Pacific Northwest
NATIONAL LABORATORY
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Modeling A Forest Fire

NRC RAMP SYMPOSIUM

June 25th, 2020

Go-To-Meeting

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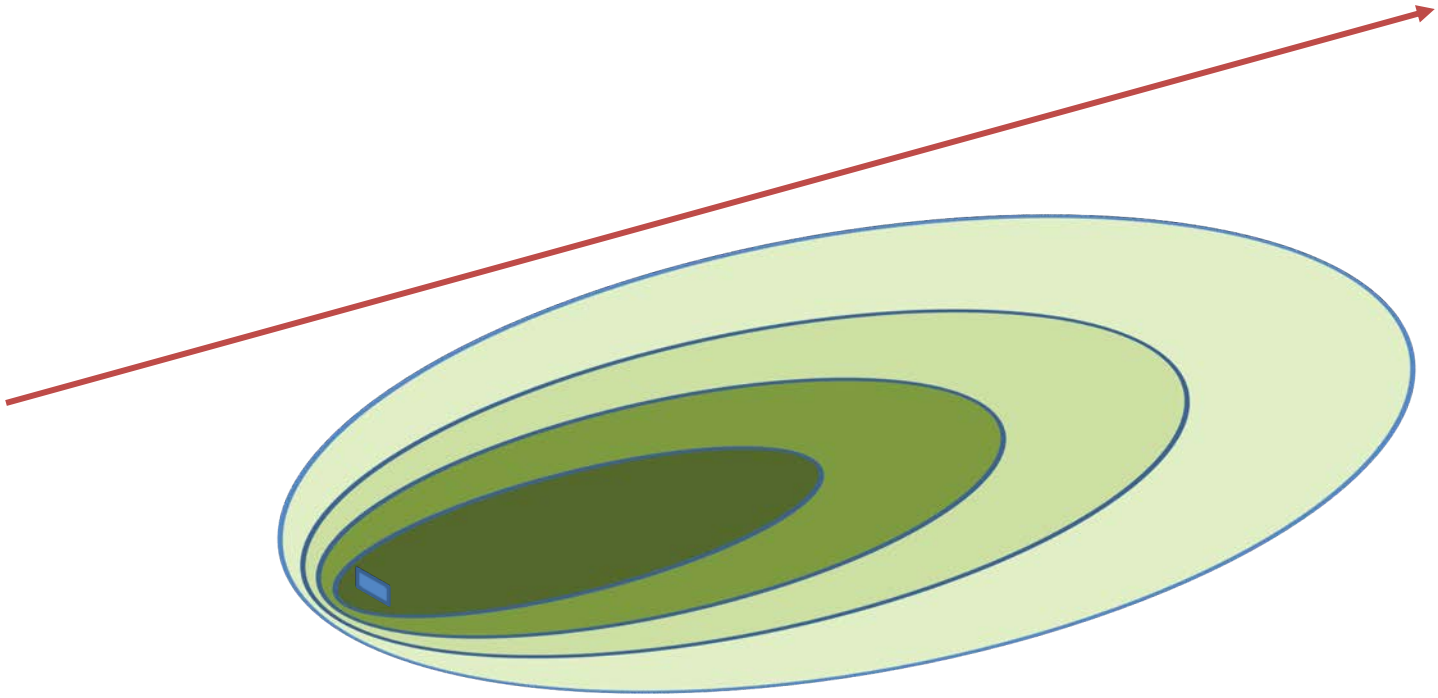
Pacific Northwest National Laboratory

PNNL-SA-153839

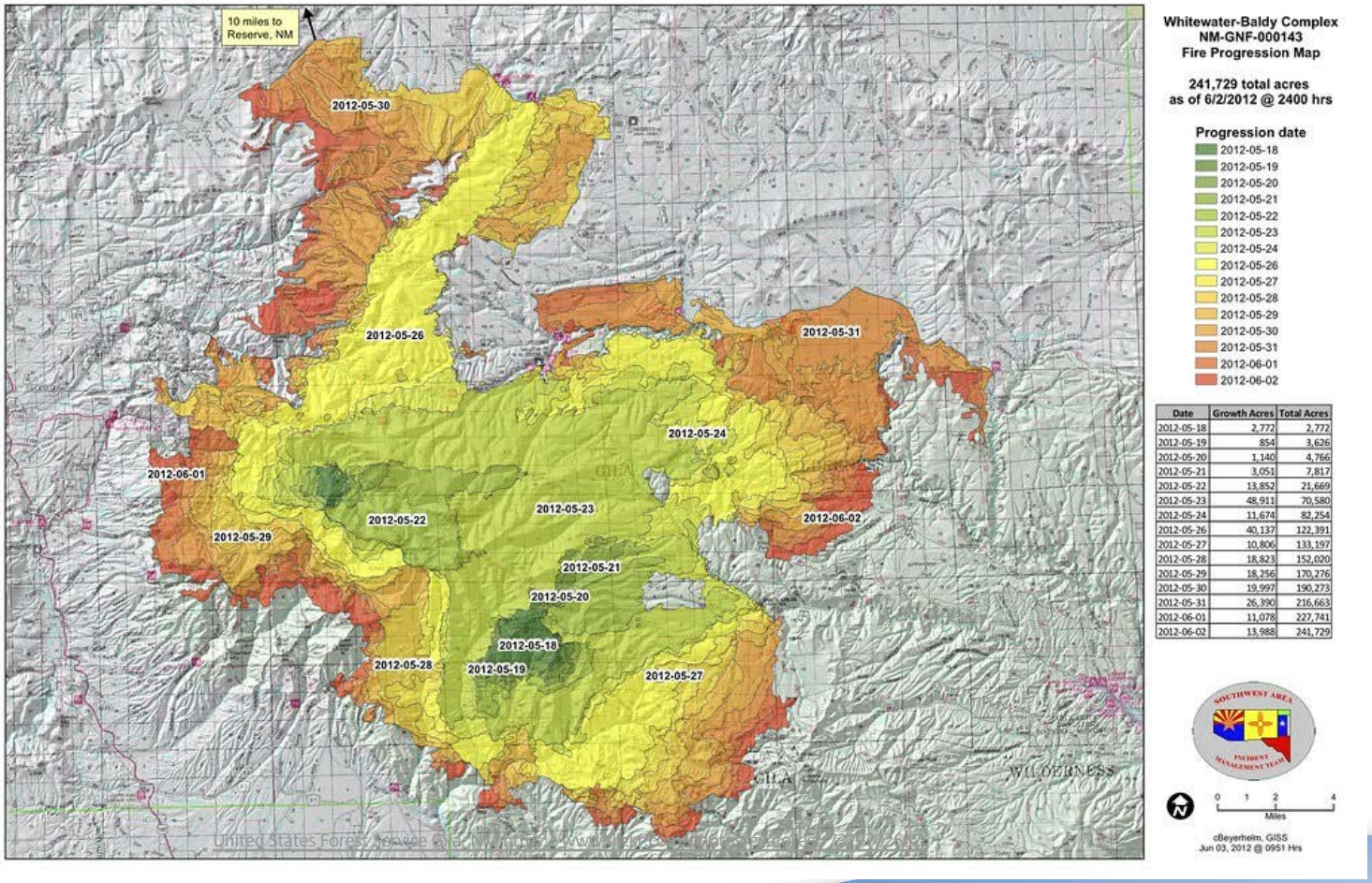
Outline

- The challenges of modeling a forest fire
  - Source term: moving area source
  - Release: what material is being released from the fire
  - Receptor: who and where is your receptor
- How to model a Forest Fire in GENII
- Upcoming GENII Release
  (Time Permitting)

Naveen Nkadaleveni (https://commons.wikimedia.org/wiki/File:Bandipur_fires_2019.jpg)



Example Fire Source Term



Date	Growth Acres	Total Acres
2012-05-18	2,772	2,772
2012-05-19	854	3,626
2012-05-20	1,140	4,766
2012-05-21	3,051	7,817
2012-05-22	13,852	21,669
2012-05-23	48,911	70,580
2012-05-24	11,674	82,254
2012-05-26	40,137	122,391
2012-05-27	10,806	133,197
2012-05-28	18,823	152,020
2012-05-29	18,256	170,276
2012-05-30	19,997	190,273
2012-05-31	26,390	216,663
2012-06-01	11,078	227,741
2012-06-02	13,988	241,729

Moving Area Source

United States Fish and Wildlife Services https://www.flickr.com/photos/usfwssoutheast/4971831248

Source Term

- Combustible biomass in an ecosystem serves as fuel
- Radionuclide concentration in biomass depends on the concentrations in the soil and the type of biomass

Daniele Pellati https://www.needpix.com/photo/1401600/branches-dry-trees-forest-nature

Transfer Ratios

- Transfer ratios of radionuclides from soil to plant biomass are necessary to determine the source term in the potential fire fuel

- Sources:
  - ICRP Published Transfer Ratios for Non-Human Biota
  - Site specific field work
    - Chernobyl Exclusion Zone (Yoschenko, Kashparov et al. 2006)

- Pine needles and dry grass can be a major fuel source for a wildfire

https://www.pickpik.com/sprouts-seedling-seedlings-green-leaves-why-vegetable-garden-154187

Resuspension Factor (R)

"The resuspension factor for the active phase of a fire was assessed as 10^{-7} – 10^{-8} m^{-1}, while the value of the resuspension rate has a 10^{-10} s^{-1} order of magnitude at a deposition velocity of 1-2 cm s^{-1}." (Kashparov, Lundin et al. 2000)

^{137} Cs and ^{90}Sr ranges from 10^{-6} to 10^{-5} m^{-1} for Cs and Sr in the plant biomass (Yoschenko, Kashparov et al. 2006)

Plutonium nuclides range from 10^{-7} to 10^{-6} m^{-1} for plutonium nuclides in the plant biomass (Yoschenko, Kashparov et al. 2006)

Resuspension Factor (R)

"Experimental and calculated data demonstrate that, even for the most unfavorable conditions, radionuclide resuspension during forest fires will not provide a significant contribution to terrestrial contamination. The additional terrestrial contamination due to a forest fire can be estimated to be in the range of 10^{-4} – 10^{-5} of its background value."

(Kashparov, Lundin et al. 2000)


GENII
Version 2.10

7 Atmospheric Transport Models

Pacific Northwest
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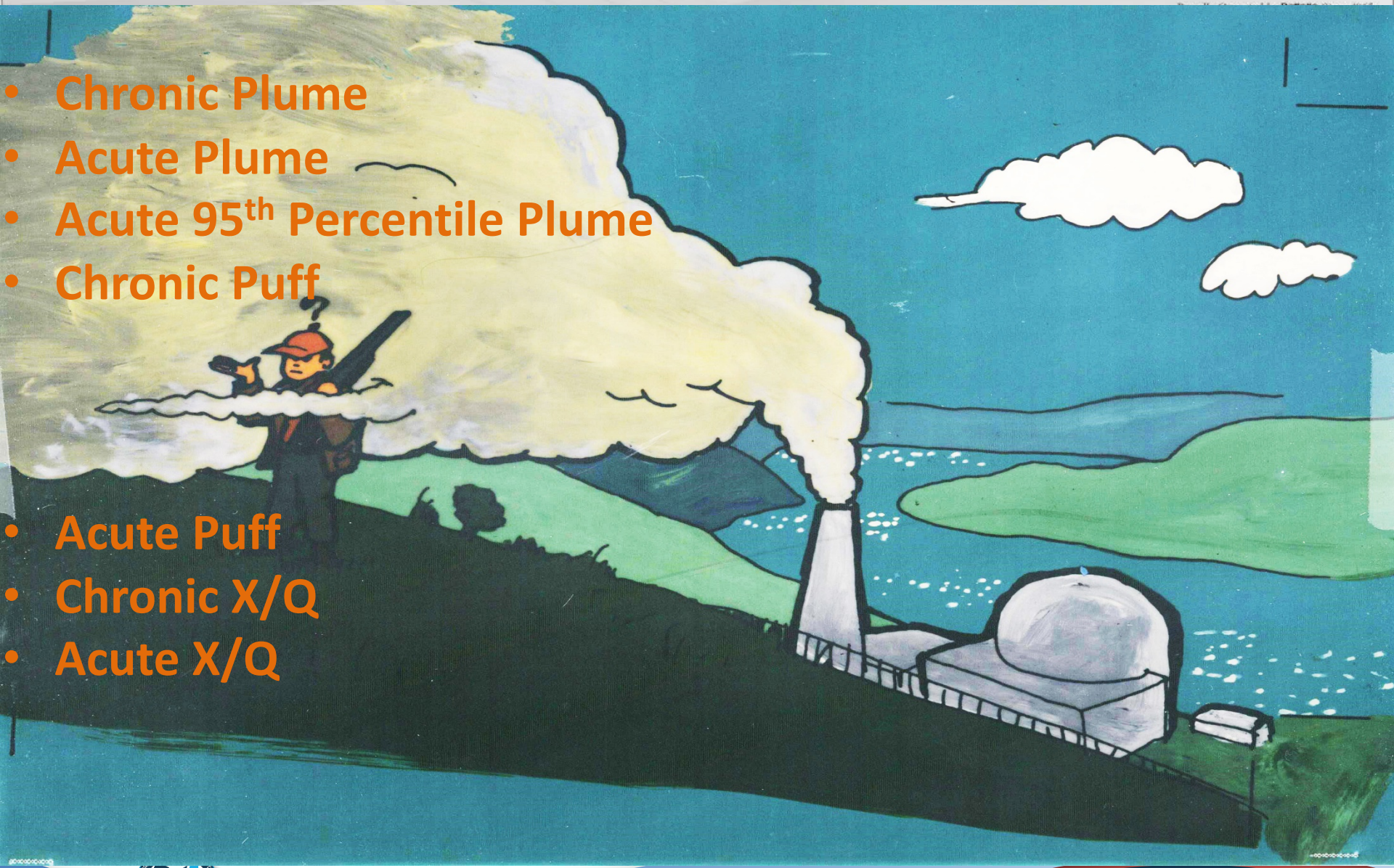
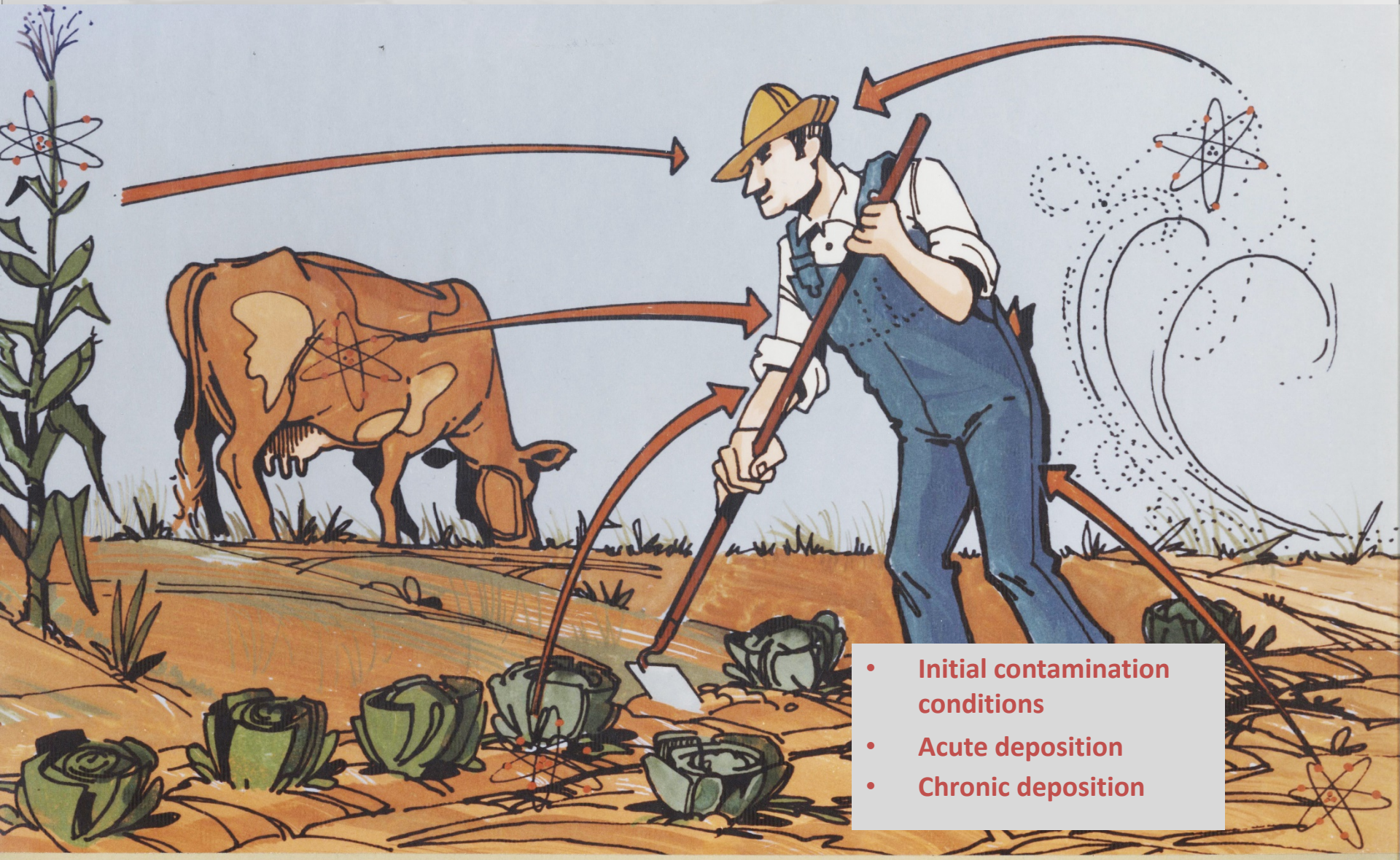


- Chronic Plume
- Acute Plume
- Acute 95th Percentile Plume
- Chronic Puff
- Acute Puff
- Chronic X/Q
- Acute X/Q

RAMP

3 Accumulation / Exposure Models

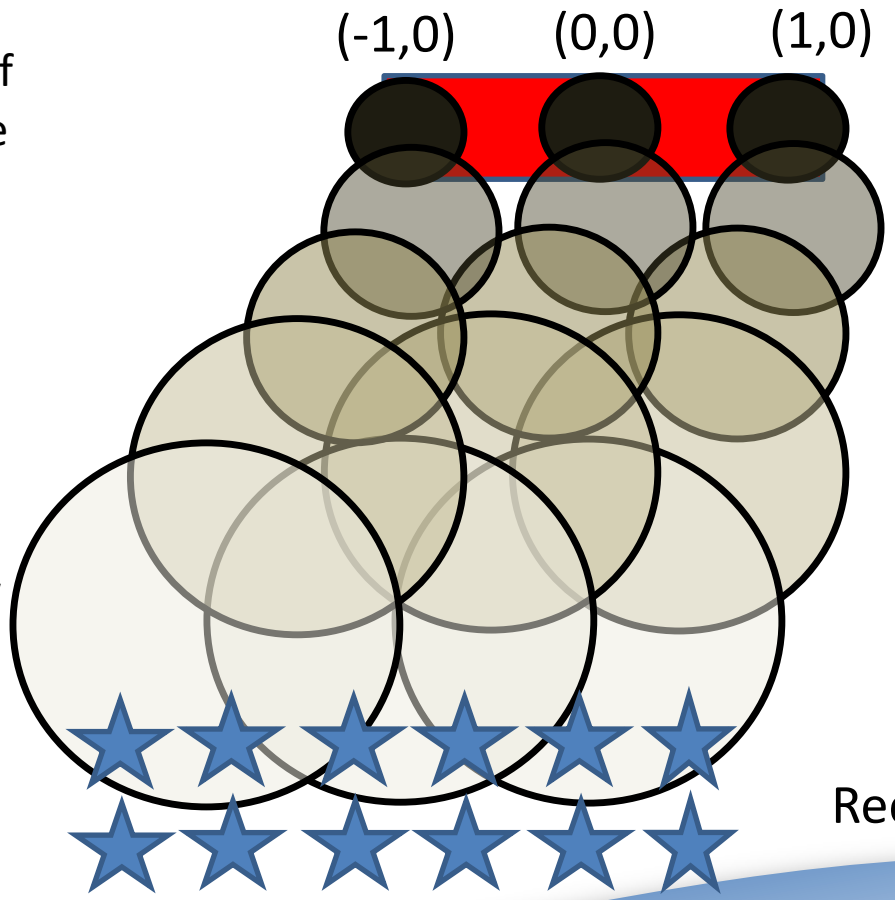


- Initial contamination conditions
- Acute deposition
- Chronic deposition

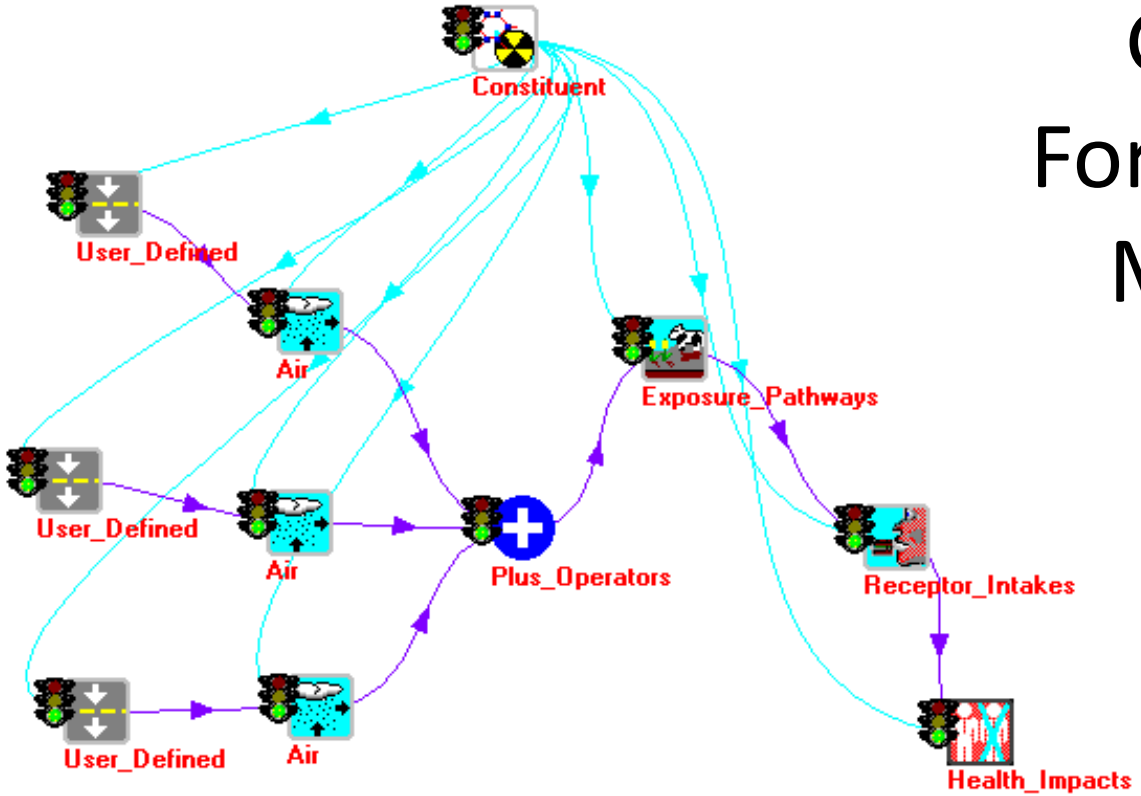
Conceptual Model of the Fire Plume

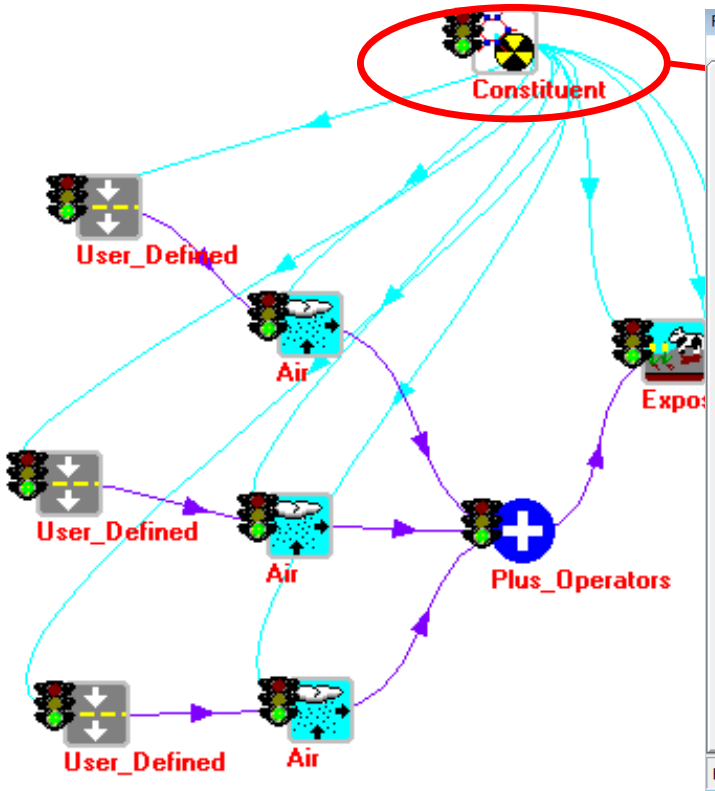
The fire is a wide, area source. Use the GENII Puff Model with 3 sources: one at the center, one 1-km east, and one 1-km west of center. Combine the 3 separate plumes into one with the FRAMES Plus Operator.

(Note: this is not currently possible in release versions of GENII without "substantial" user modifications!)



GENII Forest Fire Model





FRAMES Constituent Database Editor

File Tools Help

Select Constituents of Concern | Edit Constituent Properties

Available Constituent Groupings

Available (829)

- Chemicals
- Radionuclides
- Classification — Chemical Class — All Constituents

Select Constituents for Analysis

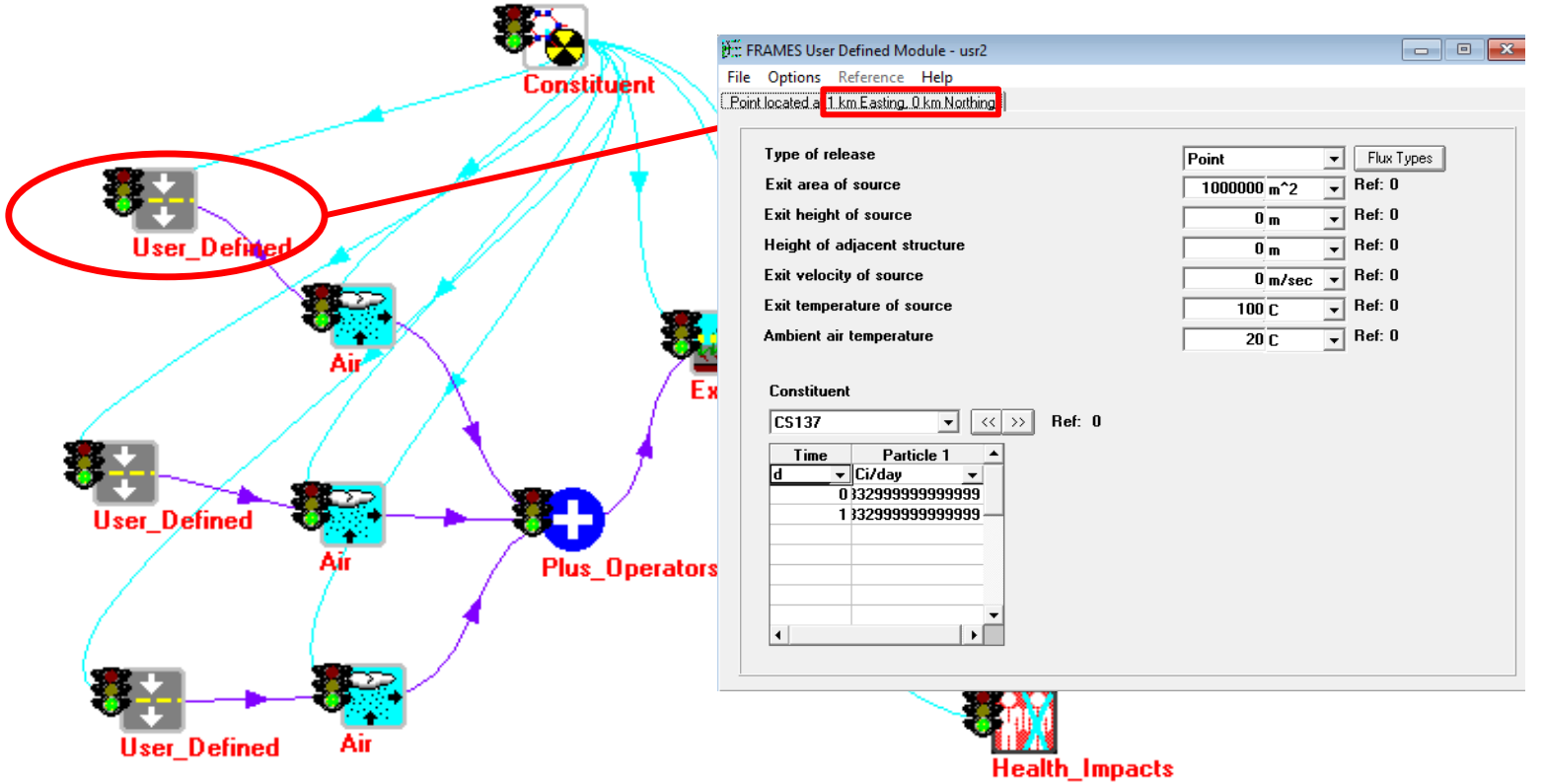
Search Next | Show CASID

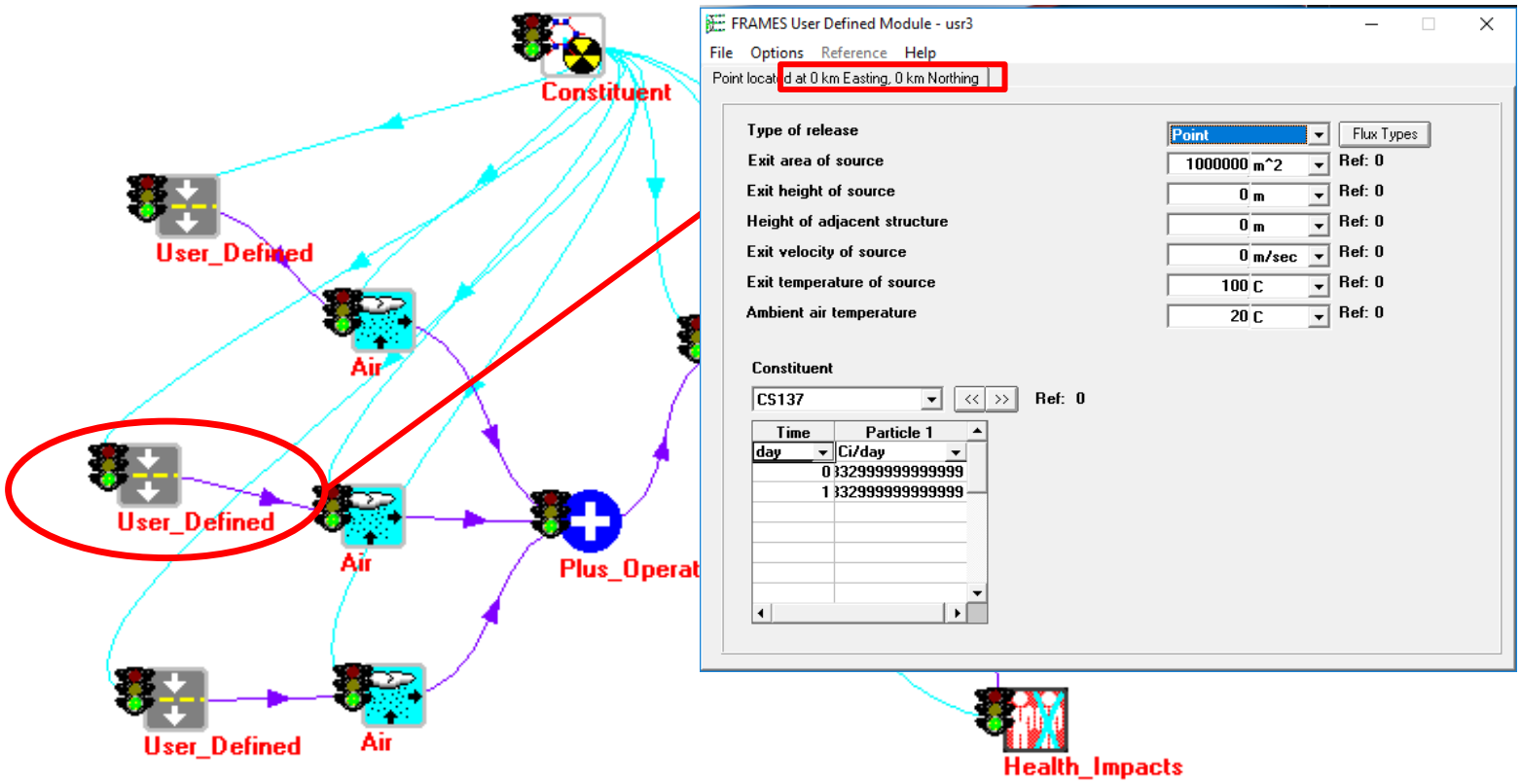
Select >>> | <<< Remove

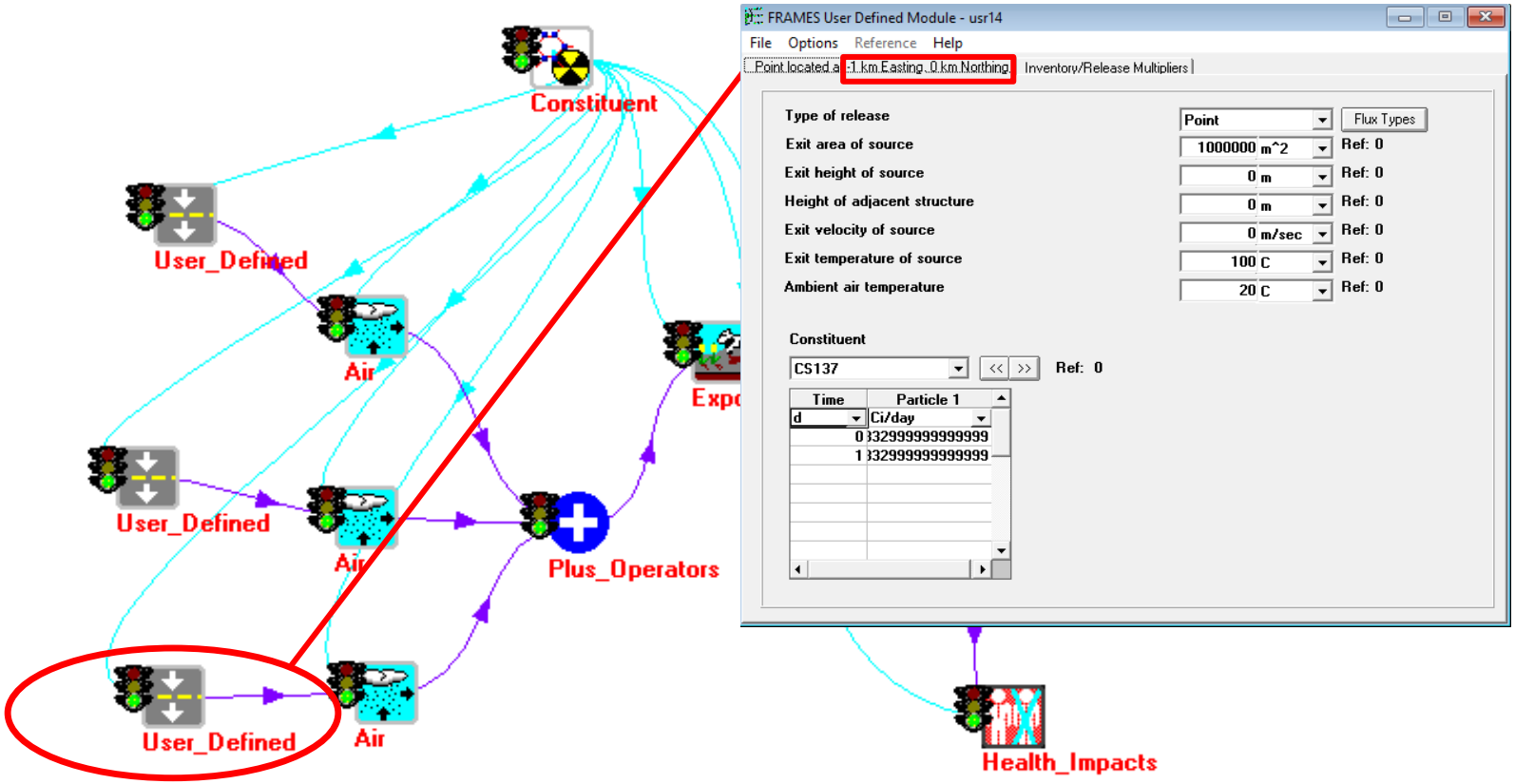
AC223
AC224
AC225
AC226
AC227
AC228
AG102
AG103
AG104
AG104m
AG105
AG106
AG106m
AG108
AG108m
AG109m
AG110

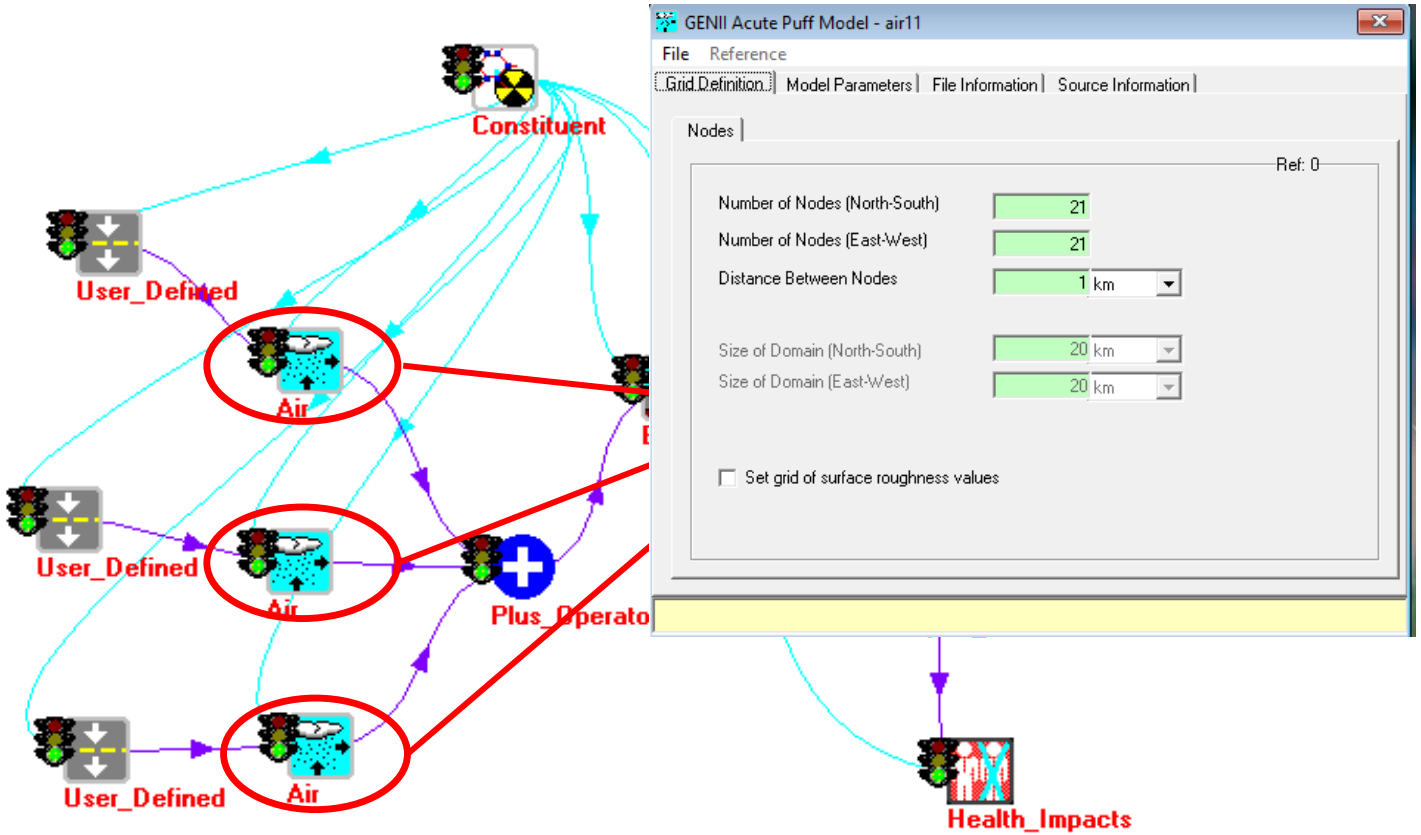
CS137

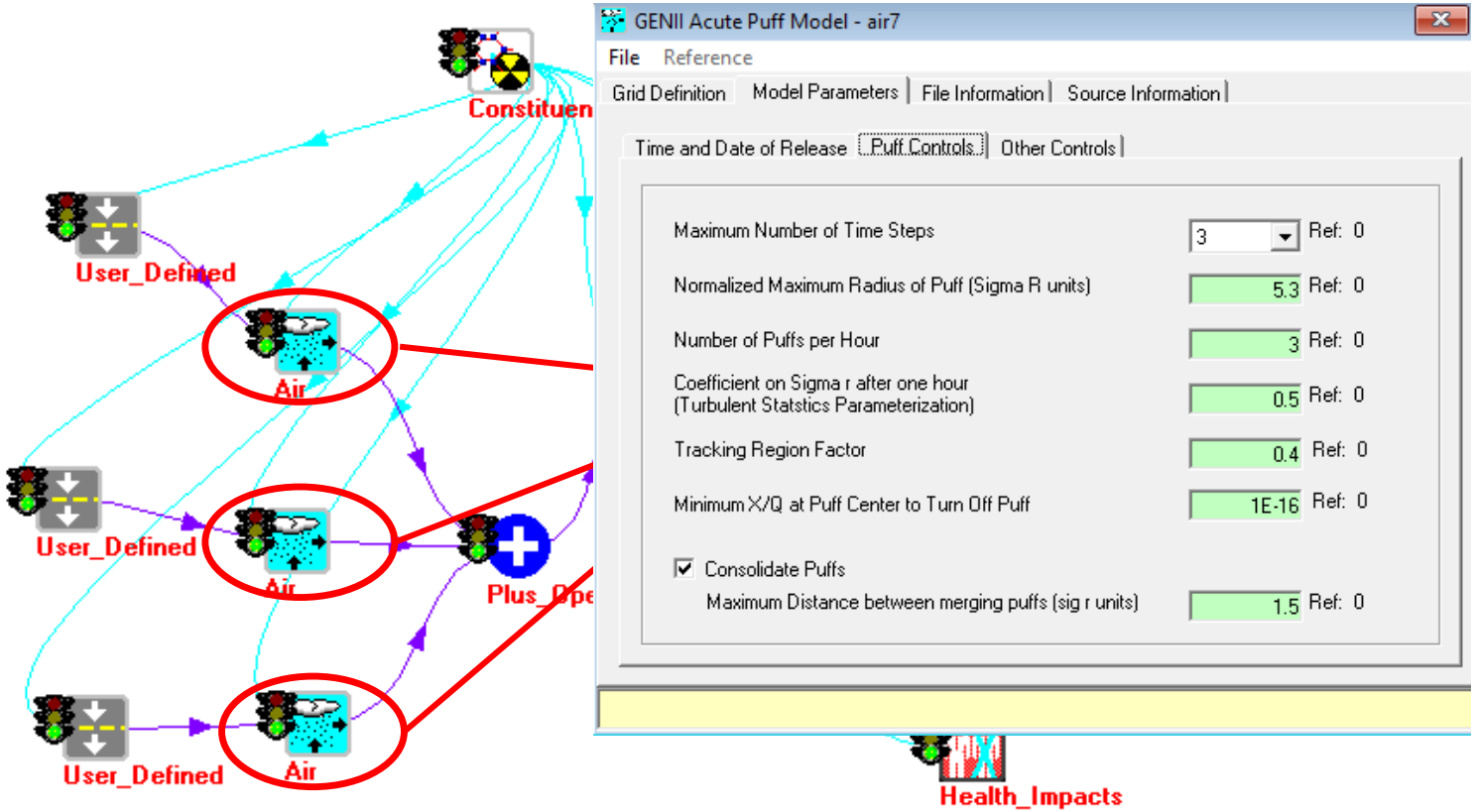
KACARE.mdb

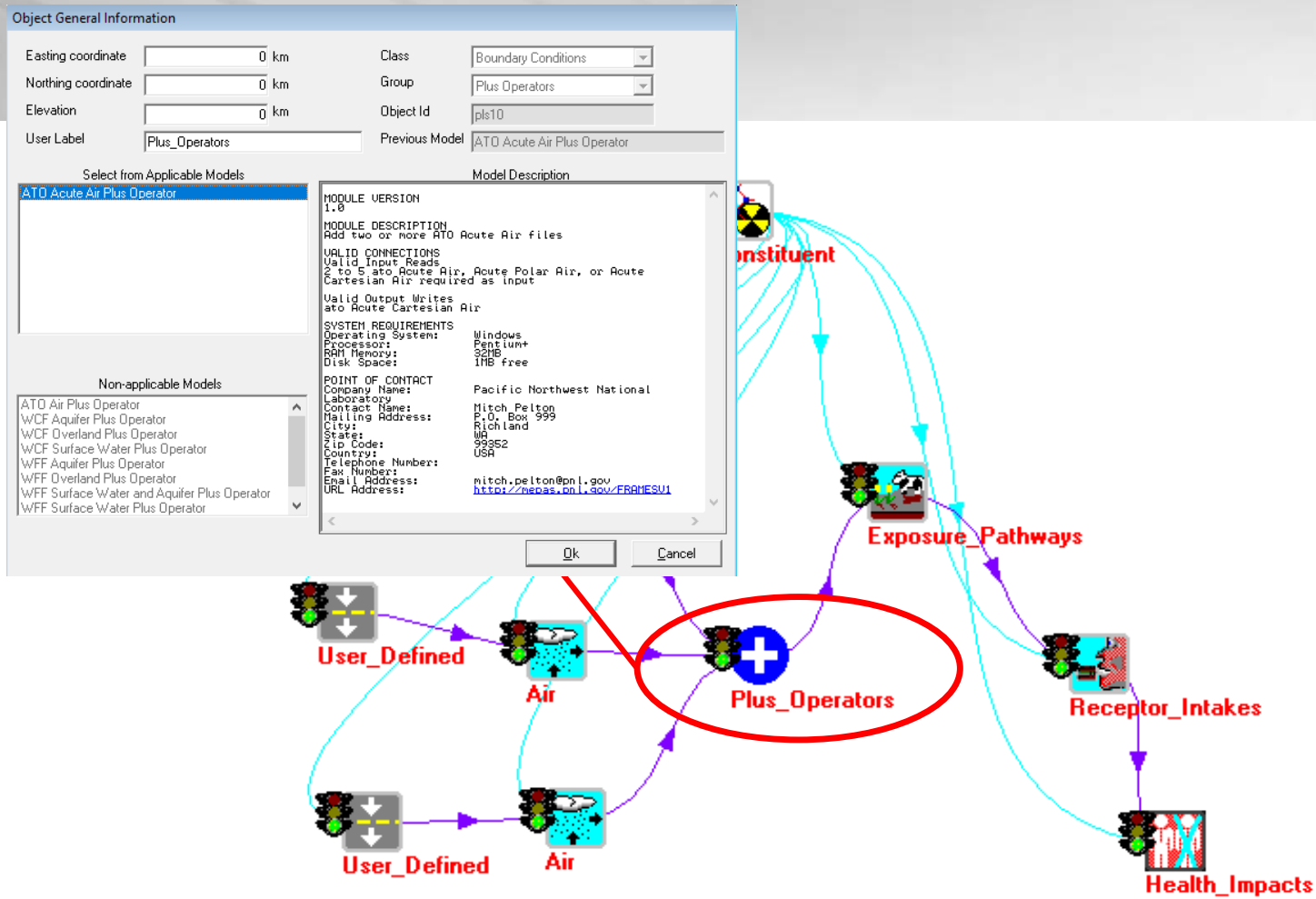

Constituent
User_Defined
Air
User_Defined
Air
Plus_Operators
User_Defined
Air
Health_Impacts
FRAMES User Defined Module - usr2
File Options Reference Help
Point located a 1 km Easting, 0 km Northing
Type of release
Point
Flux Types
Exit area of source
1000000 m^2
Ref: 0
Exit height of source
0 m
Ref: 0
Height of adjacent structure
0 m
Ref: 0
Exit velocity of source
0 m/sec
Ref: 0
Exit temperature of source
100 C
Ref: 0
Ambient air temperature
20 C
Ref: 0
Constituent
CS137
Ref: 0
Time
Particle 1
d
Ci/day
0
1

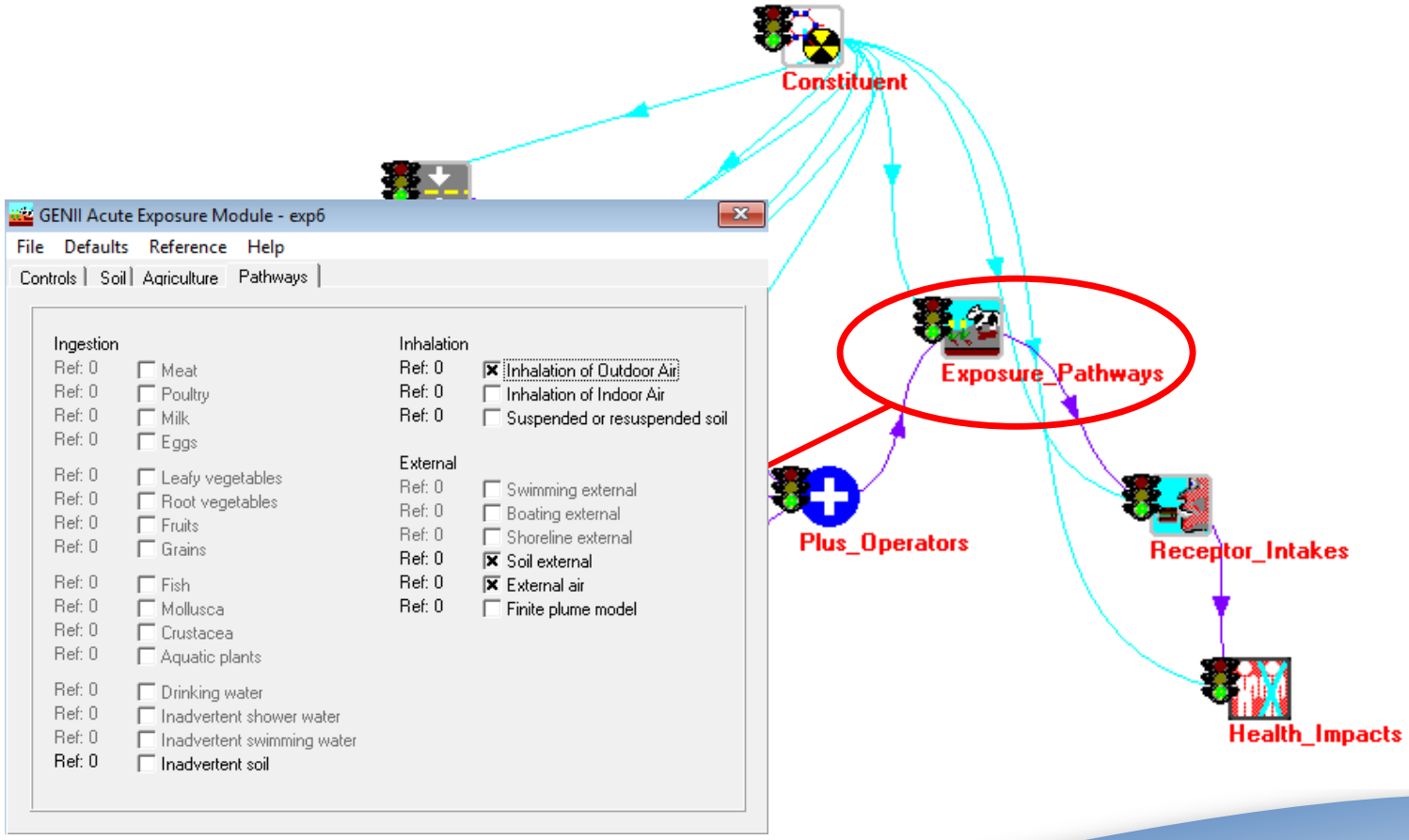

Constituent
User_Defined
Air
User_Defined
Air
Plus_Operat
User_Defined
Air
Health_Impacts
FRAMES User Defined Module - usr3
File Options Reference Help
Point located at 0 km Easting, 0 km Northing
Type of release
Point
Flux Types
Exit area of source
1000000 m^2
Ref: 0
Exit height of source
0 m
Ref: 0
Height of adjacent structure
0 m
Ref: 0
Exit velocity of source
0 m/sec
Ref: 0
Exit temperature of source
100 C
Ref: 0
Ambient air temperature
20 C
Ref: 0
Constituent
CS137
Ref: 0
Time
Particle 1
day
Ci/day

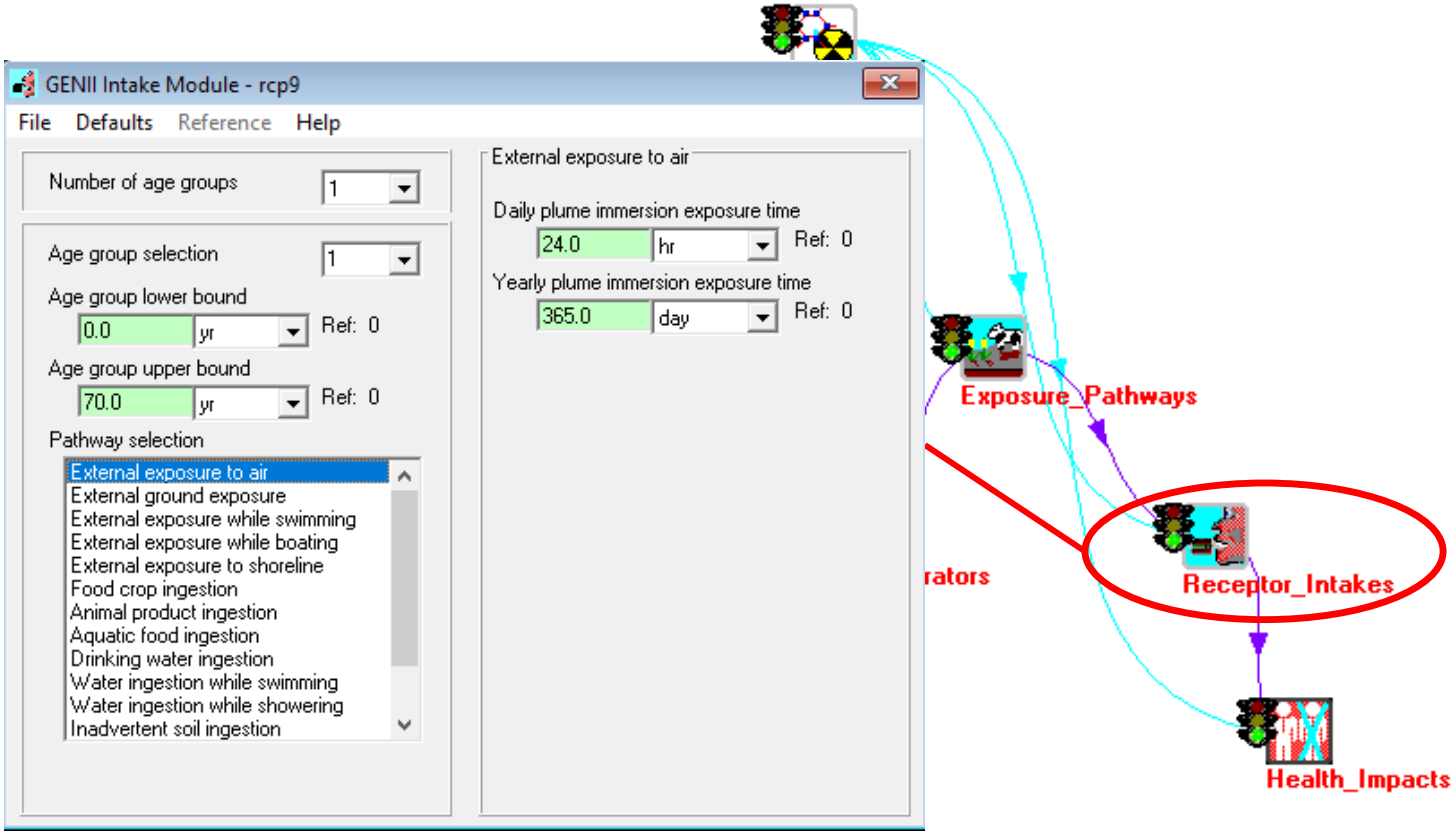

Constituent
User_Defined
Air
User_Defined
Air
Plus_Operators
User_Defined
Air
Health_Impacts
FRAMES User Defined Module - usr14
File Options Reference Help
Point located a 1 km Easting, 0 km Northing
Inventory/Release Multipliers
Type of release
Point
Flux Types
Exit area of source
1000000 m^2
Ref: 0
Exit height of source
0 m
Ref: 0
Height of adjacent structure
0 m
Ref: 0
Exit velocity of source
0 m/sec
Ref: 0
Exit temperature of source
100 C
Ref: 0
Ambient air temperature
20 C
Ref: 0
Constituent
CS137
Ref: 0
Time
Particle 1
d
Ci/day

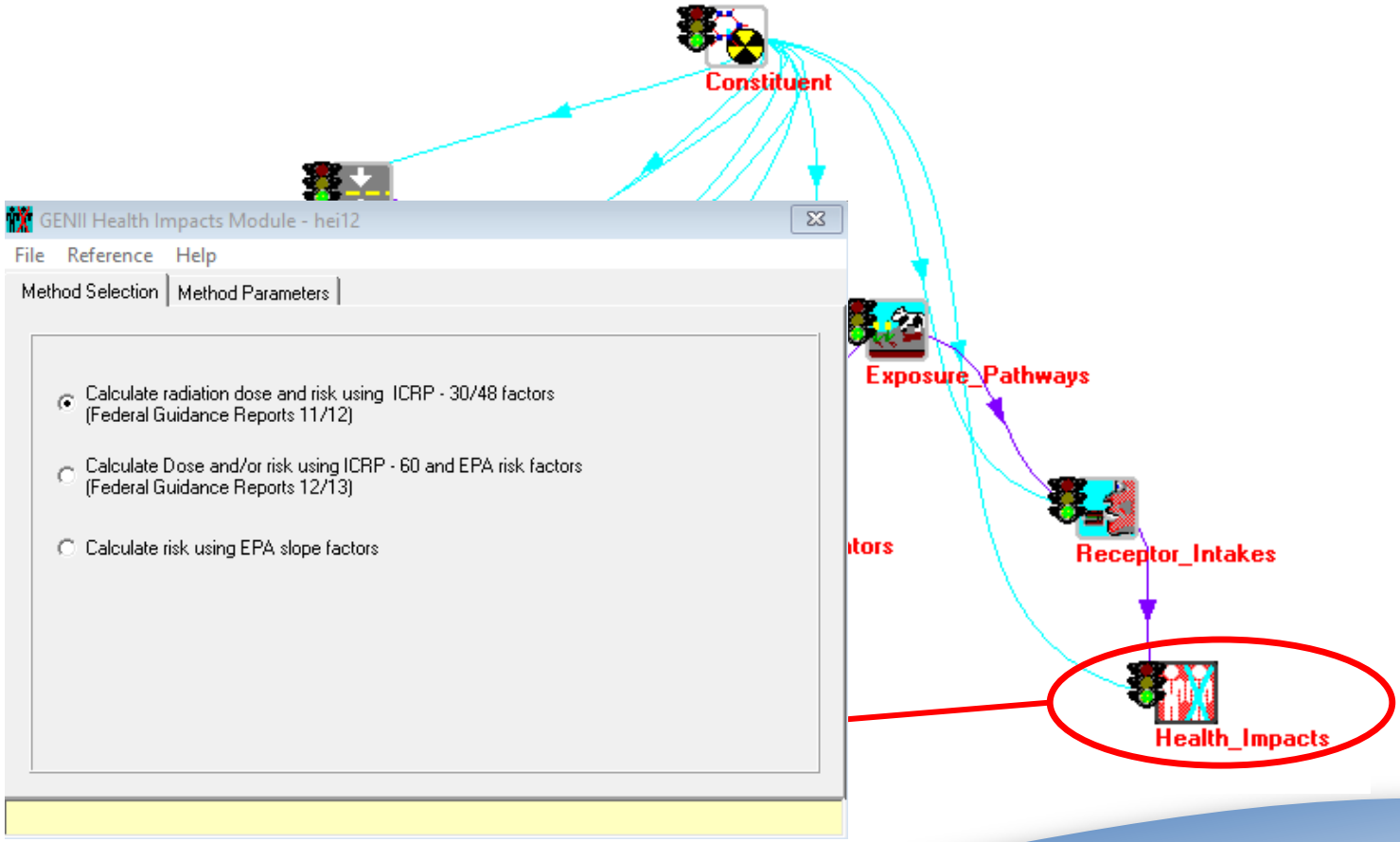

Constituent
User_Defined
Air
User_Defined
Air
Plus_Operato
User_Defined
Air
Health_Impacts
GENII Acute Puff Model - air11
File
Reference
Grid Definition
Model Parameters
File Information
Source Information
Nodes
Ref: 0
Number of Nodes (North-South)
21
Number of Nodes (East-West)
21
Distance Between Nodes
1
km
Size of Domain (North-South)
20
km
Size of Domain (East-West)
20
km
Set grid of surface roughness values


Constituen
User_Defined
Air
User_Defined
Air
Plus_Ope
User_Defined
Air
Health_Impacts
GENII Acute Puff Model - air7
File
Reference
Grid Definition
Model Parameters
File Information
Source Information
Time and Date of Release
Puff Controls
Other Controls
Maximum Number of Time Steps
3
Ref: 0
Normalized Maximum Radius of Puff (Sigma R units)
5.3
Ref: 0
Number of Puffs per Hour
3
Ref: 0
Coefficient on Sigma r after one hour
(Turbulent Statstics Parameterization)
0.5
Ref: 0
Tracking Region Factor
0.4
Ref: 0
Minimum X/Q at Puff Center to Turn Off Puff
1E-16
Ref: 0
Consolidate Puffs
Maximum Distance between merging puffs (sig r units)
1.5
Ref: 0


Object General Information
Easting coordinate
0 km
Northing coordinate
0 km
Elevation
0 km
User Label
Plus_Operators
Class
Boundary Conditions
Group
Plus Operators
Object Id
pls10
Previous Model
ATO Acute Air Plus Operator
Select from Applicable Models
ATO Acute Air Plus Operator
Model Description
MODULE VERSION
1.0
MODULE DESCRIPTION
Add two or more ATO Acute Air files
VALID CONNECTIONS
Valid Input Reads
2 to 5 ato_Acute_Air, Acute_Polar_Air, or Acute_Cartesian_Air required as input
Valid Output Writes
ato_Acute_Cartesian_Air
SYSTEM REQUIREMENTS
Operating System: Windows
Processor: Pentium+
RAM Memory: 32MB
Disk Space: 1MB free
POINT OF CONTACT
Company Name: Pacific Northwest National Laboratory
Contact Name: Mitch_Pelton
Mailing Address: P.O. Box 999
City: Richland
State: WA
Zip Code: 99352
Country: USA
Telephone Number:
Fax Number:
Email Address: mitch.pelton@pnl.gov
URL Address: http://mepas.pnl.gov/FRAMESV1
Non-applicable Models
ATO Air Plus Operator
WCF Aquifer Plus Operator
WCF Overland Plus Operator
WCF Surface Water Plus Operator
WFF Aquifer Plus Operator
WFF Overland Plus Operator
WFF Surface Water and Aquifer Plus Operator
WFF Surface Water Plus Operator
Ok
Cancel
nstituent
Exposure_Pathways
User_Defined
Air
Plus_Operators
Receptor_Intakes
User_Defined
Air
Health_Impacts


Constituent
Exposure_Pathways
Plus_Operators
Receptor_Intakes
Health_Impacts
GENII Acute Exposure Module - exp6
File Defaults Reference Help
Controls | Soil | Agriculture | Pathways |
Ingestion
Ref: 0 Meat
Ref: 0 Poultry
Ref: 0 Milk
Ref: 0 Eggs
Ref: 0 Leafy vegetables
Ref: 0 Root vegetables
Ref: 0 Fruits
Ref: 0 Grains
Ref: 0 Fish
Ref: 0 Mollusca
Ref: 0 Crustacea
Ref: 0 Aquatic plants
Ref: 0 Drinking water
Ref: 0 Inadvertent shower water
Ref: 0 Inadvertent swimming water
Ref: 0 Inadvertent soil
Inhalation
Ref: 0 Inhalation of Outdoor Air
Ref: 0 Inhalation of Indoor Air
Ref: 0 Suspended or resuspended soil
External
Ref: 0 Swimming external
Ref: 0 Boating external
Ref: 0 Shoreline external
Ref: 0 Soil external
Ref: 0 External air
Ref: 0 Finite plume model


GENII Intake Module - rcp9
File
Defaults
Reference
Help
Number of age groups
1
Age group selection
1
Age group lower bound
0.0
yr
Ref: 0
Age group upper bound
70.0
yr
Ref: 0
Pathway selection
External exposure to air
External ground exposure
External exposure while swimming
External exposure while boating
External exposure to shoreline
Food crop ingestion
Animal product ingestion
Aquatic food ingestion
Drinking water ingestion
Water ingestion while swimming
Water ingestion while showering
Inadvertent soil ingestion
External exposure to air
Daily plume immersion exposure time
24.0
hr
Ref: 0
Yearly plume immersion exposure time
365.0
day
Ref: 0
Exposure_Pathways
rators
Receptor_Intakes
Health_Impacts


Constituent
GENII Health Impacts Module - hei12
File
Reference
Help
Method Selection
Method Parameters
Calculate radiation dose and risk using ICRP - 30/48 factors
(Federal Guidance Reports 11/12)
Calculate Dose and/or risk using ICRP - 60 and EPA risk factors
(Federal Guidance Reports 12/13)
Calculate risk using EPA slope factors
Exposure_Pathways
Receptor_Intakes
Health_Impacts

GENII Results

Assume 3700 kBq/m2 (UNSCEAR)
3 sq. km. fire for 1 day
Resuspension Rate 10^{-10} /sec

Total Emission: ~100 GBq

Peak Inhalation Dose: 0.25 nSv
1-Year External Dose: 0.02 µSv

Within the order-of-magnitude estimation, the fire really is not a dose/risk problem for people outside of the fire hazard area.

km/km	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4
-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	0	0	0	0
1	0	0	0	0	0	0	3.15E-06	2.93E-03	1.49E-02	1.51E-02	1.22E-02	2.16E-04	0	0	0
2	0	0	0	0	0	4.92E-07	1.22E-04	9.82E-02	5.00E-01	5.07E-01	4.09E-01	7.26E-03	5.80E-07	0	0
3	0	0	0	0	2.30E-07	2.16E-04	7.06E-03	2.89E-02	8.84E-02	8.26E-02	6.08E-02	1.08E-03	0	0	0
4	0	0	0	1.41E-07	1.36E-05	3.27E-03	1.04E-01	2.13E-01	2.13E-01	1.12E-01	3.95E-03	5.48E-06	0	0	0
5	0	0	0	1.49E-05	1.08E-03	9.60E-03	6.42E-02	1.17E-01	1.11E-01	5.63E-02	1.96E-03	2.39E-06	0	0	0
6	0	0	1.35E-06	1.66E-04	1.05E-02	7.71E-02	1.17E-01	1.10E-01	4.32E-02	3.06E-03	4.33E-05	0	0	0	0
7	0	5.42E-07	5.52E-05	1.18E-03	1.33E-02	7.33E-02	1.07E-01	9.63E-02	3.63E-02	1.85E-03	8.93E-06	0	0	0	0
8	1.86E-07	9.42E-06	4.50E-04	7.93E-03	3.28E-02	5.15E-02	4.84E-02	2.37E-02	4.52E-03	1.79E-04	8.05E-07	0	0	0	0
9	5.29E-06	1.60E-04	1.72E-03	1.26E-02	4.23E-02	5.82E-02	4.93E-02	1.94E-02	1.99E-03	3.94E-05	1.16E-07	0	0	0	0
10	4.61E-05	1.03E-03	7.94E-03	2.32E-02	3.66E-02	3.49E-02	2.01E-02	5.68E-03	4.82E-04	8.71E-06	2.10E-08	0	0	0	0

IAEA Press Release:

IAEA Sees No Radiation-Related Risk from Fires in Chernobyl Exclusions Zone

IAEA (April 24, 2020)

- "The recent fires in the Exclusion Zone near the Chornobyl Nuclear Power Plant (NPP) in Ukraine have not led to any hazardous increase of radioactive particles in the air."

- "Basing its assessment on data provided by Ukraine, the IAEA said the increase in levels of radiation measured in the country was very small and posed no risk to human health."

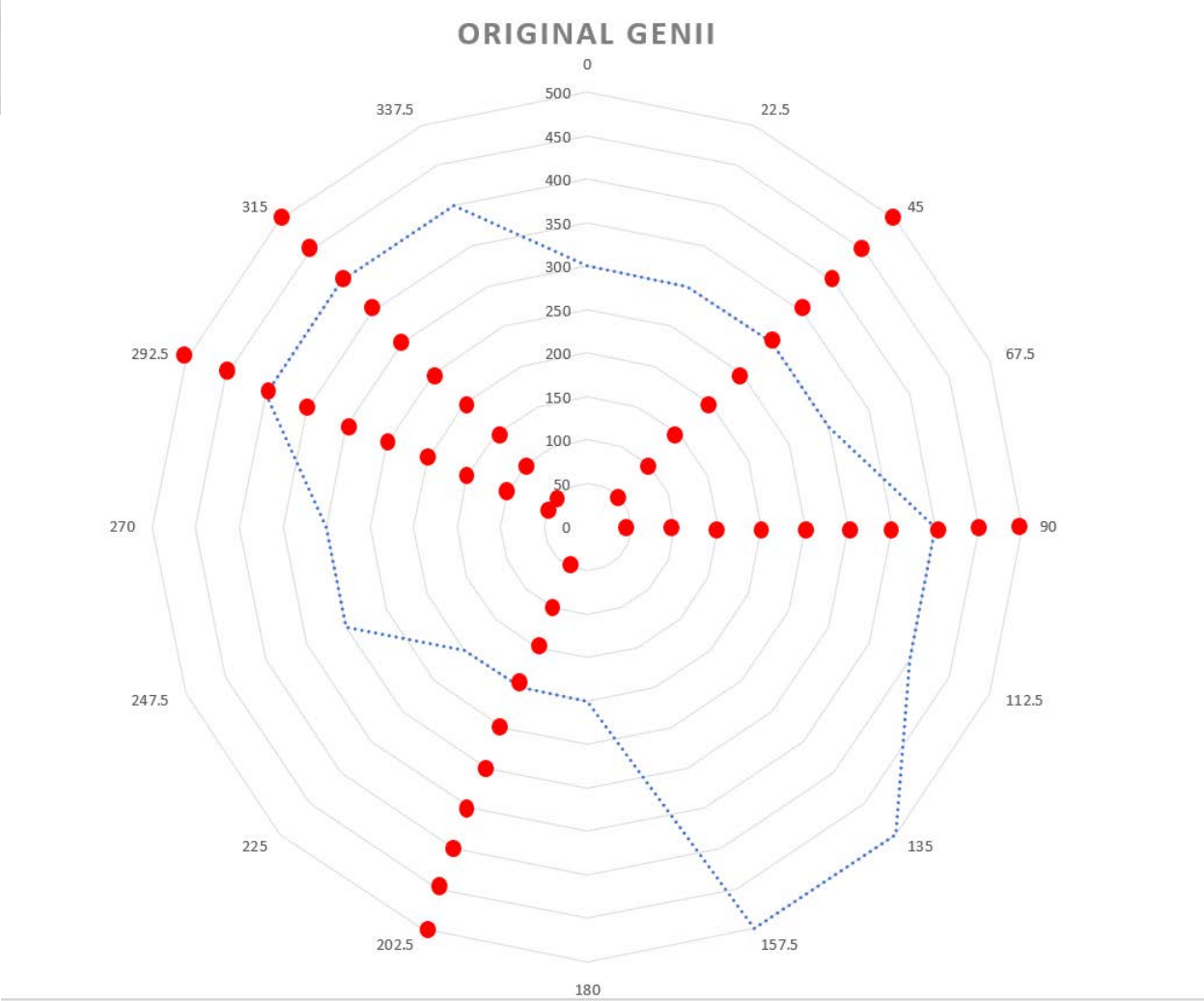
https://www.iaea.org/newscenter/pressreleases/iaea-sees-no-radiation-related-risk-from-fires-in-chornobyl-exclusion-zone

GENII New Features – Upcoming Release 2.10.3

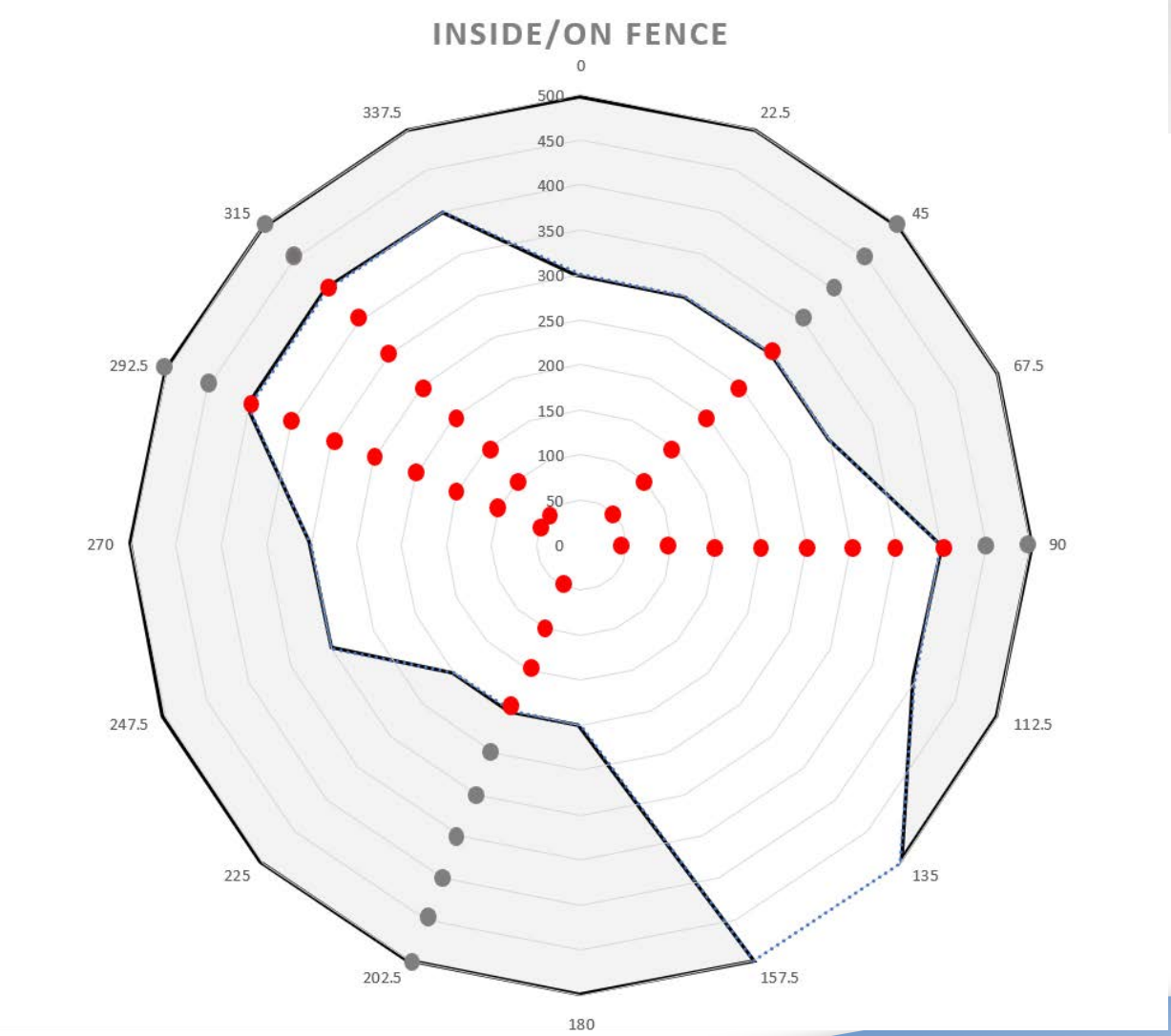
New options within the Air Module

- General Model : DOE Acute 95th Percentile
- Allows original GENII Calculations or
  - DOE/NRC Irregular Boundary – Outside the Fence (Public)
  - DOE/NRC Irregular Boundary – Inside Fence (Worker)
  - NRC 99.5th Maximum Sector (Public)
  - NRC 99.5th User Defined Sector (Public)

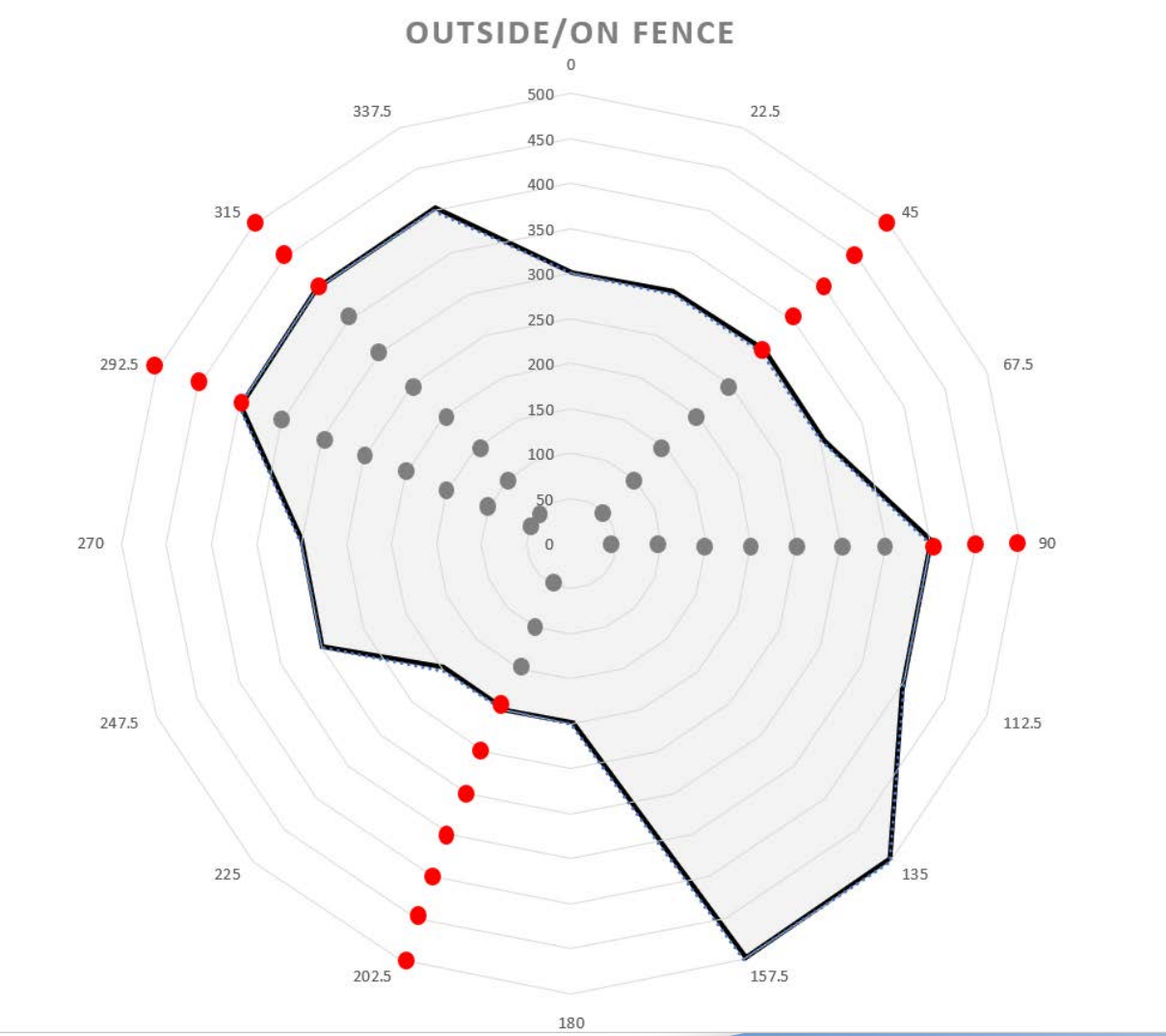
Allows for estimates accounting for a site boundary that is an irregular shape defined in 16 directions


ORIGINAL GENII
0
22.5
45
67.5
90
112.5
135
157.5
180
202.5
225
247.5
270
292.5
315
337.5
500
450
400
350
300
250
200
150
100
50
0

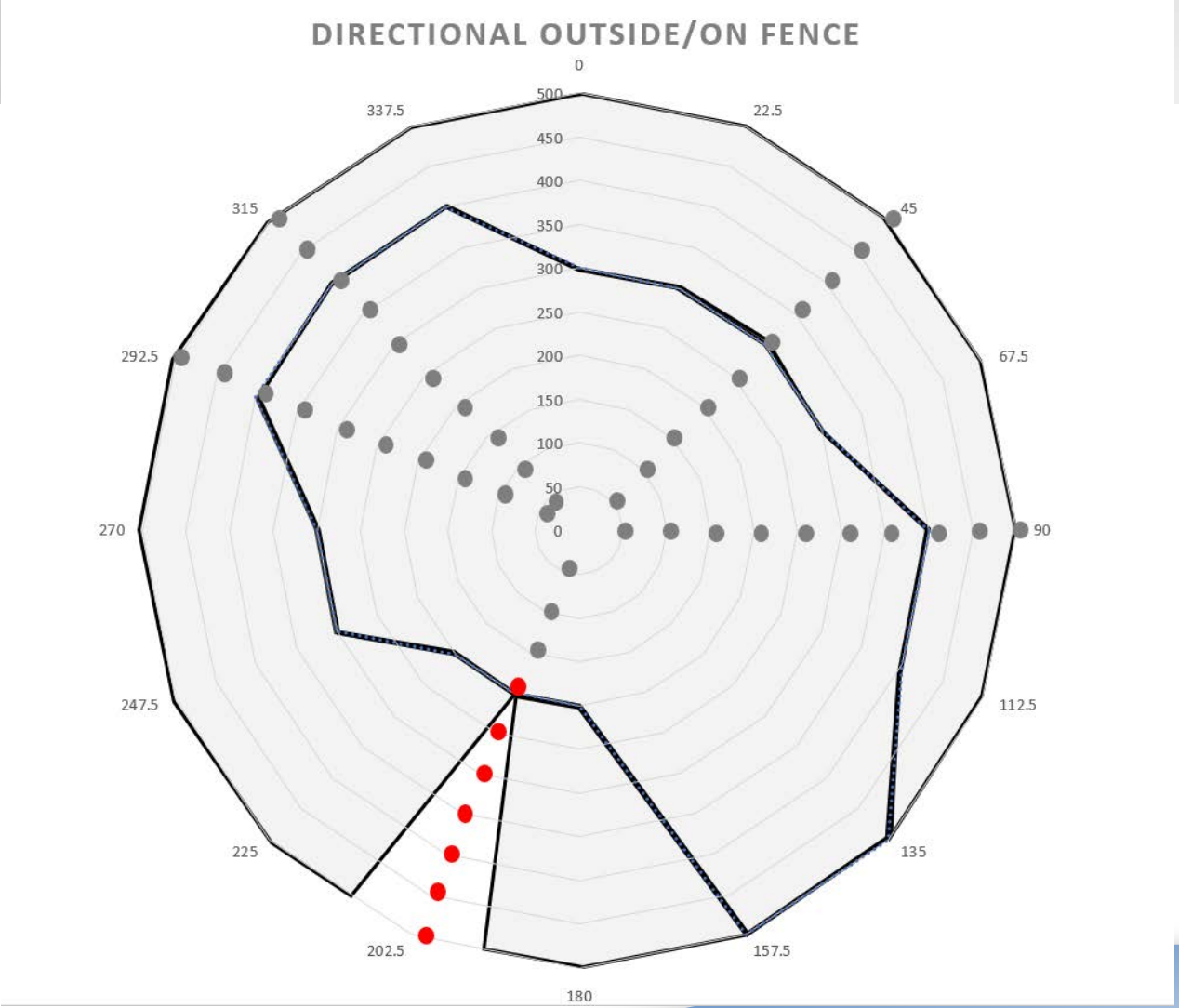
DOE/NRC Irregular Boundary – Inside Fence



DOE/NRC Irregular Boundary – Outside Fence



NRC 99.5th Maximum or User Defined Sector



References

Kashparov, V. A., et al. (2000). "Forest fires in the territory contaminated as a result of the Chernobyl accident: radioactive aerosol resuspension and exposure of fire-fighters." Journal of Environmental Radioactivity **51**: 281-298.

UNSCEAR. United Nations Scientific Committee on the Effects of Atomic Radiation. Maps of Radionuclide Deposition. Available from: https://www.unscear.org/unscear/en/chernobylmaps.html

Yoschenko, V. I., et al. (2006). "Resuspension and redistribution of radionuclides during grassland and forest fires in the Chernobyl exclusion zone: part I. Fire experiments." J Environmental Radioactivity **86**(2): 143-163.

Questions?

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