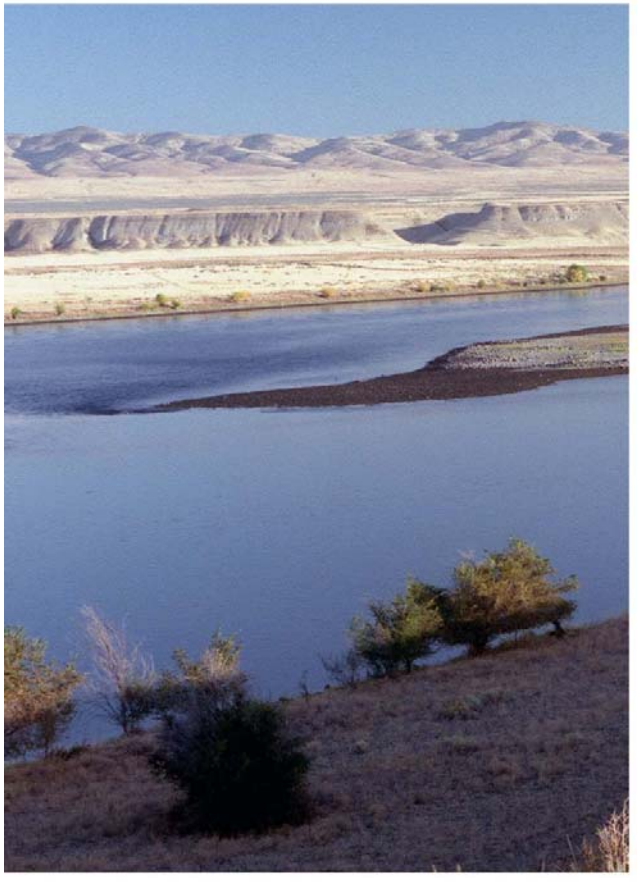
CH2MHILL
Plateau Remediation Company



Derivation and Application of Soil Contaminant Levels Protective of Groundwater at the Hanford Site

Presented to:

PA Community of Practice Technical Exchange

Presented by:

- Jim Hoover, CHPRC
- Bill McMahon, CHPRC

One Culture. One Team.

The Point

- Soil cleanup metrics protective of groundwater are needed for environmental remediation efforts at the Hanford Site to:
  - Provide a quantitative assessment of groundwater risk from vadose zone contaminants
  - Assess selection and effectiveness of remedies
  - Implement remedial actions (e.g., clean-up levels)

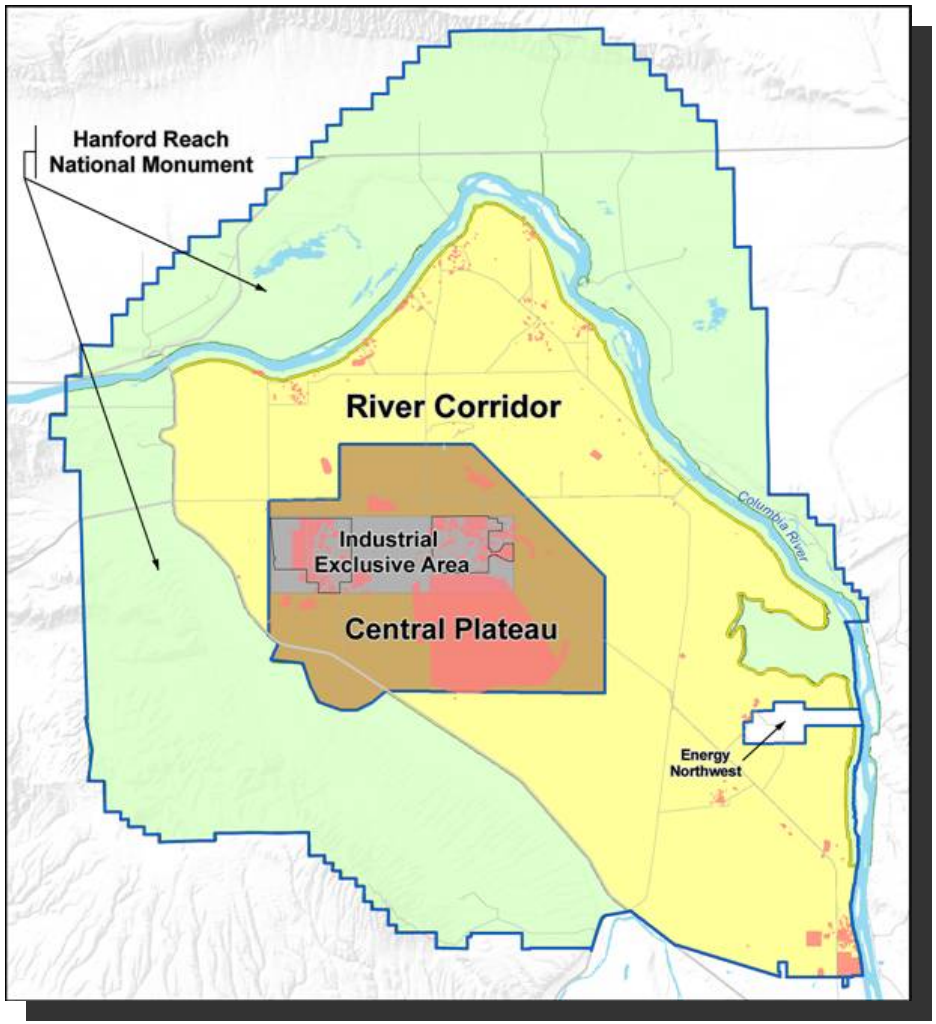
- A methodology for the determination of soil cleanup levels protective of groundwater has been developed that can provide:
  - A technical basis for defining the soil levels protective of groundwater
  - Consistent cleanup level metrics applicable to most remedial actions and cleanup efforts with a thick vadose zone (e.g., up to 300 ft.)
  - New tools to facilitate risk-based assessment efforts

Need for Soil Levels Protective of Groundwater

- Many CERCLA environmental remediation activities at the Hanford Site (remedy selection, cleanup, closeout) depend on risk-based assessments of groundwater protection from vadose zone soil contaminants to assess overall protectiveness
- Contaminant "migration to groundwater" pathway is the primary risk driver for vadose zone contamination below 15-ft bgs, and can also be the risk driver for shallow contamination
- Until recently, there has been no method for the derivation of soil cleanup levels for groundwater protection apart from default values based on:
  - Background
  - Detection limit values for some analytes (e.g., Tc-99)
  - Conservative soil screening levels (e.g., based on EPA Soil-Water Partition Equation)
- Alternatively, the assessment of risk from vadose zone contamination has been based on fate and transport forward modeling on a case-by-case basis (e.g., RESRAD)

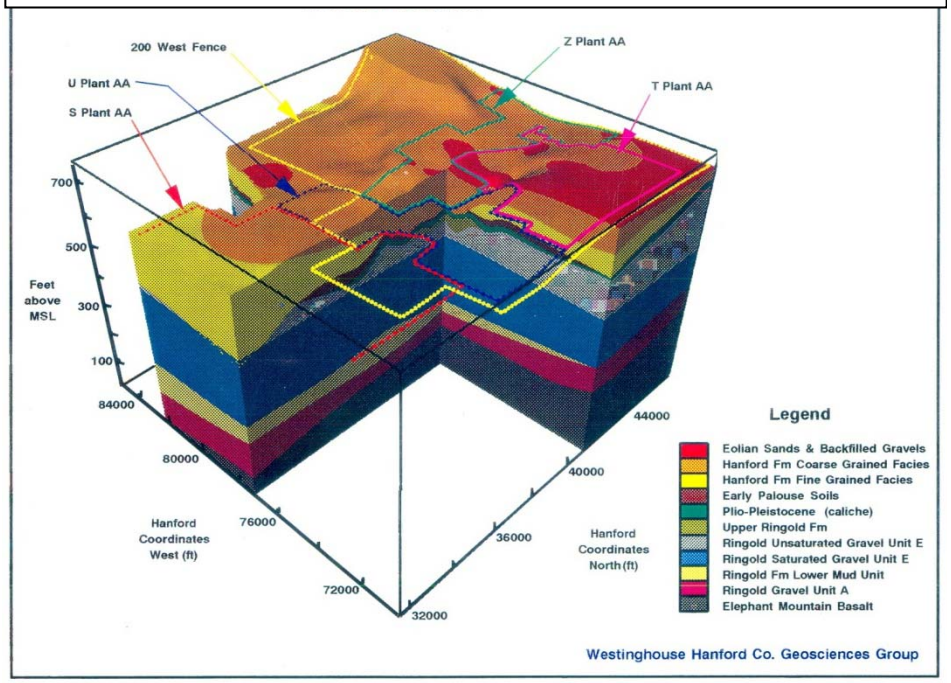
Need

Methodology Needed for the Hanford Site



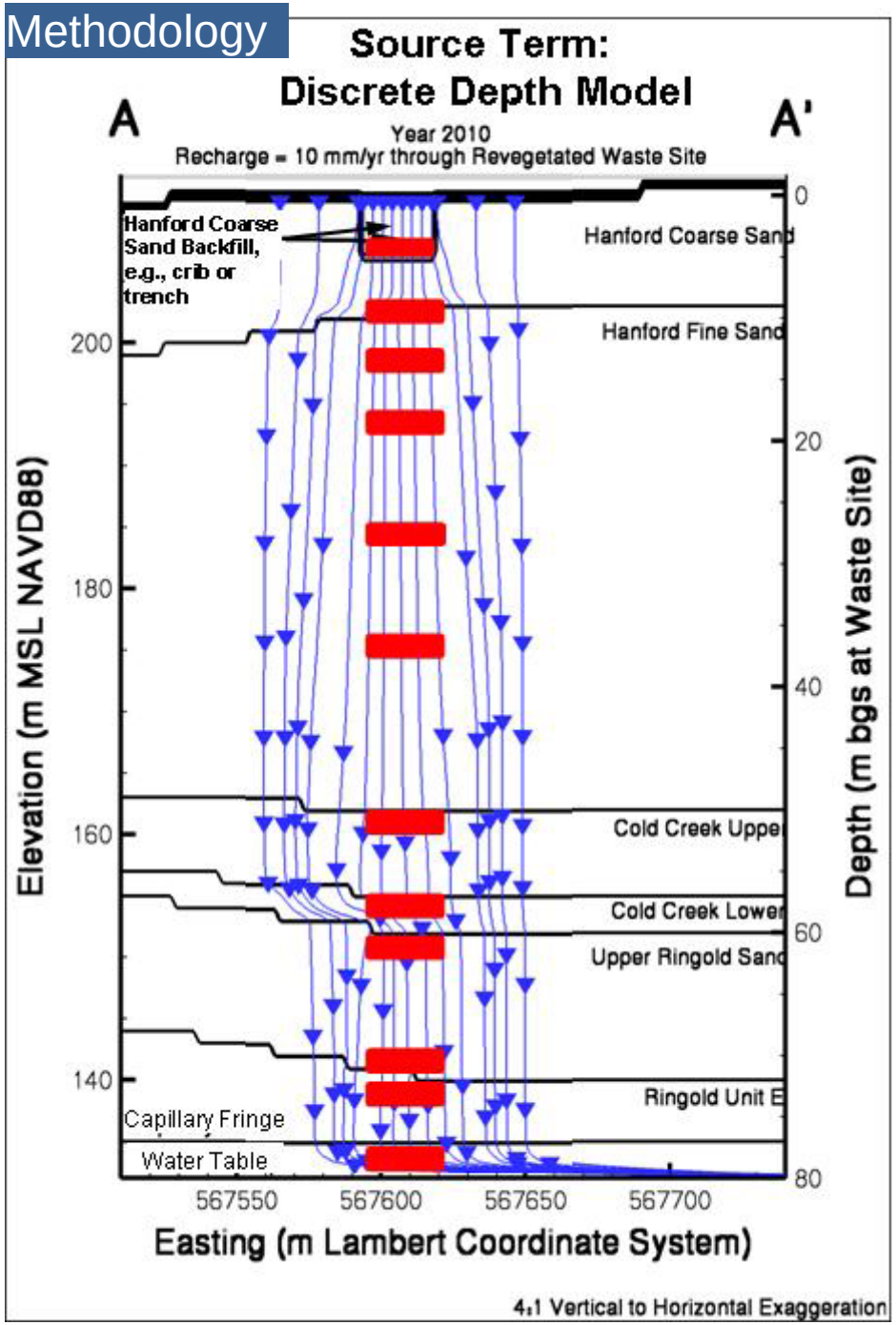
A methodology is needed for deriving soil cleanup levels that incorporates the processes and characteristics (FEPs) of the thick Hanford vadose zone system (up to 300-ft.)

Schematic diagram of the thick vadose zone in the Central Plateau (200W Area) of the Hanford Site



Methodology for the Determination Soil Levels Protective of Groundwater

Methodology



Methodology Summary

- Utilizes a reference mass for the source term at each depth (e.g., unit mass)
- Resulting modeled groundwater concentrations are proportional to the source term mass
- Soil threshold levels* are back-calculated from acceptable groundwater protectiveness metrics (post-processing)
- Soil threshold levels * = mass (activity) per meter width, normal to direction of groundwater flow
- Soil threshold levels* are specific to system characteristics (e.g., geohydrologic characteristics)
- Methodology decouples system characterization (e.g., geology, system FEPs) from source term characterization for derivation of the protectiveness metric

** Soil threshold levels protective of groundwater are also referred to as Remedial Action Goals (RAG values) in CERCLA applications*

Merits

Example of Resulting Soil RAG Values Protective of Groundwater: 200-UW-1 RTD Sites (Vadose Zone ~ 260 ft. bgs)

Groundwater Protection Default Values	Uranium	Nitrate/Nitrite	Tc-99
	3.21 mg/kg	40 mg/kg	1 pCi/g
Basis	Background	WAC CLARC Table Lookup value	Detection Limit

Values Calculated with the RAGs Methodology	Uranium			Nitrate/Nitrite			Tc-99	
Depth (ft bgs)	RAG Mass (kg)[a]	RAG Soil Conc. (mg/kg)[b]	Peak Arrival (years)[c]	RAG Mass (kg)[a]	RAG Soil Conc. (mg/kg)[b]	Peak Arrival (years)[c]	RAG Mass (Ci)[a]	RAG Soil Conc. (pCi/g)[b]
15 ft (4.6 m)	11.1	120	23,942	162	1,753	1,739	0.0146	158
45 ft (13.7 m)	10.7	116	21,432	157	1,690	1,491	0.0141	152

[a] Mass values are in kg or Ci per meter width, transverse to the direction of groundwater flow
[b] for cross-sectional contaminated volumes up to 56 m^3
[c] Denotes arrival time of peak concentration in groundwater in years following remedial action (from year 2010)
All values calculated for a 5m groundwater mixing zone

Merits of The Methodology

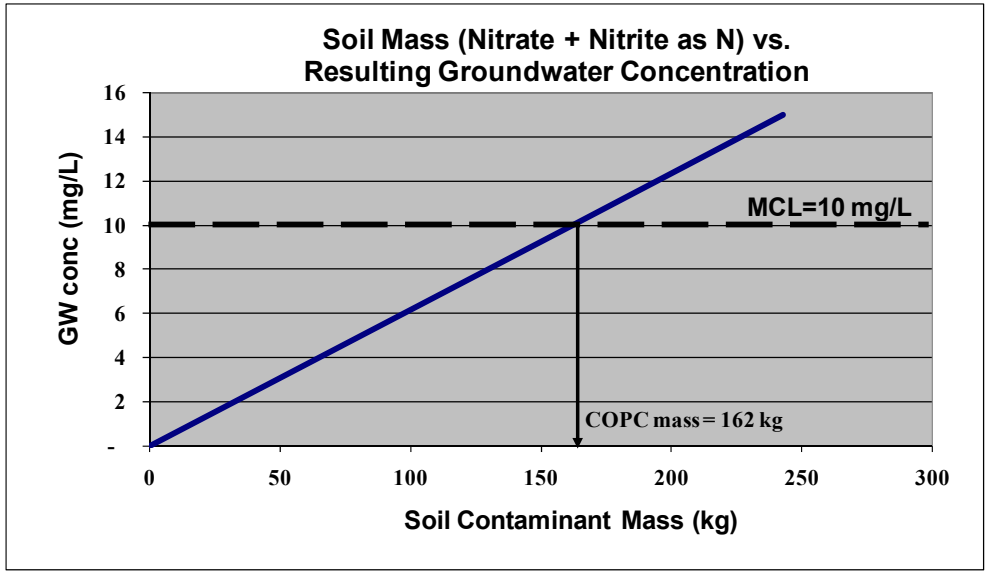
- Soil threshold levels (RAG values) are scalable with respect to key parameters (depth, source term mass, Kd, recharge)
- Scalability of RAG values provides flexibility, efficiency, and latitude in their application (e.g., scenarios, uncertainty analyses)
- Provides new assessment tools and insights
- Decouples uncertainties associated with the derivation of the protectiveness metric from those associated with source term characterization

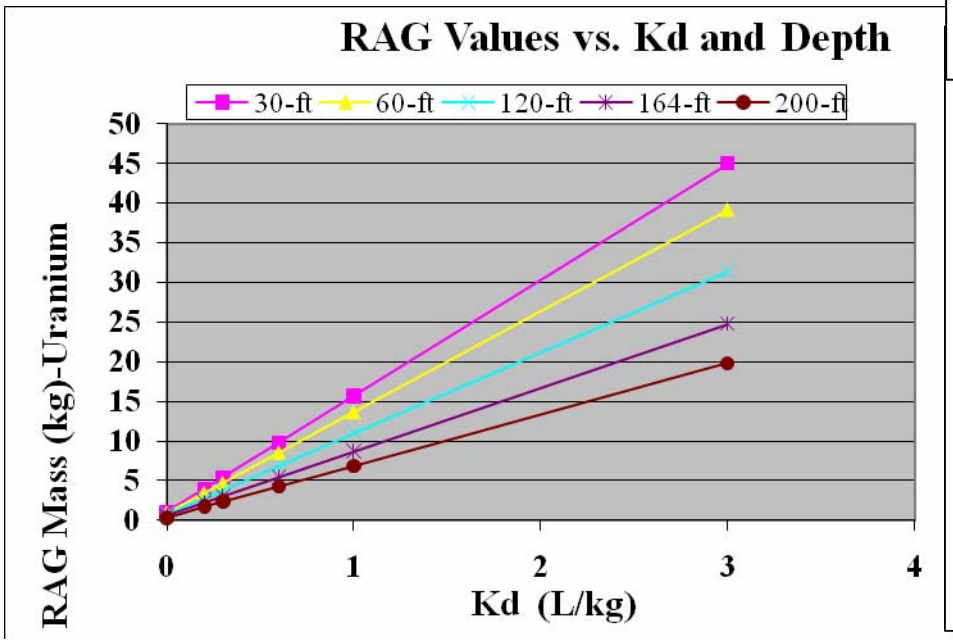
Merits

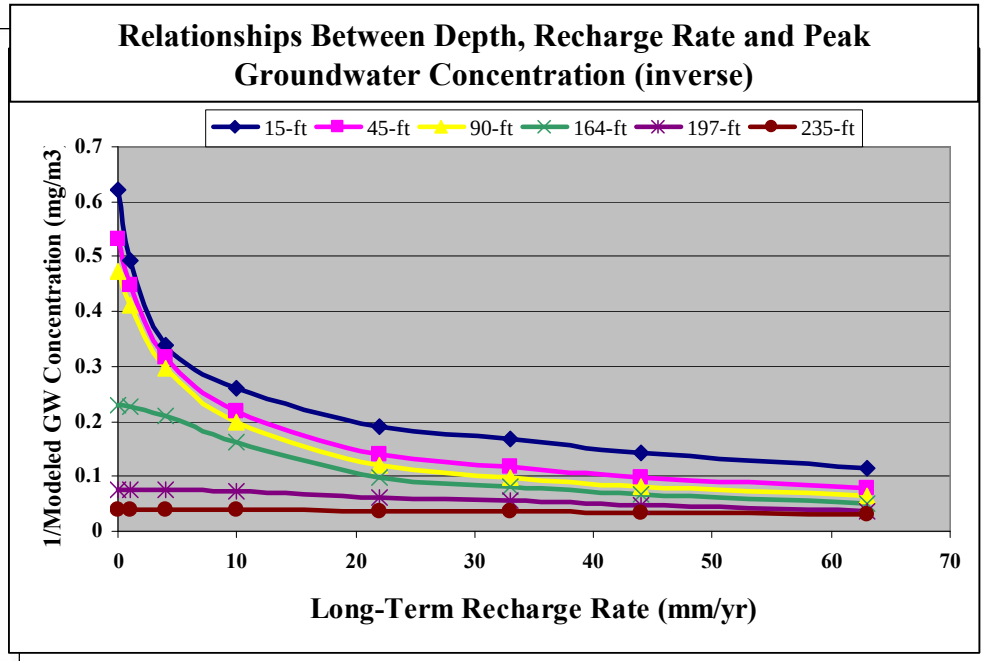
Scalability of Results and Functional Relationships

Contaminant soil levels protective of groundwater (for a given geologic system) are scalable with respect to key parameters:

- Depth
- Source term mass
- Kd value
- Long-term recharge rate







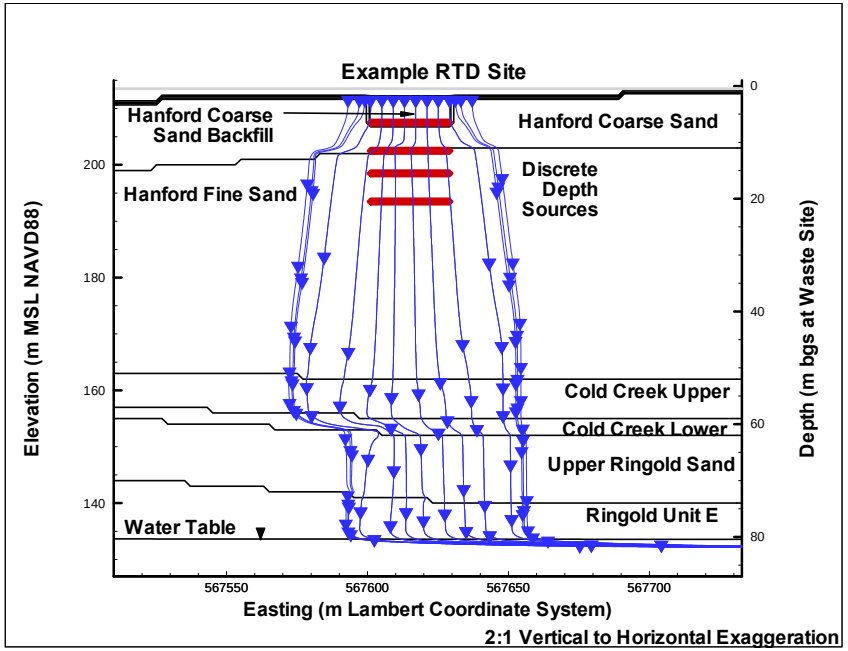
Example Applications of the RAGs Methodology at the Hanford Site

Examples of the Application of the RAGs Methodology at the Hanford Site

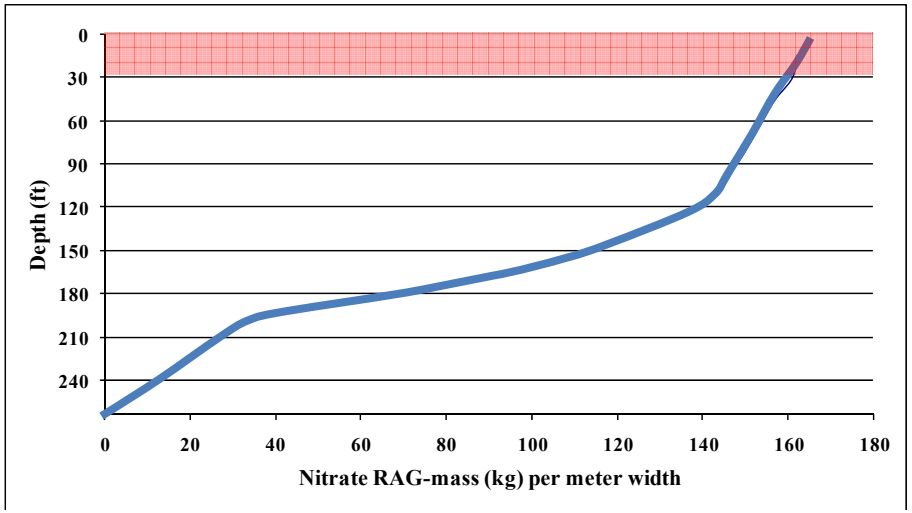
- Sites with a single vadose zone source term depth interval, e.g., shallow contamination (e.g., RTD sites, upper 30-ft)
- Broad applications: Hanford plateau-wide soil cleanup levels (RTD sites)
- Sites with multiple source term depth intervals
- New evaluation tools:
  - COPC screening
  - Vadose zone protectiveness maps
  - Remedy effectiveness
    - Barrier depth effectiveness
    - Baseline for treatment technology effectiveness

Applications

Examples: Single Depth Interval Source: 200-UW-1 RTD Sites



Soil RAG values with depth Nitrate (as N)



Soil Levels Protective of Groundwater (200-UW-1)			
depth (ft)	Nitrate (kg)	Tc-99 (Ci)	Uranium (kg)
15	162	0.0146	11.1
30	161	0.0145	10.9
45	157	0.0135	10.7
60	154	0.0133	10.7
90	148	0.0128	10.5
120	139	0.0120	10.3
164	98	0.0088	10.3
189	50	0.0045	4.0
197	35	0.00318	2.0
231	18	0.0016	1.2
235	15	0.0013	1.0
264	0	0	0

- Values = soil mass (or activity) per meter width , normal to GW flow direction
- Nitrate values based on MCLs for nitrogen as nitrate + nitrite (10 mg/L)
- Recharge = 4 mm/yr

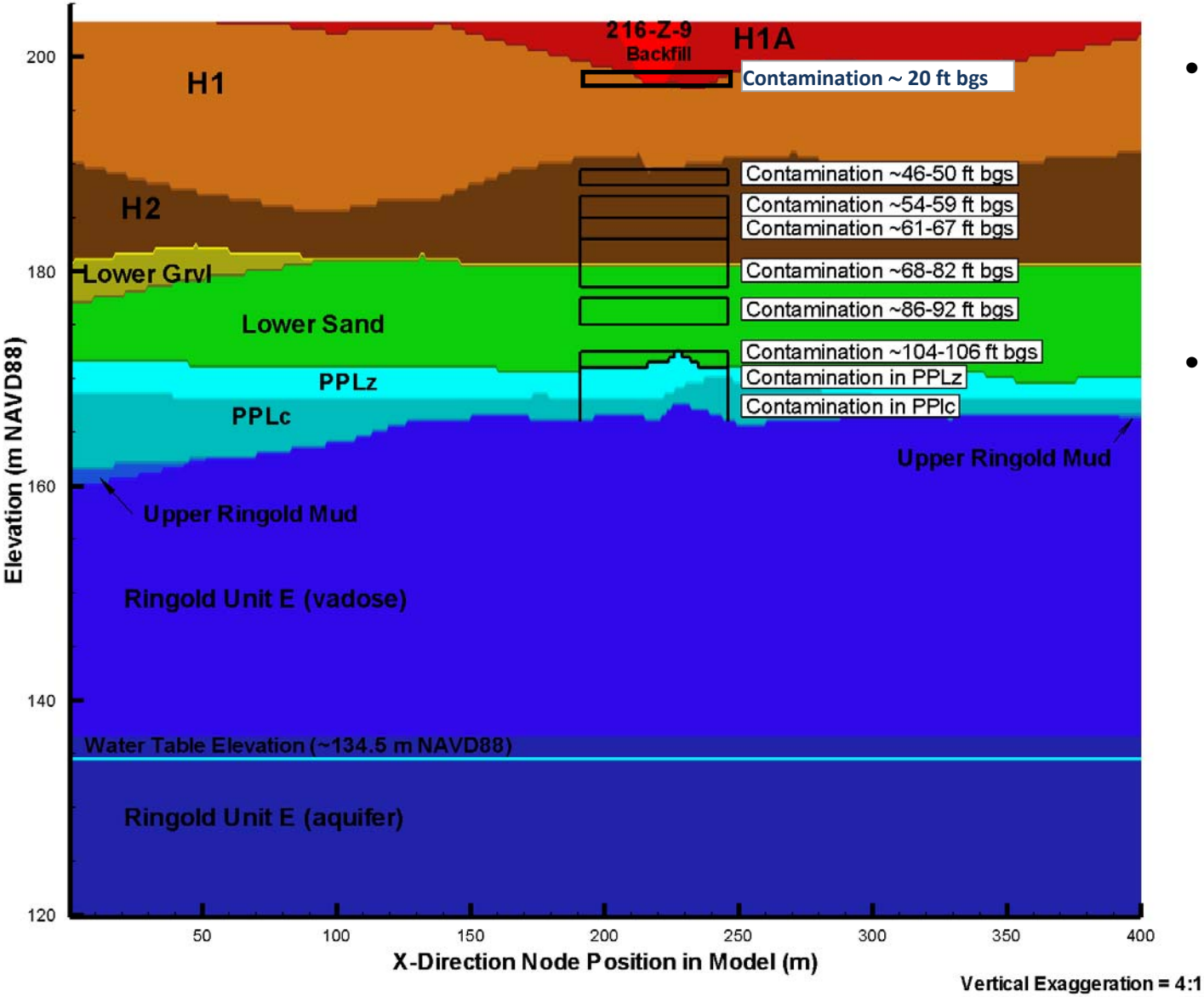
Examples: Derivation of Hanford Plateau-Wide Soil Levels Protective of Groundwater for RTD Sites (e.g., ≤ 30-ft. bgs)

- Soil cleanup levels for broader application can be derived for area with comparable system conditions (geology), e.g., Hanford Central Plateau
- Lower bounding threshold levels could be used in RTD actions throughout most of the Central Plateau as a consistent basis for screening and/or as cleanup protectiveness
- Conservatively bounding values are protective for all less conservative conditions
- Provides a consistent technical basis for defining remedy protectiveness, and for the protectiveness of "*waste left in place*"

Contaminant	Lower Bounding Soil RAG Concentration Values Protective of Groundwater*		Overall Concentration Range	Overall Limiting Peak Arrival times
	200E	200W		
Uranium mg/kg	139	143	139 to 1,288	11,537 yrs. --- 18,766
Nitrate mg/kg	2,880	3,304	2,880 to 3,530	1, 064 yrs.--1,739
Tc-99 pCi/g	259	297	259 to 316	

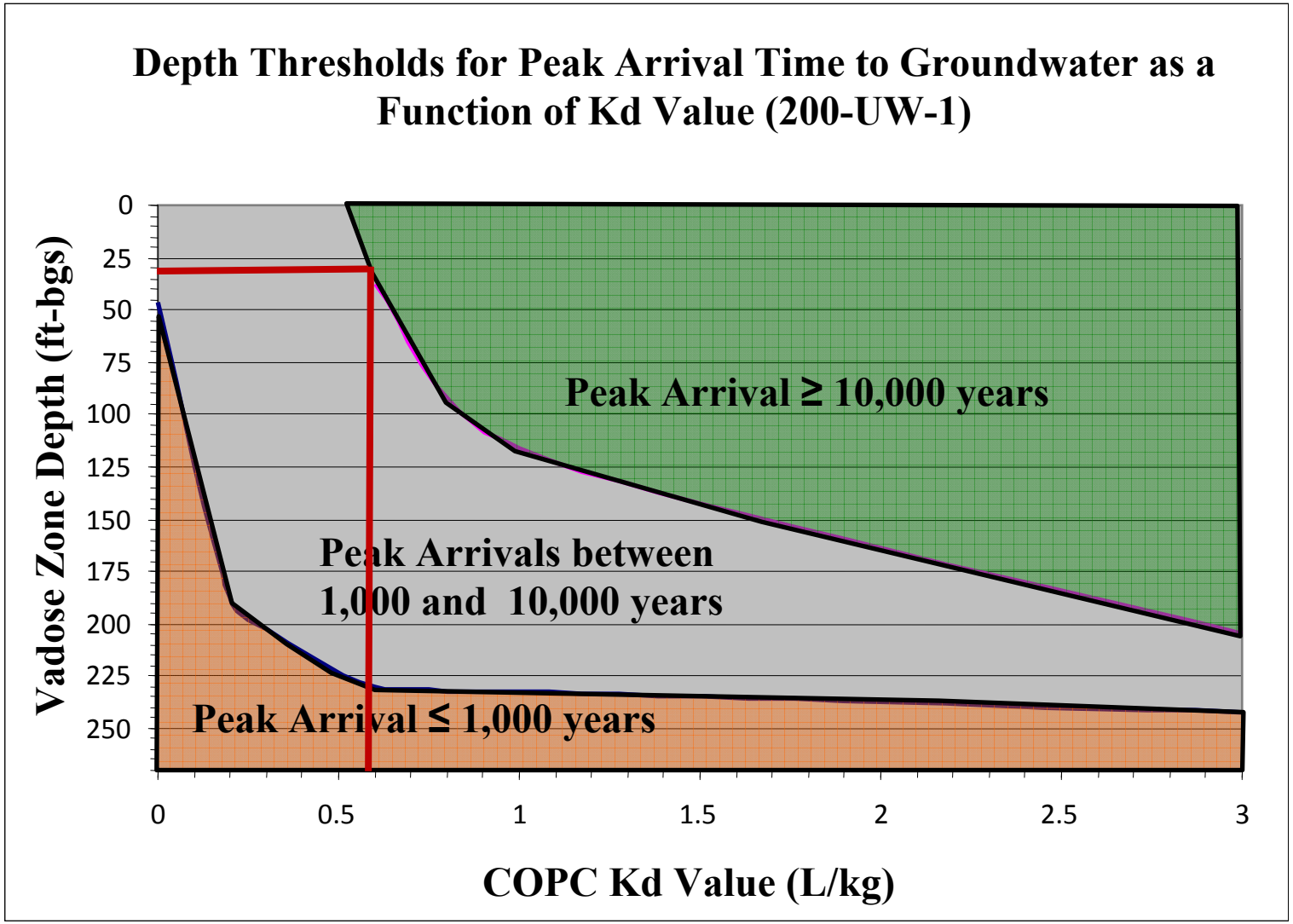
* Based on 4 mm/yr LT recharge; 10m aquifer mixing zone. RAG concentrations based on 56 m^3 cross-sectional volume

Examples: Multiple Source Term Depth Intervals



- Additive effects of groundwater contributions from multiple source terms are also scalable
- Conducive to scenario-based evaluations and sensitivity analyses

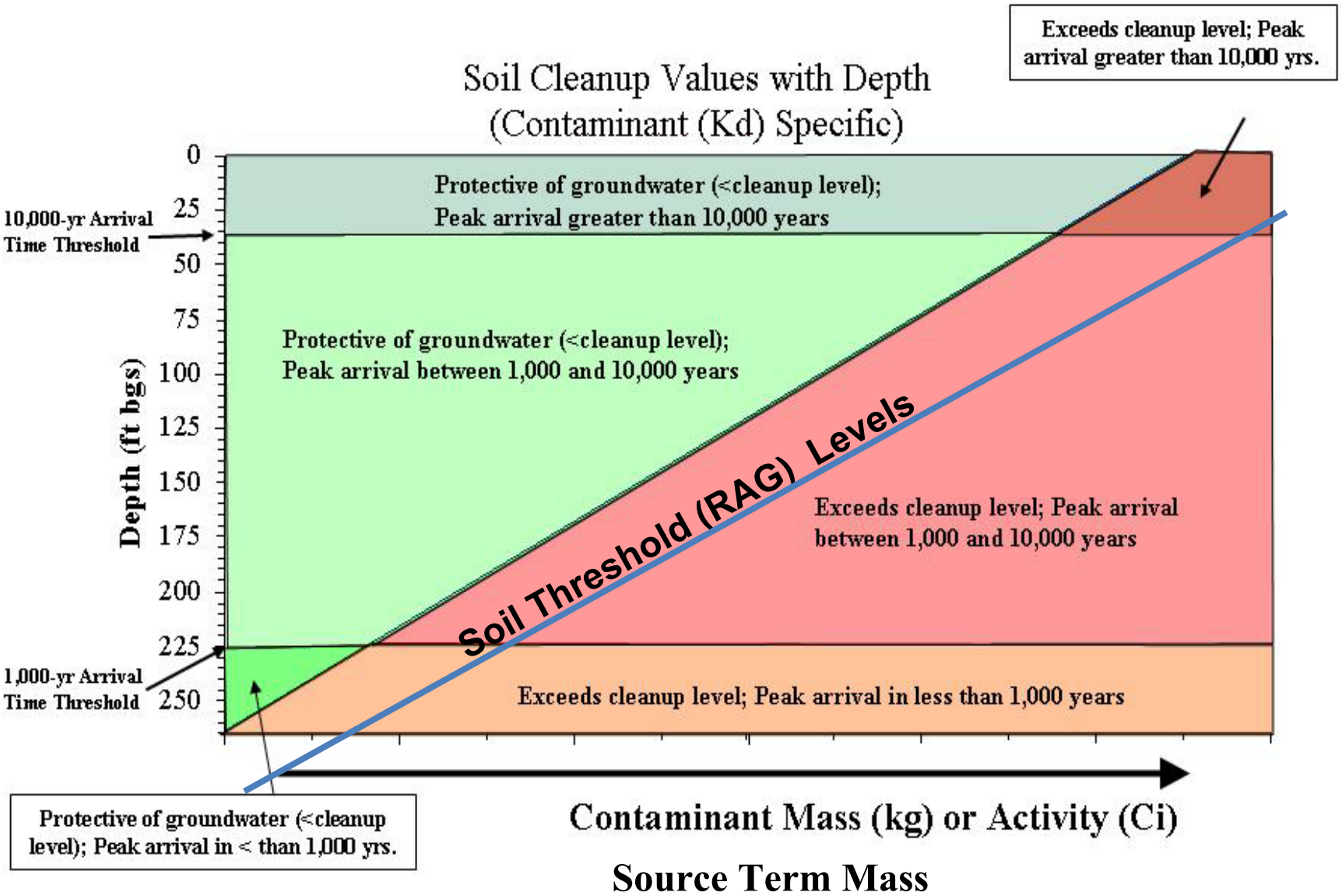
Examples: COPC Screening by Kd values and Groundwater Arrival Time



Recharge Rate = 4 mm/yr

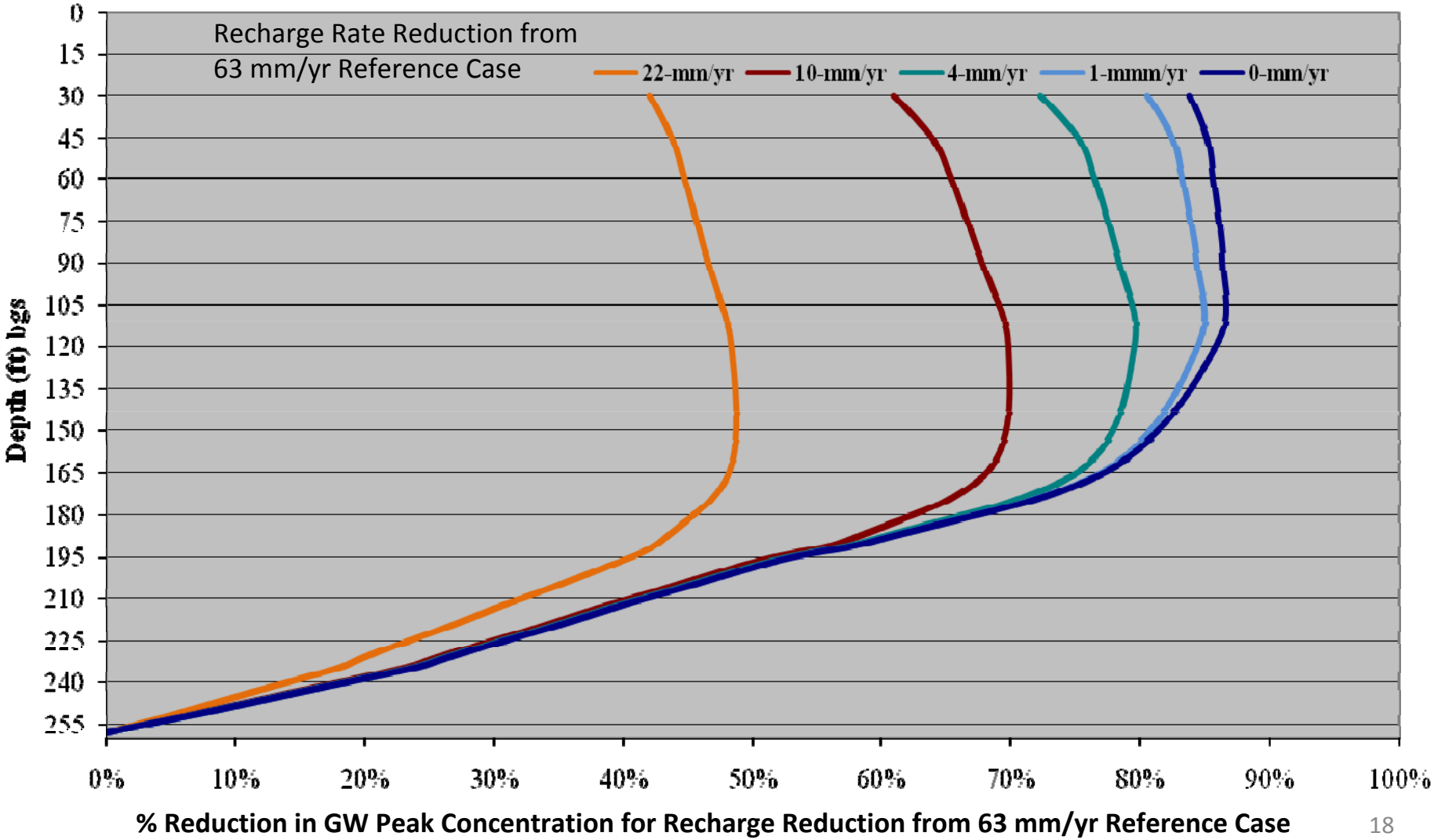
Example Applications:

Vadose Zone Protectiveness Maps: Schematic Example



Example Applications: Depth of Recharge Reduction Effectiveness (e.g., Barrier Effectiveness)

% Reduction in Peak Groundwater Concentration vs. Source Term Depth for Specified Recharge Rate Reduction Cases (from 63-mm/yr; Kd=0)



Summary

The RAGs methodology provides a technically based solution to challenges:

- Development of valid and compliant metrics for vadose zone soil contaminant levels protective of groundwater
- Groundwater protection values that are significantly larger than background or other conservative default levels
- Provides a consistent basis for defining remedy protectiveness of groundwater protection
- Provides a consistent basis for defining risk/impact to groundwater from vadose zone contaminants

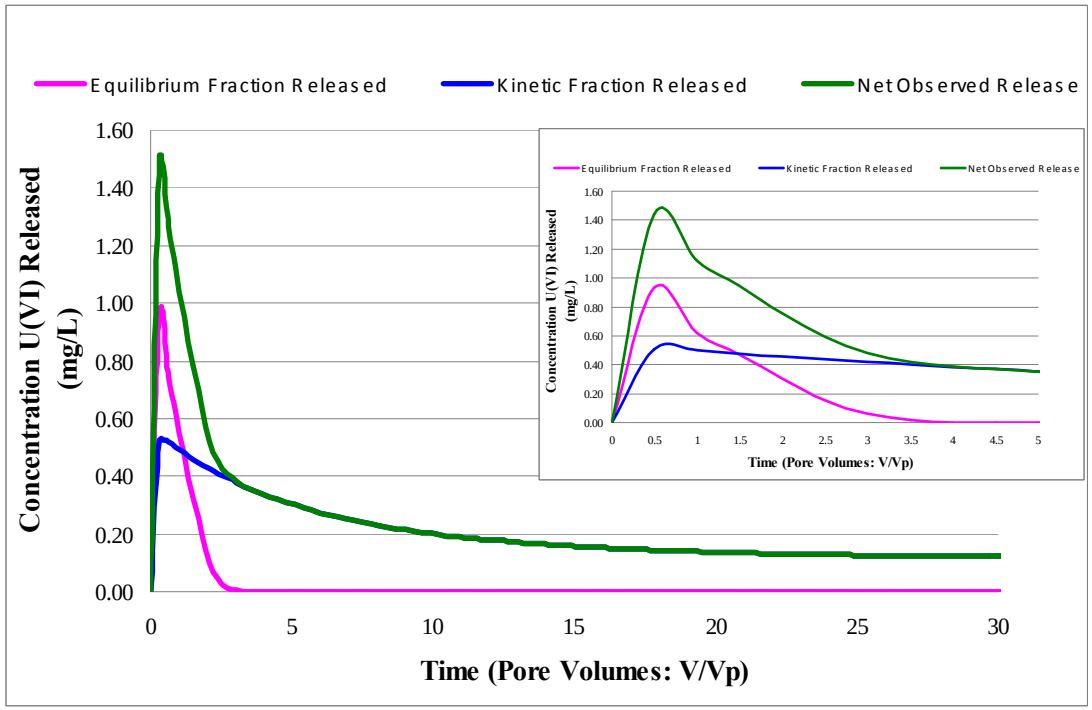
Summary

Merits of the RAGs methodology and metrics :

- The RAGs methodology and calculated RAG values are broadly applicable for assessing protectiveness for shallow and deep vadose zone contamination associated with most types of vadose zone remedial actions
- The methodology is consistent with federal and state requirements and guidelines
- The methodology provides a consistent approach, new tools and insights for remedial action efforts, decisions, and risk communication

Recommendations for the ASCEM Initiative

- Interface for generating functional relationships and translating model results to useful tools
- Accommodation of multiple contaminant release processes (e.g., uranium example)



Example: Fractions of uranium released from contaminated Hanford sediment by equilibrium and kinetic processes