WORKSHOP ON California Population Indoor Exposure Model, Version 2 --CPIEM2.0--

Presented to

California Air Resources Board

Indoor Air Division

Presented by

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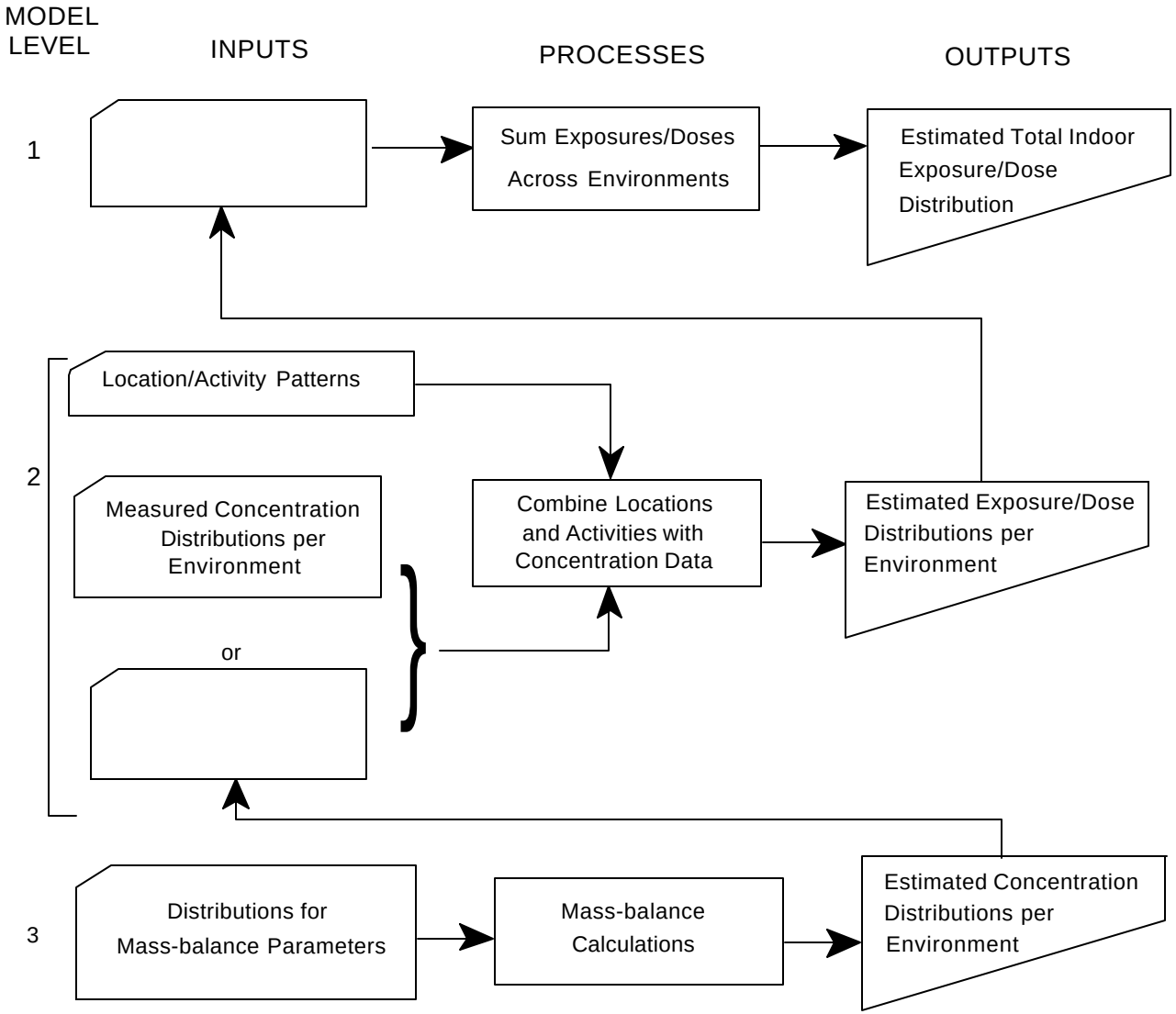
ICF Consulting

November 20, 2002

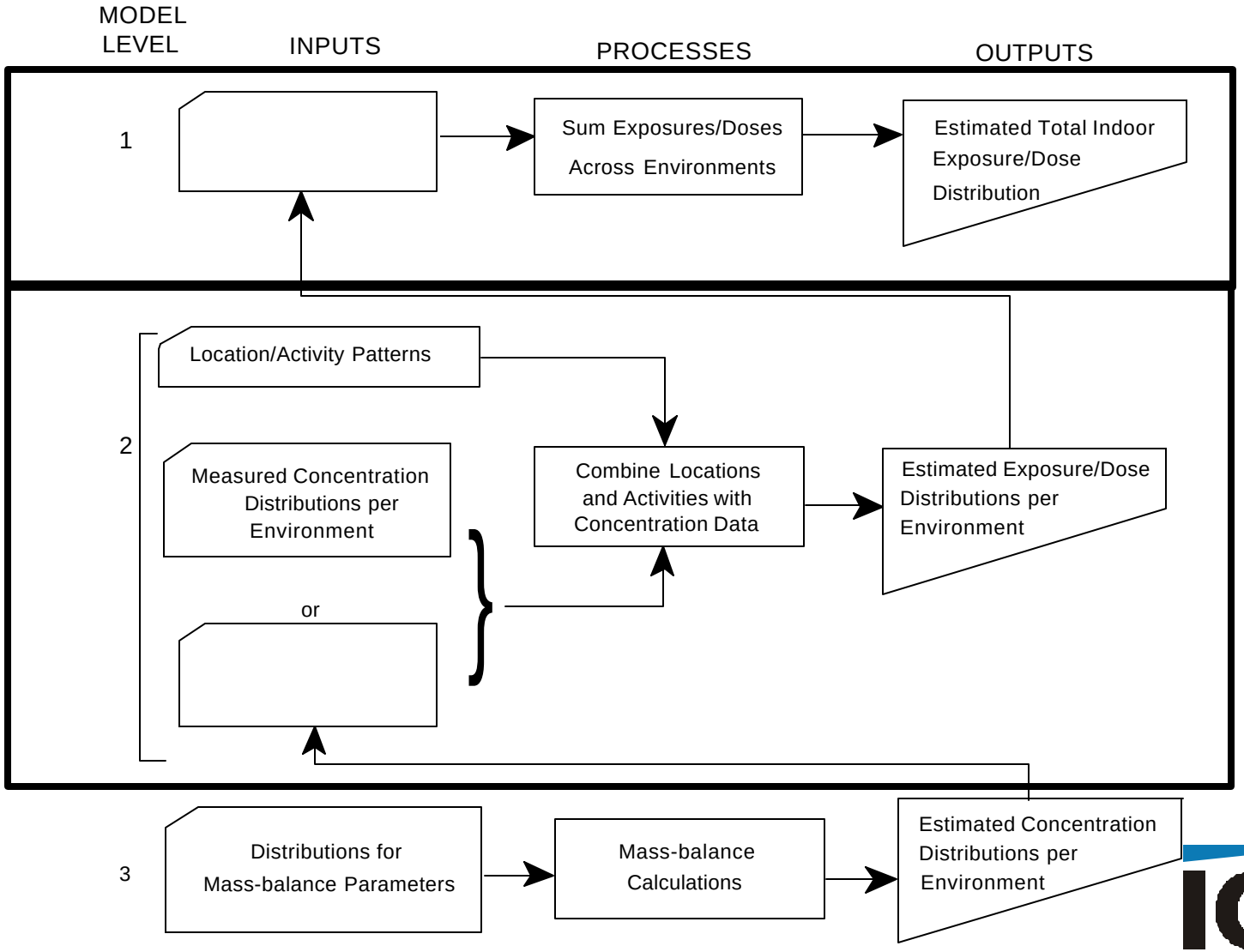
CPIEM2.0 Features

- Combines microenvironment concentrations with activity patterns
- Monte Carlo framework
- 9 microenvironments
- Optional mass-balance module
- **Large default database**
- **Uncertainty and variability treated separately**
- **User-friendly Windows platform**

CPIEM2.0 Overview



CPIEM2.0 Overview



CPIEM Level 1-2:
Integrated Exposure

$$E_T^{INT} = \sum_i E_i^{INT}$$ Level 1

$$E_i^{INT} = C_i \times t_i$$ Level 2

$\boldsymbol{E_T^{INT}}$ = integrated total exposure conc over exposure period (e.g., μg-hr/m^3 per day),
$\boldsymbol{E_i^{INT}}$ = integrated microenvironment exposure conc (e.g., μg-hr/m^3 per day),
$\boldsymbol{C_i}$ = concentration in microenvironment *i* (e.g., μg/m^3),
$\boldsymbol{t_i}$ = time in microenvironment *i* (e.g., hrs)

CPIEM Level 1-2:
Time-Weighted Average Exposure

$$E_T^{TWA} = \sum_i E_i^{TWA}$$ Level 1

$$E_i^{TWA} = \frac{C_i \times t_i}{T}, \qquad T = \sum t_i$$ Level 2

$\boldsymbol{E_T^{TWA}}$ = time-weighted average total exposure conc (e.g., μg/m^3),
$\boldsymbol{E_i^{TWA}}$ = time-weighted average microenviroment exposure conc (e.g., μg/m^3),
$\boldsymbol{C_i}$ = concentration in microenvironment *i* (e.g., μg/m^3),
$\boldsymbol{t_i}$ = time in microenvironment *i* (e.g., min), and
$\boldsymbol{T}$ = total time period of investigation (e.g., 1440 min)

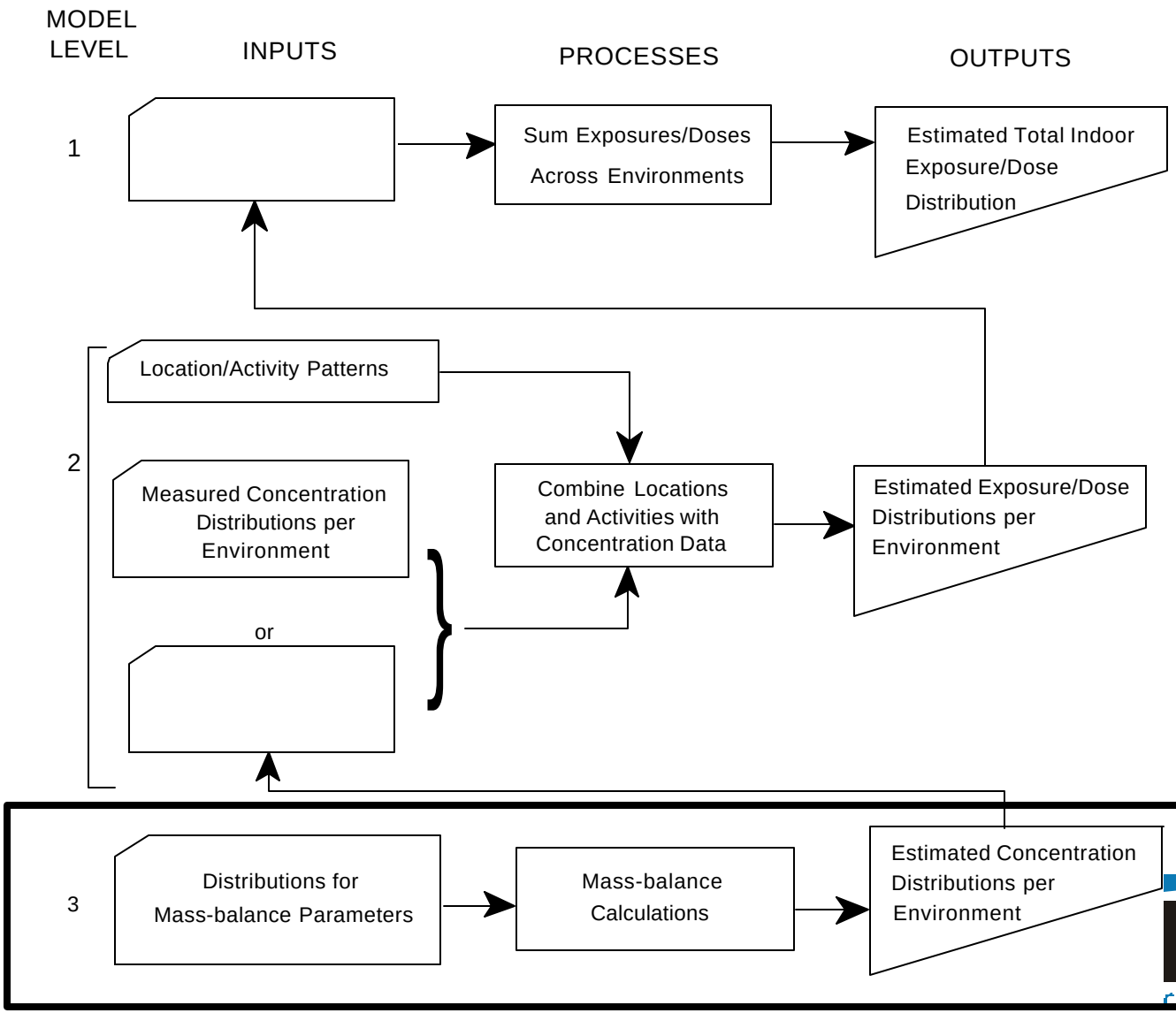
CPIEM Level 1-2: Dosage

$$D_T = \sum_i D_i$$ Level 1

$$D_i = BR \times E_i^{INT}$$ Level 2

$\boldsymbol{D_T}$ = total inhalation dosage (e.g., μg per day)
$\boldsymbol{D_i}$ = microenvironment inhalation dosage (e.g., μg per day)
$\boldsymbol{BR}$ = breathing rate (e.g., m^3/hr)
$\boldsymbol{E_i^{INT}}$ = integrated exposure conc over exposure period (e.g., μg-hr/m^3 per day),

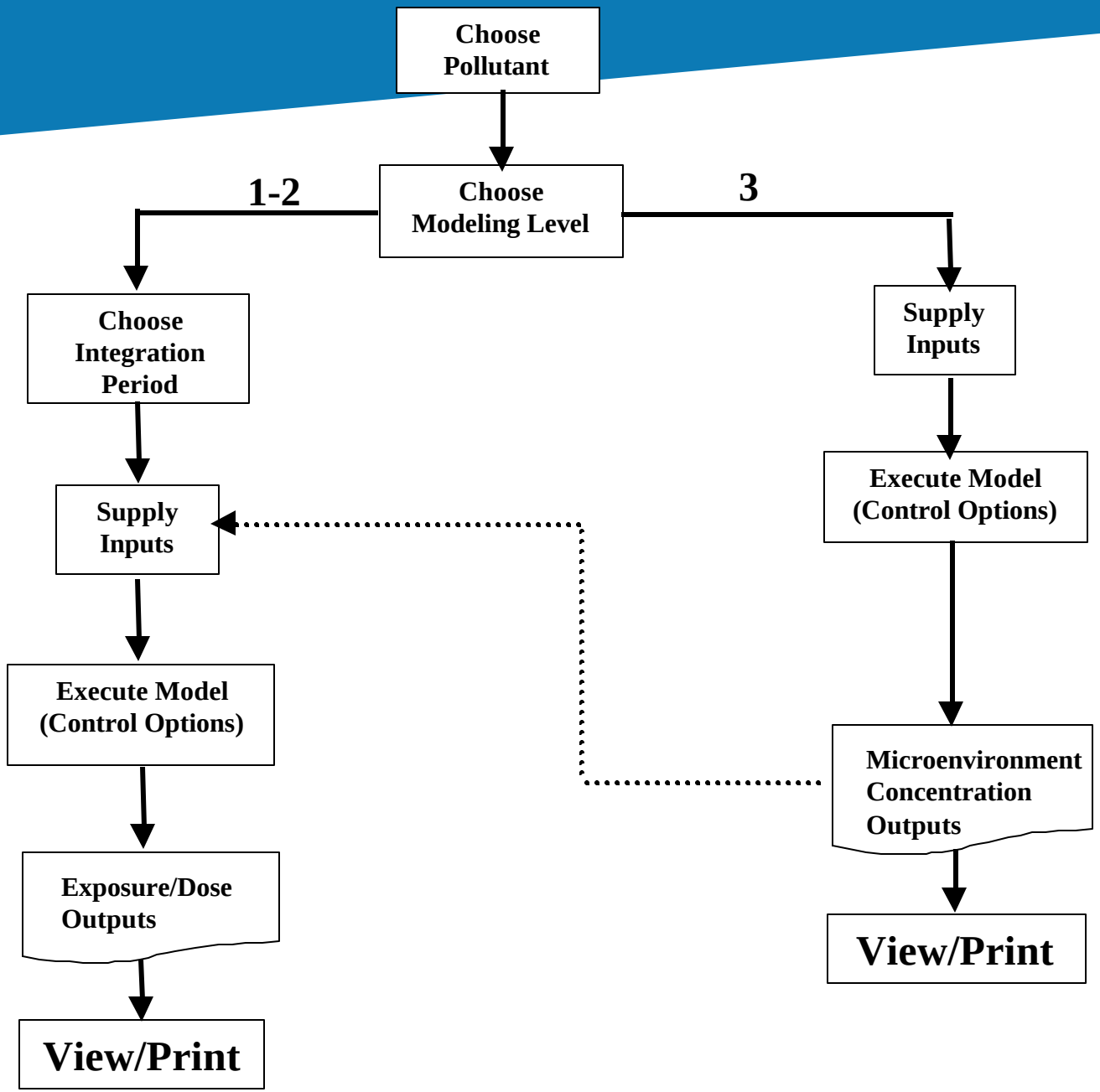
CPIEM2.0 Overview



CPIEM Level 3: Microenvironment Concentrations

$$V\frac{d}{dt}C_{in} = pQC_{out} + S - (k_1 + k_2 + k_3)VC_{in} - QC_{in}$$

C_{in} = indoor concentration (e.g.,μg/m^3)
V = enclosure volume(e.g.,m^3)
p = penetration factor (dimensionless fraction)
Q = air flow rate (m^3/hr)
C_{out} = outdoor concentration (e.g.,μg/m^3)
S = indoor generation rate (e.g.,μg/hr)
k_1 = reactive decay rate (e.g., 1/hr)
k_2 = net surface adsorption rate (i.e., adsorption – de-adsorption) (e.g., 1/hr)
k_3 = net deposition rate (i.e., deposition – resuspension) (e.g., 1/hr)


Choose Pollutant
Choose Modeling Level
1-2
3
Choose Integration Period
Supply Inputs
Execute Model (Control Options)
Exposure/Dose Outputs
View/Print
Supply Inputs
Execute Model (Control Options)
Microenvironment Concentration Outputs
View/Print

California Environmental Protection Agency

Air Resources Board

CPIEM

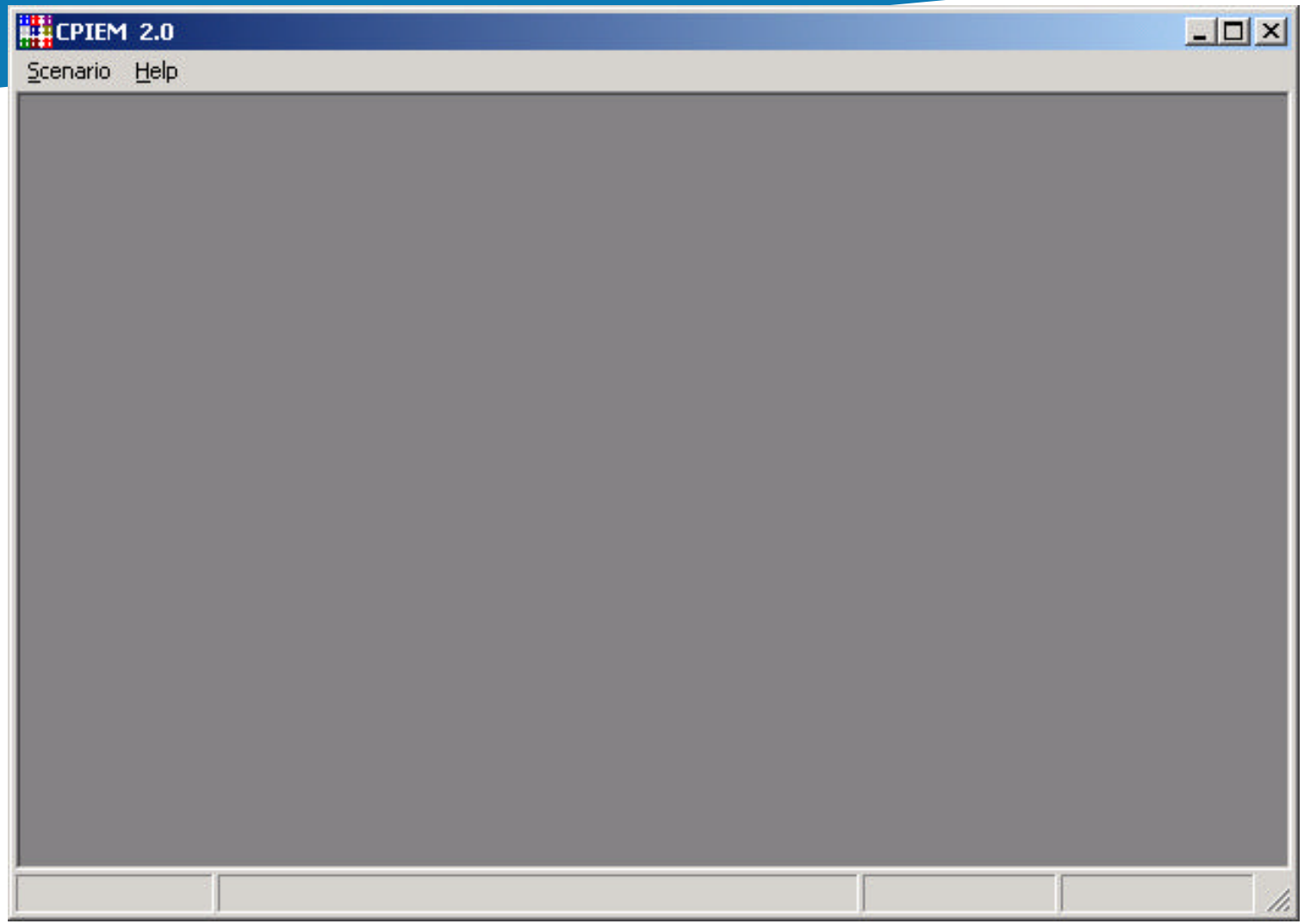
California Population Indoor Exposure Model

Version 2.0

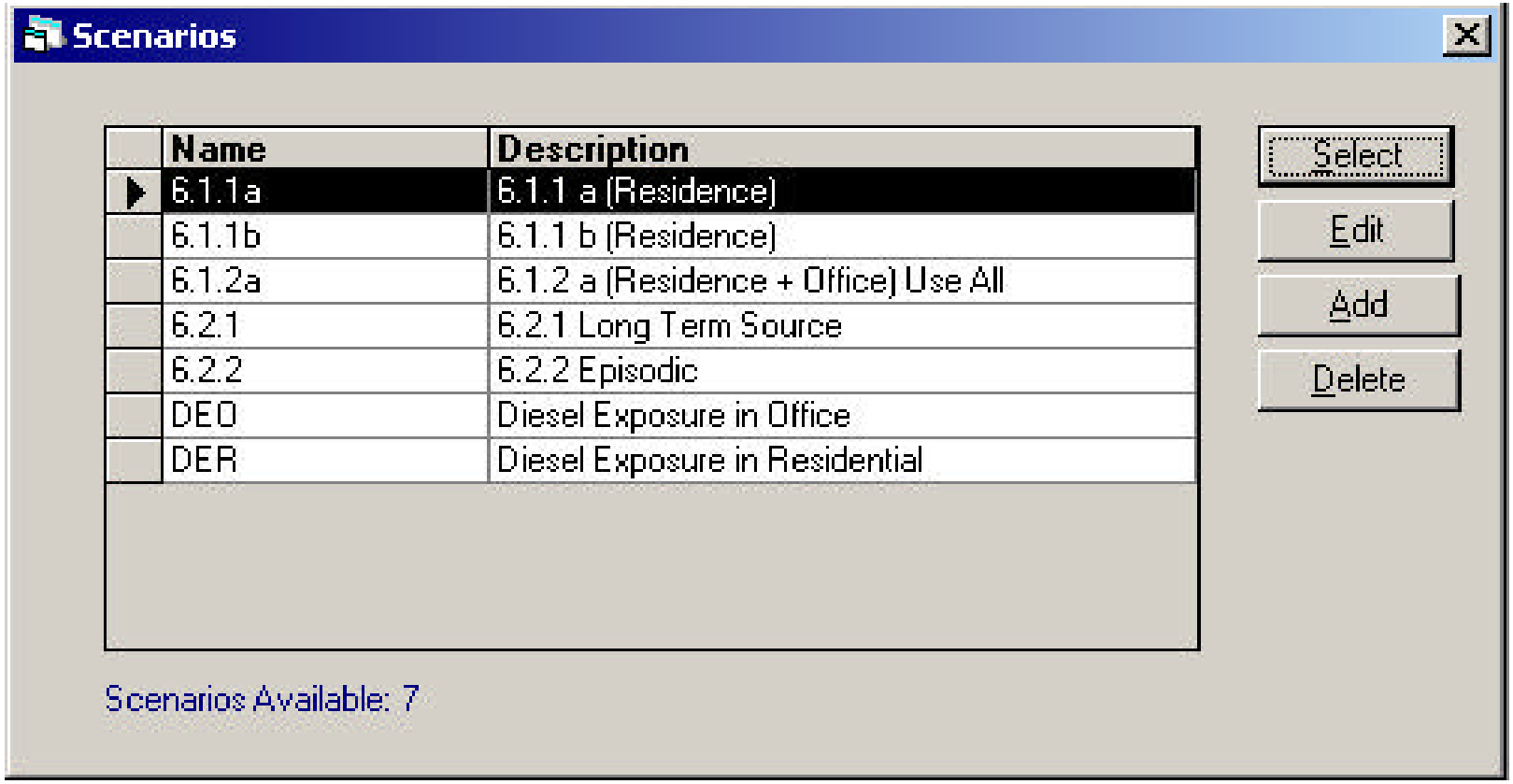
Developed by ICF Consulting

ARB Contract Number: 98-327

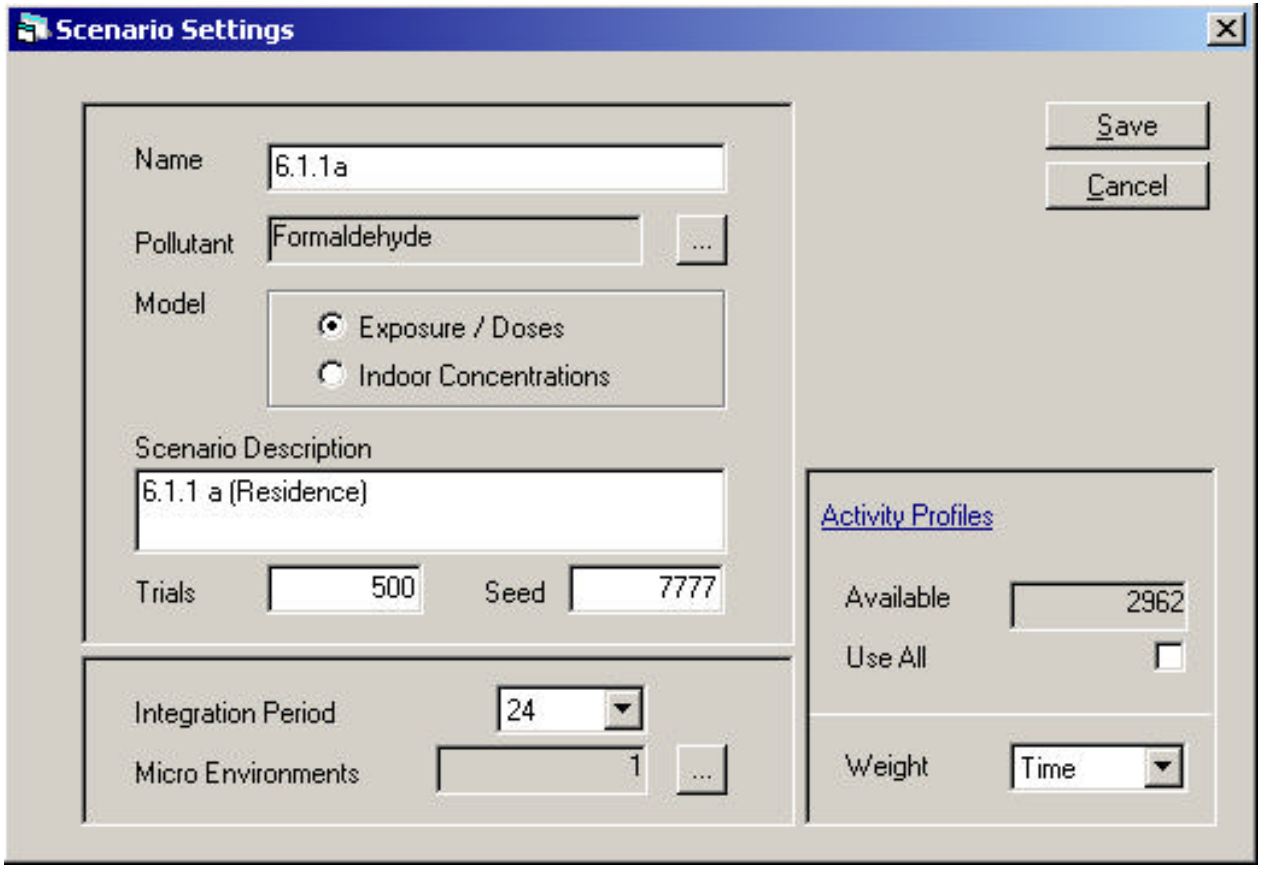
2002, California Air Resources Board


CPIEM 2.0
Scenario
Help

Scenario Selection



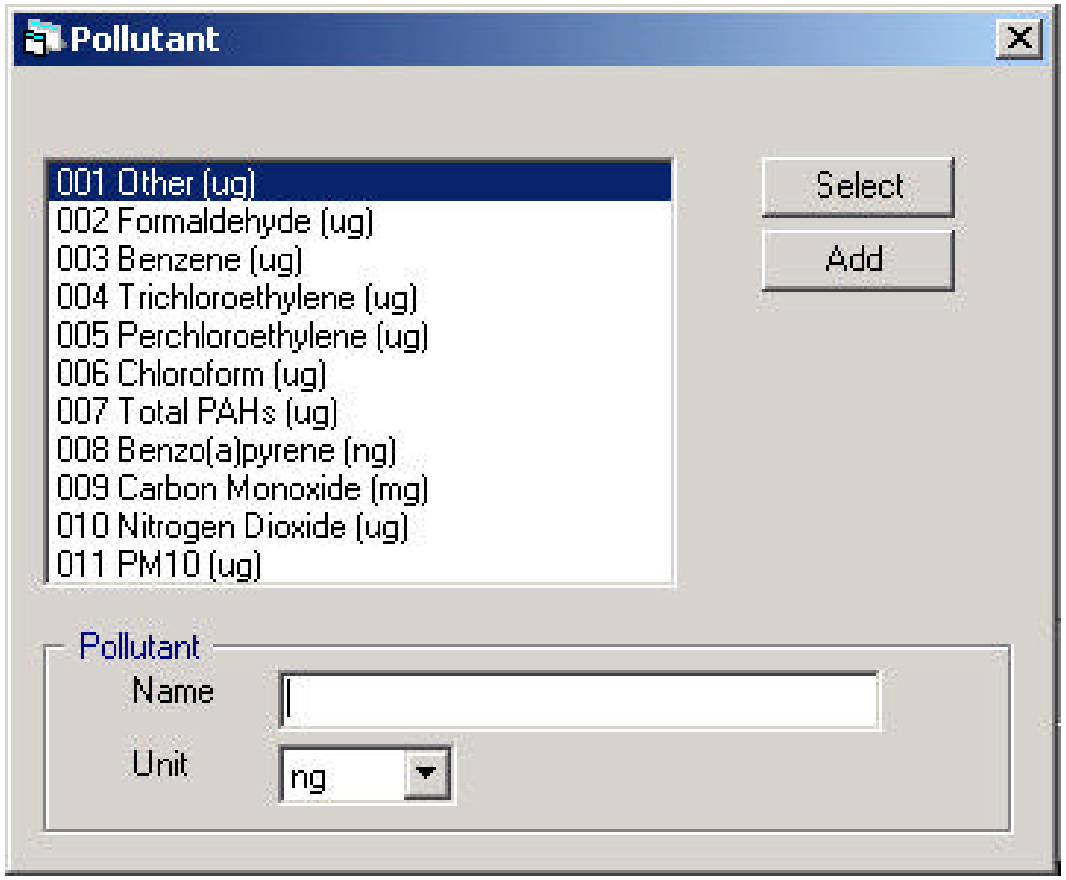
Adding or Editing Scenarios



Inputs for All Simulation Levels

- Pollutant
- Number of trials
- Random number seed

Pollutant Selection



Inputs for Level 1-2

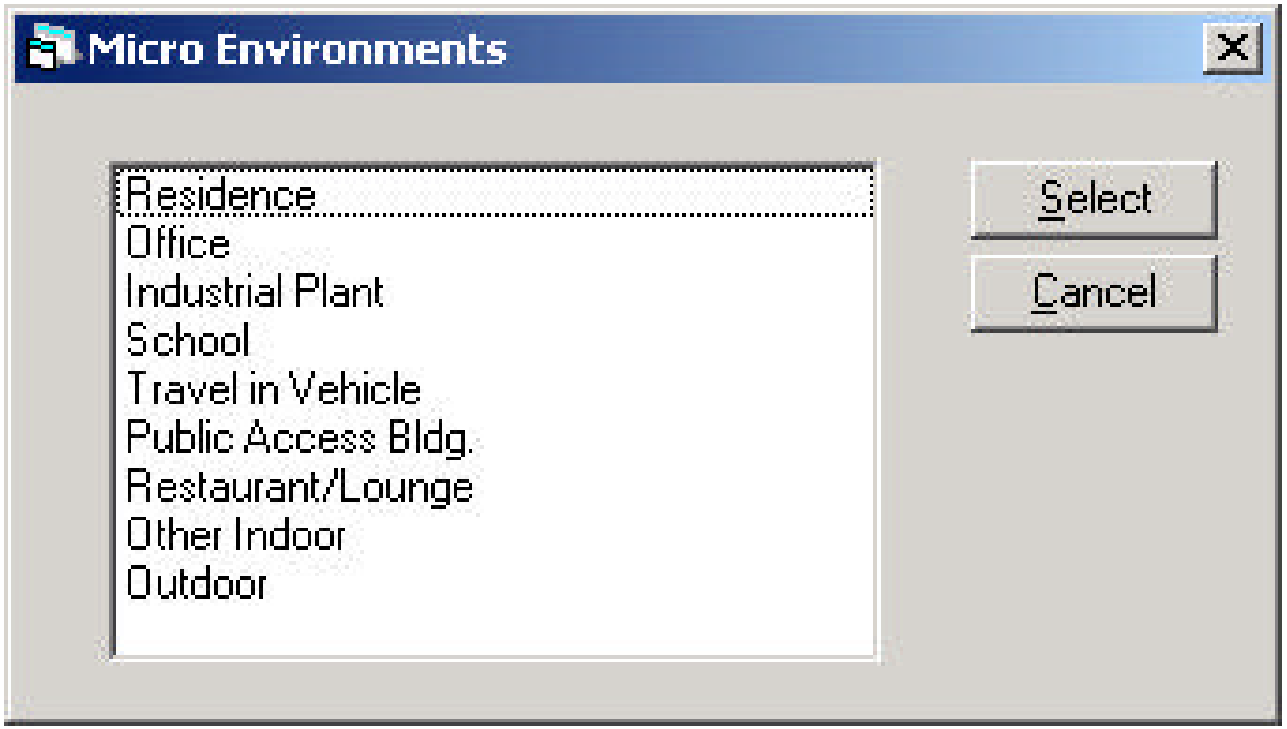
- Integration/averaging period
- Population subgroups Þ activity patterns*
- Microenvironment concentrations*
- Breathing rates (dosage)

******Probability distribution*

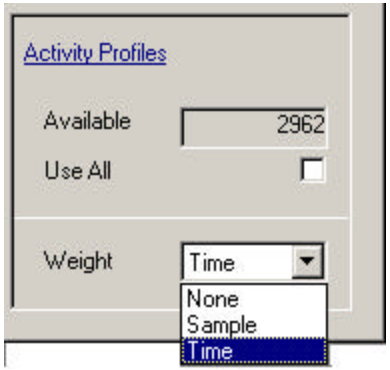
Integration Period Selection

- 24 hour ⇒ daily concentration
- 12 hour AM ⇒ daily concentration
- 12 hour PM ⇒ daily concentration
- 8 hour ⇒ 24 concentration values per day
- 1 hour ⇒ 24 concentration values per day

Microenvironment Selection

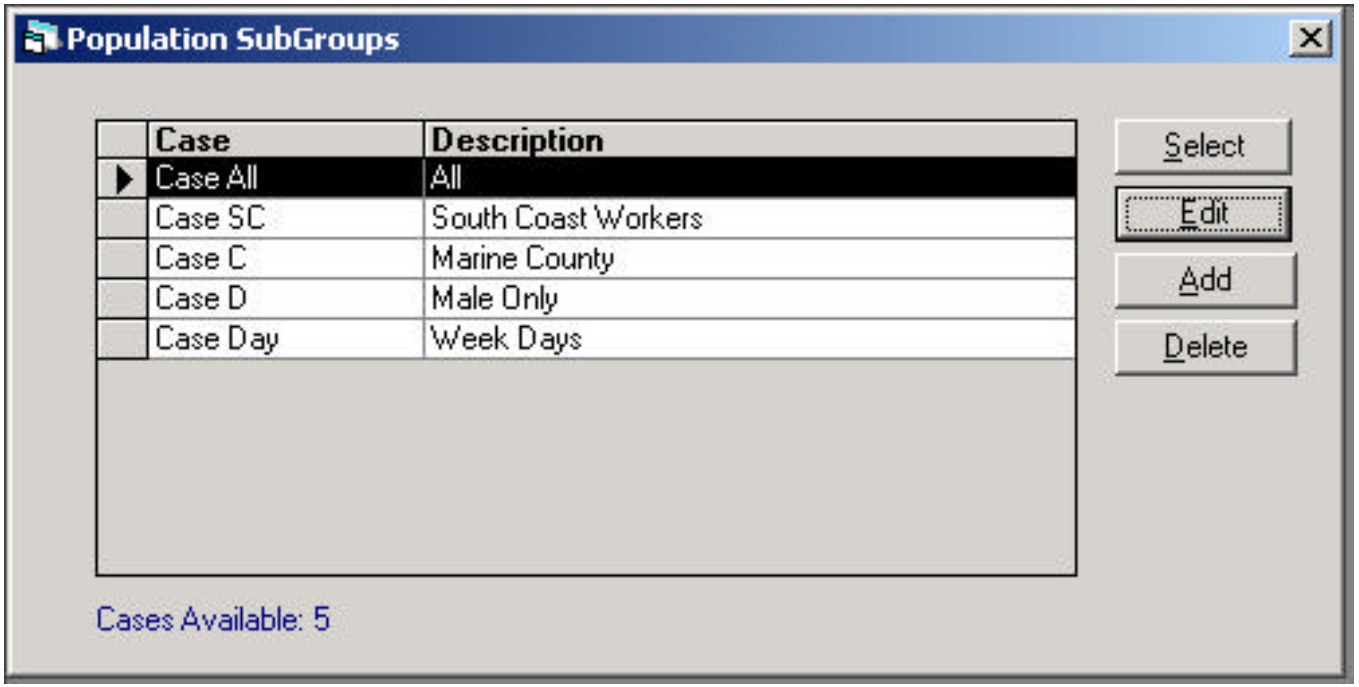


Activity Pattern Weight Selection

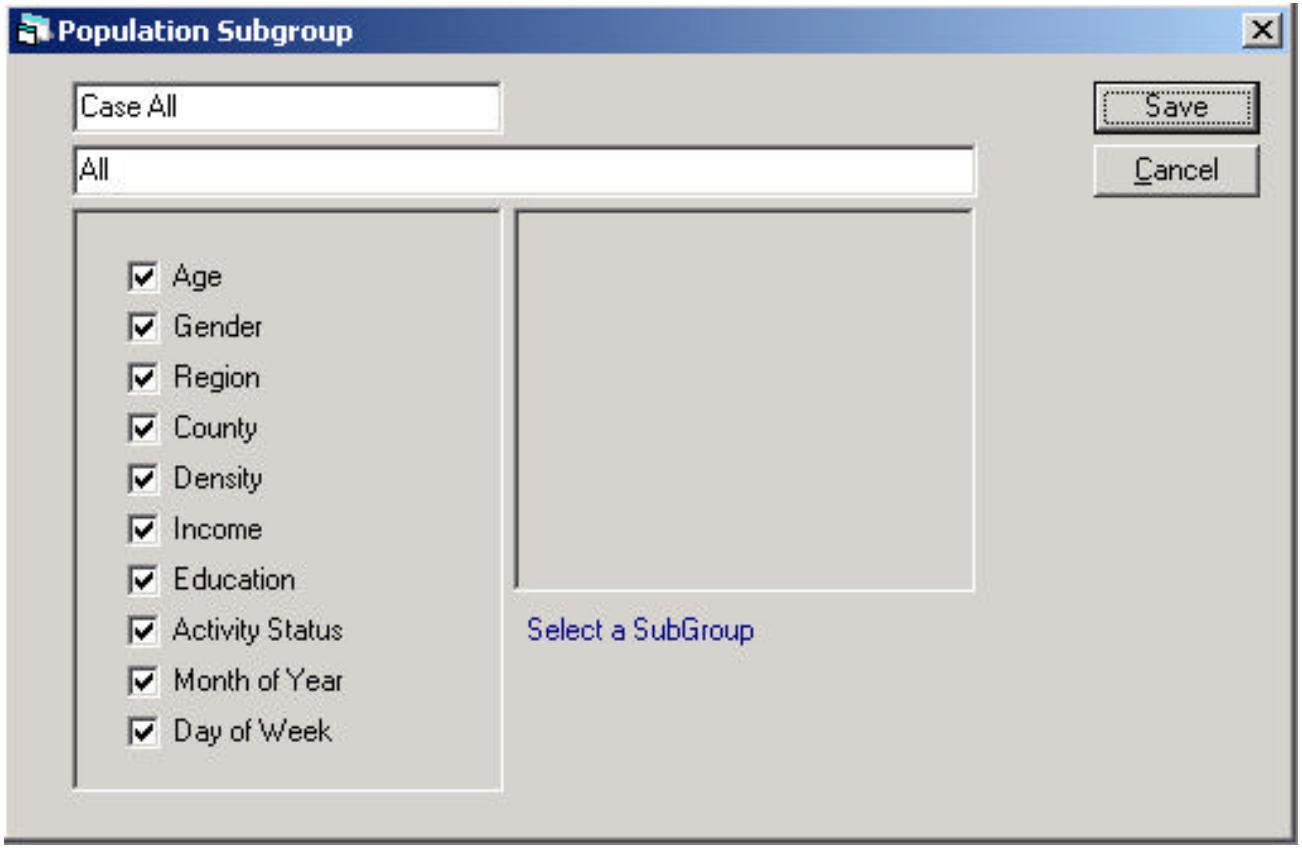


- None: all patterns selected with equal probability
- Sample: adjusts for oversampling of subpopulations
- Time: adjusts for oversampling of subpopulations and day-types

Population Subgroup Selection



Adding or Editing Population Subgroups



0 99

Age

Alameda
Apline
Amador
Buttle
Calaveras
Colusa
Contra Costa
Del Norte
El Dorado
Frezno
Glenn

+++

County

Male
Female

+++

Gender

Rural
Suburb
City

+++

Density

Some HighSchool
HighSchool Graduate
Some College
College Graduate
Teen (12-17)
Youth (<12)

+++

Education Level

January
February
March
April
May
June
July
August
September
October
November

+++

Month

South Coast
SF Bay Area
Other California

+++

Region

<10 K
10 K
10-20 K
20 K
20-30 K
30 K
30-40 K
40 K
40-50 K
50 K
50-60 K

+++

Household Income

Working
Unemployed
Retired
School
Keep House
Other
Teen (12-17)
Youth (<12)

+++

Activity Status

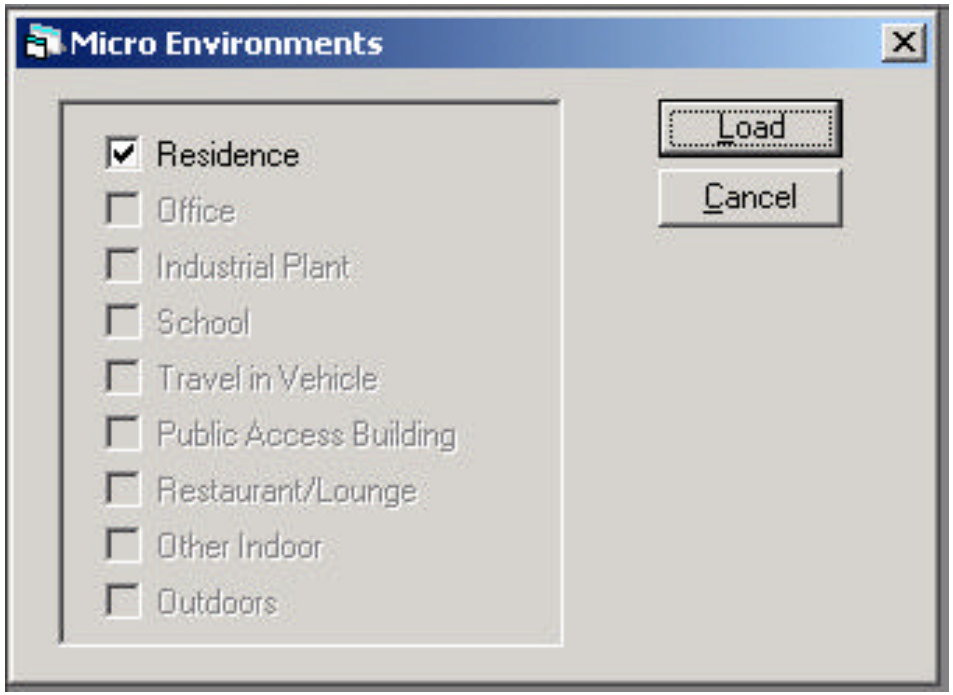
Sunday
Monday
Tuesday
Wednesday
Thursday
Friday
Saturday

+++

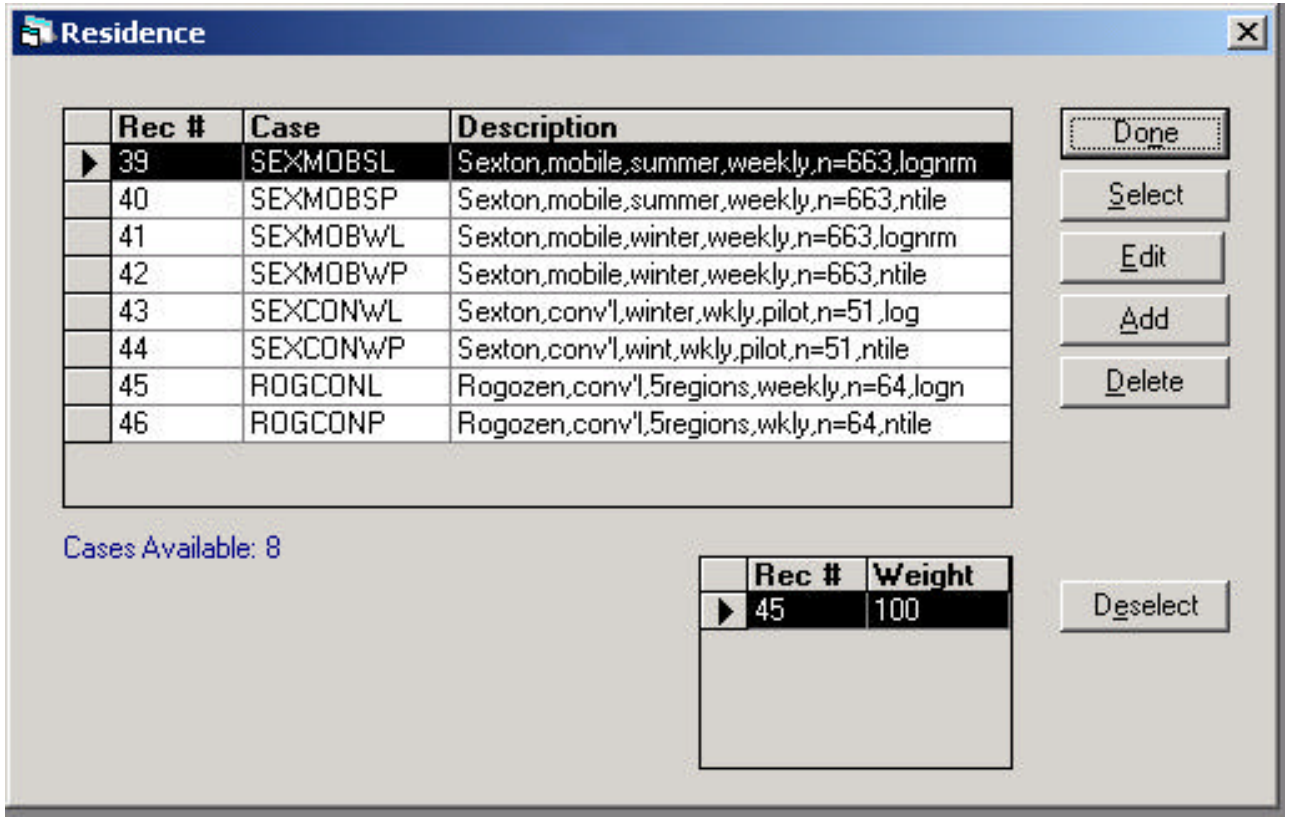
Day of Week

ICF CONSULTING

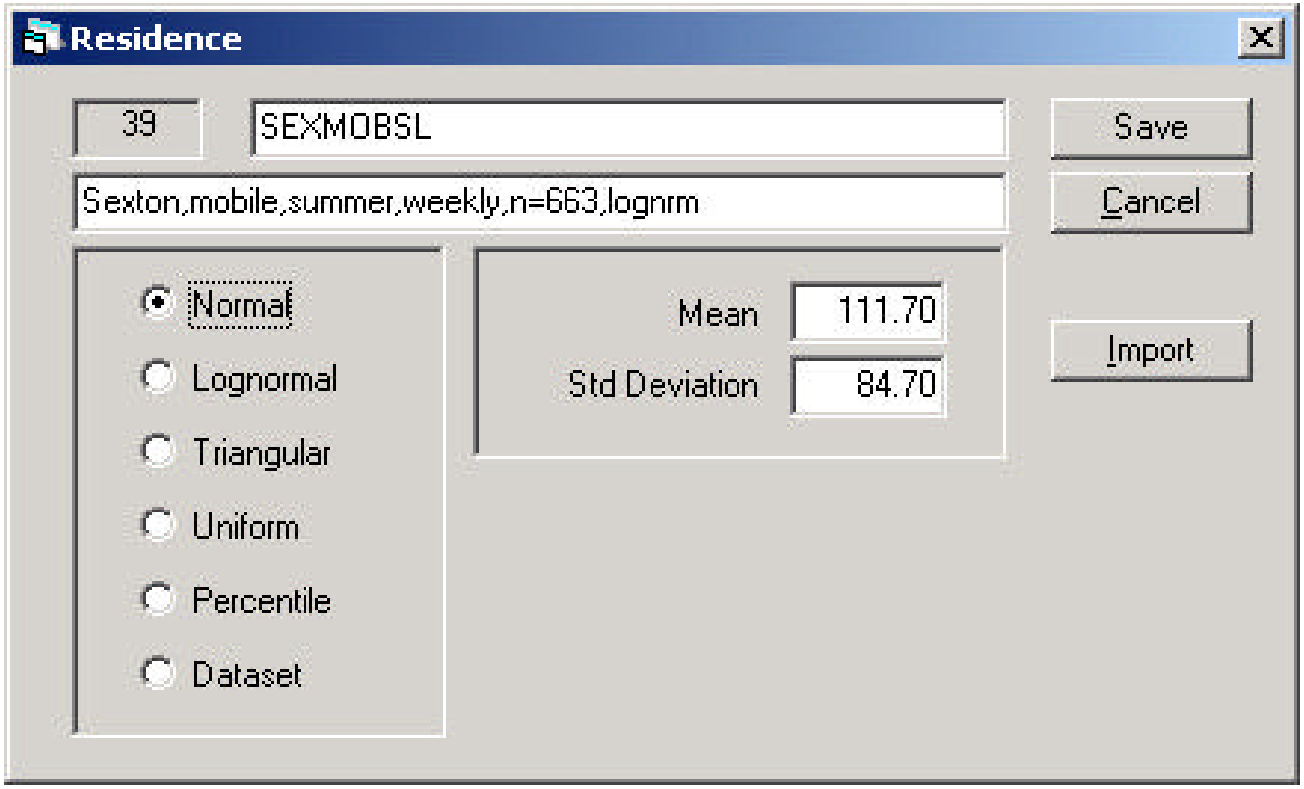
Indoor Concentration Specification



Indoor Concentration Cases



Adding or Editing Indoor Concentration Cases



Distribution Types

- Normal: arithmetic mean, std deviation
- Lognormal : arithmetic mean, std deviation
- Triangular: maximum, mode, minimum
- Uniform: maximum, minimum
- Percentile: up to 12 pairs of percentiles and associated values
- Dataset: name of MS Access file (*.mdb)

- Normal
- (•) Lognormal
- Triangular
- Uniform
- Percentile
- Dataset

Mean	111.70
Std Deviation	84.70

- Normal
- Lognormal
- (•) Triangular
- Uniform
- Percentile
- Dataset

Minimum	0.20
Mode	0.45
Maximum	1.00

- Normal
- Lognormal
- Triangular
- (•) Uniform
- Percentile
- Dataset

Minimum	30
Maximum	120

- Normal
- Lognormal
- Triangular
- Uniform
- (•) Percentile
- Dataset

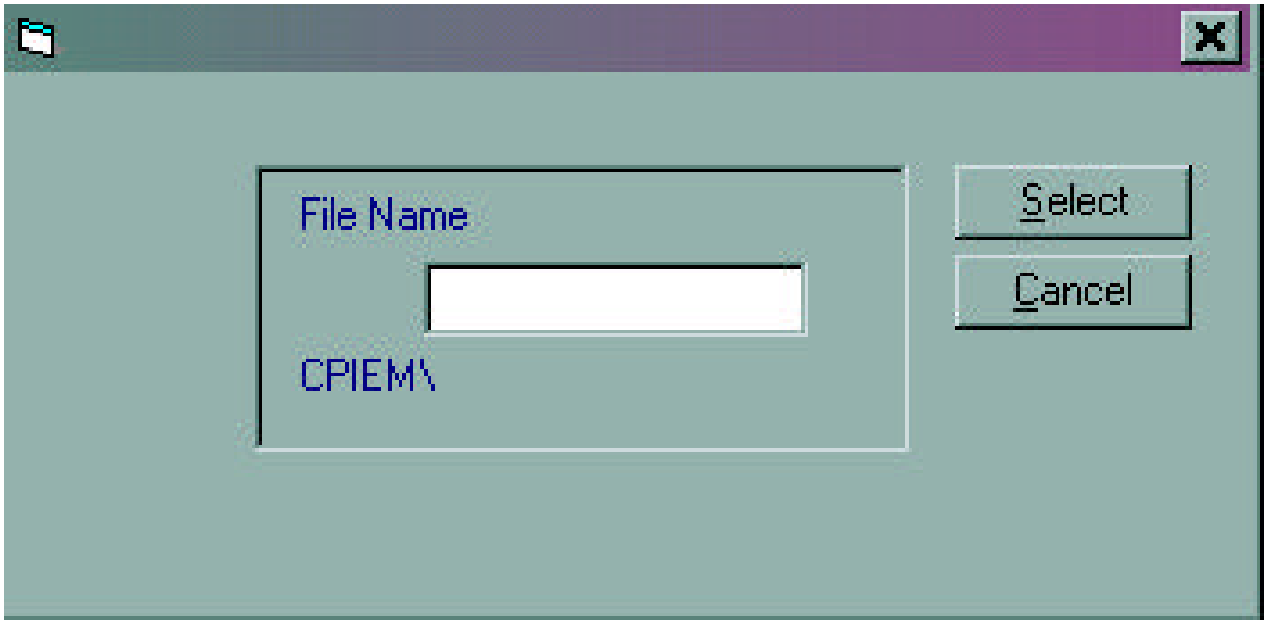
	%	Value
1.	.00	16.00
2.	10.00	24.50
3.	44.00	36.80
4.	57.00	49.10
5.	77.00	61.40
6.	91.00	73.60
7.	93.00	85.90
8.	99.00	98.20
9.	100.00	104.30
10.	.00	.00
11.	.00	.00
12.	.00	.00

- Normal
- Lognormal
- Triangular
- Uniform
- Percentile
- (•) Dataset

File Name

CPIEM\Data\

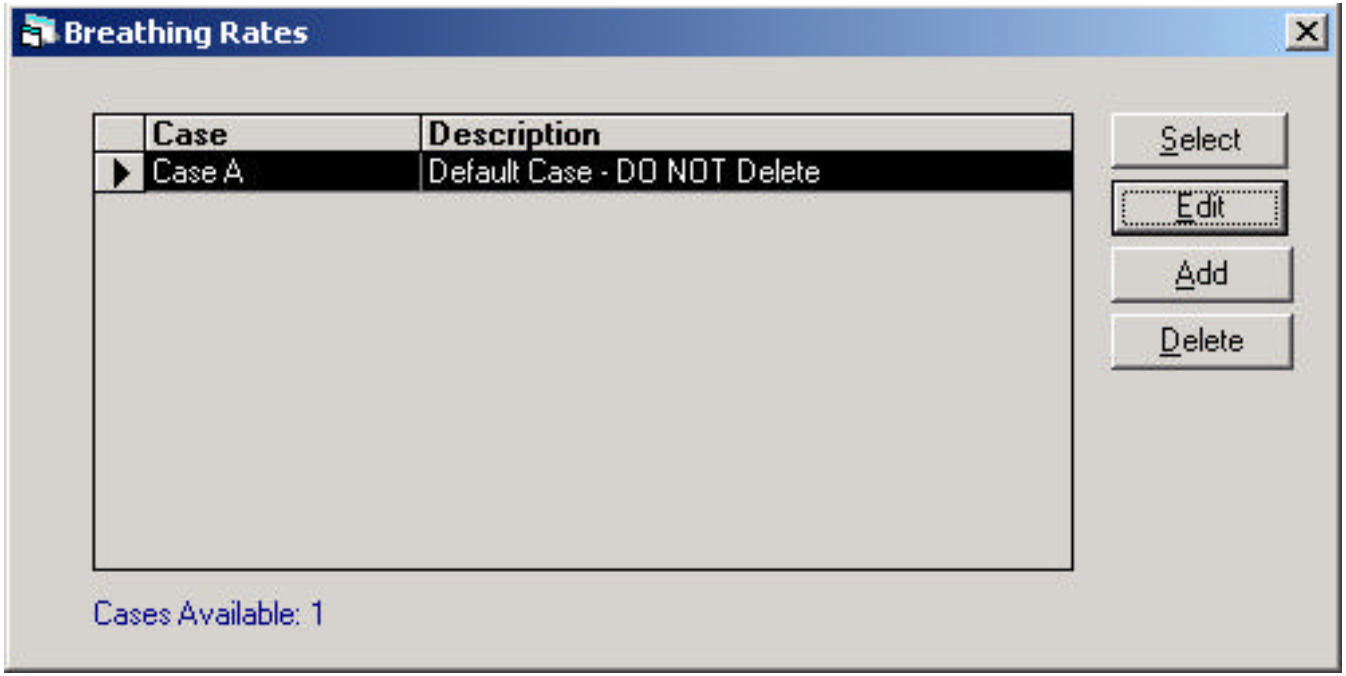
Importing Data from Level 3



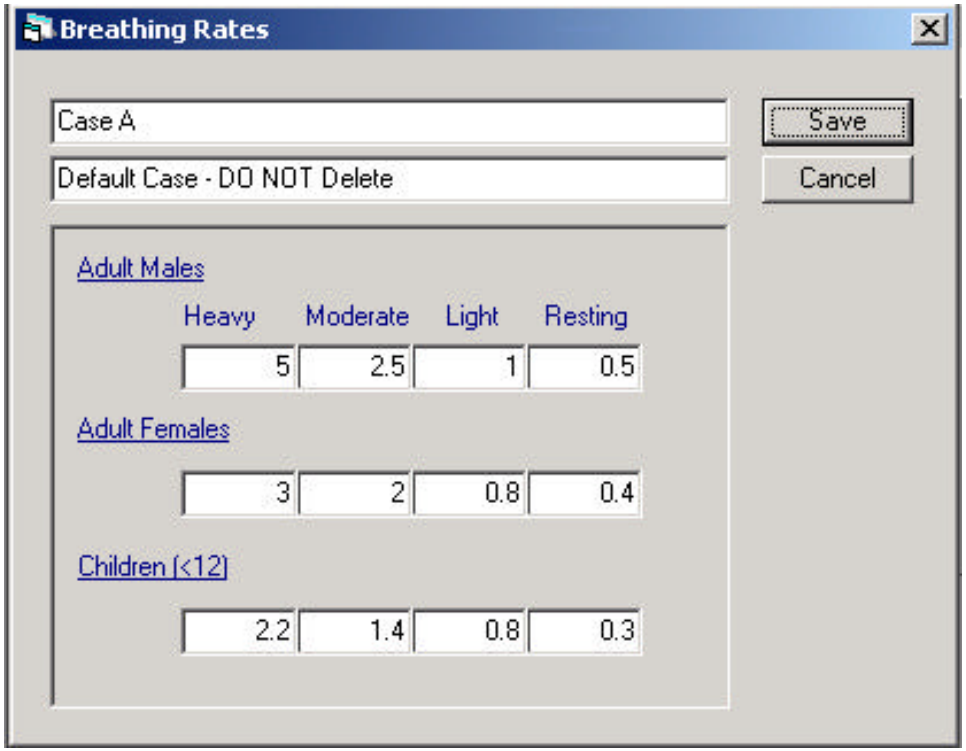
Selecting Cases and Assigning Weights

Rec #	Weight
44	50
45	50

Breathing Rate Selection



Adding or Editing Breathing Rates

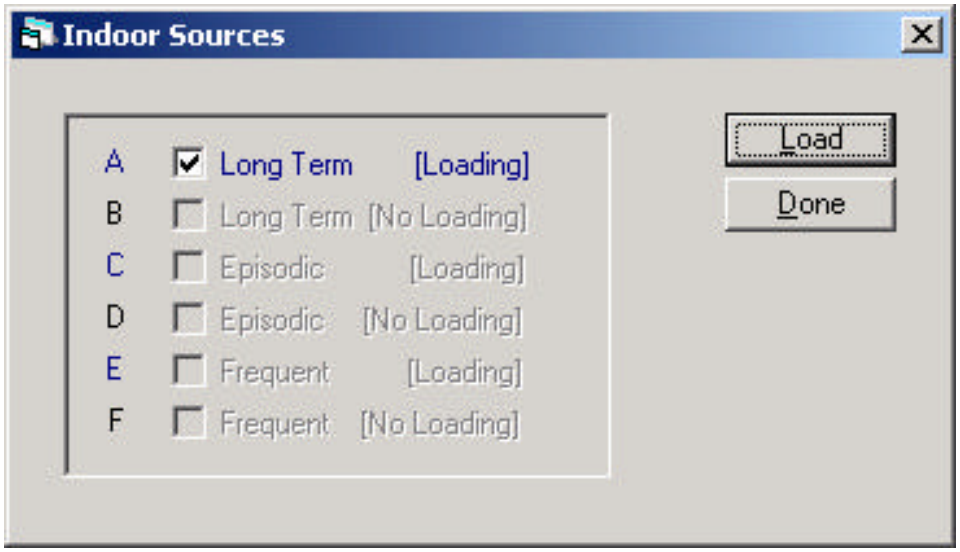


Level 3 Inputs

- Indoor emission source specification*
- Outdoor concentration*
- Penetration rate*
- Indoor sink rate*
- Enclosure volume*
- Air exchange rate*

**Probability distribution*

Indoor Source Specification



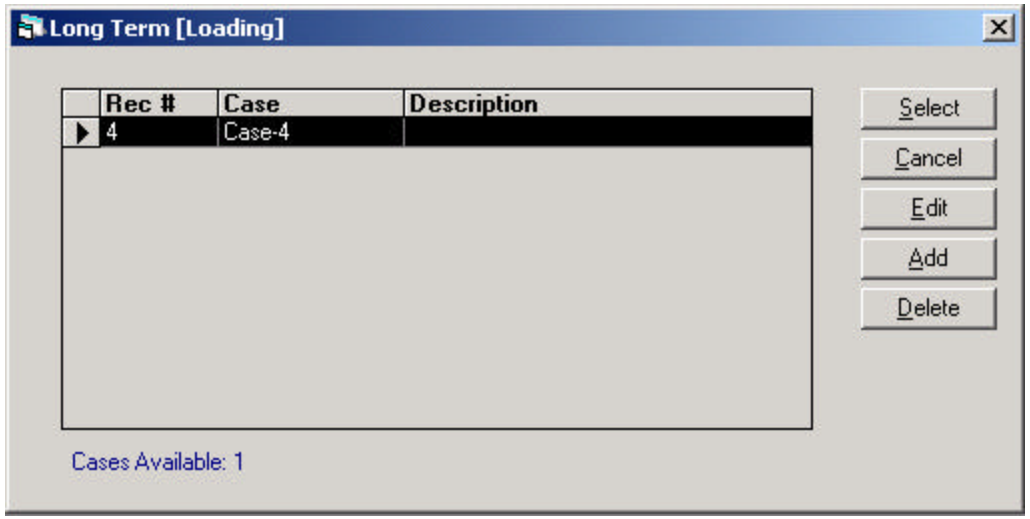
Indoor Source Types

- Long-term: static features of buildings (e.g., interior finishes, furnishings, some appliances)
- Episodic: used or present regularly or infrequently (e.g., carpet cleaning, painting, dry-cleaned clothes)
- Frequent: used on a daily basis, often more than once a day (e.g., cooking, showering, tobacco smoking)

Indoor Source Types

- Loading: quantity of material present or used described relative to building volume (e.g., square feet per cubic meter of building)
- No loading: quantity of material present or used described in absolute terms (e.g., square feet)

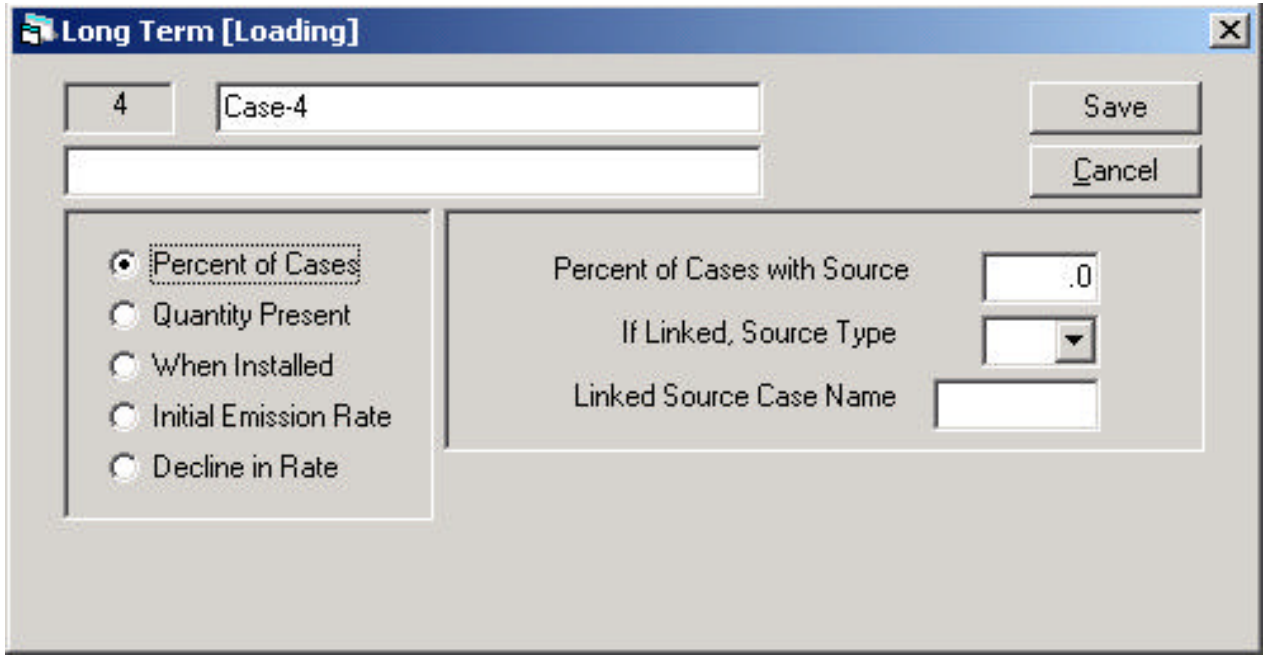
Indoor Source Case Selection



Indoor Source Specification Inputs

	SOURCE TYPE		
	Long-term	Episodic	Frequent
Percent of cases	X	X	X
Quantity present/used	X	X	X
When installed	X		
Time since use		X	
Duration of use		X	X
Episodes per day			X
Start time			X
Initial emission rate	X	X	X
Decline in rate	X	X	X

Adding or Editing a Long-term Source Case



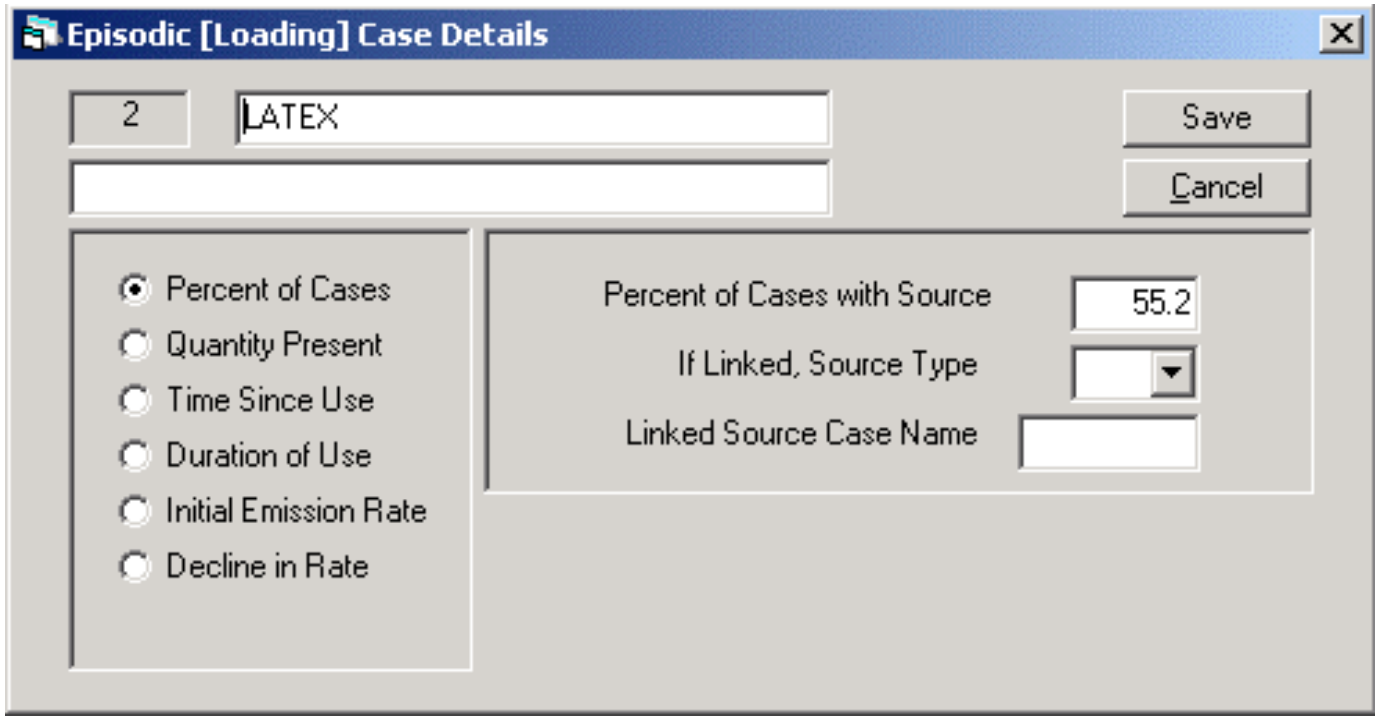
Emission Rate: Long-Term Source

Loading: $$ER = I \times Q \times V \times e^{-rt}$$

No loading: $$ER = I \times Q \times e^{-rt}$$

ER = emission rate (e.g., μg/hr)
I = initial emission rate (e.g., μg/hr/ft^2, ug/BTU)
Q = quantity present or used (e.g., ft^2/m^3, BTU/hr)
V = volume of building (m^3)
t = time since installed (months)
r = decline in rate (1/months)

Adding or Editing an Episodic Source Case



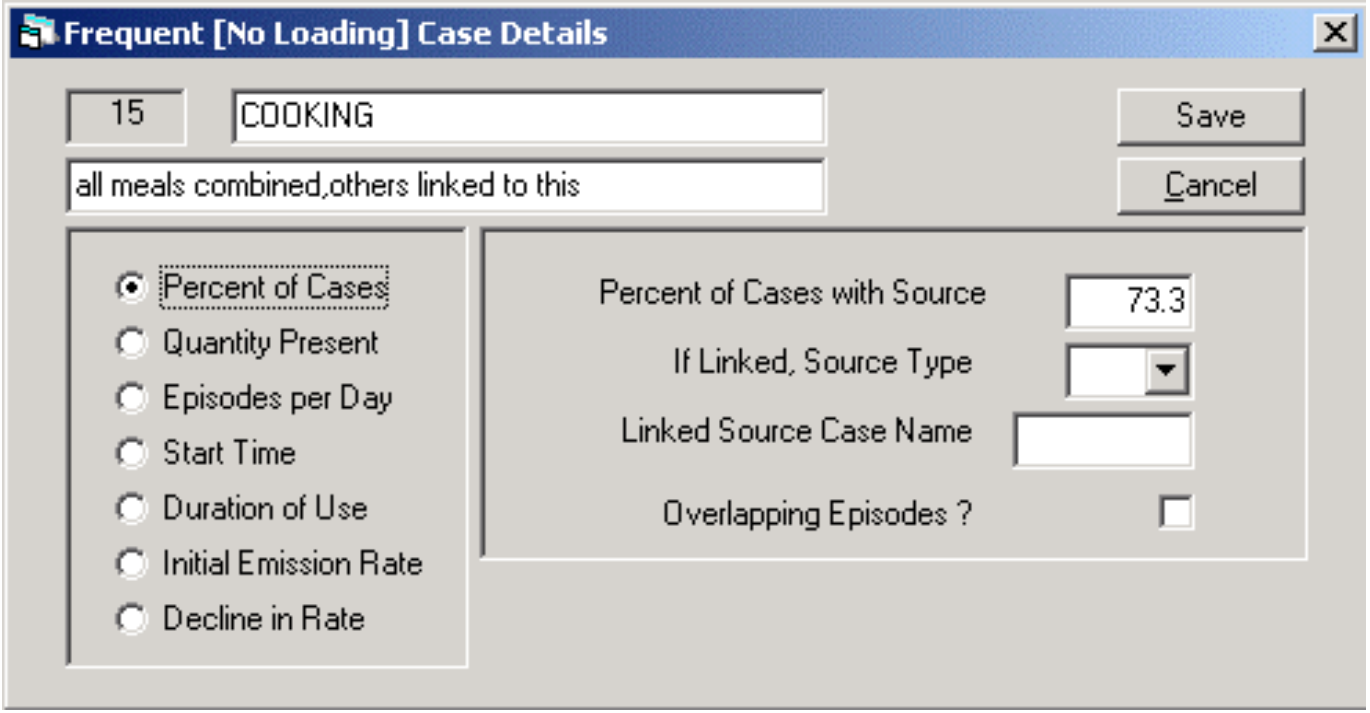
Emission Rate: Episodic Source

Loading: $$ER = I \times Q \times V \times e^{-rt}$$

No loading: $$ER = I \times Q \times e^{-rt}$$

ER = emission rate (e.g., μg/hr)
I = initial emission rate (e.g., μg/hr/ft^2, ug/BTU)
Q = quantity present or used (e.g., ft^2/m^3, BTU/hr)
V = volume of building (m^3)
t = time since use (days)
r = decline in rate (1/days)

Adding or Editing a Frequent Source Case



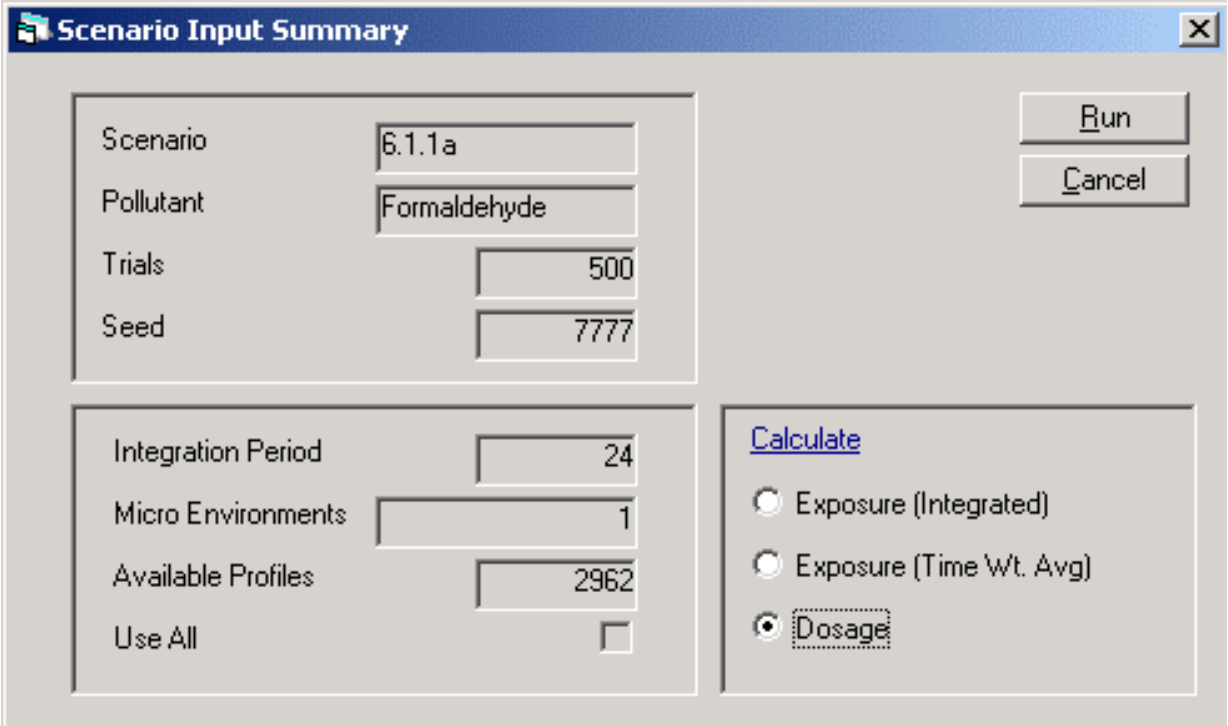
Emission Rate: Frequent Source

Loading: $$ER = I \times Q \times V \times e^{-rt}$$

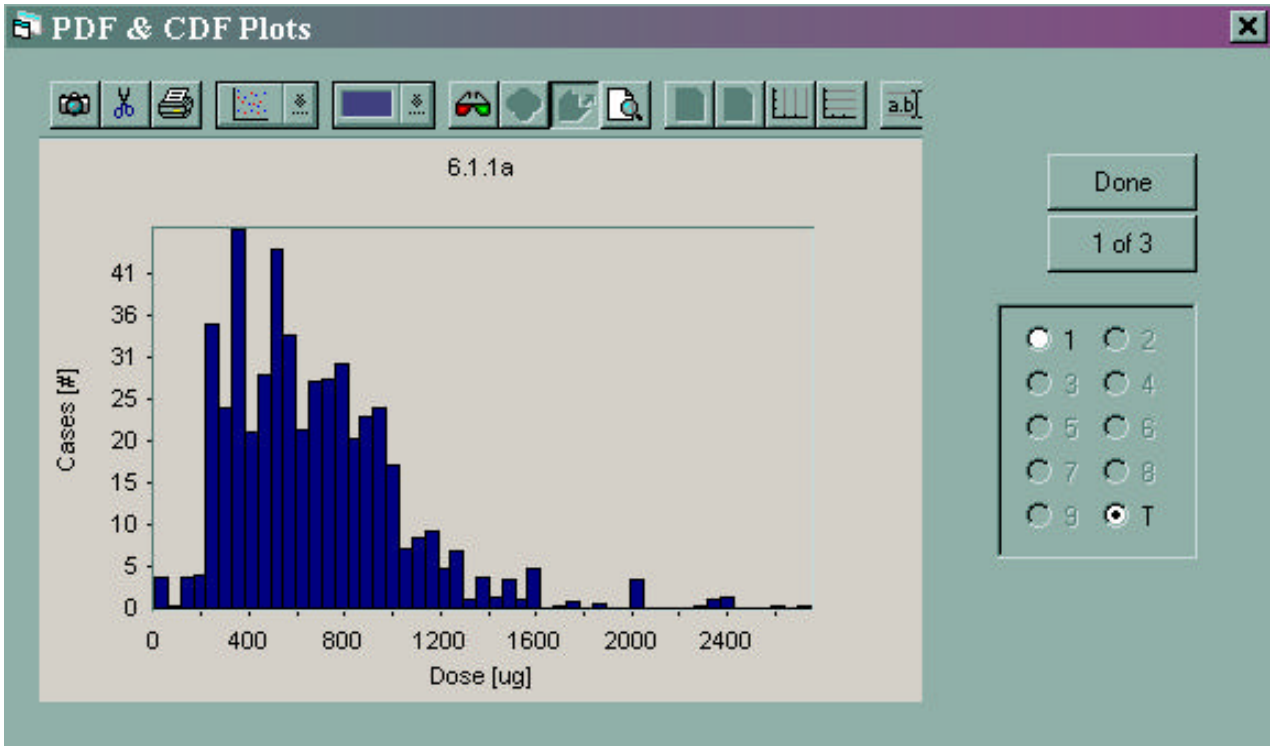
No loading: $$ER = I \times Q \times e^{-rt}$$

ER = emission rate (e.g., μg/min)
I = initial emission rate (e.g., μg/min/ft^2, ug/BTU)
Q = quantity present or used (e.g., ft^2/m^3, BTU/min)
V = volume of building (m^3)
t = time since use (days)
r = decline in rate (1/hour)

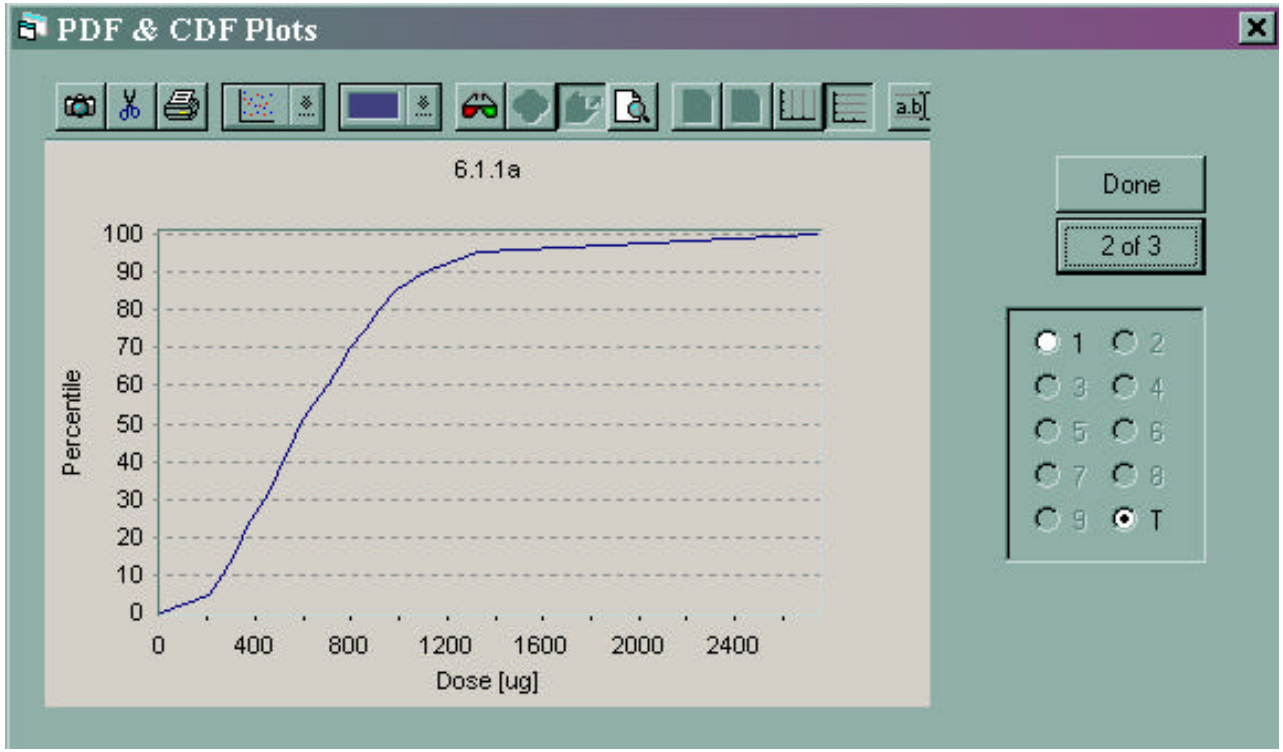
Output Metric Selection



Graphical Output Display I



Graphical Output Display II



Data View Output Display

PDF & CDF Plots

Date	6/2/2002
Pollutant	Formaldehyde [ug]
Seed	7777
Trial	500
Arithmatic Mean	663.54
Arithmatic SD	383.21
Geometric Mean	500.58
Geometric SD	5.31
Minimum	0.00
Maximum	2753.24

%	Value	%	Value
5	206.85	55	638.44
10	258.41	60	702.55
15	307.94	65	749.54
20	344.90	70	793.45
25	382.16	75	862.39
30	438.53	80	915.68
35	481.93	85	986.62
40	508.37	90	1111.41
45	556.63	95	1332.39
50	585.55	100	2753.24

Done

3 of 3

1 2
3 4
5 6
7 8
9 T

Summary Output File (*.ste)

```
Title:      6.1.1a
Description: 6.1.1 a (Residence)
Pollutant:  Formaldehyde (ug)
Int. Period: 24
Trials:     500  (2962)
Random seed: 7777


Residential (ENV1)
    Case #   Weight
      45      1
Breathing Rates
    Case #   Weight
      1      1
```

	ENV1	TOTALS
Arith Mean	663.54	663.54
Arith Std Dev	383.21	383.21
Geo Mean	500.58	500.58
Geo Std Dev	5.31	5.31
Minimum	0.00	0.00
Maximum	2753.24	2753.24
5%	206.85	206.85
10%	258.41	258.41
15%	307.94	307.94
20%	344.90	344.90
25%	382.16	382.16
30%	438.53	438.53
35%	481.93	481.93
40%	508.37	508.37
45%	556.63	556.63
50%	585.55	585.55
55%	638.44	638.44
60%	702.55	702.55
65%	749.54	749.54
70%	793.45	793.45
75%	862.39	862.39
80%	915.68	915.68
85%	986.62	986.62
90%	1111.41	1111.41
95%	1332.39	1332.39
100%	2753.24	2753.24

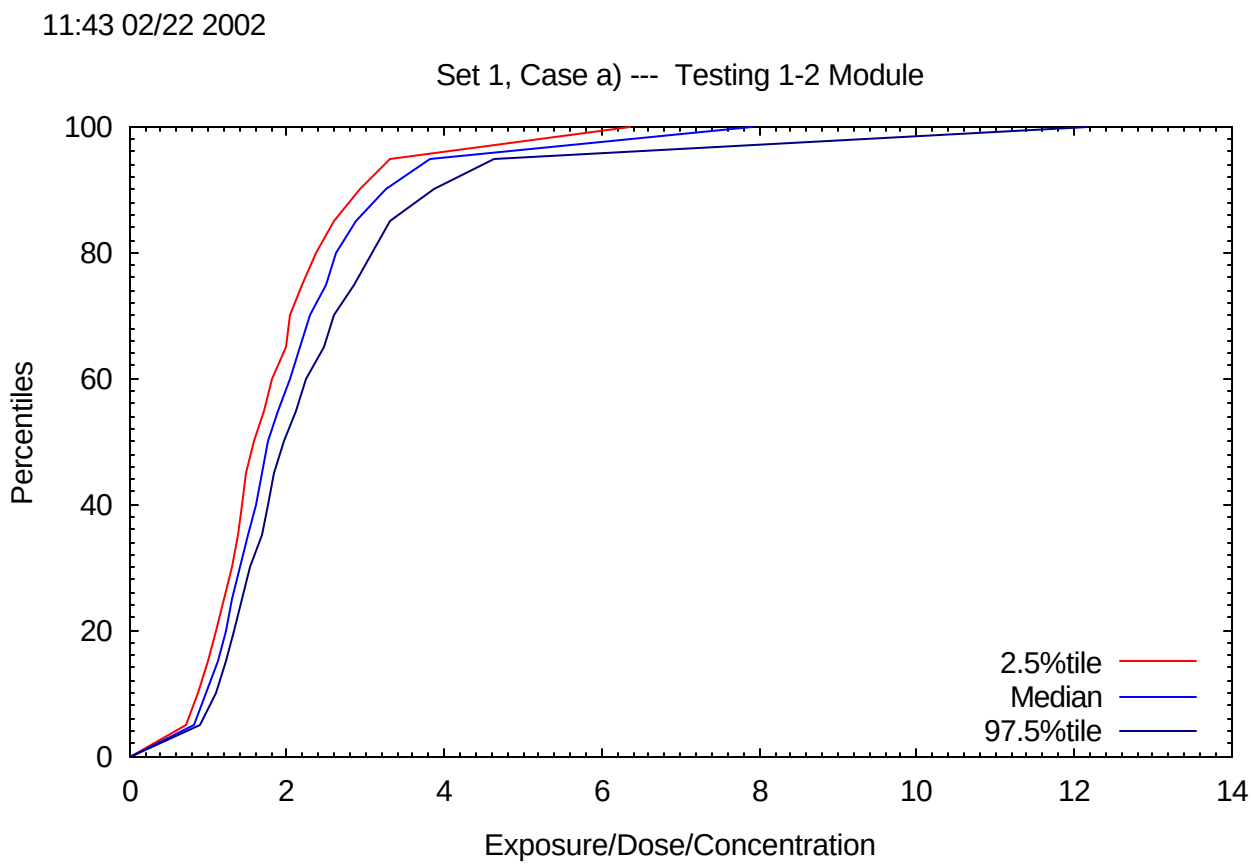
Detailed Output File for Level 1-2 (*.asc)

	ActPat ID	Sex/Age	Weight	Time	Exposure-integrated	Dose
1	48521	1	2.506	18.20	615.93	505.94
2	63995	3	0.200	24.00	1225.15	770.82
3	20181	1	1.020	18.83	1293.42	156.07
4	56805	3	0.172	15.25	1861.84	960.43
5	47311	2	0.762	21.00	1255.16	717.23
6	1581	2	1.296	21.25	368.29	318.90
7	60111	2	0.626	19.17	649.62	546.81
8	63665	3	0.254	23.00	1707.19	716.28
9	64125	3	0.200	24.00	540.44	283.73
10	53965	3	0.371	12.25	817.83	337.15
11	30581	1	0.226	17.25	1524.04	1314.21
12	4421	2	0.181	14.50	873.75	457.97
13	8901	2	0.648	19.67	946.10	660.66
14	6281	1	2.593	7.42	713.42	448.89
15	48475	3	0.054	19.72	1516.77	755.05
16	42165	3	0.377	20.00	792.78	381.53
17	31585	3	0.166	18.00	2157.90	917.11
18	5041	2	0.648	16.50	285.90	214.86
19	1403	1	0.270	21.00	2408.10	1691.40
20	26281	2	0.453	15.83	925.00	488.79

Detailed Output File for Level 3 (*.asc)

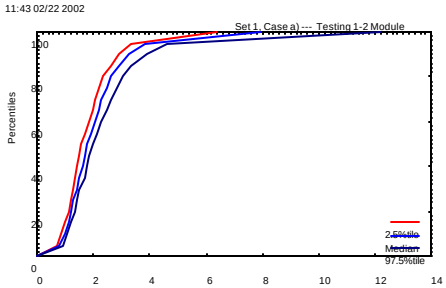
1	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	.31	
2	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	.22	
3	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	.38	
4	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	
5	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	
6	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	.06	
7	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	.30	
8	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	2.45	
9	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	.79	
10	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	.15	
11	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	.19	
12	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	
13	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	.09	
14	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	.04	
15	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	.26	
16	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	
17	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	.96	
18	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	.17	
19	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	.24	
20	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10	

Uncertainty



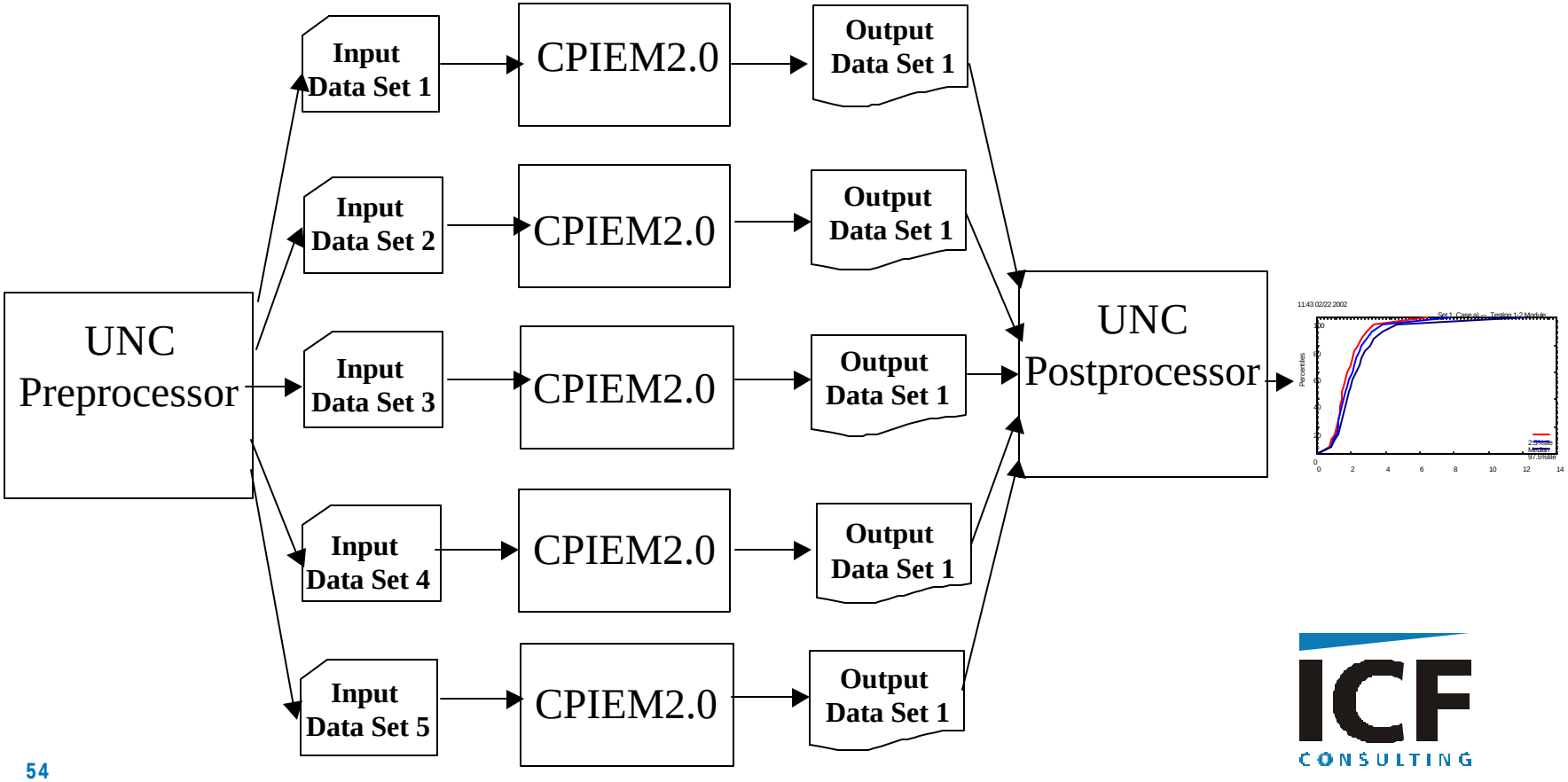
Uncertainty

Uncertainty in input distributions

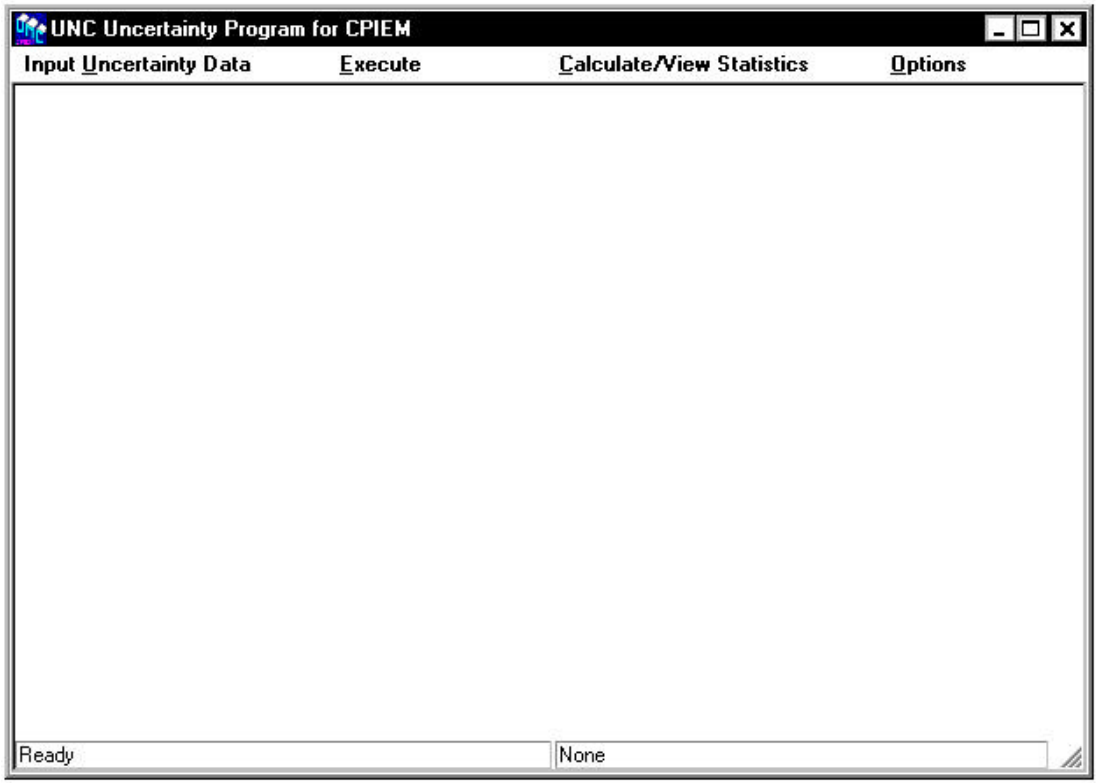


Uncertainty in output distribution

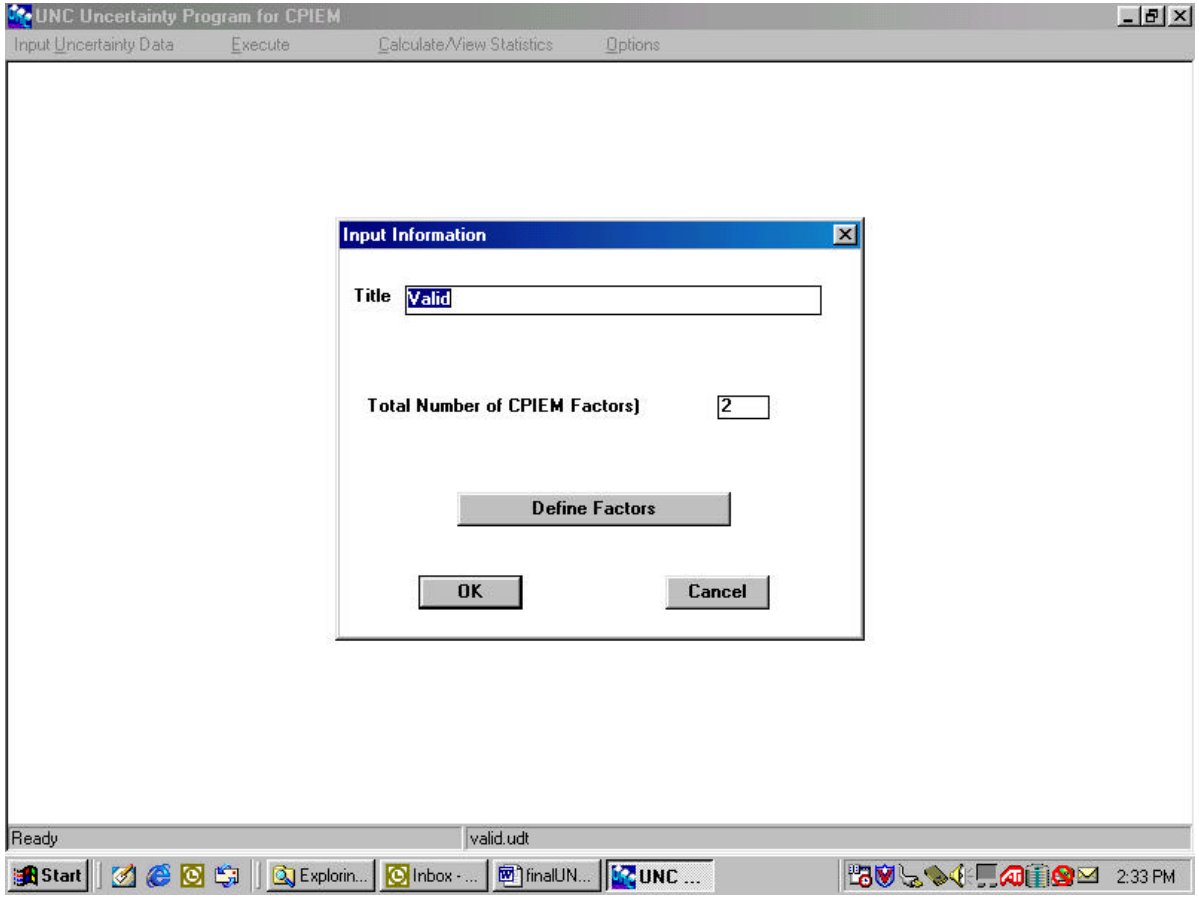
Uncertainty Overview



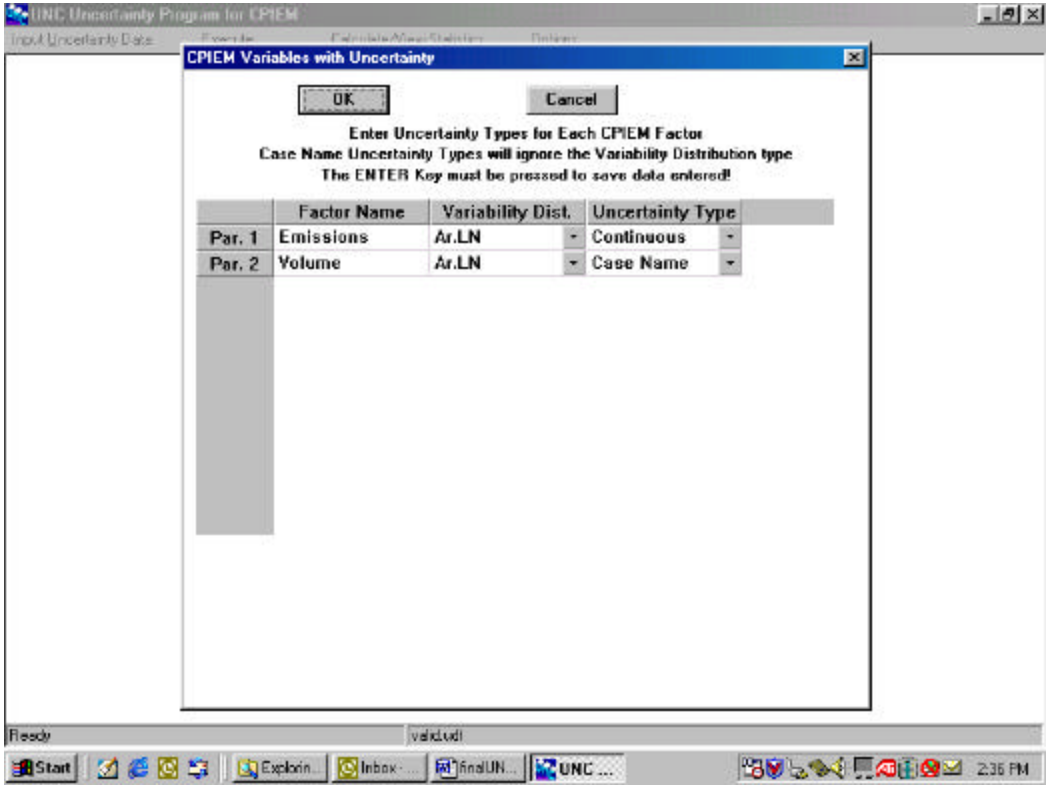
Uncertainty: CPIEMunc



Uncertainty Preprocessor: Number of Factors



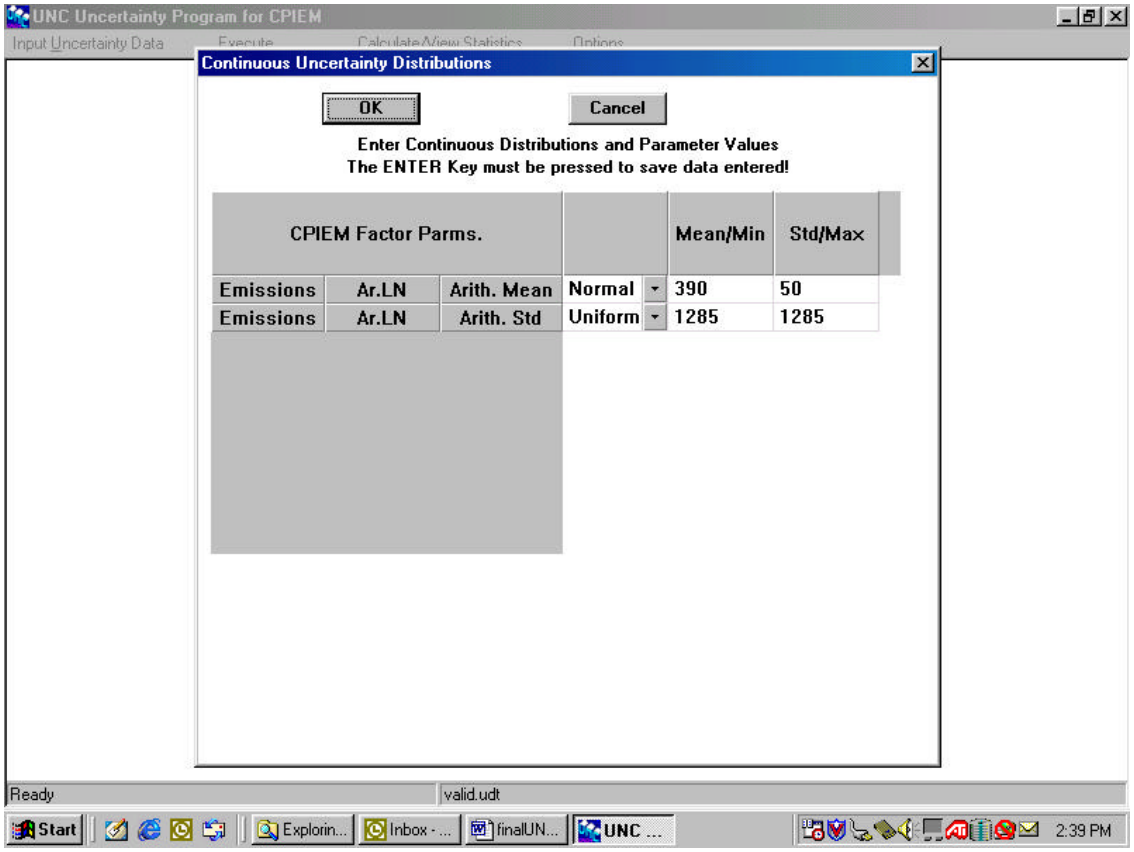
Uncertainty Preprocessor: Factor and Uncertainty Specification



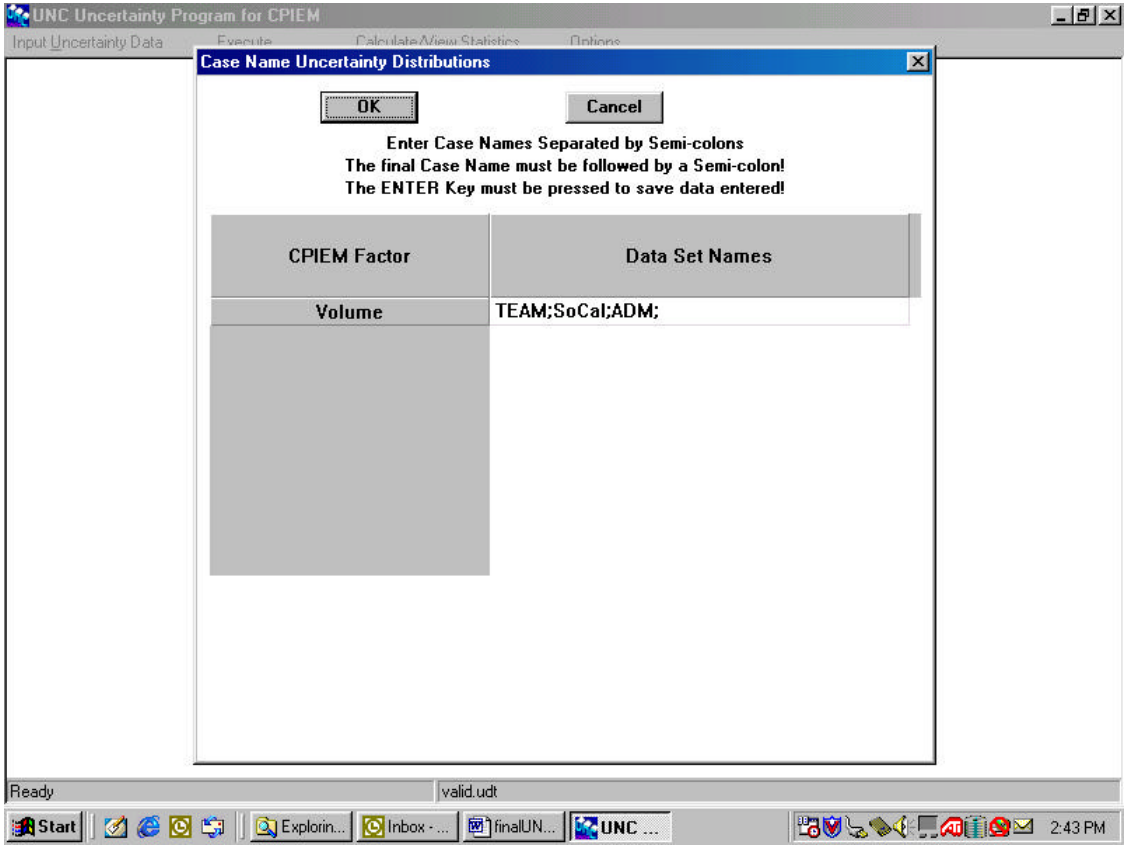
Uncertainty Types

- Continuous
- Discrete
- Default
- Case name

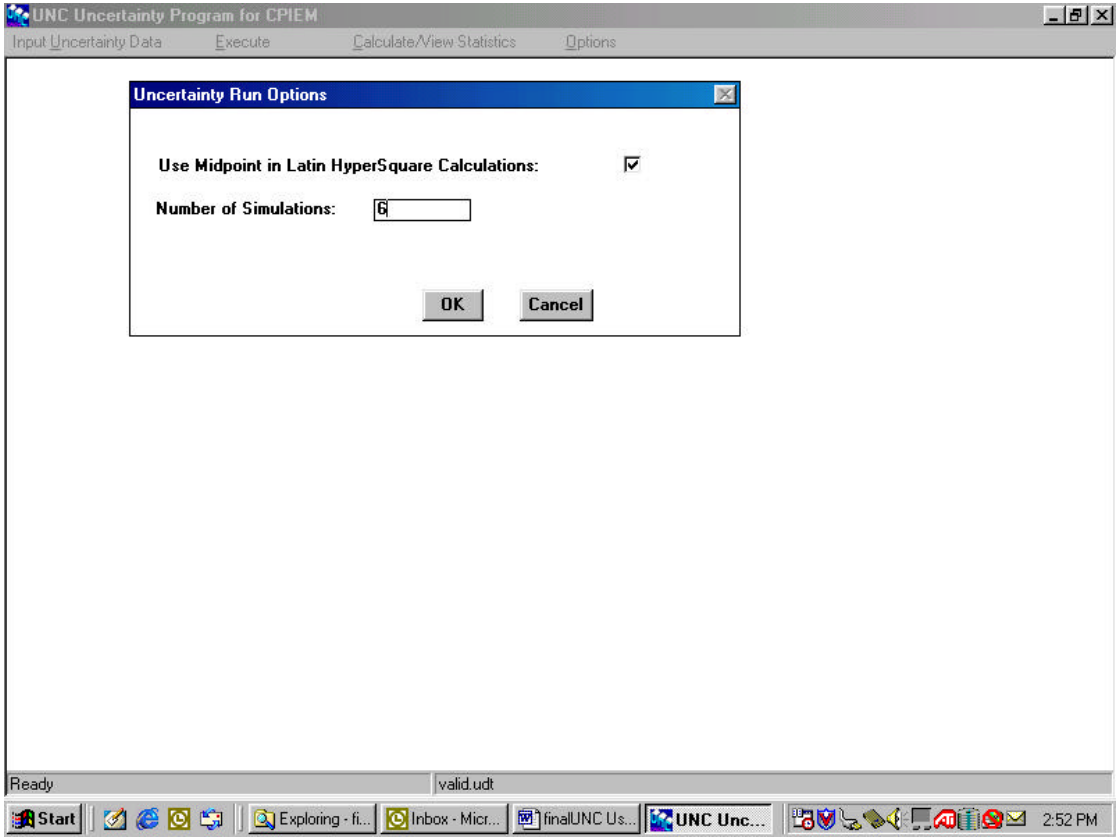
Uncertainty Preprocessor: Continuous Factors



Uncertainty Preprocessor: Case Name Factors



Uncertainty Preprocessor: Number of Simulations



Uncertainty Preprocessor: Output File

Parameter;Distribution;Sim 1;Sim 2;Sim 3;Sim 4;Sim 5;Sim 6;
Emissions;Ar.LN;(320.9,1285);(459.1,1285);(379.5,1285);(356.3,1285);(400.5,1285);(423.7,1285);The distribution for the mean parameter of the Ar.LN distribution for Cpiem Factor Emissions is poorly specified. The uncertainty distribution was truncated by 3.09535e-013% to avoid generation of impossible values.;
Volume;Case Name;(TEAM);(ADM);(SoCal);(ADM);(TEAM);(SoCal);