RASCAL Training

Unit 2 – Models Overview

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UNIT 2 OUTLINE

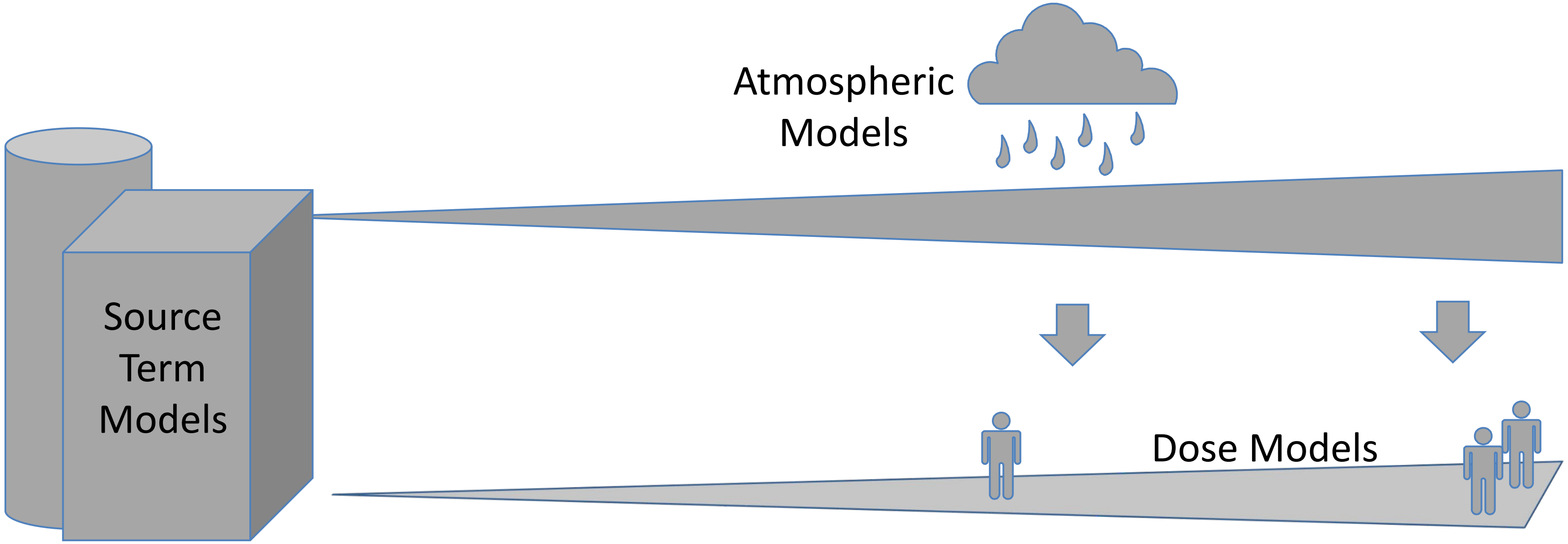
- Discussion of all the RASCAL models
  - What they are, how to use them, and when to use them
  - Specific model details not covered today, see NUREG 1940
    - Questions on technical details can be covered on Day 4

- Source Term Models
  - NPP
  - Spent Fuel
  - Fuel Cycle
  - Materials
- Atmospheric Models
- Dose Models
  - Not covered today, as there are no user settable parameters (except dose coeff)

- *Break in the middle of the session*

Source Term to Dose processes

You've likely seen this graphic or concept before, but today we are going to focus on models in each part.



GENERIC MODEL DESCRIPTIONS

INPUTS				OUTPUTS
Event Location, Source Term, Release Path: Inventory x Release Fractions x Reductions	→	**SOURCE TERM MODELS**	→	Atmospheric Source Term
Atmospheric Source Term & Meteorology: Weather	→	**ATD MODELS**	→	Concentrations & Depositions
Concentrations / Depositions & Calculate Doses: Dose Coefficients	→	**DOSE MODELS**	→	Dose Projections

Generic Model Descriptions

INPUTS			OUTPUTS
Event Location, Source Term, Release Path: Inventory x Release Fractions x Reductions	→	**SOURCE TERM MODELS**	→ Atmospheric Source Term
Meteorology: Atmospheric Source Term & Weather	→	**ATD MODELS**	→ Concentrations & Depositions
Calculate Doses: Concentrations Deposition & Dose Coefficients	→	**DOSE MODELS**	→ Dose Projections

INVENTORY USED IN CALCULATIONS

Inventory x Release Fractions x Reductions x Leakage or Flow = Atmospheric Source Term

- Nuclear Power Plant
  – Core inventory (scaled by power/burnup)
  – Coolant inventory
- Spent Fuel
  – Core inventory from above (scaled to material at risk)
- Fuel Cycle & Other Materials
  – Define material at risk

NUCLIDE	CORE INVENTORY (Ci/MWt)	NUCLIDE	CORE INVENTOR (Ci/MWt)
Ba-139	4.74E+04	La-141	4.33E+04
Ba-140	4.76E+04	La-142	4.21E+04
Ce-141	4.39E+04	Mo-99	5.30E+04
Ce-143	4.00E+04	Nb-95	4.50E+04
Ce-144*	3.54E+04	Nd-147	1.75E+04
Cm-242	1.12E+03	Np-239	5.69E+05

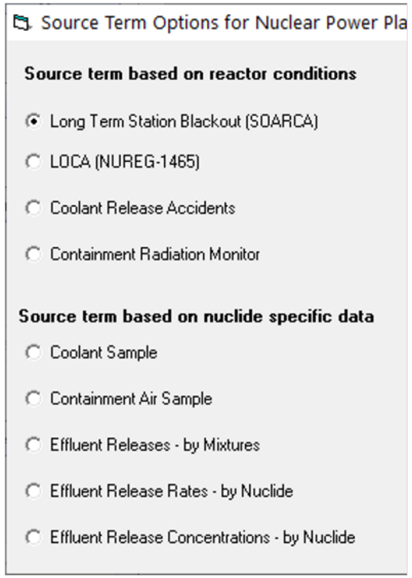
NUCLIDE	PWR COOLANT CONCENTRATION (Ci/g)	BWR COOLANT CONCENTRATION (Ci/g)
Ag-110m*	1.3E-09	1.0E-12
Ba-140	1.3E-08	4.0E-10
Br-84	1.6E-08	0.0E+00
Ce-141	1.5E-10	3.0E-11
Ce-143	2.8E-09	0.0E+00
Ce-144*	4.0E-09	3.0E-12

NUREG 1940 Tables 1-1 and 1-2

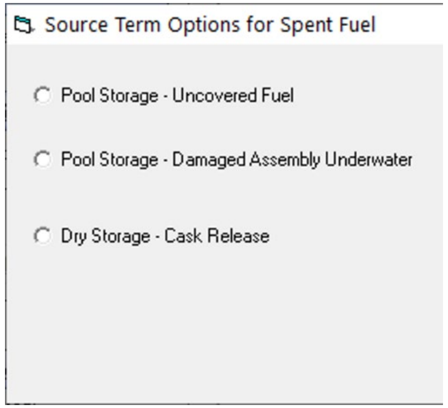
Source Terms

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

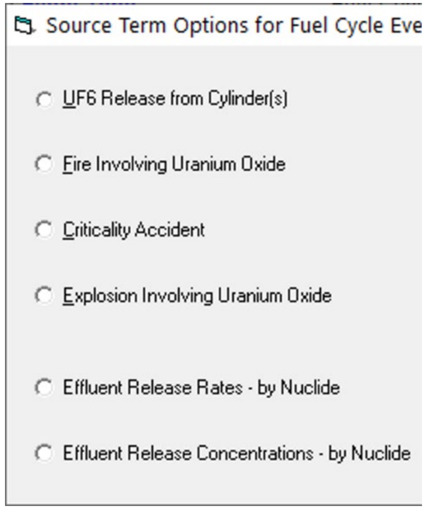
Nuclear Power Plant



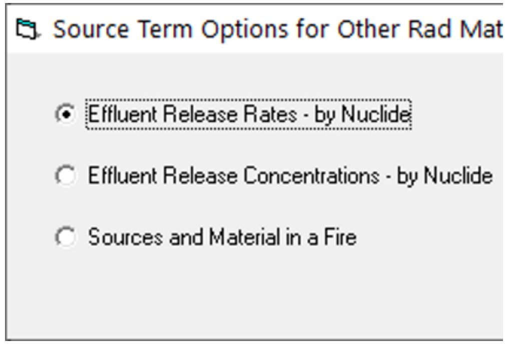
Spent Fuel



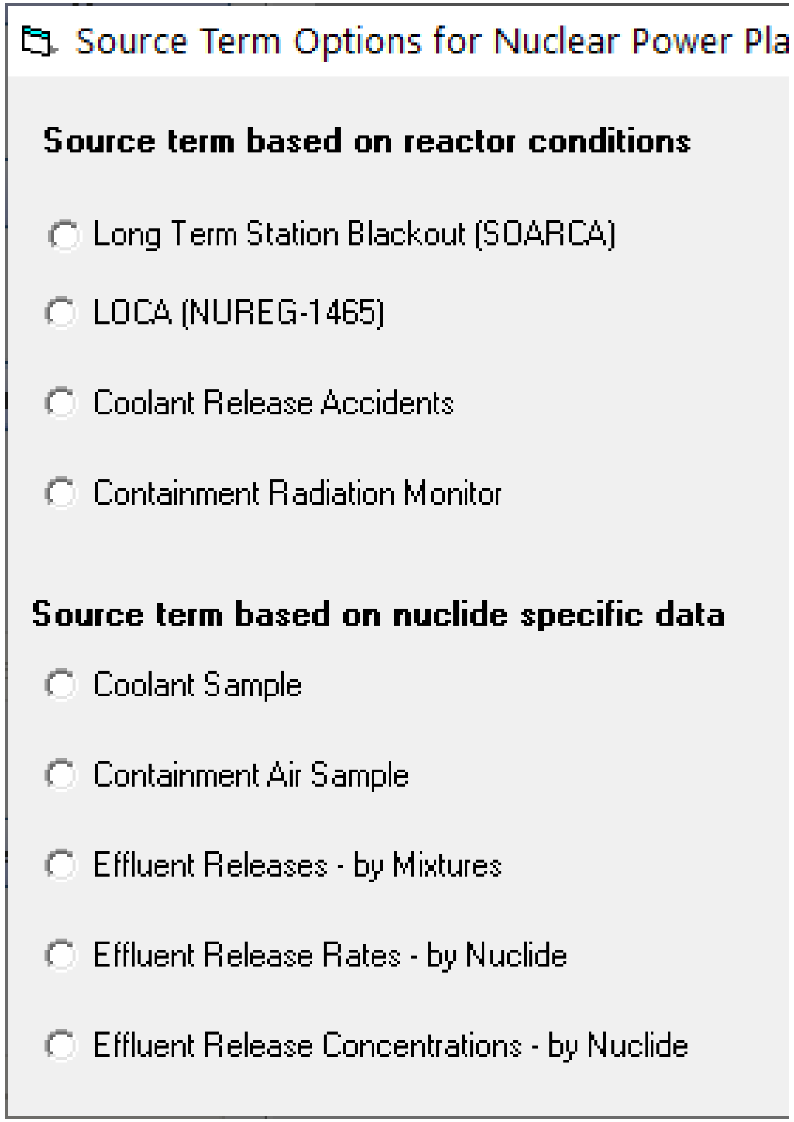
Fuel Cycle



Other Materials



Nuclear Power Plant



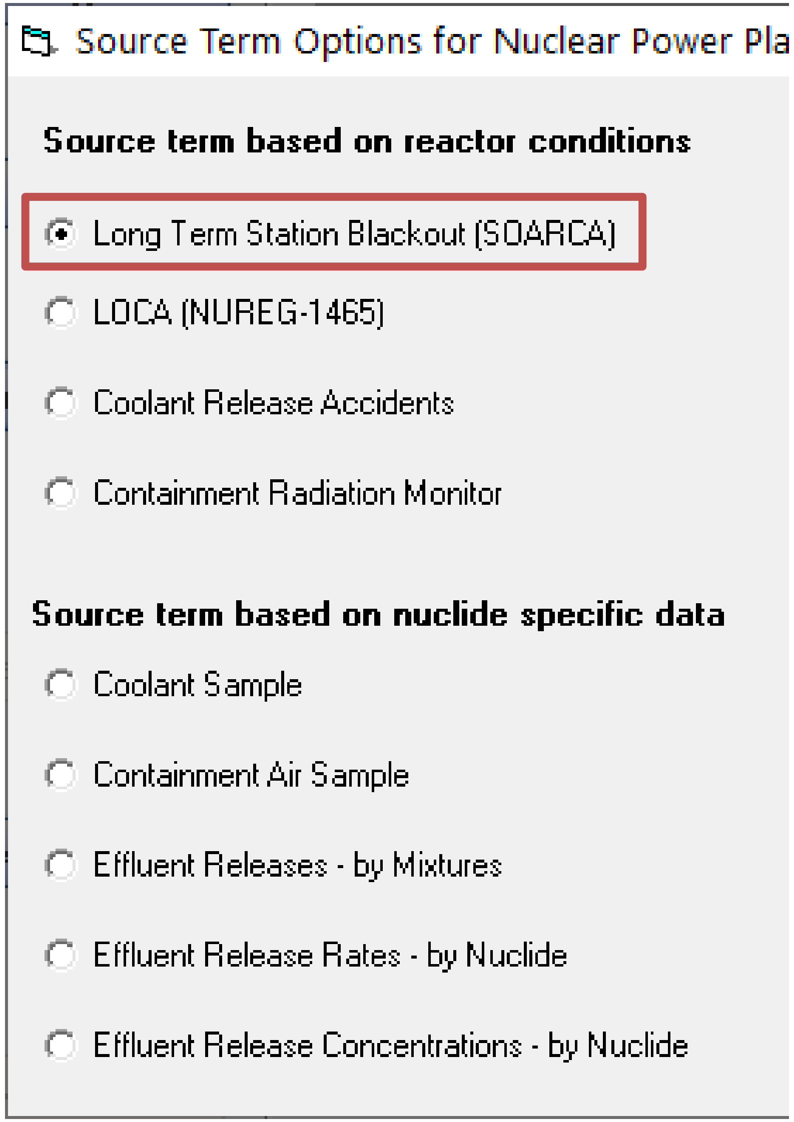
RASCAL has 9 nuclear power plant source term options:

- 4 based on reactor condition models
- 5 based on nuclide measurements

This source term screen can be seen when you:

- Select Event Type, set to Nuclear Power Plant
- Select Event Location, select any NPP location
- Select Source Term

Nuclear Power Plant → Long-Term Station Blackout



- In an LTSBO, a facility will lose all offsite and onsite AC power. Cooling is initially maintained using diesel generators and batteries. However, after these are exhausted, water in the core will start to heat and eventually boil. After the core is fully uncovered, fission products begin to release.
- Use this for LTSBO (and Short-Term Station Black Out) scenarios where RASCAL can help determine when the core may be uncovered

Nuclear Power Plant → Long Term Station Blackout

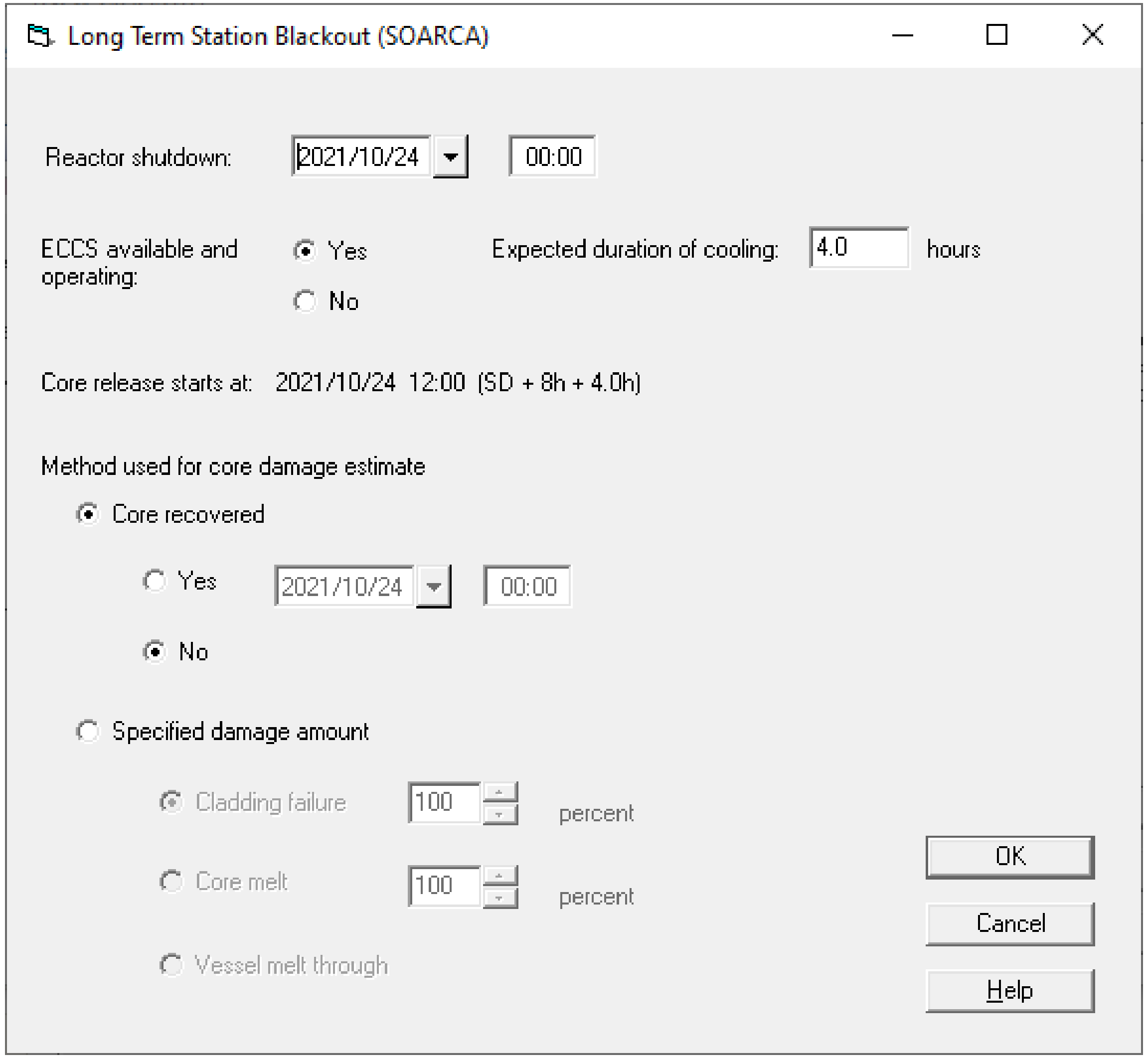
How this model works in RASCAL:

- Based on the State-of-the-Art Reactor Consequence Analysis (SOARCA) reports.

Time of Core Damage = Shutdown Time + Cooling + Heatup

  – Models determine when core becomes uncovered
  – Cooling delays time of core damage; requires diesels or batteries
  – Models automatically add heatup time
    - 8 hours for PWRs, 6 hours for BWRs

Nuclear Power Plant → Long Term Station Blackout



- Shutdown time
  - Used to decay correct all the isotopes in the core
- Cooling
  - Set duration of cooling if available
- Reactor recovery time
  - Used to stop additional nuclides from contributing to the source term

Your Turn to Use RASCAL

- **Given the scenario excerpt below, run the entire case in RASCAL.**

Location: Arkansas - Unit 1
Source Term: LTSBO

Reactor shutdown at 1000. Batteries and diesels initially provided power but became incapacitated 11 hours later. Power is restored (and core recovered) at 1000 the next day.

Release Path: Defaults (Containment, 10m height, Design leak rate, Sprays off)
Weather: Predefined -> Standard Met
Settings: ICRP 26/30

LET'S WALK THROUGH THE PROBLEM TOGETHER

Knowledge Check

Given the models in RASCAL, at what time does the core heat up to the point of damage/release?

- 1500
- 2100
- 0500 next day
- 1000 next day

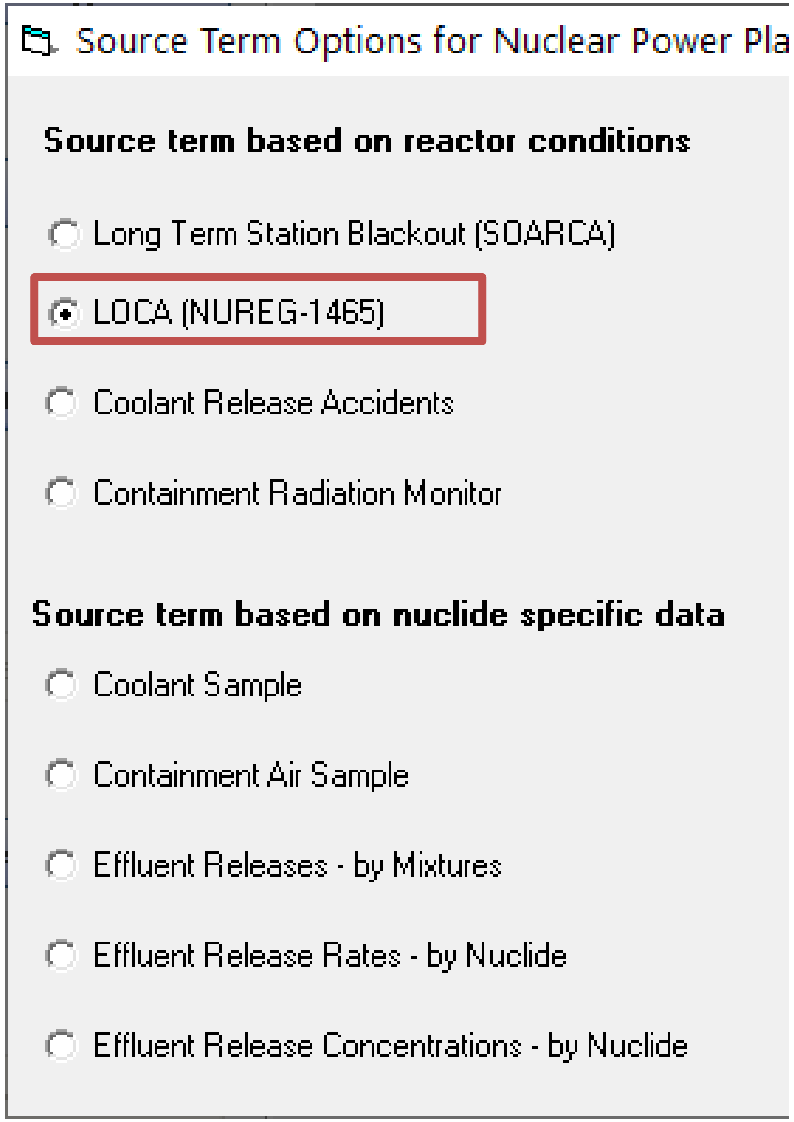
Knowledge Check

T or F, the LTSBO model is appropriate anytime there is a loss of offsite power?

- True
- False

A loss of offsite power does not necessarily result in a station blackout, and RASCAL may not be needed at all. The LTSBO model should be used for station blackouts where it is projected that operators cannot keep the core cool.

Nuclear Power Plant → Loss of Coolant Accident (LOCA)



- Large loss of reactor coolant, leads to core uncovery and fuel melt
- Use for core damage accidents
  - Similar release fractions to LTSBO events

Nuclear Power Plant → Loss of Coolant Accident (LOCA)

How this model works in RASCAL:

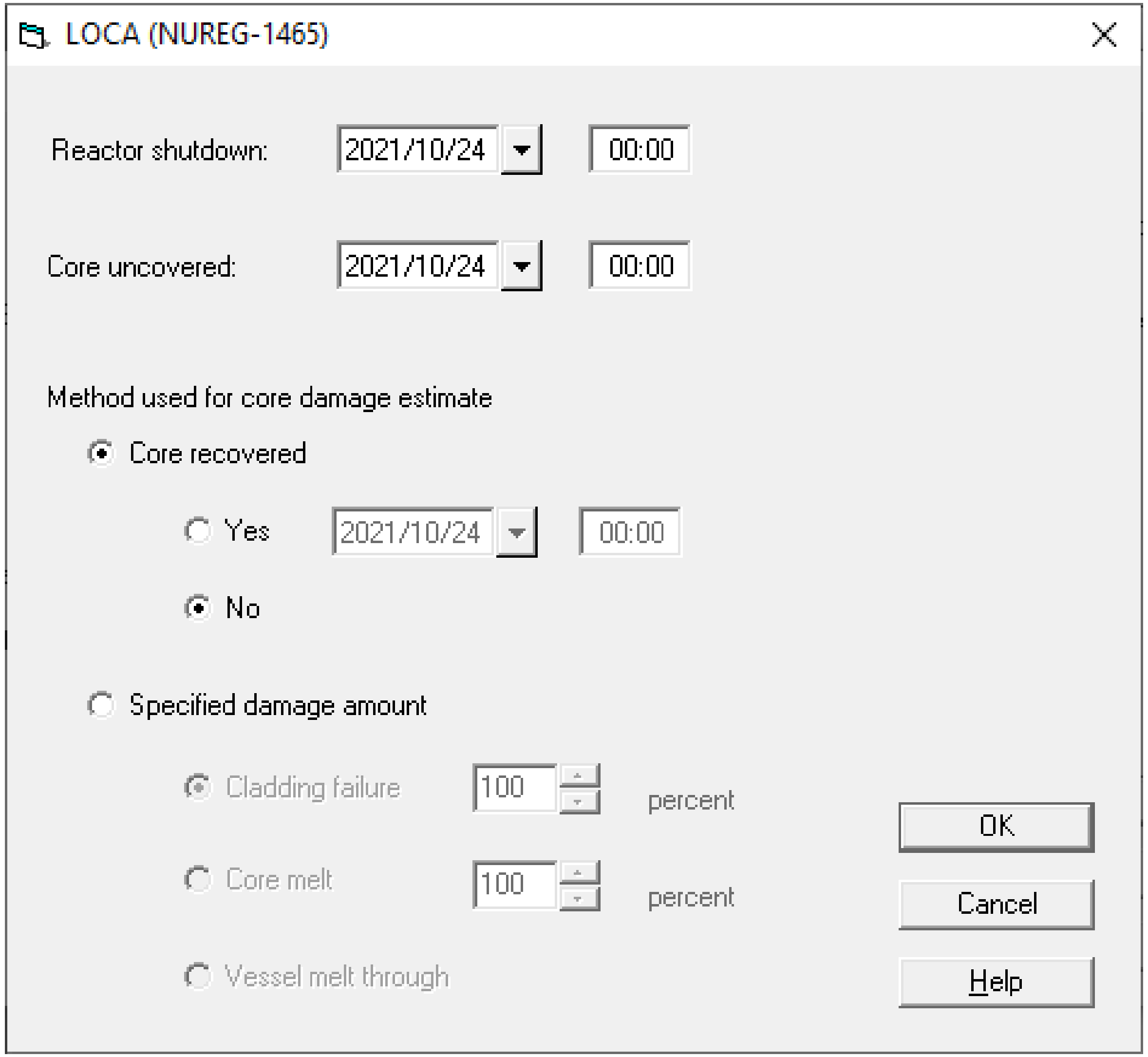
- Based on NUREG-1465
- Assumes that a core not covered by water is unable to remove enough heat and starts to heat to the point of fuel melt.
- After the reactor is uncovered, the model will release fractions of the core inventory based on these phases:
    - 30 minutes of cladding failure/gap release
    - 80-90 minutes of core melt
    - 2-3 hours of vessel melt-through

Nuclear Power Plant → Loss of Coolant Accident (LOCA)

Inventory x **Release Fractions** x Reductions x Leakage or Flow = Atmospheric Source Term

Nuclide Group	Cladding failure	Core melt	Vessel melt through
	0.5 hour duration	1.3 hour duration	2.0 hour duration
Noble gases (Xe, Kr)	0.05	0.95	0
Halogens (I, Br)	0.05	0.35	0.25
Alkali metals (Cs, Rb)	0.05	0.25	0.35
Tellurium group (Te, Sb, Se)	0	0.05	0.25
Barium, strontium (Ba, Sr)	0	0.02	0.1
Noble metals (Ru, Rh, Pd, Mo, Tc, Co)	0	0.0025	0.0025
Cerium group (Ce, Pu, Np)	0	0.0005	0.005
Lanthanides (La, Zr, Nd, Eu, Nb, Pm, Pr, Sm, Y, Cm, Am)	0	0.0002	0.005

Nuclear Power Plant → Loss of Coolant Accident (LOCA)



- Shutdown time
  - Used to decay correct all the isotopes in the core
- Core uncovered time
  - Used to start the timing sequences in NUREG 1465
- Reactor recovery time
  - Used to stop additional nuclides from contributing to the source term

Your Turn to Use RASCAL

- **Given the scenario excerpt below, run the entire case in RASCAL.**

Location: Arkansas - Unit 1
Source Term: LOCA

Reactor shutdown at 1000. Core uncovered at 0500 next day. Core recovered 5 hours later.

Release Path: Defaults (Containment, 10m height, Design leak rate, Sprays off)
Weather: Predefined -> Standard Met
Settings: ICRP 26/30

LET'S WALK THROUGH THE PROBLEM TOGETHER

**Given similar timelines, did anyone notice dose/source term differences between LOCA and LTSBO models?*

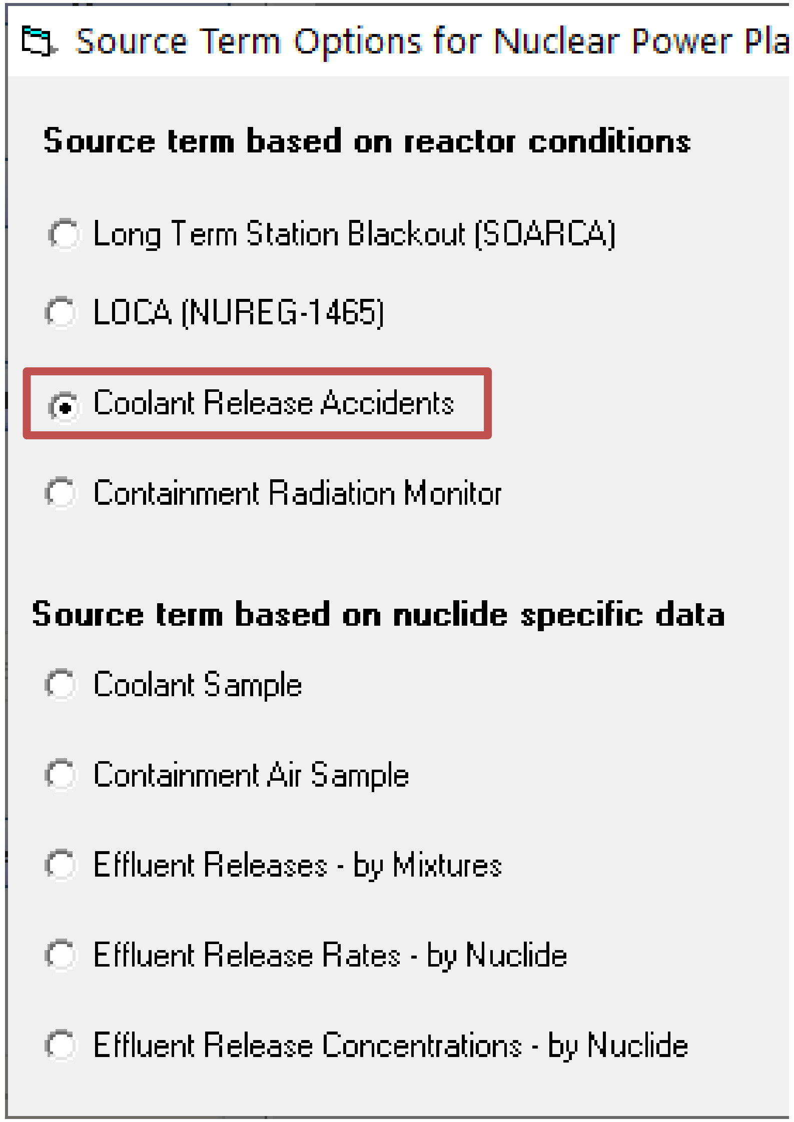
Knowledge Check

A NPP utility reports a major loss of coolant due to an earthquake, which also causes a loss of offsite power. Which source term model would be best to use?

- – LTSBO
- – LOCA

We would expect the core to become uncovered (and damaged) sooner due to water loss than due to heatup associated with a blackout.

Nuclear Power Plant → Coolant Release Accidents



- Loss of reactor coolant where only coolant is released, no core melt expected
- Very small releases
- Use this when no fuel melt is expected

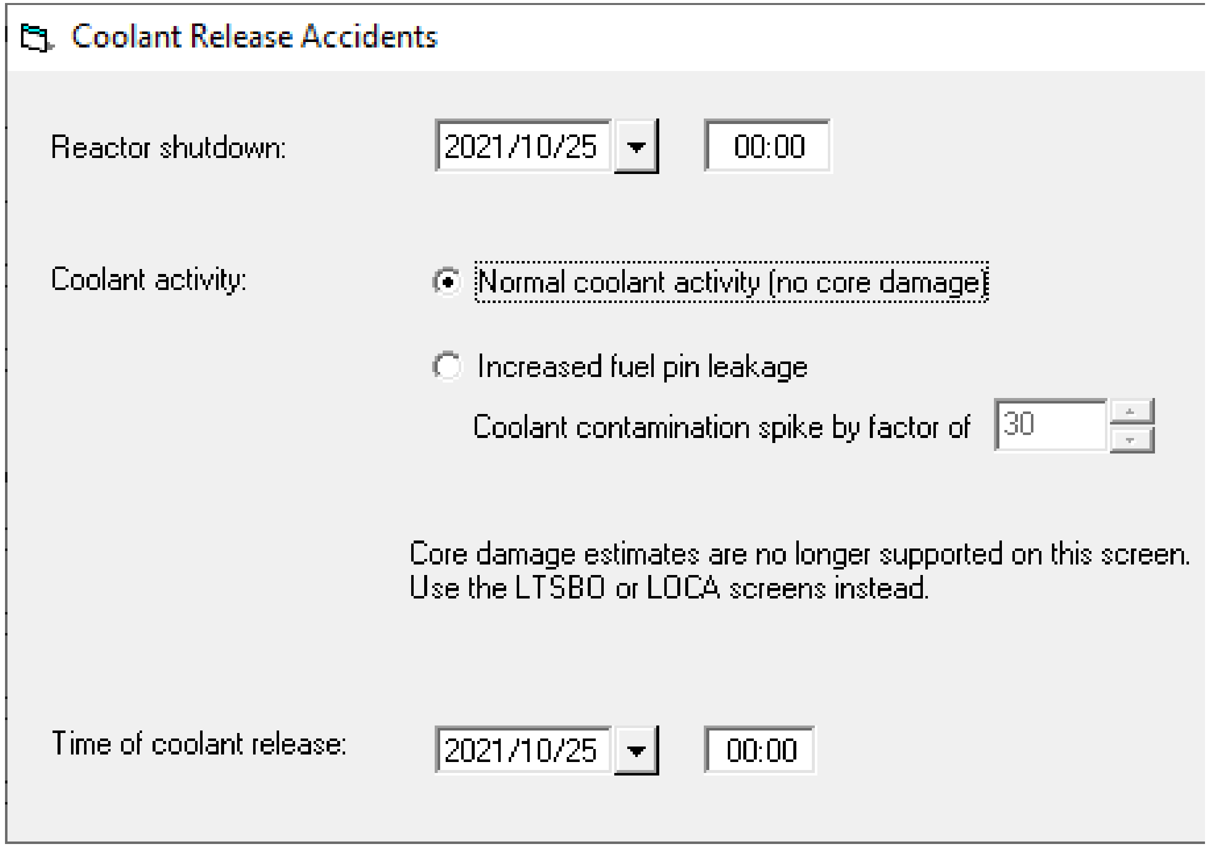
NUCLEAR POWER PLANT → COOLANT RELEASE ACCIDENTS

How this model works in RASCAL:

- All reactor system pipe breaks can be modeled 2 ways depending on volume of coolant leak:
  - LOCA (large or unrecoverable break, core melt)
  - Coolant Release (smaller break, no core melt)

- For coolant release models (simple SGTRs or small bypass LOCAs with no degrading conditions):
  - Database has information about nuclides that would be in normal coolant
  - Coolant spiking

NUCLEAR POWER PLANT → COOLANT RELEASE ACCIDENTS



- Shutdown time
  - Used to decay correct all the isotopes in the core
- Coolant Activity
  - Pin leakage increases concentration of certain isotopes
- Time of coolant release

Your Turn to Use RASCAL

- **Given the scenario excerpt below, run the entire case in RASCAL.**

Location: Arkansas - Unit 1
Source Term: Coolant Release

Steam Generator Tube Rupture and immediate reactor trip at 00:36. No indications of spiked coolant.

Release Path: Defaults (SGTR, 10m height, Default SGTR table values)
Weather: Predefined -> Standard Met
Settings: ICRP 26/30

LET'S WALK THROUGH THE PROBLEM TOGETHER

**How big is this release compared to our previous LOCA and LTSBO runs?*

Knowledge Check

NPP operators report that there is a loss of coolant. What model would you use?

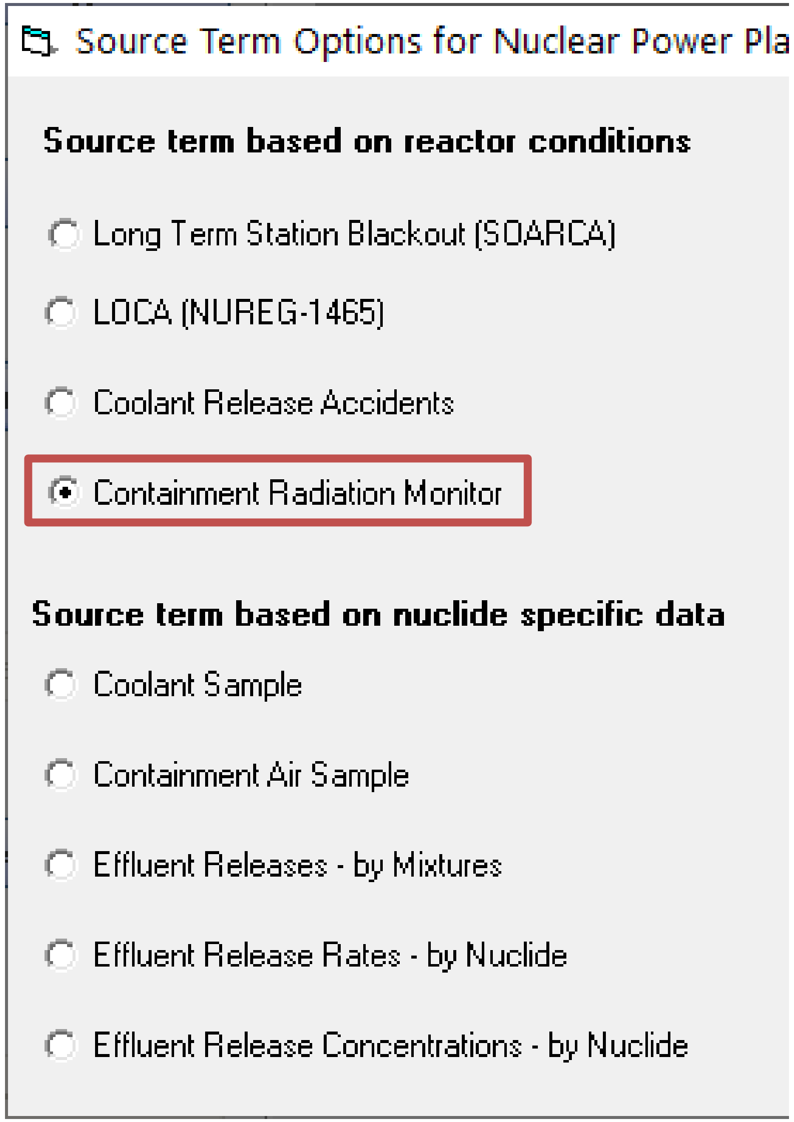
- LOCA
- Coolant Release

It depends.

- *If operators can add enough water to keep the core covered, then the accident will only include coolant water (Coolant Release model).*
- *If operators are unable to keep the core covered, then the accident will include core damage (LOCA model).*

If an accident progresses from Coolant Release to LOCA, we recommend ignoring the Coolant Release portion, as this is significantly smaller than any LOCA source term.

Nuclear Power Plant → Containment Radiation Monitor



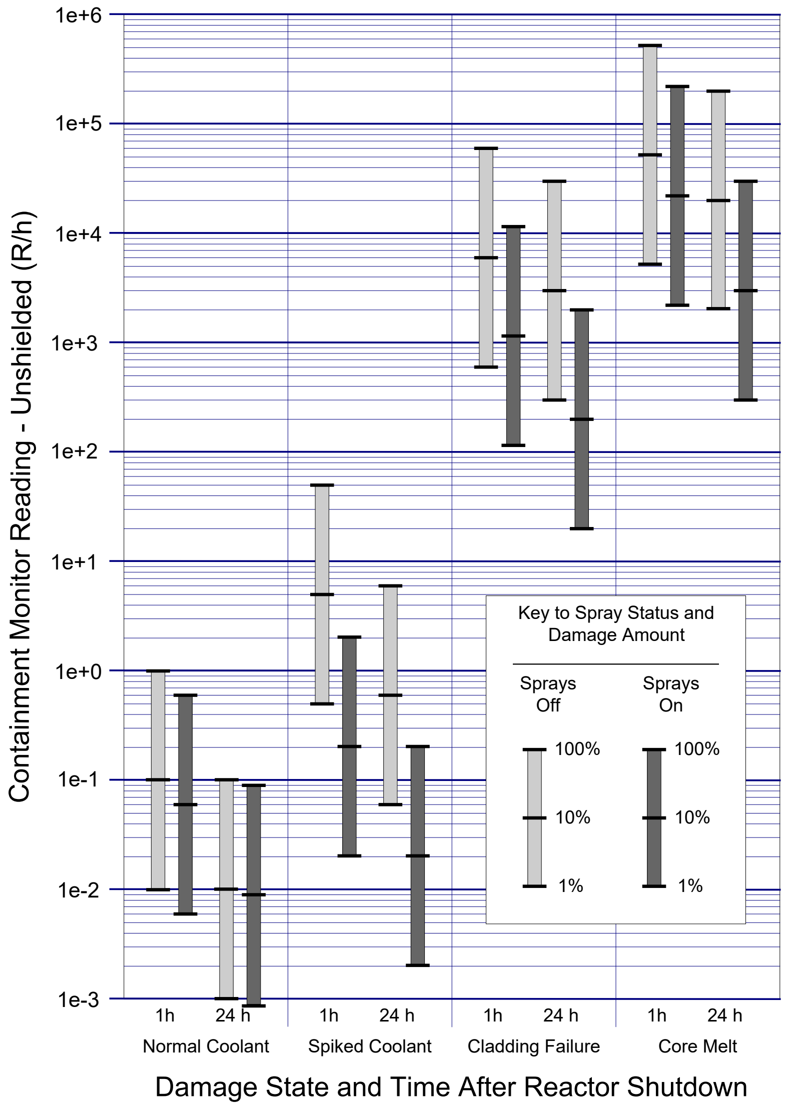
- Estimates core damage based on containment rad monitor
- Use this when no additional data is available or as a backup method

Nuclear Power Plant → Containment Radiation Monitor

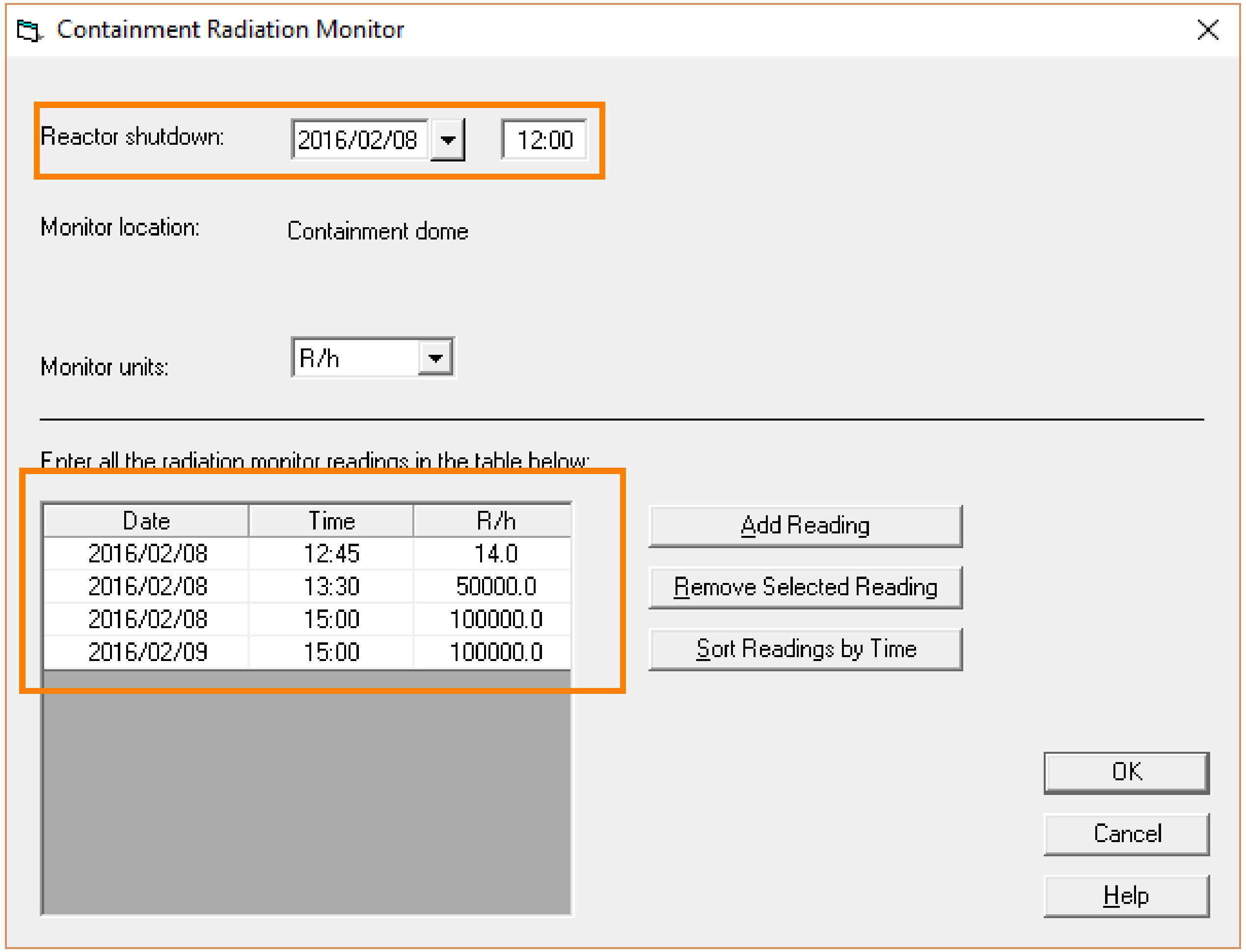
How this model works in RASCAL:

- One or more instruments inside containment used to continuously survey the containment volume for radiation (generally R/h)

- The model uses these tables to convert the reading into a damage amount. 2 additional factors are considered
  - Time since reactor shutdown
  - Whether sprays are on or off.



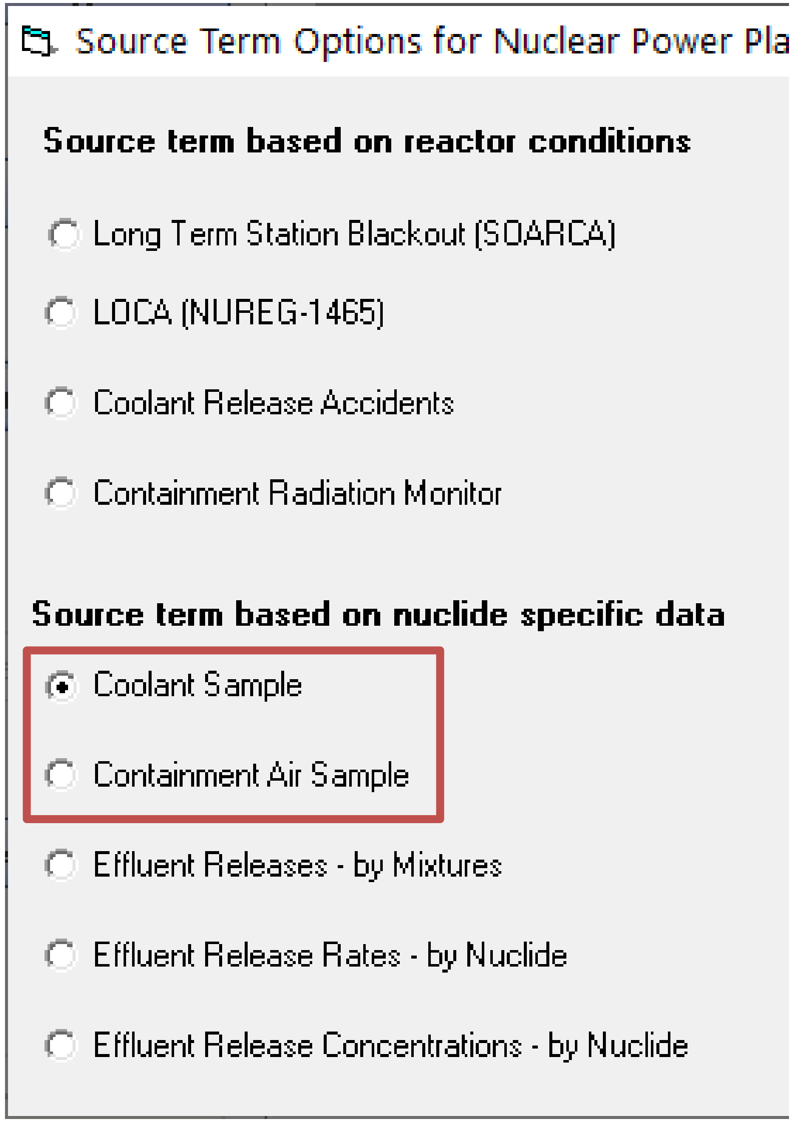
Nuclear Power Plant → Containment Radiation Monitor



The only entries required are the shutdown time and the actual rad monitor readings.

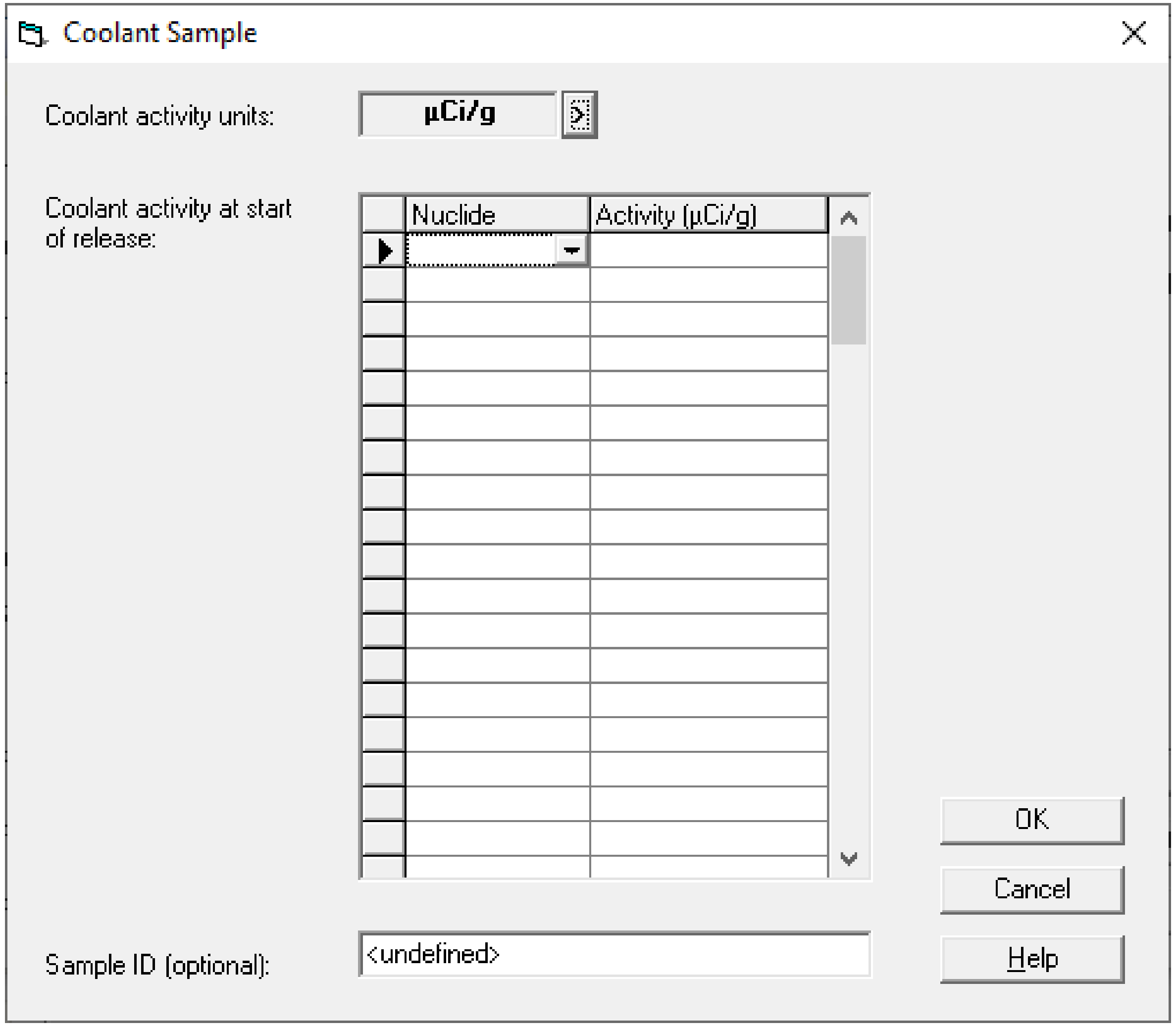
This model is not predictive and persists damage amounts until it reaches a new entry.

Nuclear Power Plant → Coolant or Containment Air Sample



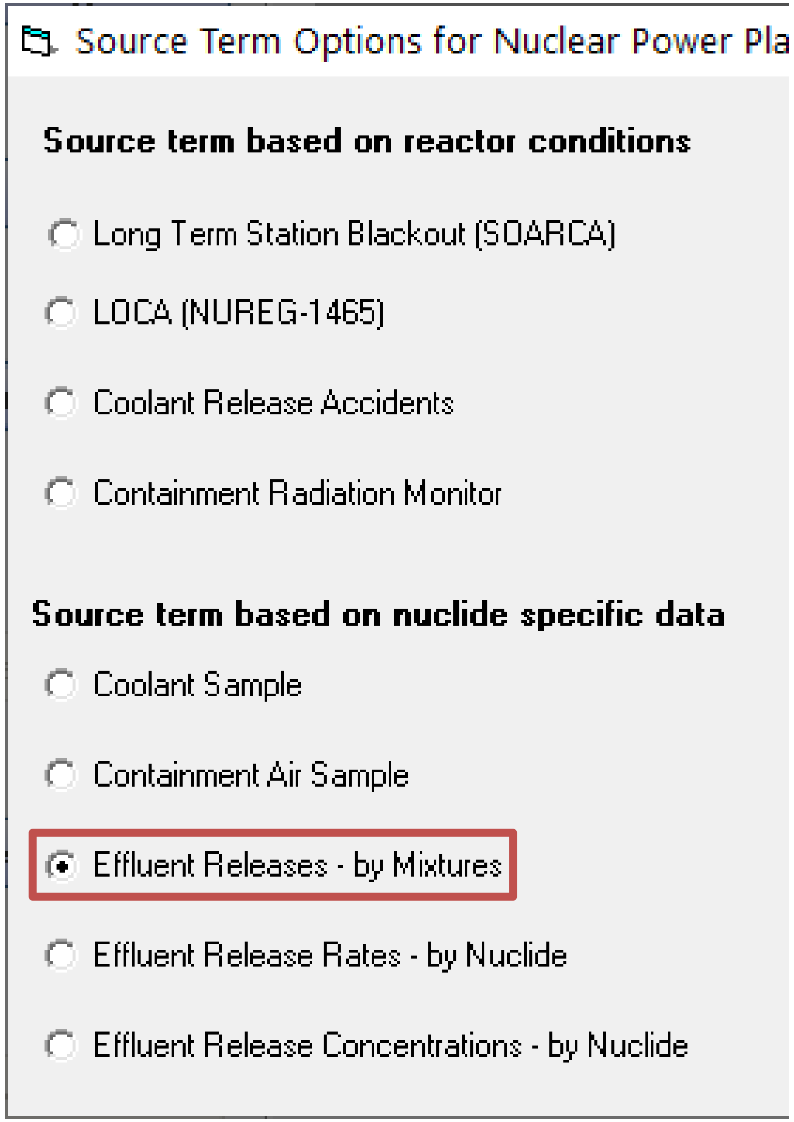
- User inputs entire source term by nuclide
- RASCAL does not extrapolate source term from subset of nuclides
- Not expected to have data during event

Nuclear Power Plant → Coolant or Containment Air Sample



- Activity Units
- Nuclide and Associated Activities
- Does not allow for changes with time

Nuclear Power Plant → Effluent Releases - Mixtures



- Monitored effluent pathways are useful indications but usually cannot identify specific radionuclides present
- Effluent monitors provide detector count rates, which can be converted to release rates for noble gases, radioiodines, and sometimes particulates
- Monitored releases will be filtered so they should be mostly noble gases but with a small proportion of iodines and particulates.

NUCLEAR POWER PLANT → EFFLUENT RELEASES - MIXTURES

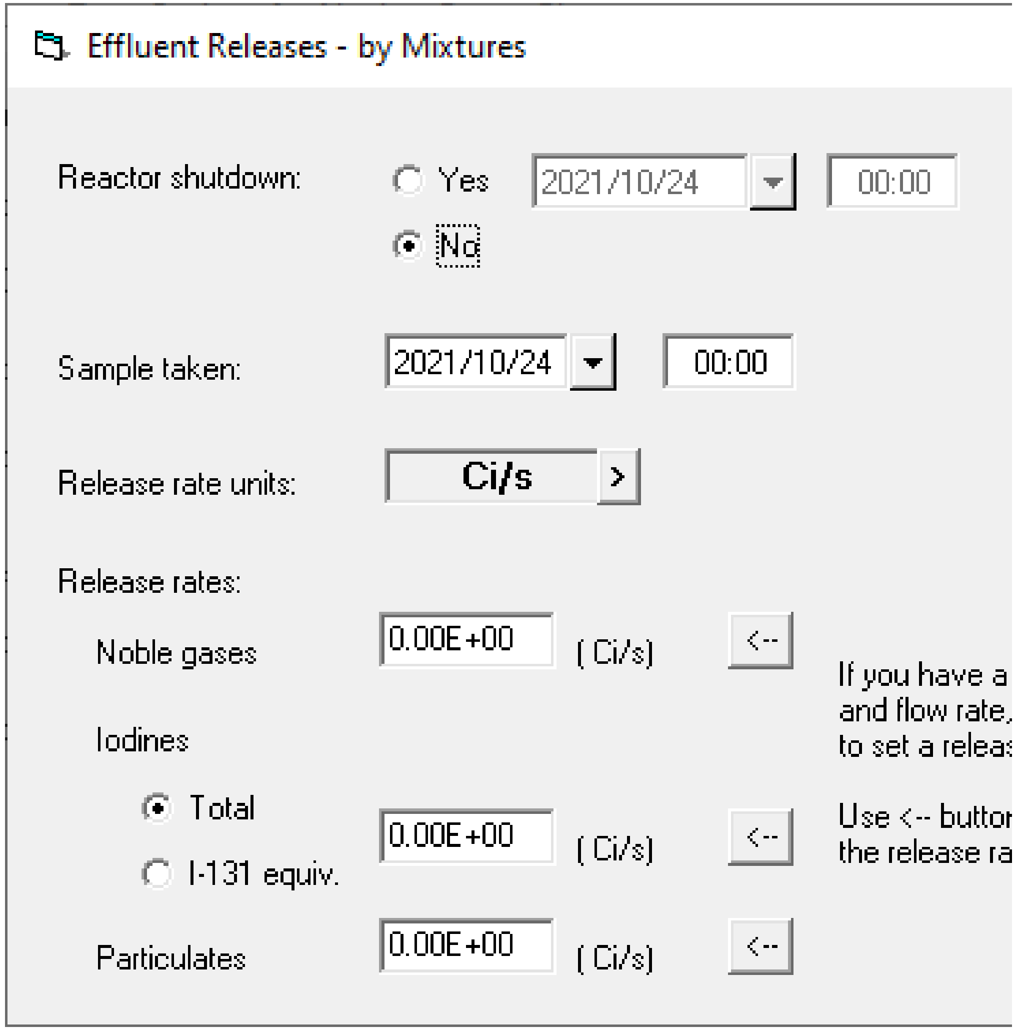
How this model works in RASCAL:

- RASCAL takes groupings of mixtures (NG, I, & P) and normalizes each nuclide within that mixtures according to reactor inventory. Example:

Input		Released Nuclides
10 Ci/s Total Iodines	→	1.1 Ci/s I-131
		1.7 Ci/s I-132
		2.3 Ci/s I-133
		2.6 Ci/s I-134
		2.3 Ci/s I-135

- Core damage states are reflected in user inputs.
- Usually requires coordination with utility calcs to convert from rates to activity/time.

Nuclear Power Plant → Effluent Releases - Mixtures



- Shutdown time
  - Used to decay correct all the isotopes in the core
- Sample Taken
- Units
- Release Rates
  - Noble Gas
  - Iodines
    - Total vs I131 equivalent
  - Particulates

Your Turn to Use RASCAL

- **Given the scenario excerpt below, run the entire case in RASCAL.**

Location: Arkansas - Unit 1
Source Term: Effluent Releases – by Mixture

Shutdown at 15:50. 10 minutes later, release started and measured to be 950 Ci/s for noble gases, 12 Ci/s for iodine radioisotopes, and 0.3 Ci/s for particulates. Release lasted for 30 minutes.

Release Path: see above
Weather: Predefined -> Standard Met
Settings: ICRP 26/30

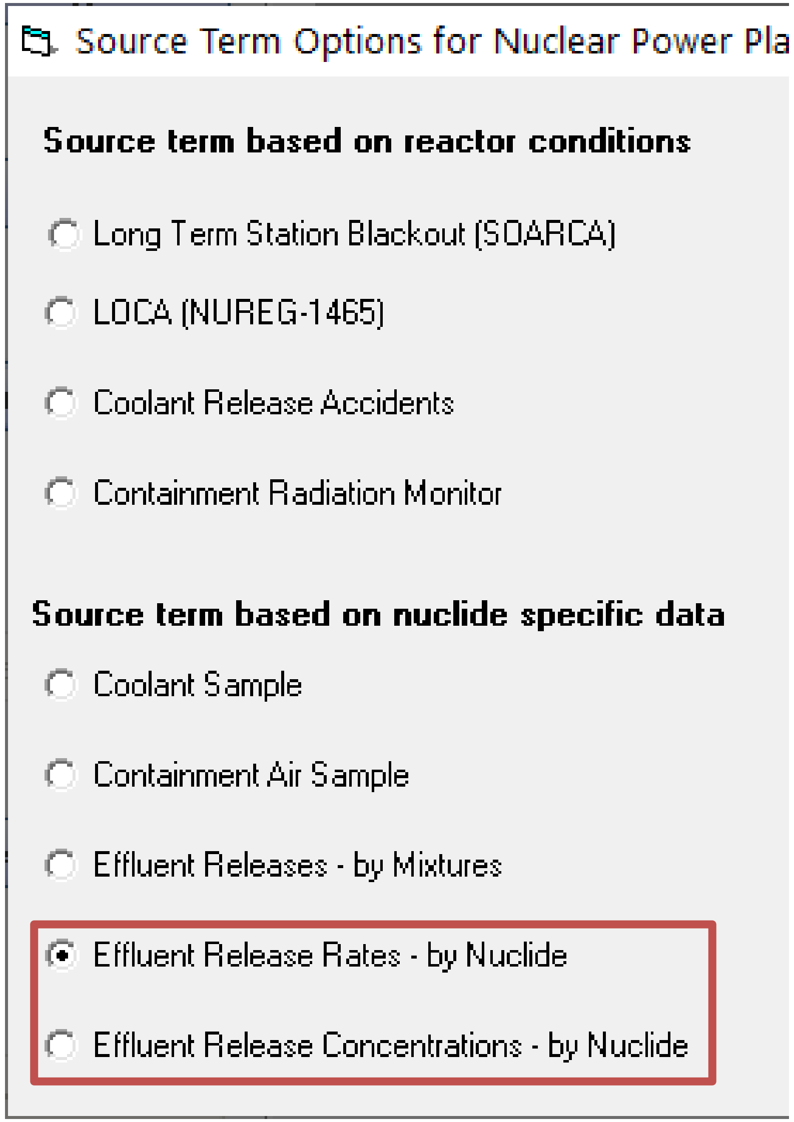
Let's walk through the problem together

Knowledge Check

Plant data states that a monitored pathway detector is reading 100,000 cpm. How could you use this in RASCAL's Effluent Releases – Mixture?

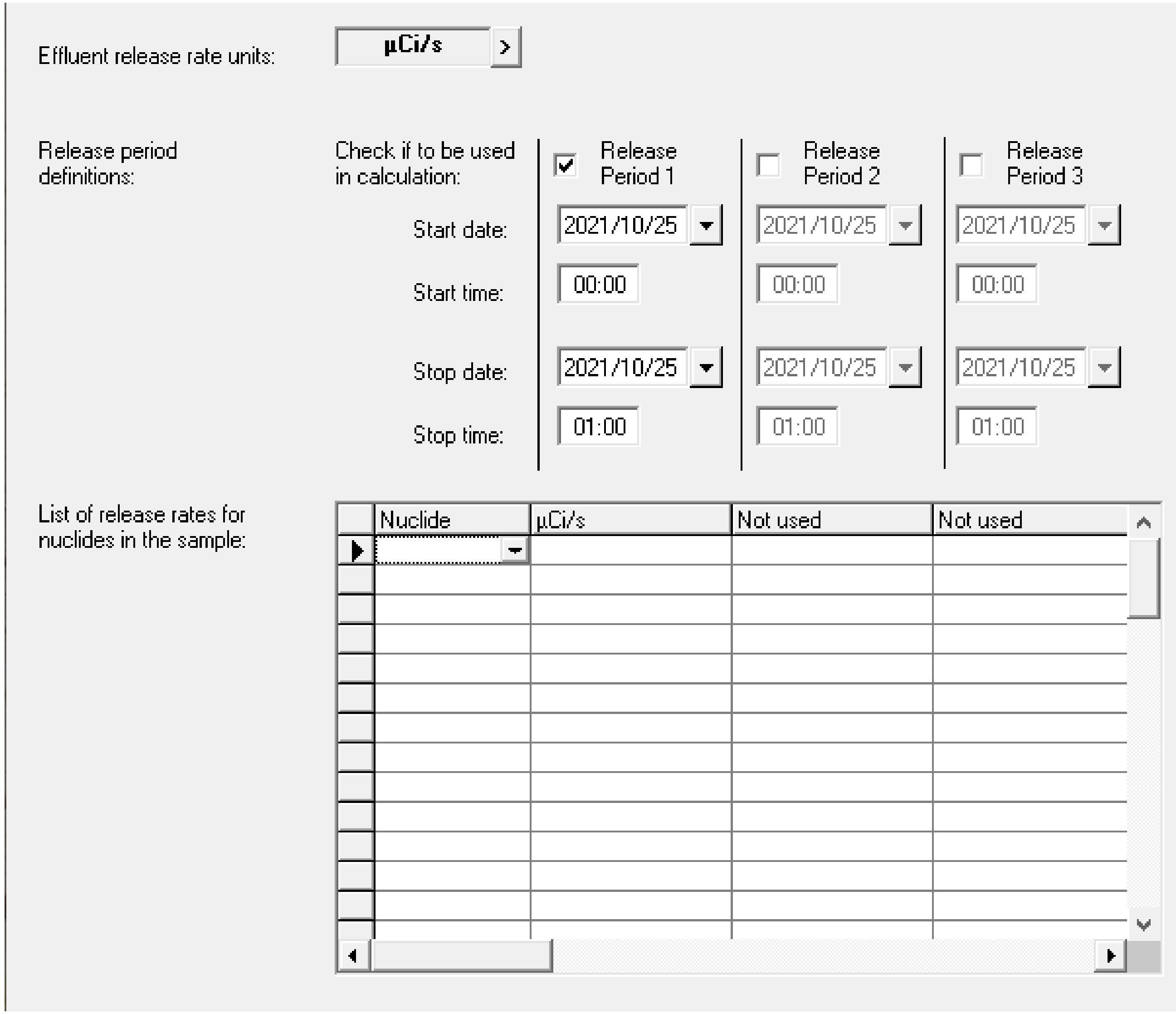
- Set NG, I, and P each to 33,000.
- Set NG to 100,000.
- Having already coordinated with NPP staff ahead of the accident, put in the corresponding activity rates using site-specific conversions.
- Use the LOCA, Coolant Release, or Containment Radiation Monitor models instead, depending on the accident conditions.

NUCLEAR POWER PLANT → EFFLUENT RELEASE RATES/CONCENTRATION



- User inputs entire atmospheric source term by nuclide
- RASCAL does not extrapolate source term from subset of nuclides
- Can be used to manually define source term, including small/custom releases

NUCLEAR POWER PLANT → EFFLUENT RELEASE RATES/CONCENTRATION



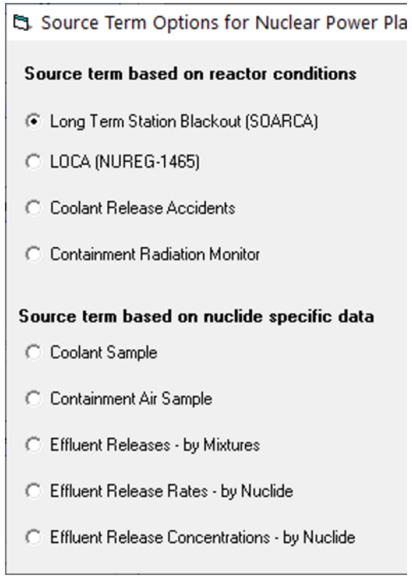
- Units
- Allows for Multiple Release Periods
  - Up to 3
- Start/Stop Time/Date
- Nuclide and Associated Activity

- Reminder, this defines the atmospheric source term (straight to atmosphere)

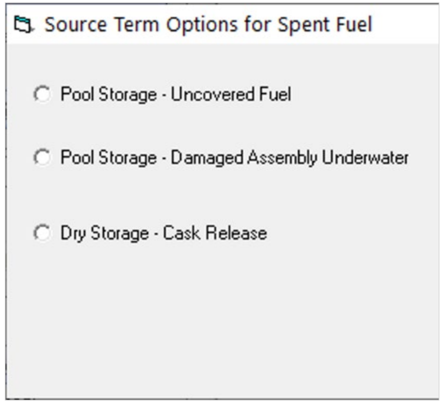
Source Terms

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

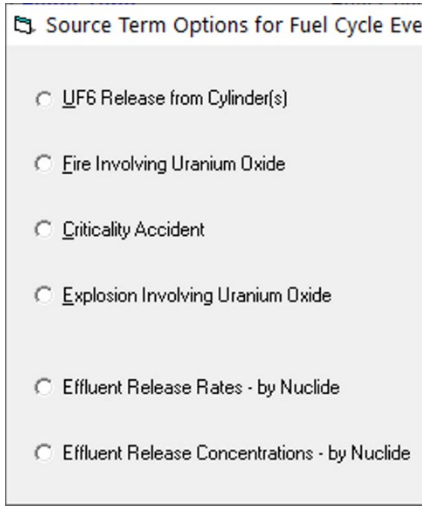
Nuclear Power Plant



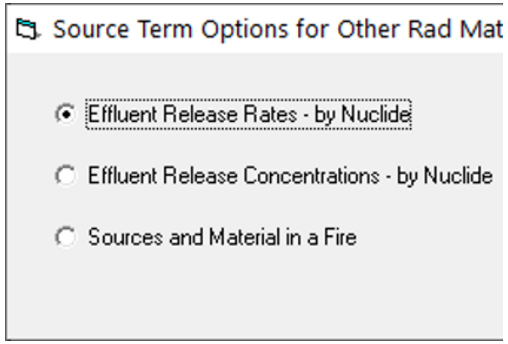
Spent Fuel



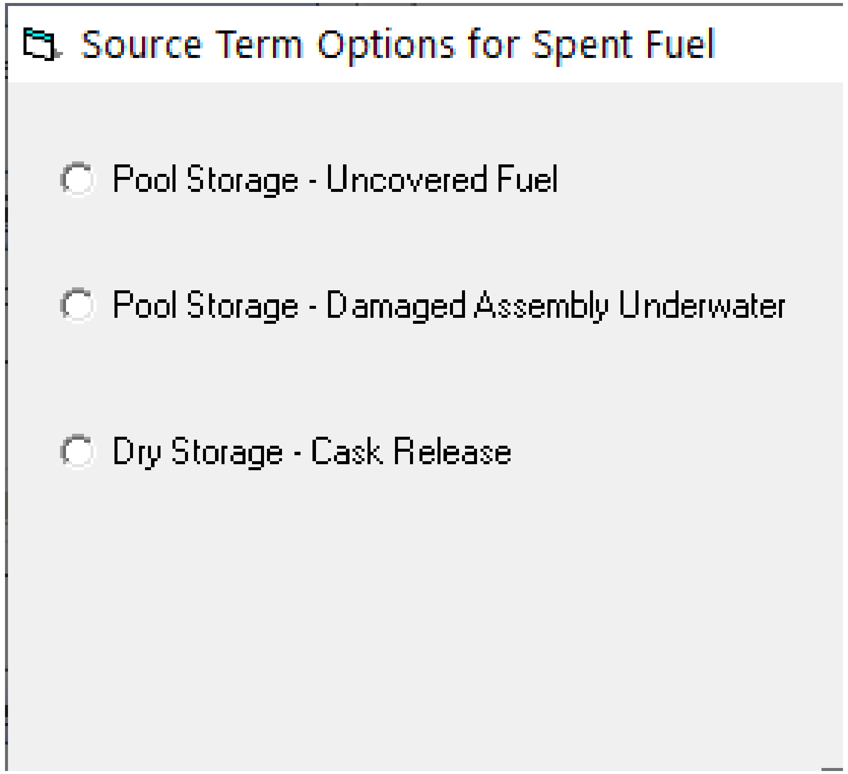
Fuel Cycle



Other Materials



Spent Fuel

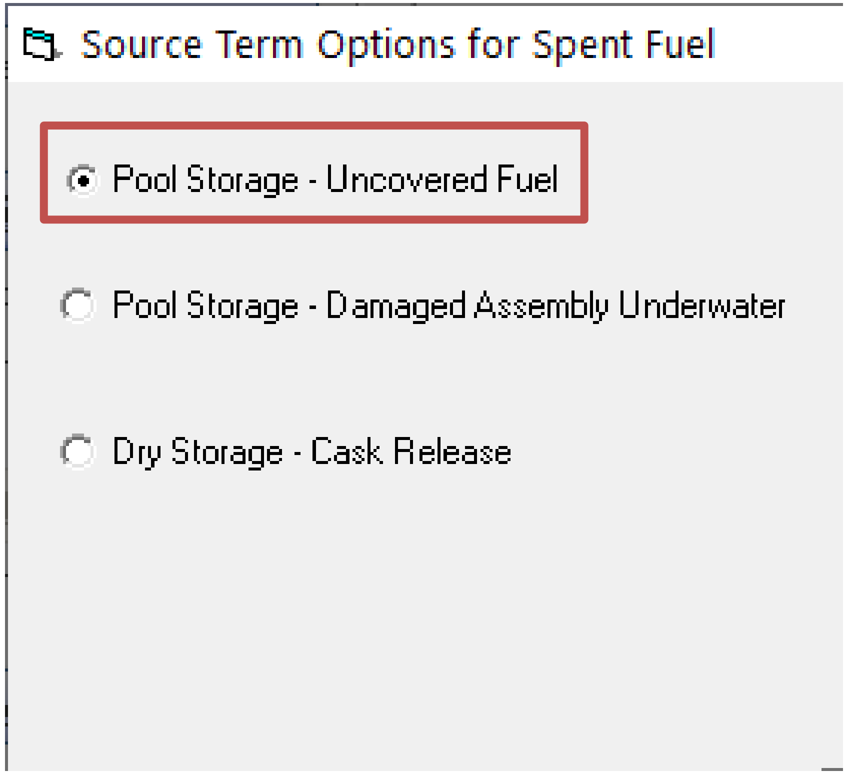


- For Spent Fuel, RASCAL has 3 source term options
- Includes both pool and dry storage
- Sites are collocated with NPPs

This source term screen can be seen when you:

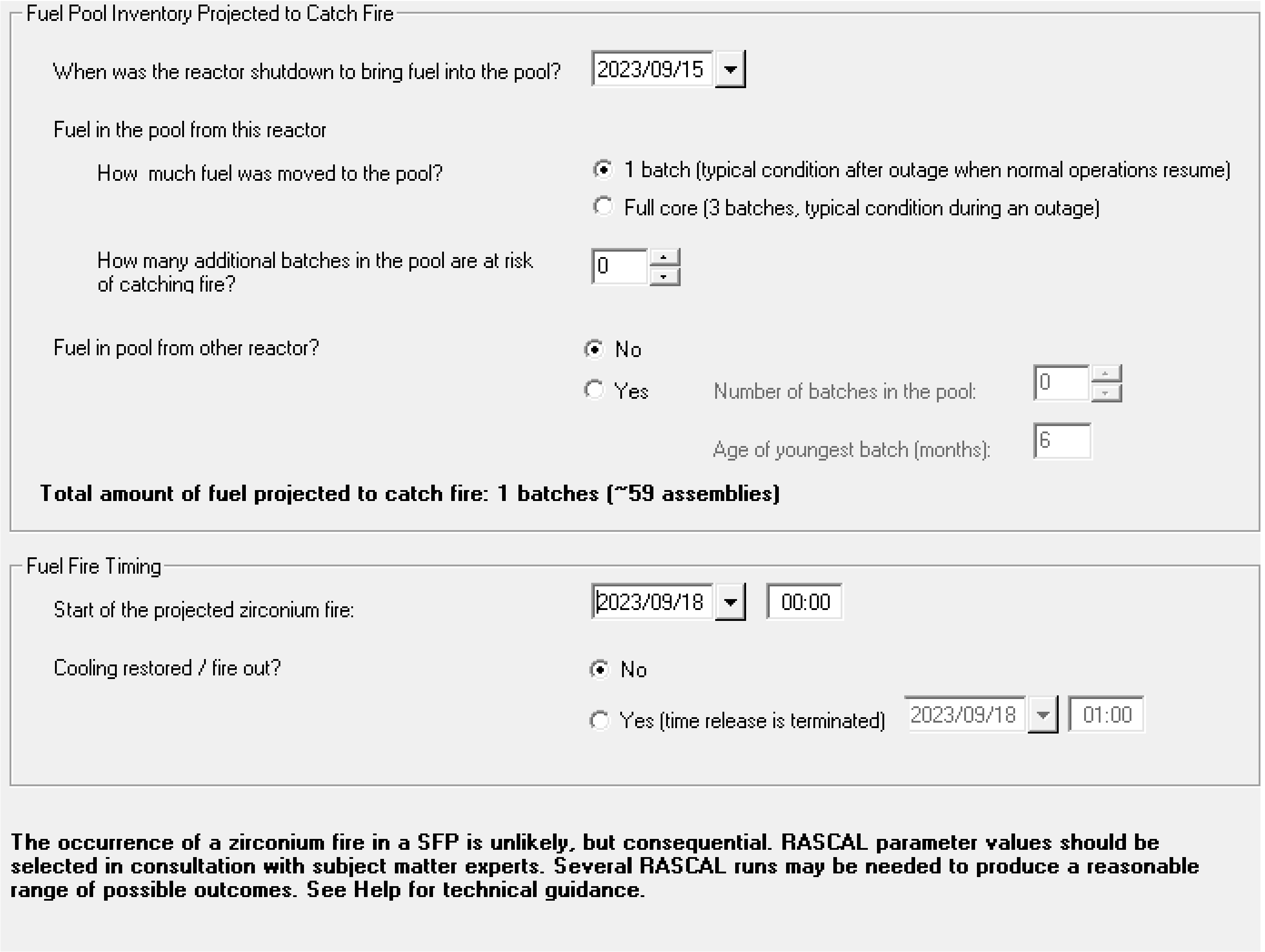
- Select Event Type, set to Spent Fuel
- Select Event Location, select any location
- Select Source Term

Spent Fuel → Pool - Uncovered Fuel



- Models clad/zirconium fire for any fuel defined in the pool
- Use this model when you expect to have a spent fuel fire, not if you need to determine whether there will be one

Spent Fuel→ Pool - Uncovered Fuel



- Shutdown time
  - Used to decay correct all the isotopes in the core
- Inventory
  - Can allow for core-offloads or shared pools
  - Recommend only setting inventory to material at risk
- Fire Start/Stop times

Knowledge Check

T or F, RASCAL will approximate when a spent fuel fire will start based on the last time that fuel was in the reactor?

– True

– False

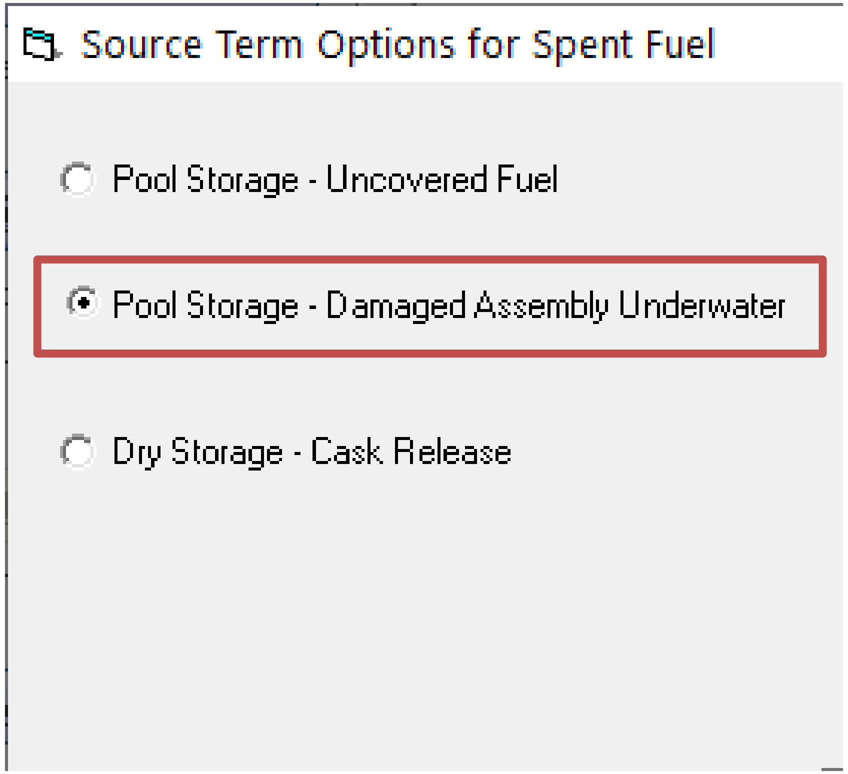
HARD QUESTION! You just finished an assessment of a spent fuel fire in RASCAL. The fuel was last irradiated in the reactor 1 year ago, but still the thyroid dose PAGs were exceeded. Is Potassium Iodide (KI) recommended?

– Yes

– No

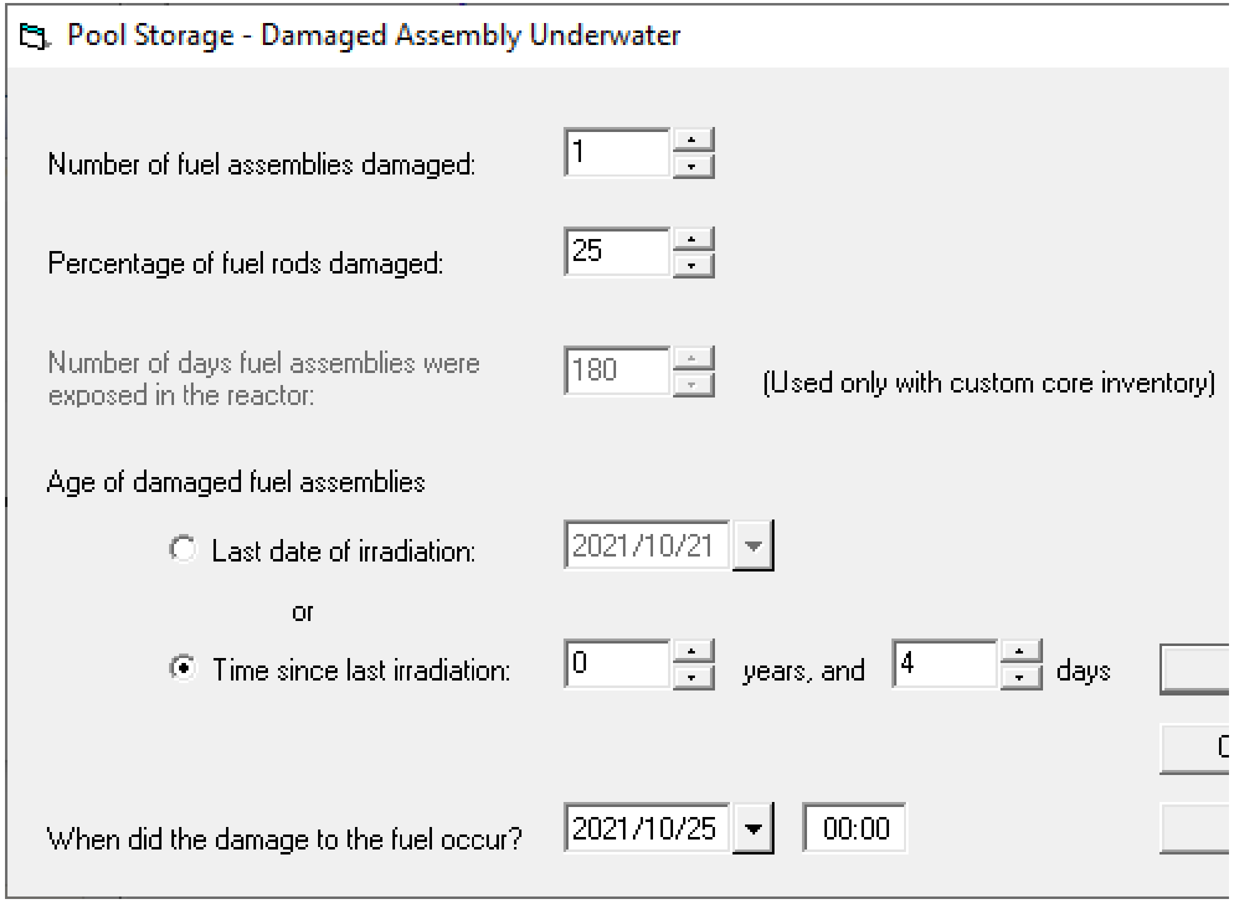
KI protects against thyroid cancer due to iodine uptake. While this accident would likely warrant some protective action, all the iodine has decayed away in the 1 year this fuel was in the pool. PAGs are exceeded due to thyroid dose from non-iodines.

Spent Fuel→ Pool - Damaged Underwater



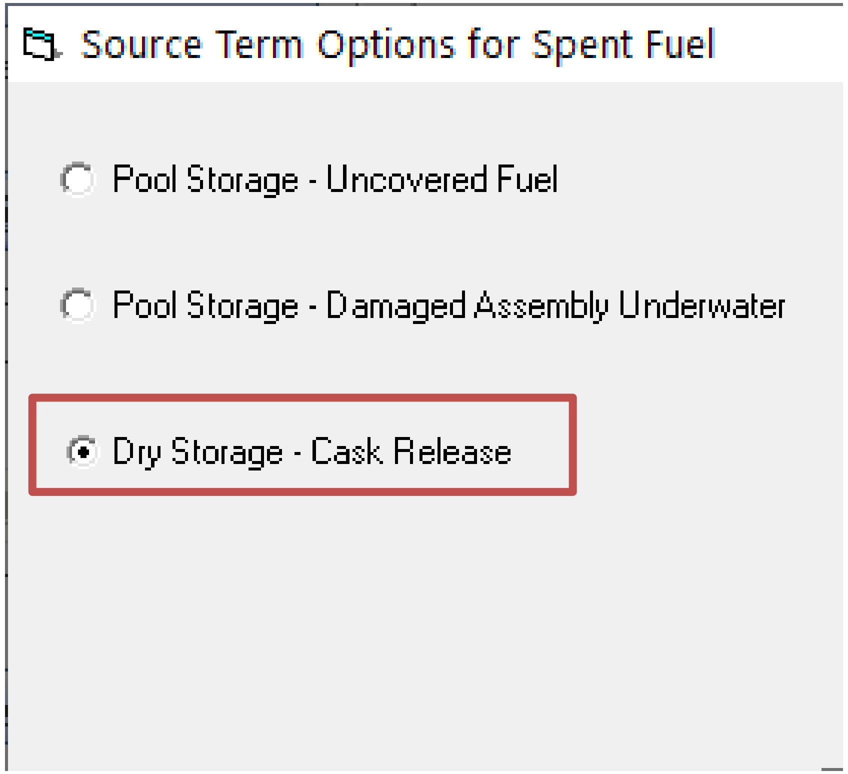
- Models cold gap releases from small amounts of fuel (e.g., several pins within an assembly)
- Only releases gap activity isotopes and scrubbed by the pool
- Very small releases
- Use this for fuel handling accidents or mechanical fuel damage

Spent Fuel→ Pool - Damaged Underwater



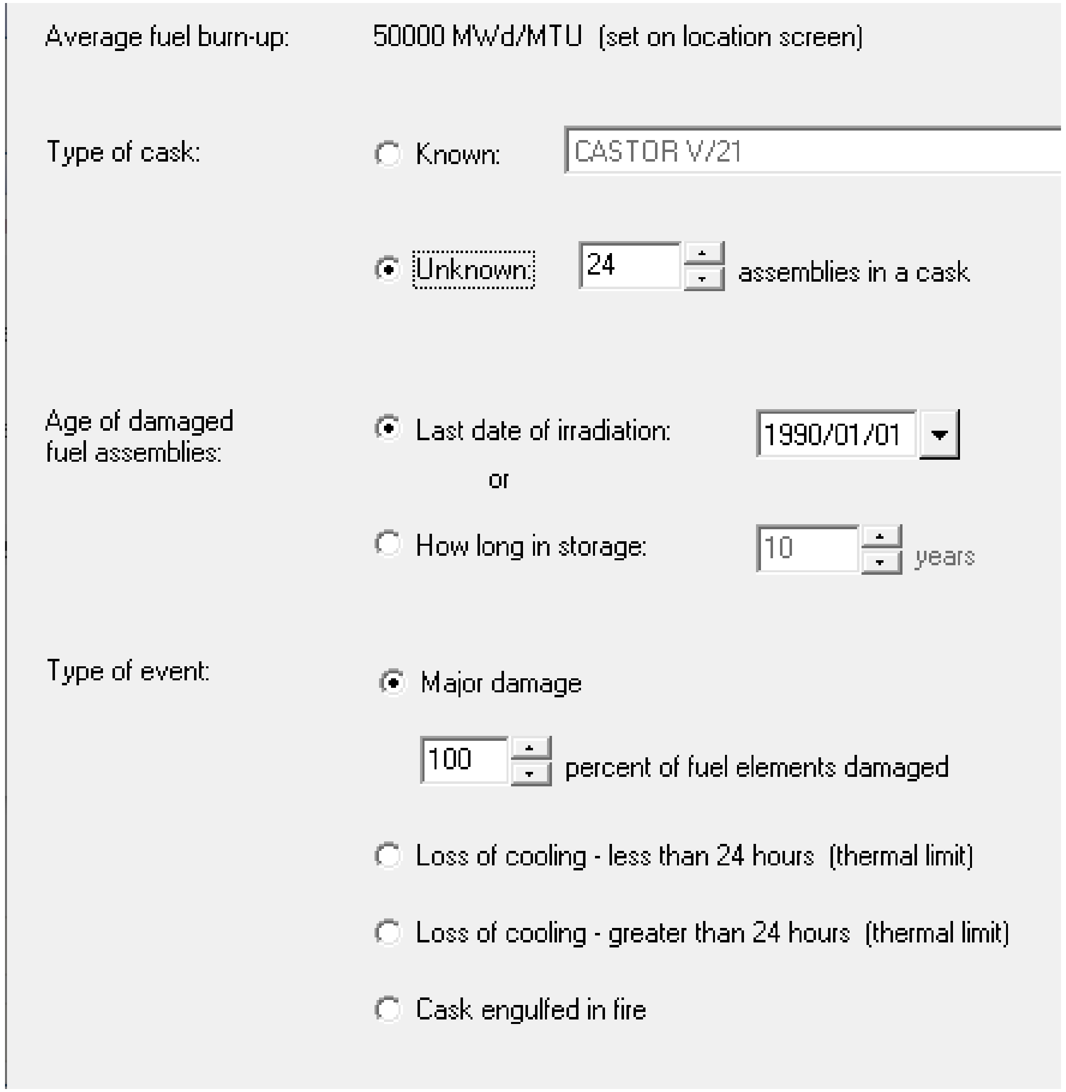
- Inventory
  - Number of assemblies and %
- Age of assemblies
  - Used to decay correct all the isotopes in the core
- Damage time
  - Starts the release

SPENT FUEL→ DRY STORAGE - CASK RELEASE



- Models different damage types to dry cask storage of spent fuel
- Expect small to no releases

SPENT FUEL→ DRY STORAGE - CASK RELEASE

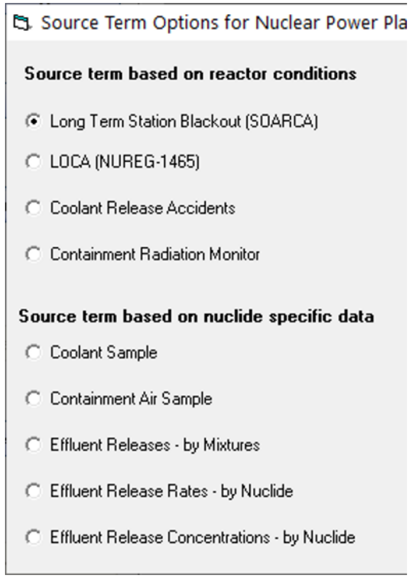


- Cask Type
  - Defines number of assemblies in cask
- Age of assemblies
  - Used to decay correct all the isotopes in the core
- Damage type
  - Sets release fractions and amounts
  - Options 2 and 4 result in no release

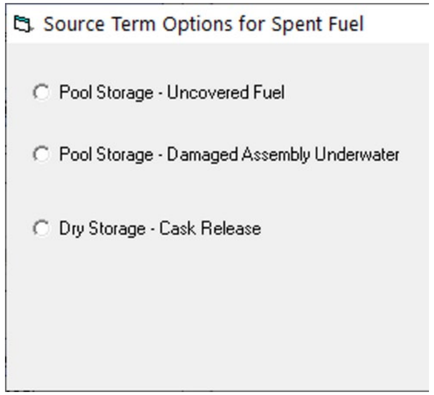
SOURCE TERMS

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

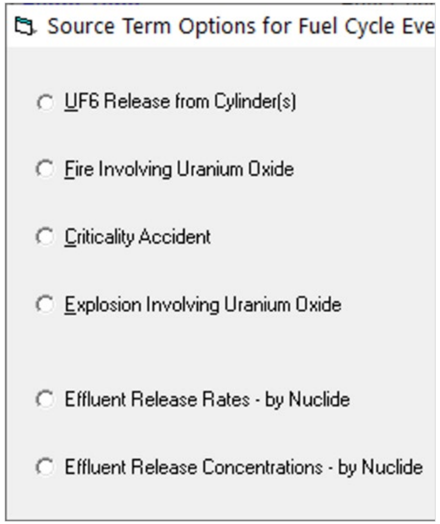
Nuclear Power Plant



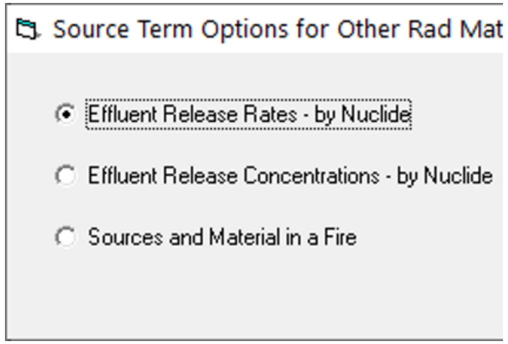
Spent Fuel



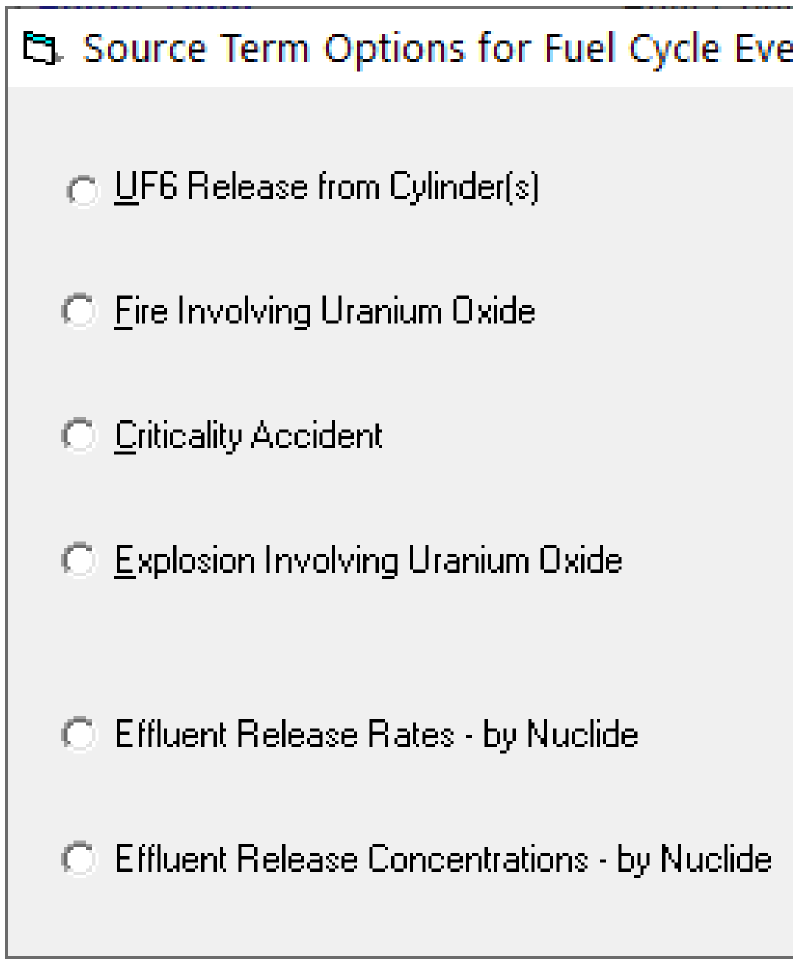
Fuel Cycle



Other Materials



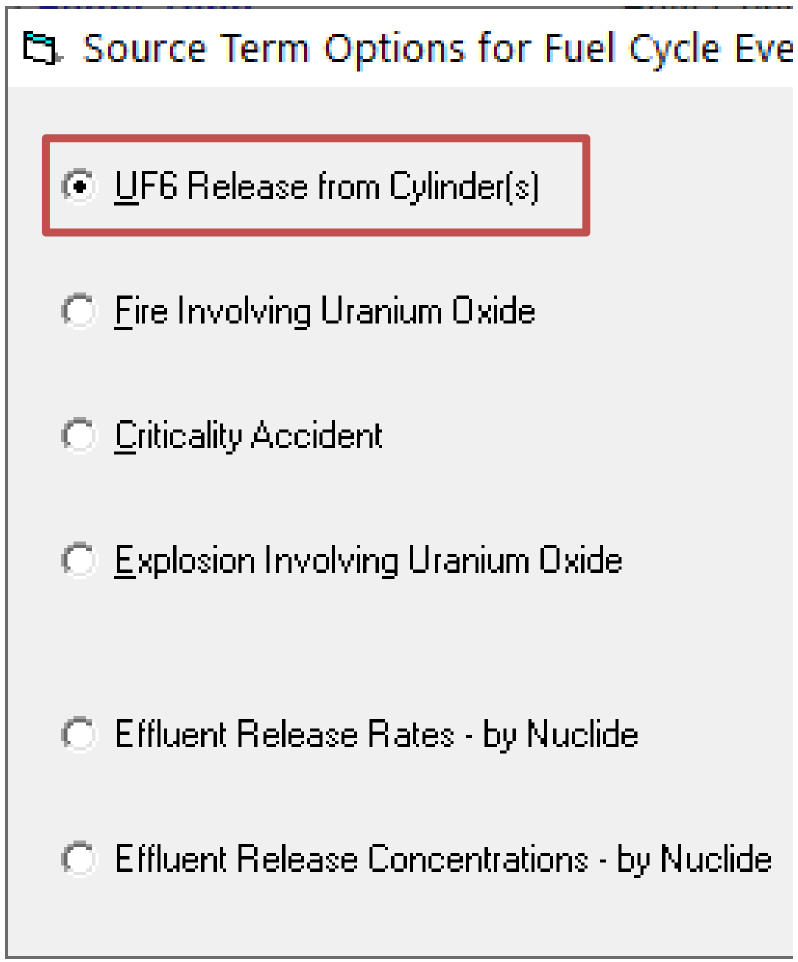
Fuel Cycle



- RASCAL can model certain events from fuel fabrication facilities
- For this section, we are only providing high-level model descriptions
  - If you want additional information on fuel cycle models, stay after class and we can discuss

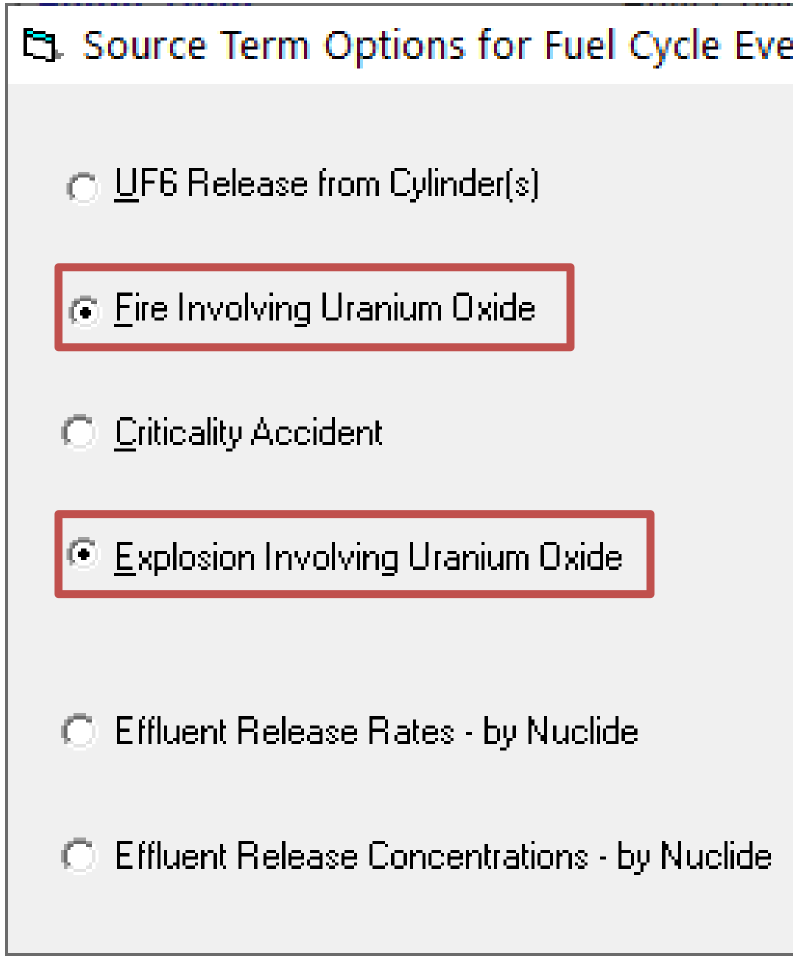
This source term screen can be seen when you:
- Select Event Type, set to Fuel Cycle
- Select Event Location, select any location
- Select Source Term

Fuel Cycle → UF6 Release from Cylinder



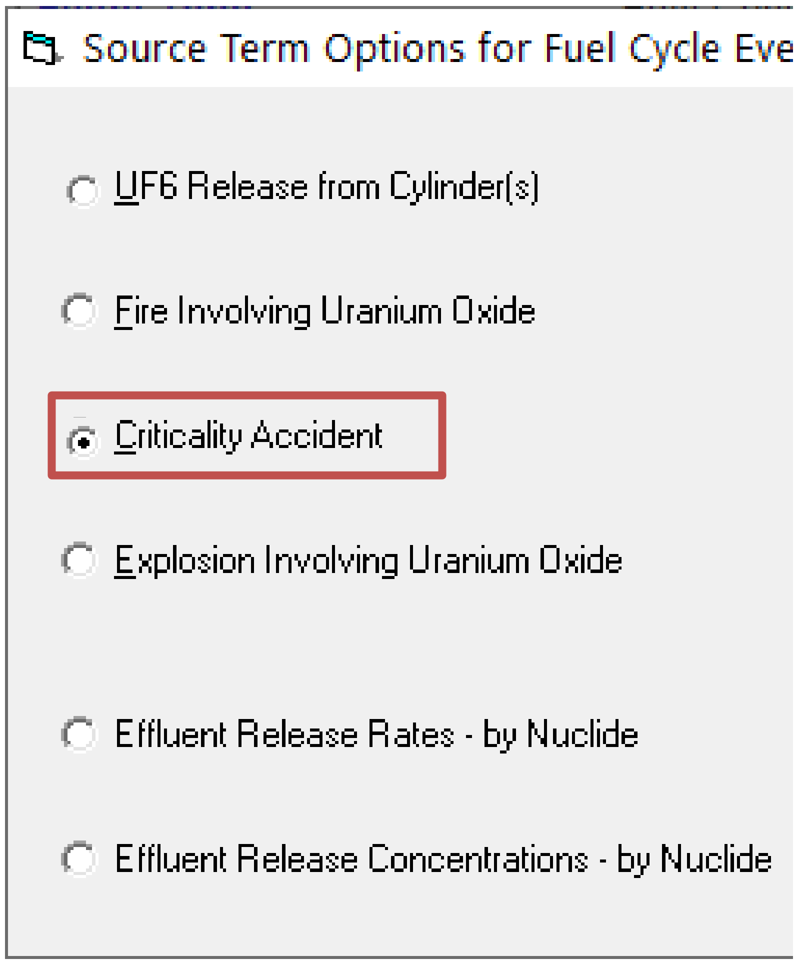
- Gaseous UF6 released
- Special plume model with chemical conversion process
- More chemically dangerous than radiological

FUEL CYCLE → FIRE OR EXPLOSION INVOLVING URANIUM OXIDE



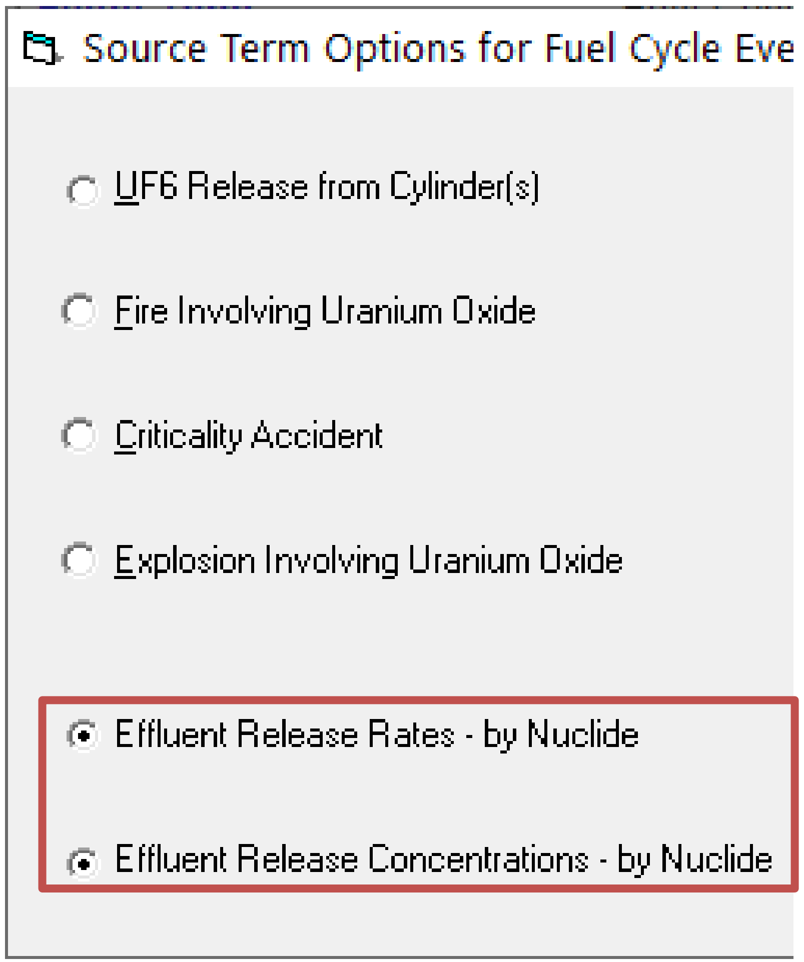
- Small amounts of material put into atmosphere from event
- User inputs material at risk and release fractions / rates

Fuel Cycle → Criticality



- Mainly focused on direct shine from criticality event
  - Very small amount of activated material put into atmosphere

Fuel Cycle → Effluent Release Rates/Concentration

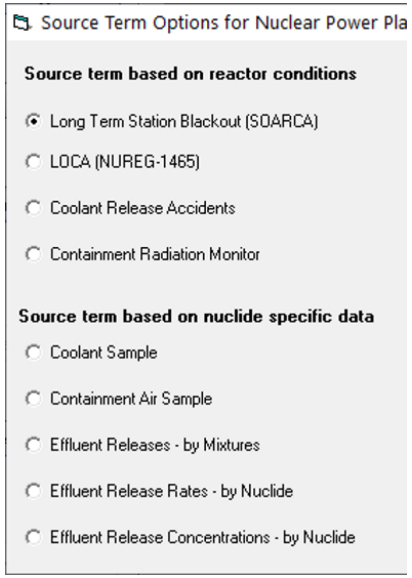


- Identical to model we showed in NPP source terms

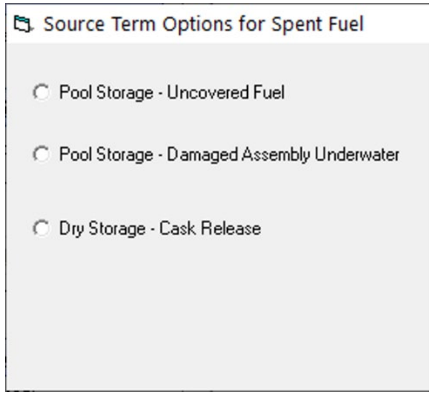
Source Terms

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

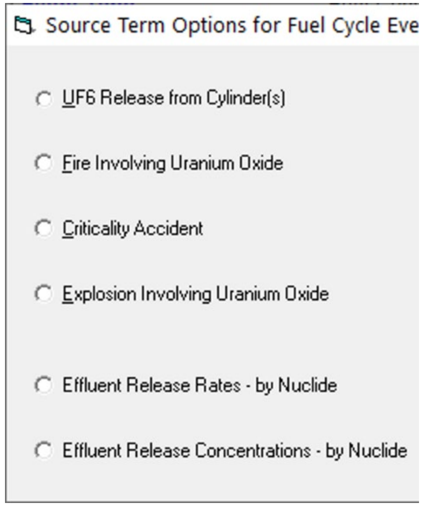
Nuclear Power Plant



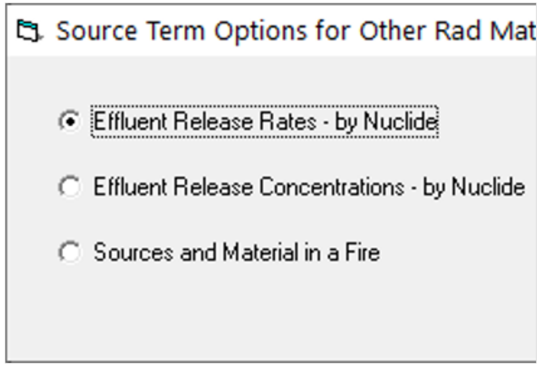
Spent Fuel



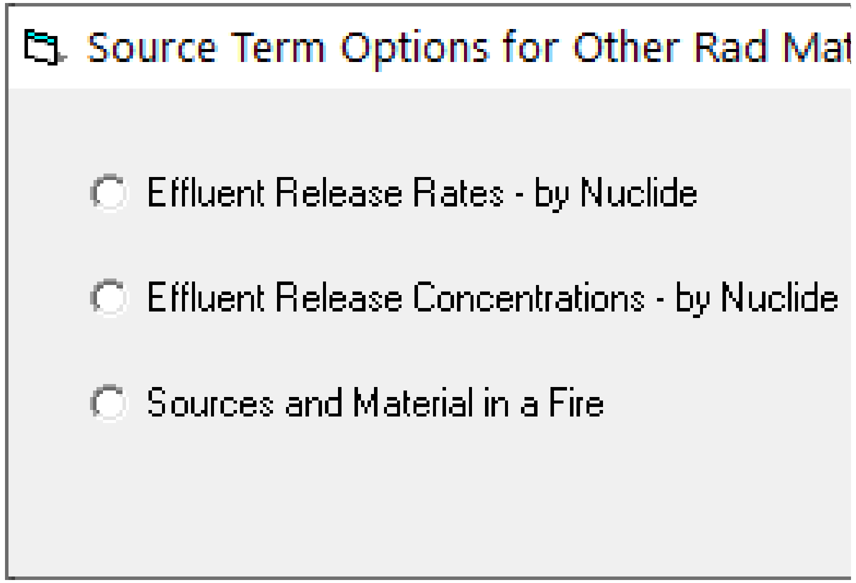
Fuel Cycle



Other Materials



OTHER MATERIALS

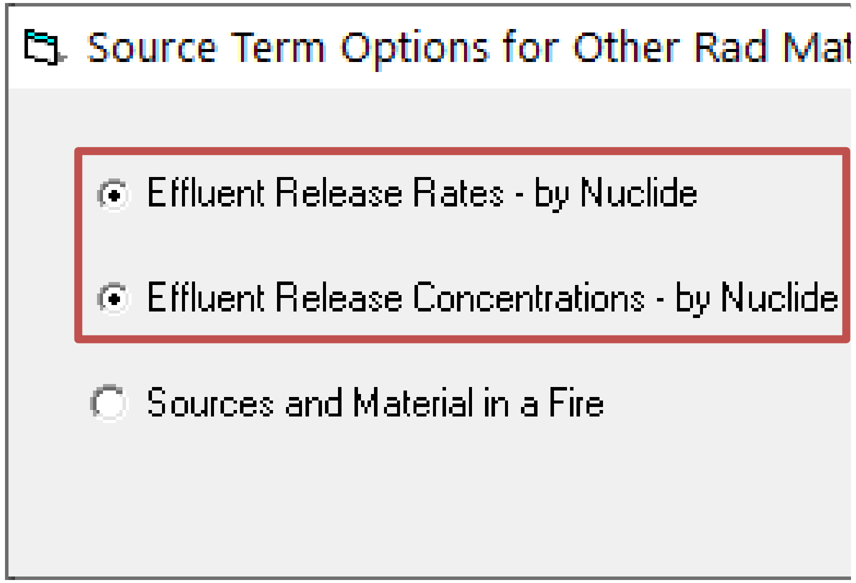


- RASCAL also has 3 “other” materials options
- Useful for modeling transportation accidents, lab accidents, etc.
- All models still focus on atmospheric releases
  - Liquid releases (like spills and leaks) are not modeled in RASCAL

This source term screen can be seen when you:

- Select Event Type, set to Other Radioactive Materials
- Select Event Location, select or define any location
- Select Source Term

OTHER MATERIALS → EFFLUENT RELEASE RATES/CONCENTRATION



- Identical to model we showed in NPP source terms

Your Turn to Use RASCAL

- **Given the scenario excerpt below, run the entire case in RASCAL.**

Event Type: Other Rad Matl

Location: Advanced Medical Systems

Source Term: Effluent Releases Rates – by Nuclide

I-131 release from a building, estimated 10 Ci/min for 45 min

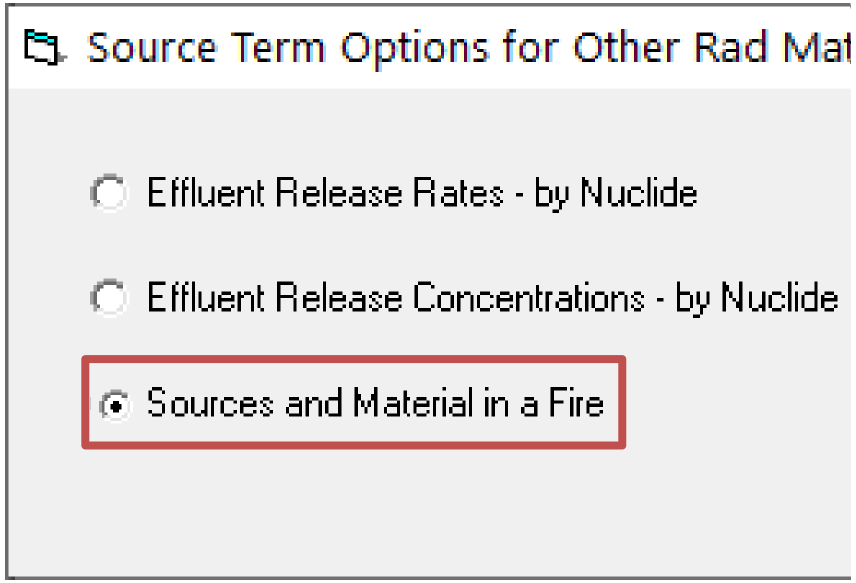
Release Path: see above

Weather: Predefined -> Standard Met

Settings: ICRP 26/30

Let's walk through the problem together

OTHER MATERIALS → SOURCES AND MATERIAL IN A FIRE

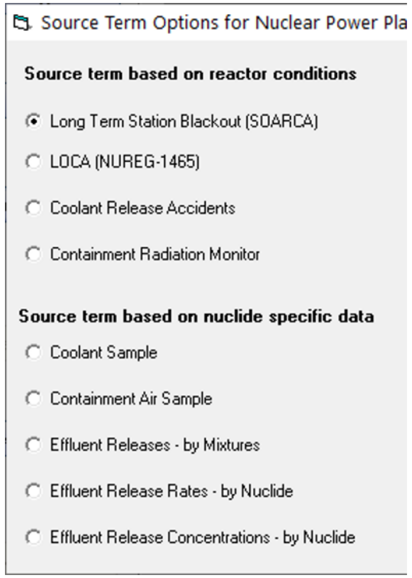


- Similar to effluent rates/concentrations, but you also need to input a release fraction
- Release fraction guidance provided, but depends on material type (e.g., metal or volatile liquid)

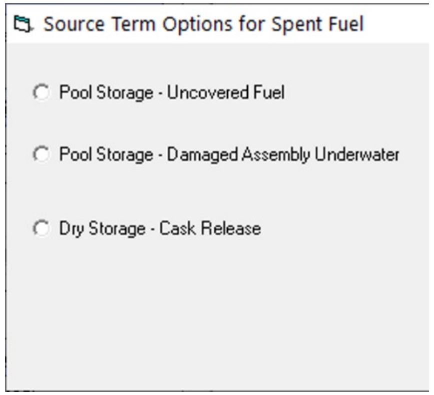
Source Terms

- Source term models calculate material that can be released
- Pick the best model; may have multiple options
- Available choices depend on Event Type

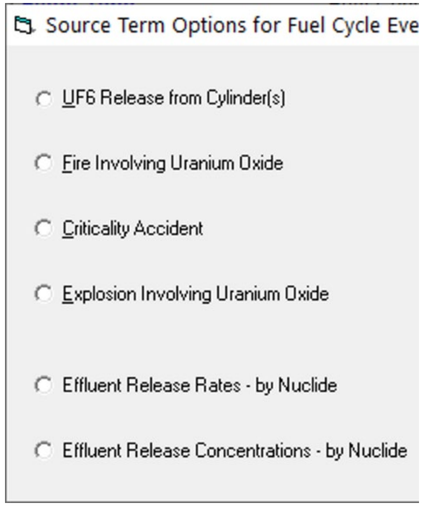
Nuclear Power Plant



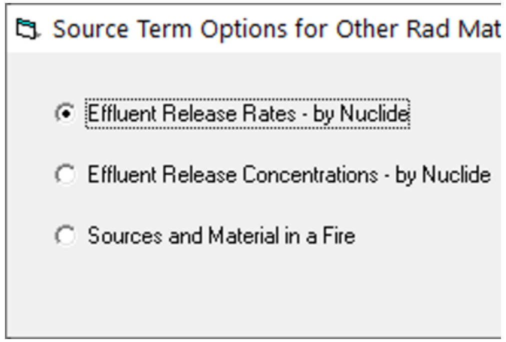
Spent Fuel



Fuel Cycle



Other Materials



Release Path

Inventory x Release Fractions x **Reductions** x Leakage or Flow = Atmospheric Source Term

While our previous source term inputs define material that can be released, the release path determines what material enters the atmosphere

Reductions, release rates, leakage timing, etc.

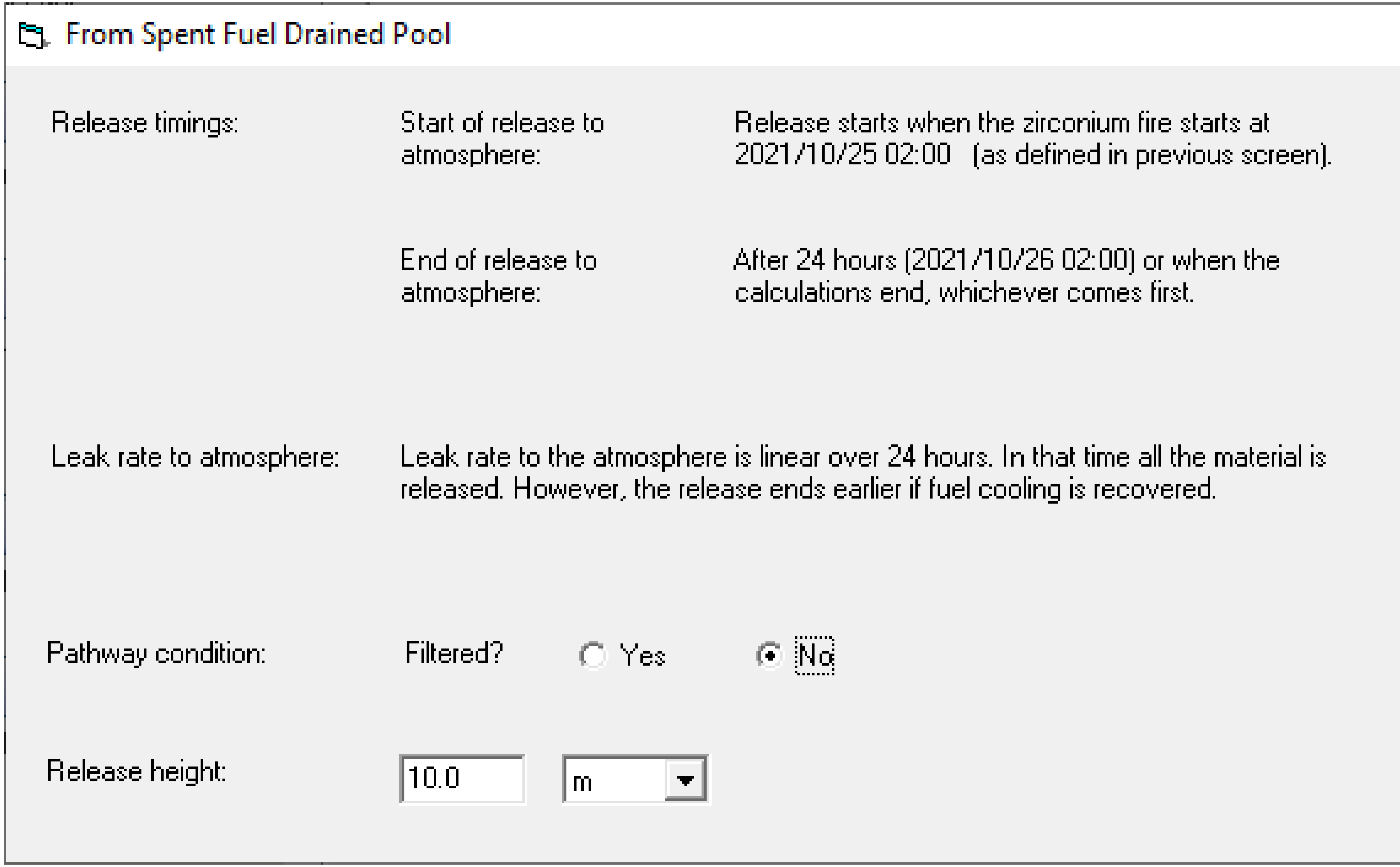
Reduction Mechanism	Reduction Factor for Noble gases	Reduction Factors for Others
Filters	1	0.01
Subcooled suppression pool	1	0.01
Saturated suppression pool	1	0.05
Sprays (exponential time dependence)	1	time factor <0.25 h e^{-12t} ≥0.25 h $e^{-0.2t}$
Containment hold-up (exponential time dependence)	1	time factor <2 h $e^{-1.2t}$ ≥2 h $e^{-0.15t}$
Plate out (containment bypass only)	1	0.4
Ice condenser—no fans or recirculation	1	0.5
Ice condenser - 1 h or more recirculation	1	0.25
Steam generator tube rupture—to secondary	1	0.02
Steam generator tube rupture—not partitioned or solid	1	0.5
Steam generator tube rupture—steam jet air ejector release	1	0.05

Now We'll look at Release Pathway

- **Pathway information is combined by the model with the source term details entered earlier to generate the atmospheric source term**
- **RASCAL will only show pathways applicable to the defined source term type**
- **For example**
  - **Effluent release rates source terms are direct to atmosphere – no options to choose from**
  - **LOCA source terms can release through containment leakage, steam generator, or containment bypass**

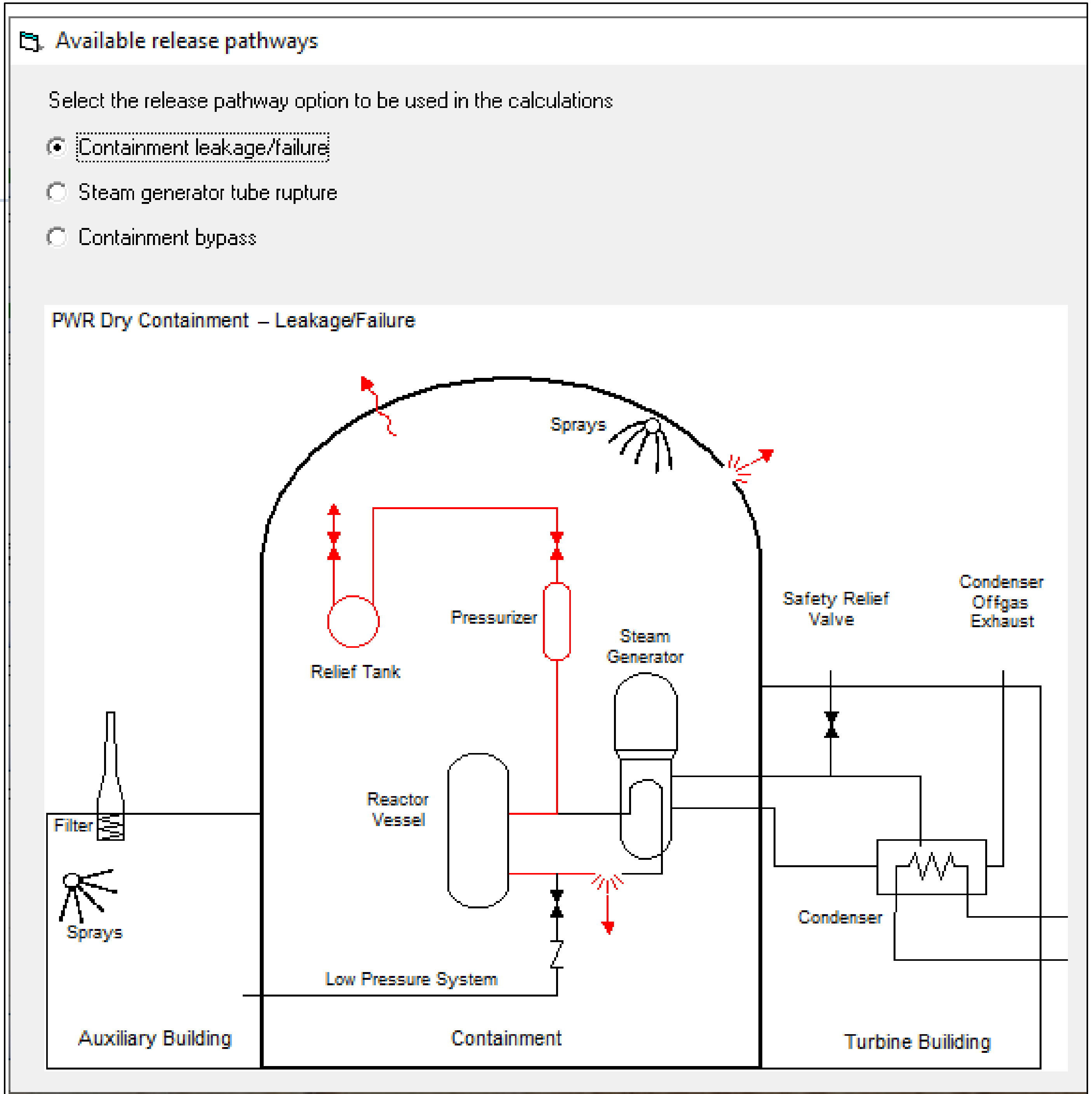
RELEASE PATH EXAMPLES

Simple pathways



Release Path examples

PWR pathways



Release Path examples

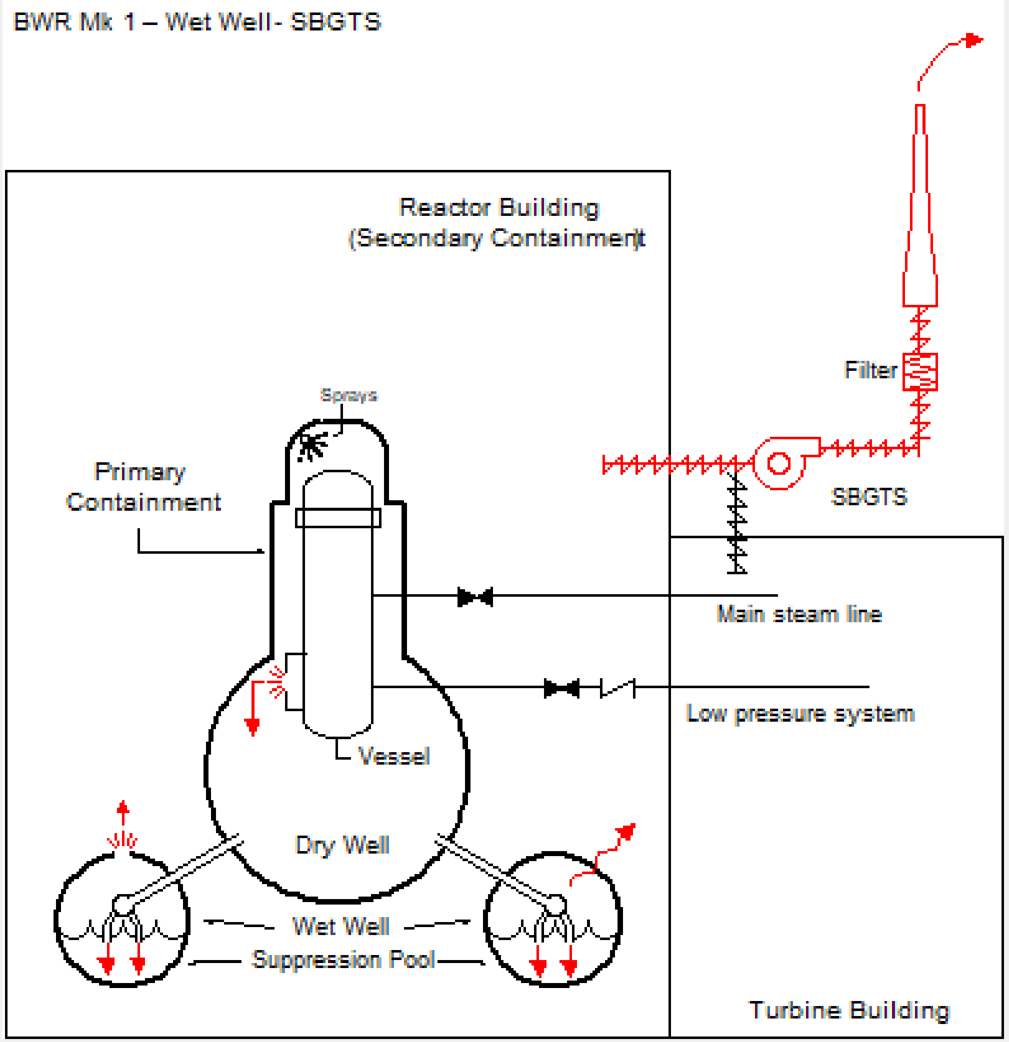
BWR pathways

Pathway from dry well to reactor building (secondary containment)

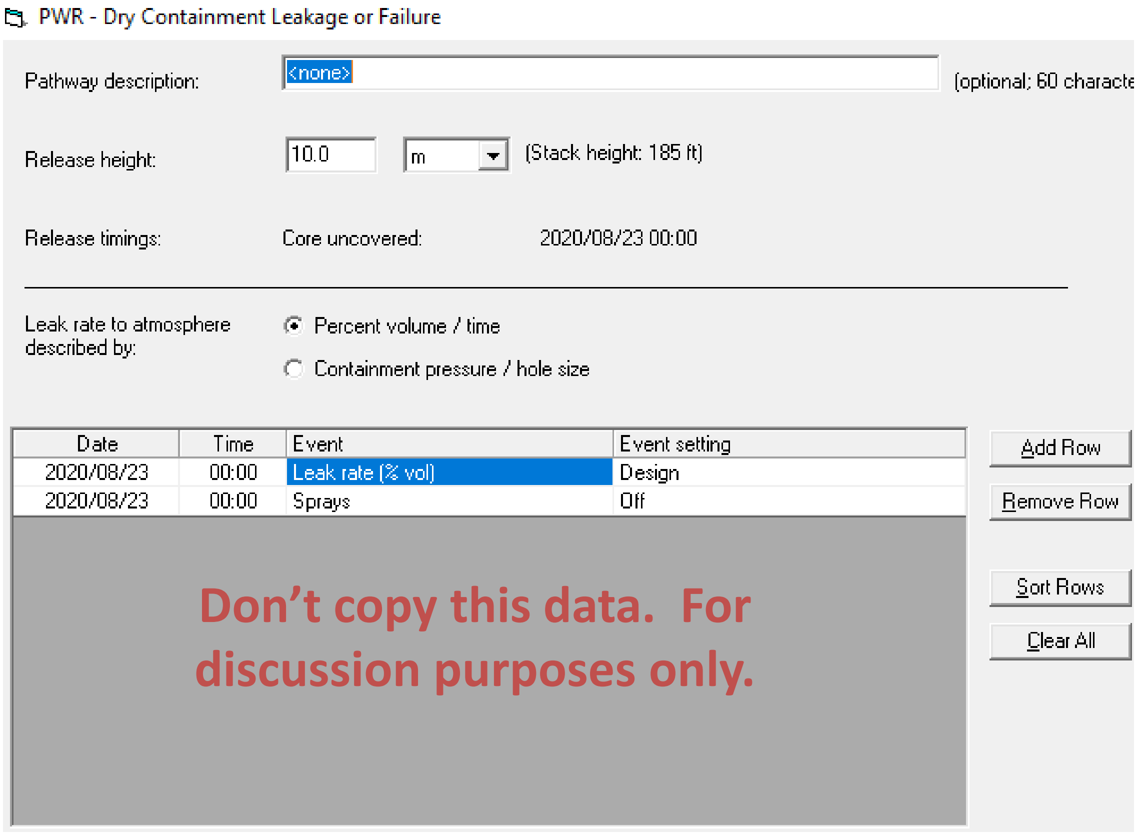
- (•) Through the suppression pool
- ( ) Through the dry well wall
- ( ) Bypass reactor building

Pathway to atmosphere

- (•) Via Standby Gas Treatment System (SBGTS)
- ( ) Direct from reactor building or other rapid, unfiltered release



NPP RELEASE PATHWAY SCREENS HAVE 3 MAIN SECTIONS

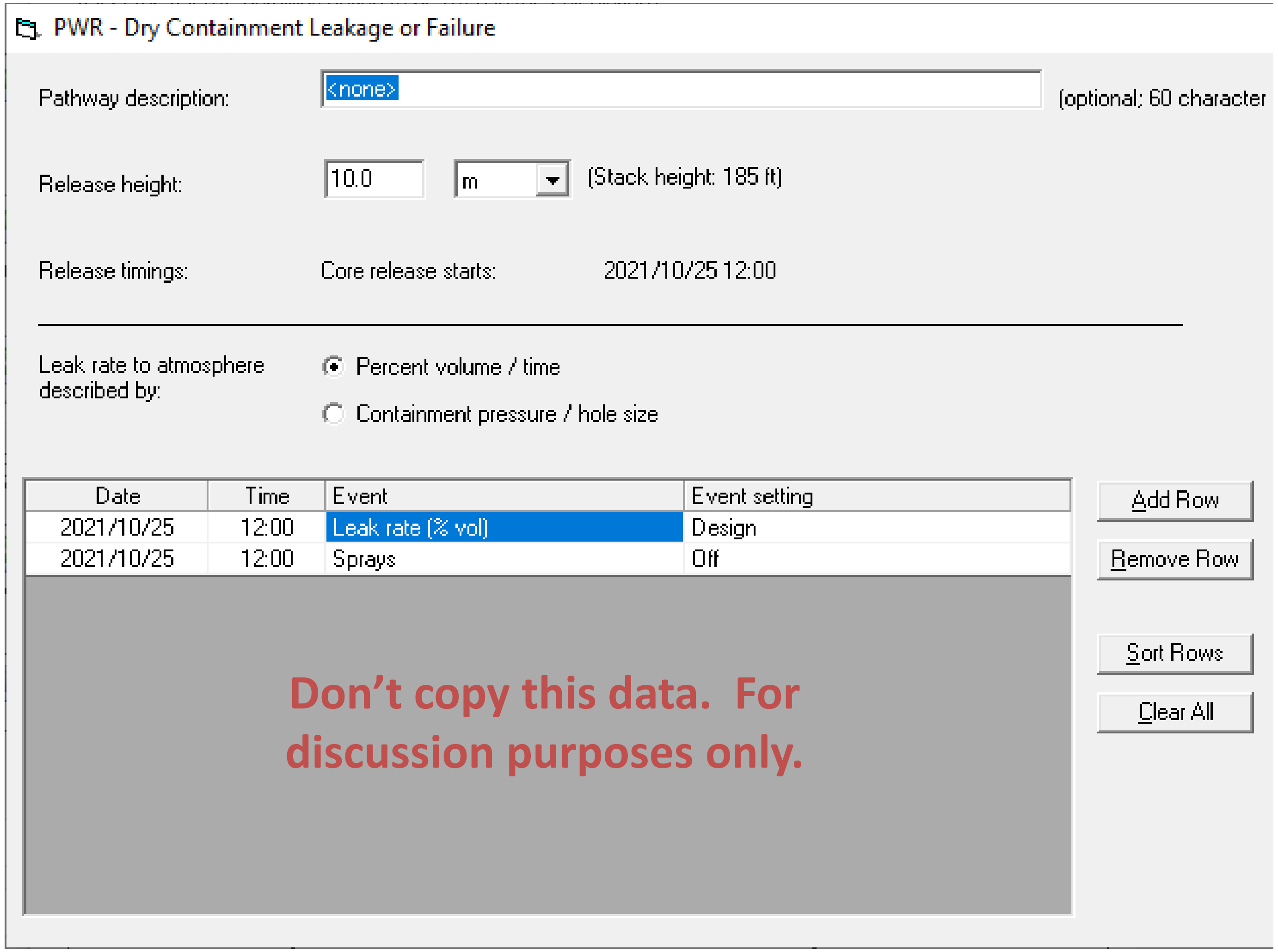


- Release height
- Leak rate type
  - Percent volume / time (e.g., 3%/hour)
  - Containment pressure / hole size (e.g., 30 psi/2 cm^2)
- Release timeline
  - Used for leak rate and additional conditions
  - Need to review/set initial conditions, then can add rows as needed

Release height

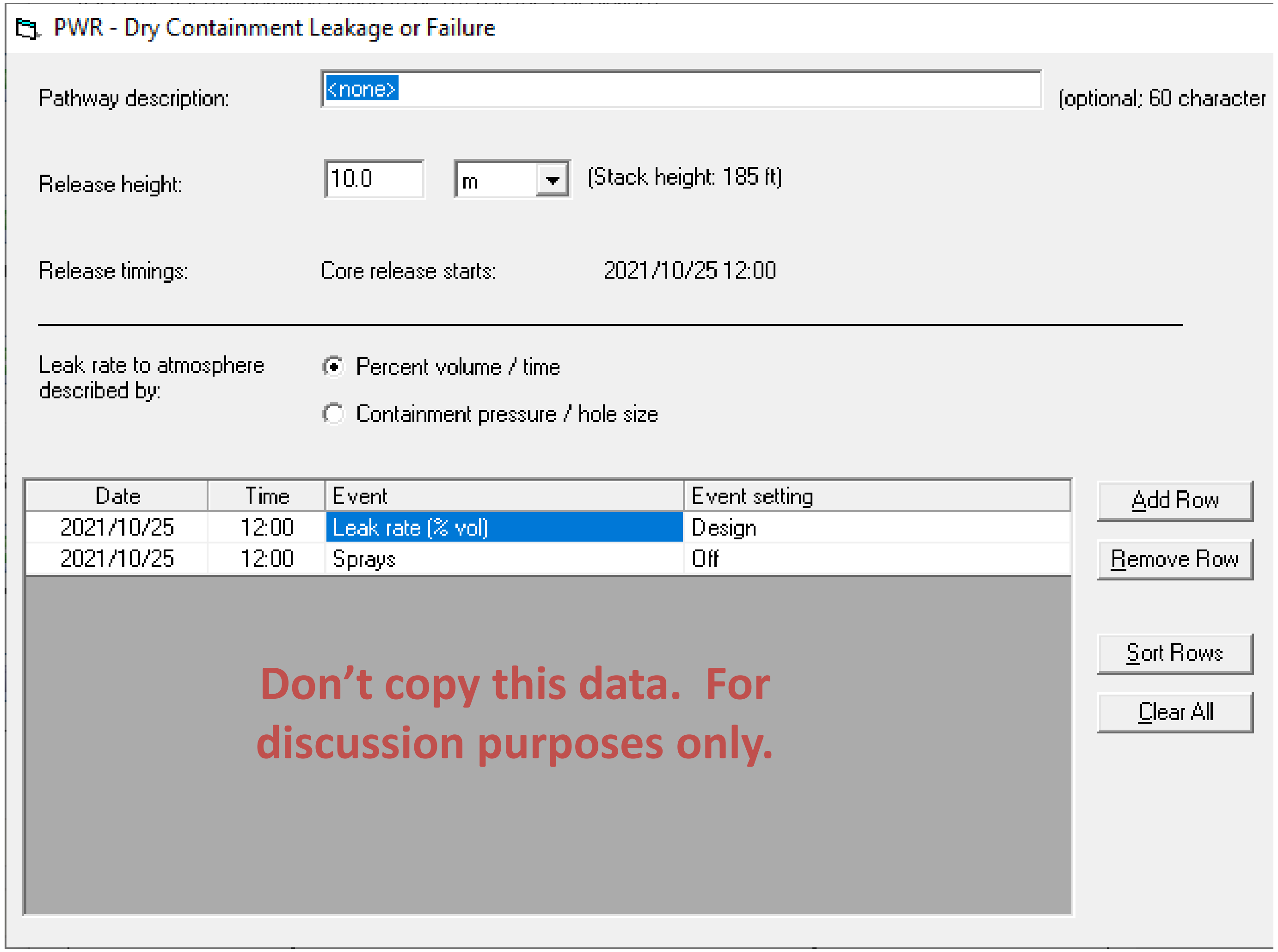
- **10 m minimum**
- **Model scales winds to the release height**
- **If there is a stack height in the facility database, the user interface echoes that value. However, if the release is via the stack you need to manually enter that number and set the units.**
- **Do your best to characterize the release height but in many cases it will be unknown.**
- **With elevated releases it takes some distance for the plume material to reach the ground. Thus, doses may be lower close to the release point and then increase with distance.**

Release Path – Leak rate type



- Percent volume / time (e.g., 3%/hour) or Containment pressure / hole size (e.g., 30 psi/2 cm^2)
- Design leak rate is the default initial value. Taken from FSAR.
- Either type gets some initial conditions set that support the release start

RELEASE PATH – EVENT TIMINGS



- The initial set will show all the options available for the release pathway type
- The initial conditions can be changed
- Additional conditions can be added at later time to define time varying conditions

All Source Term & Release Path inputs -> Atmospheric Source Term

NPP Fuel Melt Source Term

Activity (Ci) released to atmosphere (by nuclide and time step)

Interval	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	2016/02/02	20
Start	00:00	00:15	00:30	00:45	01:00	01:15	01:30	01:
Am-241	0.00E+00	0.00E+00	4.62E-10	1.46E-09	2.75E-09	4.17E-09	5.63E-09	:
Ba-139	0.00E+00	0.00E+00	5.62E+00	8.62E+00	9.99E+00	1.04E+01	1.02E+01	1
Ba-140	0.00E+00	0.00E+00	7.25E+00	1.26E+01	1.66E+01	1.95E+01	2.17E+01	3
Ce-141	0.00E+00	0.00E+00	1.67E-01	2.92E-01	3.83E-01	4.51E-01	5.01E-01	1
Ce-143	0.00E+00	0.00E+00	1.51E-01	2.61E-01	3.42E-01	4.01E-01	4.43E-01	1
Ce-144*	0.00E+00	0.00E+00	1.35E-01	2.35E-01	3.09E-01	3.64E-01	4.04E-01	1
Cm-242	0.00E+00	0.00E+00	1.71E-03	2.97E-03	3.91E-03	4.60E-03	5.11E-03	:
Cs-134	3.62E+00	6.30E+00	1.16E+01	1.56E+01	1.85E+01	2.07E+01	2.23E+01	2
Cs-136	1.48E+00	2.57E+00	4.73E+00	6.35E+00	7.53E+00	8.41E+00	9.09E+00	9
Cs-137*	2.50E+00	4.36E+00	8.05E+00	1.08E+01	1.28E+01	1.43E+01	1.54E+01	1
Cs-138	0.00E+00	1.73E+01	3.76E+01	5.65E+01	6.04E+01	5.41E+01	4.37E+01	3
I-131	2.65E+01	4.60E+01	1.05E+02	1.49E+02	1.81E+02	2.05E+02	2.23E+02	2
I-132	3.84E+01	6.49E+01	1.49E+02	2.07E+02	2.49E+02	2.81E+02	3.05E+02	2
I-133	5.37E+01	9.27E+01	2.11E+02	2.95E+02	3.57E+02	4.01E+02	4.32E+02	4
I-134	5.92E+01	8.46E+01	1.58E+02	1.85E+02	1.85E+02	1.72E+02	1.53E+02	1
I-135	5.13E+01	8.70E+01	1.94E+02	2.67E+02	3.18E+02	3.50E+02	3.71E+02	3
Kr-83m	4.08E+00	7.43E+00	3.14E+01	5.10E+01	6.69E+01	7.94E+01	8.91E+01	8
Kr-85	2.89E-01	5.78E-01	2.69E+00	4.81E+00	6.91E+00	9.00E+00	1.12E+01	1
Kr-85m	8.25E+00	1.58E+01	7.11E+01	1.22E+02	1.69E+02	2.12E+02	2.52E+02	2

2 isotope – 1 hour release

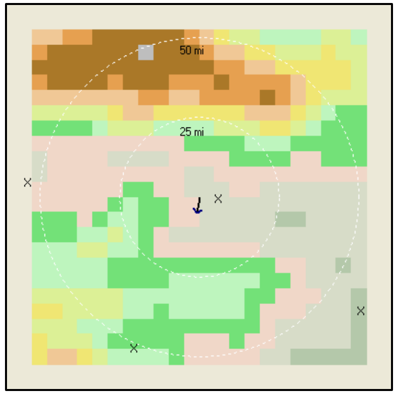
Activity (Ci) released to atmosphere (by nuclide and time step)

Interval	2023/05/08	2023/05/08	2023/05/08	2023/05/08	2023/05/08
Start	00:00	00:15	00:30	00:45	01:00
I-131	9.00E-01	9.00E-01	9.00E-01	9.00E-01	0.00E+00
Xe-133	1.80E+00	1.80E+00	1.80E+00	1.80E+00	0.00E+00

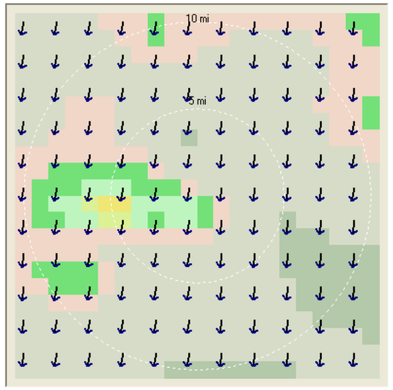
Generic Model Descriptions

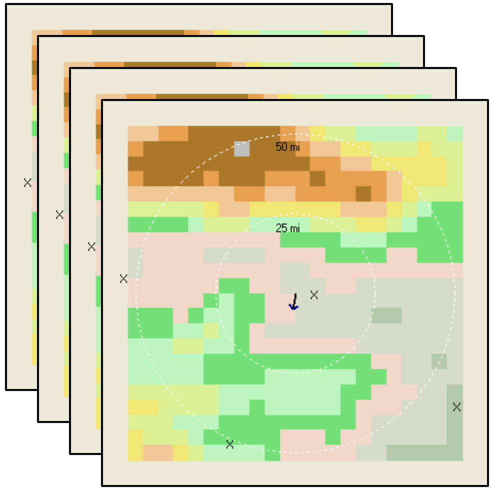
	INPUTS				OUTPUTS
Event Location Source Term Release Path	Inventory x Release Fractions x Reductions	→	SOURCE TERM MODELS	→	Atmospheric Source Term
Meteorology	Atmospheric Source Term & Weather	→	**ATD MODELS**	→	Concentrations & Depositions
Calculate Doses	Concentrations Deposition & Dose Coefficients	→	DOSE MODELS	→	Dose Projections

The meteorological data you enter for specific locations and times is processed to create a time series of gridded wind fields.

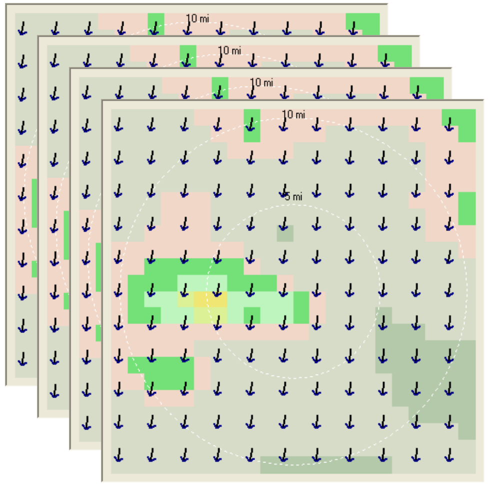


Points to gridded field

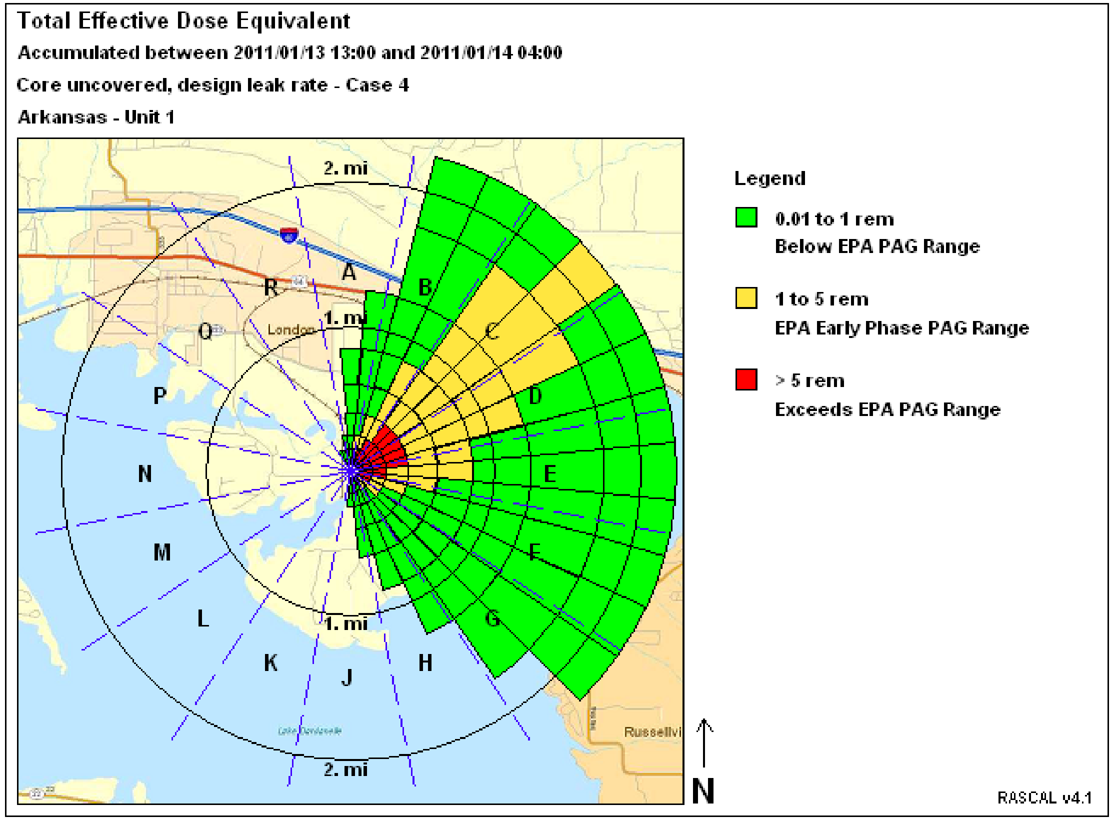




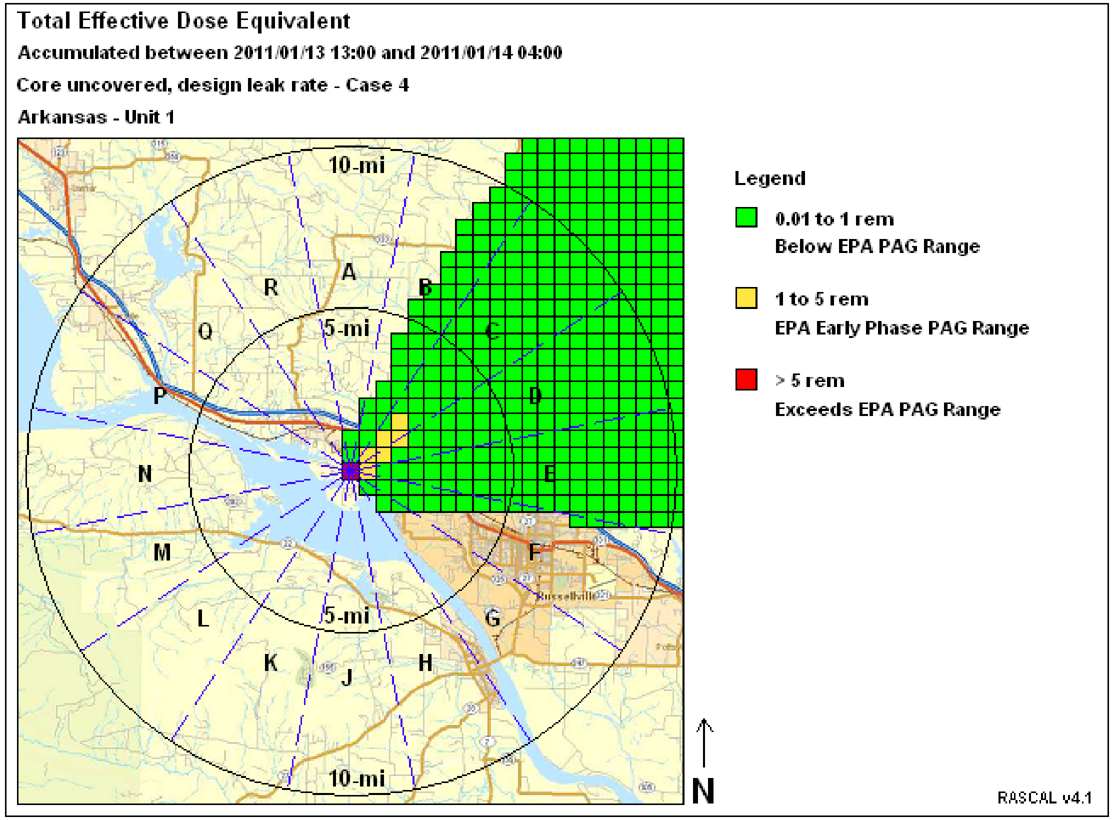
Times to 15 min steps



TWO TRANSPORT, DIFFUSION, DOSE MODELS ARE USED IN THE STDOSE CALCULATIONS



Plume Model

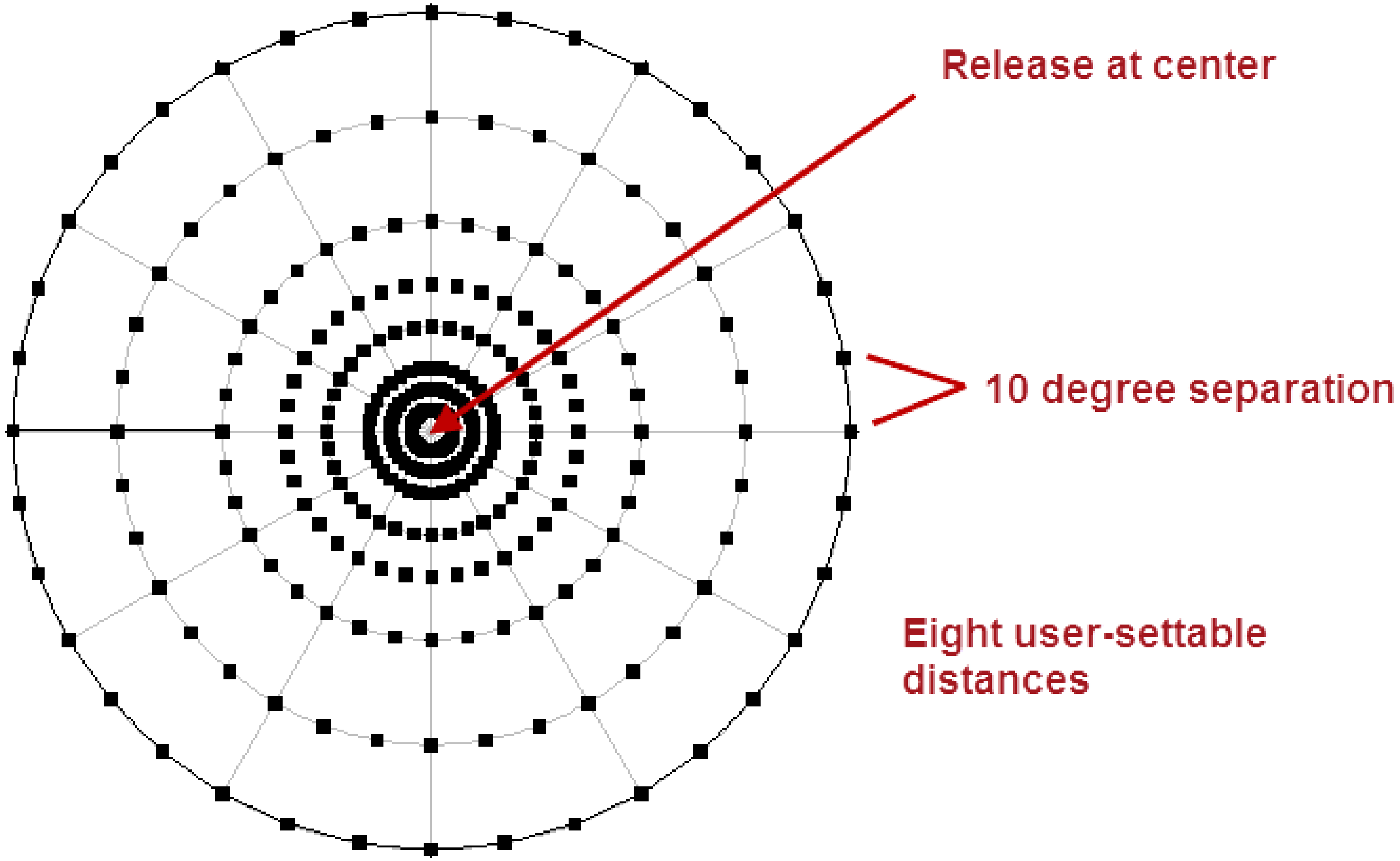


Puff Model

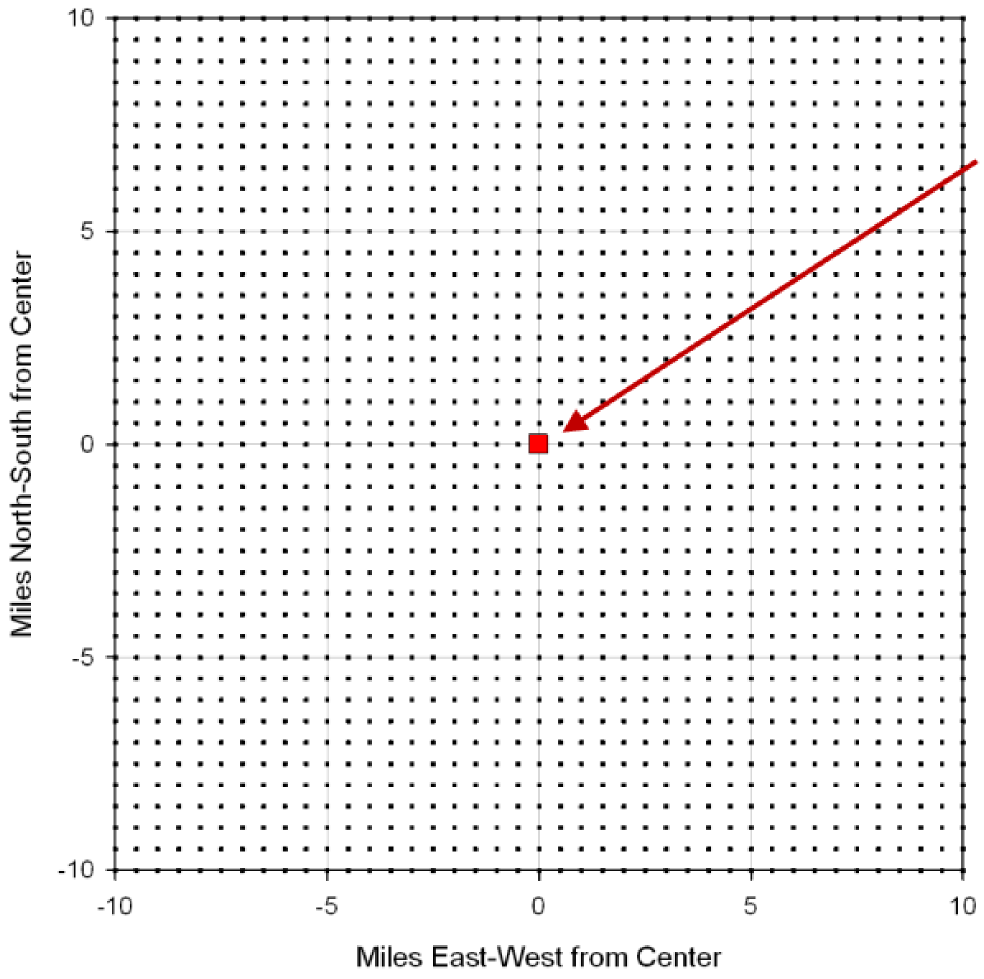
Plume vs Puff model comparison

	Plume	Puff
What it is called in the UI	Close-in (~20% of puff)	To 10, 25, 50, 100-miles
Grid shape	Polar every 10 degrees With 8 concentric rings	Cartesian 41x41 with fixed distances
Always has a centerline	Yes, code rounds as needed to nearest 10 degrees	No
Wind data accounts for topography	No	Yes
Decay and ingrowth	Yes	Yes
Dry and wet deposition	Yes	Yes
Accounts for transit time	No (except when calm)	Yes
Useful to compare dose rates	No (steady state model)	Yes

A STRAIGHT-LINE GAUSSIAN PLUME MODEL ON A POLAR GRID IS USED TO MODEL DISTANCES CLOSE TO THE RELEASE POINT



A PUFF MODEL ON A CARTESIAN GRID IS USED TO MODEL AT LONGER DISTANCES

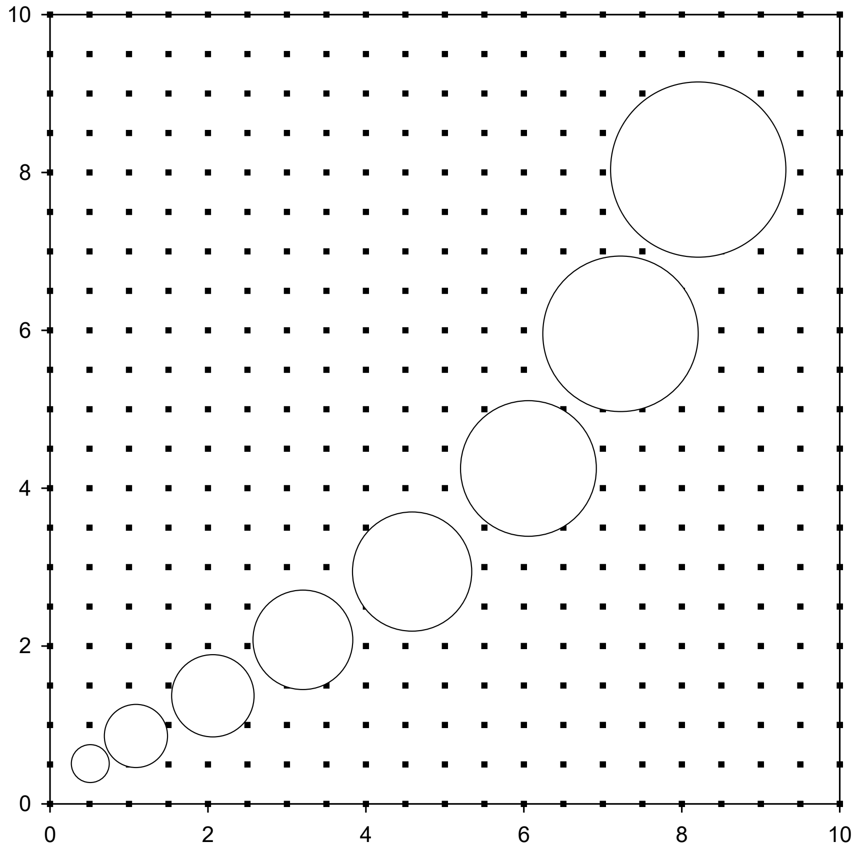


Release at center

41x41 grid of evenly spaced points

Spacing between grid points set by user selected calculation distance

A SEQUENCE OF DISCRETE PUFFS IS USED TO MODEL THE PLUME



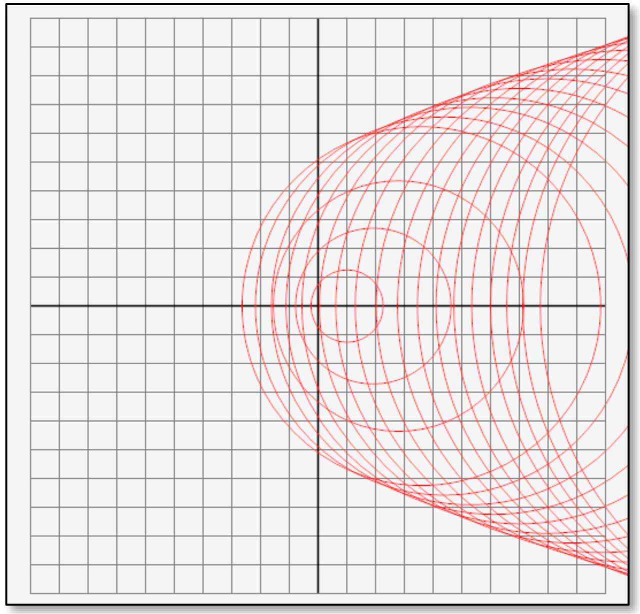
Puff centers move with the wind.

Puffs grow larger as time passes.

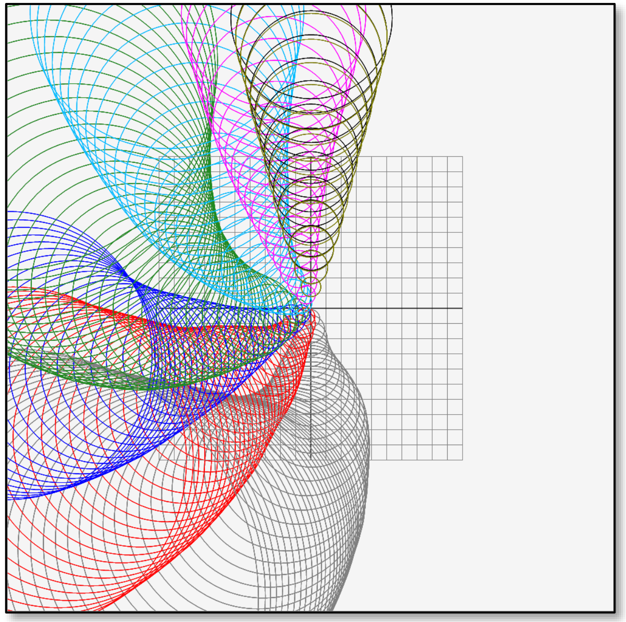
Each puff represents 5 minutes of release. That is, 12 puffs would be released each hour of the release.

VISUALIZING PUFF MOVEMENT AND GROWTH

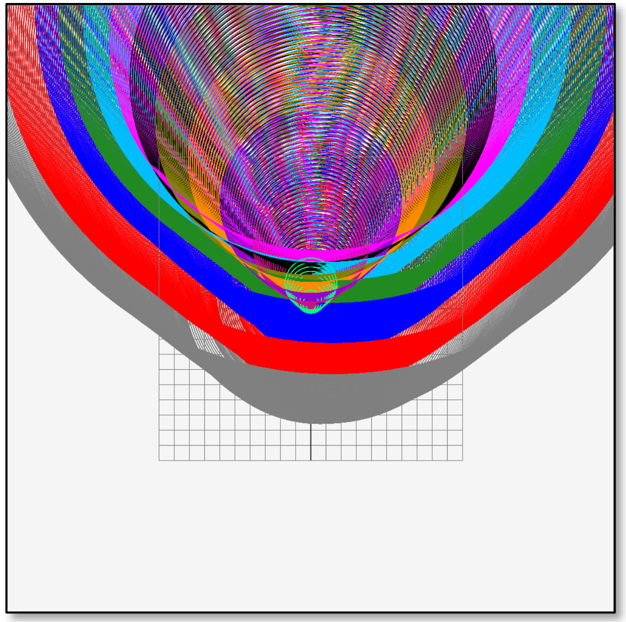
Single Puff,
Simple Winds



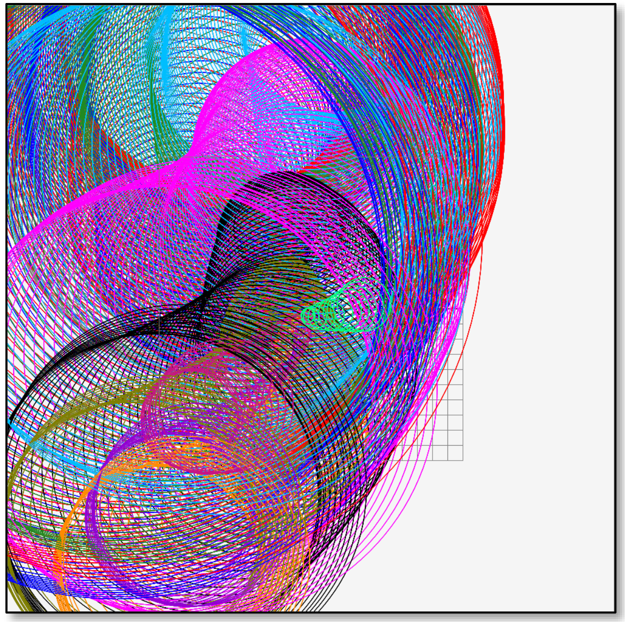
Multiple puffs,
varying winds



Multiple Puffs,
Calm Winds

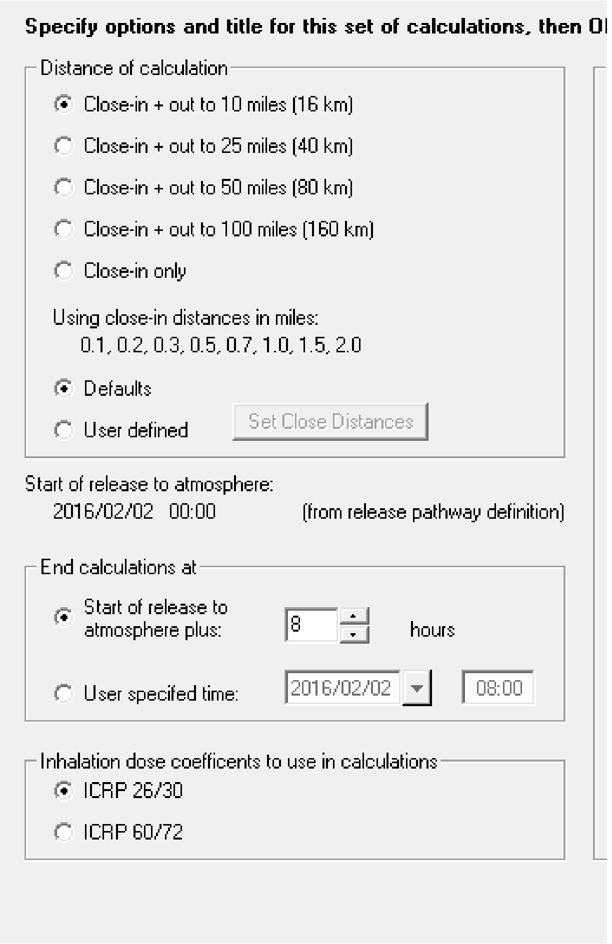


Multiple Puffs,
Actual Weather



[Puff Visualization Videos]

Atmospheric Models also need a few additional parameters



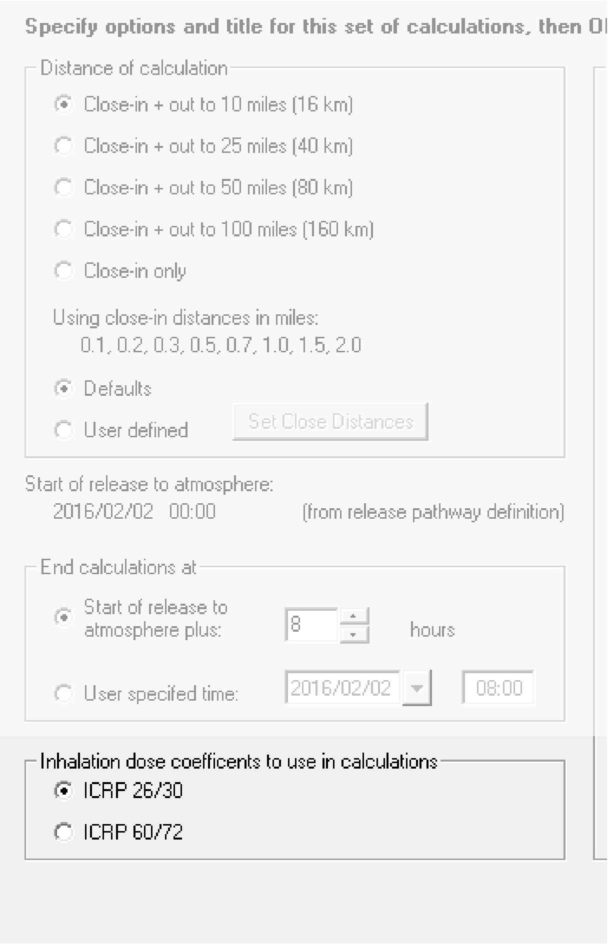
In the Calculation Settings:

- Calculation Distance
  - Start with shorter distances; they provide higher resolution
- Calculation Duration
  - Must be long enough to account for plume travel time

GENERIC MODEL DESCRIPTIONS

INPUTS		OUTPUTS
Event Location; Source Term; Release Path — Inventory x Release Fractions x Reductions →	SOURCE TERM MODELS	→ Atmospheric Source Term
Meteorology — Atmospheric Source Term & Weather →	ATD MODELS	→ Concentrations & Depositions
Calculate Doses — Concentrations Deposition & Dose Coefficients →	**DOSE MODELS**	→ Dose Projections

Dose Models only take 1 user input



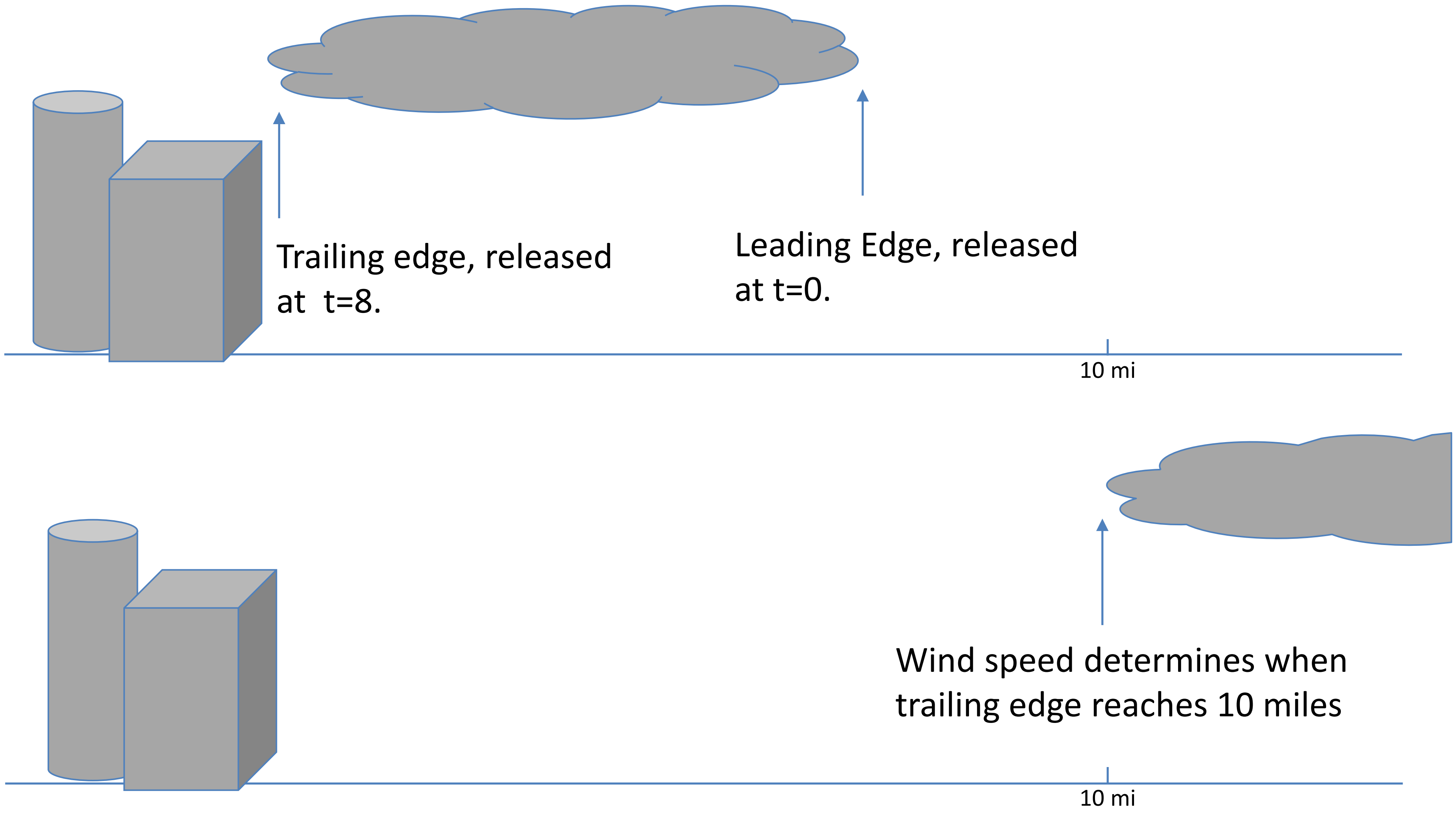
In the Calculation Settings there are options for the dose coefficients to be used by dose models:

ICRP 23/30 or IRCP 60/72

Dose model details

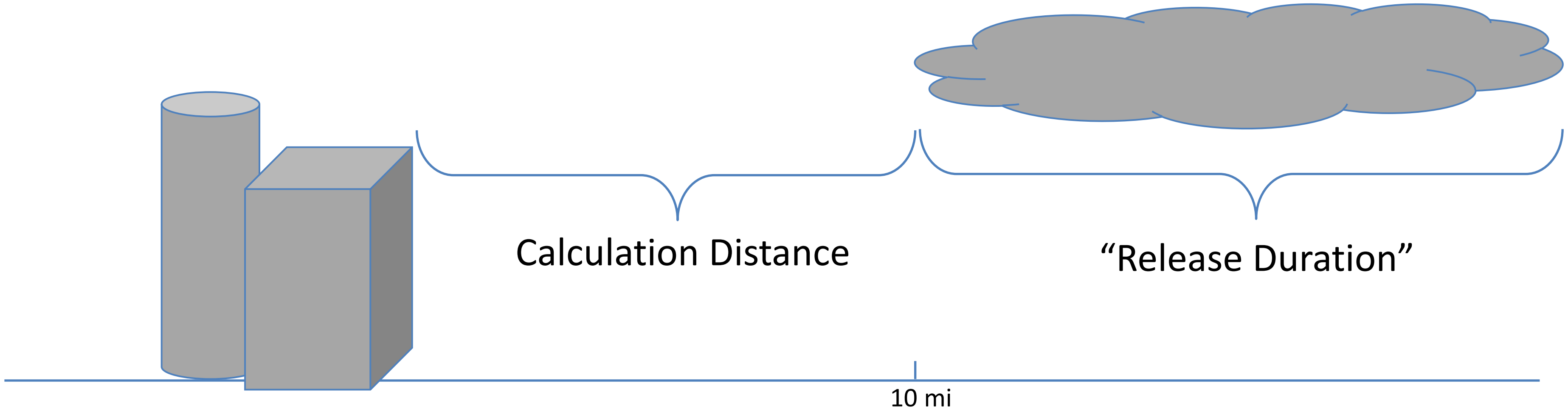
- Based on ICRP methods
  - TEDE = cloudshine + inhalation + 4-day groundshine
  - Reference man standing outside unshielded for 4 days
  - Remainder of RASCAL calc duration counts out to 4 days
    - No difference in results if plume has already passed
- PAG assumptions
  - Avoidable dose
- Intermediate phase based on projected ground deposition
  - If you have field measurement data, use that instead
- RASCAL does not account for background

SET CALCULATION DURATION TO ALLOW FOR TRAILING PLUME EDGE TO REACH SET DISTANCE



THERE IS A RULE-OF-THUMB FOR ESTIMATING THE CALCULATION DURATION

$$Calculation\ Duration \geq \left(Release\ Duration + \frac{Calculation\ Distance}{Wind\ Speed}\right) \times 1.1$$

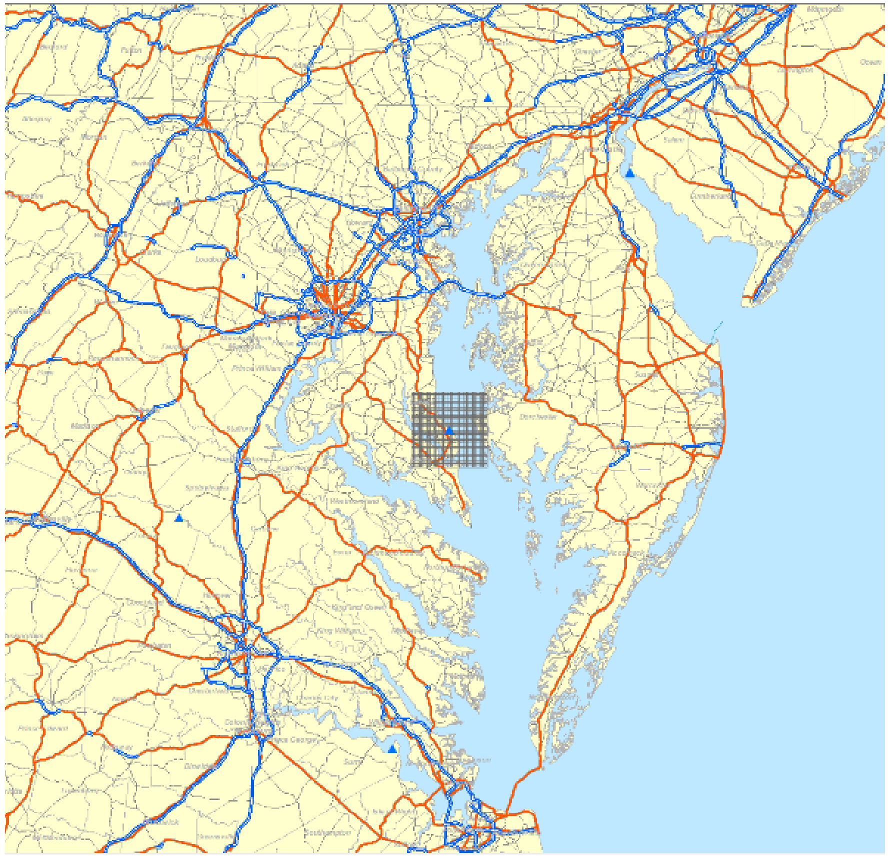


For a 7.5 hour release with 2 mph winds, calculate a duration for a 10 mile grid.

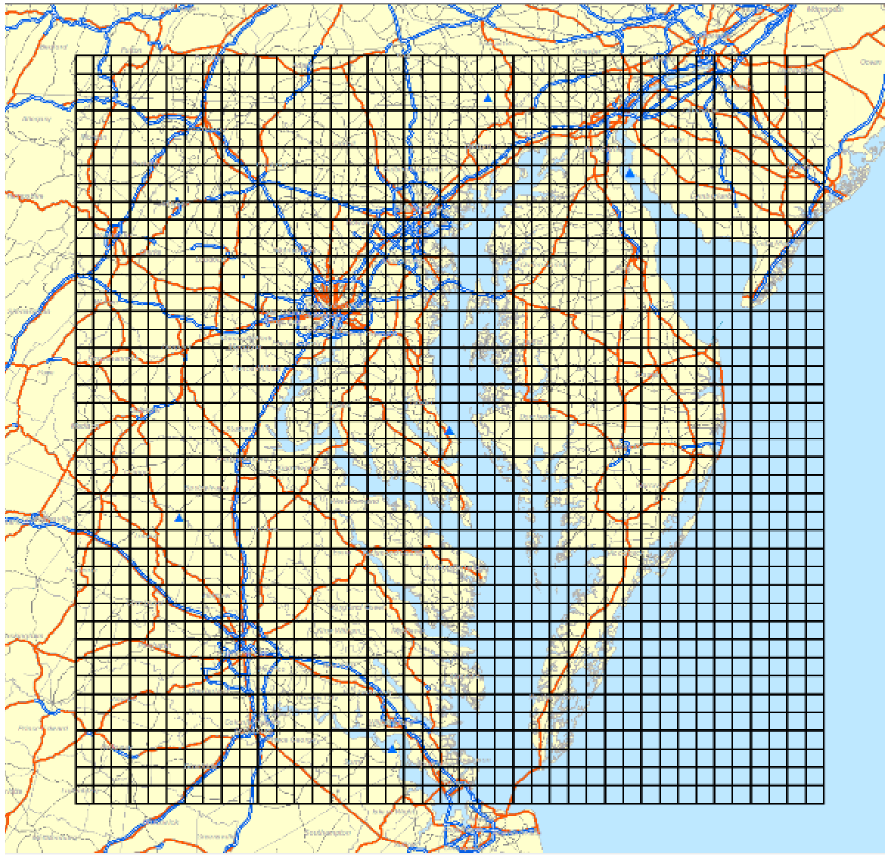
7.5 hours + (10 miles / 2 mph) = 12.5 hours

Add 10% to get 13.75, then round up to the nearest hour (14)

Review - Closer calc distances provide better resolution if you don't need to see further out



10 mile grid – cells are .5 mile wide



100 mile grid – cells are 5 miles wide

LET'S LOOK A BIT CLOSER AT ONE OF THESE CELLS

Could be up to 5 miles wide

Results calculated for cell center point

May not be exactly the value near the cell edge

Generic Model Descriptions

	INPUTS				OUTPUTS
Event Location Source Term Release Path	Inventory x Release Fractions x Reductions	→	**SOURCE TERM MODELS**	→	Atmospheric Source Term
Meteorology	Atmospheric Source Term & Weather	→	**ATD MODELS**	→	Concentrations & Depositions
Calculate Doses	Concentrations Deposition & Dose Coefficients	→	**DOSE MODELS**	→	Dose Projections

This concludes our Models Overview unit

Remember that resources & training can be found at:

https://ramp.nrc-gateway.gov/