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Development of a Biosphere Dose Model (BDOSE) for Waste Incidental-to-Reprocessing and Non-High-Level Waste Determination Consultations

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Presentation Outline

- Purpose/Background
- Model Development
- Receptors and Pathways
- Groundwater-Dependent Pathways
- Chronic Intruder Pathways
- Example Calculation
- Sample of BDOSE
- Conclusions and Remarks

Purpose/Background

- Ronald W. Reagan National Defense Authorization Act of 2005
  - Requires NRC to consult on non-high-level waste determinations prepared by the U.S. Department of Energy (DOE)
  - Dose-based performance objectives in 10 CFR Part 61, Subpart C
- NRC tasked CNWRA to develop a probabilistic dose model in GoldSim (registered trademark of GoldSim Technology Group LLC)
  - Used to independently evaluate DOE performance assessments
  - Waste form degradation and transport models exist that could be coupled with BDOSE
- Project scope
  - Estimate probabilistic dose to adult receptor given radionuclide concentrations in groundwater or underground storage area
  - Use existing models/codes to the extent practical
  - Validate models and justify input parameters

Model Development

- Source term
  - Identified key or highly radioactive radionuclides from Savannah River, West Valley, Hanford, and Idaho sites
- Methods
  - Consistent with common industrial practices
- Quality assurance
  - Adopted practices standard in the software development industry
    - Software requirements description
    - Software acceptance testing
    - Software validation testing

Receptors

- Resident farmer
  - Irrigates with contaminated groundwater
- Resident gardener
  - Subset of resident farmer
- Recreationist
  - Exposure via recreational type pathways: swimming, boating and hunting
- Acute intruder
  - Drills a well or excavates directly into waste and is exposed during drilling/exhuming process
- Chronic intruder
  - Follow on to acute intruder who farms on contaminated area where contaminated waste has been spread

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Pathways

Pathways	Resident Farmer	Resident Gardener	Recreationist	Acute Intruder	Chronic Intruder
Ingestion					
Ingestion of Drinking Water	X	X			X
Ingestion of Vegetables	X	X			X
Ingestion of Milk	X				X
Ingestion of Beef	X				X
Ingestion of Game	X		X		
Ingestion of Fish	X	X	X		X
Ingestion of Soil	X	X	X	X	X
Inhalation	X	X	X	X	X
External					
Surface	X	X	X	X	X
Submersion in Air	X	X	X	X	X
Submersion in Water			X		

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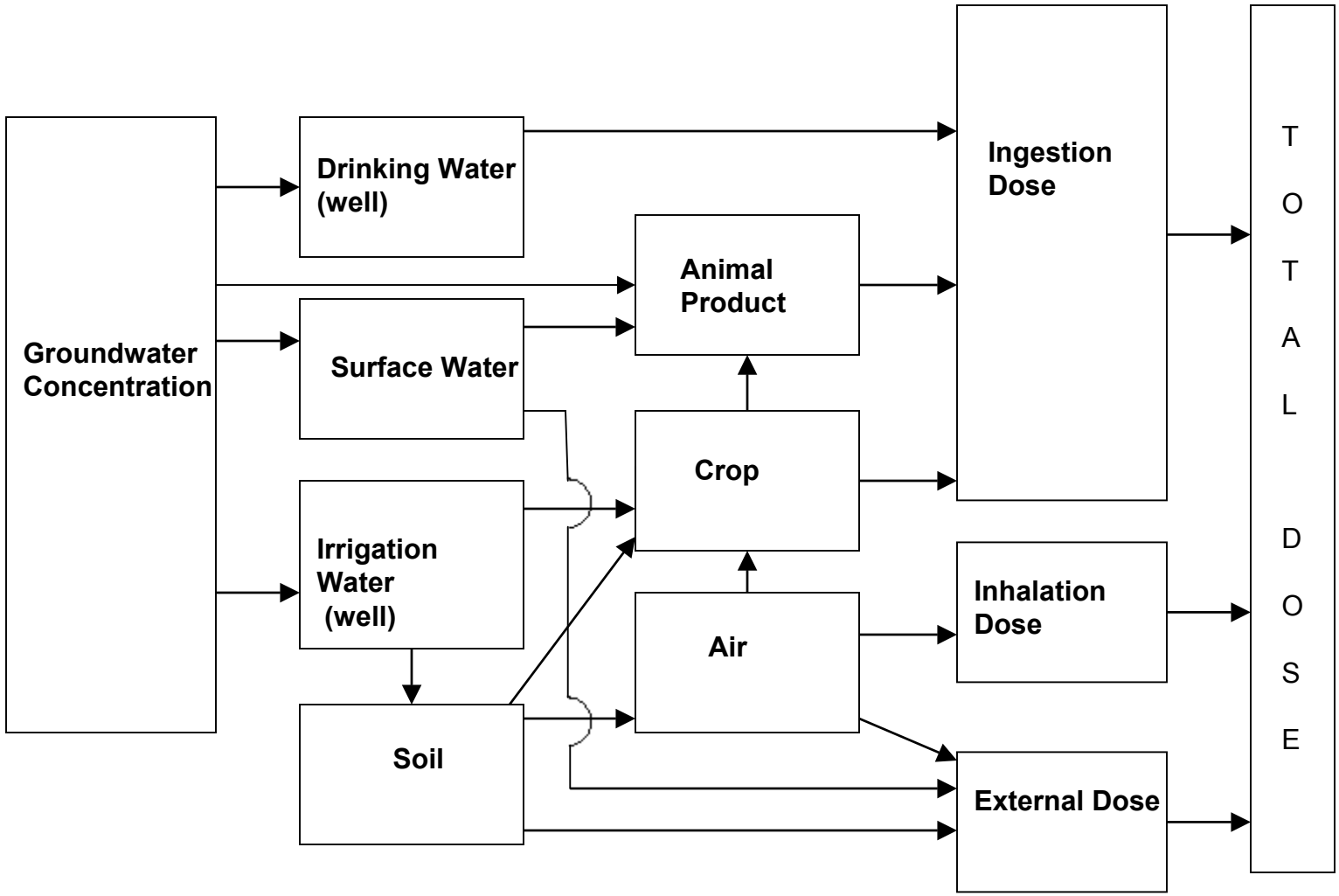
Groundwater-Dependent Pathways



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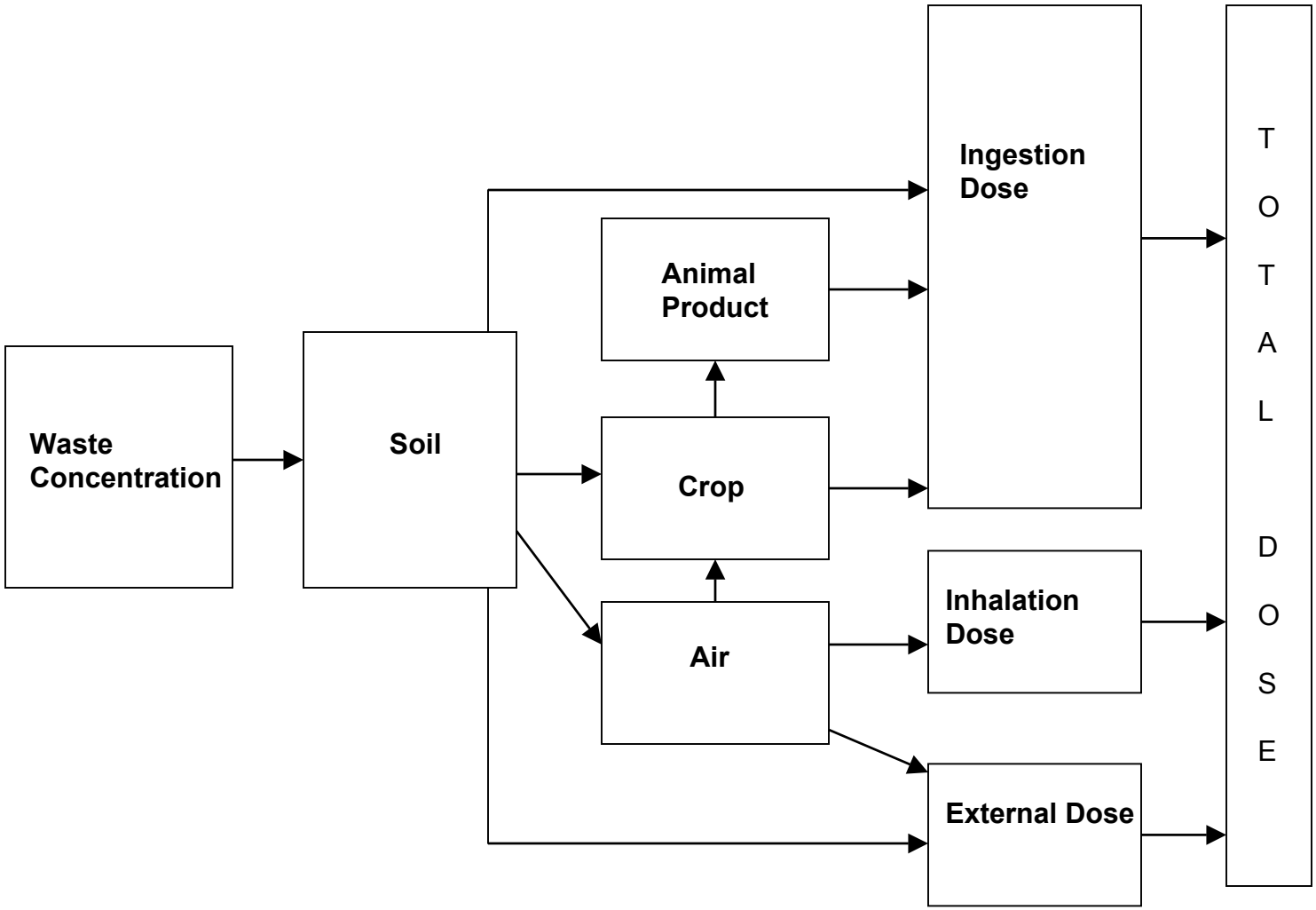
Chronic Intruder Pathways



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Example Calculation: Vegetable Ingestion Dose

Irrigation deposition rate = groundwater concentration × irrigation rate

Soil concentration = irrigation deposition rate × buildup over time

$$C_{soil,i}(t) = ID_i \left[\frac{1 - e^{-(\lambda_i + \lambda_{l,i} + \lambda_e)t}}{\lambda_i + \lambda_{l,i} + \lambda_e} \right]$$

- Leaching and erosion rates are computed values and assumed to be time invariant
- Several different soil models are available to enhance flexibility

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Example Calculation: Vegetable Ingestion Dose (continued)

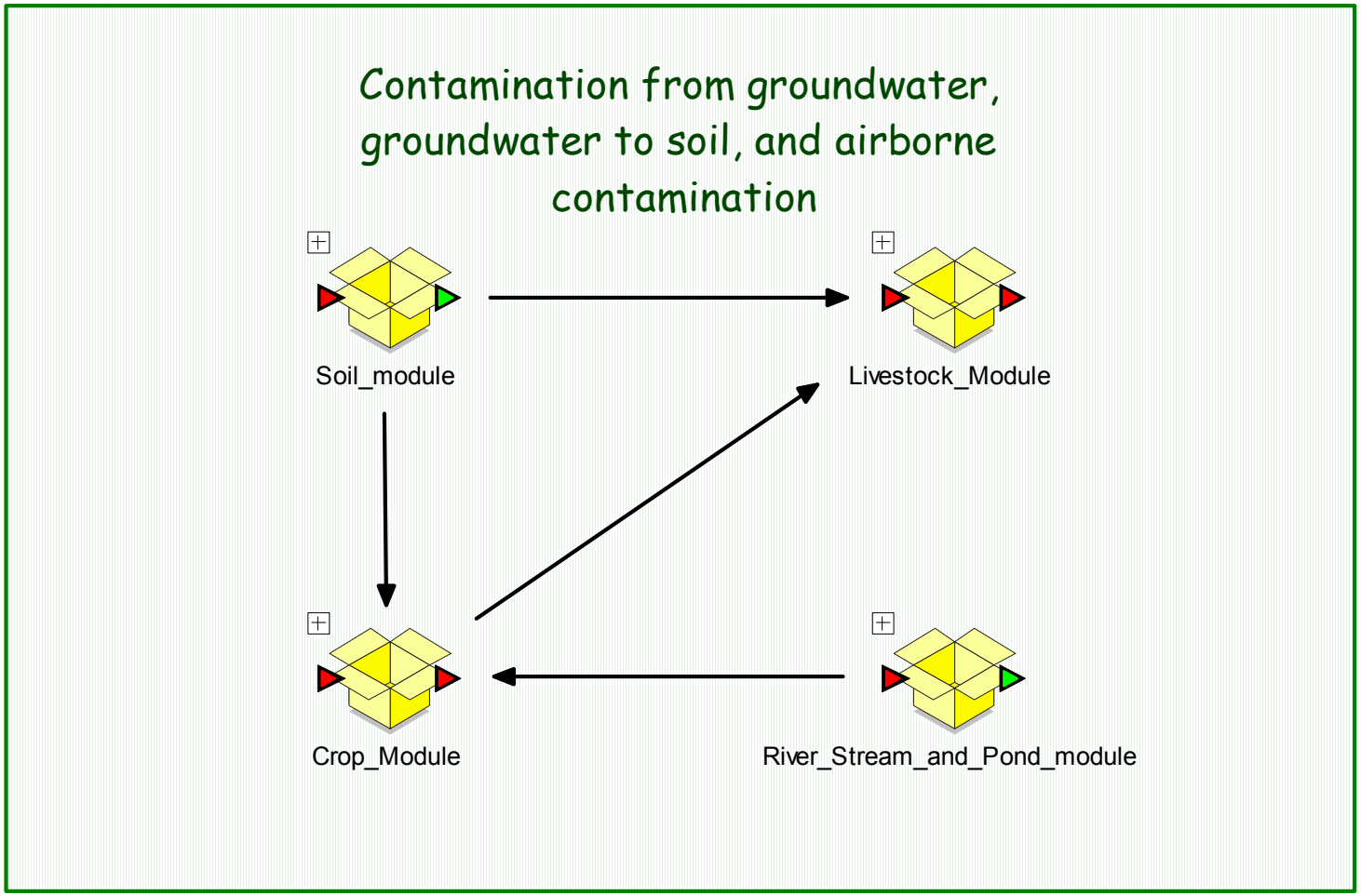
Concentration in vegetation = deposition on plant surface + root uptake

$$C_{p,i}(t) = [ID_i \frac{12}{M_p} r_{i,p} + C_{soil,i}(t) RF v_{d,i} r_{d,p} CF] \frac{TV_p}{B_p} \left[\frac{1 - e^{-(\lambda_w + \lambda_i) T_{g,p}}}{\lambda_w + \lambda_i} \right] + \frac{C_{soil,i}(t) f_{rz,p} BV_{p,i} f_p}{P}$$

Ingestion dose = concentration in vegetation × usage rate × dose coefficient

- Virtually all parameters are user defined and can be modeled stochastically

Sample of BDOSE



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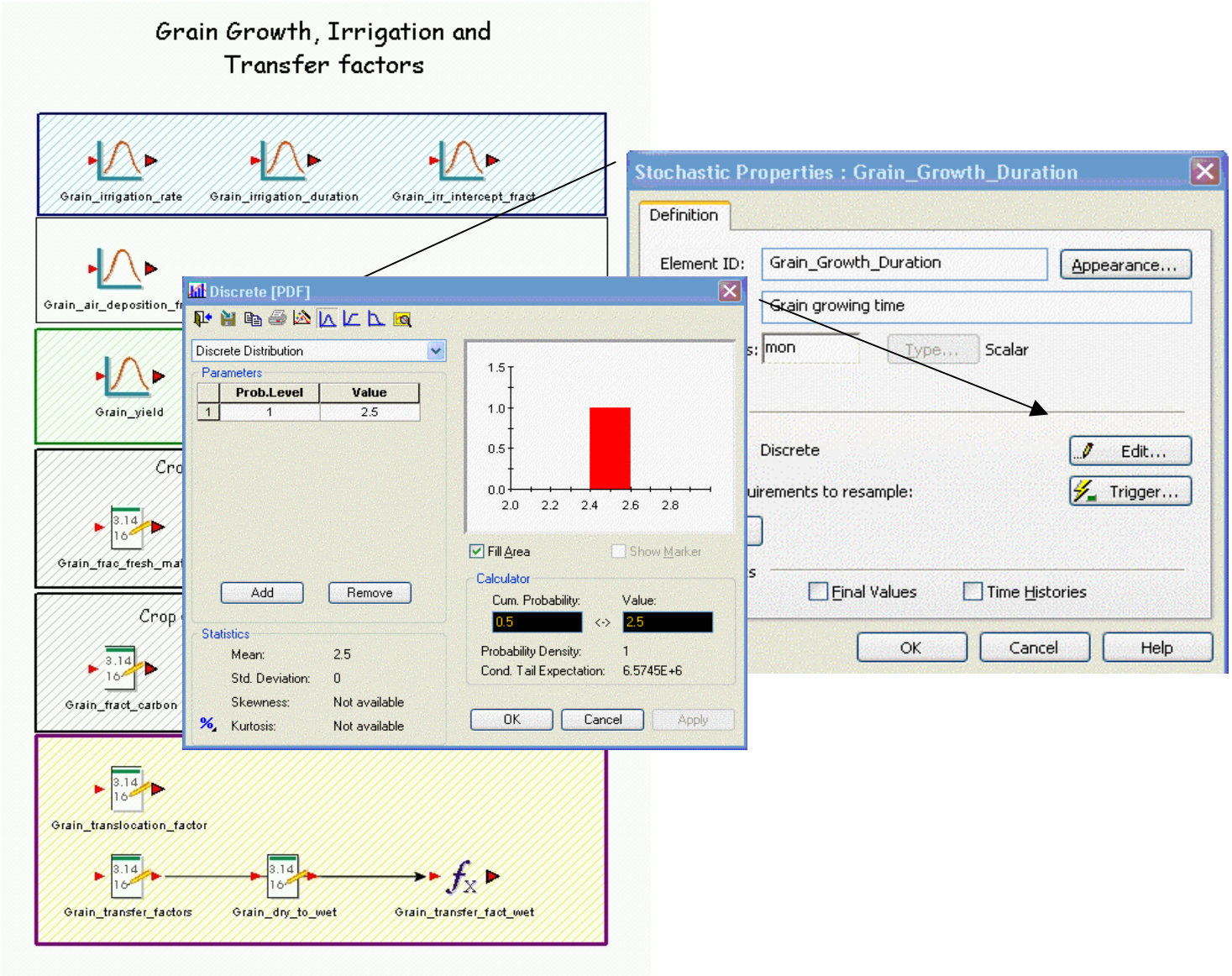
Sample of BDOSE (continued)



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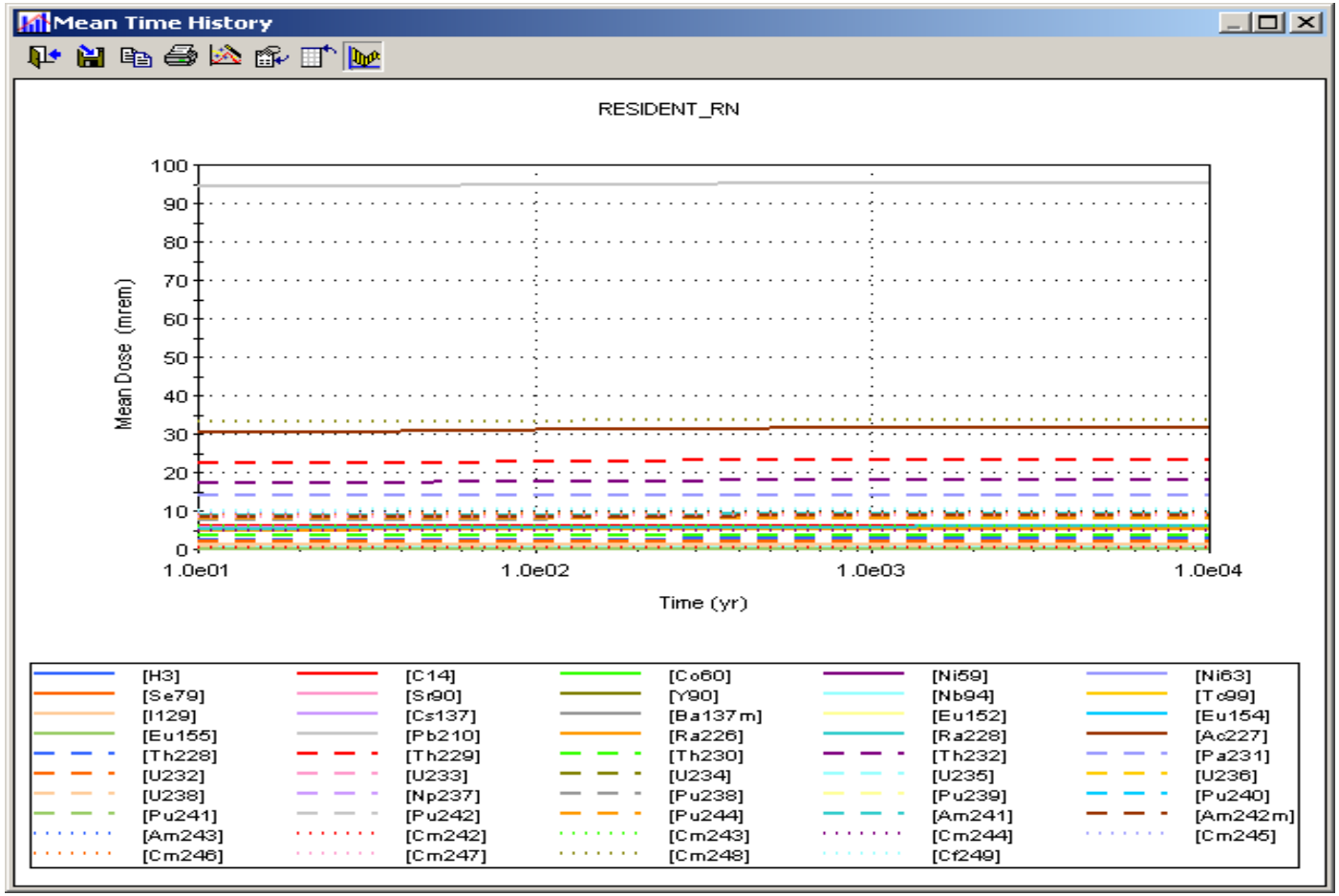
Sample Output



Conclusions and Remarks

- Probabilistic pathway dose model
  - Generic default parameter set included
  - Time-dependent dose calculated
  - Output by receptor, pathway, and radionuclide
- Model strengths
  - Track soil concentrations through time
  - Fully stochastic approach to propagate uncertainties
  - Efficient sensitivity analyses algorithms available in GoldSim (easy identification of relevant parameters, which could guide additional model development/enhancement)
- BDOSE is highly flexible (very efficient to add/remove/enhance capabilities and test new ideas)

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