# FEPs and Conceptual Model Updating within an Iterative PA Cycle

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# A Structured Decision Analysis Approach to PA, Including FEPs and CSM Development

Structured Decision Making: A Practical Guide to Environmental Management Choices

Robin Gregory, Lee Failing, Michael Harstone,
Graham Long, Tim McDaniels, Dan Ohlson

Wiley, March 2012

# Decision Analysis is Formalized Common Sense!

- Organized, inclusive, transparent
- Thoughtful consideration of values and consequences
  - Values Focused Thinking (Keeney)
  - Bayesian Decision Analysis
- Prescriptive
  - Based on formal decision theory but applied practically to support real world decision making
- Iterative
  - The decision context drives the resources dedicated to the decision analysis.
- Optimization, cost-benefit, economics, ALARA…

# Decision Analysis Approach

- Stakeholder involvement
  - Negotiate inputs, not the values of endpoints
  - Let formal DA take care of the rest
- Defensibility, traceability, transparency, openness, vetting, agreement, etc.
- Iteration – prune, refine, add new (with new evidence/data)
  - Iteration should involve the whole cycle of model building and evaluation
  - And should pass through revising CSM and hence FEPs

# Decision Analysis Cycle

- Identify objectives and decision options
- Build a model with available information
  - Probabilistic model (uncertainty)
  - Costs and value judgments
- Evaluate model – uncertainty analysis
- Can decision be made or should more information be collected? (gets at confidence in the decision)
- Perform sensitivity analysis and value of information analysis
- **Iterate**

# Decision Analysis Overview

- In the long run, you will be better off if you choose the alternative (decision option) that gives you the best expected outcome, *given what you know or believe about future events*
- *I.e.,* ***Maximize expected societal welfare***
- *Expectation implies uncertainty*
  - Maximize Expected Utility (EU), or
  - Minimize Expected Losses

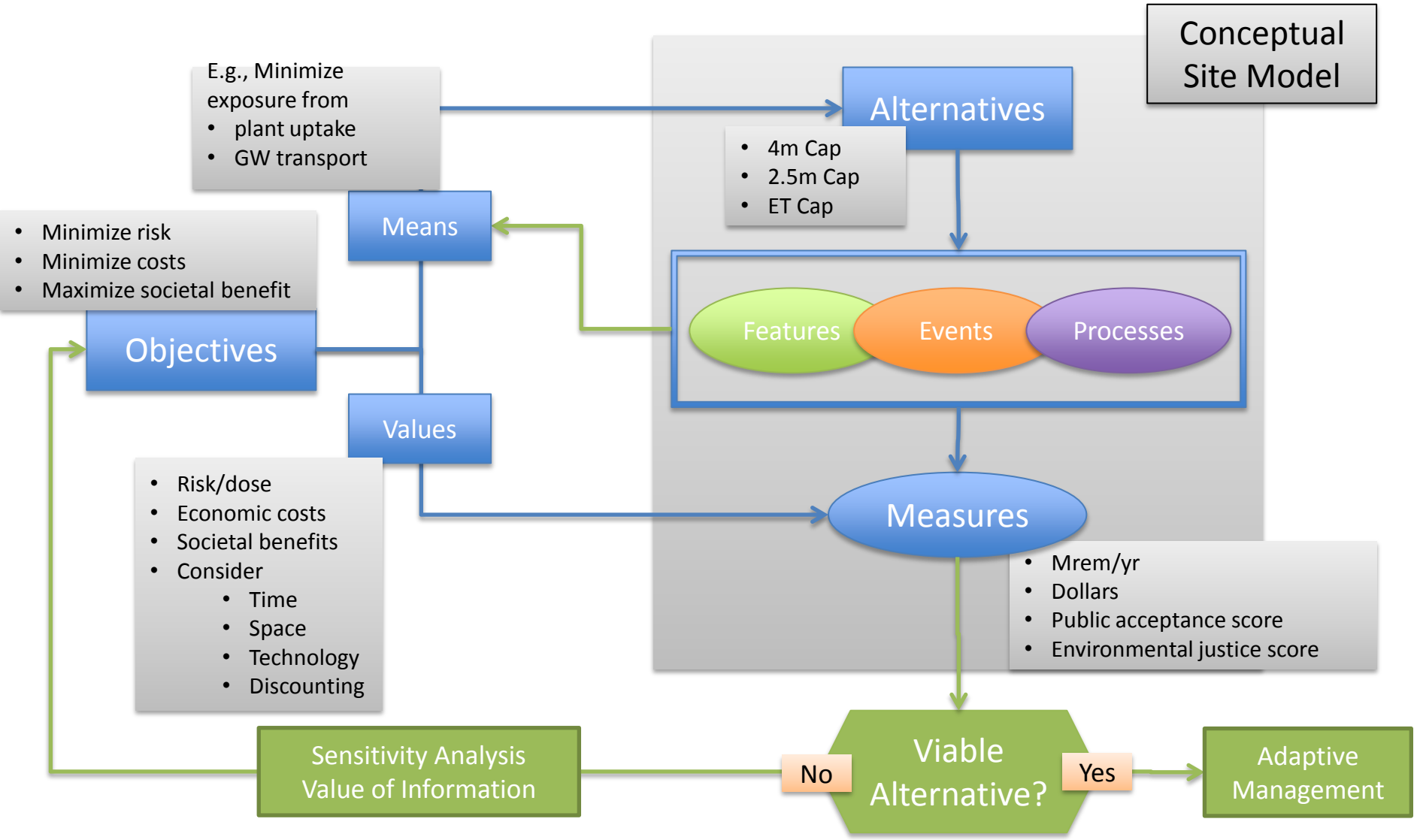
# Applying Decision Analysis

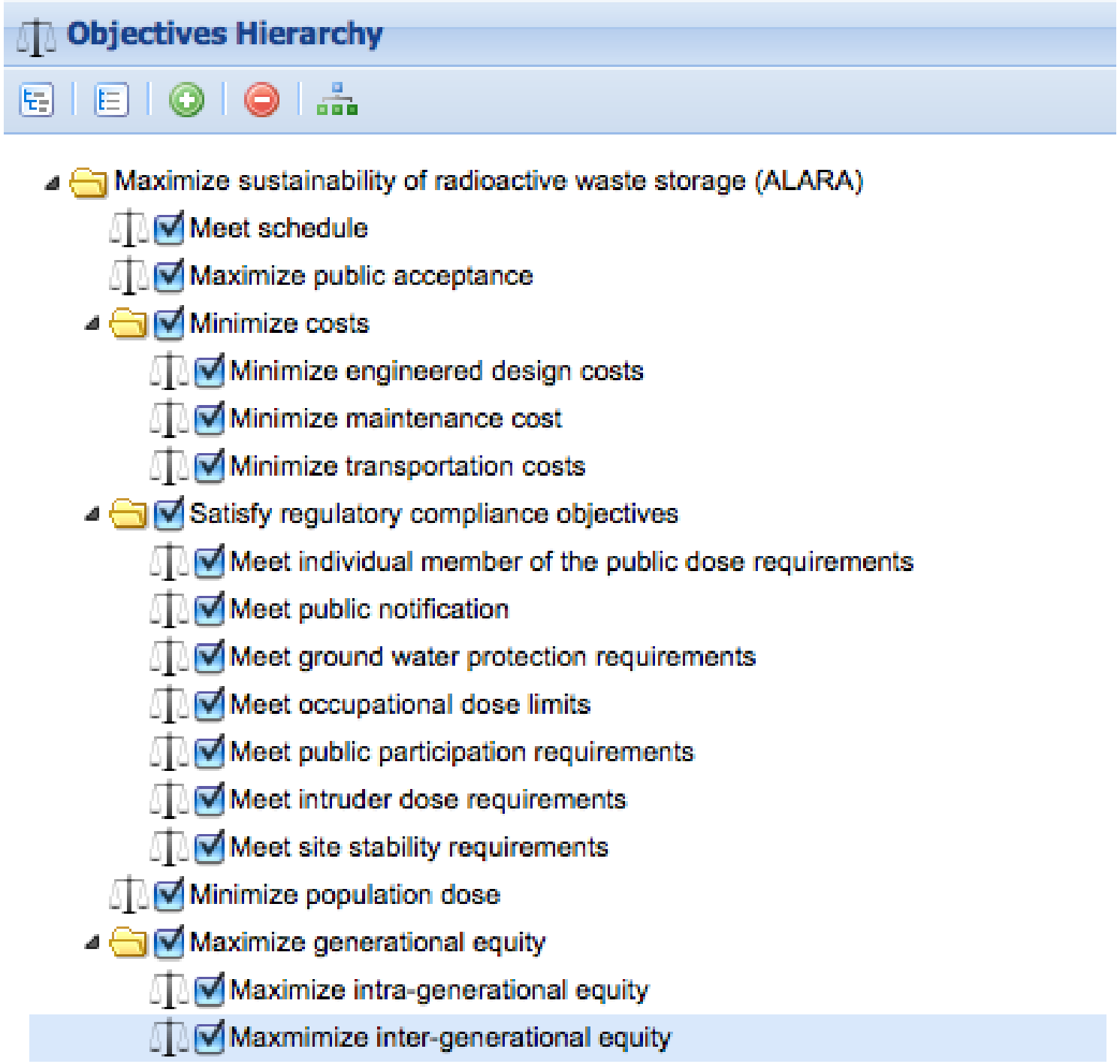
- Identify objectives, decision options, and events that define the decision analysis
- Clearly communicate judgments about utilities (costs and value judgments), uncertainty (probabilities), and risks (EU) in an unambiguous way
- Actively involve stakeholders, customers or users of the decision model at all stages of the decision analysis process (instead of only at later stages, which is more typical)

# Decision Analysis for PA

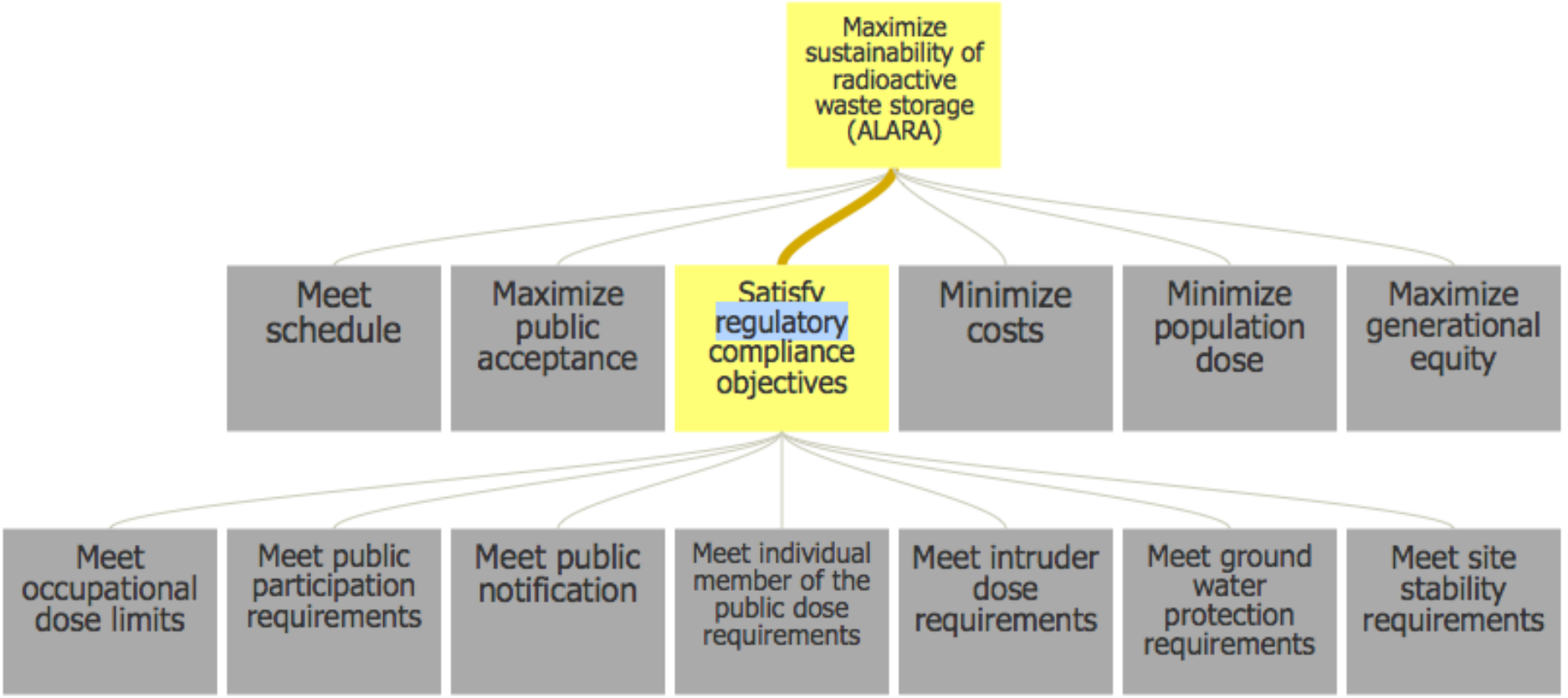
- Organizes or structures PA
  - PA objectives hierarchy (compliance, ALARA)
  - Decision options (e.g., engineered design, placement of waste, institutional controls)
- Helps focus on issues that are relevant to the PA decision making
  - Metrics
  - Costs/Values
- Builds transparency through stakeholder interaction

# PA as a Structured Decision Analysis Process




Objectives Hierarchy
Maximize sustainability of radioactive waste storage (ALARA)
Meet schedule
Maximize public acceptance
Minimize costs
Minimize engineered design costs
Minimize maintenance cost
Minimize transportation costs
Satisfy regulatory compliance objectives
Meet individual member of the public dose requirements
Meet public notification
Meet ground water protection requirements
Meet occupational dose limits
Meet public participation requirements
Meet intruder dose requirements
Meet site stability requirements
Minimize population dose
Maximize generational equity
Maximize intra-generational equity
Maxmimize inter-generational equity

# Objectives Hierarchy



# Values, Compliance Period & Discounting

- Discounting
  - Temporal - Spatial
  - Social - Technological
- Value of Future Generations
- Compliance Period implies discount rate = 0 for the duration, and then a value of 0 thereafter
  - This is a discount function, rather than a simple rate
  - Current generation bear the full cost (pay now to protect future generations)
  - Can have unintended impacts on near-term generations

# ALARA

- as low as reasonably achievable
- 10 CFR 20.1101(b) requires that:
- "The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).”
- Implies value, implies objectives, implies decision analysis

# Decision Analysis and FEPs

- Iterative as the PA evolves
  - From screening (initial building) to updating (stable model)
- Model building is an art – some formalisms can help with organization and structure
  - Decision analysis concepts/constructs
  - **If FEPs are a helpful tool then great, use them**
- Consistent with ALARA
  - PA Maintenance (DOE)
- Philosophically – Bayesian decision analysis

# FEPs and CSM Development

- DA structure helps focus on FEPs that are relevant to the PA decision making
- Iterative as the PA evolves
  - From screening to updating
  - PA Maintenance (DOE)
  - Bayesian decision analysis
- **Builds transparency through stakeholder interaction**
- FEPs built through stakeholder involvement tools?
  - Open-source, interactive, web-based

# Tools for FEPs and CSM Development

- FEPs can be built using open-source, interactive, web-based tools
  - Project/information sharing among stakeholders
  - Organization, structure built interactively
  - Can attach content, link to other information, provide help and advice, etc.
  - Social network analysis
- No set process to this, model building is an art
  - build influence diagrams or flowcharts that describe CSM and can be translated into numerical model
  - Graphical object-oriented interface like a whiteboard

Overview | Understand Context | Define Objectives | Develop Options | **Evaluate Options** | Take Action | Sharing

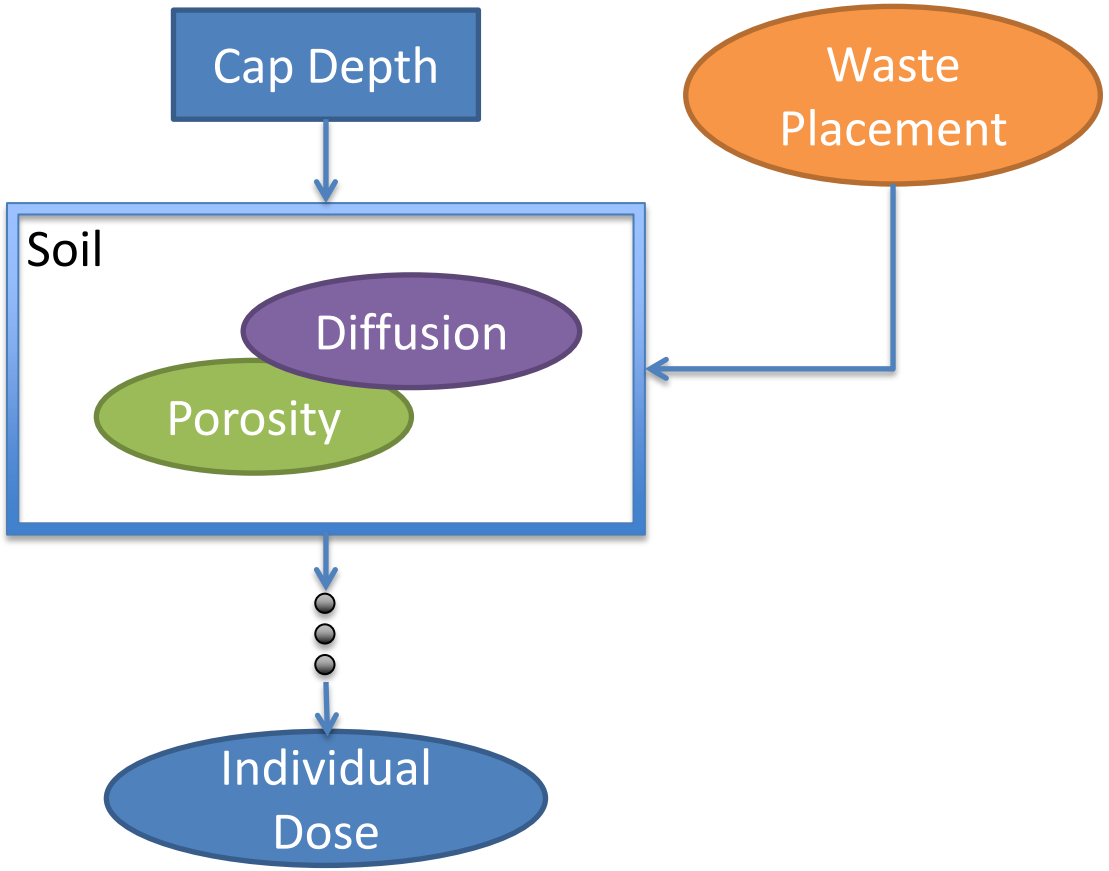
Overview | Model Map | FEP | Decision Map

**Features, Events, Processes**

Porosity: measure of the void spaces in soil.

- Features Events Processes
  - Features
    - Water
    - Human
    - Soil
      - Porosity
  - Events
    - Human
      - Waste Placement
      - Well Drilling
    - Tectonic Seismic Volcani
  - Processes
    - Water
    - Air
    - Soil
      - Diffusion
    - Human

**Conceptual Site Model**



# FEPs Categories for the NTS LLW PAs

- Inventory
- Source release
  - radon
- Engineered features
  - cover thickness
  - subsidence
- Meteorological
  - infiltration
- Hydrological
  - upward advection
- Hydrogeological
  - tortuosity
- Geochemical
  - Kd, solubility
- Geological
  - alluvium
- Air Diffusion
  - tortuosity
  - radon
- Air Dispersion
- Biotic processes
  - plants
  - animals
- Human processes
  - management controls
- Exposure scenarios
- Scaling
  - temporal, spatial

Note–FEPs analysis was not formally performed at NTS; this is retrospective

# FEPs Screening for NTS (NNSS) LLW

- Screening step removed some possible FEPs
- Containerization – decided to take no credit
- Celestial – only 1,000 year model
- Climate change – only a 1,000 year model
- Meteorological (some) – insignificant consequence (e.g., flooding), site returned to near-grade
- Erosion – site returned to grade, aggrading
- Tectonic/seismic/volcanic – no effect

# FEPs and CSM Iteration

- Iterate to improve model
- Model pruning (structural deletion)
- Model structural changes
- Model structural additions
- Model specification updates

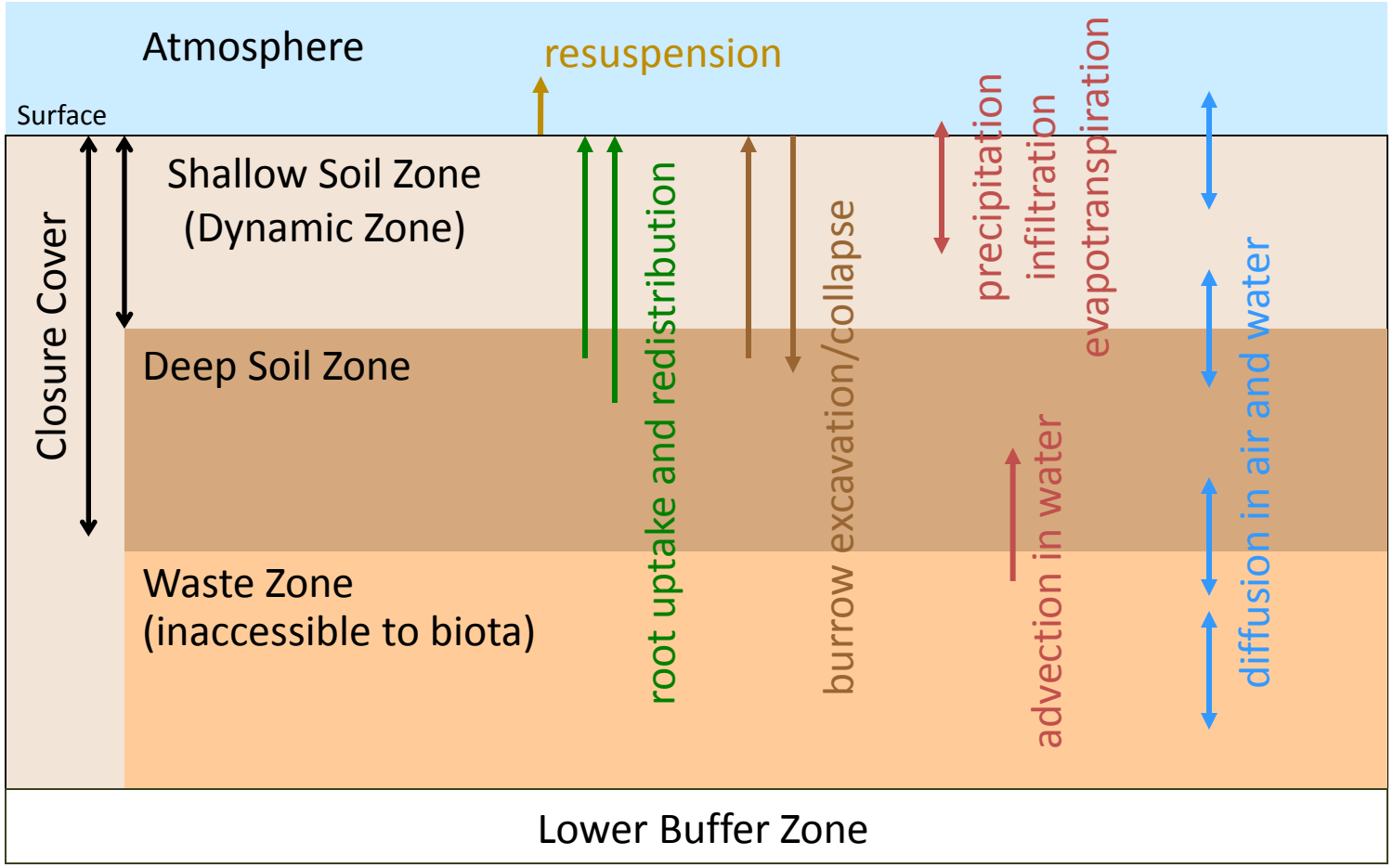
All depends on what is found in the model iterations (using sensitivity analysis, etc.)

# Area 5 Radioactive Waste Management Site

Disposal configurations:

- Shallow pits and trenches: LLW
- Greater confinement boreholes: classified TRU materials
- Deep trenches: Rn-producing LLW
- Mixed waste trench: MLLW

# Conceptual Model of Shallow Land Burial at the Area 5 RWMS




Not to scale

Figure denotes the upper ~10 m of the disposal unit

[no groundwater pathway]

# Area 5 RWMS Model Improvements

- Biotic pathways
  - Removed conservatism
  - Corrected spatio-temporal scaling
  - Collected field data for 3 years
    - Plants
    - Mammals
    - Ants and termites
  - Restructured model
- Simplified animal burrow and plant root depth model based on site-specific data analysis
- Changed effect of FEPs on CSM from deep impacts to shallow impacts

# Area 5 RWMS Model Improvements

- Upward advection
  - Advection dominated from ET
  - Abstracted a site-specific process-level model (FEHM) – based on chloride profile data
- Restructured GoldSim model to focus on advection of water
- Removed FEPs, changed CSM, changed model structure

# Area 5 RWMS Model Improvements

- Inventory
  - Removed conservatism
  - Corrected spatio-temporal scaling
- Separate GoldSim model for inventory updating
- Reworked facility cells for consistent area and volume numbers in “virtual cell” averaging
- Added disposal configurations for candidate waste streams

# Area 5 RWMS Model Improvements

- Improved radon model
- Radon calibration procedures incorporated within GoldSim model
  - Rogers/Nielsen gas-phase tortuosity
  - consistency with NRC model (NRC regualtory guide 3.64 for radon diffusion through a simple uranium mill tailings cap)
- Radon emanation factors added

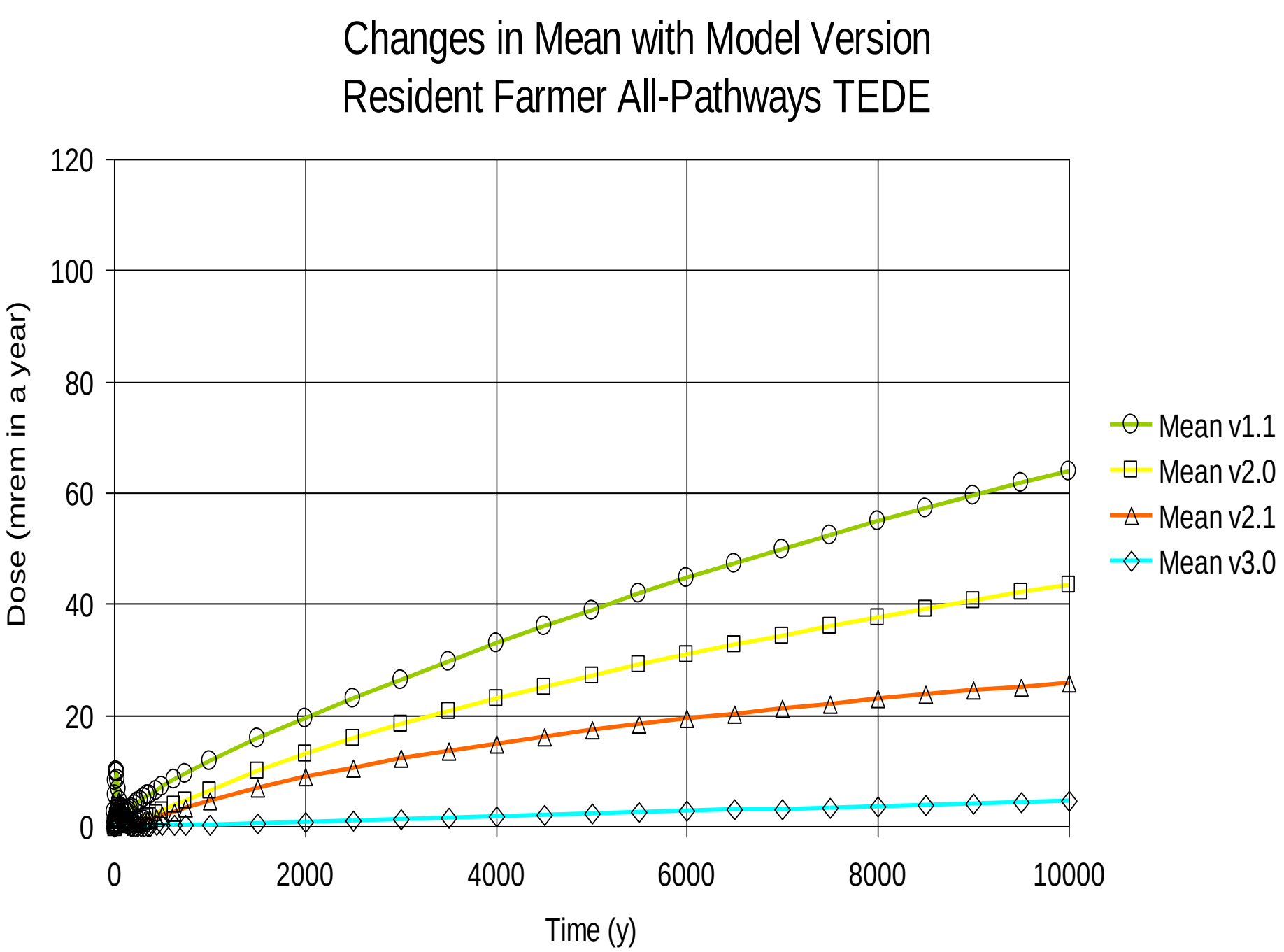
# Area 5 RWMS Model Improvements

- Receptor scenarios
- Site-specific – Residential:
  - Homesteading
  - Community expansion from Las Vegas
  - Independent community in Frenchman Flat
  - Independent community in Jackass Flats with overflow in Frenchman
- Probabilistic intrusion from these scenarios
- Demographic information from the State

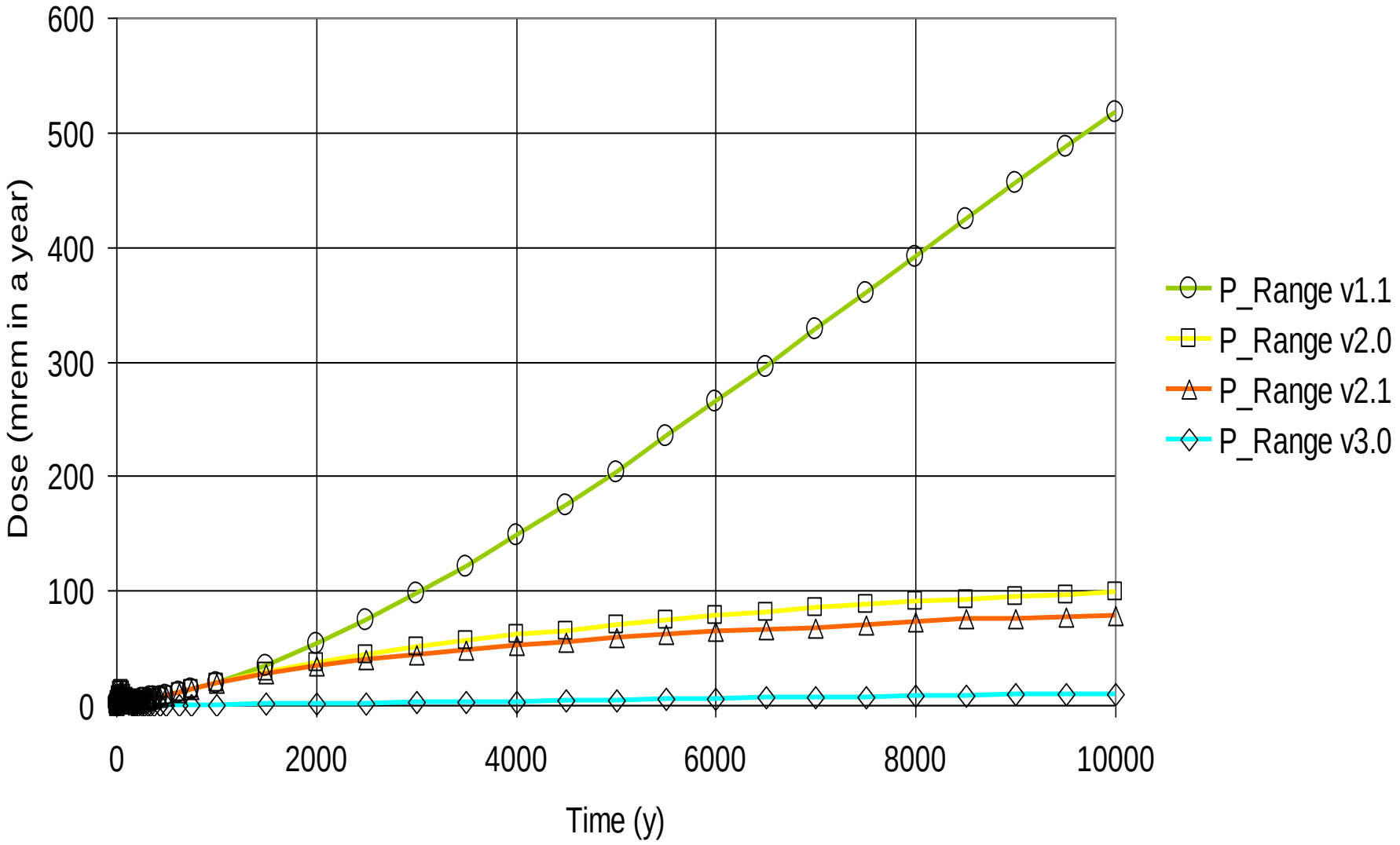
# Effective changes in FEPs/CSM

- Focus on Biotic model
  - Removed deep effects
  - Included mammals and insects
    - Then excluded termites based on model consequences
  - Changed plant model
- Focus on upward advection from ET effect
- Added radon emanation
- Focus on site-specific receptor scenarios

Each iteration ended up with changes to the CSM, and effectively, the underlying FEPs


Changes in Mean with Model Version
Resident Farmer All-Pathways TEDE
Dose (mrem in a year)
120
100
80
60
40
20
0
0
2000
4000
6000
8000
10000
Time (y)
Mean v1.1
Mean v2.0
Mean v2.1
Mean v3.0

# Changes in 95th - 5th Percentile Range with Model Versions
## Resident Farmer All-Pathways TEDE



# Decision Analysis Structuring for FEPs

- FEPs have often been large unorganized lists, but we can do better by considering:
  - Relationship between F, E, and P (and A (activities)!)
  - Separating FEPs into obvious categories
  - Cause and effect (links between FEPs)
- Use tools such as Influence Diagrams for organization
  - Structured “wiki”, GoldSim, other?
- Stakeholder involvement through use of these tools
  - Defensibility, traceability, transparency, etc.
- Goal is to use FEPs to support the CSM
  - FEPs is a tool for building the CSM
  - CSM -> Model structure -> Numerical model -> UA -> SA -> VoI -> **Iterate** !!

# Other thoughts on FEPs development

- Model building is an art that moves towards a science
  - let DA drive it from a top-down perspective – an art with a methodology – hence DA
- FEPs can be over the top – it is a tool available to support CSM development
  - "Models should be as simple as possible and no simpler"
  - Aligned with top-down modeling
    - Find out what matter, before investing time and money in components
  - Model evaluation (e.g., sensitivity analysis) should be used to focus or refine/revise FEPs/CSM through the iterative cycle of modeling
- Screening can be subjective
  - Objective options exist for probabilistic screening (Yucca Mountain)
  - And consequence screening, but still qualitative
  - Could be made quantitative, but best left to DA cycle