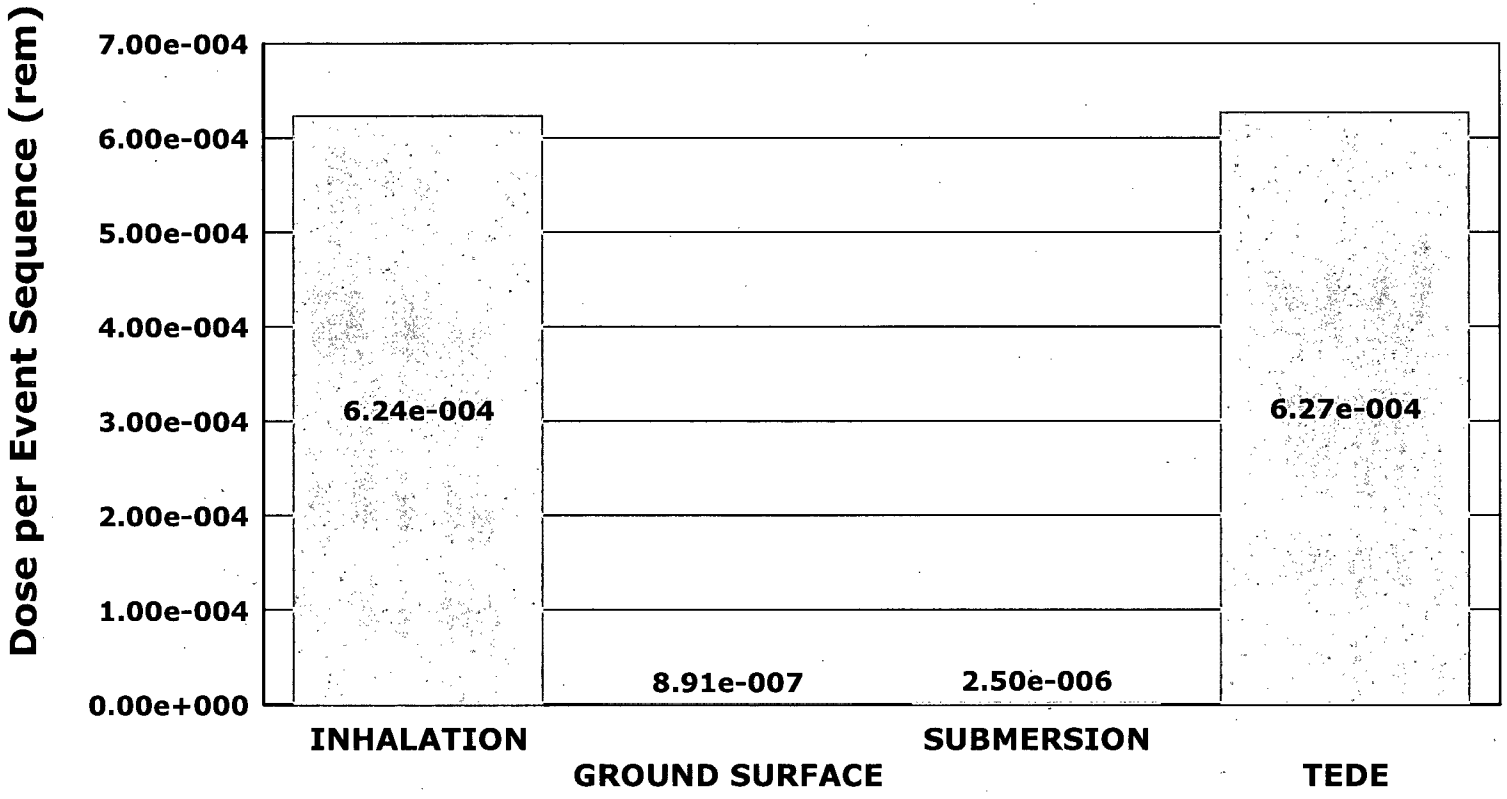
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02
GROUND SURFACE	1.56E-05	1.56E-05	1.56E-05	1.56E-05	1.56E-05	1.56E-05
SUBMERSION	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05	2.49E-05
TEDE	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

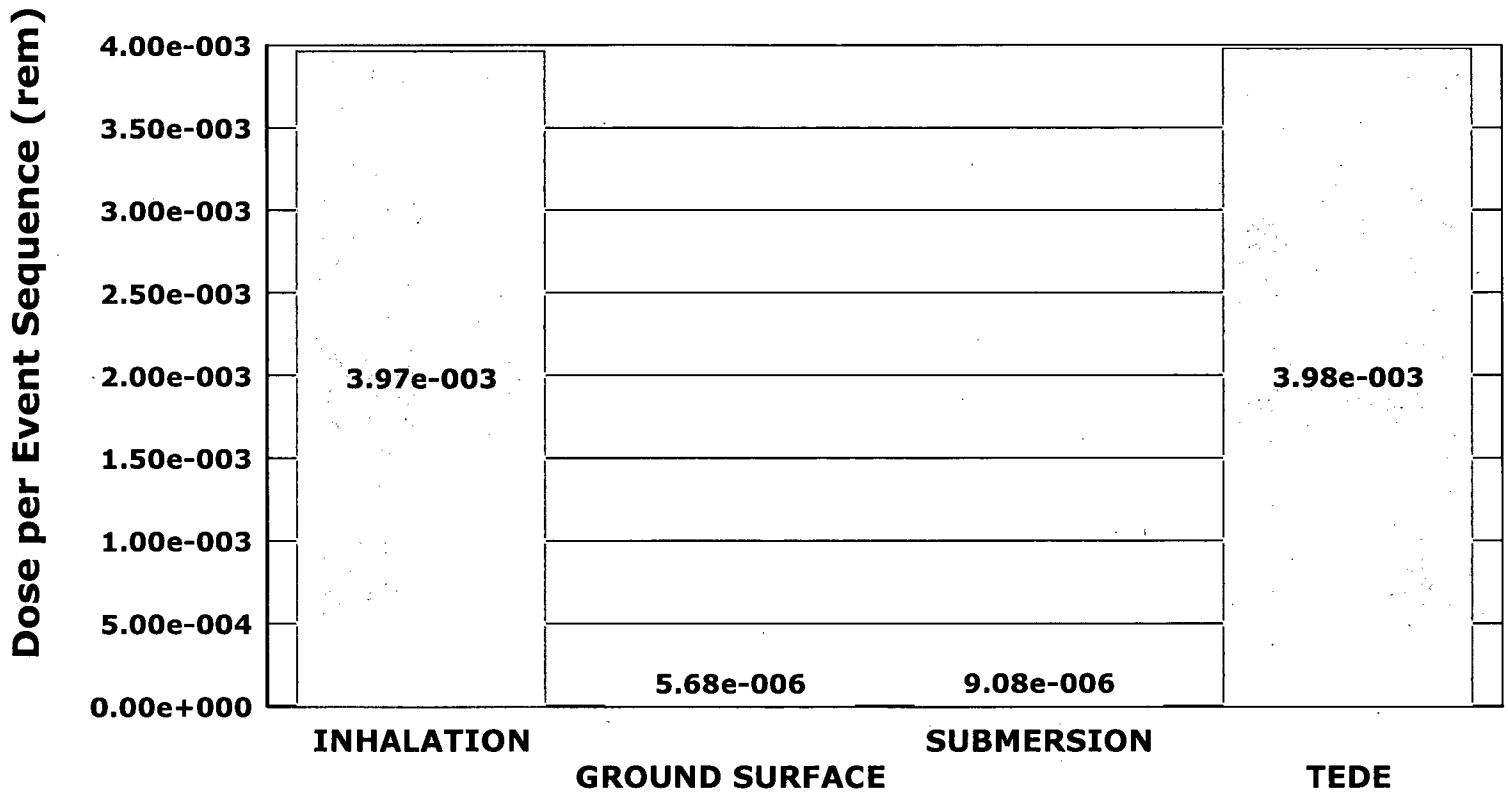
Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	6.24E-04	6.24E-04	6.24E-04	6.24E-04	6.24E-04	6.24E-04
GROUND SURFACE	8.91E-07	8.91E-07	8.91E-07	8.91E-07	8.91E-07	8.91E-07
SUBMERSION	2.50E-06	2.50E-06	2.50E-06	2.50E-06	2.50E-06	2.50E-06
TEDE	6.27E-04	6.27E-04	6.27E-04	6.27E-04	6.27E-04	6.27E-04

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

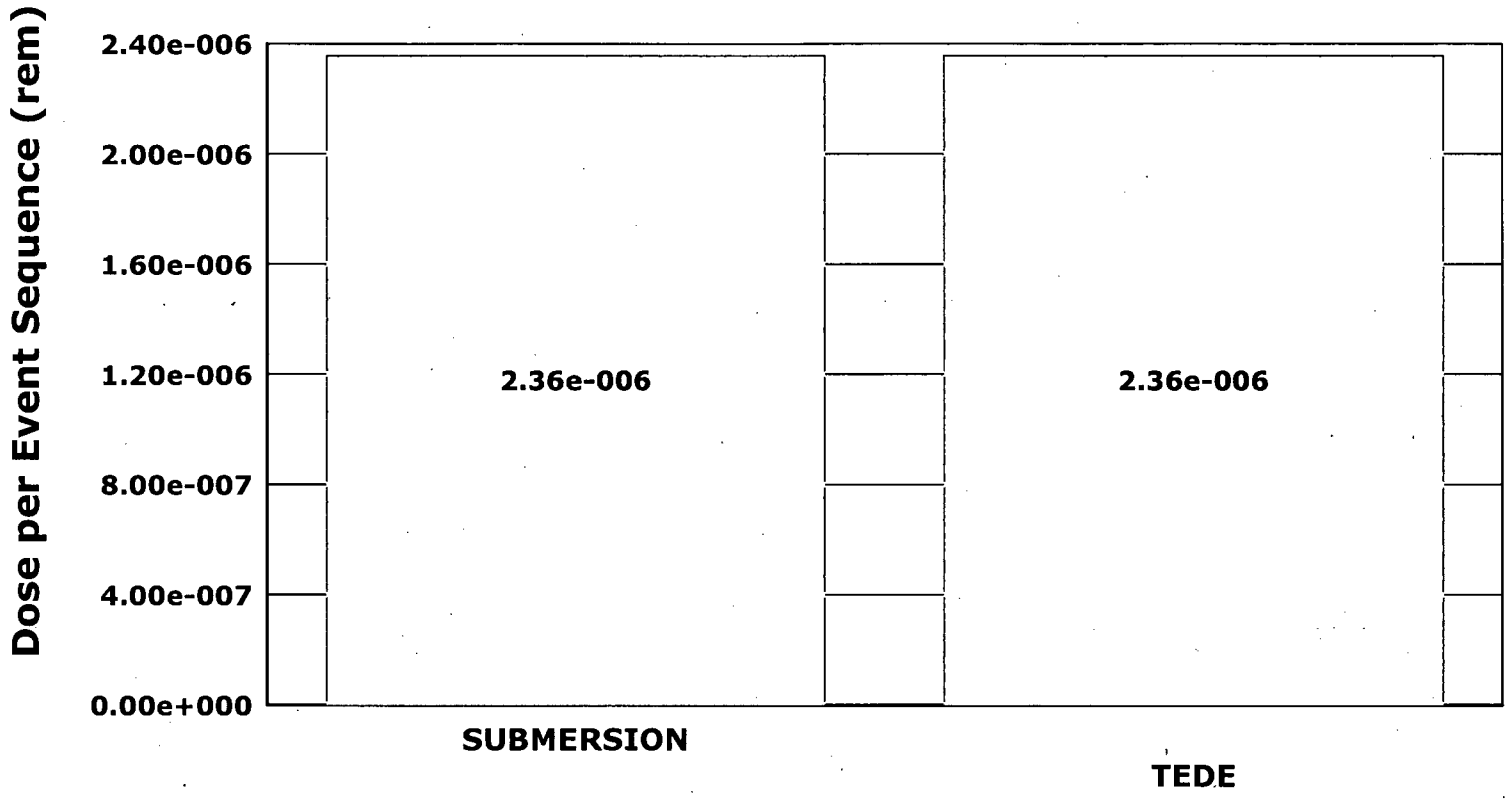
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06
SUBMERSION	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06
TEDE	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

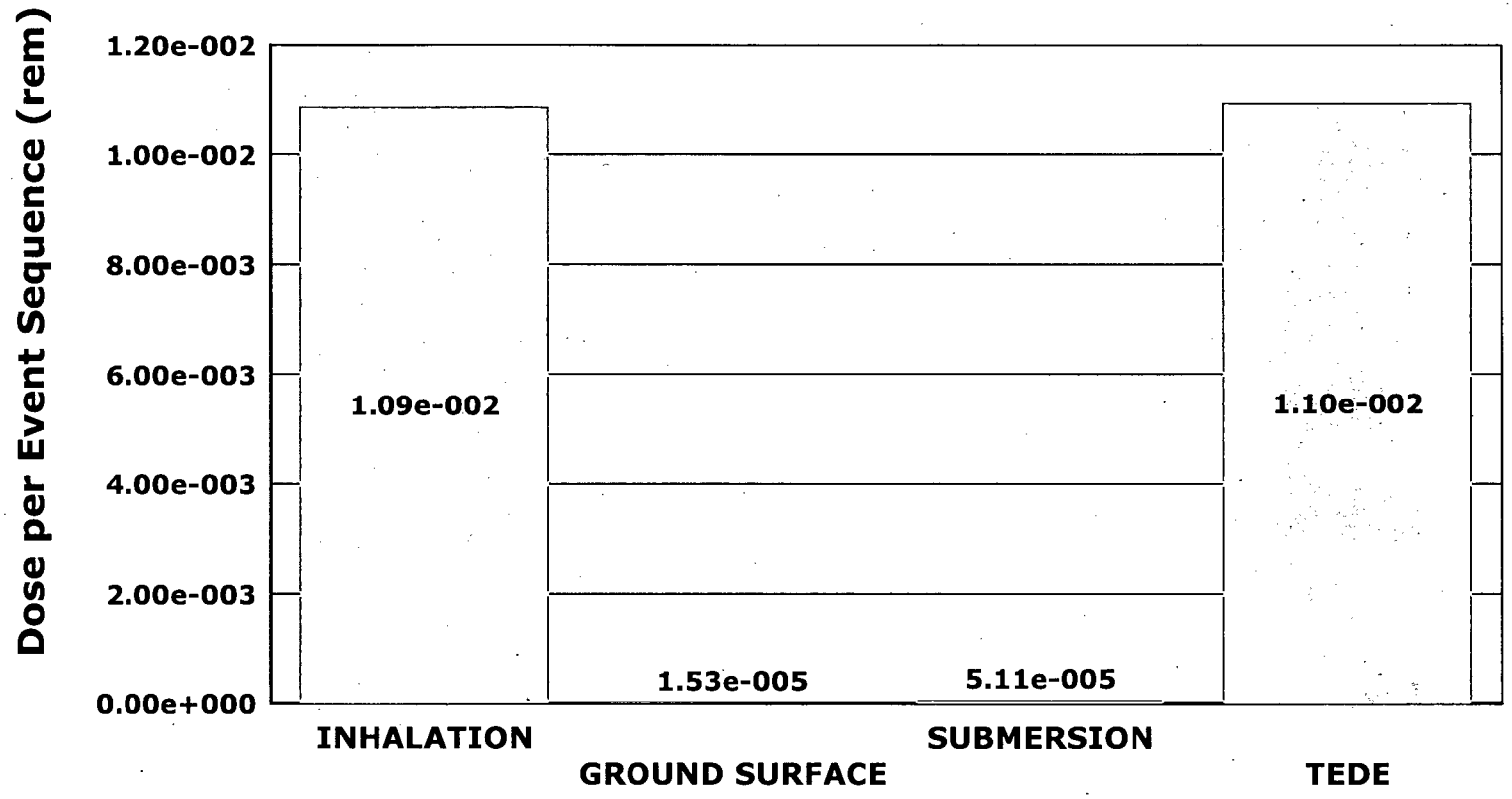
Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
SUBMERSION	2.36E-06	2.36E-06	2.36E-06	2.36E-06	2.36E-06	2.36E-06
TEDE	2.36E-06	2.36E-06	2.36E-06	2.36E-06	2.36E-06	2.36E-06

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

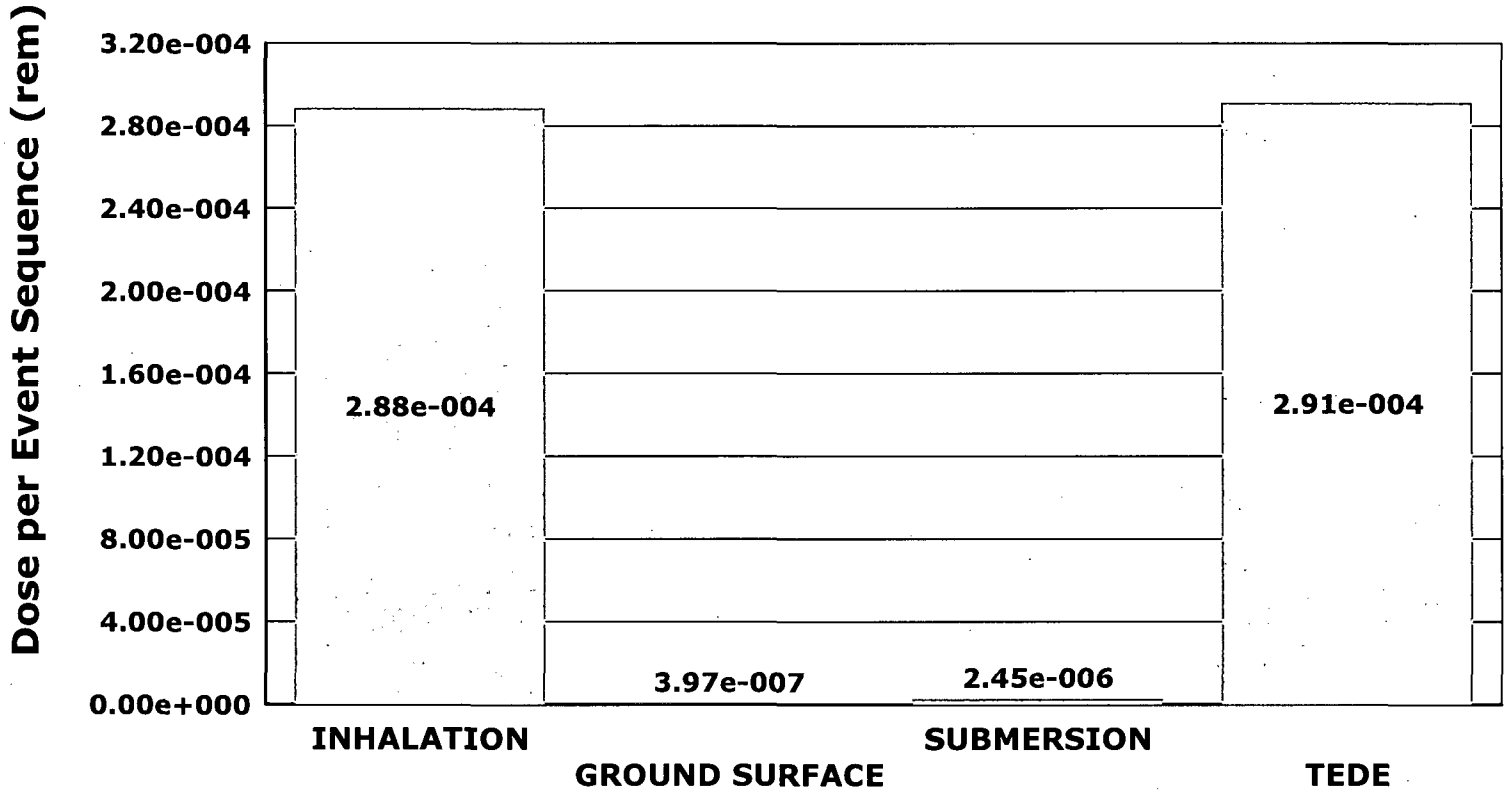
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02
GROUND SURFACE	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05	1.53E-05
SUBMERSION	5.11E-05	5.11E-05	5.11E-05	5.11E-05	5.11E-05	5.11E-05
TEDE	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02	1.10E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

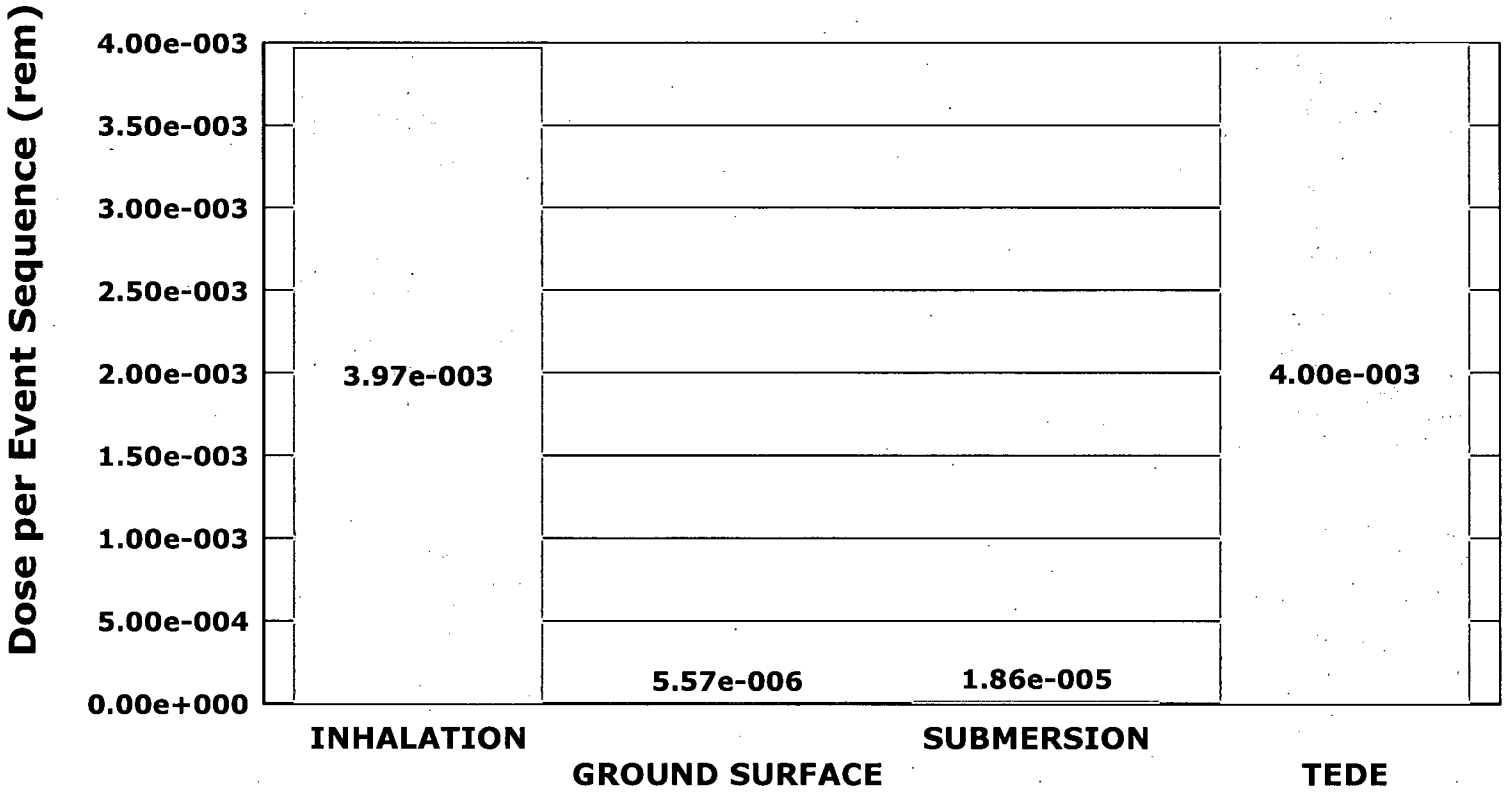
Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	2.88E-04	2.88E-04	2.88E-04	2.88E-04	2.88E-04	2.88E-04
GROUND SURFACE	3.97E-07	3.97E-07	3.97E-07	3.97E-07	3.97E-07	3.97E-07
SUBMERSION	2.45E-06	2.45E-06	2.45E-06	2.45E-06	2.45E-06	2.45E-06
TEDE	2.91E-04	2.91E-04	2.91E-04	2.91E-04	2.91E-04	2.91E-04

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

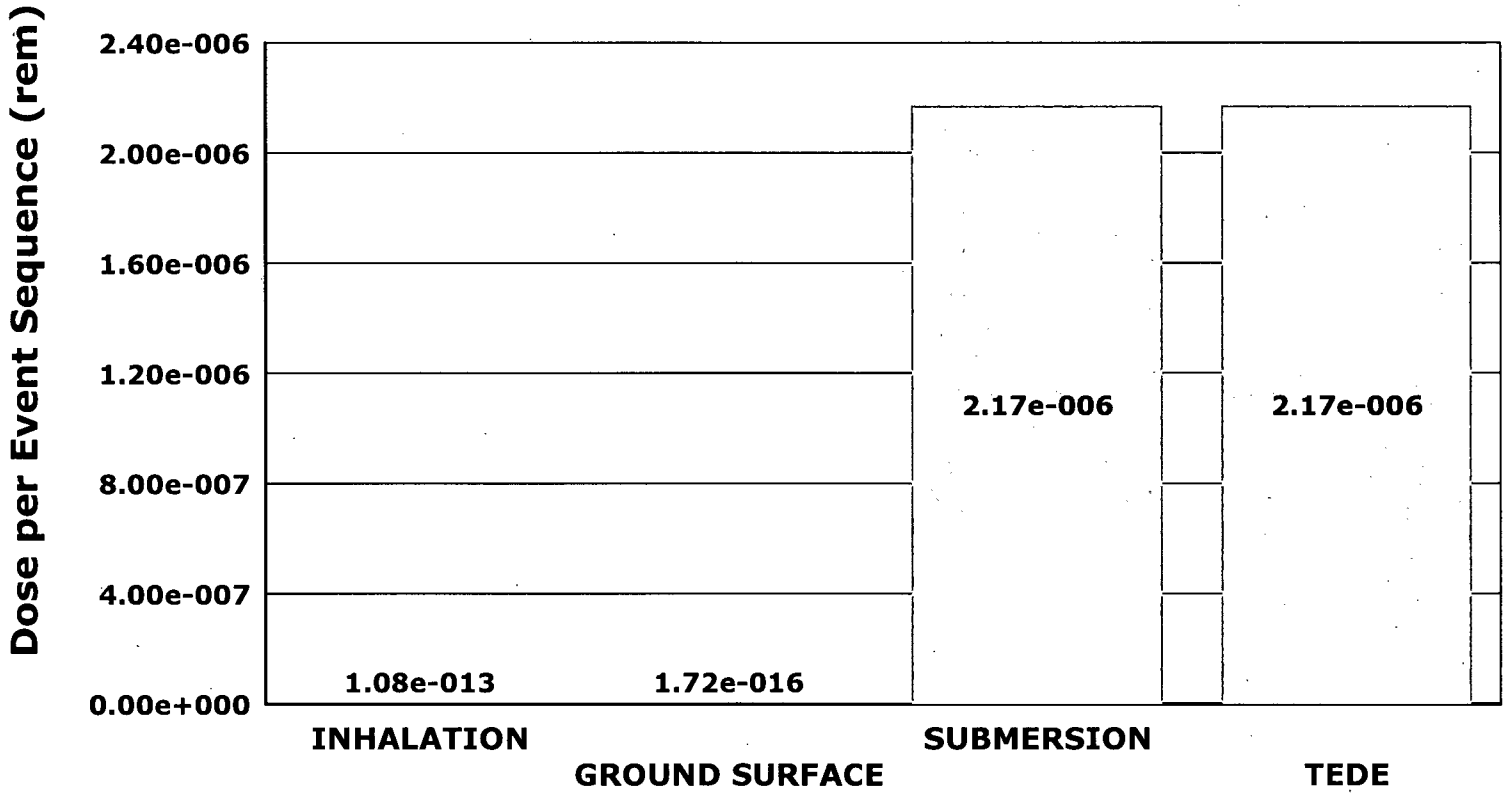
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06
SUBMERSION	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05
TEDE	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

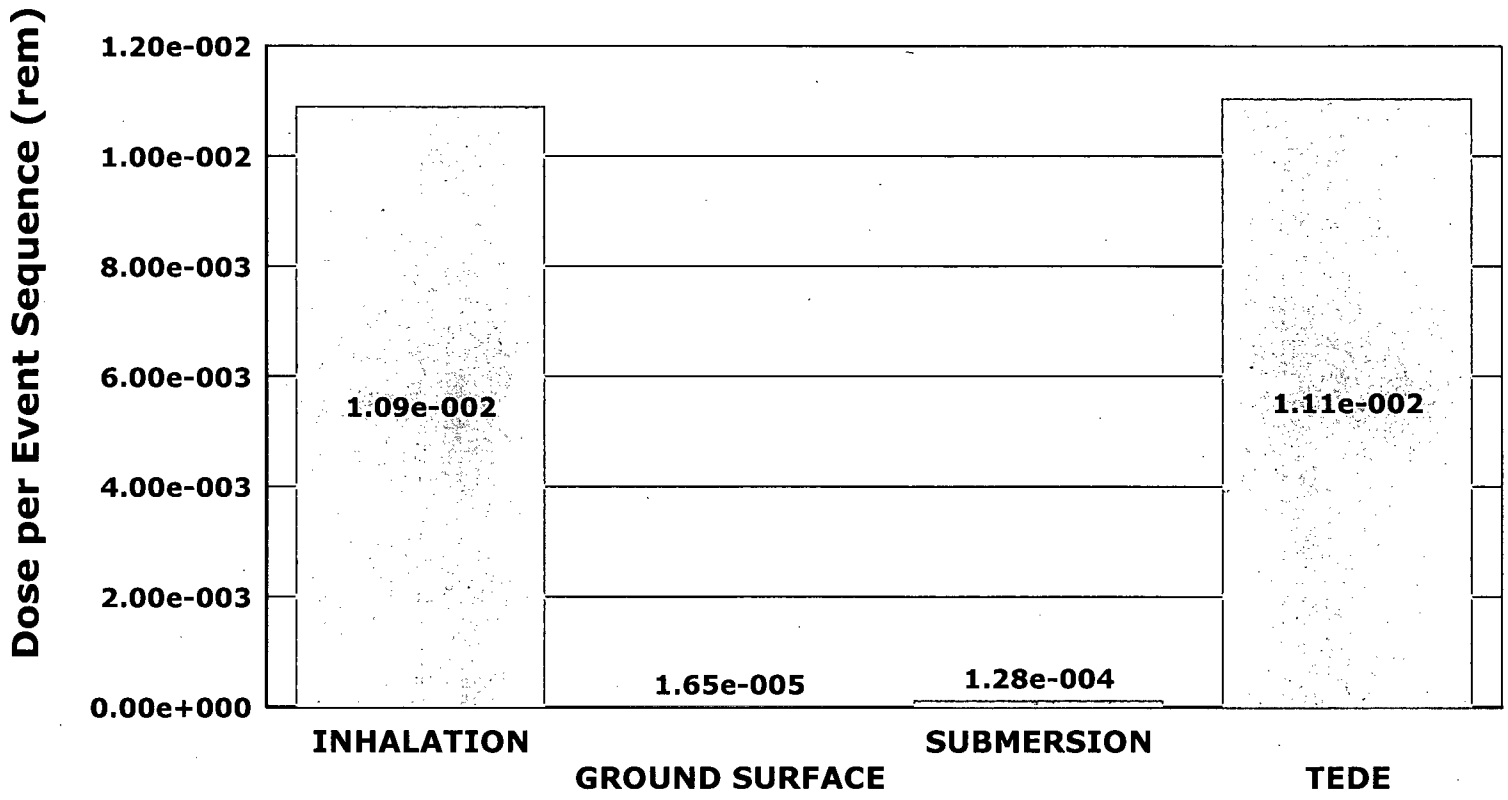
Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.08E-13	1.08E-13	1.08E-13	1.08E-13	1.08E-13	1.08E-13
GROUND SURFACE	1.72E-16	1.72E-16	1.72E-16	1.72E-16	1.72E-16	1.72E-16
SUBMERSION	2.17E-06	2.17E-06	2.17E-06	2.17E-06	2.17E-06	2.17E-06
TEDE	2.17E-06	2.17E-06	2.17E-06	2.17E-06	2.17E-06	2.17E-06

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

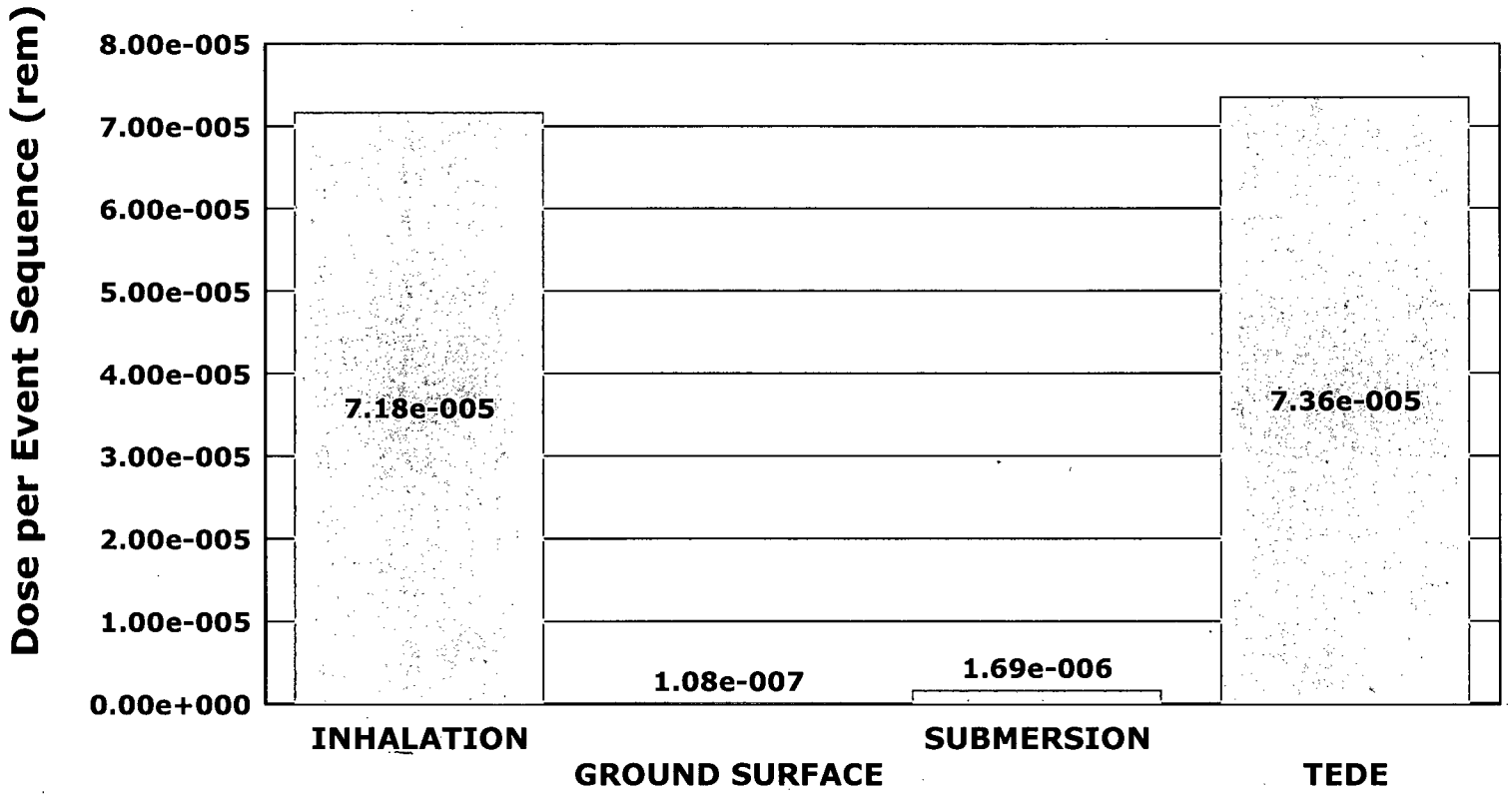
Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02	1.09E-02
GROUND SURFACE	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05	1.65E-05
SUBMERSION	1.28E-04	1.28E-04	1.28E-04	1.28E-04	1.28E-04	1.28E-04
TEDE	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.11E-02	1.11E-02

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

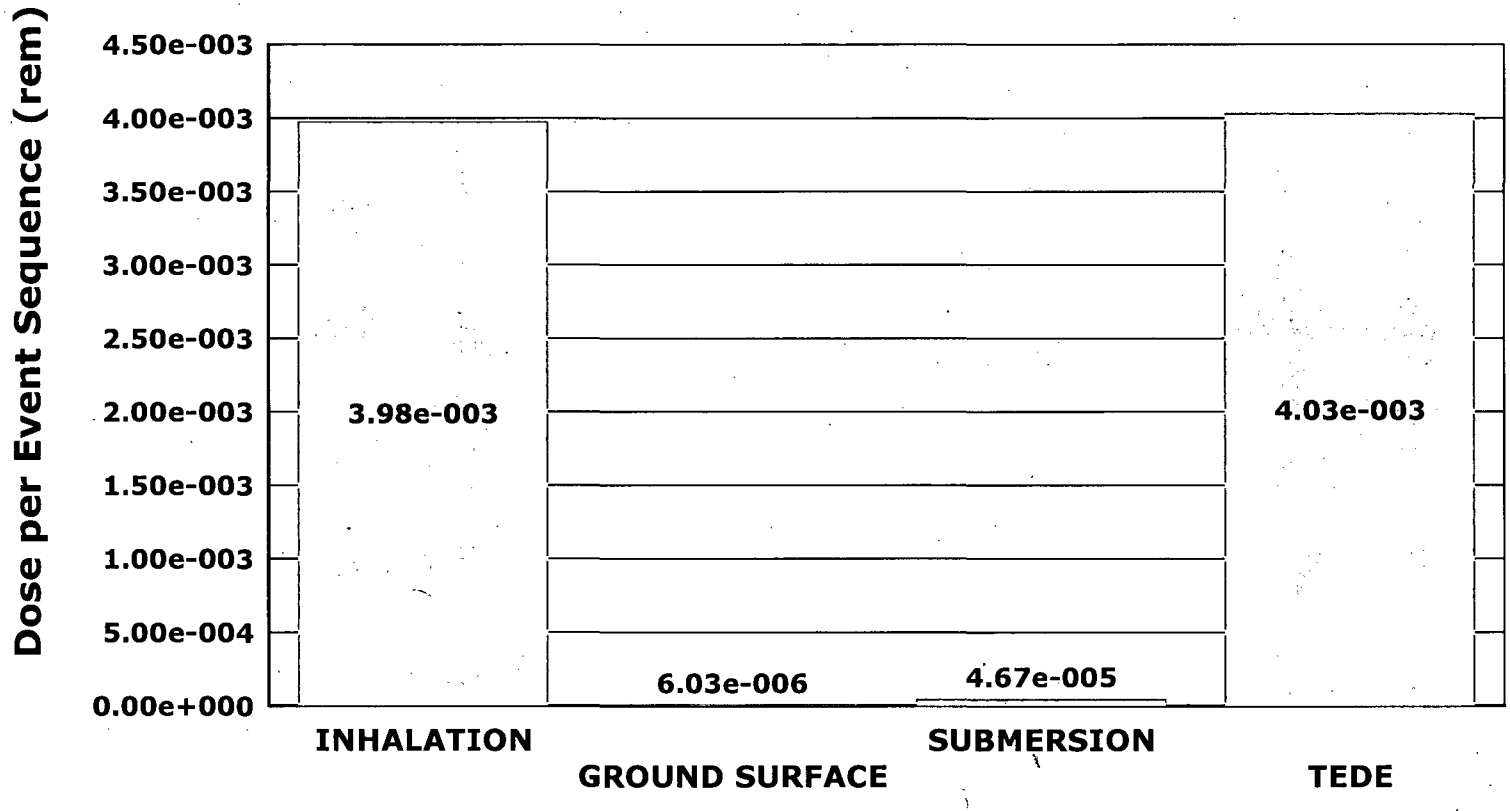
Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	7.18E-05	7.18E-05	7.18E-05	7.18E-05	7.18E-05	7.18E-05
GROUND SURFACE	1.08E-07	1.08E-07	1.08E-07	1.08E-07	1.08E-07	1.08E-07
SUBMERSION	1.69E-06	1.69E-06	1.69E-06	1.69E-06	1.69E-06	1.69E-06
TEDE	7.36E-05	7.36E-05	7.36E-05	7.36E-05	7.36E-05	7.36E-05

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

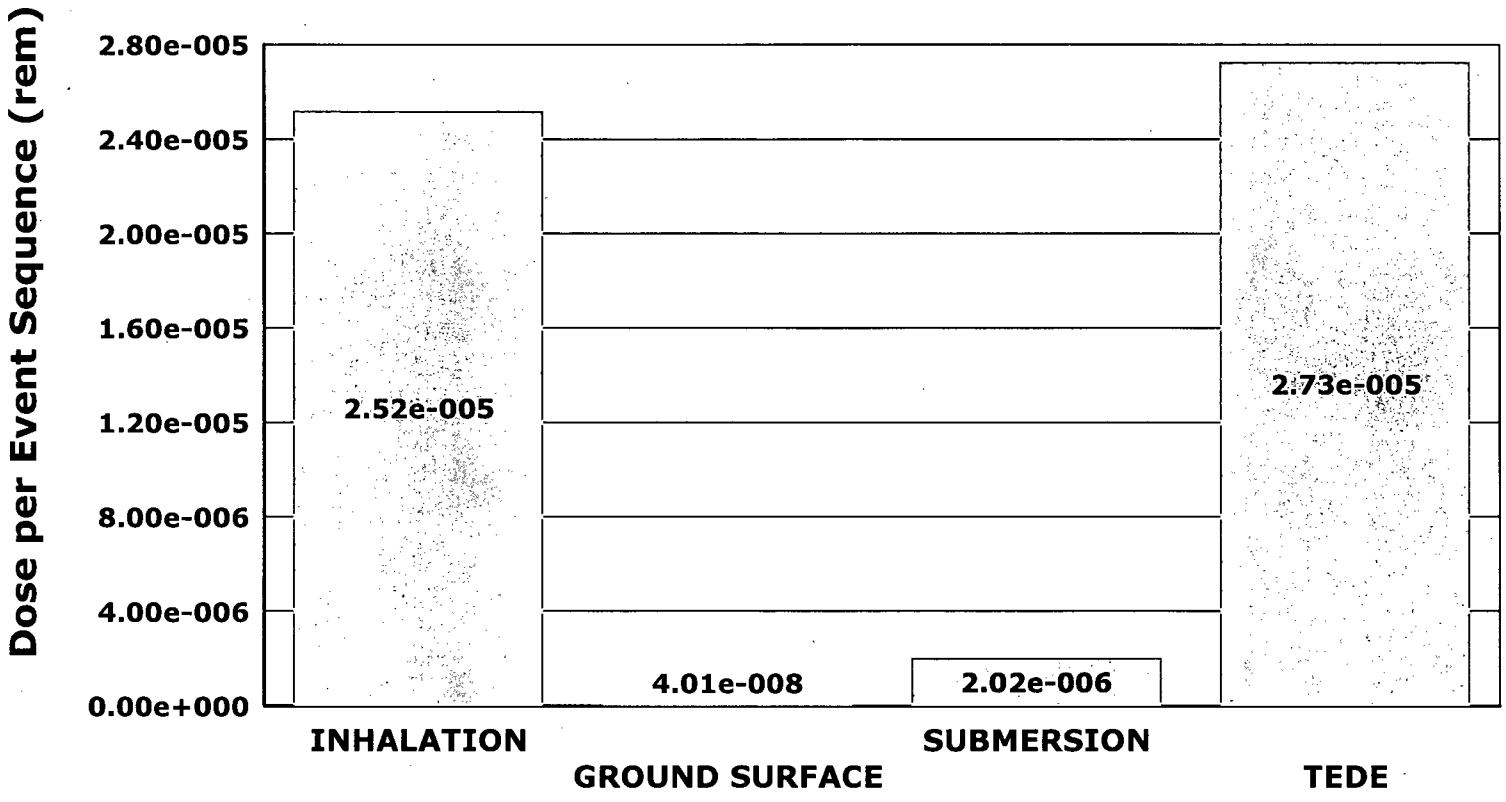
Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03
GROUND SURFACE	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06
SUBMERSION	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05
TEDE	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	13.00		

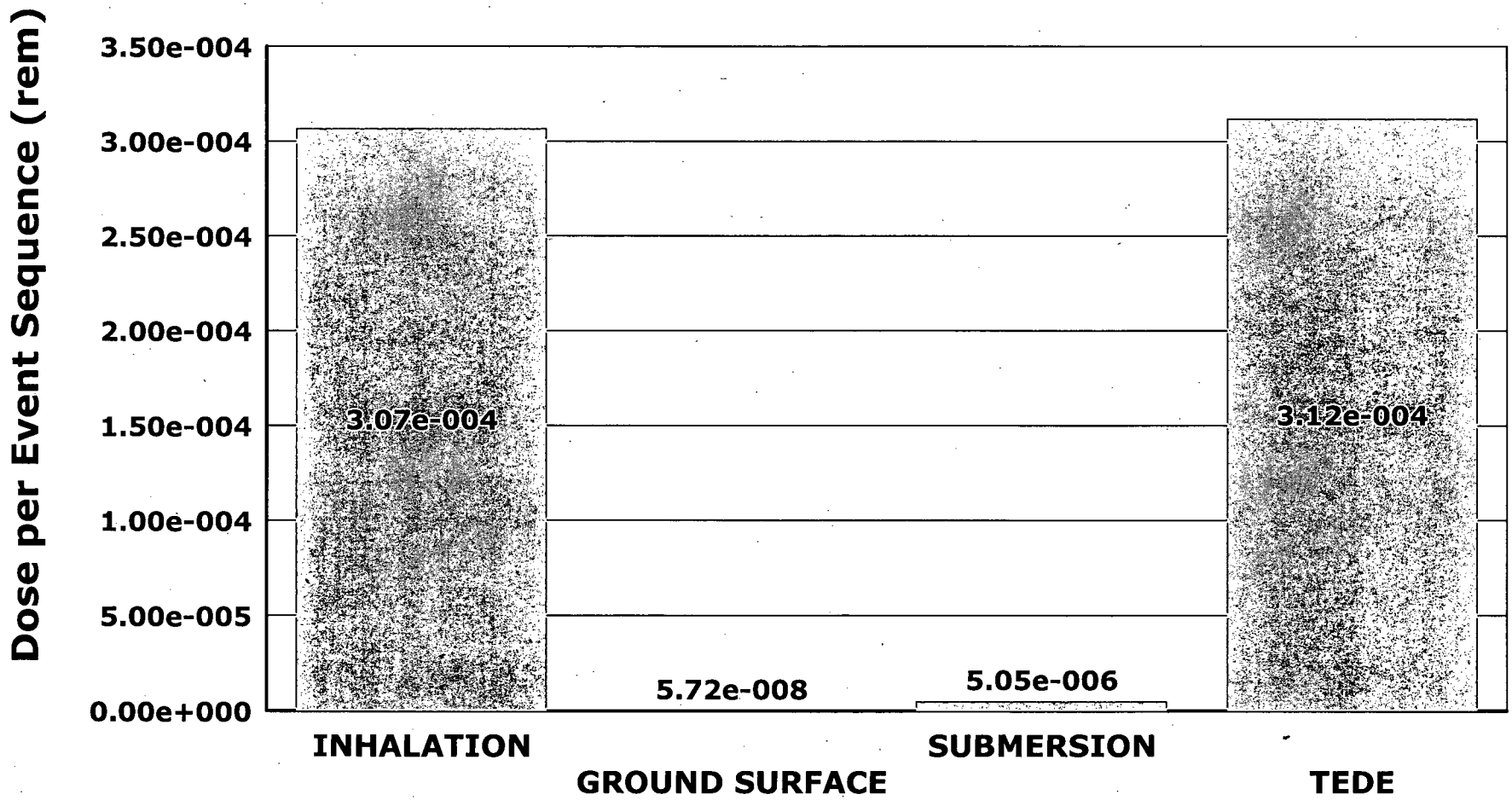
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	2.52E-05	2.52E-05	2.52E-05	2.52E-05	2.52E-05	2.52E-05
GROUND SURFACE	4.01E-08	4.01E-08	4.01E-08	4.01E-08	4.01E-08	4.01E-08
SUBMERSION	2.02E-06	2.02E-06	2.02E-06	2.02E-06	2.02E-06	2.02E-06
TEDE	2.73E-05	2.73E-05	2.73E-05	2.73E-05	2.73E-05	2.73E-05

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

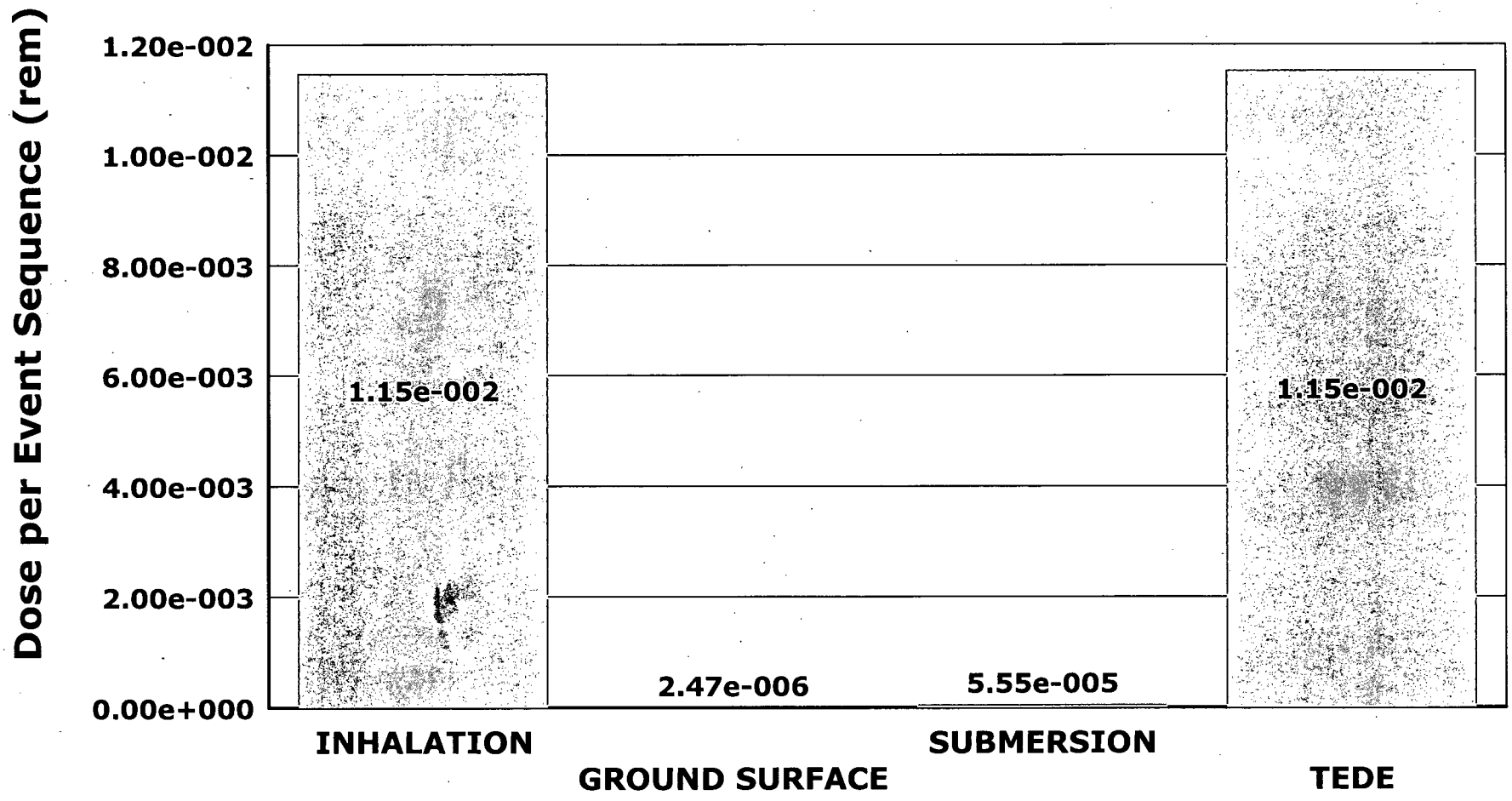
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.07E-04	3.07E-04	3.07E-04	3.07E-04	3.07E-04	3.07E-04
GROUND SURFACE	5.72E-08	5.72E-08	5.72E-08	5.72E-08	5.72E-08	5.72E-08
SUBMERSION	5.05E-06	5.05E-06	5.05E-06	5.05E-06	5.05E-06	5.05E-06
TEDE	3.12E-04	3.12E-04	3.12E-04	3.12E-04	3.12E-04	3.12E-04

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

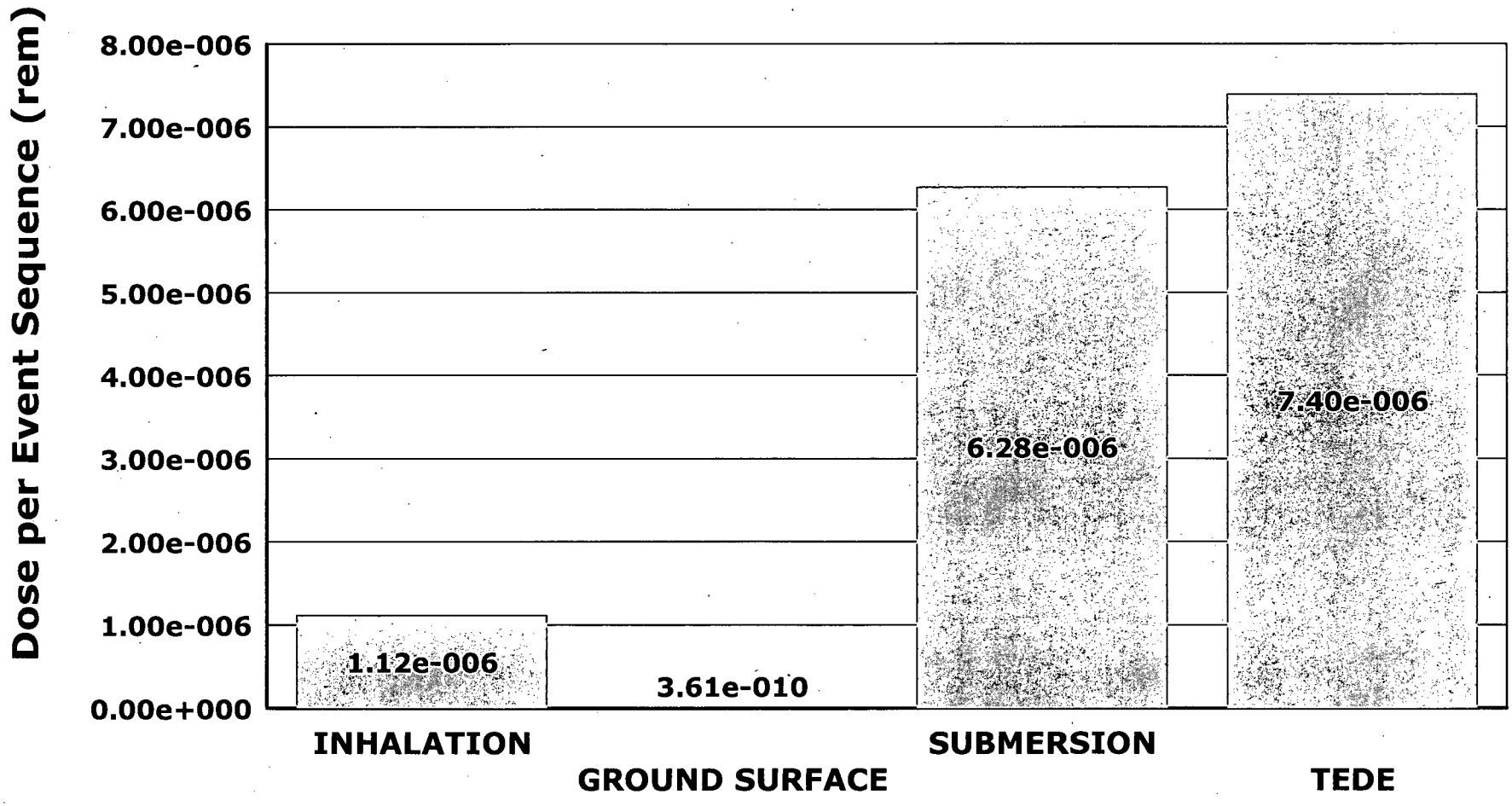
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06	2.47E-06
SUBMERSION	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05	5.55E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

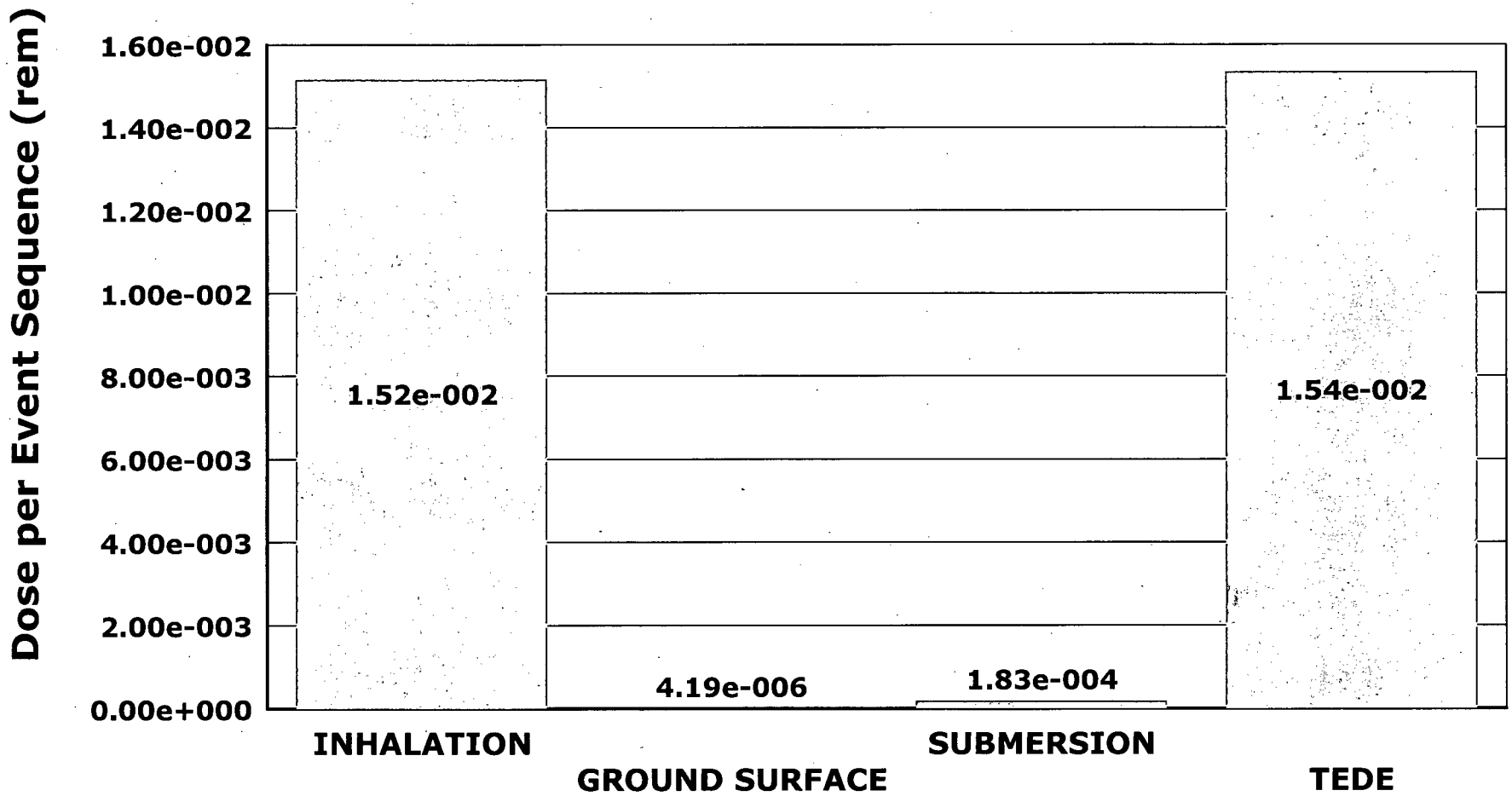
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.12E-06	1.12E-06	1.12E-06	1.12E-06	1.12E-06	1.12E-06
GROUND SURFACE	3.61E-10	3.61E-10	3.61E-10	3.61E-10	3.61E-10	3.61E-10
SUBMERSION	6.28E-06	6.28E-06	6.28E-06	6.28E-06	6.28E-06	6.28E-06
TEDE	7.40E-06	7.40E-06	7.40E-06	7.40E-06	7.40E-06	7.40E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

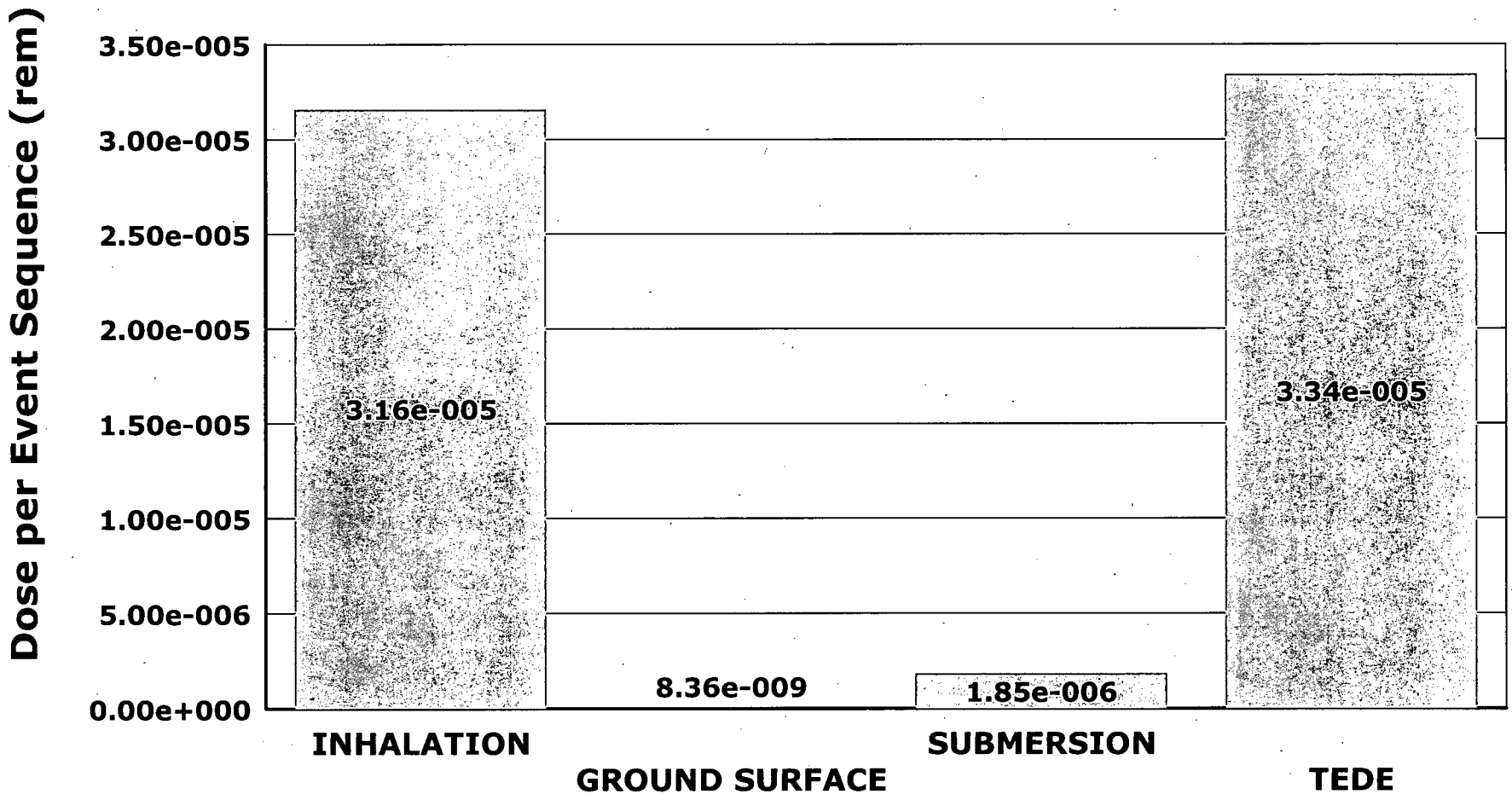
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02
GROUND SURFACE	4.19E-06	4.19E-06	4.19E-06	4.19E-06	4.19E-06	4.19E-06
SUBMERSION	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04	1.83E-04
TEDE	1.54E-02	1.54E-02	1.54E-02	1.54E-02	1.54E-02	1.54E-02

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

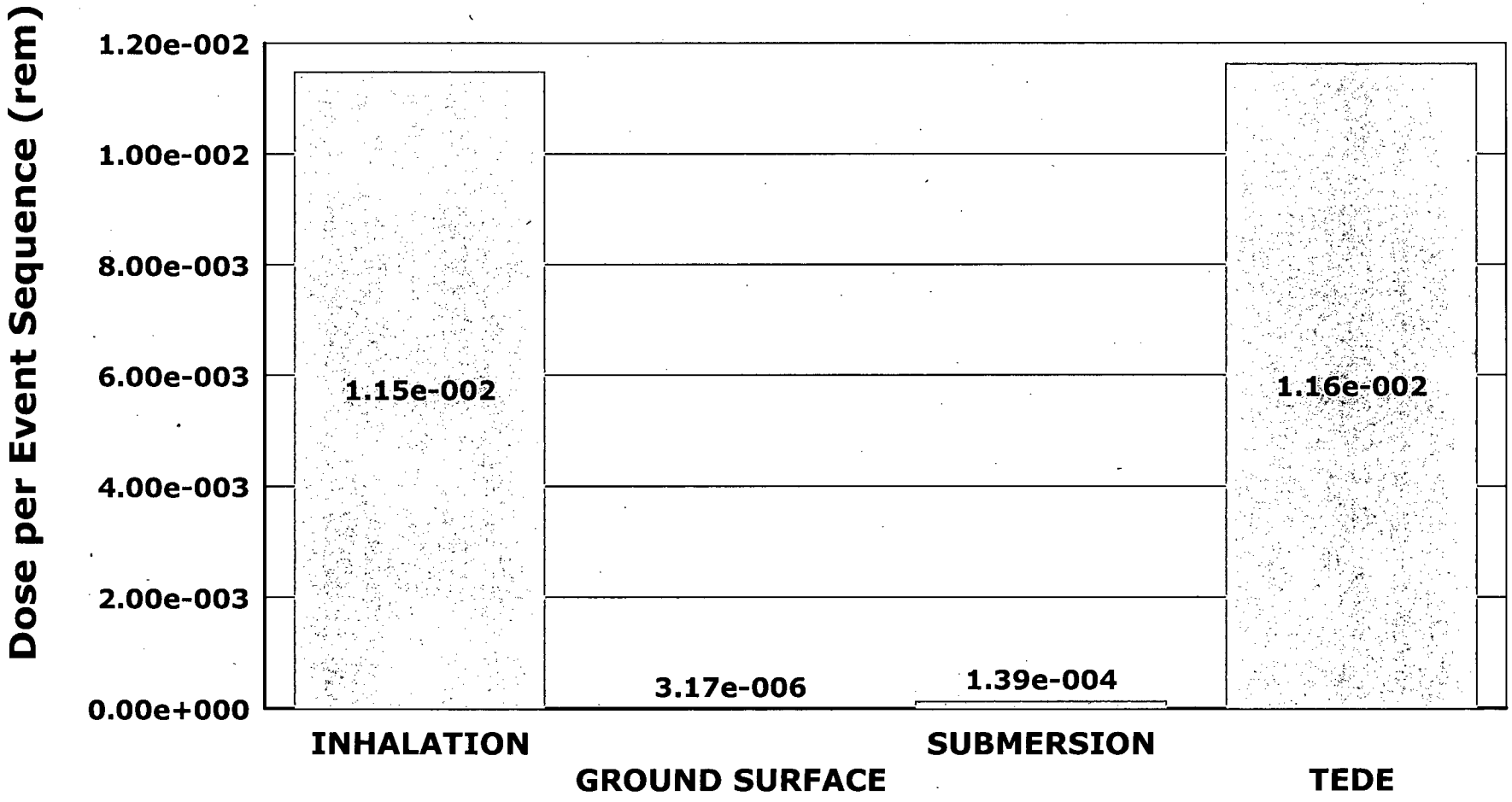
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.16E-05	3.16E-05	3.16E-05	3.16E-05	3.16E-05	3.16E-05
GROUND SURFACE	8.36E-09	8.36E-09	8.36E-09	8.36E-09	8.36E-09	8.36E-09
SUBMERSION	1.85E-06	1.85E-06	1.85E-06	1.85E-06	1.85E-06	1.85E-06
TEDE	3.34E-05	3.34E-05	3.34E-05	3.34E-05	3.34E-05	3.34E-05

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

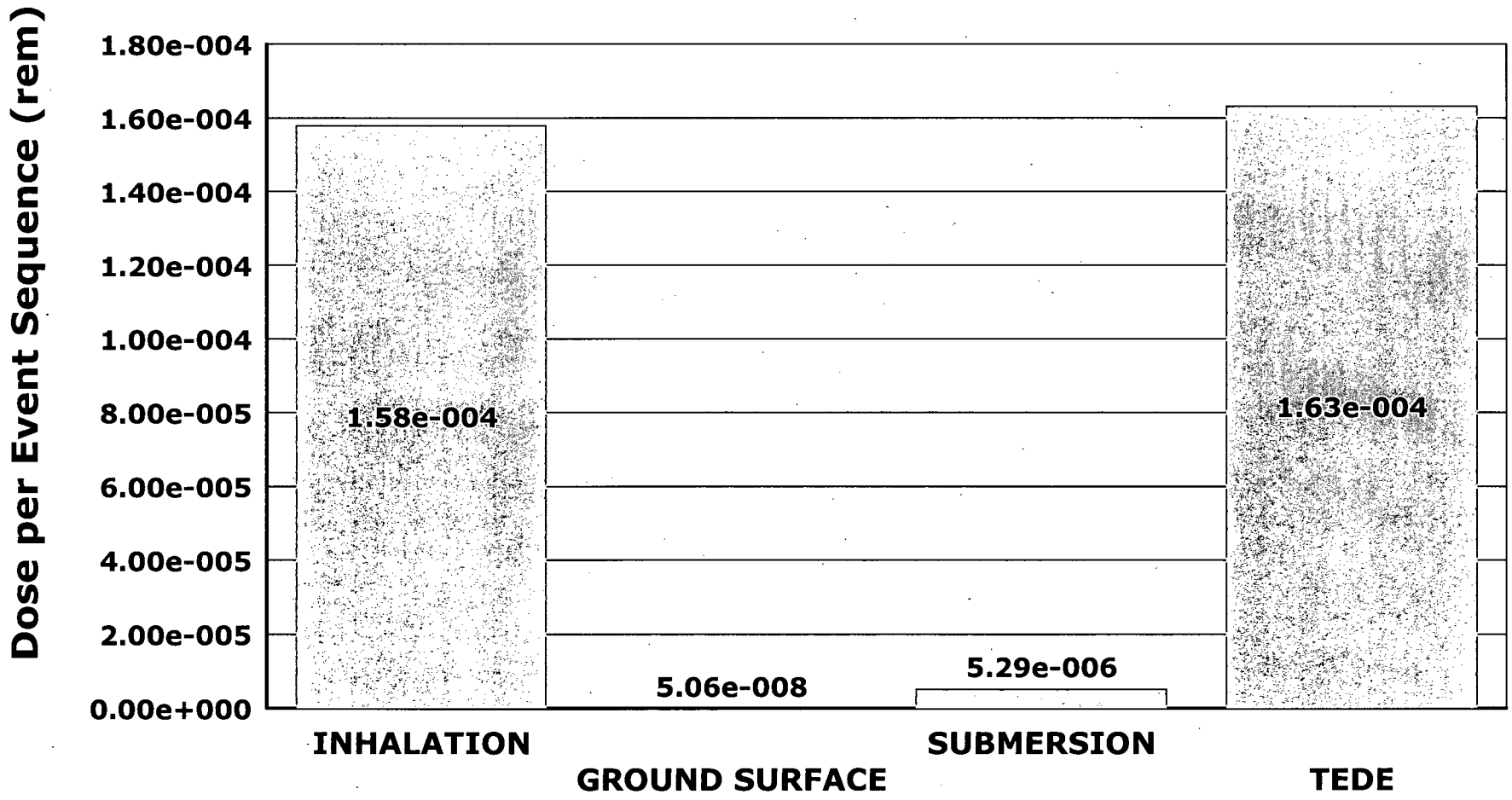
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06	3.17E-06
SUBMERSION	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04	1.39E-04
TEDE	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02	1.16E-02

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

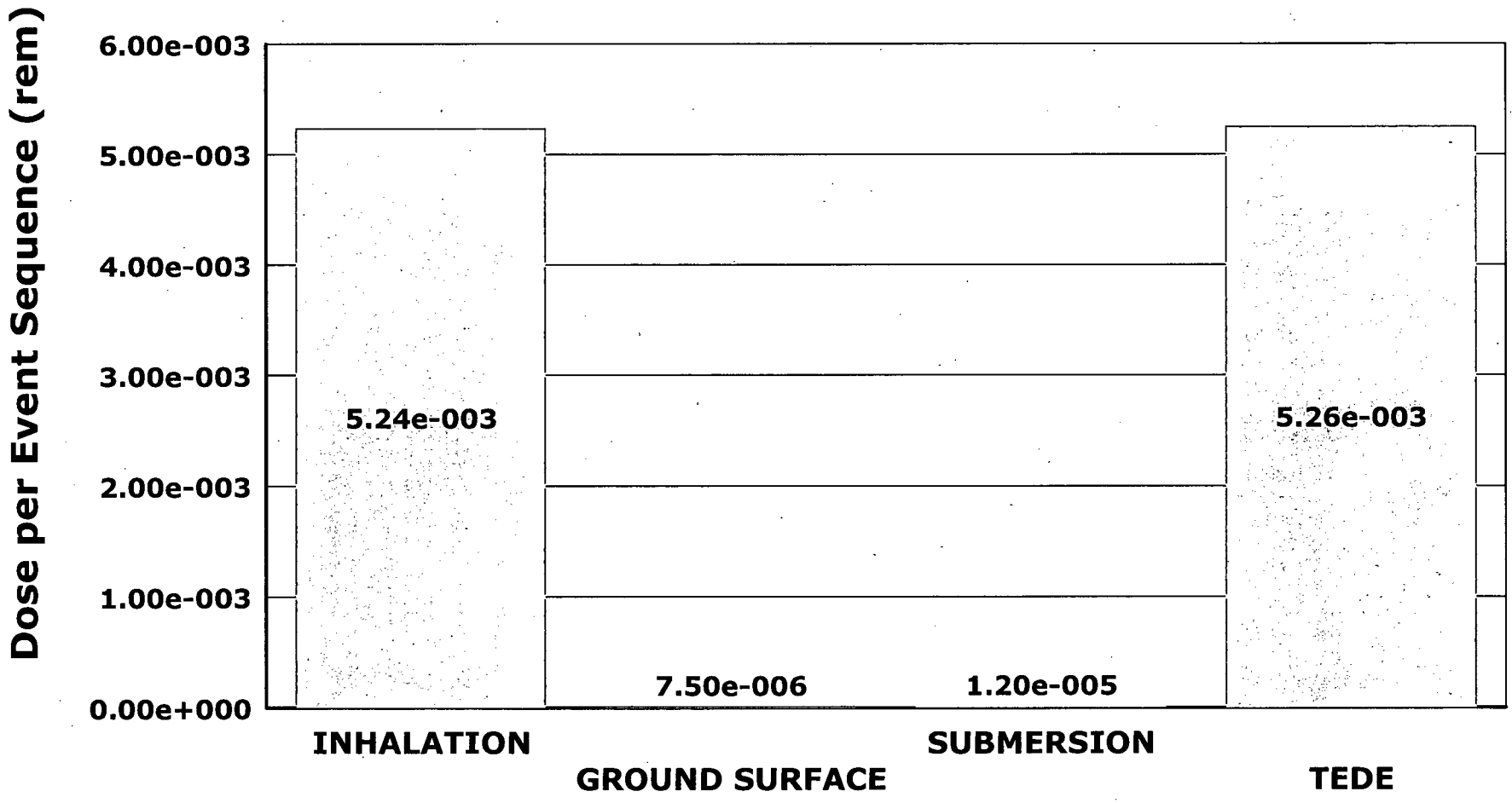
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04	1.58E-04
GROUND SURFACE	5.06E-08	5.06E-08	5.06E-08	5.06E-08	5.06E-08	5.06E-08
SUBMERSION	5.29E-06	5.29E-06	5.29E-06	5.29E-06	5.29E-06	5.29E-06
TEDE	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04	1.63E-04

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

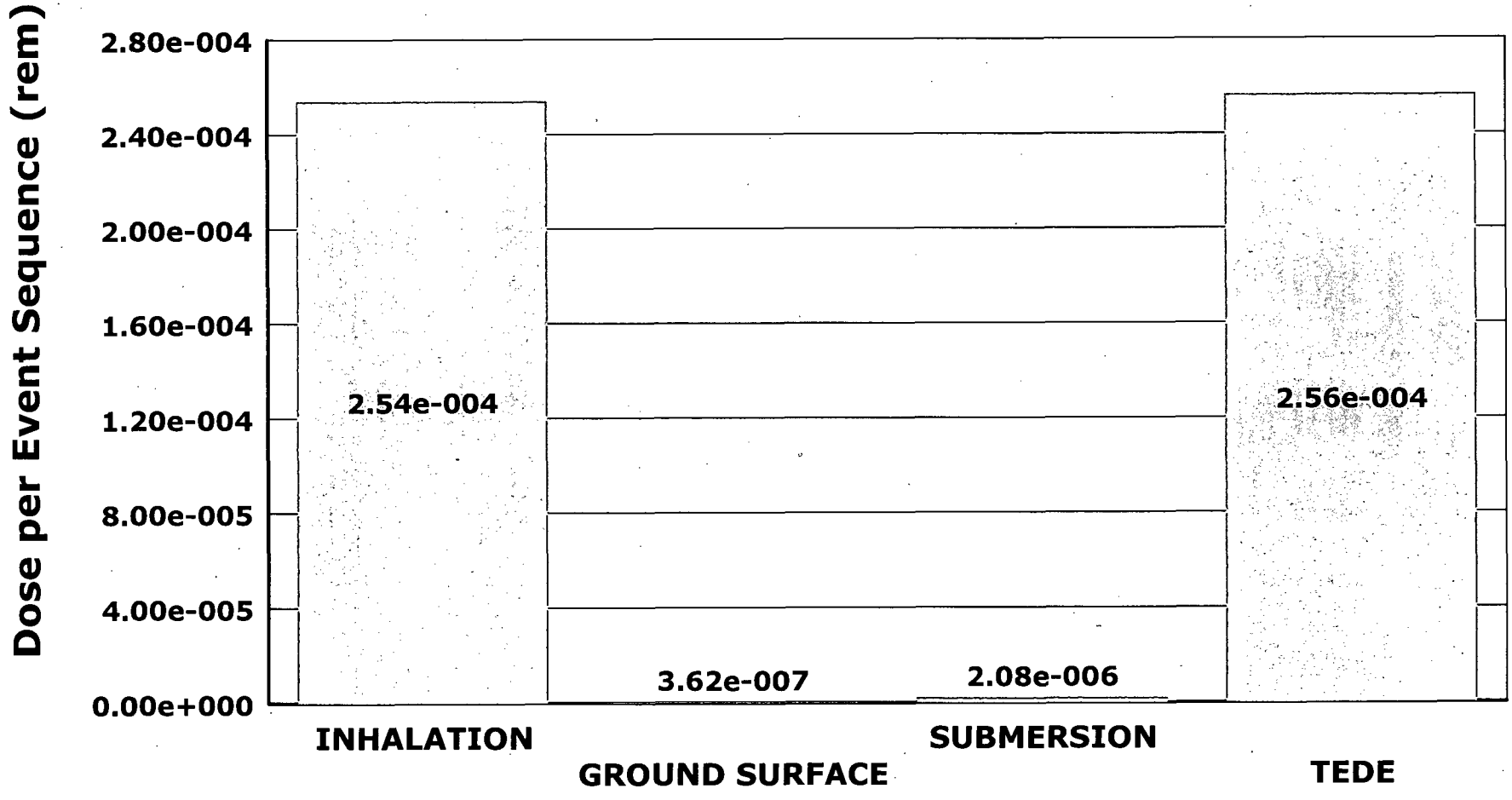
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	5.24E-03	5.24E-03	5.24E-03	5.24E-03	5.24E-03	5.24E-03
GROUND SURFACE	7.50E-06	7.50E-06	7.50E-06	7.50E-06	7.50E-06	7.50E-06
SUBMERSION	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05	1.20E-05
TEDE	5.26E-03	5.26E-03	5.26E-03	5.26E-03	5.26E-03	5.26E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

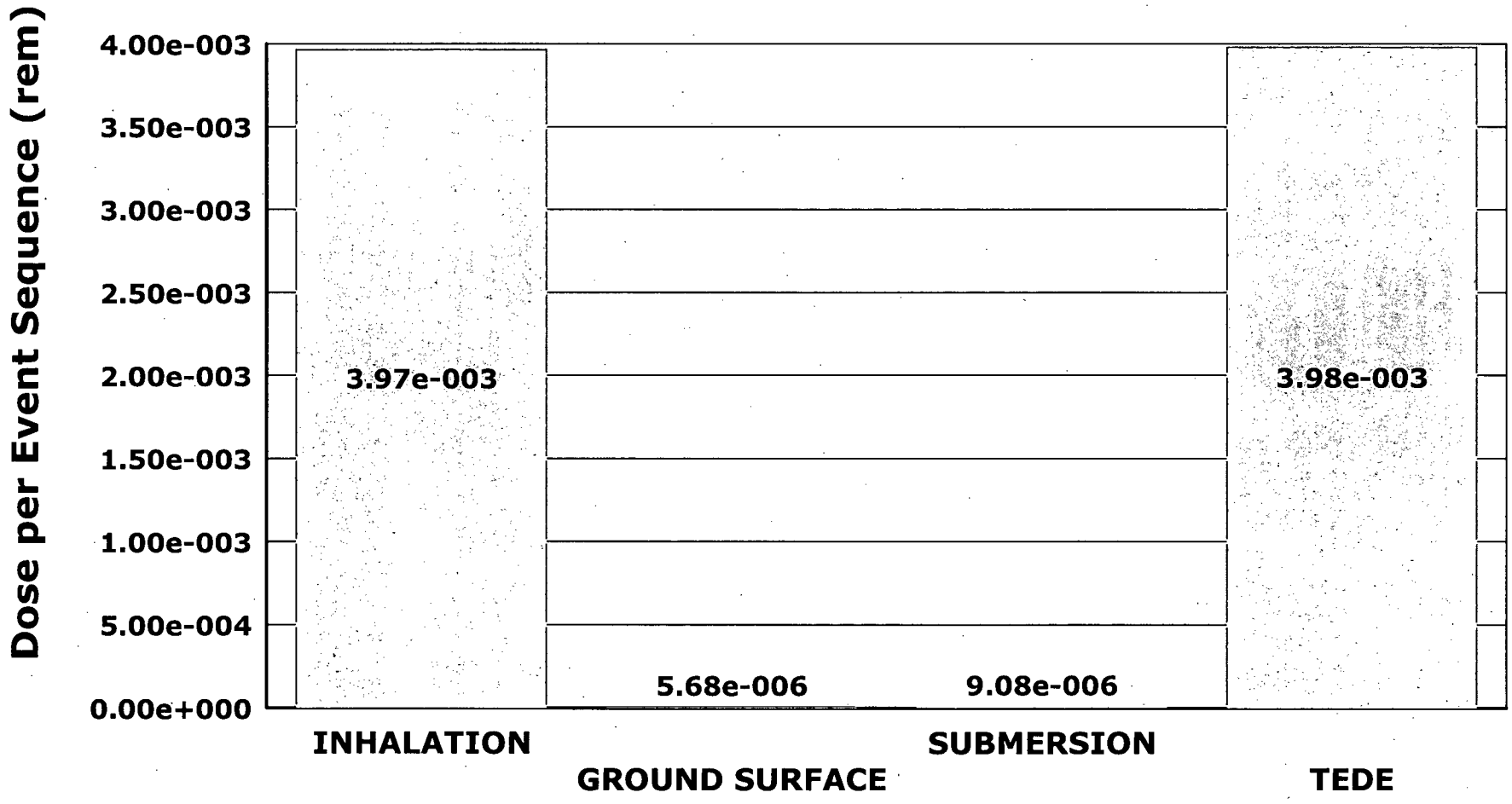
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	2.54E-04	2.54E-04	2.54E-04	2.54E-04	2.54E-04	2.54E-04
GROUND SURFACE	3.62E-07	3.62E-07	3.62E-07	3.62E-07	3.62E-07	3.62E-07
SUBMERSION	2.08E-06	2.08E-06	2.08E-06	2.08E-06	2.08E-06	2.08E-06
TEDE	2.56E-04	2.56E-04	2.56E-04	2.56E-04	2.56E-04	2.56E-04

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

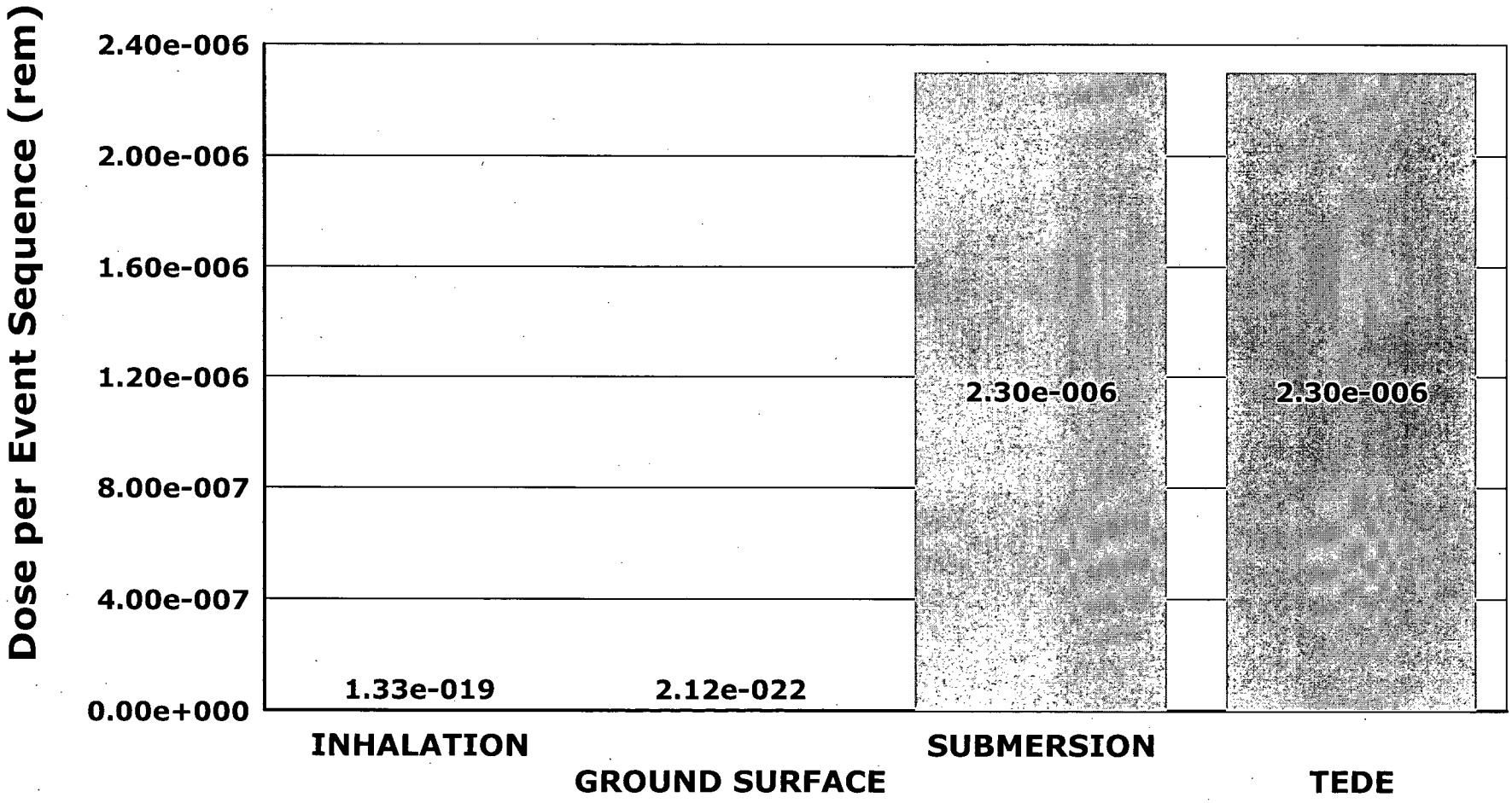
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06	5.68E-06
SUBMERSION	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06	9.08E-06
TEDE	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

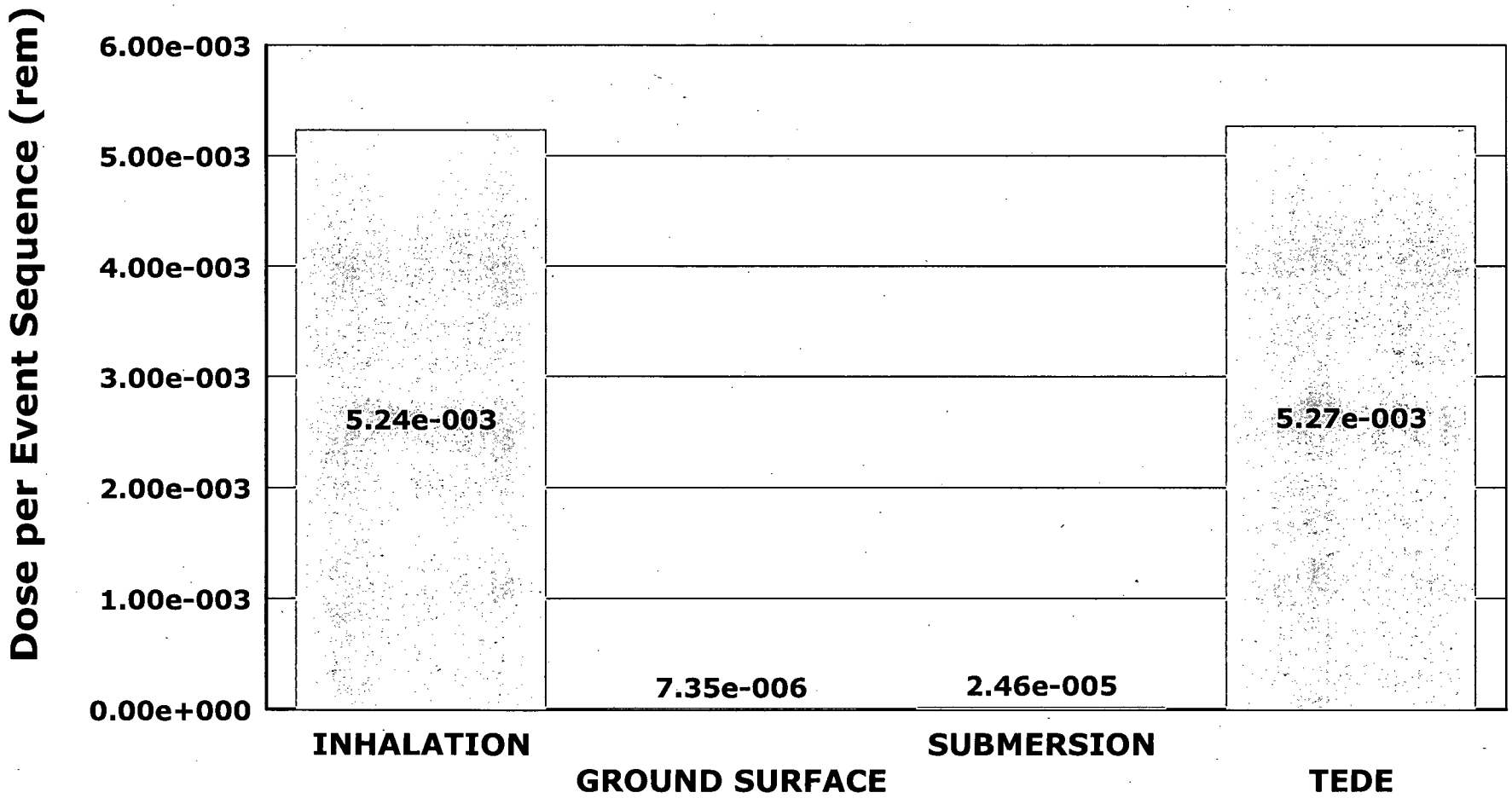
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.33E-19	1.33E-19	1.33E-19	1.33E-19	1.33E-19	1.33E-19
GROUND SURFACE	2.12E-22	2.12E-22	2.12E-22	2.12E-22	2.12E-22	2.12E-22
SUBMERSION	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06
TEDE	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06	2.30E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

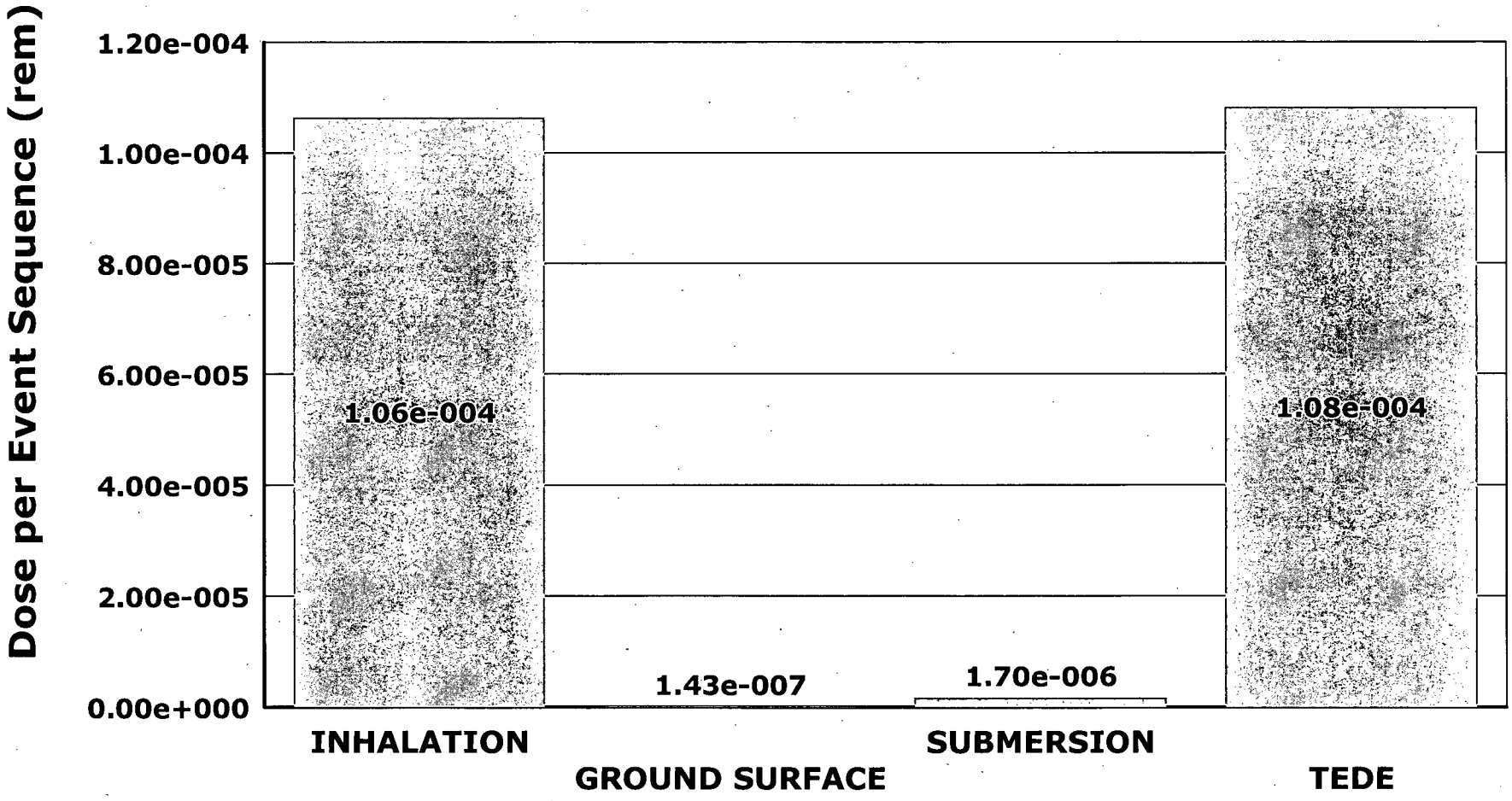
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	5.24E-03	5.24E-03	5.24E-03	5.24E-03	5.24E-03	5.24E-03
GROUND SURFACE	7.35E-06	7.35E-06	7.35E-06	7.35E-06	7.35E-06	7.35E-06
SUBMERSION	2.46E-05	2.46E-05	2.46E-05	2.46E-05	2.46E-05	2.46E-05
TEDE	5.27E-03	5.27E-03	5.27E-03	5.27E-03	5.27E-03	5.27E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

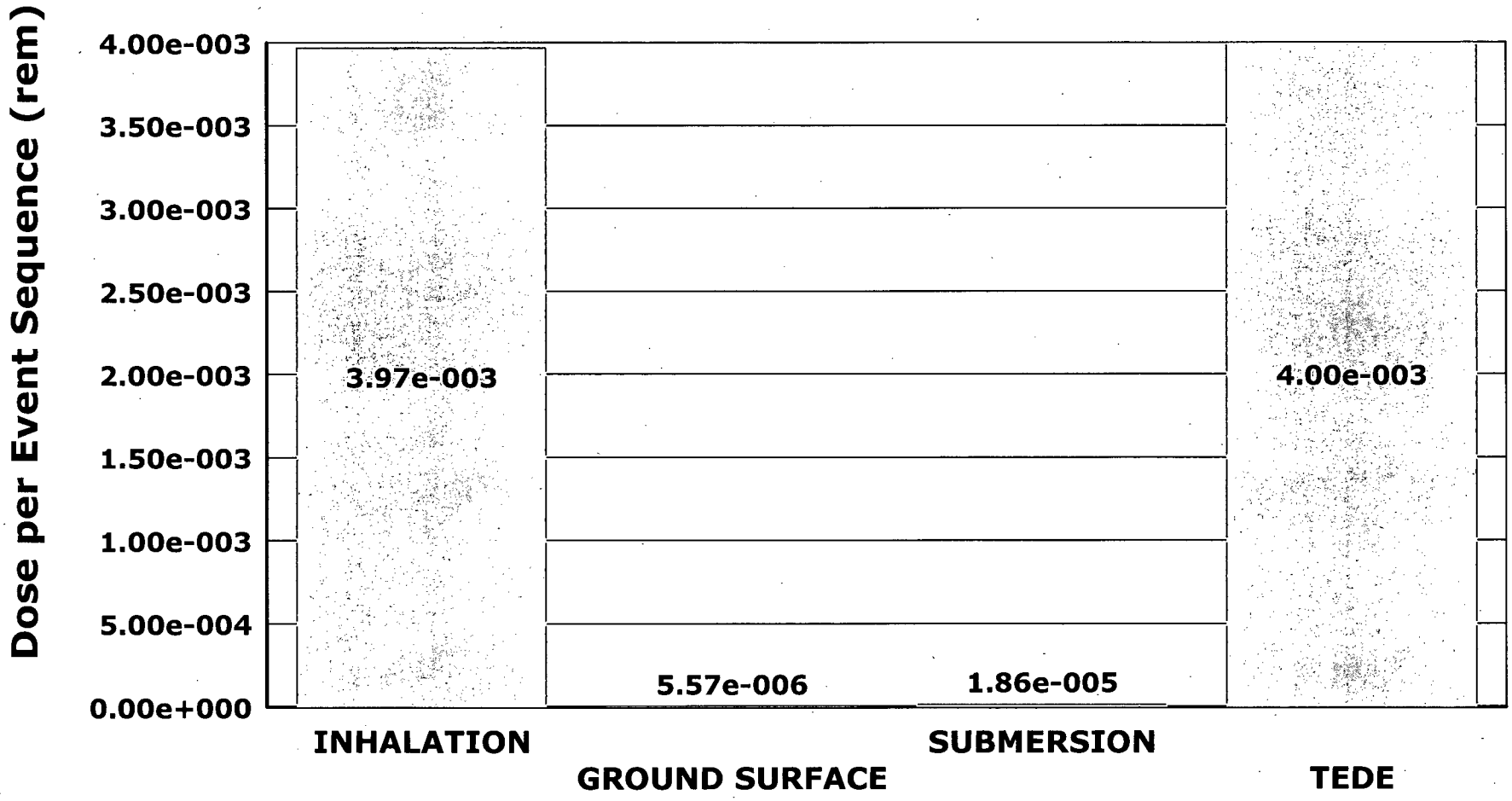
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04	1.06E-04
GROUND SURFACE	1.43E-07	1.43E-07	1.43E-07	1.43E-07	1.43E-07	1.43E-07
SUBMERSION	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06
TEDE	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04	1.08E-04

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

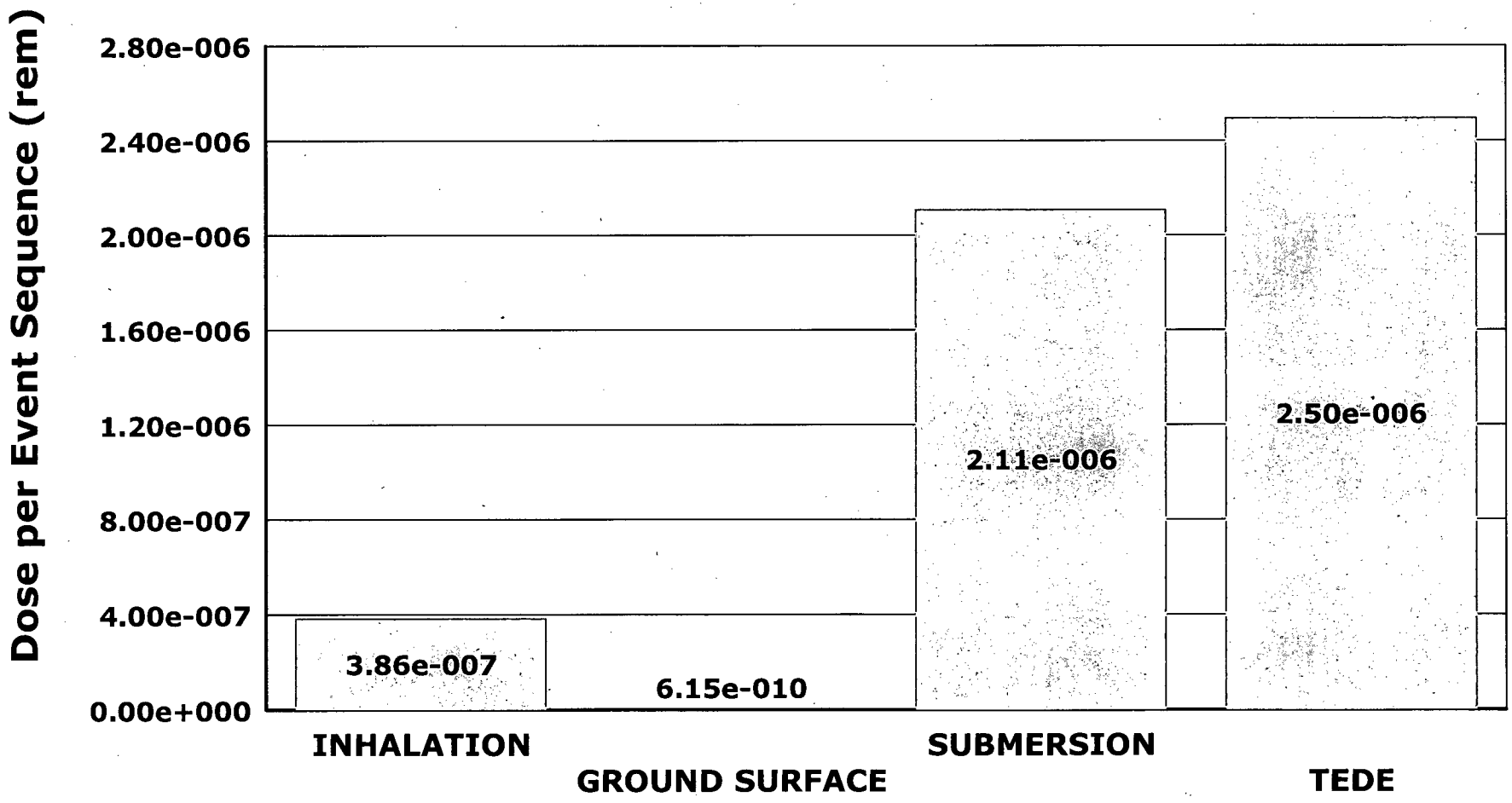
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03	3.97E-03
GROUND SURFACE	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06	5.57E-06
SUBMERSION	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05	1.86E-05
TEDE	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03	4.00E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

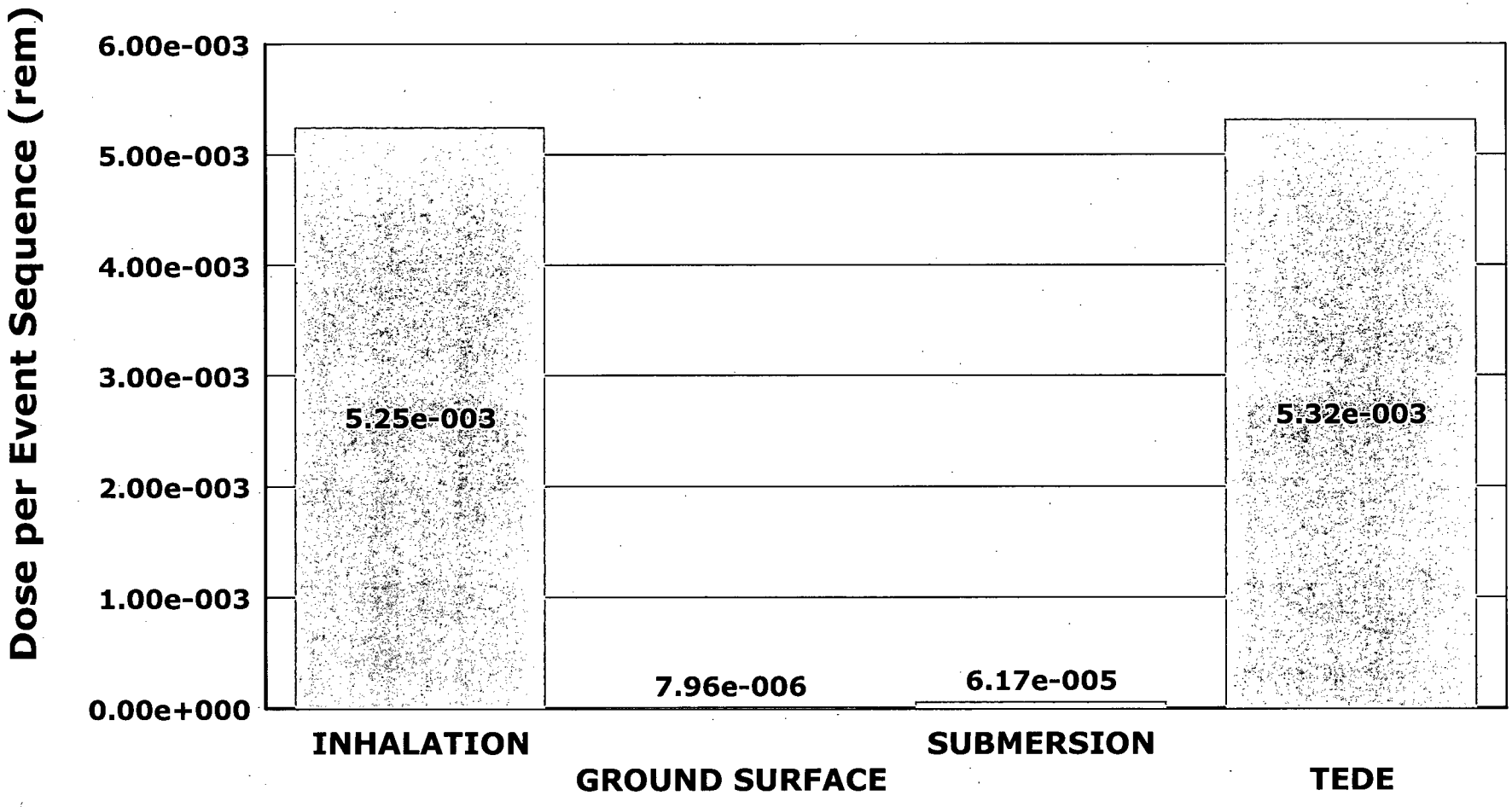
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07	3.86E-07
GROUND SURFACE	6.15E-10	6.15E-10	6.15E-10	6.15E-10	6.15E-10	6.15E-10
SUBMERSION	2.11E-06	2.11E-06	2.11E-06	2.11E-06	2.11E-06	2.11E-06
TEDE	2.50E-06	2.50E-06	2.50E-06	2.50E-06	2.50E-06	2.50E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

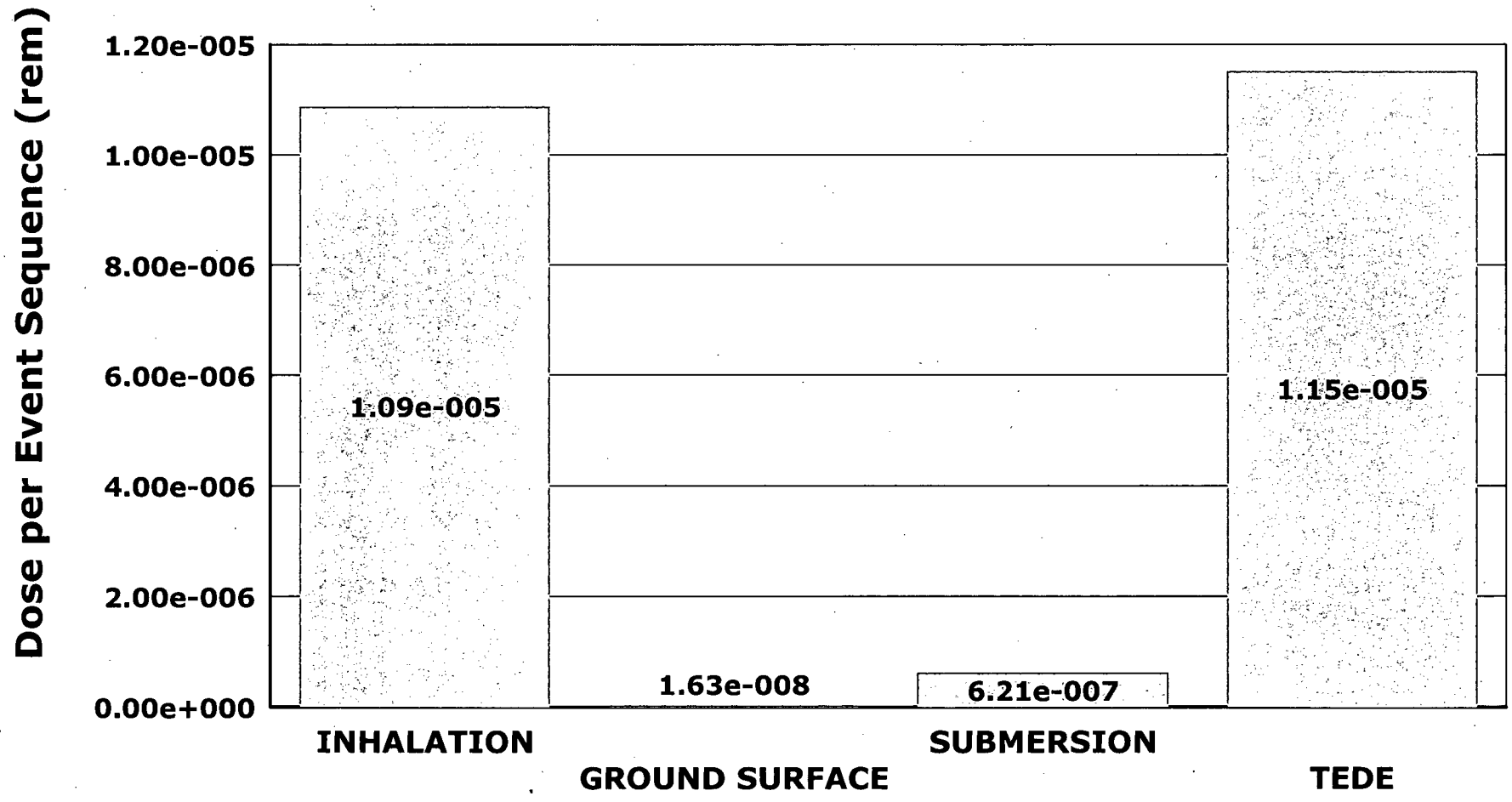
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	5.25E-03	5.25E-03	5.25E-03	5.25E-03	5.25E-03	5.25E-03
GROUND SURFACE	7.96E-06	7.96E-06	7.96E-06	7.96E-06	7.96E-06	7.96E-06
SUBMERSION	6.17E-05	6.17E-05	6.17E-05	6.17E-05	6.17E-05	6.17E-05
TEDE	5.32E-03	5.32E-03	5.32E-03	5.32E-03	5.32E-03	5.32E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Wake Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	35.00		
	Building Width (m):	75.00		

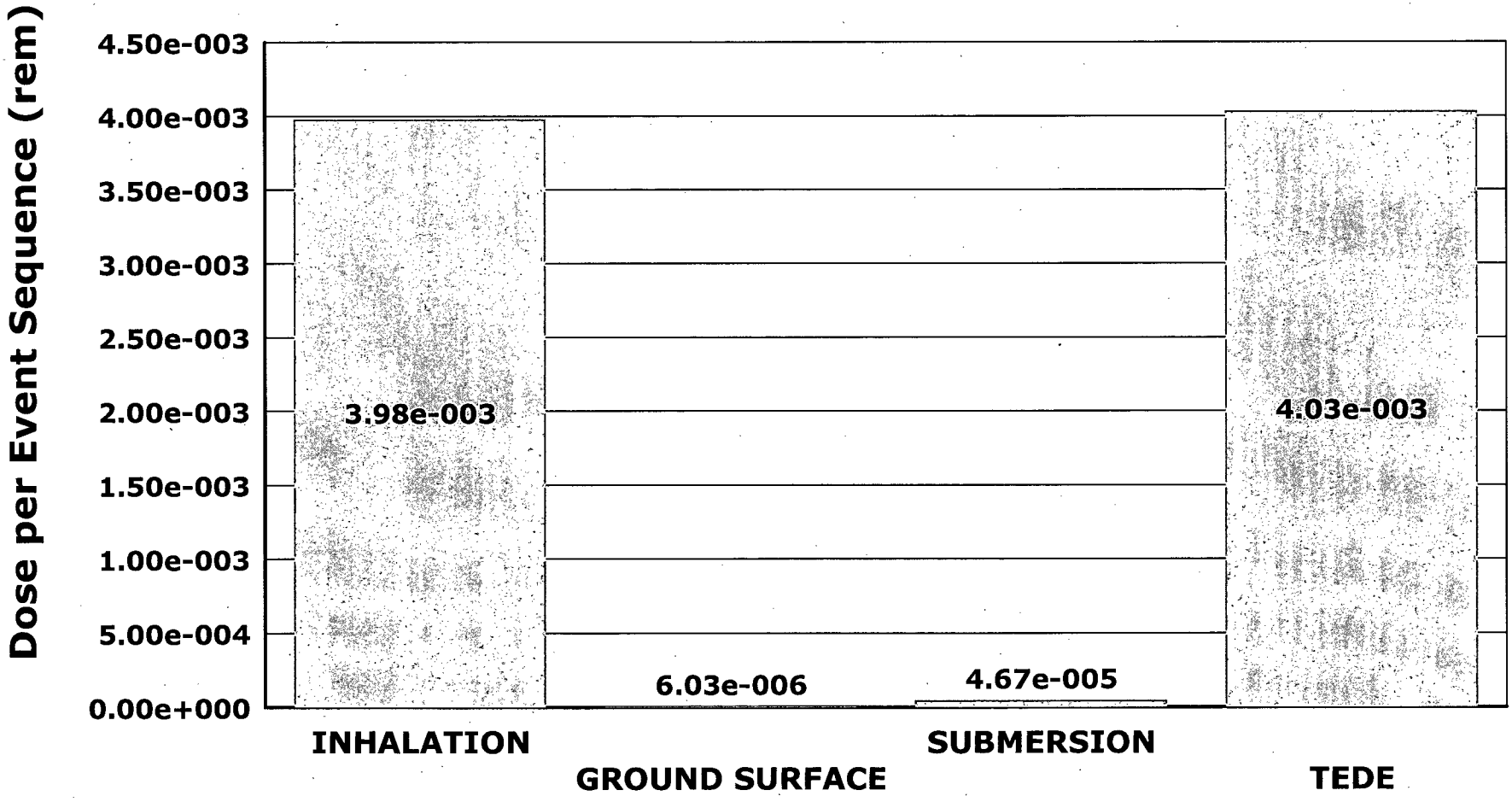
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.09E-05	1.09E-05	1.09E-05	1.09E-05	1.09E-05	1.09E-05
GROUND SURFACE	1.63E-08	1.63E-08	1.63E-08	1.63E-08	1.63E-08	1.63E-08
SUBMERSION	6.21E-07	6.21E-07	6.21E-07	6.21E-07	6.21E-07	6.21E-07
TEDE	1.15E-05	1.15E-05	1.15E-05	1.15E-05	1.15E-05	1.15E-05

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

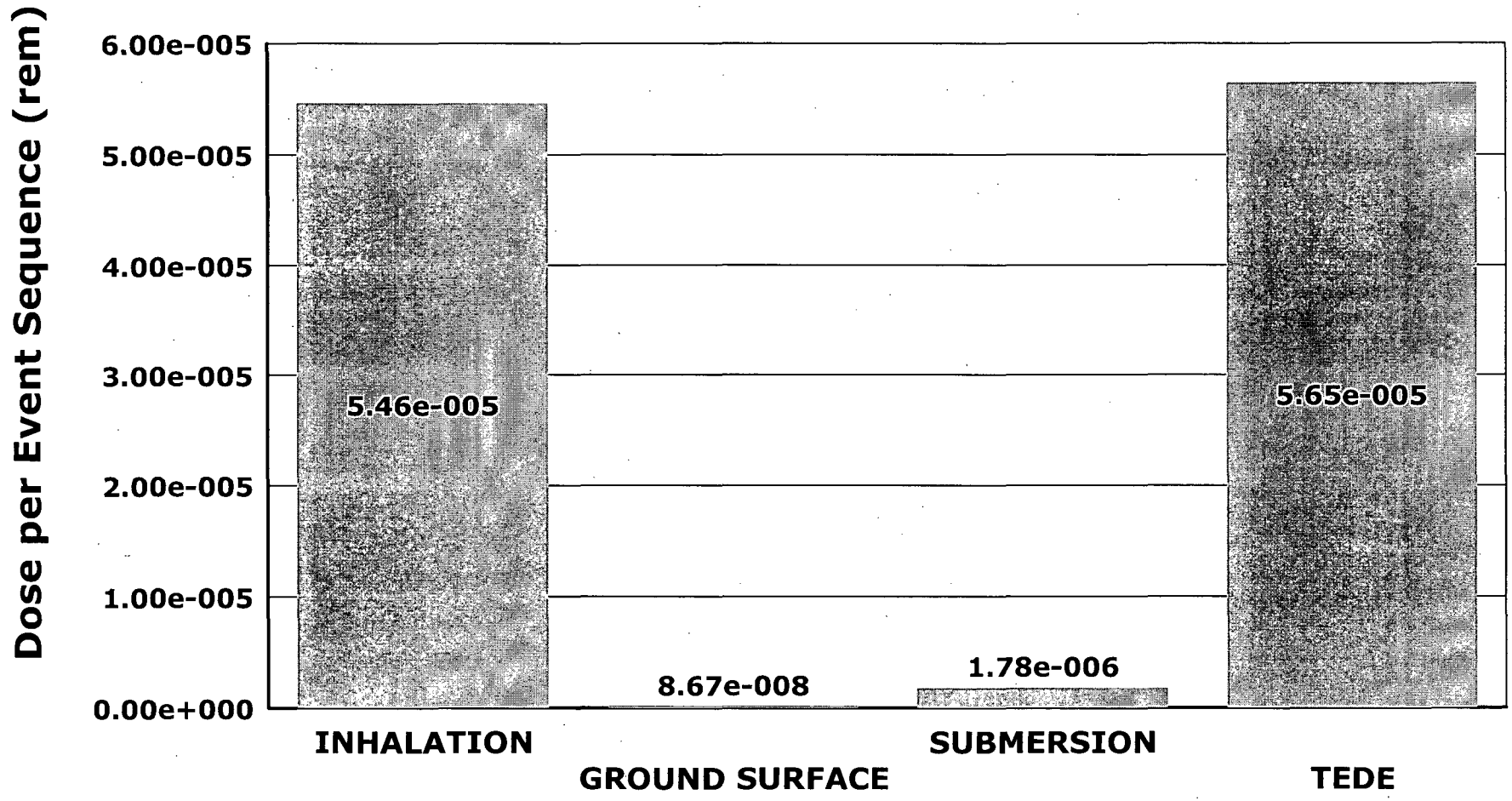
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03	3.98E-03
GROUND SURFACE	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06	6.03E-06
SUBMERSION	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05	4.67E-05
TEDE	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03	4.03E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	5.46E-05	5.46E-05	5.46E-05	5.46E-05	5.46E-05	5.46E-05
GROUND SURFACE	8.67E-08	8.67E-08	8.67E-08	8.67E-08	8.67E-08	8.67E-08
SUBMERSION	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06	1.78E-06
TEDE	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05	5.65E-05

		Nominal	
Wind Speed m/s	U	3	
Building Length (m)	LB	150	Assume the length is oriented perpendicular to the wind flow.
Building Width (m)	WB	135	Assume the width is oriented in the direction of wind flow.
Building Height (m)	HB	34	
Source Height (m)	HS	34	

		in	cm	A (m2)	R2 (m)	R (m)	D (m)	nominal (m)	nominal area
duct size	w	16	40.64	0.165161	0.052572	0.229287	0.458573	0.5	0.19635

		room volun	building vo	air change	flow (m3/s)	nominal velocity	plume rise (m)
duct flow	V	5097.032	20388.13	8	11.32674	57.68661	28.8433
		179997.8					

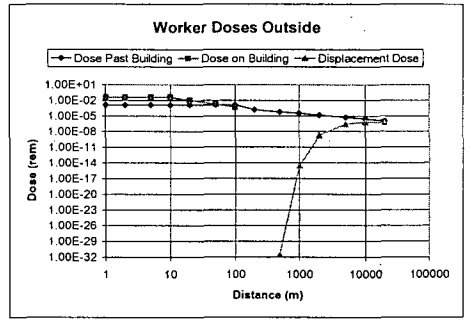
WB	150	m
HB	34	m
AB	5100	m2
QB	178.5357	m

85

	Window	Minimum	Maximum Distance
Same Side in Stack	8	0	1.5
Same Side near Stack	9	1.5	135
Cavity Zone	7	0	178.5357
Wake Zone	5	178.5357	∞
Displacement Zone			

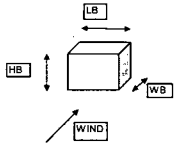
Note: minimum value for Cavity Zone is indeterminate; however x is the downwind distance, so it can be zero, if the worker is not on the same side.

Note: The upper range of x is infinity; at large x, the effects of an elevated release and increased dispersion coefficient are negligible, so the concentration is the same as in the displacement zone.



	RSAC Output HS=0			HS=34 ON Building					HS=34 OFF Building			HS≥2.5HB HS=90					Previous Spreadsheet			
	CEDE	chi/Q	X	X-3D			Corr. Factc	Dose	QB-X	X≤QB	Corr. Factc	Dose	X	chi/Q	dose		Column N	Column O	Col T/π	Col U/π
				1	-0.5	In Stack ON Buildin FV	7.92E+00	3.94E-02	177.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	1			8.79E-01	4.38E-03	0.279882	0.001394
				2	0.5	Near Stack ON Buildin FS	7.92E+00	3.94E-02	176.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	2			8.79E-01	4.38E-03	0.279882	0.001394
				5	3.5	Near Stack ON Buildin FS	7.92E+00	3.94E-02	173.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	5			8.79E-01	4.38E-03	0.279882	0.001394
				10	8.5	Near Stack ON Buildin FS	7.92E+00	3.94E-02	168.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	10			8.79E-01	4.38E-03	0.279882	0.001394
				20	18.5	Near Stack ON Buildin FS	2.24E+00	1.12E-02	158.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	20			8.79E-01	4.38E-03	0.279882	0.001394
σz	CEDE	chi/Q		50	48.5	Near Stack ON Buildin FS	3.59E-01	1.79E-03	128.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	50	chi/Q	dose	8.79E-01	4.38E-03	0.279882	0.001394
2.37E+00	4.98E-03	1.12E-02		100	98.5	Near Stack ON Buildin FS	8.97E-02	4.47E-04	78.5357	Cavity Zon	2.80E-01	1.39E-03	Displacem	100	0.00E+00	0.00E+00	8.79E-01	4.38E-03	0.279882	0.001394
4.01E+00	1.55E-03	3.46E-03		200	198.5	Near Stack OFF Buildi	NA		-21.4643	Wake Zon	9.91E-02	1.54E-04	Displacem	200	0.00E+00	0.00E+00				
7.92E+00	3.27E-04	7.34E-04		500	498.5	Near Stack OFF Buildi	NA		-321.464	Wake Zon	1.93E-01	6.31E-05	Displacem	500	6.51E-32	2.94E-32				
1.29E+01	1.04E-04	2.33E-04		1000	998.5	Near Stack OFF Buildi	NA		-821.464	Wake Zon	3.05E-01	3.17E-05	Displacem	1000	6.24E-15	2.83E-15				
2.03E+01	3.45E-05	7.73E-05		2000	1998.5	Near Stack OFF Buildi	NA		-1821.46	Wake Zon	4.50E-01	1.55E-05	Displacem	2000	4.12E-09	1.87E-09				
3.44E+01	8.79E-06	1.98E-05		5000	4998.5	Near Stack OFF Buildi	NA		-4821.46	Wake Zon	6.50E-01	5.71E-06	Displacem	5000	6.47E-07	2.94E-07				
4.82E+01	3.40E-06	7.66E-06		10000	9998.5	Near Stack OFF Buildi	NA		-9821.46	Wake Zon	7.67E-01	2.61E-06	Displacem	10000	1.34E-06	6.07E-07				
6.33E+01	1.43E-06	3.22E-06		20000	19998.5	Near Stack OFF Buildi	NA		-19821.5	Wake Zon	8.44E-01	1.21E-06	Displacem	20000	1.17E-06	5.31E-07				

FV = 1/{V [chi/Q]}
FS = 30/{UA x^2 [chi/Q]}
FC = 1/{UA π HB K [chi/Q]}
FW = σz / σzmod zmod = [(σz)2 + (AB/π)]½



Note the jump between FV and FS at the common point x=1.5 m

FV/chi/Q	1/V	8.83E-02
FS/chi/Q	30/UA*x^2	4.44E+00 Which in this case is a factor of about 50.

Note the jump between FC and FS at the end of the building, i.e. x=135 m

FS/chi/Q	30/UA*x^2	5.49E-04
FC/chi/Q	1/UA*HB*ł	9.80E-03

ENHANCED DEPOSITION PARAMETERS
PARTICLE DIAMETER = 0.000E+00 (m) PARTICLE DENSITY = 0.000E+00 (g/cm3)

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/cu m)
1.000E+02	0.000E+00	4.011E+00	2.372E+00	1.115E-02
2.000E+02	0.000E+00	7.642E+00	4.011E+00	3.461E-03
5.000E+02	0.000E+00	1.826E+01	7.918E+00	7.337E-04
1.000E+03	0.000E+00	3.531E+01	1.290E+01	2.330E-04
2.000E+03	0.000E+00	6.764E+01	2.029E+01	7.732E-05
5.000E+03	0.000E+00	1.561E+02	3.442E+01	1.975E-05
1.000E+04	0.000E+00	2.876E+02	4.818E+01	7.657E-06
2.000E+04	0.000E+00	5.202E+02	6.333E+01	3.221E-06

RADIOLOGICAL SAFETY ANALYSIS COMPUTER PROGRAM (RSAC-6)
(RSAC-6, REV 6.2, 03/11/02) SERIAL 1 DATE 20040720 TIME 17:13 PAGE 4

(RSAC-6, REV 6.2, 03/11/02) SERIAL 1 DATE 20040720 TIME 17:52 PAGE 3
: Dose Calcs for inhalation, NOT ingestion, ground surface, & submersi

DOWNWIND DISTANCE	STACK HEIGHT (m)	SIGY (m)	SIGZ (m)	CHI/Q (s/cu m)
1.000E+02	9.000E+01	4.011E+00	2.372E+00	0.000E+00
2.000E+02	9.000E+01	7.642E+00	4.011E+00	0.000E+00
5.000E+02	9.000E+01	1.826E+01	7.918E+00	6.509E-32
1.000E+03	9.000E+01	3.531E+01	1.290E+01	6.243E-15
2.000E+03	9.000E+01	6.764E+01	2.029E+01	4.121E-09
5.000E+03	9.000E+01	1.561E+02	3.442E+01	6.472E-07
1.000E+04	9.000E+01	2.876E+02	4.818E+01	1.338E-06
2.000E+04	9.000E+01	5.202E+02	6.333E+01	1.173E-06

*** FRACTION OF PLUME REMAINING AIRBORNE FOLLOWING DEPLETION BY DEPOSITION

24 0.00E+00 0.00E+00 2.94E-32 2.83E-15 1.87E-09 2.94E-07 6.07E-07 5.31E-07

DRAFT FOR DISCUSSION

Approach for Implementing Downwind Worker Dose Model

Please consider this approach as DRAFT for discussion.

There are at least three configurations involving the worker, obstacle, and source that may be of interest in preclosure repository safety:

1. The source and obstacle are located at the same location; the worker may be collocated or located downwind.
2. The source is upstream from the obstacle; the worker is collocated or downwind of the obstacle.
3. The source is upstream from the obstacle; the worker and obstacle(s) are collocated.

See Figure 1 for a diagram of these configurations. Case 1 most closely resembles the configurations discussed in IAEA Safety Series 19, where the source and obstacle are collocated.

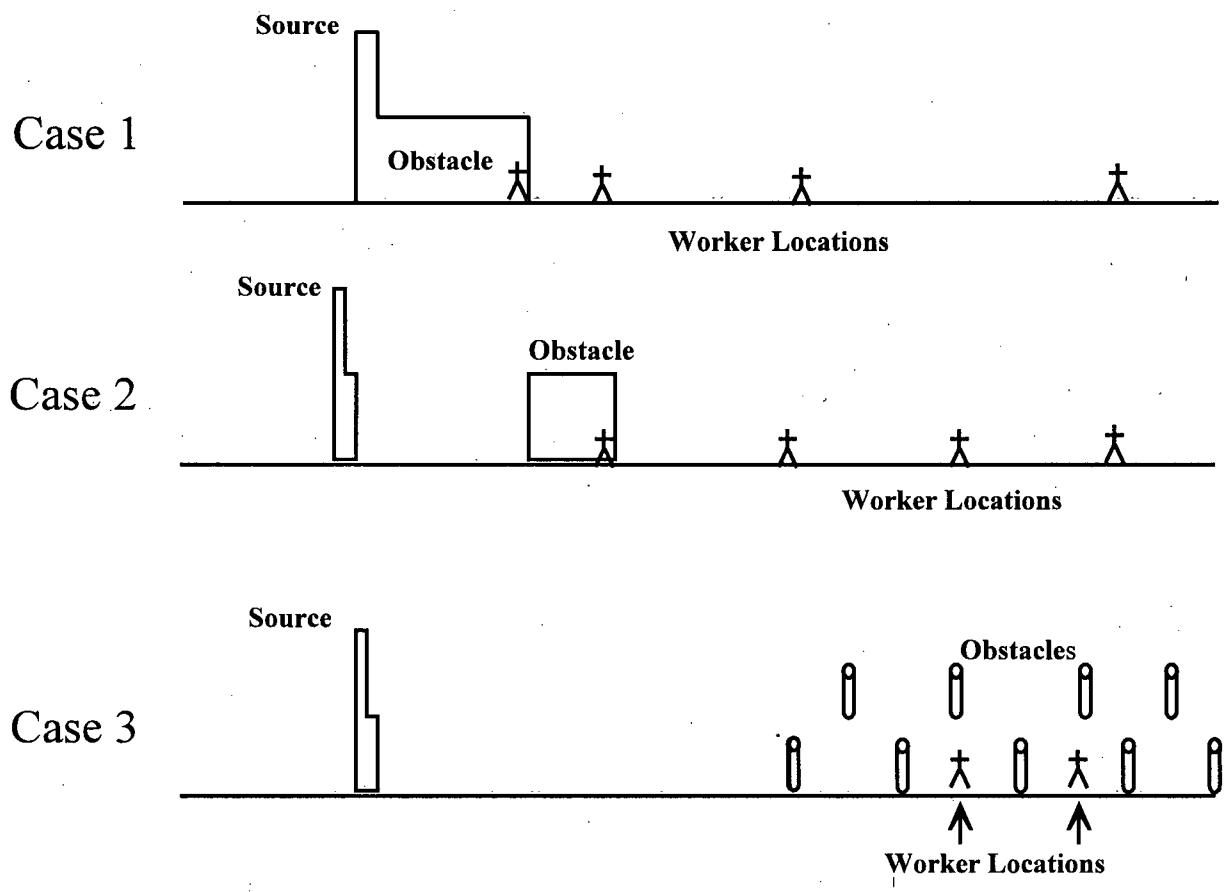


Figure 1. Three configurations for worker dose.

This may be an important configuration in repository safety analysis. Case 2 considers the situation, that may present for some workers at the repository, where there is one or more buildings intervening between the worker and the source. In this configuration, the downwind building is likely to cause increased mixing of the contaminant plume. For this reason, the doses calculated from this configuration are likely to be bounded by other configurations.[1] Case 3 is directed at considering the storage area, where there may be a large number of obstacles with workers in the space between the obstacles. Because the contaminant plume will flow through this array of objects, mixing with uncontaminated air may be greatly reduced by a channeling effect. This configuration may require a different approach. **This initial implementation of downwind worker dose will consider Case 1 only.**

To adapt the IAEA approach, we must recognize the following. The IAEA approach was developed to consider chronic (long-term) releases from a facility prior to licensing and operation. The focus of the IAEA analysis is routine releases from a facility and whether such releases induce acceptable concentrations for receptors downwind of the releases. To the contrary, we are concerned with acute, accidental releases. As we proceed, some parts of the IAEA approach may need to be modified to account for this difference. Another assumption based on the intent of the IAEA approach is that the source is on the building which creates the wake; however, the source may be elevated to a height that is substantially greater than the building height. This would be an expected configuration for a facility routinely allowing releasing from a stack.

The IAEA document defines three zones determined by the flow of air over and around the building: (1) displacement zone, (2) wake zone, and (3) cavity zone as shown in Figure 2 (Figure 4 in the IAEA document). The displacement zone is a region some distance downwind from the building, where the concentration is relatively unaffected by the building and its wake. Since the source is considered to be at some elevation, the contaminant plume must travel some distance before it reaches ground level. The displacement zone begins approximately at the point where the contaminant plume first touches down to ground level. This assumes a ground-level receptor,

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[1]There may be slightly higher concentrations immediately downwind of the building in its cavity zone, because contaminants will be recirculated in a finite volume. However, the obstacle building is likely to be 65 to 100 m downwind of the source building. For a nominal building height of 34m and width between 135m and 150m the cavity zone is likely to extend no more than $2.5xA^{1/2}$, which is approximately equal to 2.5x70.7m = 175m. Thus a receptor in the cavity zone is likely to be 2 to 3 times the distance of the obstacle building from the source building. If a worker is within the cavity zone, his dose will be significantly higher than the dose to a worker at the same distance, but not in the cavity zone. This is because the worker in the cavity zone will experience a concentration close to that ahead of the obstacle (say the 75 m concentration), while the worker in the plume with no obstruction will experience the concentration at up to 175m. At these small distances, such changes will cause significant changes in concentration. However, the dose to a worker between the source and obstacle building will be higher than either of these.

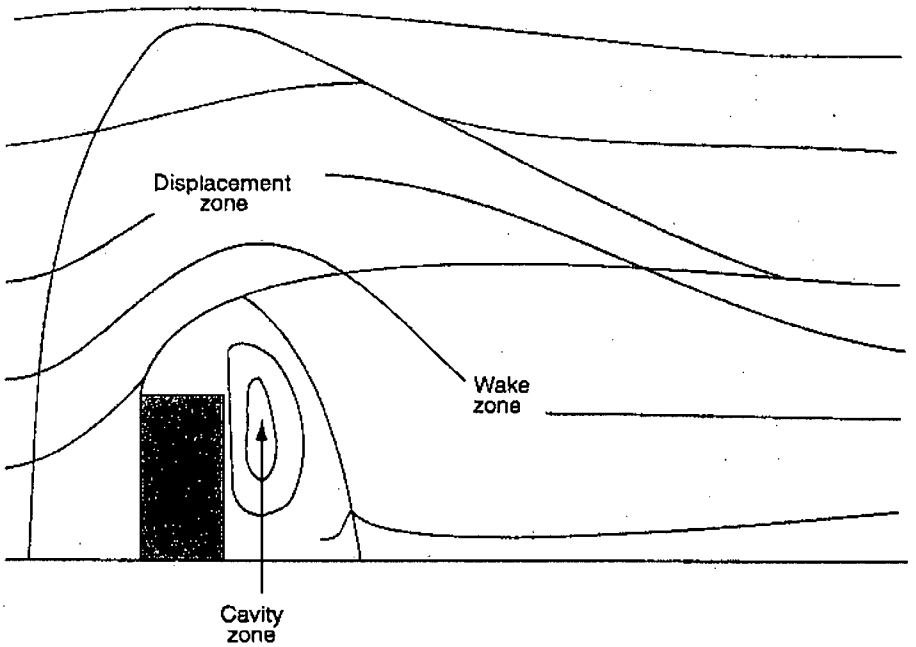


Figure 2. Air flow around a building, showing the three main zones of flow: displacement zone, wake zone and cavity zone.

which is consistent with this worker dose scenario. The cavity zone is immediately leeward of the building. Because contaminants may become trapped in the cavity zone (an attached vortex), the concentration in the cavity zone is strongly affected by the presence of the building. Concentration in the wake zone, which is essentially between the displacement zone and cavity zone, are reduced over what might be expected if no building were present. This is because the building provides additional turbulent mixing which reduces the concentration.

A receptor may be located at ground level and at any distance, x, downwind from the building. This distance, x, will determine in which of these three zones the receptor is located; depending on the zone, a different model is used for estimating concentration. The IAEA approach for determining zones is illustrated in Figure 3 (Figure 5 in the IAEA document). To implement this approach in the PCSA Tool a number of sequential windows will need to be used. At various points in this discussion these windows will be indicated.

WINDOW 1.

The user must specify the building height in meters, H_B, and the source height in meters, H_S. These numbers must be zero or greater.

If $H_S > 2.5 \cdot H_B$ then go to Window 2; if $H_S \leq 2.5 \cdot H_B$ then go to Window 3.

WINDOW 2.

The plume does not touch down until after the wake zone. Use the RSAC model with a receptor

elevation equal to zero. The user must specify the distance between the building and the receptor, x, in meters; then proceed with the RSAC calculation. Values for $x \leq 2.5 \cdot H_B$ will

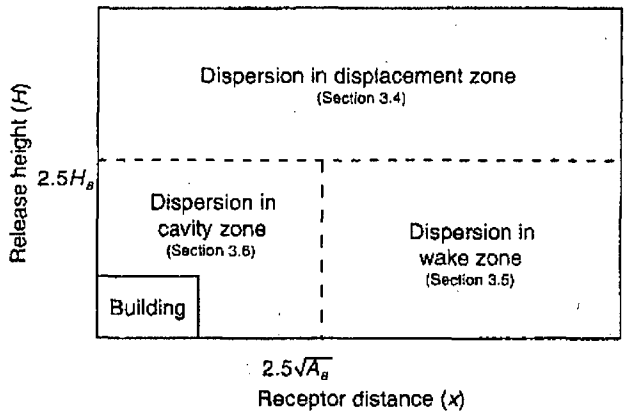


Figure 3. *Relationship between release height and receptor distance for determination of the type of dispersion model to be used.*

probably not yield meaningful results (the receptor is located closer to the building before the location where the plume touches down; after all, this is why releases are elevated). Consider providing a warning if a close distance is chosen or do not allow a calculation for small distances ($x \leq 2.5 \cdot H_B$).

Window 3.

Input the building width or length, W_B, in meters. This could also be whatever length the user desires to characterize the dimension of the building in the direction perpendicular to the direction of the wind. A bigger W_B will produce a bigger cross-wind area, which will increase the size of the cavity zone; i.e., bigger buildings have bigger trapped vortex zones. Calculate:

$$A_B = W_B \cdot H_B \quad (m^2)$$

Input the receptor distance, x, in meters. Calculate the quantity:

$$Q_B = 2.5 \cdot [A_B]^{1/2}$$

If $x \leq Q_B$, then go to Window 4.

If $x > Q_B$, then go to Window 5.

Window 4.

Is the receptor on the same surface of the building as the release? For example, is the receptor on

the roof with a roof vent releasing radionuclides; or is the receptor at a window on the side of a building that has a vent releasing radionuclides?
If yes, then go to Window 6.
If no, then go to Window 7.

Window 6.
Input the diameter of the vent or stack, D_S, in meters.
If $x \leq 3 \cdot D_S$, then go to Window 8
If $x > 3 \cdot D_S$, then go to Window 9.

Window 8.
Input the flow rate, V, in m^3/s, through the vent emitting radionuclides.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of 100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of chi/Q, in s/m^3, from the RSAC run, as well as the dose from each pathway and organ. Calculate the scaling factor:

$$F_V = 1/\{V \cdot [chi/Q]\}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (V - vent). Sum the pathway doses to obtain the total dose for this case.
This essentially assumes the receptor has his head in the stack and is breathing undiluted contaminated air as it is released from the vent; he may also get a dose from immersion.

Window 9.
Remember that for this screen the distance from the receptor to source should be:

$$3 \cdot D_S < x \leq Q_B$$

and the receptor should be on the same side of the building as the release vent.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of 100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the mean wind speed, U_A, in m/s, as well as (3) the dose from each pathway and organ. Calculate the scaling factor:

$$F_S = 30/\{U_A \cdot x^2 \cdot [chi/Q]\}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (S - side). Sum the pathway doses to obtain the total dose for this case.
This essentially assumes the releases from the vent may be recirculated close to the side of the building ; because of zones of stagnation and building wakes, high concentrations, hence doses, may be experienced.
Consider adding a test to assure that the correction factor can be no higher than F_V computed in Window 8.

Window 7.
This receptor is in the cavity zone, but is not on the same side of the building as the vent.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of

100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the mean wind speed, U_A, in m/s, as well as (3) the dose from each pathway and organ. Let $L_B = \min\{W_B, H_B\}$ Calculate the scaling factor:

$$F_C = 1/\{U_A \cdot \pi \cdot L_B \cdot K \cdot [chi/Q]\}$$

Where K=1m and is included to make the units consistent. Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (C - cavity). Sum the pathway doses to obtain the total dose for this case.

This essentially assumes the releases from the vent or stack are recirculated in the cavity zone; the quantity of radioactivity released per unit time (Q) is diluted by a flow equal to the product of π m and L_B (the smallest dimension of the building facing the wind) and U_A (the wind speed).

Consider adding a test to assure that the correction factor can be no higher than F_V computed in Window 8.

Consider adding a test to assure that the distance from the stack does not exceed the building dimension in that direction.

Window 5.

This receptor is in the wake zone. For this case x must be within certain limits:

$$2.5 \cdot H_B \geq x > Q_B = 2.5 \cdot [A_B]^{1/2}$$

For an ordinary Gaussian plume the concentration at ground level is given by:

$$C=(Q/U) \cdot [\exp-\{(h/\sigma_z)^2\}]/[\pi\, \sigma_z\, \sigma_y];$$

What we will assume for the wake zone is that the release is at ground level (this increases the concentration), but the vertical dispersion coefficient is increased (this decreases the concentration). Therefore: Run RSAC using the standard release (whatever that has been determined to be) at the distance x, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the value of the vertical dispersion coefficient, σ_z, (sigz in the RSAC output), as well as (3) the dose from each pathway and organ. Compute the quantity:

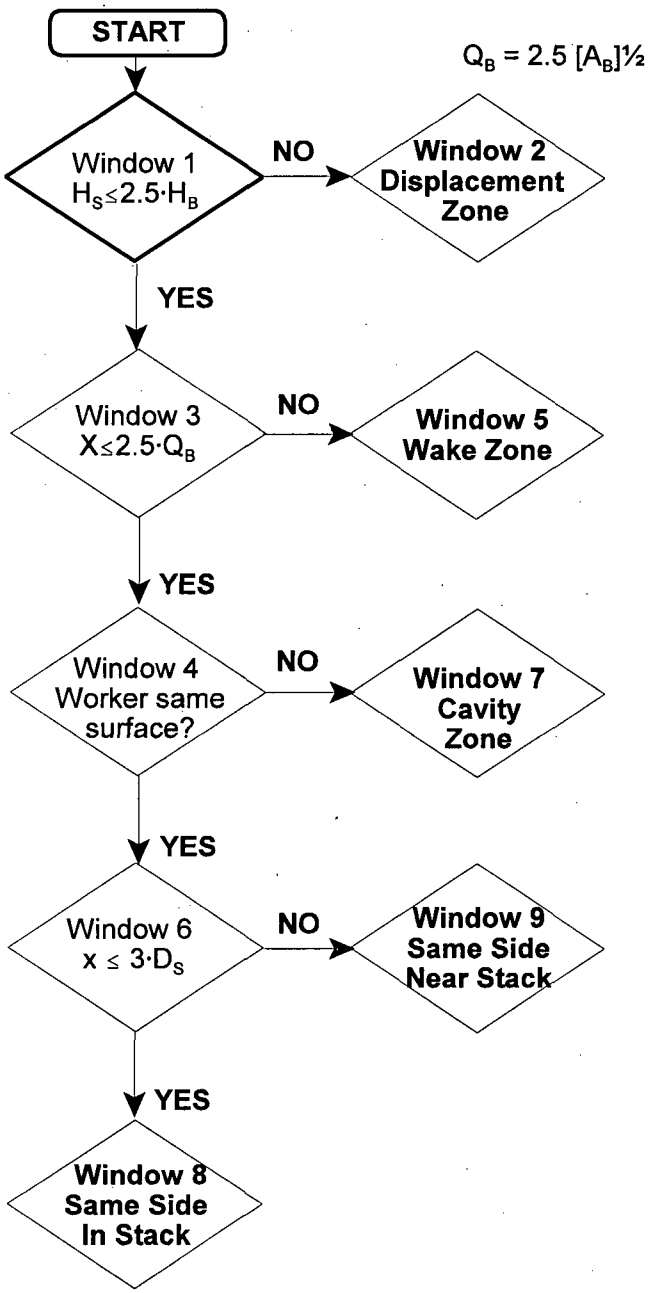
$$\sigma_{zmod} = [(\sigma_z)^2 + (A_B/\pi)]^{1/2}$$

Compute the scaling factor:

$$F_W = \sigma_z / \sigma_{zmod}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (W - wake). Sum the pathway doses to obtain the total dose for this case.

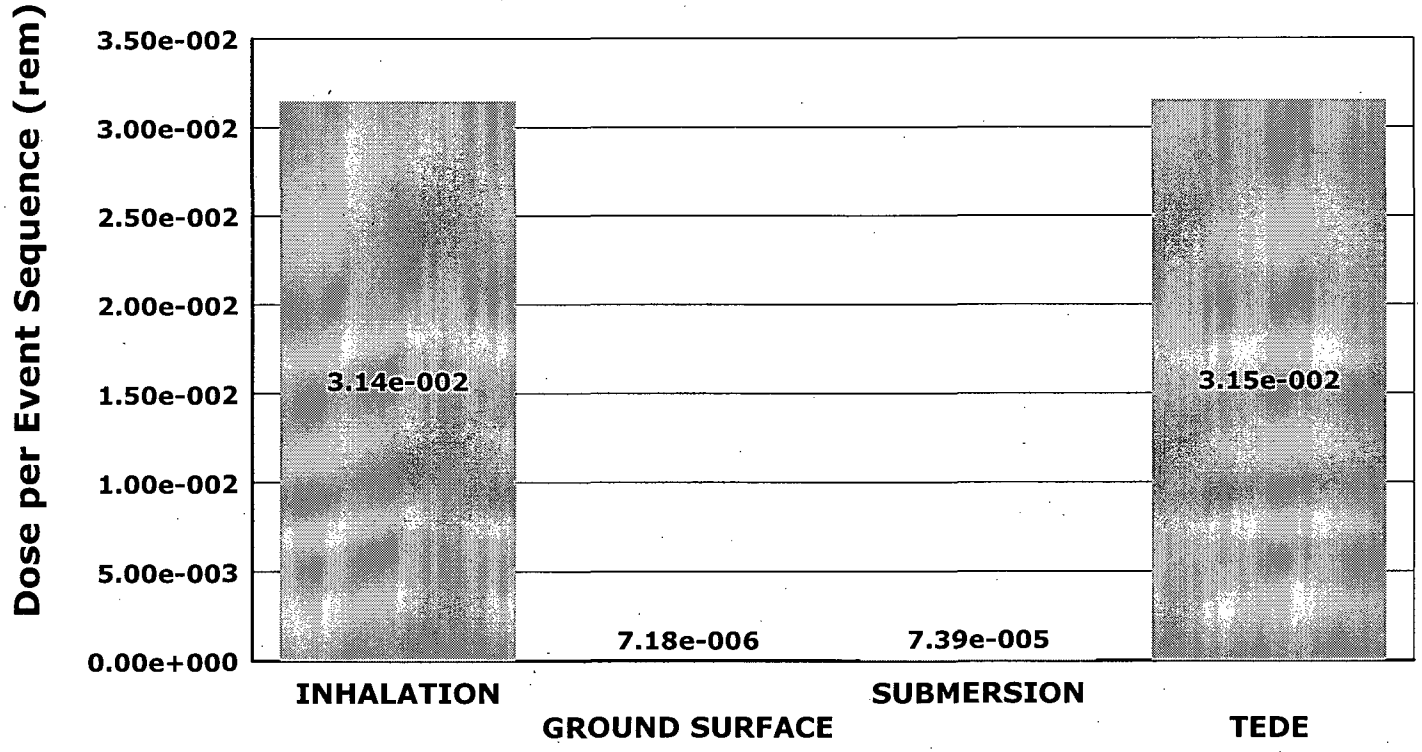
DRAFT FOR DISCUSSION



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

		Nominal	
Wind Speed m/s	U	3	
Building Length (m)	LB	150	Assume the length is oriented perpendicular to the wind flow
Building Width (m)	WB	135	Assume the width is oriented in the direction of wind flow
Building Height (m)	HB	34	
Source Height (m)	HS	34	

		in	cm	A (m2)	R2 (m)	R (m)	D (m)	nominal (n nominal area
duct size	w	16	40.64	0.185161	0.062572	0.229287	0.458573	0.5 0.19635

		room volur	building vc	air change flow (m3/s)		nominal velocity	plume rise (m)
duct flow	V	5097.032	20388.13	8	11.32674	57.68661	28.8433

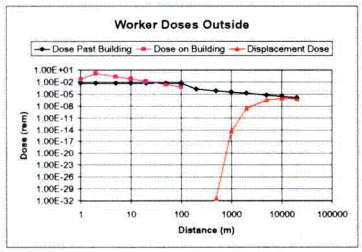
WB	150 m		
HB	34 m	85	
AB	5100 m2		
QB	178.5357 m		

		Minimum I	Maximum Distance
Window			
Same Side in Stack	8	0	1.5
Same Side near Stack	9	1.5	135
Cavity Zone	7	0	178.5357
Wake Zone	5	178.5357	∞
Displacement Zone			

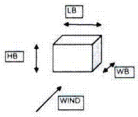
Note: minimum value for Cavity Zone is indeterminate; however x is the downwind distance, so it can be zero if the worker is not on the same side.

Note: The upper range of x is infinity; at large x, the effects of an elevated release and increased dispersion coefficient are negligible, so the concentration is the same as in the displacement zone.

	RSAC Output HS=0				HS=34 ON Building						HS=34 OFF Building					HS at 5HB HS=90		
	CEDE	chi/Q	X	X-3D				Corr	Facti	Dose	QB-X	X<QB	Corr	Facti	Dose	X	chi/Q	dose
				1	-0.5	In Stack	ON Buildir	FV	7.92E+00	3.94E-02	177.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	1		
				2	0.5	Near Stacl	ON Buildir	FS	2.24E+02	1.12E+00	176.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	2		
				5	3.5	Near Stacl	ON Buildir	FS	3.59E+01	1.79E-01	173.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	5		
				10	8.5	Near Stacl	ON Buildir	FS	8.97E+00	4.47E-02	168.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	10		
				20	18.5	Near Stacl	ON Buildir	FS	2.24E+00	1.12E-02	158.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	20		
	oz	CEDE	chi/Q	50	48.5	Near Stacl	ON Buildir	FS	3.59E-01	1.79E-03	128.5357	Cavity Zon	8.79E-01	4.38E-03	Displacem	50	chi/Q	dose
	2.37E+00	4.84E-03	1.12E-02	100	98.5	Near Stacl	ON Buildir	FS	8.97E-02	4.47E-04	78.53571	Cavity Zon	8.79E-01	4.38E-03	Displacem	100	0.00E+00	0.00E+00
	4.01E+00	1.56E-03	3.46E-03	200	198.5	Near Stacl	OFF Build	NA			-21.4643	Wake Zon	9.91E-02	1.54E-04	Displacem	200	0.00E+00	0.00E+00
	7.92E+00	3.27E-04	7.34E-04	500	498.5	Near Stacl	OFF Build	NA			-321.464	Wake Zon	1.93E-01	6.31E-05	Displacem	500	6.51E-32	2.94E-32
	1.29E+01	1.04E-04	2.33E-04	1000	998.5	Near Stacl	OFF Build	NA			-821.464	Wake Zon	3.05E-01	3.17E-05	Displacem	1000	6.24E-15	2.83E-15
	2.03E+01	3.46E-06	7.73E-06	2000	1998.5	Near Stacl	OFF Build	NA			-1821.46	Wake Zon	4.50E-01	1.55E-05	Displacem	2000	4.12E-09	1.87E-09
	3.44E+01	8.79E-06	1.98E-05	5000	4998.5	Near Stacl	OFF Build	NA			-4821.46	Wake Zon	6.50E-01	5.71E-06	Displacem	5000	6.47E-07	2.94E-07
	4.82E+01	3.40E-06	7.66E-06	10000	9998.5	Near Stacl	OFF Build	NA			-9821.46	Wake Zon	7.67E-01	2.61E-06	Displacem	10000	1.34E-06	6.07E-07
	6.33E+01	1.43E-06	3.22E-06	20000	19998.5	Near Stacl	OFF Build	NA			-19821.5	Wake Zon	8.44E-01	1.21E-06	Displacem	20000	1.17E-06	5.31E-07



FV = 1/(V [chi/Q])
FS = 30/(UA x^2 [chi/Q])
FC = 1/(UA HB K [chi/Q])
FW = oz / ozmod zmod = [(oz)2 + (AB/π)]^4



Note the jump between FV and FS at the common point x=1.5 m

FV/chi/Q	1/V	8.83E-02
FS/chi/Q	30/UA^x^2	4.44E+00 Which in this case is a factor of about 50

Note the jump between FC and FS at the end of the building, i.e. x=135 m.

FS/chi/Q	30/UA^x^2	5.49E-04
FC/chi/Q	1/UA^HB^K	9.80E-03

ENHANCED DEPOSITION PARAMETERS:
PARTICLE DIAMETER = 0.000E+00 (m) PARTICLE DENSITY = 0.000E+00 (g/cm3)

DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+02	0.000E+00	4.011E+00	2.372E+00	1.115E-02
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+02	0.000E+00	7.642E+00	4.011E+00	3.461E-03
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
5.000E+02	0.000E+00	1.826E+01	7.918E+00	7.337E-04
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+03	0.000E+00	3.531E+01	1.290E+01	2.330E-04
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+03	0.000E+00	6.764E+01	2.029E+01	7.732E-05
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
5.000E+03	0.000E+00	1.561E+02	3.442E+01	1.975E-05
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+04	0.000E+00	2.876E+02	4.818E+01	7.657E-06
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+04	0.000E+00	5.202E+02	6.333E+01	3.221E-06

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RADIOLOGICAL SAFETY ANALYSIS COMPUTER PROGRAM (RSAC-6)

(RSAC-6 REV 6.2, 03/11/02) SERIAL 1 DATE 20040720 TIME 17:52 PAGE 3
Dose Calcs for inhalation, NOT ingestion, ground surface, & submersi

DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+02	9.000E+01	4.011E+00	2.372E+00	0.000E+00
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+02	9.000E+01	7.642E+00	4.011E+00	0.000E+00
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
5.000E+02	9.000E+01	1.826E+01	7.918E+00	6.509E-32
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+03	9.000E+01	3.531E+01	1.290E+01	6.243E-15
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+03	9.000E+01	6.764E+01	2.029E+01	4.121E-09
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
5.000E+03	9.000E+01	1.561E+02	3.442E+01	1.472E-07
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
1.000E+04	9.000E+01	2.876E+02	4.818E+01	1.338E-06
DOWNWIND DISTANCE	STACK	SIGY	SIGZ	CHI/Q
HEIGHT (m)	(m)	(m)	(s/cu m)	
2.000E+04	9.000E+01	5.202E+02	6.333E+01	1.173E-06

*** FRACTION OF PLUME REMAINING AIRBORNE FOLLOWING DEPLETION BY DEPOSITION

24 0.00E+00 0.00E+00 2.94E-32 2.83E-15 1.87E-09 2.94E-07 6.07E-07 5.31E-07

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.14E-02	3.14E-02	3.14E-02	3.14E-02	3.14E-02	3.14E-02
GROUND SURFACE	7.18E-06	7.18E-06	7.18E-06	7.18E-06	7.18E-06	7.18E-06
SUBMERSION	7.39E-05	7.39E-05	7.39E-05	7.39E-05	7.39E-05	7.39E-05
TEDE	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02	3.15E-02

Davoud Feizollahi

From: Roland Benke
Sent: Friday, July 28, 2006 10:49 AM
To: Ali Simpkins
Subject: FW: Scientific Notebook
Attachments: SN612-8E.wpd; wdmodelevalGAmod+06.xls; composite1n00.xls; downwindworker2.wpd; downwindworker3.wpd; Note on Dose Calculations.wpd; SN612-8E.wpd; wdmodeleval.xls; wdmodelevalGAmod.xls; 1115.xls; 1101.xls; 1102.xls; 1103.xls; 1104.xls; 1105.xls; 1106.xls; 1107.xls; 1108.xls; 1112.xls; 1112inp.xls; 1113.xls; 1114.xls; 1215.xls; 1201.xls; 1202.xls; 1203.xls; 1204.xls; 1205.xls; 1206.xls; 1207.xls; 1208.xls; 1212.xls; 1213.xls; 1214.xls; 1315.xls; 1301.xls; 1302.xls; 1303.xls; 1304.xls; 1305.xls; 1306.xls; 1307.xls; 1308.xls; 1312.xls; 1313.xls; 1314.xls; 2115.xls; 2101.xls; 2102.xls; 2103.xls; 2104.xls; 2105.xls; 2106.xls; 2107.xls; 2108.xls; 2112.xls; 2113.xls; 2114.xls; 2215.xls; 2201.xls; 2202.xls; 2203.xls; 2204.xls; 2205.xls; 2206.xls; 2207.xls; 2208.xls; 2212.xls; 2213.xls; 2214.xls; 2315.xls; 2301.xls; 2302.xls; 2303.xls; 2304.xls; 2305.xls; 2306.xls; 2307.xls; 2308.xls; 2312.xls; 2313.xls; 2314.xls

Ali,

More documentation of the outdoor worker dose calculations performed by our consultant attached.

Roland

-----Original Message-----
From: Bis Dasgupta [mailto:bdasgupta@swri.edu]
Sent: Thursday, July 27, 2006 3:10 PM
To: 'Roland Benke'
Subject: FW: Scientific Notebook

-----Original Message-----
From: Norman A. Eisenberg [mailto:naeisenberg@comcast.net]
Sent: Wednesday, April 19, 2006 7:59 PM
To: Biswajit Dasgupta
Subject: Scientific Notebook

Dear Biswajit Dasgupta:

Attached is a copy of my Scientific Notebook and associated files.

I also have the PDSA Tool input files, if you wish to have them; however, there are already a large number of files attached.

Please let me know if this satisfies your need.

NAE

Norman A. Eisenberg, Ph.D.
3200 N. Leisure World Blvd. Apt. 416
Silver Spring, MD 20906-7615

301-438-2226 naeisenberg@comcast.net

Return-path: <rbenke@cnwra.swri.edu>
Received: from PHOENIX ([129.162.200.28])
by rogain.cnwra.swri.edu (Sun ONE Messaging Server 6.0 (built Oct 29 2003))
with ESMTP id <0J34002UTBTS3JB0@rogain.cnwra.swri.edu> for
asimpkins@cnwra.swri.edu; Fri, 28 Jul 2006 09:49:11 -0500 (CDT)
Date: Fri, 28 Jul 2006 09:48:51 -0500
From: Roland Benke <rbenke@cnwra.swri.edu>
Subject: FW: Scientific Notebook
To: Ali Simpkins <asimpkins@cnwra.swri.edu>
Reply-to: rbenke@cnwra.swri.edu
Message-id: <00b101c6b254$f1839fd0$1cc8a281@cnwra.swri.edu>
MIME-version: 1.0
X-MIMEOLE: Produced By Microsoft MimeOLE V6.00.2800.1506
X-Mailer: Microsoft Outlook CWS, Build 9.0.2416 (9.0.2910.0)
Content-type: multipart/mixed;
boundary="----=_NextPart_000_00B2_01C6B22B.08AD97D0"
Importance: Normal
X-Priority: 3 (Normal)
X-MSMail-priority: Normal
Original-recipient: rfc822;asimpkins@cnwra.swri.edu

SCIENTIFIC NOTEBOOK

665-8E

SN612
-8E

of

Norman A. Eisenberg
3200 N. Leisure World Blvd. Apt. 416
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for
Southwest Research Institute
Center for Nuclear Waste Regulatory Analyses
San Antonio, Texas

INITIAL ENTRIES

Scientific Notebook: #665-8E

Issued to: Norman A. Eisenberg

Issue Date: June 8, 2004

Account Number:

Title: Repository Safety Analysis

Participants: N. Eisenberg
Biswajit Dasgupta, Project Leader
Asadul Chowdhury, Project Manager

Objective:
This scientific notebook will document the work related to repository safety.

In-Process Entries

6/14/04 PCSA Tool Evaluation:

Evaluate the RSAC module of the PCSA Tool for its ability to model onsite worker dose, especially the treatment of building wakes.

Building characteristics from B. Dasgupta e-mail message of 6/8/04:

1. The building dimensions are following

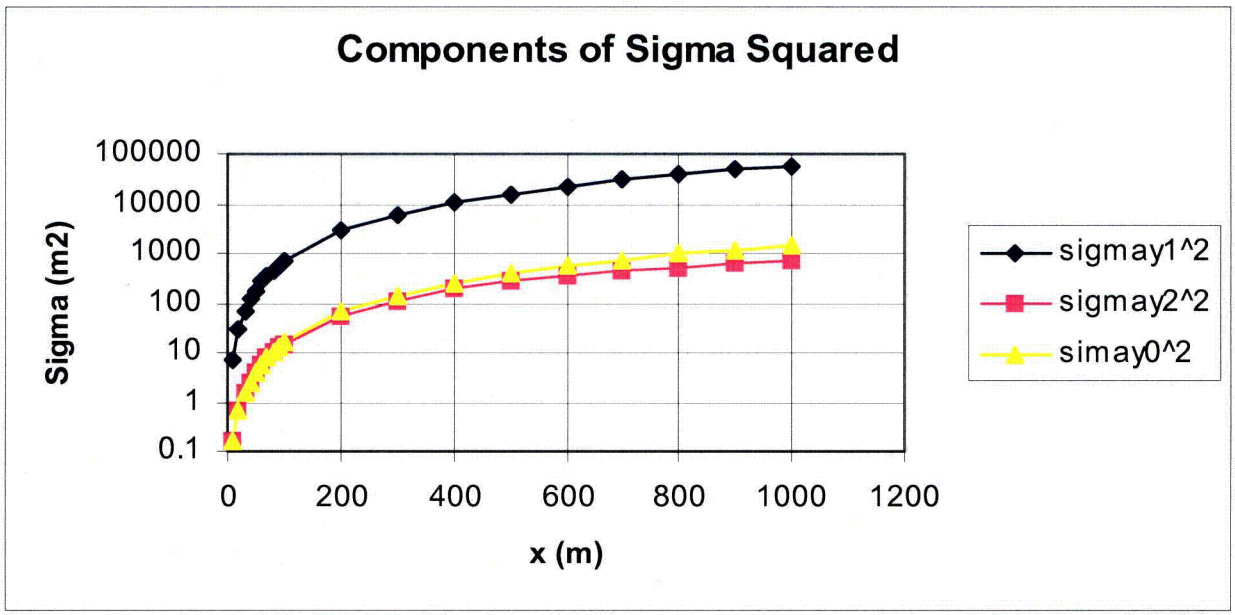
Length: 492 ft (150 m)
Width: 442 ft (135m)
Height: 114ft (34 m)

2. Stack was not observed in the drawings

3. Estimated distances of adjacent buildings: 200 ft on one side and 300 ft on the other side.

From these data the range of cross-sectional areas are: 34m x 135m = 4590m^2 to 34m x 150m = 5100m^2. A good nominal value is probably 5000m^2.

This value for area was used, along with three values of wind speed (2.5 m/s nominal, 0.25 m/s low, 6 m/s high) to evaluate the various terms in Equation A-13 (the equation for transverse dispersion (sigma y) of the RSAC code manual. Equations (A-15) and (A-17) were used respectively for "low wind speed corrections" and "building wake corrections", respectively. For the standard Hilsmeier-Gifford dispersion coefficient, the analytical expressions in Table 4-7



of "Chemical Fate and Transport in the Environment" by Hemond and Fechner-Levy was used. Category F stability class was assumed for consistency with cases in the PCSA Tool.

Data compiled in the file, sigma012.xls, show that the correction for low wind speed dominates the value for sigma, as shown in the following graph, which is for a wind speed of 2.5 m/s:

This shows that the square of the building wake correction (sigmay2) is slightly larger than the square of the nominal dispersion coefficient (sigmay0); however, the correction for low wind

speed appears to be a factor of 15 to 90 higher than either of these two. This seems to indicate that the concentration corrected for a building wake (using both correction terms) will be significantly lower than the concentration calculated using just the normal dispersion coefficient. This seems contrary to the IAEA Safety Series #19 concept in which the concentrations close to the building (especially in the cavity zone and wake zone) are higher than one would predict using the normal dispersion coefficients.

The conclusion from this is that if this is what the RSAC code is doing, it may not be suitable for modeling repository releases. Two lines of investigation should be pursued: (1) run RSAC for simple cases to confirm that the code follows the equations in Appendix A of the documentation and (2) obtain and evaluate NUREG/CR 6331 (Ramsdell, J.V., Jr., Simonen, C.A., 1997, Atmospheric Relative Concentrations in Building Wakes, Report NUREG/CR-6331. U.S. Nuclear Regulatory Commission, Washington, D.C.), which is cited as the source for these models, to determine that the model is appropriate and correctly implemented.

6/17/04 Further PCSA Tool Evaluation:

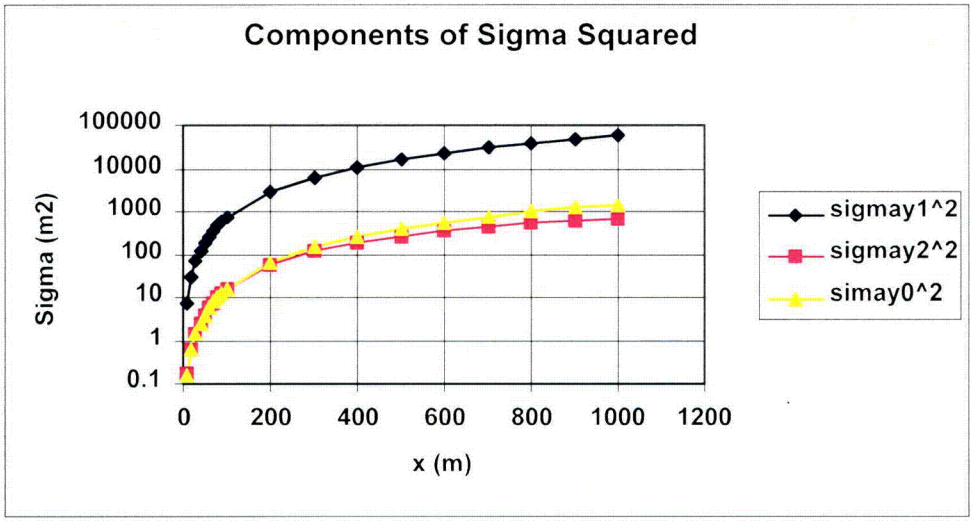
Some of this entry repeats the previous entry, because it is largely taken from a note sent to the CNWRA staff.

First I examined the analytical formulation used by RSAC to model building wakes, as stated in Appendix A, pp. 7-8 of the RSAC manual. The square of the air dispersion coefficients in the transverse (y) and vertical (z) directions are assumed to be the sum of three components squared (equations A-13&14). The three components are:

1. the normal, flat terrain air dispersion coefficient -- σ_0;
2. a term representing a "low wind speed" correction -- σ_1;
3. a term representing the building wake -- σ_2;

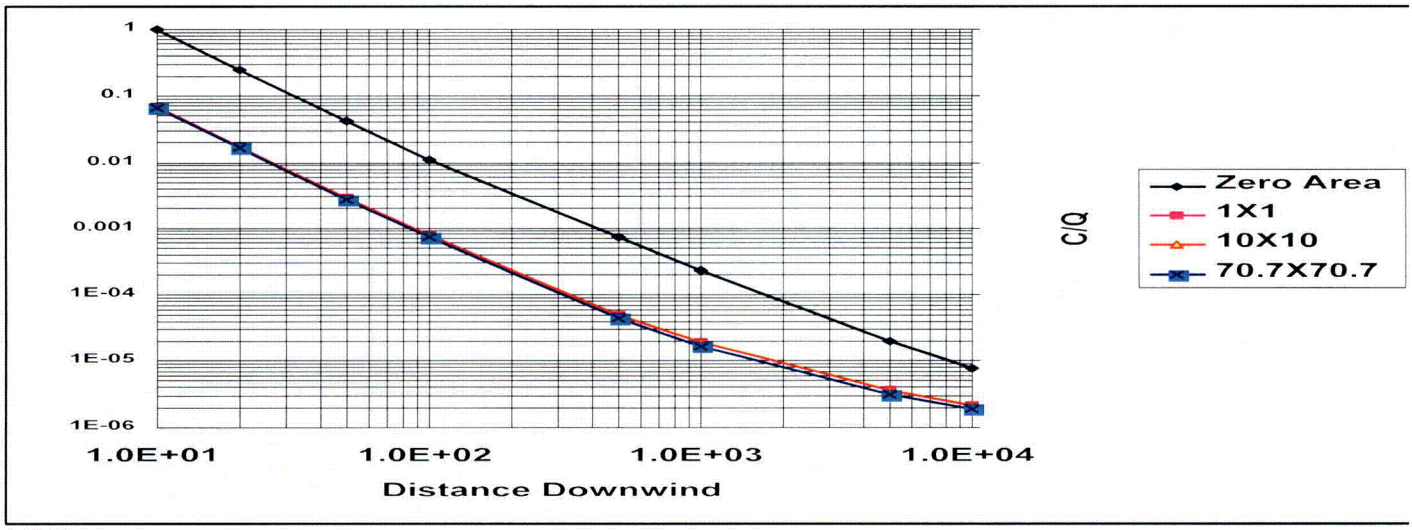
At first examination, this approach does not seem consistent with the IAEA concepts of a cavity zone and wake zone, both of which may have concentrations higher than one would expect in flat terrain at the same distance from the source. By adding squares of sigma's the concentrations can only be lowered.

To check this, I computed each term at various distances. I only did this for the transverse, y, dispersion coefficient, but the same trend should hold for the vertical coefficient. For the σ_0 I used an analytical expression (Table 4-7 of "Chemical Fate and Transport in the Environment" by Hemond and Fechner-Levy) for stability class F. It seemed to match up pretty well with RSAC values. The result of these computations is presented graphically below:



This shows that the square of the building wake correction (sigmay2; pink) is slightly larger than the square of the nominal dispersion coefficient (sigmay0; yellow); however, the correction for low wind speed appears (sigmay1-dark blue) to be a factor of 15 to 90 higher than either of these two, depending on the distance from the source. This seems to indicate that the concentration corrected for a building wake (using both correction terms) will be significantly lower than the concentration calculated using just the normal dispersion coefficient. Since the low wind speed term appears to dominate, this means that the result will depend very little on the building area chosen; for the repository problem, this doesn't seem correct.

To confirm that RSAC was indeed using this approach, a series of computer calculations using RSAC were undertaken. At the suggestion of George Adams, these runs were accomplished through the "Advanced RSAC" feature of the PCSA tool. The results of these calculations are shown below:



Doses were calculated at a sequence of distances: 10, 20, 50, 100, 500, 1000, 5000, and 10,000 m. This was accomplished using the feature of the RSAC code that allows specification of up to 8 distances (however, contrary to the impression in the manual, the instruction line must always be 5101, not 510X, X=1, 2...8, as stated in the text). Since RSAC reports out Chi over Q (C/Q in the above graph), which is the concentration normalized by release rate, this measure of downwind concentration was used. The above graph is both dramatic and definitive. To activate the building wake feature in RSAC, one must assume a ground level release; this was done. However, assuming a ground-level release is not a very physical assumption for the repository case. For no entries for building width (DUMMY) and height (DUMMZ), the building wake correction factor is not supposed to be activated; this appears to be the case as shown on the curve marked "Zero Area". For building dimensions of 1m X 1m, 10m X 10m, and 70.7 m X 70.7 m, concentrations appear to be anywhere from a factor of about 0.07 to .25 smaller than the "Zero Area" case; furthermore, the difference in concentrations for these three cases are slight. This is even for a difference in area by a factor of 5000. [Note: the case of 70.7 m X 70.7 m has an area of 5000 m^2, which is typical of the cross sectional area of the current repository design with building dimensions of Length: 492 ft (150 m); Width: 442 ft (135m); Height: 114ft (34 m); since only area is used in the formula, this should be OK.] Another anomaly apparent is that even a small obstacle of 1m high by 1m wide will cause a significant decrease in concentration; this does not appear to be a physically correct result.

This appears to show that the concentrations (and therefore doses) calculated by RSAC, when the building wake correction is activated, is much lower than the corresponding flat terrain concentrations. This is inconsistent with the IAEA approach and inconsistent with most of the

approaches described in a standard text on these types of calculations ("Atmospheric Science and Power Production", DOE/TIC-27601, D. Randerson, Ed.). Therefore this does not appear to be a good approach for the PCSA Tool. It is not clear whether this approach: (1) is not correctly implemented in the RSAC code, (2) is correctly implemented, but has not been limited to large distances, or (3) is not appropriate for fuel cycle facilities and accidents. I am trying to obtain NUREG/CR 6331, which is cited in the RSAC manual as the basis for their model, to clarify this.

There appears to be three alternative approaches to this problem:

1. Find another code that may implement a near-field wake calculation suitable for fuel cycle facilities and accidents;
2. Program an adaptation of the IAEA approach, including the source term and dose calculation;
3. Scale-up flat terrain RSAC dose calculations for a number of the near field conditions postulated in the IAEA document.

I would prefer to pursue approach number 3 for several reasons:

1. The release and dose calculations are already embedded in the RSAC code;
2. This would almost guarantee consistency between these calculations and other dose estimates produced using the RSAC code (e.g., public doses);
3. The RSAC output contains the "Chi over Q" value used for the dose calculation; knowing this value would make scaling the results relatively simple.

I would like to discuss the next step forward with George Adams, Biswajit Dasgupta, and others, as appropriate. Issues for discussion include:

1. Whether the output of an RSAC run can be processed by the computer to provide the scaled doses;
2. Whether it is appropriate to eliminate ingestion and contaminated ground plane doses; I would assume that there should be no food crops grown on-site and any seriously contaminated ground should be cleaned up;
3. How many receptors on-site should be modeled and how should they be located.

Records of computer code runs (the PCSA Tool) are contained in the directory: "RSAC Tests" which is a subdirectory of this Scientific Notebook directory.

7/02/04 Initial Development of Outside Worker Dose Calculation:

An initial draft of an approach to estimating outside worker dose was compiled in the document: "downwindworker2.wpd" which is included in the scientific notebook directory. This was sent to G. Adams and B. Dasgupta.

7/07/04 Minor Issue:

This is just a minor issue, but one that could be easily addressed in the next update to the PCSA Tool. On the form for the internal worker dose, there is a tab "Source Term". This tab lists the dose conversion factors (DCF's) for inhalation and submersion for each radionuclide used. The column headings for the submersion DCF's are: "Sv/Bq" and "Rem/Ci". I believe it may be more correct to make these headings: "(Sv/s)/(Bq/m3)" and "(Rem/s)/(Ci/m3)". The column headings for the inhalation DCF's should remain as they are. CNWRA staff was apprised of this minor issue.

7/21/04 Further Development of Outside Worker Dose Approach:

Several documents related to the worker dose problem were developed and transmitted to the CNWRA staff for review and evaluation: 1. Note on Dose Calculations for Downwind Workers: including (1) a small correction and rationale for the approach to dose calculation; (2) sample calculations for worker doses with a discussion; and (3) an explanation/derivation of the formulas proposed for this calculation, which are adaptations of an IAEA approach. [Note on Dose Calculation.wpd]; 2. The spreadsheet that supports the dose calculations. [wdmodeleval.xls]; 3. The output from two RSAC runs that support the dose calculations. [rsac6test11.out; rsac6test12.out in the "RSAC Tests" directory]; 4. A revised "Approach for Implementing Downwind Worker Dose Model" with suggestions for enhancements based on lessons-learned from the sample calculations [downwindworker3.wpd]. Also included is a flow-chart.

7/21/04 Clarification of Outside Worker Dose Approach:

The following clarification of the previously submitted approach was provided to G. Adams:

1. The building height and width should be zero for all RSAC runs; we do not want to invoke the RSAC model for building wakes. Although the RSAC runs should have zero building height and width, the PCSA Tool patch should include finite values for these dimensions.
2. The RSAC runs should be at a distance of 100m for all cases except the displacement zone and the **wake zone**.
3. For the **wake zone**, the distance should be whatever is specified by the user (but it should not be less than the extent of the cavity zone). The receptor elevation should be zero.
4. For the displacement zone, the receptor elevation should be zero. For the RSAC runs, the stack height should be as specified by the user.

8/04/04 Probably Error in Spreadsheet for Outside Worker Dose:

G. Adams submitted a revised spreadsheet indicating the likely omission of a factor of pi from a set of calculations. See [wdmodelevalGAmod.xls].

8/04/04 Resolution of Error in Spreadsheet for Outside Worker Dose:

With regard to the omission of the factor of pi, this was an error. I think what may have happened is that I copied the formulas from the WordPerfect document, but the symbols didn't reproduce in Excel. I confirmed that the factor should be there, so the doses are lower by a factor of about 3 in the Cavity Zone.

With regard to the limit in Window 9 so the "On the Building" dose cannot be greater than the "In the Stack" dose, this is also correct; however, I did not implement the suggested change in the spreadsheet.

To reconfirm our earlier conversation, it should be correct to list dose contributions by radionuclide and to scale these by the same correction factors that are used for total dose. There may be a small error, because some nuclides will be deposited out and others will not. However, at these distances, I expect these errors to be very small.

8/12/04 Results from Production Runs of PCSA Tool including Outside Worker Dose Module:

Data characterizing doses to workers outside are documented. This is the result of 32 PCSA Tool runs. A WordPerfect document [OutsideWorkerDoses.wpd] contains a text table characterizing the various runs and contains a graph with the different flow zones indicated. An Excel spreadsheet [combined.xls] contains the same information and a graph without the flow zones designated. Files are in the "OutsideWorker100" directory.

One surprising result is that in some cases the ground plane dose dominates. For high doses, this may not be reasonable, because actions will be taken to clean up the contamination. Also, for dose to persons on the building, some sort of remediation is very likely and the "ground plane" has limited extent. On the other hand, these calculations show the need for some cleanup action (possibly another item identified for review focus?). According to how I read the RSAC manual, the code as currently configured assumes a 1-year exposure to ground contamination in performing the dose calculation. This time seems excessive considering: (1) the time of exposure for inhalation and cloud immersion is about 3 seconds; (2) even if cleanup is not performed, resuspension and weathering is likely to reduce the level of contamination

considerably over a year (I do not believe RSAC considers such processes). One area where the results seem to be driven by this are runs 111-114, in the cavity zone. In these cases, the inhalation dose dominates, except for the BWR without the HEPA on (112); for that case, ground surface dose is highest. Not so for the PWR cases (113 & 114). This is likely due to the different inventory of gamma emitters (probably Co-60) in the two types of fuels.

8/12/04 Results from Production Runs of PCSA Tool for the Inside Worker Dose:

Several files provide the results of the inside worker analysis: (1) a combined spreadsheet for both cases (1 BWR and 1PWR) [combinedinside.xls], (2) a report for BWR [101.doc], and (3) a report for the PWR [102.doc]. There doesn't seem much to say about these except: (1) inhalation dose dominates; (2) the PWR dose is a little over twice the BWR dose; and (3) the doses are large: 34 rem for BWR; 71 rem for PWR. This may result from the 8 hour exposure assumption. Files are in the "InsideWorker100" directory.

2/7/06 Attempted Worker Dose Run:

Attempting to run outside worker dose per instructions from G. Adams. Input data through screens to obtain output. Then "load saved analysis" to input source term assumptions over writes previously input values for building height, stack height, building width, etc. It is not clear at all that the outside worker dose modeling is being invoked (it appears to be a straight RSAC run). Need to seek clarification to be able to perform analyses.

2/7/06 Clarification of Outside Worker Run:

Discussion of issue with G. Adams clarified code operation. "load saved analysis" inputs inventories for different cases, but does not input release fractions, which must be entered manually. Also meteorological conditions, i.e. wind speed and stability class must be entered manually. If "perform analysis" is selected, the outside worker dose calculation is performed, but with RSAC inputs regarding inventory, release fraction, and meteorological conditions as stated.

2/7/06 Run 1001:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR

	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

2/7/06 Run 1002:

Parameter Category	**Parameter**	**Value**
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)

Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	50 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.51E-02
GROUND SURFACE		4.05E-19
SUBMERSION		3.55E-05
TEDE		1.52E-02

2/7/06 Run 1003:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m

	receptor distance	100 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		3.78E-03
GROUND SURFACE		1.01E-19
SUBMERSION		8.89E-06
TEDE		3.79E-03

2/7/06 Run 1004:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	200 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.80E-03
GROUND SURFACE		2.24E-20
SUBMERSION		7.42E-06
TEDE		1.81E-03

2/7/06 Run 1005:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	500 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		7.34E-04
GROUND SURFACE		2.72E-20
SUBMERSION		6.18E-06
TEDE		7.41E-04

2/7/06 Run 1006:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
GROUND SURFACE		8.35E-19
SUBMERSION		1.52E-04
TEDE		3.16E-02
INHALATION		3.15E-02

2/7/06 Run 1007:

Parameter Category	Parameter	Value

Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	50 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.51E-02
GROUND SURFACE		4.02E-19
SUBMERSION		7.32E-05
TEDE		1.52E-02

2/7/06 Run 1008:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative

Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	100 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		3.79E-03
GROUND SURFACE		1.00E-19
SUBMERSION		1.83E-05
TEDE		3.80E-03

2/7/06 Run 1009:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m

	building width	75 m
	receptor distance	200 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		8.33E-04
GROUND SURFACE		1.01E-20
SUBMERSION		7.31E-06
TEDE		8.40E-04

2/7/06 Run 1010:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	500 m
	receptor on same surface	Yes

	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

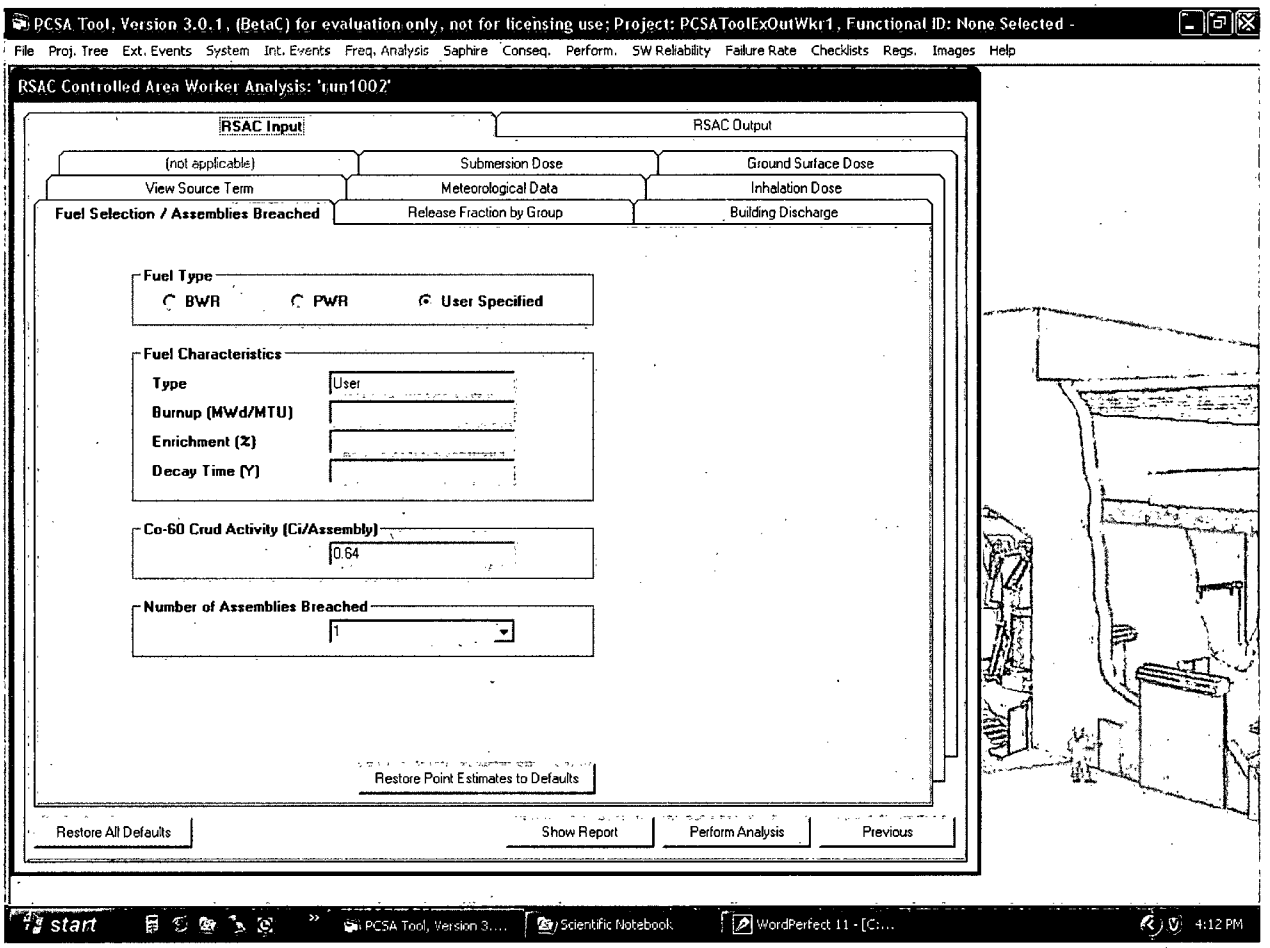
Pathway		Mean
INHALATION		3.07E-04
GROUND SURFACE		1.10E-20
SUBMERSION		5.05E-06
TEDE		3.12E-04

2/8/06 Run Series 1100

Parameter Category	Parameter	Potential Values
Source Term	Inventory	PWR_AVE_WKR; BWR_AVE_WKR; PWR_MAX_WKR; BWR_MAX_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative / Not Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F), 4(D), 1(A)
Outside Worker	stack height	35 m
	building height	35 m, 10 m
	building width	75 m
	receptor distance	10, 50, 100, 200, 500
	receptor on same surface	Yes / No
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Ground Surface Dose	Ground surface exposure time	0.22831 (2000 h/ 8760 h)
	Building shielding factor	0.7

Screenshots of RSAC Input Screens Follow:


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
(not applicable)
Submersion Dose
Ground Surface Dose
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
Fuel Type
BWR
PWR
User Specified
Fuel Characteristics
Type
User
Burnup (MWd/MTU)
Enrichment (%)
Decay Time (Y)
Co-60 Crud Activity (Ci/Assembly)
0.64
Number of Assemblies Breached
1
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
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PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

Release Fraction Source: User Specified

Description: User-Specified values (initially PCSA Tool defaults)

Group ID	Group Name	Release Fraction	HEPA Mitigation Operative	Radionuclides In Group
Group 1	H-3	3.00e-01	1.0	H-3
Group 2	Ruthenium	2.00E-05	0.0003	Ru-106
Group 3	Iodine	2.30E-03	1.0	I-129
Group 4	Cesium	2.00E-05	0.0003	Cs-134, Cs-135, Cs-137
Group 5	Noble gases	3.00E-01	1.0	Ar-39, Kr-85, Rn-219, Rn-220, Rn-222
Group 6	Strontium	2.00E-05	0.0003	Sr-90
Group 8	Co-60 Crud	1.50e-01	0.0003	Co-60 Crud
Group 9	Other particulates and fuel fines	2.00E-05	0.0003	All others

HEPA Filtration: Operative / Inoperative

Release in: Air / Pool

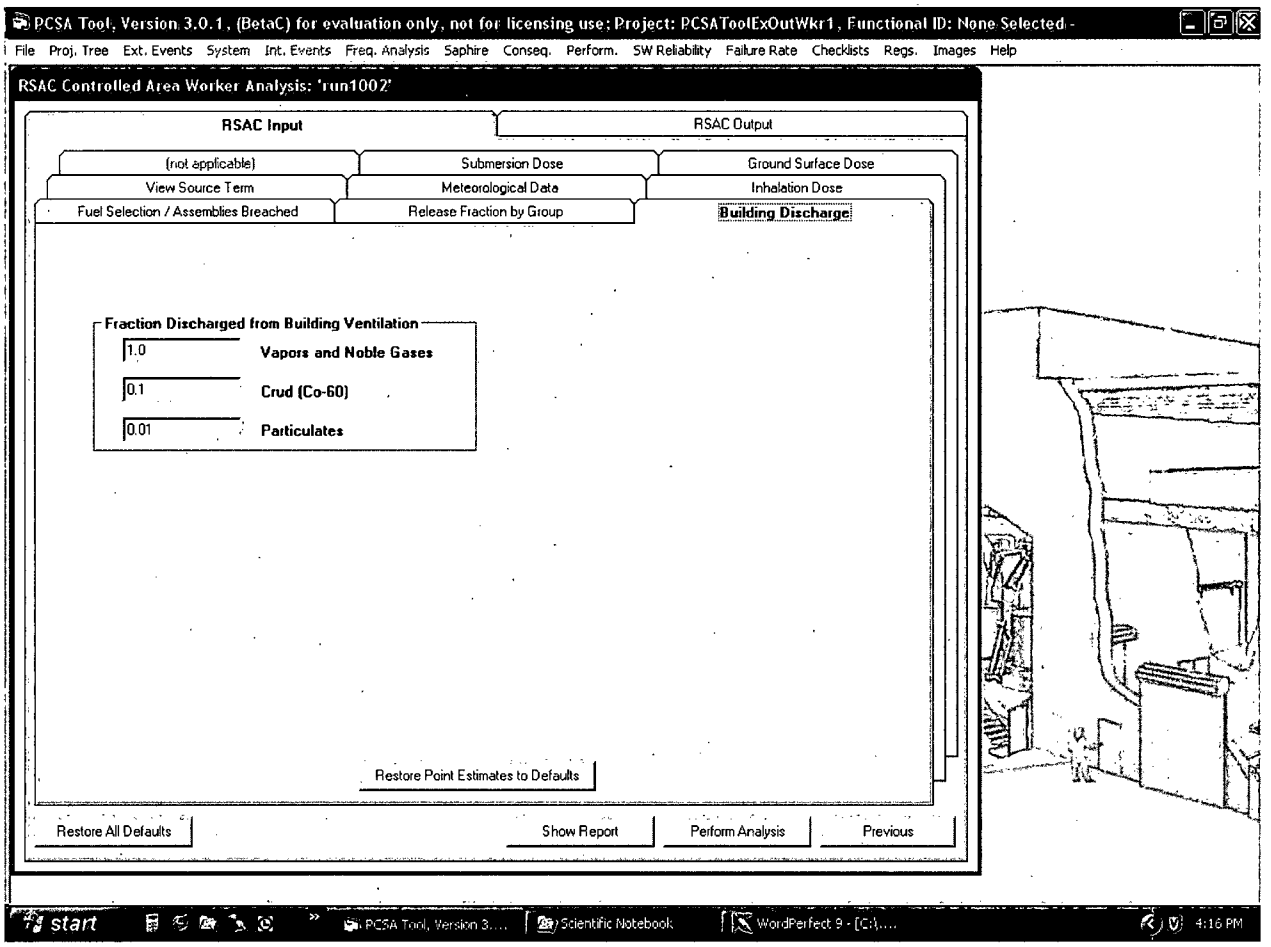
Restore Release Fraction Point Estimates to Defaults

Restore HEPA Mitigation to Defaults

Restore All Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:15 PM


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
(not applicable)
Submersion Dose
Ground Surface Dose
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
Fraction Discharged from Building Ventilation
1.0
Vapors and Noble Gases
0.1
Crud (Co-60)
0.01
Particulates
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
Scientific Notebook
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PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Radionuclide	Inventory (Ci/Assembly)	Release Fraction	LHS	Bldg Discharge Fraction	HEPA Mitigation	Assemblies	Released Activity (Ci)
H 3	1.14E+02	3.00e-01	No	1.00e+00	1.00e+00	1	3.42e+01
C 14	3.32E-01	2.00E-05	No	1.00e-02	3.00e-04	1	1.99e-11
CL 36	6.80E-03	2.00E-05	No	1.00e-02	3.00e-04	1	4.08e-13
AR 39	5.22E-05	3.00E-01	No	1.00e+00	1.00e+00	1	1.57e-05
FE 55	3.46E+00	2.00E-05	No	1.00e-02	3.00e-04	1	2.08e-10
NI 59	2.09E+00	2.00E-05	No	1.00e-02	3.00e-04	1	1.25e-10
CO 60	3.13E+02	2.00E-05	No	1.00e-02	3.00e-04	1	1.88e-08
CO 60 Crud	6.40e-01	1.50e-01	No	1.00e-01	3.00e-04	1	2.88e-06
NI 63	2.52E+02	2.00E-05	No	1.00e-02	3.00e-04	1	1.51e-08
SE 79	4.57E-02	2.00E-05	No	1.00e-02	3.00e-04	1	2.74e-12
KR 85	1.13E+03	3.00E-01	No	1.00e+00	1.00e+00	1	3.39e+02
SR 90	2.72E+04	2.00E-05	No	1.00e-02	3.00e-04	1	1.63e-06
Y 90	2.72E+04	2.00E-05	No	1.00e-02	3.00e-04	1	1.63e-06
MO 93	4.14E-02	2.00E-05	No	1.00e-02	3.00e-04	1	2.48e-12
NB 93M	1.30E+01	2.00E-05	No	1.00e-02	3.00e-04	1	7.80e-10
ZR 93	8.94E-01	2.00E-05	No	1.00e-02	3.00e-04	1	5.36e-11
NB 94	8.39E-01	2.00E-05	No	1.00e-02	3.00e-04	1	5.03e-11
TC 99	8.98E+00	2.00E-05	No	1.00e-02	3.00e-04	1	5.39e-10
RH106	1.23E-02	2.00E-05	No	1.00e-02	3.00e-04	1	7.38e-13
RU106	1.23E-02	2.00E-05	No	1.00e-02	3.00e-04	1	7.38e-13
PD107	8.41E-02	2.00E-05	No	1.00e-02	3.00e-04	1	5.05e-12
SN121M	1.59E+00	2.00E-05	No	1.00e-02	3.00e-04	1	9.54e-11
SB125	9.71E+00	2.00E-05	No	1.00e-02	3.00e-04	1	5.83e-10

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:17 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Input Parameter	Input Value	Remarks	Default Value
Average wind velocity (m/s)	0.9	float - Most-probable velocity (site-specific estimate)	4.3
Stack release height (m)	0.0	float - Estimation of stack height	40.0
Mixing layer height (m)	1420.0	float - Average mixing height based data from Desert Rock, NV	1420.0
Air density (g/m^3)	1.29e+03	float - Site-specific mean value (Mohanty et al., 2000)	1.29e+03
Wet deposition scavenging coefficient	0.0	float - No plume depletion by wet deposition	0.0
Plume depletion by dry deposition	1	integer Yes	1
Deposition velocities to be entered	Yes		Yes
Deposition velocities (m/s) Solids	0.001	float - RSAC-5 default value	0.001
Deposition velocities (m/s) Halogens	0.01	float - RSAC-5 default value	0.01
Deposition velocities (m/s) Noble gases	0.0	float - RSAC-5 default value	0.0
Deposition velocities (m/s) Cesium	0.001	float - RSAC-5 default value	0.001
Deposition velocities (m/s) Ruthenium	0.001	float - RSAC-5 default value	0.001
Downwind distance (m)	100.0	float - Site-specific approximation (U.S. Department of Energy, 1998c)	11000.0
Linear constant in decay function (1/s)	1.0	float - RSAC default value for instantaneous release	1.0
Exponential constant in decay function	0.0	float - RSAC default value for instantaneous release	0.0
Crosswind distances to be entered	No	text - Assuming critical group is directly downwind	No
Diffusion definition	2	integer - Program calculates standard deviations	2
Type of sigma (standard deviation) set	1	integer - Hilsmeier-Gifford for < 15 min releases at desert sites	1
Building width (m)	0.0	float - RSAC-5 default value	0.0
Building height (m)	0.0	float - RSAC-5 default value	0.0
Weather class	6	integer - 6 relates to class F, the most-probable class (site-specific	6
Plume rise indicator	0	integer - No plume rise	0

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:18 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

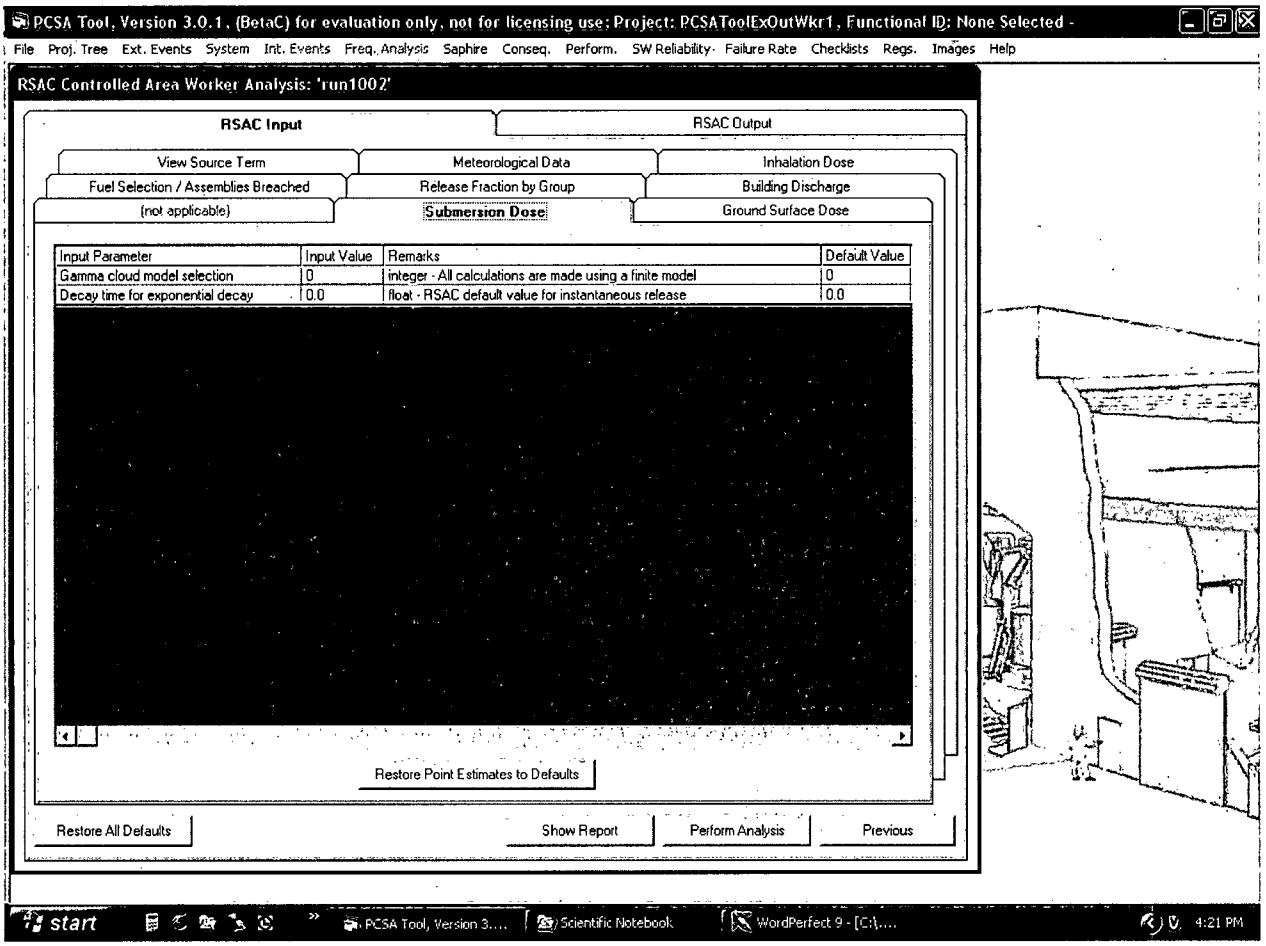
View Source Term | Meteorological Data | Inhalation Dose

Input Parameter	Input Value	Remarks	Default Value
Type of dose calculation	1	integer - International Commission on Radiological Protection-30 inhalation	1
Output control for dose	-2	integer - Only dose summaries	-2
Dose unit	1	integer - Output in rem	1
Elements for calculation	0	integer - All elements	0
Organ choice	1	integer - All organs	1
For inhalation, breathing rate (m^3/s)	3.33e-04	float - RSAC 24-hour average default	3.33e-04
Decay time for exponential decay	0.0	float - RSAC default value for instantaneous release	0.0
Activity mean aerodynamic diameter	1.0	float - RSAC default value	1.0
Clearance classes	3	integer - RSAC default classes	3

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:20 PM


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
(not applicable)
Submersion Dose
Ground Surface Dose
Input Parameter | Input Value | Remarks | Default Value
Gamma cloud model selection | 0 | integer - All calculations are made using a finite model | 0
Decay time for exponential decay | 0.0 | float - RSAC default value for instantaneous release | 0.0
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
Scientific Notebook
WordPerfect 9 - [C:\....
4:21 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker: New or Modified Analysis

RSAC Input | RSAC Output

View Source Term | Meteorological Data | Inhalation Dose

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | **Ground Surface Dose**

Input Parameter	Input Value	Remarks	Default Value
Type of dose calculation	4	integer - Ground surface dose calculation	4
Output control for dose	-2	integer - Only dose summaries	-2
Dose unit	1	integer - Output in rem	1
Elements for calculation	0	integer - All elements	0
Organ choice	1	integer - All organs	1
Decay time for exponential decay	0.0	float - RSAC default value for instantaneous release	0.0
TB - Ground surface exposure time (y)	0.22831	float - Annual dose is calculated	1.0
Building shielding factor (dimensionless)	0.7	float - Assigns RSAC default value of 0.7	0.7

Restore Point Estimates to Defaults

Restore All Defaults | Load Saved Analysis | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | Calculator | 4:23 PM

2/8/06 Run 1101

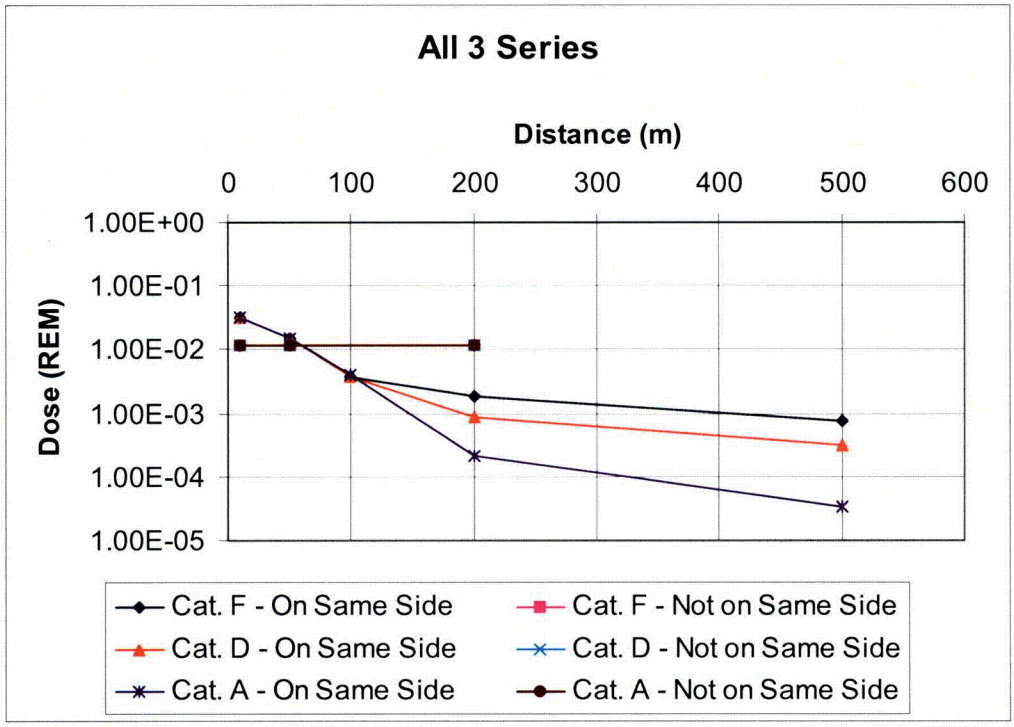
Parameter Category	Parameter	Potential Values
Source Term	Inventory	PWR_AVE_WKR;
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative / Not Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s
Ground Surface Dose	Ground surface exposure time	0.22831 (2000 h/ 8760 h)
	Building shielding factor	0.7

Subsequent Runs in Series 1100, 1200, and 1300 use these data except for receptor distance and stability class as shown in the following Table 1100-1300:

Run Identifier	Receptor Distance	On Same Surface	Stability Class
1101	10	Y	6
1102	50	Y	6

1103	100	Y	6
1104	200	Y	6
1105	500	Y	6
1106	10	N	6
1107	50	N	6
1108	100	N	6
1201	10	Y	4
1202	50	Y	4
1203	100	Y	4
1204	200	Y	4
1205	500	Y	4
1206	10	N	4
1207	50	N	4
1208	100	N	4
1301	10	Y	1
1302	50	Y	1
1303	100	Y	1
1304	200	Y	1
1305	500	Y	1
1306	10	N	1
1307	50	N	1
1308	100	N	1

2/8/06



Doses (TEDE from inhalation (mostly), submersion and ground plane) are given in REM and plotted below:

for this configuration (35 m tall building and stack) the end of the cavity zone is between 100 m and 200 m, at approximately 128.1 m. That is why the doses (on-same-side) for all three stability classes lie atop one another for 10m, 50m, and 100 m; however, the doses diverge beginning at 200 m. As expected, decreased stability reduces the concentration and doses in the wake zone.

I am somewhat puzzled by the fact that the ratio of ground surface dose to total dose is virtually constant for stability categories F and A, but not for D!

Source data for the chart is contained in: composite1n00.xls .

3/10/06 Additional Runs

Additional runs will be undertaken to show model results for the case when the stack is sufficiently high relative to the building height that building wake effects are not considered. To

force the model to consider receptors to be in the "displacement zone", the building height will be changed from 35 m to 13 m. Note that 35m/2.5 = 14m. This choice of building height should force the model to consider all receptors to be in the displacement zone. This has the advantage of keeping the stack height the same, which means that dilution by dispersion will be the same as in other cases. Note that a receptor at 10 m is not allowed for the displacement zone.

Key to run numbering:

XYZW

X - Source Term
- 1 - PWR Average Worker
- 2 - BWR Average Worker
- 3 - PWR Maximum Worker
- 4 - BWR Maximum Worker

Y - Stability Class
- 1 - F, very stable, 6
- 2 - D, neutral, 4
- 3 - A, unstable, 1

Z - Building Height
- 0 - 35 m → wake zone or cavity zone
- 1 - 13 m → displacement zone

W - receptor location, distance and building side
- 1 - 10 m, stack side
- 2 - 50 m, stack side
- 3 - 100 m, stack side
- 4 - 200 m, stack side
- 5 - 500 m, stack side
- 6 - 10 m, not on stack side
- 7 - 50 m, not on stack side
- 8 - 100 m, not on stack side

DRAFT FOR DISCUSSION

Approach for Implementing Downwind Worker Dose Model

Please consider this approach as DRAFT for discussion.

There are at least three configurations involving the worker, obstacle, and source that may be of interest in preclosure repository safety:

1. The source and obstacle are located at the same location; the worker may be collocated or located downwind.
2. The source is upstream from the obstacle; the worker is collocated or downwind of the obstacle.
3. The source is upstream from the obstacle; the worker and obstacle(s) are collocated.

See Figure 1 for a diagram of these configurations. Case 1 most closely resembles the configurations discussed in IAEA Safety Series 19, where the source and obstacle are collocated.

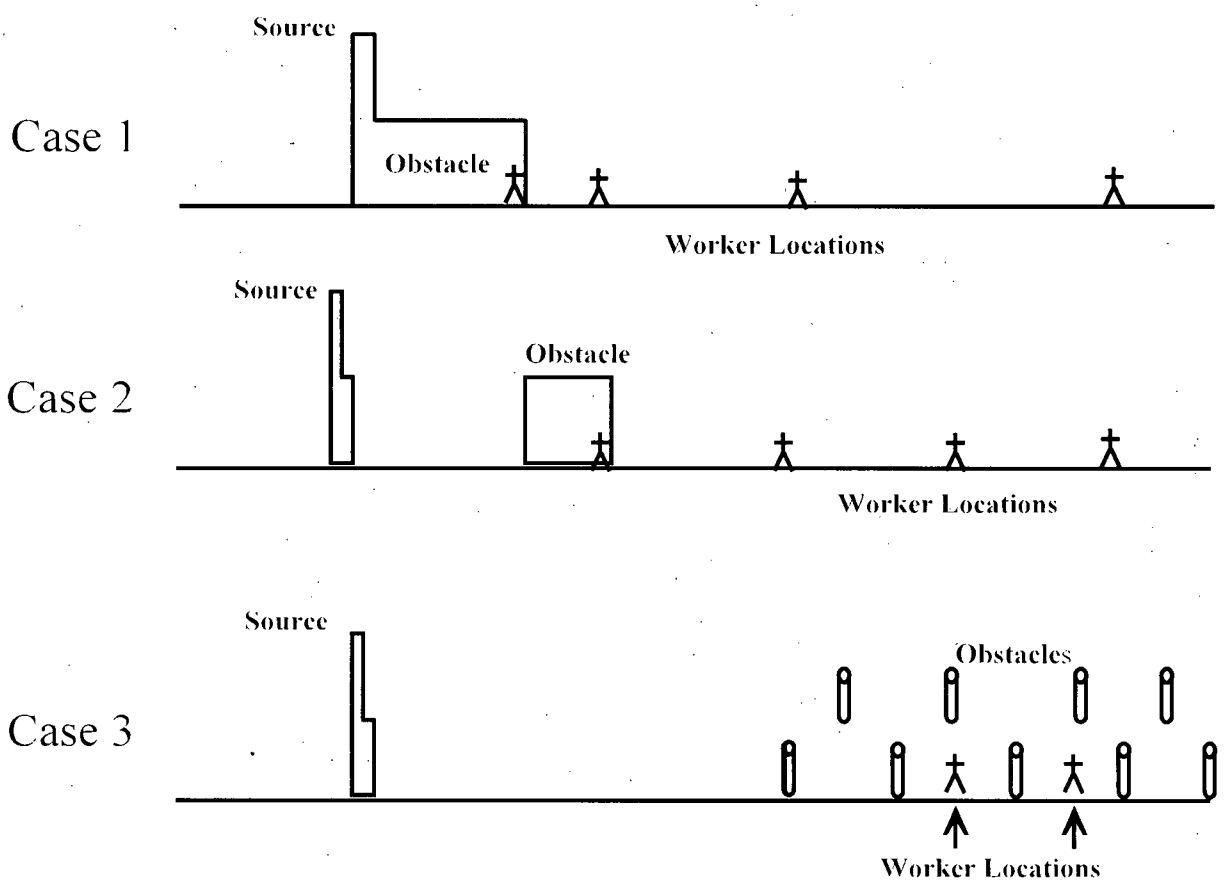


Figure 1. Three configurations for worker dose.

This may be an important configuration in repository safety analysis. Case 2 considers the situation, that may present for some workers at the repository, where there is one or more buildings intervening between the worker and the source. In this configuration, the downwind building is likely to cause increased mixing of the contaminant plume. For this reason, the doses calculated from this configuration are likely to be bounded by other configurations.[1] Case 3 is directed at considering the storage area, where there may be a large number of obstacles with workers in the space between the obstacles. Because the contaminant plume will flow through this array of objects, mixing with uncontaminated air may be greatly reduced by a channeling effect. This configuration may require a different approach. **This initial implementation of downwind worker dose will consider Case 1 only.**

To adapt the IAEA approach, we must recognize the following. The IAEA approach was developed to consider chronic (long-term) releases from a facility prior to licensing and operation. The focus of the IAEA analysis is routine releases from a facility and whether such releases induce acceptable concentrations for receptors downwind of the releases. To the contrary, we are concerned with acute, accidental releases. As we proceed, some parts of the IAEA approach may need to be modified to account for this difference. Another assumption based on the intent of the IAEA approach is that the source is on the building which creates the wake; however, the source may be elevated to a height that is substantially greater than the building height. This would be an expected configuration for a facility routinely allowing releasing from a stack.

The IAEA document defines three zones determined by the flow of air over and around the building: (1) displacement zone, (2) wake zone, and (3) cavity zone as shown in Figure 2 (Figure 4 in the IAEA document). The displacement zone is a region some distance downwind from the building, where the concentration is relatively unaffected by the building and its wake. Since the source is considered to be at some elevation, the contaminant plume must travel some distance before it reaches ground level. The displacement zone begins approximately at the point where the contaminant plume first touches down to ground level. This assumes a ground-level receptor,

---

[1]There may be slightly higher concentrations immediately downwind of the building in its cavity zone, because contaminants will be recirculated in a finite volume. However, the obstacle building is likely to be 65 to 100 m downwind of the source building. For a nominal building height of 34m and width between 135m and 150m the cavity zone is likely to extend no more than $2.5xA^{½}$, which is approximately equal to 2.5x70.7m = 175m. Thus a receptor in the cavity zone is likely to be 2 to 3 times the distance of the obstacle building from the source building. If a worker is within the cavity zone, his dose will be significantly higher than the dose to a worker at the same distance, but not in the cavity zone. This is because the worker in the cavity zone will experience a concentration close to that ahead of the obstacle (say the 75 m concentration), while the worker in the plume with no obstruction will experience the concentration at up to 175m. At these small distances, such changes will cause significant changes in concentration. However, the dose to a worker between the source and obstacle building will be higher than either of these.

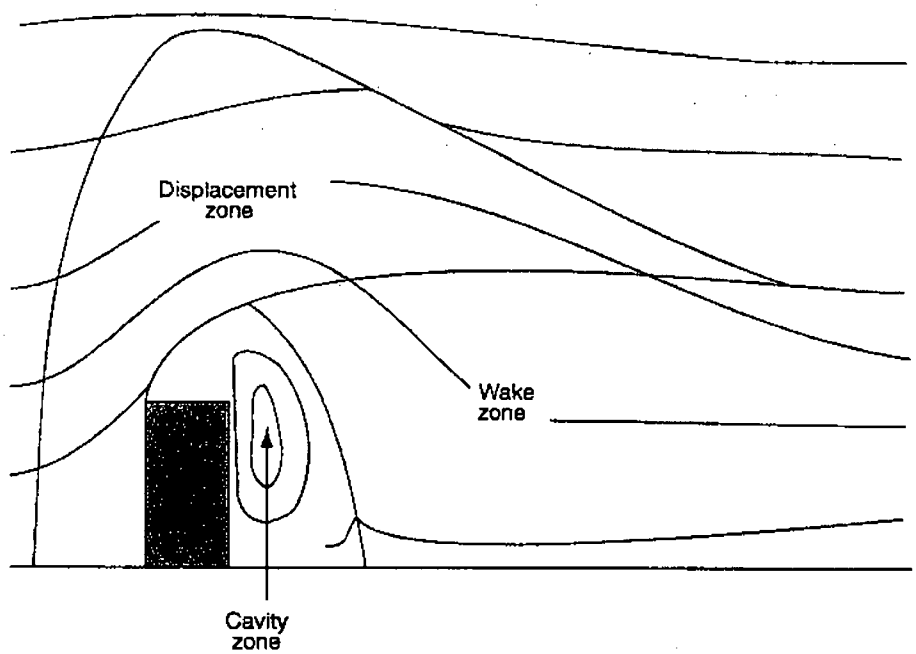


Figure 2. Air flow around a building, showing the three main zones of flow: displacement zone, wake zone and cavity zone.

which is consistent with this worker dose scenario. The cavity zone is immediately leeward of the building. Because contaminants may become trapped in the cavity zone (an attached vortex), the concentration in the cavity zone is strongly affected by the presence of the building. Concentration in the wake zone, which is essentially between the displacement zone and cavity zone, are reduced over what might be expected if no building were present. This is because the building provides additional turbulent mixing which reduces the concentration.

A receptor may be located at ground level and at any distance, x, downwind from the building. This distance, x, will determine in which of these three zones the receptor is located; depending on the zone, a different model is used for estimating concentration. The IAEA approach for determining zones is illustrated in Figure 3 (Figure 5 in the IAEA document). To implement this approach in the PCSA Tool a number of sequential windows will need to be used. At various points in this discussion these windows will be indicated.

WINDOW 1.

The user must specify the building height in meters, H_B, and the source height in meters, H_S. These numbers must be zero or greater.

If $H_S > 2.5 \cdot H_B$ then go to Window 2; if $H_S \leq 2.5 \cdot H_B$ then go to Window 3.

WINDOW 2.

The plume does not touch down until after the wake zone. Use the RSAC model with a receptor

elevation equal to zero. The user must specify the distance between the building and the receptor, x, in meters; then proceed with the RSAC calculation. Values for $x \leq 2.5 \cdot H_B$ will

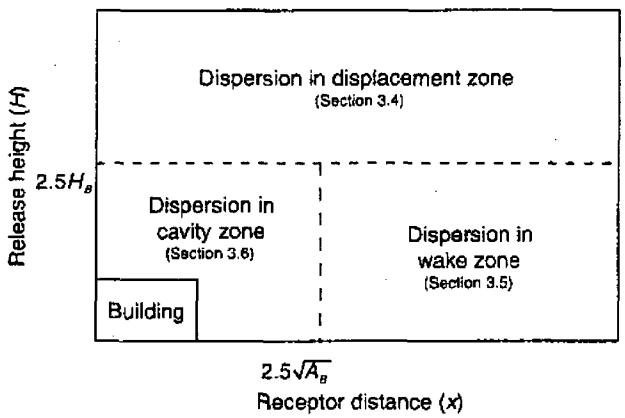


Figure 3. Relationship between release height and receptor distance for determination of the type of dispersion model to be used.

probably not yield meaningful results (the receptor is located closer to the building before the location where the plume touches down; after all, this is why releases are elevated). Consider providing a warning if a close distance is chosen or do not allow a calculation for small distances ($x \leq 2.5 \cdot H_B$).

Window 3.

Input the building width or length, W_B, in meters. This could also be whatever length the user desires to characterize the dimension of the building in the direction perpendicular to the direction of the wind. A bigger W_B will produce a bigger cross-wind area, which will increase the size of the cavity zone; i.e., bigger buildings have bigger trapped vortex zones. Calculate:

$$A_B = W_B \cdot H_B \quad (m^2)$$

Input the receptor distance, x, in meters. Calculate the quantity:

$$Q_B = 2.5 \cdot [A_B]^{1/2}$$

If $x \leq Q_B$, then go to Window 4.

If $x > Q_B$, then go to Window 5.

Window 4.

Is the receptor on the same surface of the building as the release? For example, is the receptor on

the roof with a roof vent releasing radionuclides; or is the receptor at a window on the side of a building that has a vent releasing radionuclides?
If yes, then go to Window 6.
If no, then go to Window 7.

Window 6.
Input the diameter of the vent or stack, D_S, in meters.
If $x \leq 3 \cdot D_S$, then go to Window 8
If $x > 3 \cdot D_S$, then go to Window 9.

Window 8.
Input the flow rate, V, in m^3/s, through the vent emitting radionuclides.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of 100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of chi/Q, in s/m^3, from the RSAC run, as well as the dose from each pathway and organ. Calculate the scaling factor:

$$F_V = 1/\{V \cdot [chi/Q]\}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (V - vent). Sum the pathway doses to obtain the total dose for this case.
This essentially assumes the receptor has his head in the stack and is breathing undiluted contaminated air as it is released from the vent; he may also get a dose from immersion.

Window 9.
Remember that for this screen the distance from the receptor to source should be:

$$3 \cdot D_S < x \leq Q_B$$

and the receptor should be on the same side of the building as the release vent.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of 100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the mean wind speed, U_A, in m/s, as well as (3) the dose from each pathway and organ. Calculate the scaling factor:

$$F_S = 30/\{U_A \cdot x^2 \cdot [chi/Q]\}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (S - side). Sum the pathway doses to obtain the total dose for this case.
This essentially assumes the releases from the vent may be recirculated close to the side of the building ; because of zones of stagnation and building wakes, high concentrations, hence doses, may be experienced.

Window 7.
This receptor is in the cavity zone, but is not on the same side of the building as the vent.
Run RSAC using the standard release (whatever that has been determined to be) at a distance of 100m, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the mean wind speed, U_A, in m/s, as well as (3) the dose from each

pathway and organ. Let $L_B = \min\{W_B, H_B\}$ Calculate the scaling factor:

$$F_S = 1/\{U_A \cdot \pi \cdot L_B \cdot K \cdot [chi/Q]\}$$

Where K=1m and is included to make the units consistent. Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (C - cavity). Sum the pathway doses to obtain the total dose for this case.

This essentially assumes the releases from the vent or stack are recirculated in the cavity zone; the quantity of radioactivity released per unit time (Q) is diluted by a flow equal to the product of π m and L_B (the smallest dimension of the building facing the wind) and U_A (the wind speed).

Window 5.

This receptor is in the wake zone. For this case x must be within certain limits:

$$2.5 \cdot H_B \geq x > Q_B = 2.5 \cdot [A_B]^{1/2}$$

For an ordinary Gaussian plume the concentration at ground level is given by:

$$C=(Q/U)\cdot[\exp-\{(h/\sigma_z)^2\}]/[\pi\, \sigma_z\, \sigma_y];$$

What we will assume for the wake zone is that the release is at ground level (this increases the concentration), but the vertical dispersion coefficient is increases (this decreases the concentration). Therefore: Run RSAC using the standard release (whatever that has been determined to be) at the distance x, **but assume a ground level release (H_B=0)**. Extract the numerical value of: (1) chi/Q, in s/m^3, from the RSAC run, (2) the value of the vertical dispersion coefficient, σ_z , (sigz in the RSAC output), as well as (3) the dose from each pathway and organ. Compute the quantity:

$$\sigma_{zmod} = [(\sigma_z)^2 + (A_B/\pi)]^{1/2}$$

Compute the scaling factor:

$$F_W = \sigma_z / \sigma_{zmod}$$

Multiply the dose from each pathway and organ by the scaling factor; the results are the pathway and organ doses for this case (W - wake). Sum the pathway doses to obtain the total dose for this case.

SCIENTIFIC NOTEBOOK

665-8E

of

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for
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INITIAL ENTRIES

Scientific Notebook: #665-8E

Issued to: Norman A. Eisenberg

Issue Date: June 8, 2004

Account Number:

Title: Repository Safety Analysis

Participants: N. Eisenberg
Biswajit Dasgupta, Project Leader
Asadul Chowdhury, Project Manager

Objective:
This scientific notebook will document the work related to repository safety.

In-Process Entries

6/14/04 PCSA Tool Evaluation:

Evaluate the RSAC module of the PCSA Tool for its ability to model onsite worker dose, especially the treatment of building wakes.

Building characteristics from B. Dasgupta e-mail message of 6/8/04:

1. The building dimensions are following

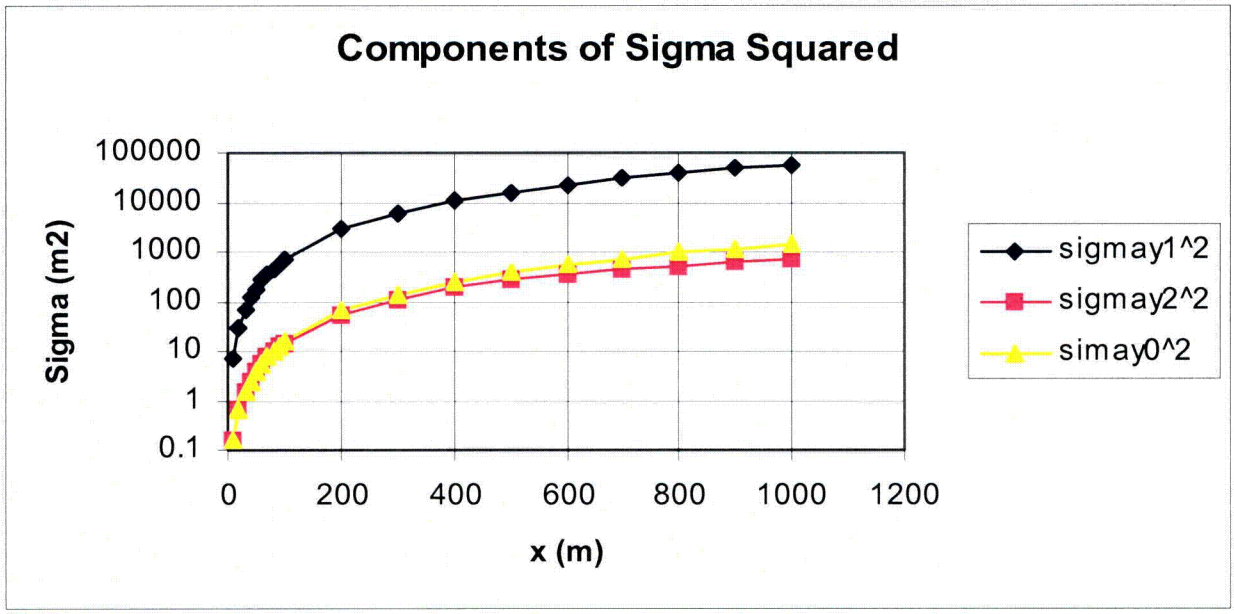
Length: 492 ft (150 m)
Width: 442 ft (135m)
Height: 114ft (34 m)

2. Stack was not observed in the drawings

3. Estimated distances of adjacent buildings: 200 ft on one side and 300 ft on the other side.

From these data the range of cross-sectional areas are: 34m x 135m = 4590m^2 to 34m x 150m = 5100m^2. A good nominal value is probably 5000m^2.

This value for area was used, along with three values of wind speed (2.5 m/s nominal, 0.25 m/s low, 6 m/s high) to evaluate the various terms in Equation A-13 (the equation for transverse dispersion (sigma y) of the RSAC code manual. Equations (A-15) and (A-17) were used respectively for "low wind speed corrections" and "building wake corrections", respectively. For the standard Hilsmeier-Gifford dispersion coefficient, the analytical expressions in Table 4-7



of "Chemical Fate and Transport in the Environment" by Hemond and Fechner-Levy was used. Category F stability class was assumed for consistency with cases in the PCSA Tool.

Data compiled in the file, sigma012.xls, show that the correction for low wind speed dominates the value for sigma, as shown in the following graph, which is for a wind speed of 2.5 m/s:

This shows that the square of the building wake correction (sigmay2) is slightly larger than the square of the nominal dispersion coefficient (sigmay0); however, the correction for low wind

speed appears to be a factor of 15 to 90 higher than either of these two. This seems to indicate that the concentration corrected for a building wake (using both correction terms) will be significantly lower than the concentration calculated using just the normal dispersion coefficient. This seems contrary to the IAEA Safety Series #19 concept in which the concentrations close to the building (especially in the cavity zone and wake zone) are higher than one would predict using the normal dispersion coefficients.

The conclusion from this is that if this is what the RSAC code is doing, it may not be suitable for modeling repository releases. Two lines of investigation should be pursued: (1) run RSAC for simple cases to confirm that the code follows the equations in Appendix A of the documentation and (2) obtain and evaluate NUREG/CR 6331 (Ramsdell, J.V., Jr., Simonen, C.A., 1997, Atmospheric Relative Concentrations in Building Wakes, Report NUREG/CR-6331. U.S. Nuclear Regulatory Commission, Washington, D.C.), which is cited as the source for these models, to determine that the model is appropriate and correctly implemented.

6/17/04 Further PCSA Tool Evaluation:

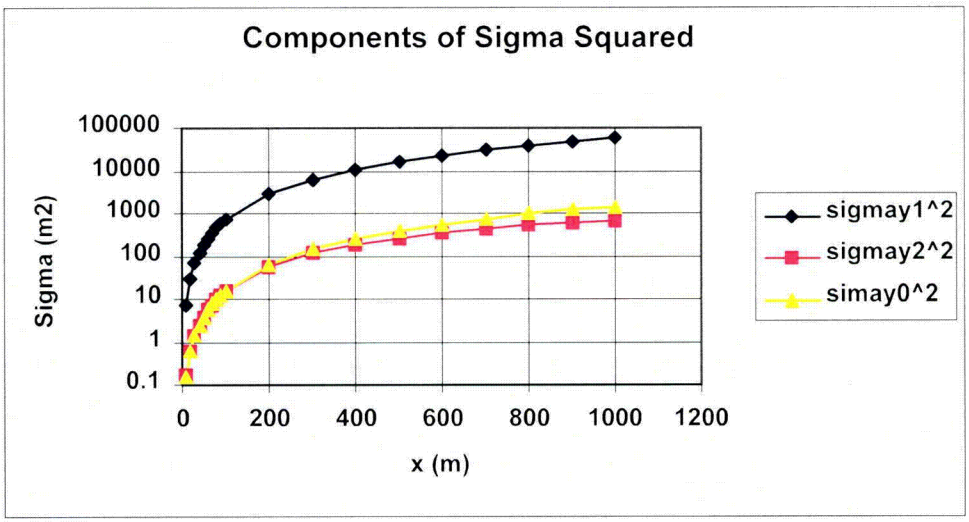
Some of this entry repeats the previous entry, because it is largely taken from a note sent to the CNWRA staff.

First I examined the analytical formulation used by RSAC to model building wakes, as stated in Appendix A, pp. 7-8 of the RSAC manual. The square of the air dispersion coefficients in the transverse (y) and vertical (z) directions are assumed to be the sum of three components squared (equations A-13&14). The three components are:

1. the normal, flat terrain air dispersion coefficient -- σ_0;
2. a term representing a "low wind speed" correction -- σ_1;
3. a term representing the building wake -- σ_2;

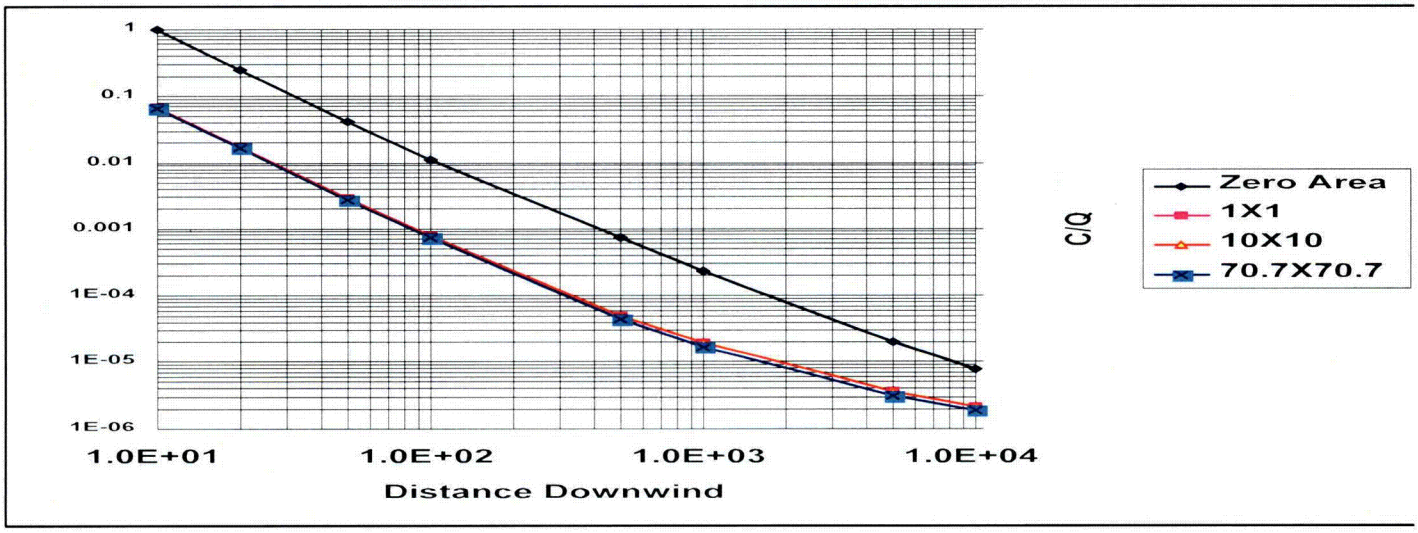
At first examination, this approach does not seem consistent with the IAEA concepts of a cavity zone and wake zone, both of which may have concentrations higher than one would expect in flat terrain at the same distance from the source. By adding squares of sigma's the concentrations can only be lowered.

To check this, I computed each term at various distances. I only did this for the transverse, y, dispersion coefficient, but the same trend should hold for the vertical coefficient. For the σ_0 I used an analytical expression (Table 4-7 of "Chemical Fate and Transport in the Environment" by Hemond and Fechner-Levy) for stability class F. It seemed to match up pretty well with RSAC values. The result of these computations is presented graphically below:



This shows that the square of the building wake correction (sigmay2; pink) is slightly larger than the square of the nominal dispersion coefficient (sigmay0; yellow); however, the correction for low wind speed appears (sigmay1-dark blue) to be a factor of 15 to 90 higher than either of these two, depending on the distance from the source. This seems to indicate that the concentration corrected for a building wake (using both correction terms) will be significantly lower than the concentration calculated using just the normal dispersion coefficient. Since the low wind speed term appears to dominate, this means that the result will depend very little on the building area chosen; for the repository problem, this doesn't seem correct.

To confirm that RSAC was indeed using this approach, a series of computer calculations using RSAC were undertaken. At the suggestion of George Adams, these runs were accomplished through the "Advanced RSAC" feature of the PCSA tool. The results of these calculations are shown below:



Doses were calculated at a sequence of distances: 10, 20, 50, 100, 500, 1000, 5000, and 10,000 m. This was accomplished using the feature of the RSAC code that allows specification of up to 8 distances (however, contrary to the impression in the manual, the instruction line must always be 5101, not 510X, X=1, 2...8, as stated in the text). Since RSAC reports out Chi over Q (C/Q in the above graph), which is the concentration normalized by release rate, this measure of downwind concentration was used. The above graph is both dramatic and definitive. To activate the building wake feature in RSAC, one must assume a ground level release; this was done. However, assuming a ground-level release is not a very physical assumption for the repository case. For no entries for building width (DUMMY) and height (DUMMZ), the building wake correction factor is not supposed to be activated; this appears to be the case as shown on the curve marked "Zero Area". For building dimensions of 1m X 1m, 10m X 10m, and 70.7 m X 70.7 m, concentrations appear to be anywhere from a factor of about 0.07 to .25 smaller than the "Zero Area" case; furthermore, the difference in concentrations for these three cases are slight. This is even for a difference in area by a factor of 5000. [Note: the case of 70.7 m X 70.7 m has an area of 5000 m^2, which is typical of the cross sectional area of the current repository design with building dimensions of Length: 492 ft (150 m); Width: 442 ft (135m); Height: 114ft (34 m); since only area is used in the formula, this should be OK.] Another anomaly apparent is that even a small obstacle of 1m high by 1m wide will cause a significant decrease in concentration; this does not appear to be a physically correct result.

This appears to show that the concentrations (and therefore doses) calculated by RSAC, when the building wake correction is activated, is much lower than the corresponding flat terrain concentrations. This is inconsistent with the IAEA approach and inconsistent with most of the

approaches described in a standard text on these types of calculations ("Atmospheric Science and Power Production", DOE/TIC-27601, D. Randerson, Ed.). Therefore this does not appear to be a good approach for the PCSA Tool. It is not clear whether this approach: (1) is not correctly implemented in the RSAC code, (2) is correctly implemented, but has not been limited to large distances, or (3) is not appropriate for fuel cycle facilities and accidents. I am trying to obtain NUREG/CR 6331, which is cited in the RSAC manual as the basis for their model, to clarify this.

There appears to be three alternative approaches to this problem:

1. Find another code that may implement a near-field wake calculation suitable for fuel cycle facilities and accidents;
2. Program an adaptation of the IAEA approach, including the source term and dose calculation;
3. Scale-up flat terrain RSAC dose calculations for a number of the near field conditions postulated in the IAEA document.

I would prefer to pursue approach number 3 for several reasons:

1. The release and dose calculations are already embedded in the RSAC code;
2. This would almost guarantee consistency between these calculations and other dose estimates produced using the RSAC code (e.g., public doses);
3. The RSAC output contains the "Chi over Q" value used for the dose calculation; knowing this value would make scaling the results relatively simple.

I would like to discuss the next step forward with George Adams, Biswajit Dasgupta, and others, as appropriate. Issues for discussion include:

1. Whether the output of an RSAC run can be processed by the computer to provide the scaled doses;
2. Whether it is appropriate to eliminate ingestion and contaminated ground plane doses; I would assume that there should be no food crops grown on-site and any seriously contaminated ground should be cleaned up;
3. How many receptors on-site should be modeled and how should they be located.

Records of computer code runs (the PCSA Tool) are contained in the directory: "RSAC Tests" which is a subdirectory of this Scientific Notebook directory.

7/02/04 Initial Development of Outside Worker Dose Calculation:

An initial draft of an approach to estimating outside worker dose was compiled in the document: "downwindworker2.wpd" which is included in the scientific notebook directory. This was sent to G. Adams and B. Dasgupta.

7/07/04 Minor Issue:

This is just a minor issue, but one that could be easily addressed in the next update to the PCSA Tool. On the form for the internal worker dose, there is a tab "Source Term". This tab lists the dose conversion factors (DCF's) for inhalation and submersion for each radionuclide used. The column headings for the submersion DCF's are: "Sv/Bq" and "Rem/Ci". I believe it may be more correct to make these headings: "(Sv/s)/(Bq/m3)" and "(Rem/s)/(Ci/m3)". The column headings for the inhalation DCF's should remain as they are. CNWRA staff was apprised of this minor issue.

7/21/04 Further Development of Outside Worker Dose Approach:

Several documents related to the worker dose problem were developed and transmitted to the CNWRA staff for review and evaluation: 1. Note on Dose Calculations for Downwind Workers: including (1) a small correction and rationale for the approach to dose calculation; (2) sample calculations for worker doses with a discussion; and (3) an explanation/derivation of the formulas proposed for this calculation, which are adaptations of an IAEA approach. [Note on Dose Calculation.wpd]; 2. The spreadsheet that supports the dose calculations. [wdmodeleval.xls]; 3. The output from two RSAC runs that support the dose calculations. [rsac6test11.out; rsac6test12.out in the "RSAC Tests" directory]; 4. A revised "Approach for Implementing Downwind Worker Dose Model" with suggestions for enhancements based on lessons-learned from the sample calculations [downwindworker3.wpd]. Also included is a flow-chart.

7/21/04 Clarification of Outside Worker Dose Approach:

The following clarification of the previously submitted approach was provided to G. Adams:

1. The building height and width should be zero for all RSAC runs; we do not want to invoke the RSAC model for building wakes. Although the RSAC runs should have zero building height and width, the PCSA Tool patch should include finite values for these dimensions.
2. The RSAC runs should be at a distance of 100m for all cases except the displacement zone and the **wake zone**.
3. For the **wake zone**, the distance should be whatever is specified by the user (but it should not be less than the extent of the cavity zone). The receptor elevation should be zero.
4. For the displacement zone, the receptor elevation should be zero. For the RSAC runs, the stack height should be as specified by the user.

8/04/04 Probably Error in Spreadsheet for Outside Worker Dose:

G. Adams submitted a revised spreadsheet indicating the likely omission of a factor of pi from a set of calculations. See [wdmodelevalGAmod.xls].

8/04/04 Resolution of Error in Spreadsheet for Outside Worker Dose:

With regard to the omission of the factor of pi, this was an error. I think what may have happened is that I copied the formulas from the WordPerfect document, but the symbols didn't reproduce in Excel. I confirmed that the factor should be there, so the doses are lower by a factor of about 3 in the Cavity Zone.

With regard to the limit in Window 9 so the "On the Building" dose cannot be greater than the "In the Stack" dose, this is also correct; however, I did not implement the suggested change in the spreadsheet.

To reconfirm our earlier conversation, it should be correct to list dose contributions by radionuclide and to scale these by the same correction factors that are used for total dose. There may be a small error, because some nuclides will be deposited out and others will not. However, at these distances, I expect these errors to be very small.

8/12/04 Results from Production Runs of PCSA Tool including Outside Worker Dose Module:

Data characterizing doses to workers outside are documented. This is the result of 32 PCSA Tool runs. A WordPerfect document [OutsideWorkerDoses.wpd] contains a text table characterizing the various runs and contains a graph with the different flow zones indicated. An Excel spreadsheet [combined.xls] contains the same information and a graph without the flow zones designated. Files are in the "OutsideWorker100" directory.

One surprising result is that in some cases the ground plane dose dominates. For high doses, this may not be reasonable, because actions will be taken to clean up the contamination. Also, for dose to persons on the building, some sort of remediation is very likely and the "ground plane" has limited extent. On the other hand, these calculations show the need for some cleanup action (possibly another item identified for review focus?). According to how I read the RSAC manual, the code as currently configured assumes a 1-year exposure to ground contamination in performing the dose calculation. This time seems excessive considering: (1) the time of exposure for inhalation and cloud immersion is about 3 seconds; (2) even if cleanup is not performed, resuspension and weathering is likely to reduce the level of contamination

considerably over a year (I do not believe RSAC considers such processes). One area where the results seem to be driven by this are runs 111-114, in the cavity zone. In these cases, the inhalation dose dominates, except for the BWR without the HEPA on (112); for that case, ground surface dose is highest. Not so for the PWR cases (113 & 114). This is likely due to the different inventory of gamma emitters (probably Co-60) in the two types of fuels.

8/12/04 Results from Production Runs of PCSA Tool for the Inside Worker Dose:

Several files provide the results of the inside worker analysis: (1) a combined spreadsheet for both cases (1 BWR and 1PWR) [combinedinside.xls], (2) a report for BWR [101.doc], and (3) a report for the PWR [102.doc]. There doesn't seem much to say about these except: (1) inhalation dose dominates; (2) the PWR dose is a little over twice the BWR dose; and (3) the doses are large: 34 rem for BWR; 71 rem for PWR. This may result from the 8 hour exposure assumption. Files are in the "InsideWorker100" directory.

2/7/06 Attempted Worker Dose Run:

Attempting to run outside worker dose per instructions from G. Adams. Input data through screens to obtain output. Then "load saved analysis" to input source term assumptions over writes previously input values for building height, stack height, building width, etc. It is not clear at all that the outside worker dose modeling is being invoked (it appears to be a straight RSAC run). Need to seek clarification to be able to perform analyses.

2/7/06 Clarification of Outside Worker Run:

Discussion of issue with G. Adams clarified code operation. "load saved analysis" inputs inventories for different cases, but does not input release fractions, which must be entered manually. Also meteorological conditions, i.e. wind speed and stability class must be entered manually. If "perform analysis" is selected, the outside worker dose calculation is performed, but with RSAC inputs regarding inventory, release fraction, and meteorological conditions as stated.

2/7/06 Run 1001:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR

	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

2/7/06 Run 1002:

Parameter Category	**Parameter**	**Value**
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)

Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	50 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.51E-02
GROUND SURFACE		4.05E-19
SUBMERSION		3.55E-05
TEDE		1.52E-02

2/7/06 Run 1003:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m

	receptor distance	100 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		3.78E-03
GROUND SURFACE		1.01E-19
SUBMERSION		8.89E-06
TEDE		3.79E-03

2/7/06 Run 1004:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	200 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.80E-03
GROUND SURFACE		2.24E-20
SUBMERSION		7.42E-06
TEDE		1.81E-03

2/7/06 Run 1005:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	500 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		7.34E-04
GROUND SURFACE		2.72E-20
SUBMERSION		6.18E-06
TEDE		7.41E-04

2/7/06 Run 1006:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
GROUND SURFACE		8.35E-19
SUBMERSION		1.52E-04
TEDE		3.16E-02
INHALATION		3.15E-02

2/7/06 Run 1007:

Parameter Category	Parameter	Value

Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	50 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		1.51E-02
GROUND SURFACE		4.02E-19
SUBMERSION		7.32E-05
TEDE		1.52E-02

2/7/06 Run 1008:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative

Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	100 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		3.79E-03
GROUND SURFACE		1.00E-19
SUBMERSION		1.83E-05
TEDE		3.80E-03

2/7/06 Run 1009:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m

	building width	75 m
	receptor distance	200 m
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

Pathway		Mean
INHALATION		8.33E-04
GROUND SURFACE		1.01E-20
SUBMERSION		7.31E-06
TEDE		8.40E-04

2/7/06 Run 1010:

Parameter Category	Parameter	Value
Source Term	Inventory	PWR_AVE_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative
Meteorology	wind speed	0.9 m/s
	stability class	4 (D) ←
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	500 m
	receptor on same surface	Yes

	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Worker Dose:

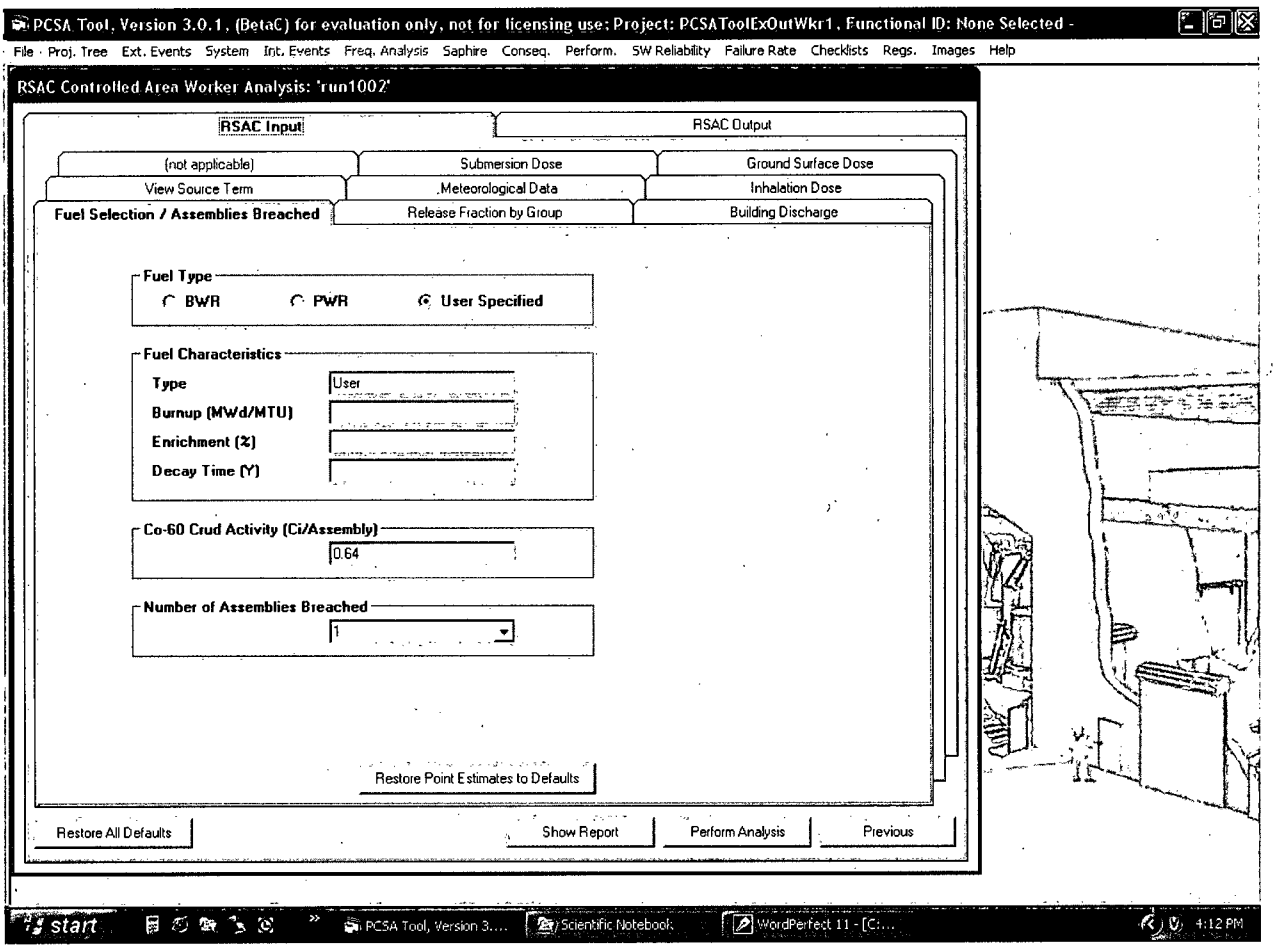
Pathway		Mean
INHALATION		3.07E-04
GROUND SURFACE		1.10E-20
SUBMERSION		5.05E-06
TEDE		3.12E-04

2/8/06 Run Series 1100

Parameter Category	Parameter	Potential Values
Source Term	Inventory	PWR_AVE_WKR; BWR_AVE_WKR; PWR_MAX_WKR; BWR_MAX_WKR
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative / Not Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F), 4(D), 1(A)
Outside Worker	stack height	35 m
	building height	35 m, 10 m
	building width	75 m
	receptor distance	10, 50, 100, 200, 500
	receptor on same surface	Yes / No
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s

Ground Surface Dose	Ground surface exposure time	0.22831 (2000 h/ 8760 h)
	Building shielding factor	0.7

Screenshots of RSAC Input Screens Follow:


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use: Project: PCSAToolExOutWkr1, Functional ID: None Selected -
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
(not applicable)
Submersion Dose
Ground Surface Dose
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
Fuel Type
BWR
PWR
User Specified
Fuel Characteristics
Type
User
Burnup (MWd/MTU)
Enrichment (%)
Decay Time (Y)
Co-60 Crud Activity (Ci/Assembly)
0.64
Number of Assemblies Breached
1
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
Scientific Notebook
WordPerfect 11 - [C:...
4:12 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

Release Fraction Source: User Specified

Description: User-Specified values (initially PCSA Tool defaults)

Group ID	Group Name	Release Fraction	HEPA Mitigation Operative	Radionuclides In Group
Group 1	H-3	3.00e-01	1.0	H-3
Group 2	Ruthenium	2.00E-05	0.0003	Ru-106
Group 3	Iodine	2.30E-03	1.0	I-129
Group 4	Cesium	2.00E-05	0.0003	Cs-134, Cs-135, Cs-137
Group 5	Noble gases	3.00E-01	1.0	Ar-39, Kr-85, Rn-219, Rn-220, Rn-222
Group 6	Strontium	2.00E-05	0.0003	Sr-90
Group 8	Co-60 Crud	1.50e-01	0.0003	Co-60 Crud
Group 9	Other particulates and fuel fines	2.00E-05	0.0003	All others

[redacted]

HEPA Filtration: Operative / Inoperative

Release in: Air / Pool

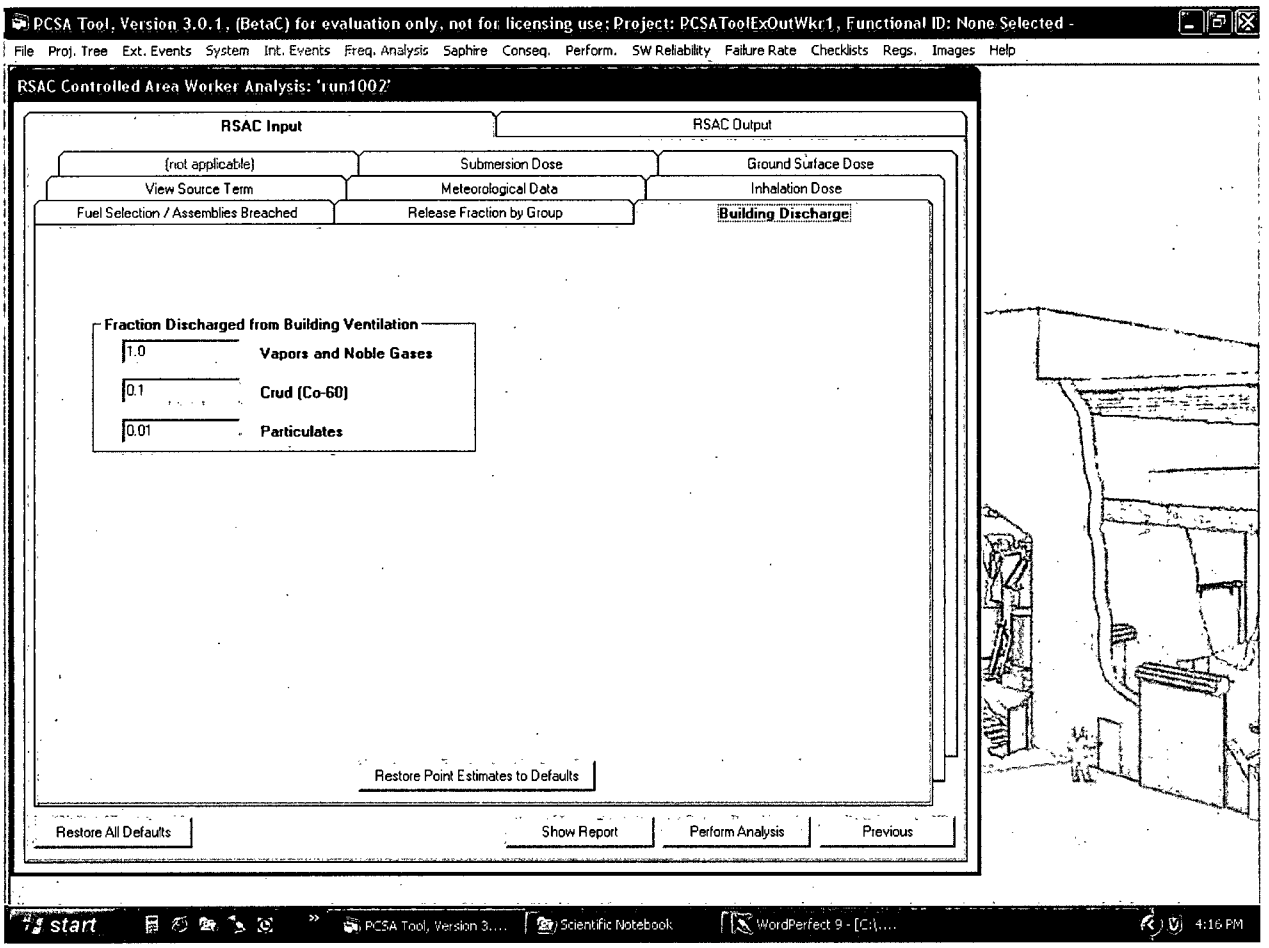
Restore Release Fraction Point Estimates to Defaults

Restore HEPA Mitigation to Defaults

Restore All Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:15 PM


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
(not applicable)
Submersion Dose
Ground Surface Dose
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
Fraction Discharged from Building Ventilation
1.0
Vapors and Noble Gases
0.1
Crud (Co-60)
0.01
Particulates
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
Scientific Notebook
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4:16 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Radionuclide	Inventory (Ci/Assembly)	Release Fraction	LHS	Bldg Discharge Fraction	HEPA Mitigation	Assemblies	Released Activity (Ci)
H 3	1.14E+02	3.00e-01	No	1.00e+00	1.00e+00	1	3.42e+01
C 14	3.32E-01	2.00E-05	No	1.00e-02	3.00e-04	1	1.99e-11
CL 36	6.80E-03	2.00E-05	No	1.00e-02	3.00e-04	1	4.08e-13
AR 39	5.22E-05	3.00E-01	No	1.00e+00	1.00e+00	1	1.57e-05
FE 55	3.46E+00	2.00E-05	No	1.00e-02	3.00e-04	1	2.08e-10
NI 59	2.09E+00	2.00E-05	No	1.00e-02	3.00e-04	1	1.25e-10
CO 60	3.13E+02	2.00E-05	No	1.00e-02	3.00e-04	1	1.88e-08
CO 60 Crud	6.40e-01	1.50e-01	No	1.00e-01	3.00e-04	1	2.88e-06
NI 63	2.52E+02	2.00E-05	No	1.00e-02	3.00e-04	1	1.51e-08
SE 79	4.57E-02	2.00E-05	No	1.00e-02	3.00e-04	1	2.74e-12
KR 85	1.13E+03	3.00E-01	No	1.00e+00	1.00e+00	1	3.39e+02
SR 90	2.72E+04	2.00E-05	No	1.00e-02	3.00e-04	1	1.63e-06
Y 90	2.72E+04	2.00E-05	No	1.00e-02	3.00e-04	1	1.63e-06
MO 93	4.14E-02	2.00E-05	No	1.00e-02	3.00e-04	1	2.48e-12
NB 93M	1.30E+01	2.00E-05	No	1.00e-02	3.00e-04	1	7.80e-10
ZR 93	8.94E-01	2.00E-05	No	1.00e-02	3.00e-04	1	5.36e-11
NB 94	8.39E-01	2.00E-05	No	1.00e-02	3.00e-04	1	5.03e-11
TC 99	8.98E+00	2.00E-05	No	1.00e-02	3.00e-04	1	5.39e-10
RH106	1.23E-02	2.00E-05	No	1.00e-02	3.00e-04	1	7.38e-13
RU106	1.23E-02	2.00E-05	No	1.00e-02	3.00e-04	1	7.38e-13
PD107	8.41E-02	2.00E-05	No	1.00e-02	3.00e-04	1	5.05e-12
SN121M	1.59E+00	2.00E-05	No	1.00e-02	3.00e-04	1	9.54e-11
SB125	9.71E+00	2.00E-05	No	1.00e-02	3.00e-04	1	5.83e-10

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook: | WordPerfect 9 - [C:\.... | 4:17 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

View Source Term | Meteorological Data | Inhalation Dose

Input Parameter	Input Value	Remarks	Default Value
Average wind velocity (m/s)	0.9	float - Most-probable velocity (site-specific estimate)	4.3
Stack release height (m)	0.0	float - Estimation of stack height	40.0
Mixing layer height (m)	1420.0	float - Average mixing height based data from Desert Rock, NV	1420.0
Air density (g/m^3)	1.29e+03	float - Site-specific mean value (Mohanty et al., 2000)	1.29e+03
Wet deposition scavenging coefficient	0.0	float - No plume depletion by wet deposition	0.0
Plume depletion by dry deposition	1	integer Yes	1
Deposition velocities to be entered	Yes		Yes
Deposition velocities (m/s) Solids	0.001	float - RSAC-5 default value	0.001
Deposition velocities (m/s) Halogens	0.01	float - RSAC-5 default value	0.01
Deposition velocities (m/s) Noble gases	0.0	float - RSAC-5 default value	0.0
Deposition velocities (m/s) Cesium	0.001	float - RSAC-5 default value	0.001
Deposition velocities (m/s) Ruthenium	0.001	float - RSAC-5 default value	0.001
Downwind distance (m)	100.0	float - Site-specific approximation (U.S. Department of Energy, 1998c)	11000.0
Linear constant in decay function (1/s)	1.0	float - RSAC default value for instantaneous release	1.0
Exponential constant in decay function	0.0	float - RSAC default value for instantaneous release	0.0
Crosswind distances to be entered	No	text - Assuming critical group is directly downwind	No
Diffusion definition	2	integer - Program calculates standard deviations	2
Type of sigma (standard deviation) set	1	integer - Hilsmeier-Gifford for < 15 min releases at desert sites	1
Building width (m)	0.0	float - RSAC-5 default value	0.0
Building height (m)	0.0	float - RSAC-5 default value	0.0
Weather class	6	integer - 6 relates to class F, the most-probable class (site-specific	6
Plume rise indicator	0	integer - No plume rise	0

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:18 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker Analysis: 'run1002'

RSAC Input | RSAC Output

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | Ground Surface Dose

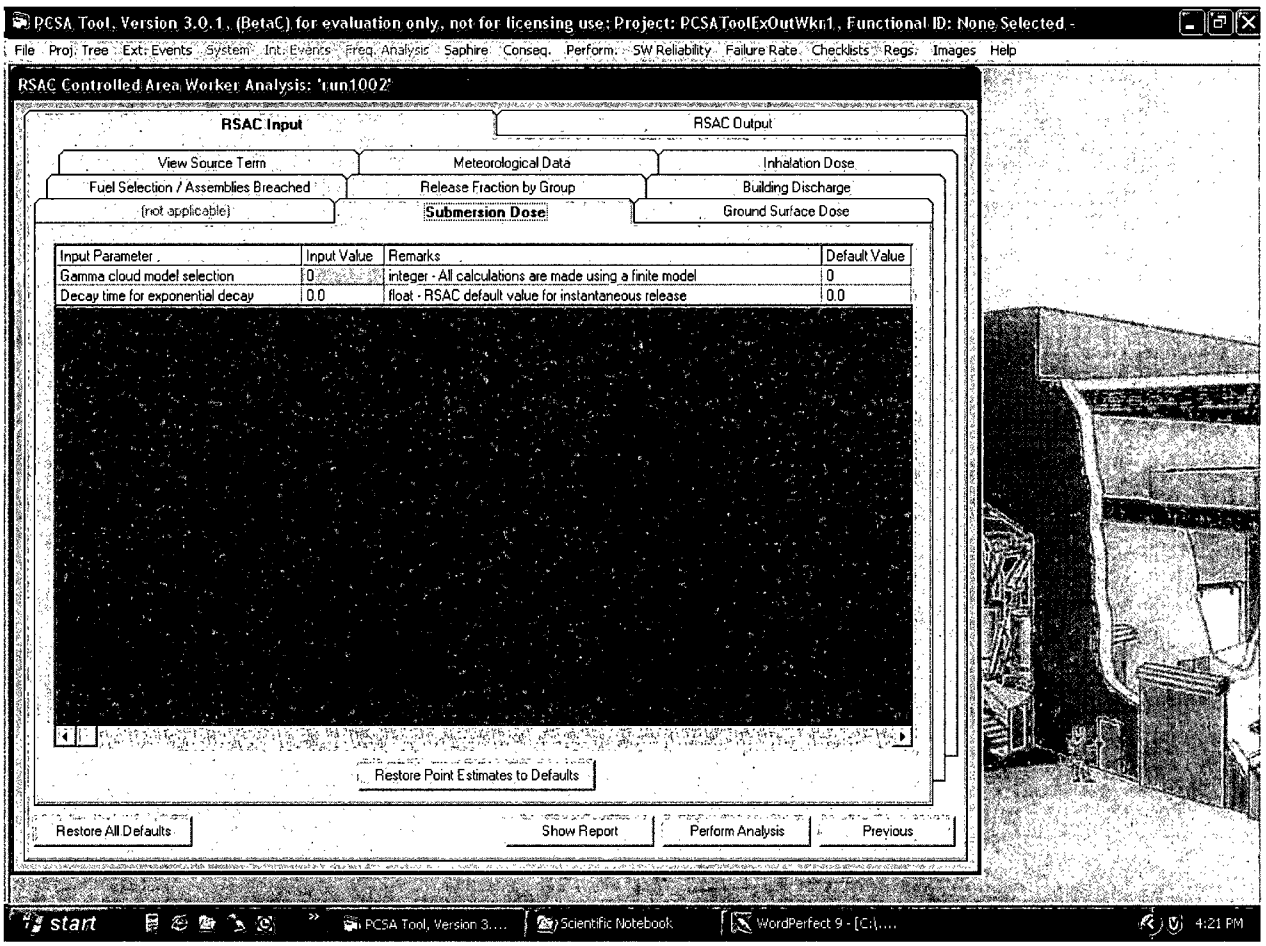
View Source Term | Meteorological Data | Inhalation Dose

Input Parameter	Input Value	Remarks	Default Value
Type of dose calculation	1	integer - International Commission on Radiological Protection-30 inhalation	1
Output control for dose	-2	integer - Only dose summaries	-2
Dose unit	1	integer - Output in rem	1
Elements for calculation	0	integer - All elements	0
Organ choice	1	integer - All organs	1
For inhalation, breathing rate (m^3/s)	3.33e-04	float - RSAC 24-hour average default	3.33e-04
Decay time for exponential decay	0.0	float - RSAC default value for instantaneous release	0.0
Activity mean aerodynamic diameter	1.0	float - RSAC default value	1.0
Clearance classes	3	integer - RSAC default classes	3

Restore Point Estimates to Defaults

Restore All Defaults | Show Report | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | 4:20 PM


PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use; Project: PCSAToolExOutWkn1, Functional ID: None Selected
File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help
RSAC Controlled Area Worker Analysis: 'run1002'
RSAC Input
RSAC Output
View Source Term
Meteorological Data
Inhalation Dose
Fuel Selection / Assemblies Breached
Release Fraction by Group
Building Discharge
(not applicable)
Submersion Dose
Ground Surface Dose
Input Parameter
Input Value
Remarks
Default Value
Gamma cloud model selection
0
integer - All calculations are made using a finite model
0
Decay time for exponential decay
0.0
float - RSAC default value for instantaneous release
0.0
Restore Point Estimates to Defaults
Restore All Defaults
Show Report
Perform Analysis
Previous
start
PCSA Tool, Version 3....
Scientific Notebook
WordPerfect 9 - [C:\....
4:21 PM

PCSA Tool, Version 3.0.1, (BetaC) for evaluation only, not for licensing use: Project: PCSAToolExOutWkr1, Functional ID: None Selected -

File Proj. Tree Ext. Events System Int. Events Freq. Analysis Saphire Conseq. Perform. SW Reliability Failure Rate Checklists Regs. Images Help

RSAC Controlled Area Worker: New or Modified Analysis

RSAC Input | RSAC Output

View Source Term | Meteorological Data | Inhalation Dose

Fuel Selection / Assemblies Breached | Release Fraction by Group | Building Discharge

(not applicable) | Submersion Dose | **Ground Surface Dose**

Input Parameter	Input Value	Remarks	Default Value
Type of dose calculation	4	integer - Ground surface dose calculation	4
Output control for dose	-2	integer - Only dose summaries	-2
Dose unit	1	integer - Output in rem	1
Elements for calculation	0	integer - All elements	0
Organ choice	1	integer - All organs	1
Decay time for exponential decay	0.0	float - RSAC default value for instantaneous release	0.0
TB - Ground surface exposure time (y)	0.22831	float - Annual dose is calculated	1.0
Building shielding factor (dimensionless)	0.7	float - Assigns RSAC default value of 0.7	0.7

Restore Point Estimates to Defaults

Restore All Defaults | Load Saved Analysis | Perform Analysis | Previous

start | PCSA Tool, Version 3.... | Scientific Notebook | WordPerfect 9 - [C:\.... | Calculator | 4:23 PM

2/8/06 Run 1101

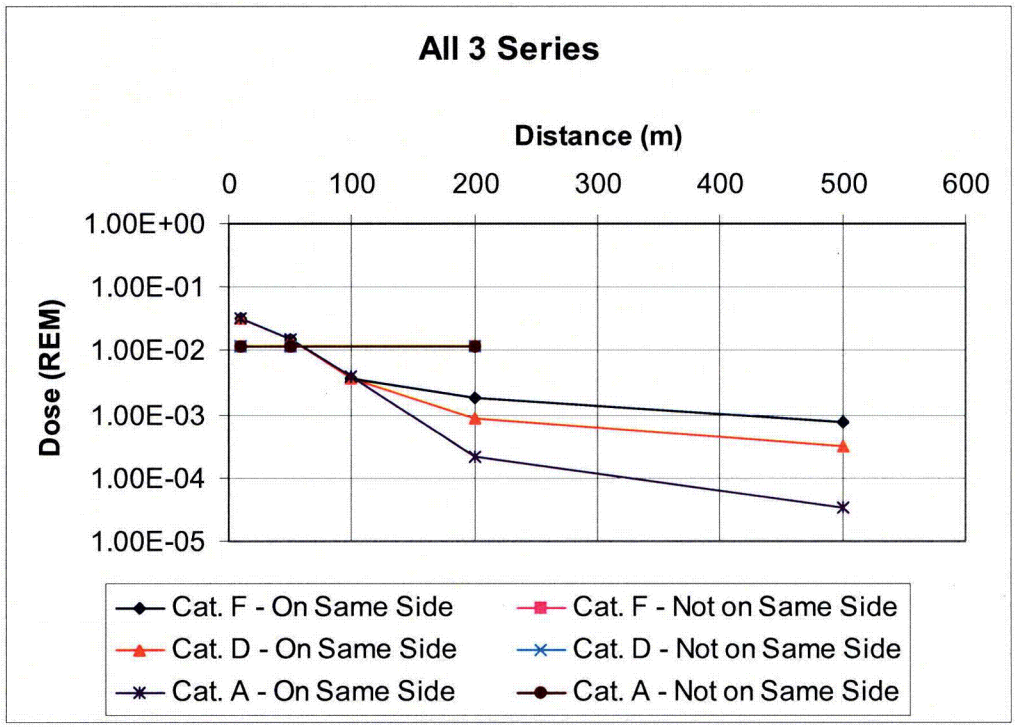
Parameter Category	Parameter	Potential Values
Source Term	Inventory	PWR_AVE_WKR;
	Release Fractions	Best Estimate Constant Value
	HEPA Mitigation	Operative / Not Operative
Meteorology	wind speed	0.9 m/s
	stability class	6 (F)
Outside Worker	stack height	35 m
	building height	35 m
	building width	75 m
	receptor distance	10
	receptor on same surface	Yes
	stack diameter	2.7432 m
	flow rate	36.10 m^3/s
Ground Surface Dose	Ground surface exposure time	0.22831 (2000 h/ 8760 h)
	Building shielding factor	0.7

Subsequent Runs in Series 1100, 1200, and 1300 use these data except for receptor distance and stability class as shown in the following Table 1100-1300:

Run Identifier	Receptor Distance	On Same Surface	Stability Class
1101	10	Y	6
1102	50	Y	6

1103	100	Y	6
1104	200	Y	6
1105	500	Y	6
1106	10	N	6
1107	50	N	6
1108	100	N	6
1201	10	Y	4
1202	50	Y	4
1203	100	Y	4
1204	200	Y	4
1205	500	Y	4
1206	10	N	4
1207	50	N	4
1208	100	N	4
1301	10	Y	1
1302	50	Y	1
1303	100	Y	1
1304	200	Y	1
1305	500	Y	1
1306	10	N	1
1307	50	N	1
1308	100	N	1

2/8/06



Doses (TEDE from inhalation (mostly), submersion and ground plane) are given in REM and plotted below:

for this configuration (35 m tall building and stack) the end of the cavity zone is between 100 m and 200 m, at approximately 128.1 m. That is why the doses (on-same-side) for all three stability classes lie atop one another for 10m, 50m, and 100 m; however, the doses diverge beginning at 200 m. As expected, decreased stability reduces the concentration and doses in the wake zone.

I am somewhat puzzled by the fact that the ratio of ground surface dose to total dose is virtually constant for stability categories F and A, but not for D!

Source data for the chart is contained in: composite1n00.xls .

3/10/06 Additional Runs

Additional runs will be undertaken to show model results for the case when the stack is sufficiently high relative to the building height that building wake effects are not considered. To

force the model to consider receptors to be in the "displacement zone", the building height will be changed from 35 m to 13 m. Note that 35m/2.5 = 14m. This choice of building height should force the model to consider all receptors to be in the displacement zone. This has the advantage of keeping the stack height the same, which means that dilution by dispersion will be the same as in other cases. Note that a receptor at 10 m is not allowed for the displacement zone.

Key to run numbering:

XYZW

X - Source Term
1 - PWR Average Worker
2 - BWR Average Worker
3 - PWR Maximum Worker
4 - BWR Maximum Worker

Y - Stability Class
1 - F, very stable, 6
2 - D, neutral, 4
3 - A, unstable, 1

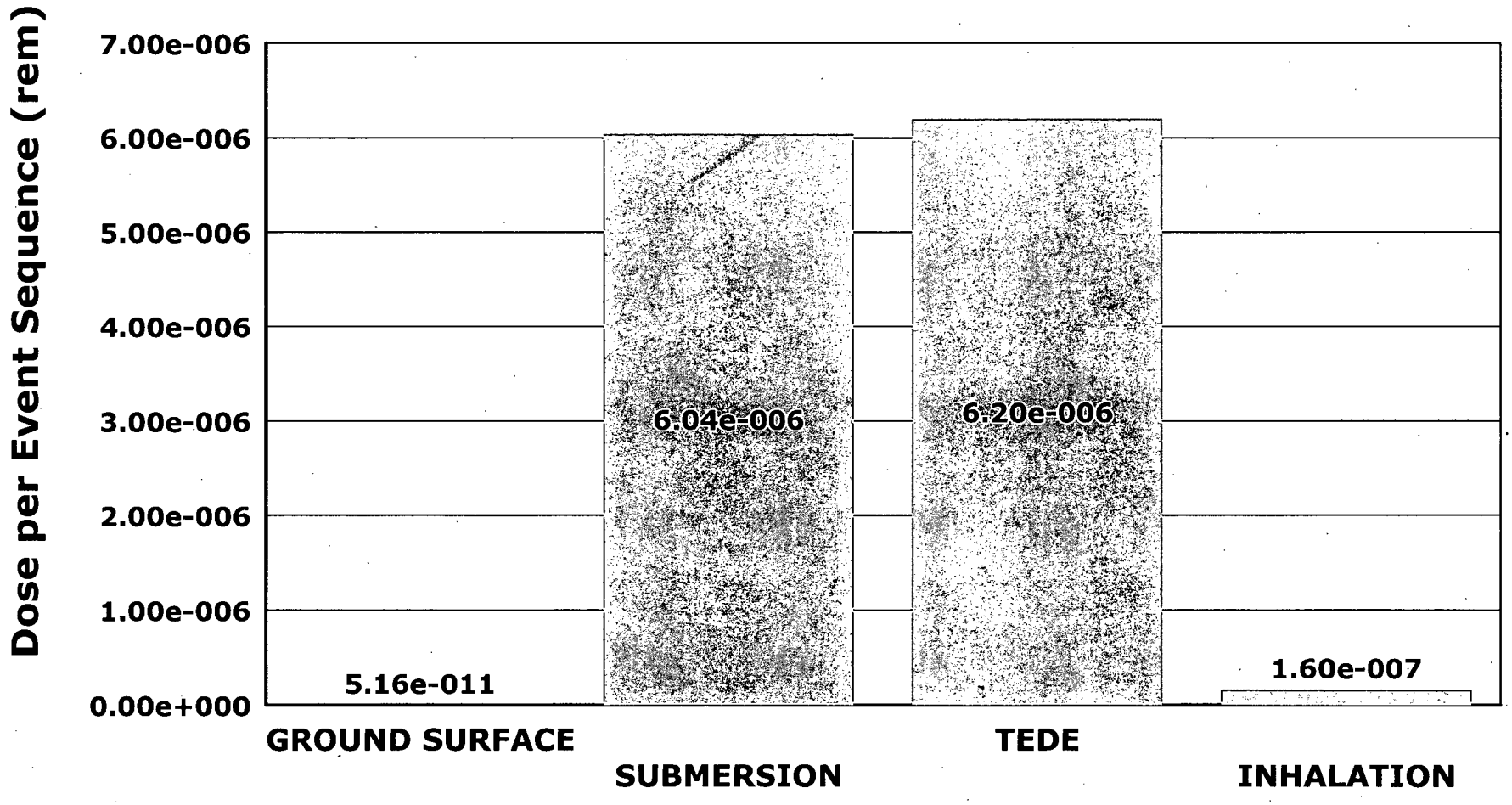
Z - Building Height
0 - 35 m → wake zone or cavity zone
1 - 13 m → displacement zone

W - receptor location, distance and building side
1 - 10 m, stack side
2 - 50 m, stack side
3 - 100 m, stack side
4 - 200 m, stack side
5 - 500 m, stack side
6 - 10 m, not on stack side
7 - 50 m, not on stack side
8 - 100 m, not on stack side

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	500.00
	Building Height (m):	13.00		

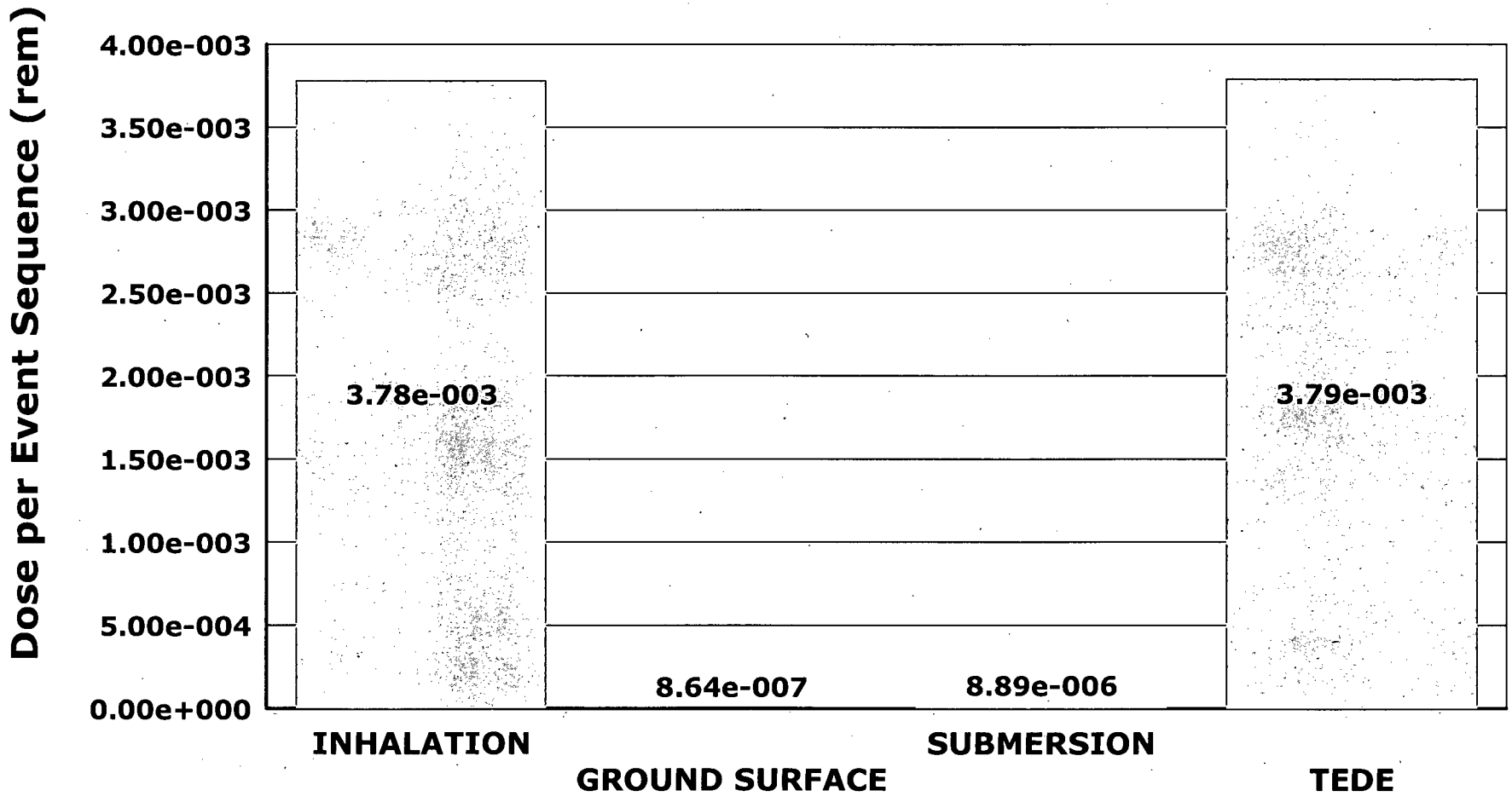
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
GROUND SURFACE	5.16E-11	5.16E-11	5.16E-11	5.16E-11	5.16E-11	5.16E-11
SUBMERSION	6.04E-06	6.04E-06	6.04E-06	6.04E-06	6.04E-06	6.04E-06
TEDE	6.20E-06	6.20E-06	6.20E-06	6.20E-06	6.20E-06	6.20E-06
INHALATION	1.60E-07	1.60E-07	1.60E-07	1.60E-07	1.60E-07	1.60E-07

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	100.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

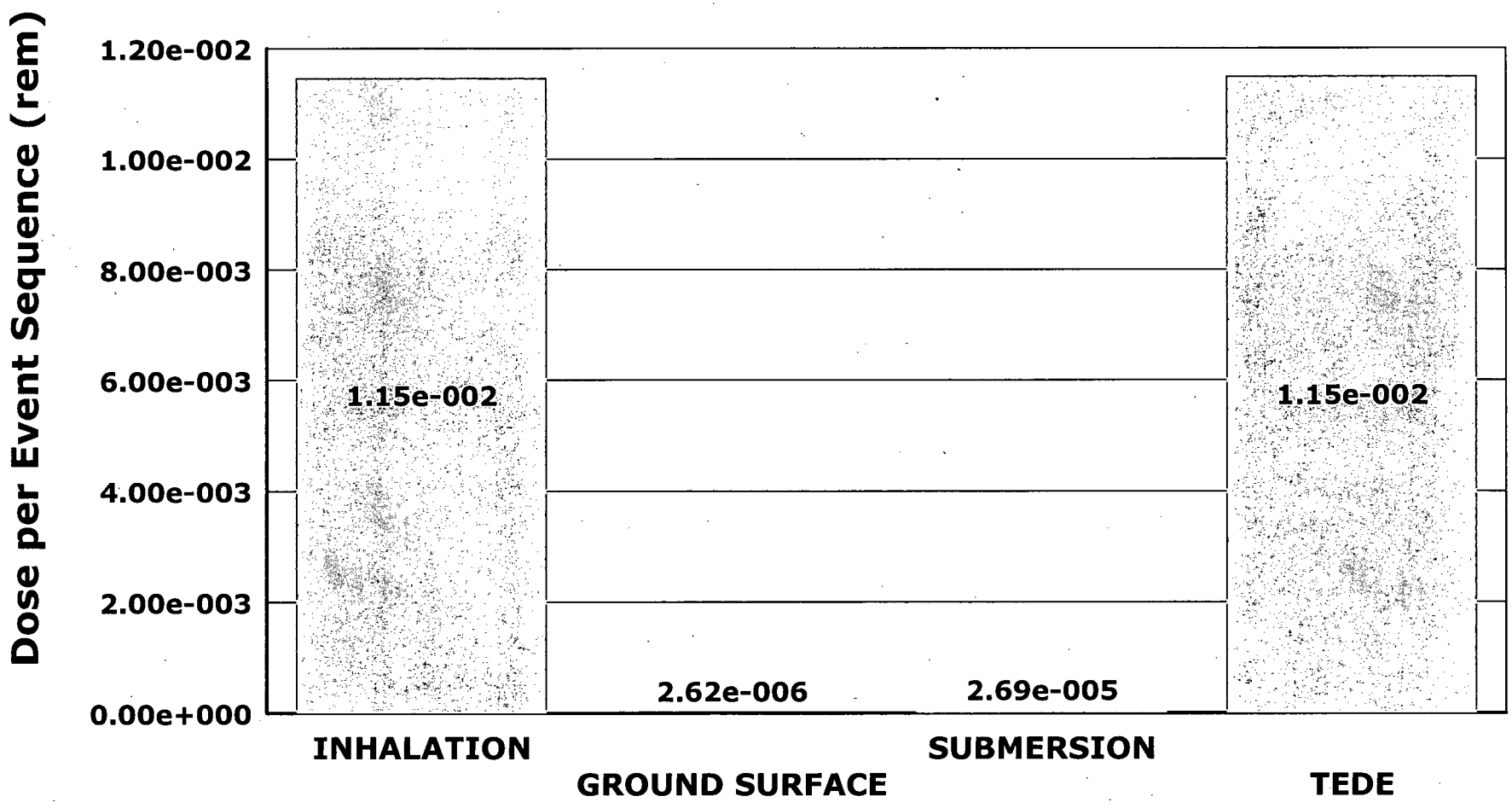
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.78E-03	3.78E-03	3.78E-03	3.78E-03	3.78E-03	3.78E-03
GROUND SURFACE	8.64E-07	8.64E-07	8.64E-07	8.64E-07	8.64E-07	8.64E-07
SUBMERSION	8.89E-06	8.89E-06	8.89E-06	8.89E-06	8.89E-06	8.89E-06
TEDE	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03	3.79E-03

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Cavity Zone Not On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	10.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00		

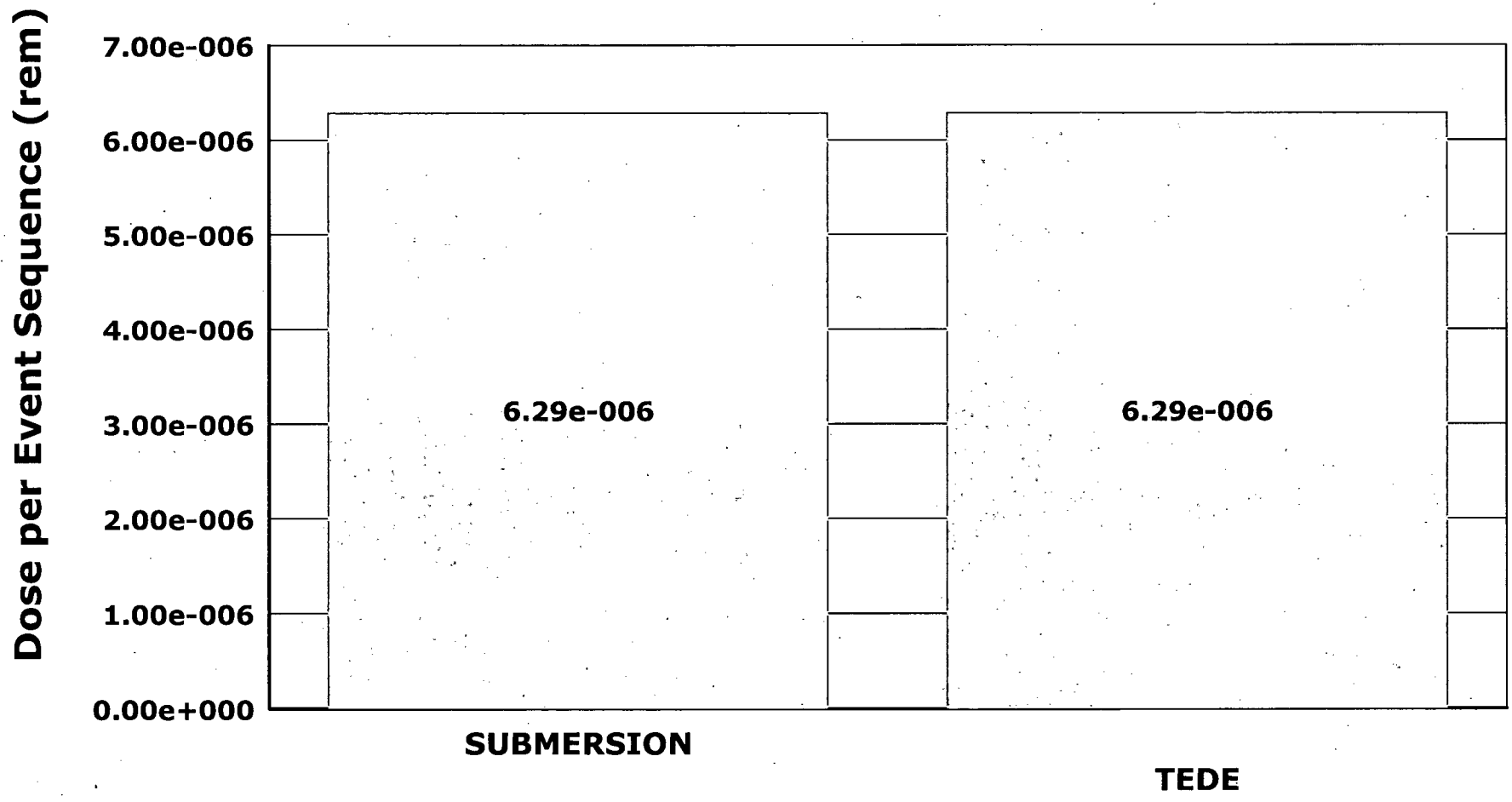
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02
GROUND SURFACE	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06	2.62E-06
SUBMERSION	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05	2.69E-05
TEDE	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02	1.15E-02

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	13.00		

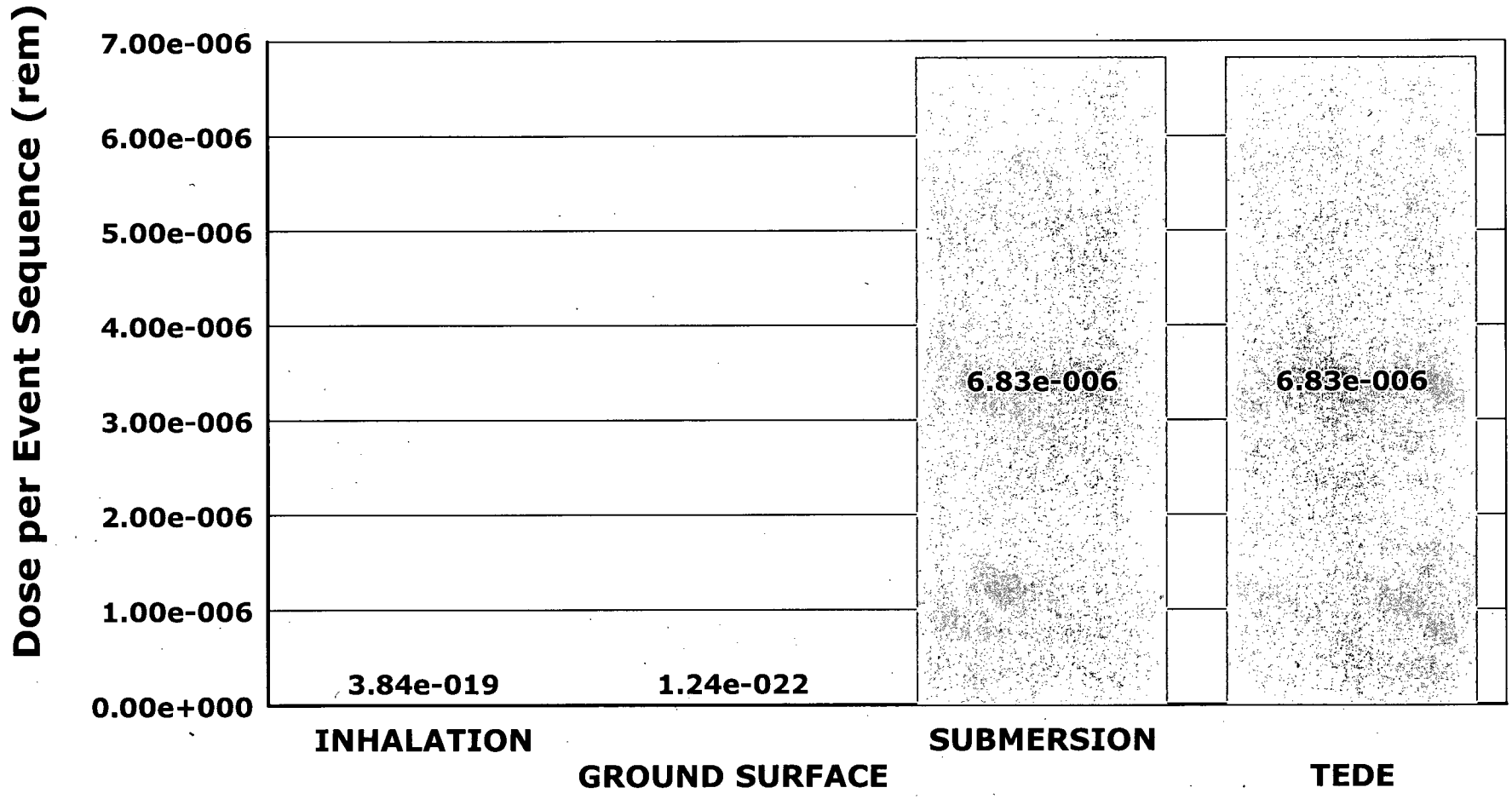
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
SUBMERSION	6.29E-06	6.29E-06	6.29E-06	6.29E-06	6.29E-06	6.29E-06
TEDE	6.29E-06	6.29E-06	6.29E-06	6.29E-06	6.29E-06	6.29E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Displacement Zone	Stack Height (m):	35.00	Receptor Distance (m):	200.00
	Building Height (m):	13.00		

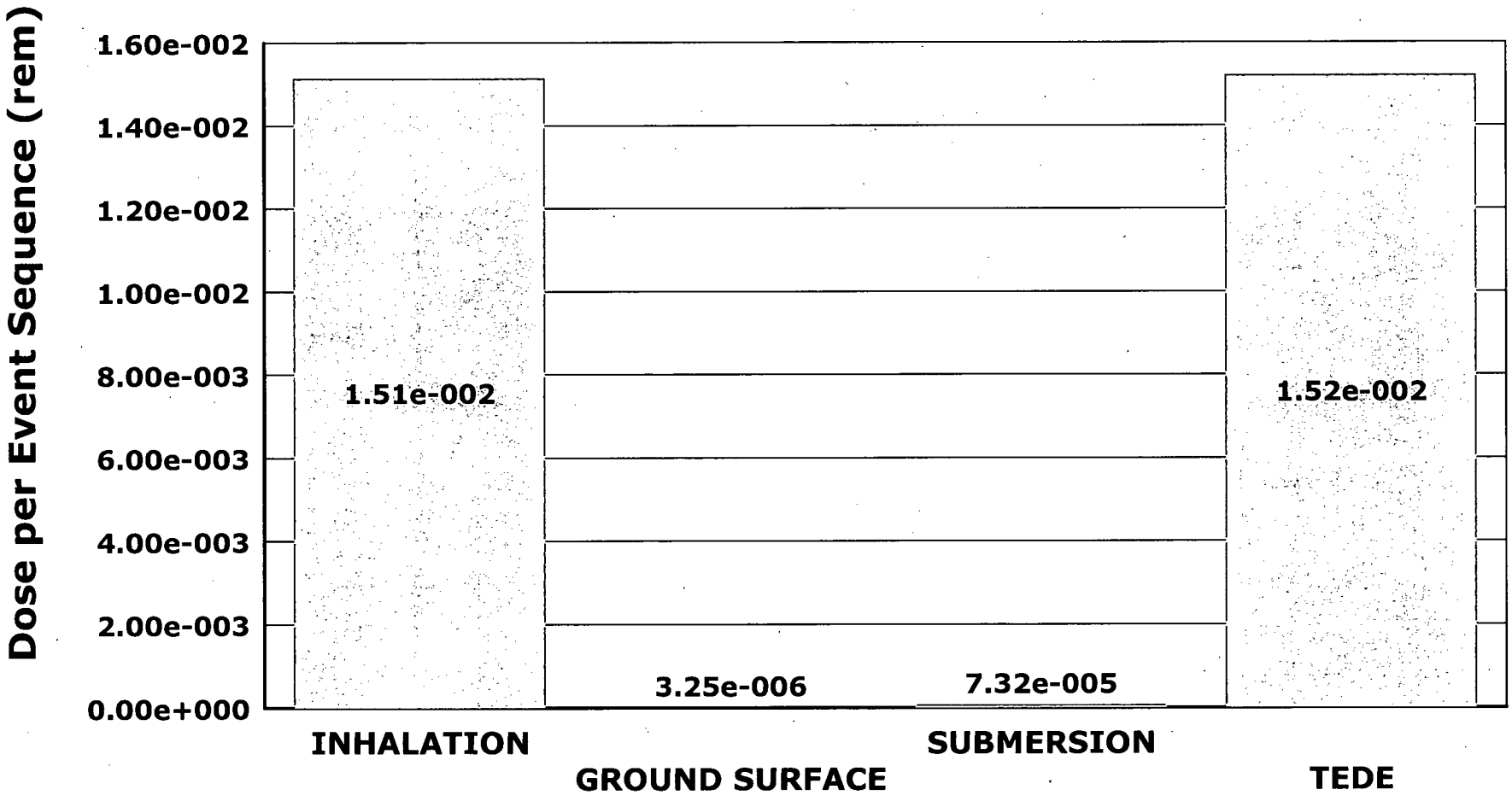
RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	3.84E-19	3.84E-19	3.84E-19	3.84E-19	3.84E-19	3.84E-19
GROUND SURFACE	1.24E-22	1.24E-22	1.24E-22	1.24E-22	1.24E-22	1.24E-22
SUBMERSION	6.83E-06	6.83E-06	6.83E-06	6.83E-06	6.83E-06	6.83E-06
TEDE	6.83E-06	6.83E-06	6.83E-06	6.83E-06	6.83E-06	6.83E-06

PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

RSAC Output - Pathway Summary



PCSA Controlled Area Worker RSAC Output

Project: PCSAToolExOutWkr1

Input Parameters

Receptor On Same Surface	Stack Height (m):	35.00	Receptor Distance (m):	50.00
	Building Height (m):	35.00	Flow Rate (m^3/s):	36.10
	Building Width (m):	75.00	Stack Diameter (m):	2.74

RSAC Output - Pathway Summary

Pathway	Mean	Minimum	5th Percentile	50th Percentile	95th Percentile	Maximum
INHALATION	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02	1.51E-02
GROUND SURFACE	3.25E-06	3.25E-06	3.25E-06	3.25E-06	3.25E-06	3.25E-06
SUBMERSION	7.32E-05	7.32E-05	7.32E-05	7.32E-05	7.32E-05	7.32E-05
TEDE	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02	1.52E-02