Hanford Site

Waste Management Area C Performance Assessment (PA)

Current Status

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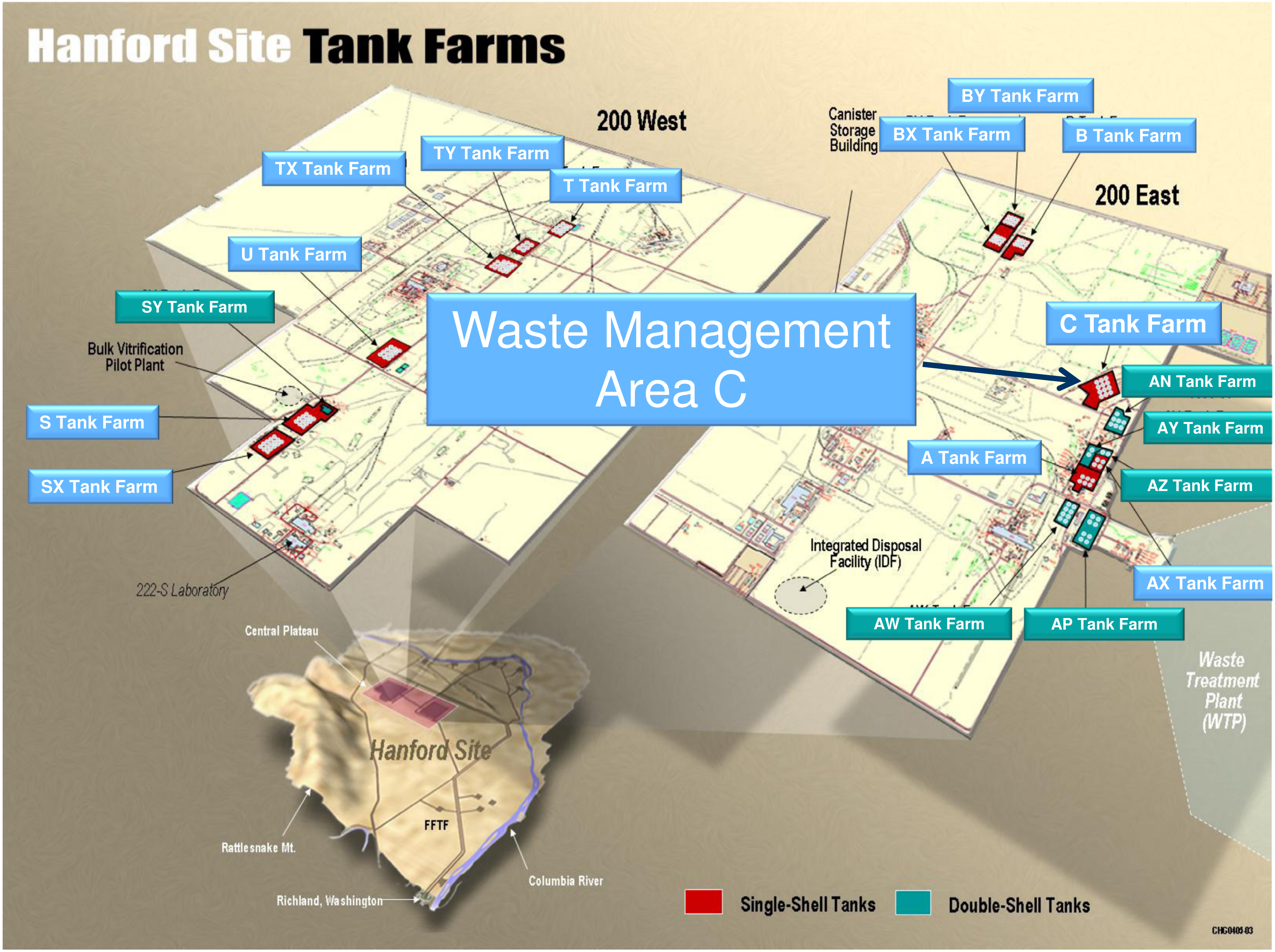
Alaa Aly INTERA

Performance and Risk Assessment
Community of Practice Technical Exchange
December 11-12, 2014

Presentation Outline

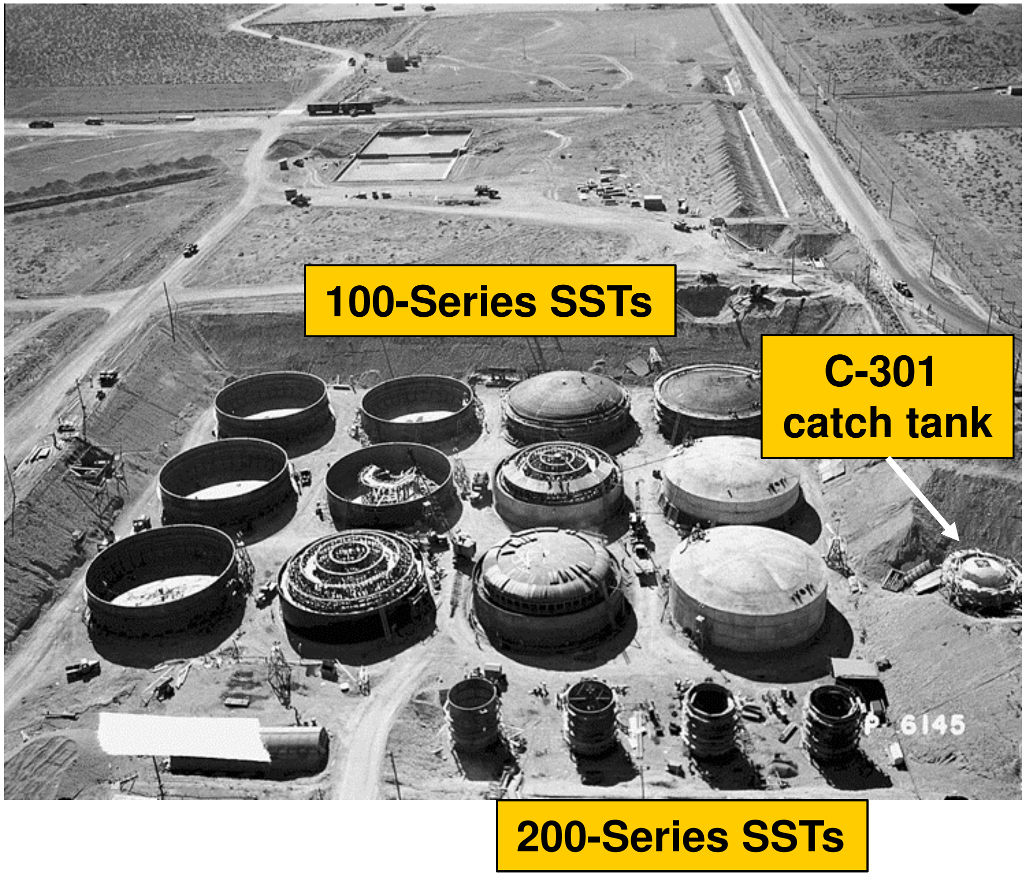
- Background and Status: Waste Management Area C Performance Assessment
- Selected Topics
  - Tank and Grout Degradation Modeling Approach
  - Evaluating Effects of Vadose Zone Heterogeneities on Model Results.



Hanford Site Tank Farms
200 West
200 East
TX Tank Farm
TY Tank Farm
T Tank Farm
U Tank Farm
SY Tank Farm
Bulk Vitrification Pilot Plant
S Tank Farm
SX Tank Farm
222-S Laboratory
Canister Storage Building
BY Tank Farm
BX Tank Farm
B Tank Farm
Waste Management Area C
C Tank Farm
AN Tank Farm
AY Tank Farm
A Tank Farm
AZ Tank Farm
Integrated Disposal Facility (IDF)
AX Tank Farm
AW Tank Farm
AP Tank Farm
Waste Treatment Plant (WTP)
Central Plateau
Hanford Site
FFTF
Rattlesnake Mt.
Columbia River
Richland, Washington
Single-Shell Tanks
Double-Shell Tanks

WMA C Operational History

- Constructed in 1943-1944
- Operated from 1946 through mid-1980s storing and transferring waste
- Due long operational history, WMA C received waste generated by essentially all of the Hanford Site major chemical processing operations

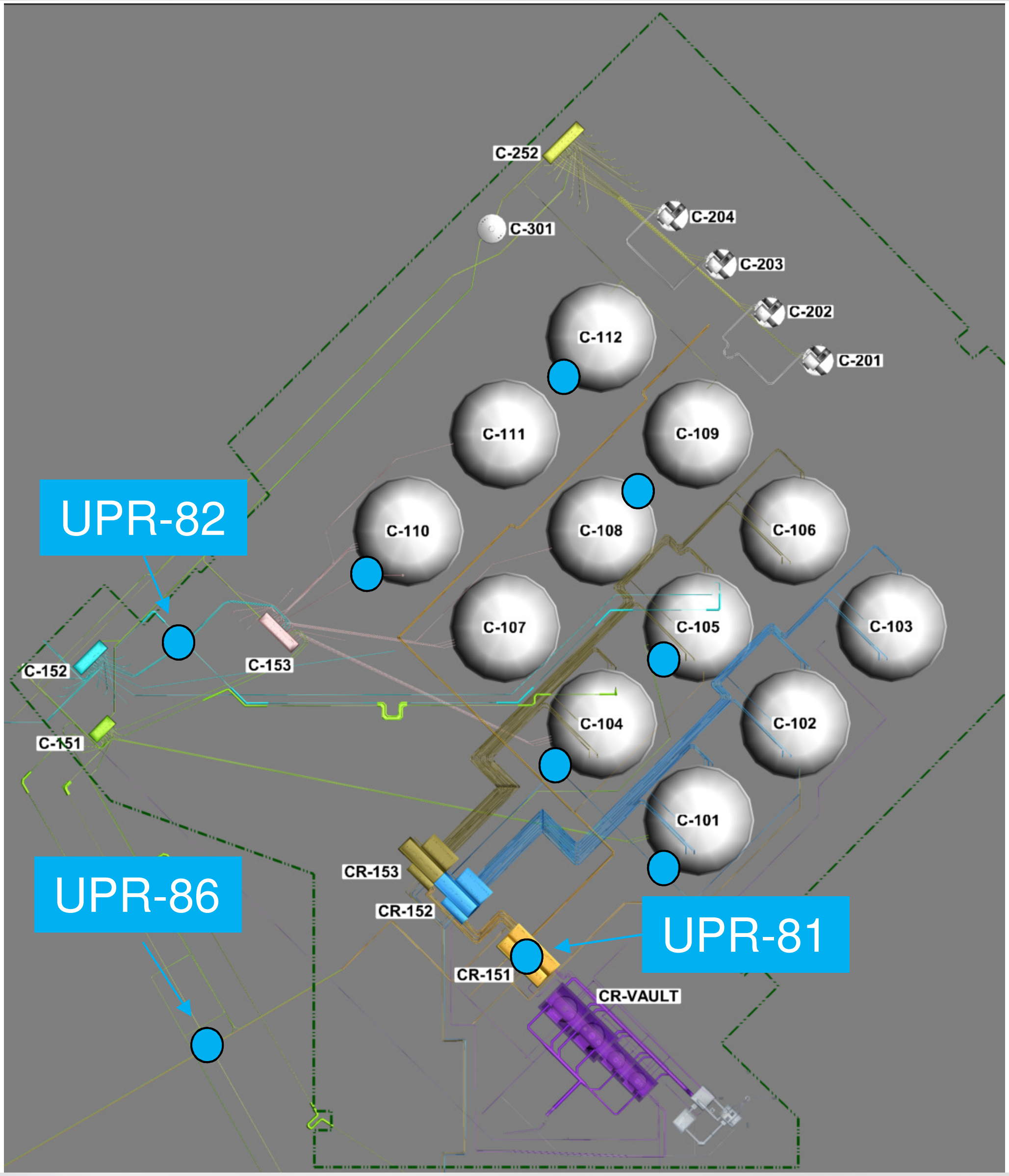


WMA C Operational Period Releases*

Summary of Past Releases

C-101	→	37,000 Gal
C-104	→	28,000 Gal
C-105	→	2,000 Gal
C-108	→	18,000 Gal
C-110	→	2,000 Gal
C-112	→	7,000 Gal
UPR-81	→	36,000 Gal
UPR-82	→	2,600 Gal
UPR-86	→	17,000 Gal
Total Releases	→	**149,600 Gal**

* RPP-ENV-33418, 2014, ***Hanford C-Farm Leak Assessments Report***, Rev. 3.



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WMA C Tank Retrieval Status

Ten Single Shell Tanks

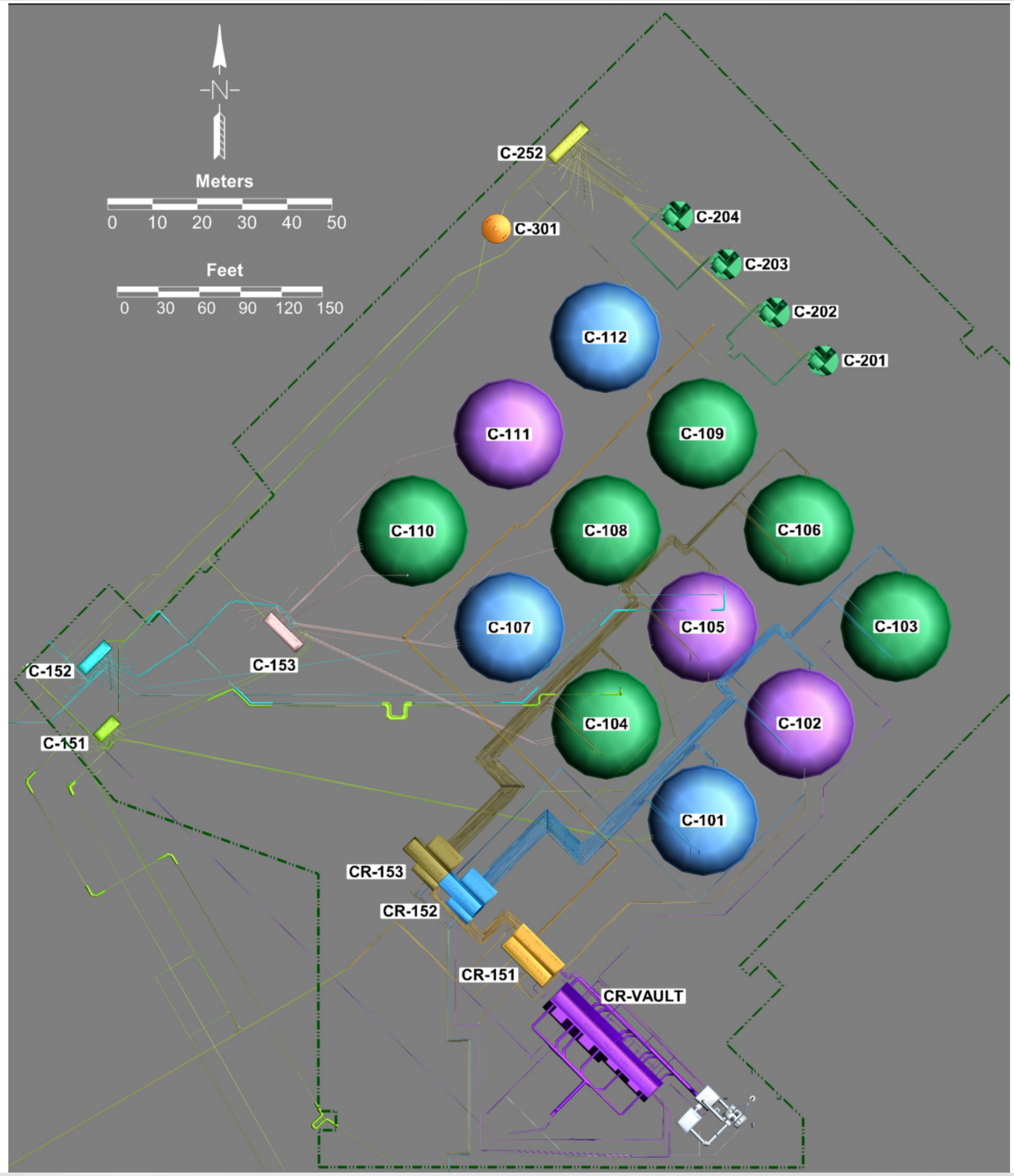
- Retrieval complete
- Inventory based on sampled residuals and final residual volumes
- Seven tanks with release rate studies*

Three Single Shell Tanks

- Retrieval complete and sampling underway
- Inventory estimated from chemical process knowledge and final residual volumes

Three Single Shell Tanks

- Retrieval Ongoing
- Inventory estimated from chemical process knowledge and estimated volume at closure



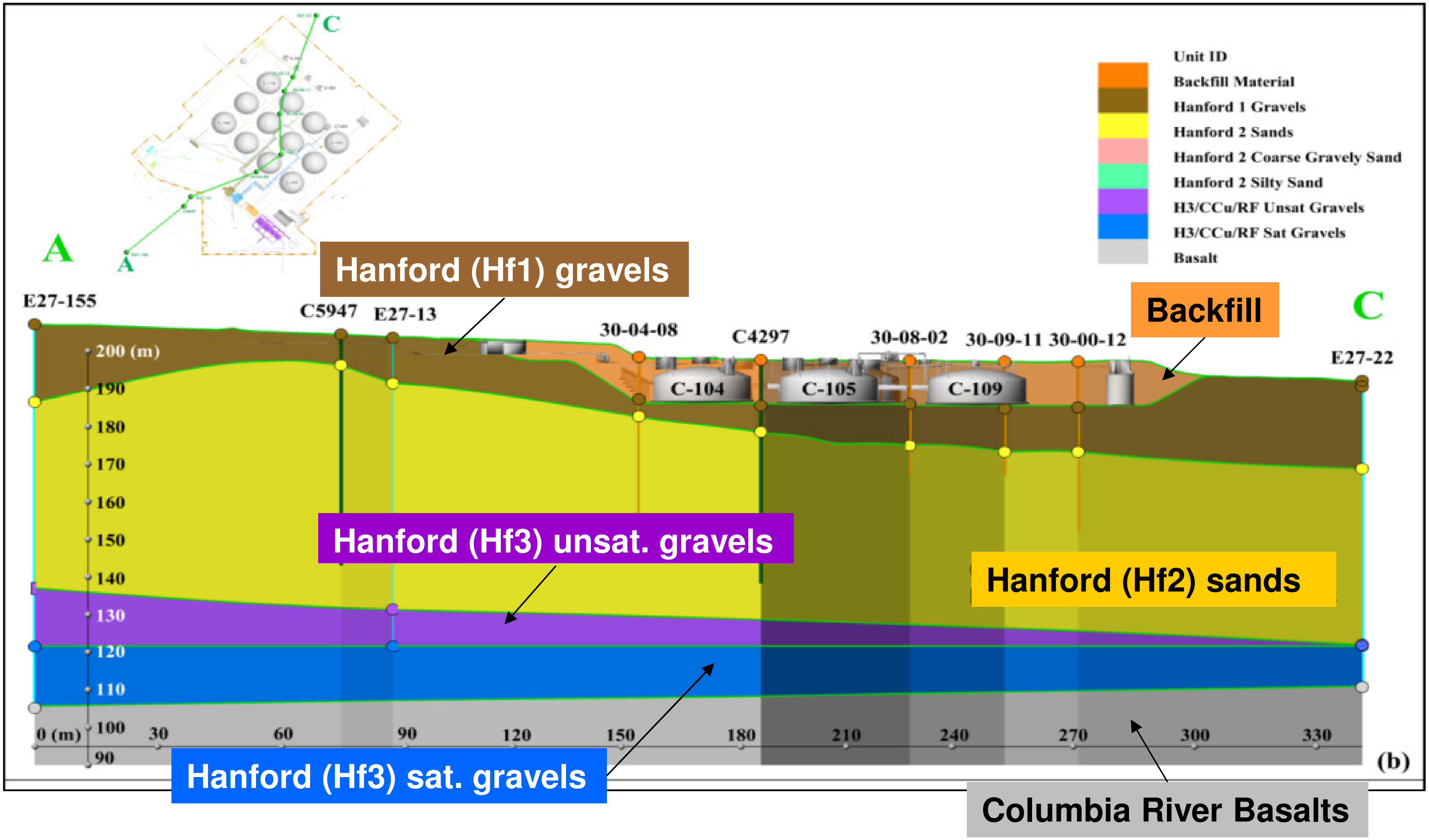
* PNNL has completed release rate studies on tank residuals for tanks C-103, C-106, C-108, C-203, C-203, C-204, and is starting on C-104

Residual Inventories of Key COPCs at Closure*

	^{99}Tc (Ci)	Total Uranium (kg)	Chromium (kg)
Retrieved Single-Shell Tanks	7.81E-01	4.92E+03	7.26E+01
Single-Shell Tanks Undergoing Retrieval**	1.00E+00	1.07E+03	2.62E+01
Ancillary Equipment	5.45E-02	1.08E+03	2.94E+01
Pipelines	4.61E-02	9.12E+02	2.49E+01
Total	**1.91E+00**	**8.58E+03**	**1.69E+02**

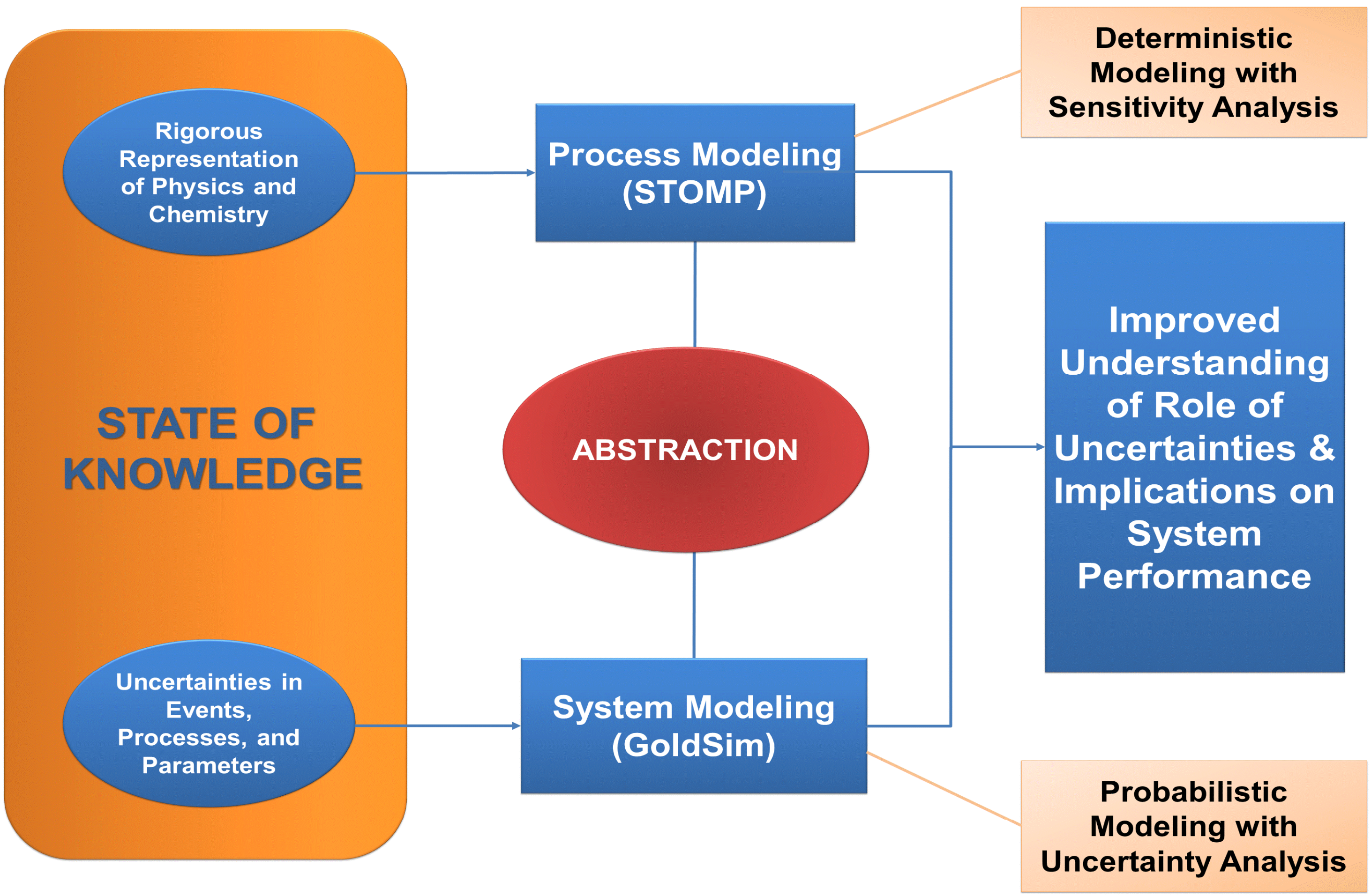
* RPP-RPT-42323, 2014, ***Hanford C-Farm Tank and Ancillary Equipment Residual Waste Inventory Estimates***, Rev. 2

** Inventory estimated using regulatory goal for retrieval of ~2,700 gals



* RPP-RPT-56356, 2014, ***Development of Alternative Digital Geologic Models of Waste Management Area C, Rev. 0***

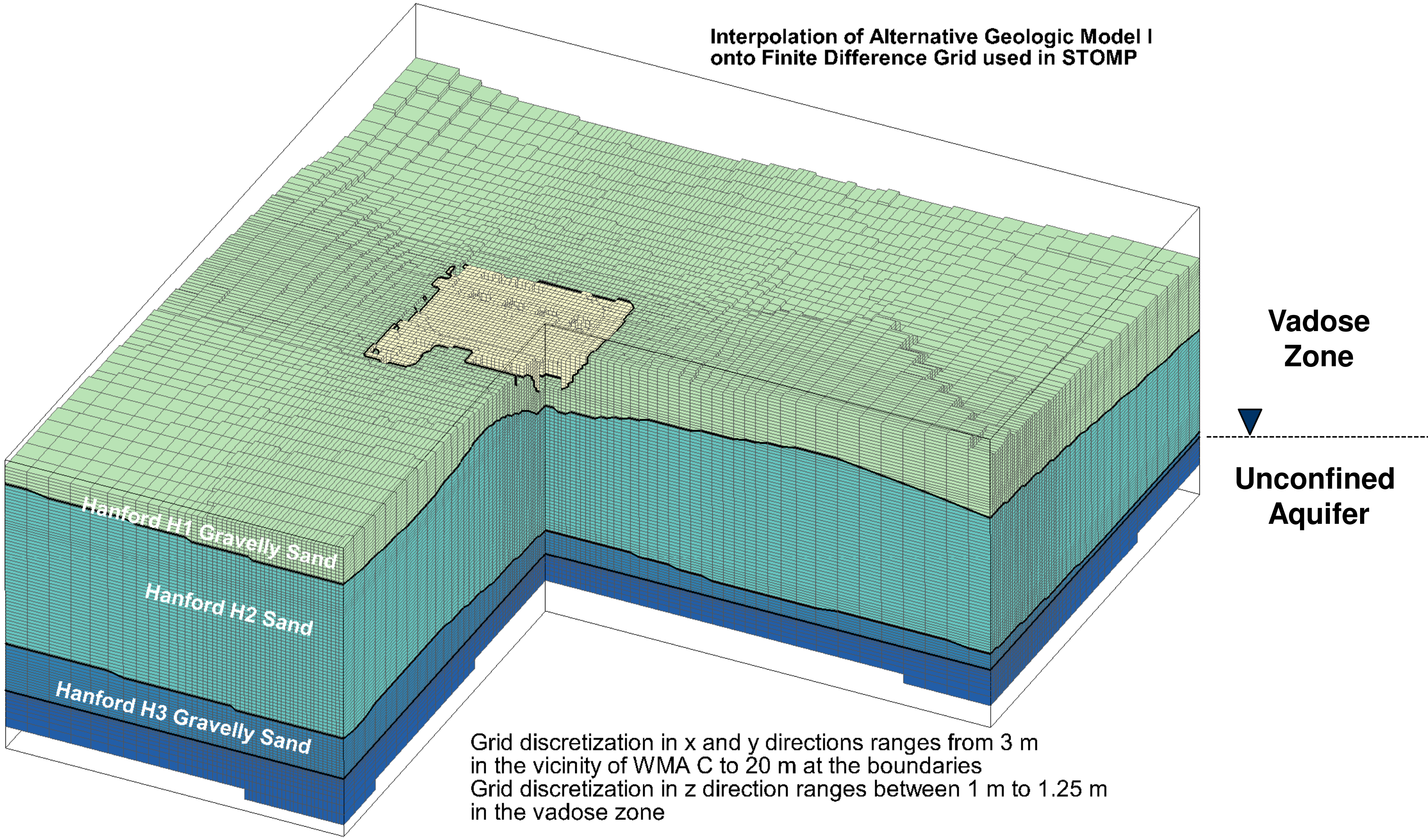
Complimentary Use of Process- Level & System-Level Models



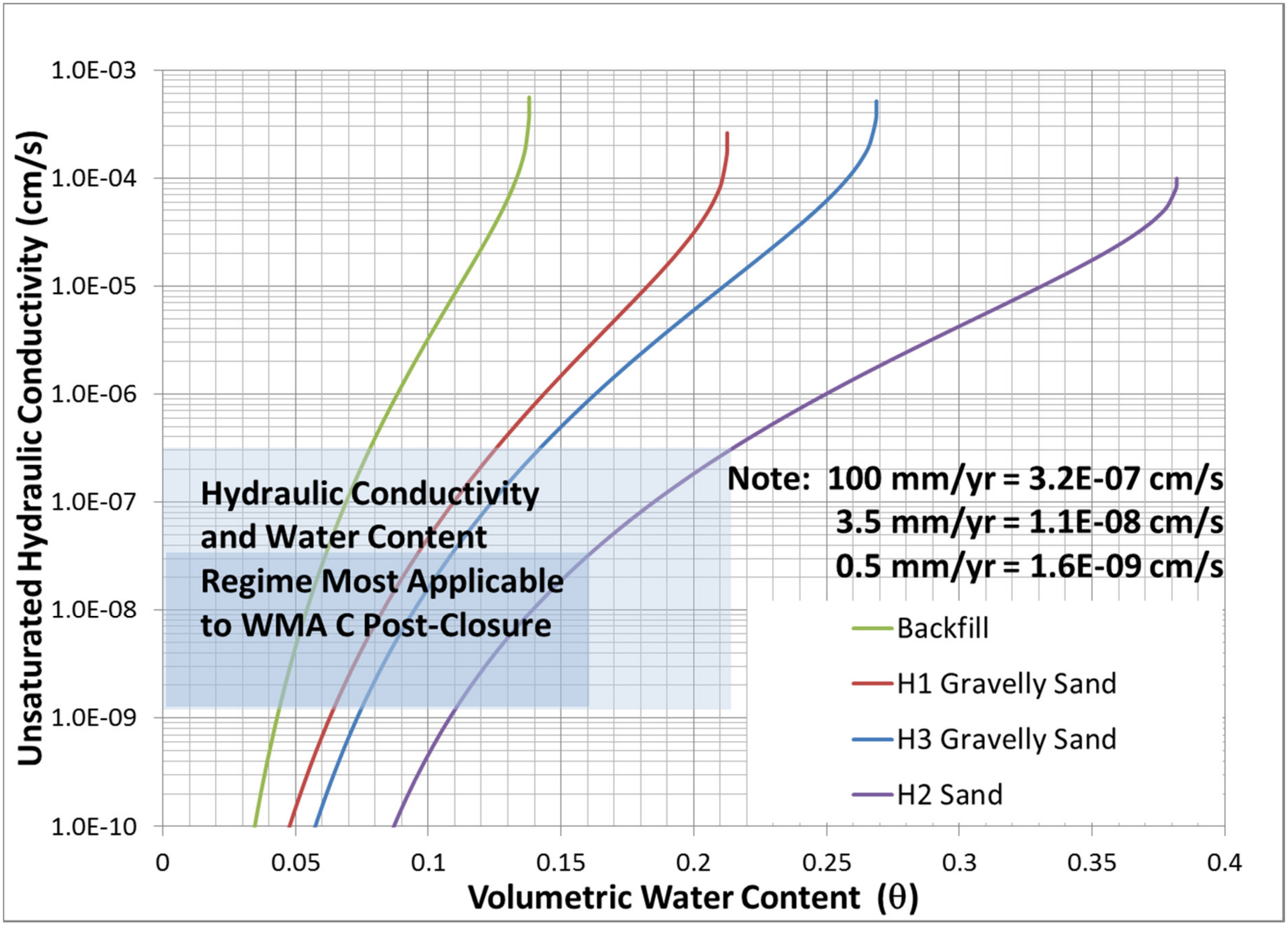
Performance Assessment Approach with Numerical Model

- **Denominator Case** (Established in Scoping)
  - Current estimates of tank residuals
  - Diffusion-controlled release for grouted tanks and equipment. Advection-controlled release for pipelines
- **Sensitivity Cases**
  - Selected tank degradation cases (diffusion-controlled to advection-controlled releases at selected tank degradation times after closure)
  - Selected recharge sensitivity cases
  - Selected upper bound residual inventories
  - Alternative hydrogeologic conceptual model sensitivity cases
    - Hydrogeologic Conceptual Model from Nez Perce Tribe
    - Highly Heterogeneous Representation

Denominator Case Model Based on STOMP



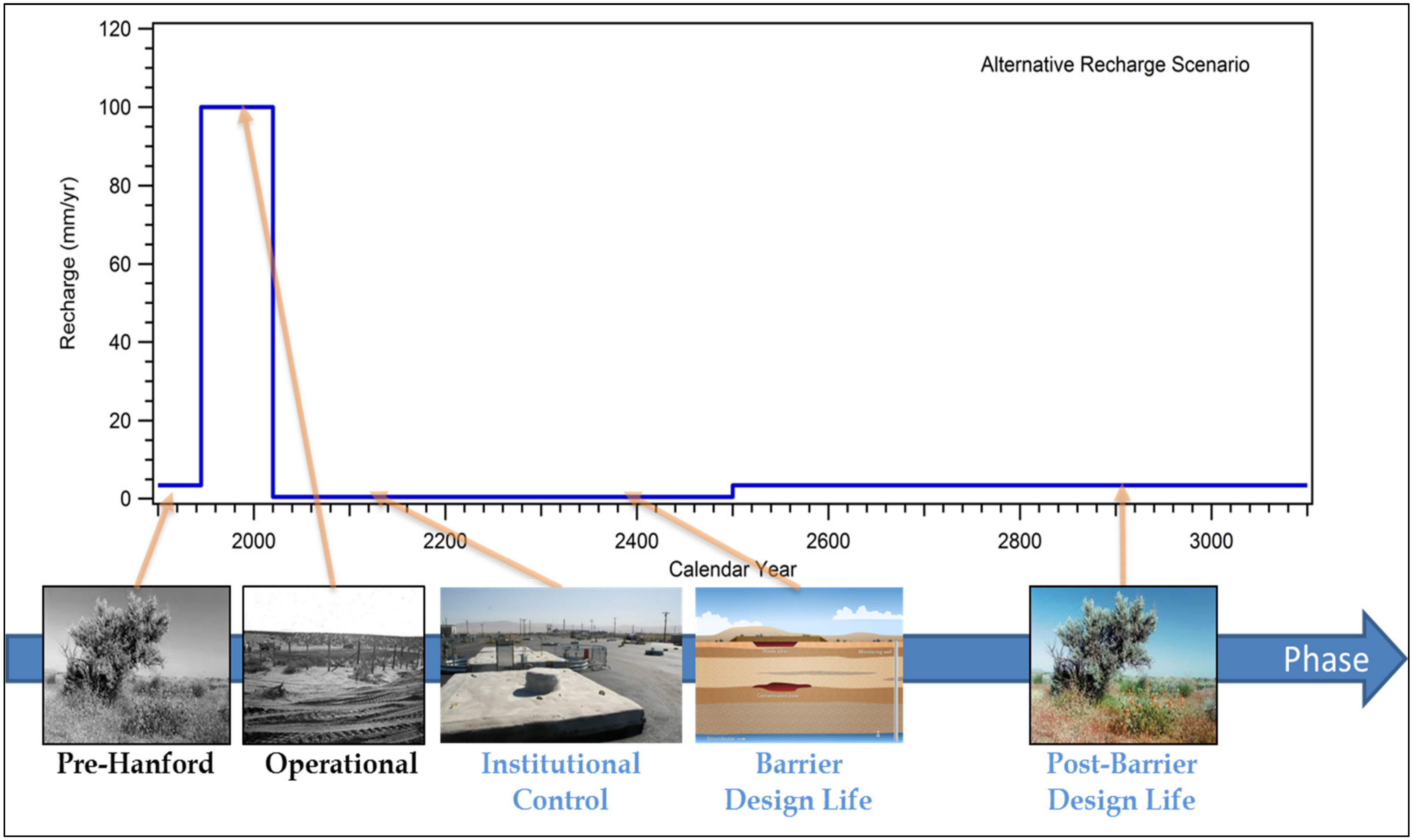
Hydraulic Properties of WMA C Model



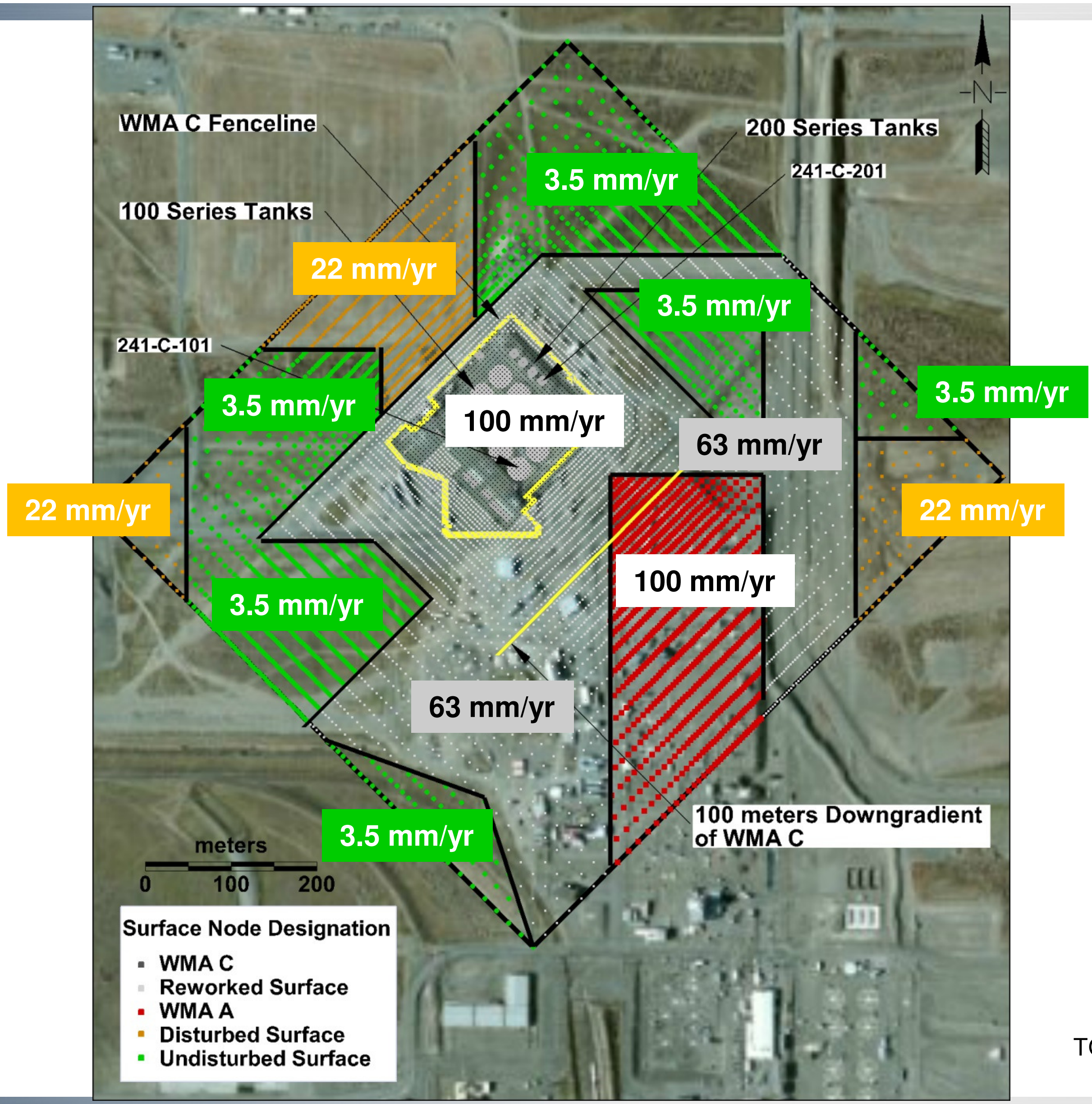
Denominator Case Recharge Rates

Surface Soil Type	Historic Simulation (pre-2020) (initial hydraulic conditions)		Predictive Simulation (post-2020) (calculation of peak groundwater concentration)		
	Pre-Hanford Phase (Before 1945)	Hanford Operations Phase (1945-2020)	Institutional Control Phase (2021-2120)	Barrier Design Life Phase (2121-2520)	Post-Barrier Design Life Phase (After 2520)
Hanford sand, disturbed	3.5	100.0	0.5	0.5	3.5

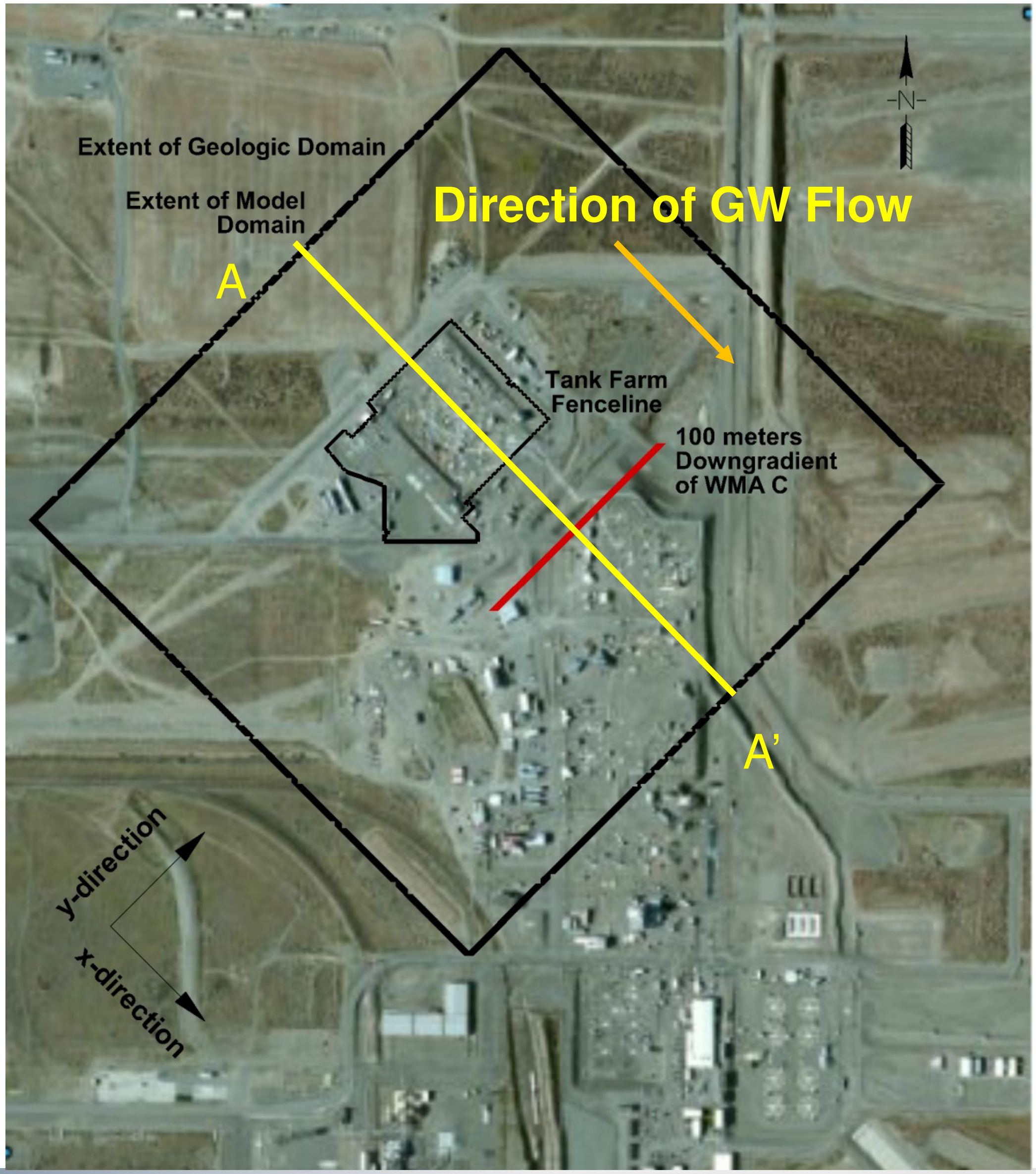
Denominator Case Recharge Rates



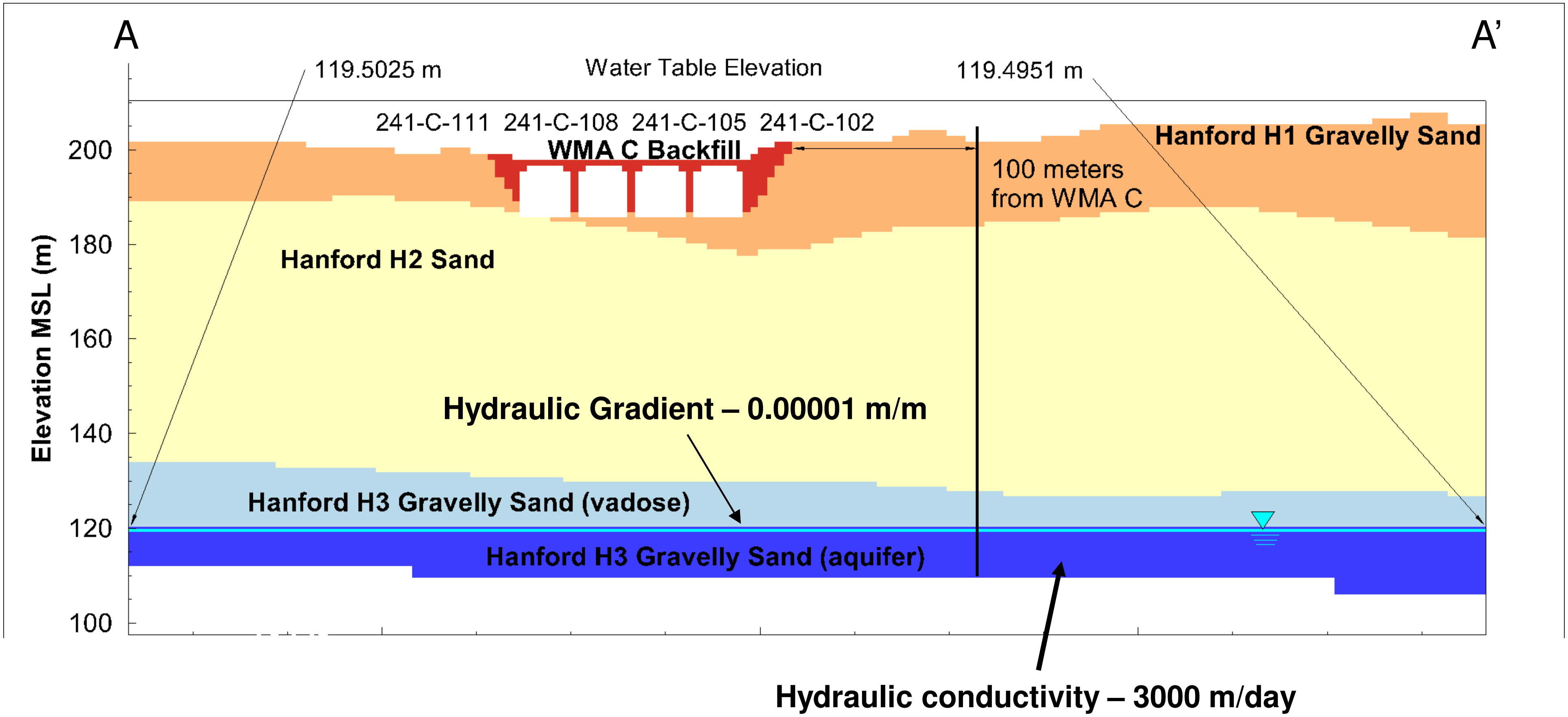
Recharge Rates Outside of WMA C (Operational Period)



WMA C Model Domain and Points of Calculation in Groundwater

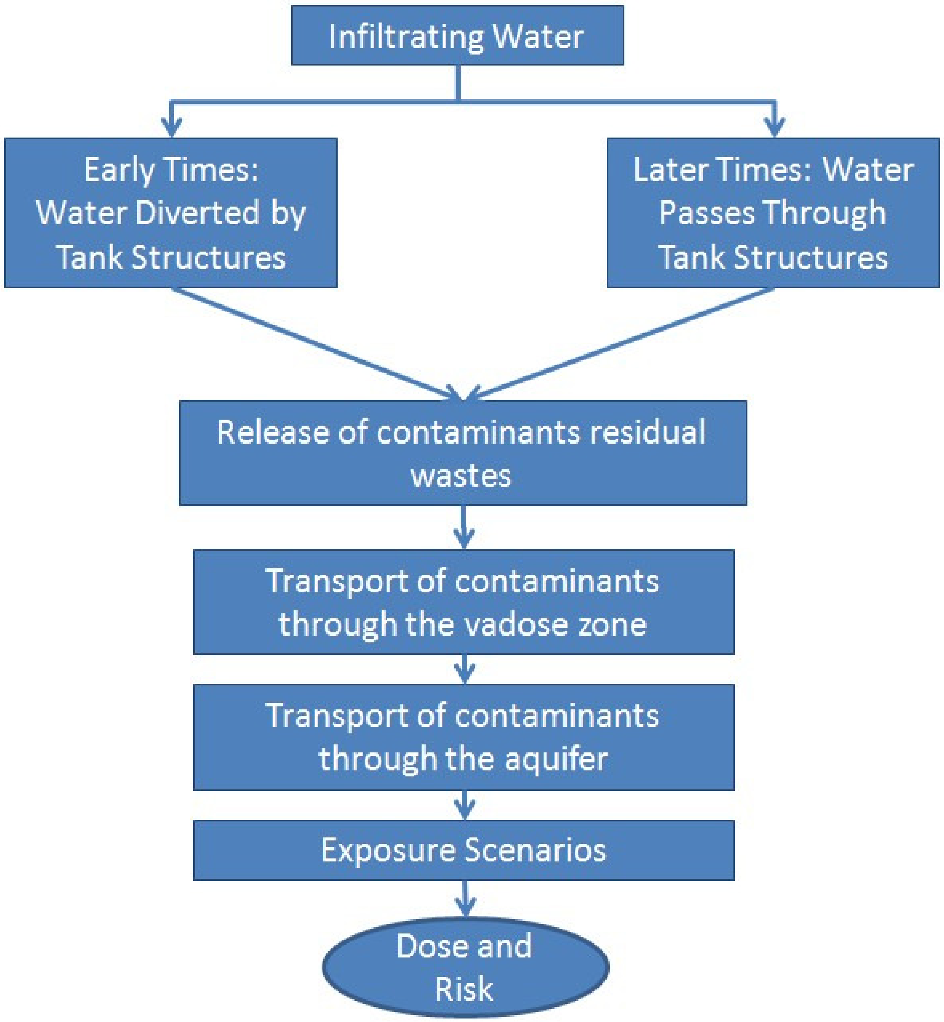


Unconfined Aquifer Properties



Basic Modeling Approach

- **Flow field (and select transport analysis) calculated with STOMP**
  - initial period (tanks intact)
  - late period (tanks degraded)
- **Flow field abstracted into GoldSim system model**
- **System model used for:**
  - Release from residuals,
  - Contaminant transport
  - Exposure-related calculations



System Modeling Implementation Status

- **Flow Abstracted and Evaluated in GoldSim-based System Model**
  - For intact and fully degraded tank cases
- **Working system-level models for all sources**
  - Twelve 100-series tanks
  - Four 200-series tanks
  - CR-Vault
  - C-301 Catch Tank
  - Pipelines

System Modeling Implementation Status

- **Waste release models implemented in system-level models**
  - Diffusion-controlled release
  - Advection-controlled release
  - Release models from PNNL waste release experiments (Tc-99, Cr, and Uranium)
- **Exposure Scenarios**
  - All pathways
  - Air pathway/radon transport
  - Groundwater protection
  - Inadvertent Intruder (acute and chronic exposure)

Anticipated PA Schedule

- **Complete and submit PA Rev. 0 documentation for tank residual impacts** – October 2015
  - 435.1 PA for radiological impacts
  - RCRA Closure Analysis for hazardous chemicals impacts
- **Conduct LFRG and Ecology review –** Oct. to Dec. 2015

Presentation Outline

- Background and Status: Waste Management Area C Performance Assessment
- Selected Topics
  - **Tank and Grout Degradation Modeling Approach**
  - Tests for Effects of Vadose Zone Heterogeneities on Model Results.

Proposed Approach for Tank and Grout Degradation Modeling for WMA C PA

- Single shell tanks will be filled with grout
- Several studies and emerging literature
- Current studies indicate that grout is expected to influence water flow for a fairly long time.

Figure 6-1. Conceptual Model of Tank Filled with Cementitious Grout Anticipated after Site Closure

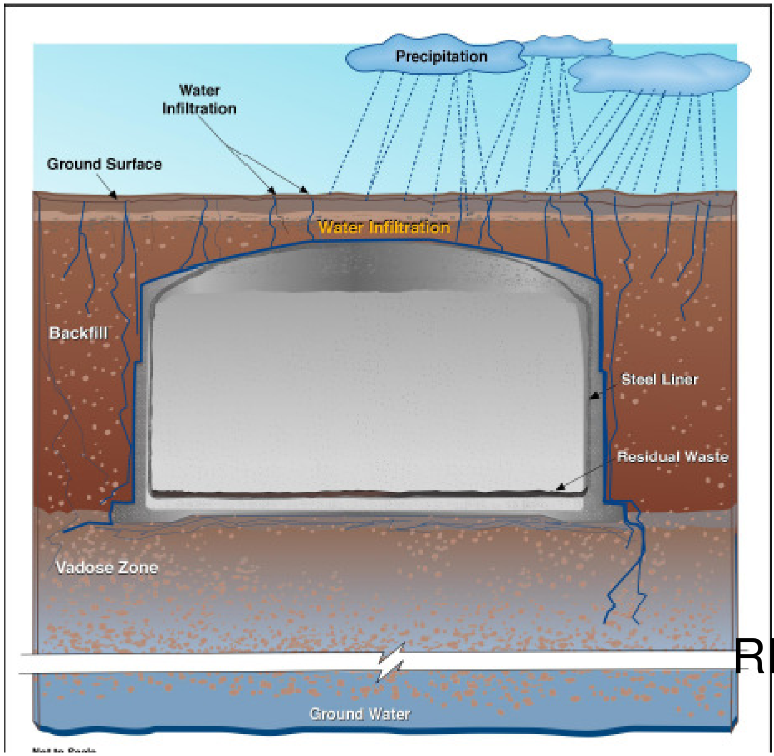
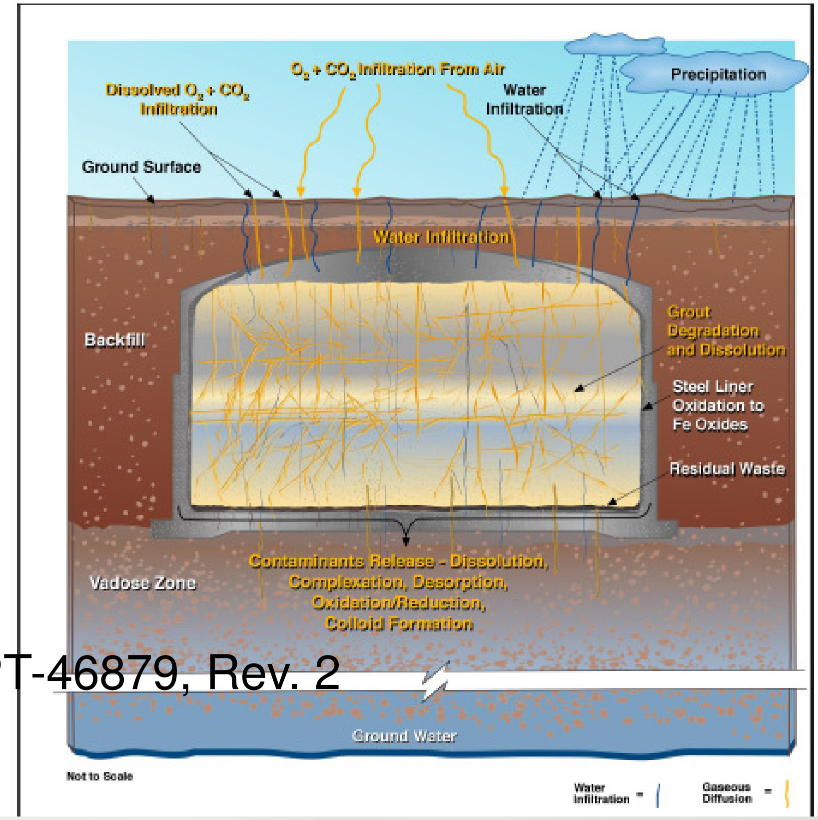


Figure 6-2. Conceptual Model of Contaminant Release from an Aged Tank Containment System Resulting from Physical and Chemical Degradation and Infiltrating of Water, Carbon Dioxide and Oxygen



241-C-107 Dome Plug

- 55-inch diameter of reinforced concrete was removed in December 2010 from dome of C-107*
- Cutting was performed using a combination of high pressure water and garnet abrasive
- No cracks were observed
- 14 cores taken (4.2” diameter)
  - 12 cores underwent mechanical testing
  - 2 cores were sent for petrographic examination
- No evidence of chemical attack or significant alkali-aggregate reactions were observed
- Depth of carbonation was shallow and about 1 to 2 mm from top surface

Figure 6. SST 241-C-107 Dome Plug

* WRPS-51711-FP, 2012, ***Overview of Hanford Single-Shell Tank (SST) Structural Integrity***

Brown et al., 2013, Modeling Carbonation of High-Level Waste Tank Integrity and Closure, EPJ Web of Conferences, v. 56.

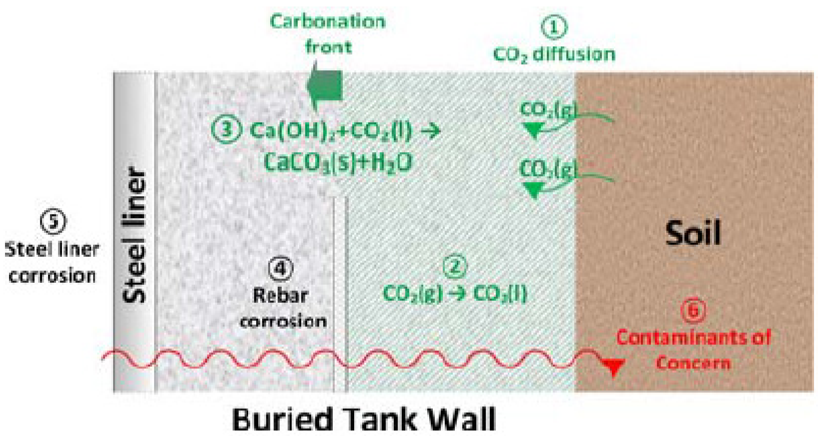


Table 1. Materials Considered in this Report (wt%). All materials characterized except for silica fume (SF); a representative composition was used for this material.

Material	HPC	BGM	SVC	VCO	VCT
Blast Furnace Slag (BFS)	0.00	13.48	8.03	7.12	7.31
Fly Ash – Type F (FAF)	0.00	6.62	16.93	0.00	4.29
Ordinary Portland Cement (OPC)	22.20	5.40	5.40	10.75	5.60
Silica Fume (SF)	0.00	0.00	0.00	0.00	1.22
Quartz Sand (QS)	66.70	62.25	55.02	29.12	24.73
Gross Aggregate (GA)	0.00	0.00	0.00	46.19	50.14
Water	11.10	11.76	14.62	6.83	6.86

HPC – Hydrated Portland Cement
BGM – Backfill Grout Material
SVC – Standard Vault Concrete
VCO – Vault Concrete One
VCT – Vault Concrete Two

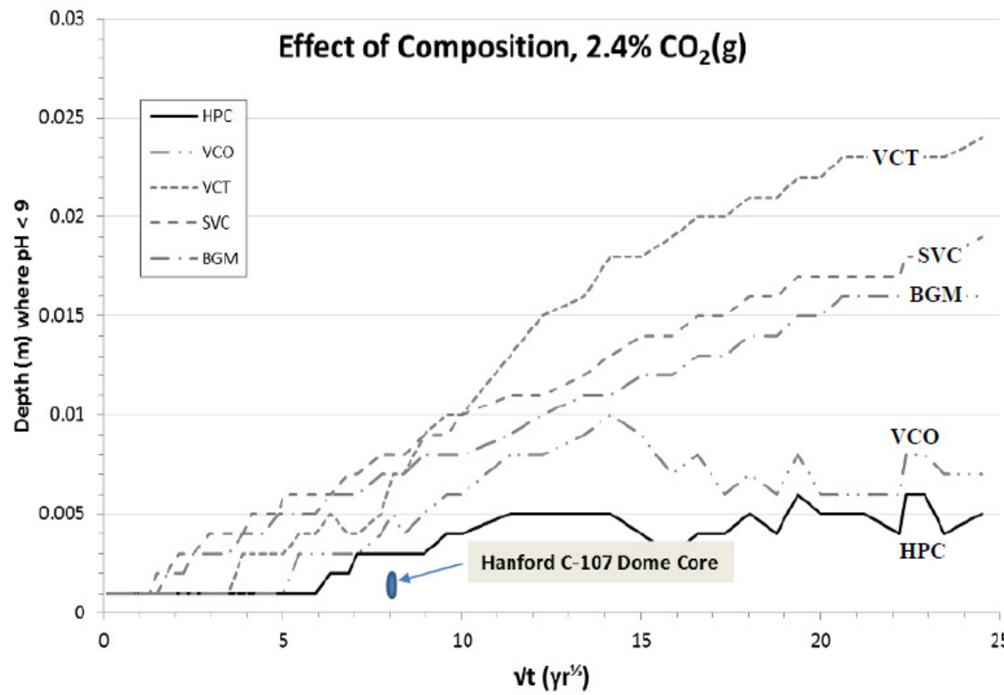


Fig. 5. Carbonation Model Results (2.4% Soil-Gas CO_2; 90% Saturation) for the Materials Studied.

Concrete Carbonation rate = **1.5 to 3 cm in 1000 years**

The carbonation depth (**0.001-0.002 m in 65 years**) for a dome core from the Hanford C-107 HLW tank appears to reasonably agree with predictions, considering uncertainties in field conditions and likely differences among assumed and actual transport parameters

Carbonation of Hanford Site Structures* (1)

- Core samples were obtained from above-ground, concrete structures on the Hanford Site:
- Weathering for about 14, 28, and 57 years
- Transverse slices taken and then characterized by petrographic analysis

* PNNL-23841, 2014, **Radionuclide Migration through Sediment and Concrete: 16 Years of Investigations**

Carbonation of Hanford Site Structures (2)

Table 5.2. Characteristics of concrete cores from Hanford Site

Characteristic	FLTF	622C	213J
Age	14	28	57
Carbonation Depth (mm)	1 – 10	2 – 8	48 – 53
Air Content (%)	4 – 5	2 – 4	1 – 2
Water/Cement Ratio	0.50 – 0.55	0.50 – 0.55	0.52 – 0.57
Secondary Deposits	Abundant ettringite lining voids	Ettringite lining voids	None in outer 50 mm – minor ettringite lining voids
Microcracks	Minor	Minor	Common in outer 50 mm
Unit Weight (pcf)	153	152	148
Steel	#4 ~103 mm cover	None	#4 ~80 mm cover
Aggregates	Well-graded siliceous gravel, 19 mm top size	Well-graded siliceous gravel, 23 mm top size	Well-graded siliceous gravel, 21 mm top size
Paste-Aggregate Bond	Moderately tight	Moderately tight	Moderately tight to moderately weak

- Given the limited information the rate of carbonation can be approximated to be: **30 cm to 90 cm/1000 year**

Tank Vault Concrete Degradation Rates* (July 2010 Engineered System II Session)

- Sulfate attack – 1.7 cm in 1,000 years
- Alkali aggregate attack – low alkali content and resistant aggregates so not applicable
- Acid leaching – 6.5 cm in 1,000 years
- Carbonation dominant degradation rate from reinforced concrete (rebar corrosion) – ***20.8 cm in 1,000 years***

* Kent Rosenberger (SRR) - **Concrete and Grout Degradation Findings and Implementation – Savannah River Site (July 28, 2010)**

Tank Fill Grout Degradation Rates* (July 2010 Engineered System II Session)

- Sulfate attack – 1.2 cm in 1,000 years
- Alkali aggregate attack – low alkali content and resistant aggregates so not applicable
- Acid leaching – ***8.2 cm in 1,000 years***
- Carbonation applicable for reinforced concrete (rebar corrosion) and used for tanks with cooling coils (i.e., Types I, III, and IIIA) – ***35.6 cm in 1,000 years***

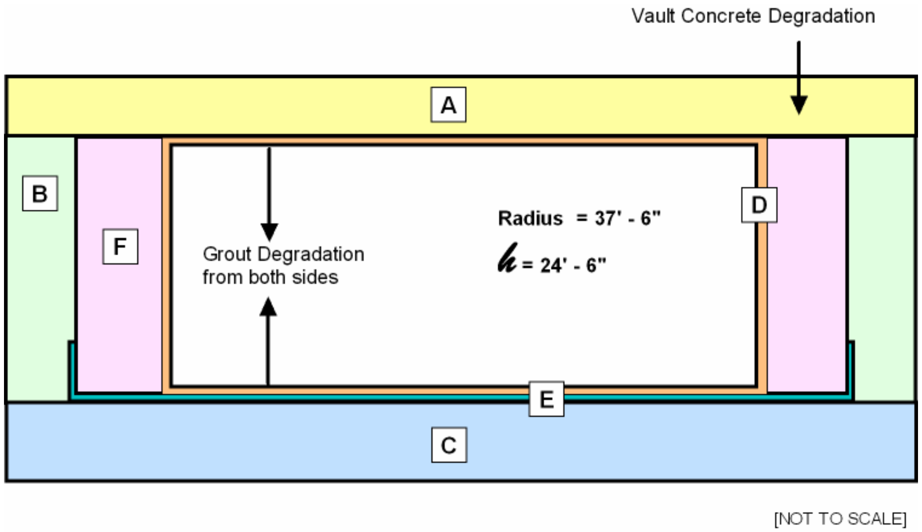
* Kent Rosenberger (SRR) - **Concrete and Grout Degradation Findings and Implementation – Savannah River Site (July 28, 2010)**

Calculation of Degradation Times* (July 2010 Engineered System II Session)

- For each tank type first calculated minimum thickness of tank concrete
- Assumed that hydraulic degradation began when front reached ½ of the minimum thickness
- Tank fill grout degradation began after tank concrete fully degraded and full degradation after the front reached ½ of the thickness since degradation front moving from both sides
- See Type I tank example

* Kent Rosenberger (SRR) - **Concrete and Grout Degradation Findings and Implementation – Savannah River Site (July 28, 2010)**

Calculation of Degradation Times* (July 2010 Engineered System II Session)



LABEL	THICKNESS
A Concrete Roof	22"
B Concrete Wall	22"
C Concrete Basemat	30"
D Primary Liner	0.5"
E Secondary Liner	5' high and 0.5" thick
F Grouted Annulus	30"

Minimum concrete thickness= 22" (55.88 cm)

½ thickness=11" (27.94 cm)

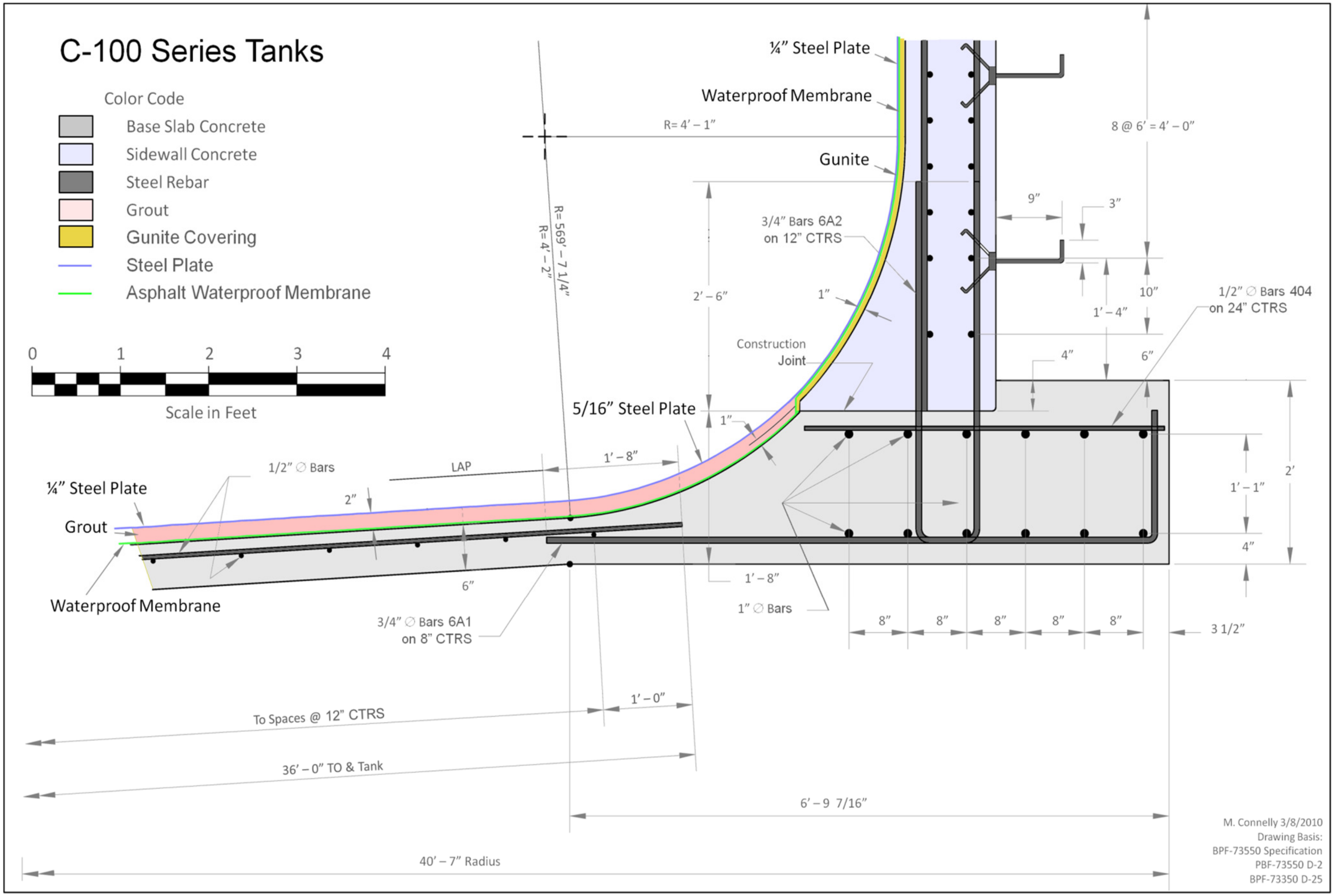
Time for front to reach ½ thickness=27.94 cm/21 cm/ 1000 yr~1,300 yr

Time for front to reach full thickness~2,600 yr

* Kent Rosenberger (SRR) - **Concrete and Grout Degradation Findings and Implementation – Savannah River Site (July 28, 2010)**

Concrete-Grout Carbonation Based Degradation Calculation

- C-107 dome core indicates carbonation degradation rate of **1.5 to 3 cm/1000 years**
  - However the modeling indicated that carbonation rates could be higher by factor of 2 to 4 (~**6 cm/1000 years**)
- Brown et al. (2013) used an approximate rate of **100 cm/1000 years** for tanks where carbonation rate is not known
- SRS PA used a carbonation rate of **21 to 36 cm/1000 years** for reinforced concrete
- Hanford concrete (above ground) indicates carbonation rate of **30 to 90 cm/1000 years**
- The range appears to be: 3 cm to 100 cm/1000 years with a (bounding) best estimate of about **30 cm/1000 year**



Concrete + Grout: 12 inch side wall thickness; 8 inch base thickness

Concrete-Grout Base Thickness Carbonation Degradation Calculation

- Minimum thickness of concrete + grout layer is at the base = 8 inches (20.3 cm)
- Taking the C-107 carbonation rate of 3 cm/1000 years and doubling it to 6 cm/1000 years (conservative)
- The carbonation front will take 3300 years to penetrate 8-inch thickness

Summary – Grout Degradation Calculation

- Considering only 5.49 m thickness of grout in-fill within 100 Series tank and assuming carbonation front moves from both top and bottom direction
- Effective half-thickness is about 2.745 m
- Using carbonation rate of 30 cm/1000 years the time to reach half-thickness will be about 9,100 years
- Total time for carbonation front to reach half-thickness will be = 3,300 yr + 9,100 yr = **12,400 years**.
- In order to develop uncertainty, a factor of two increase/decrease in carbonation rate can be considered, leading to a range of **6,200 and 24,800 years**.
- Continue to consult with Cementitious Barrier Partnership to refine approach

Backup slides

- Selected Topic #2

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  - **Evaluating Effects of Vadose Zone Heterogeneities on Model Results.**

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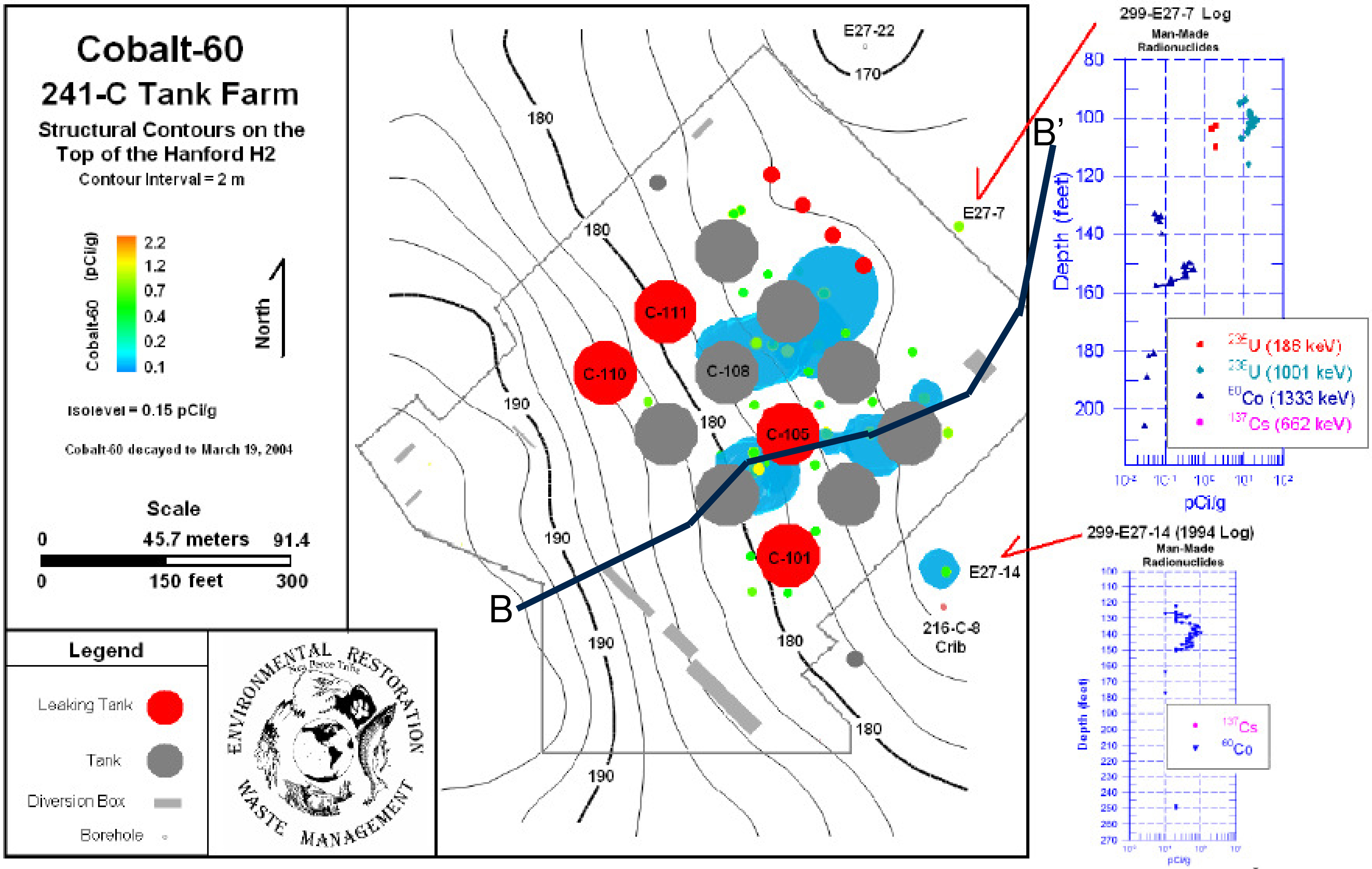
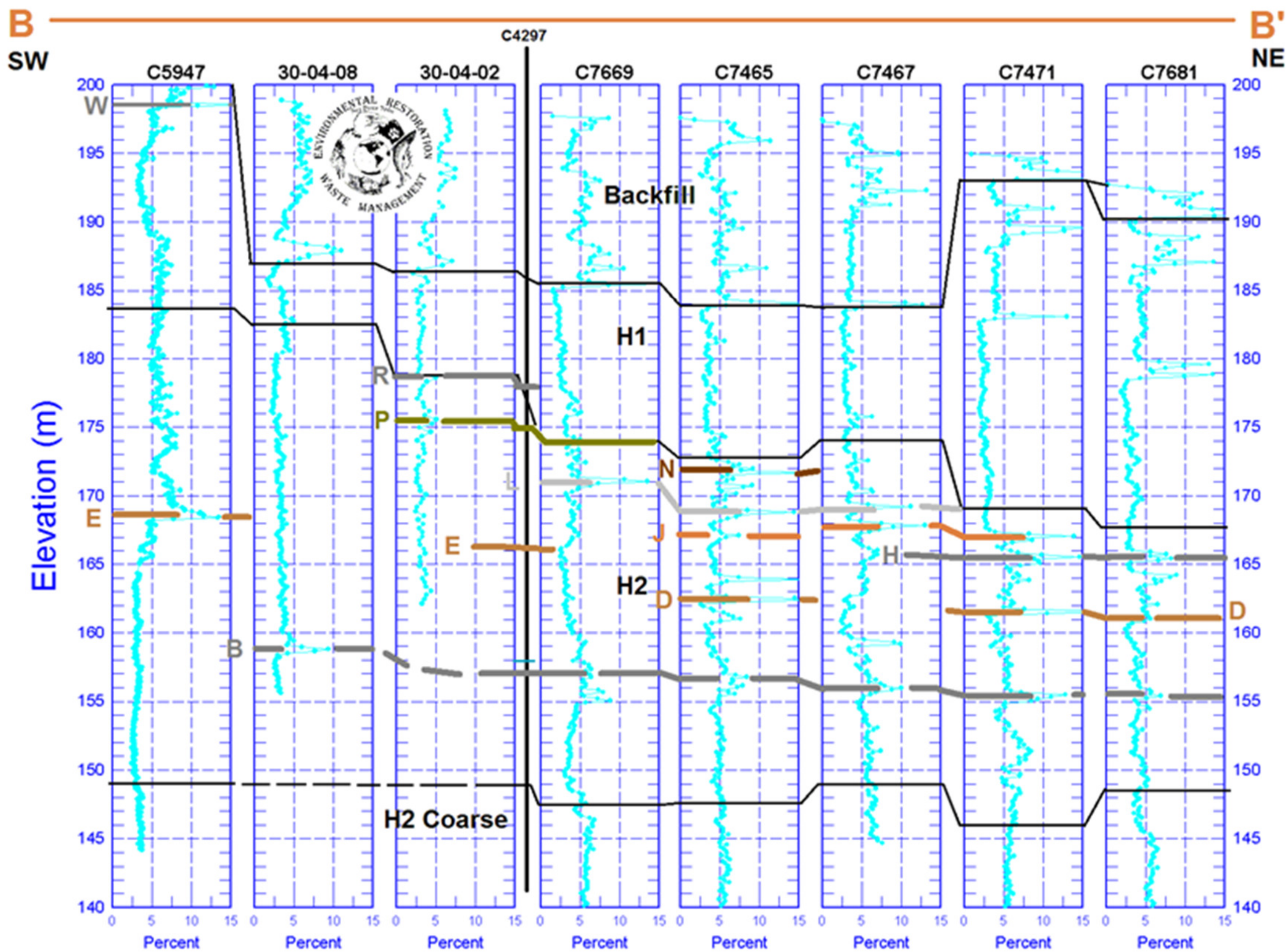
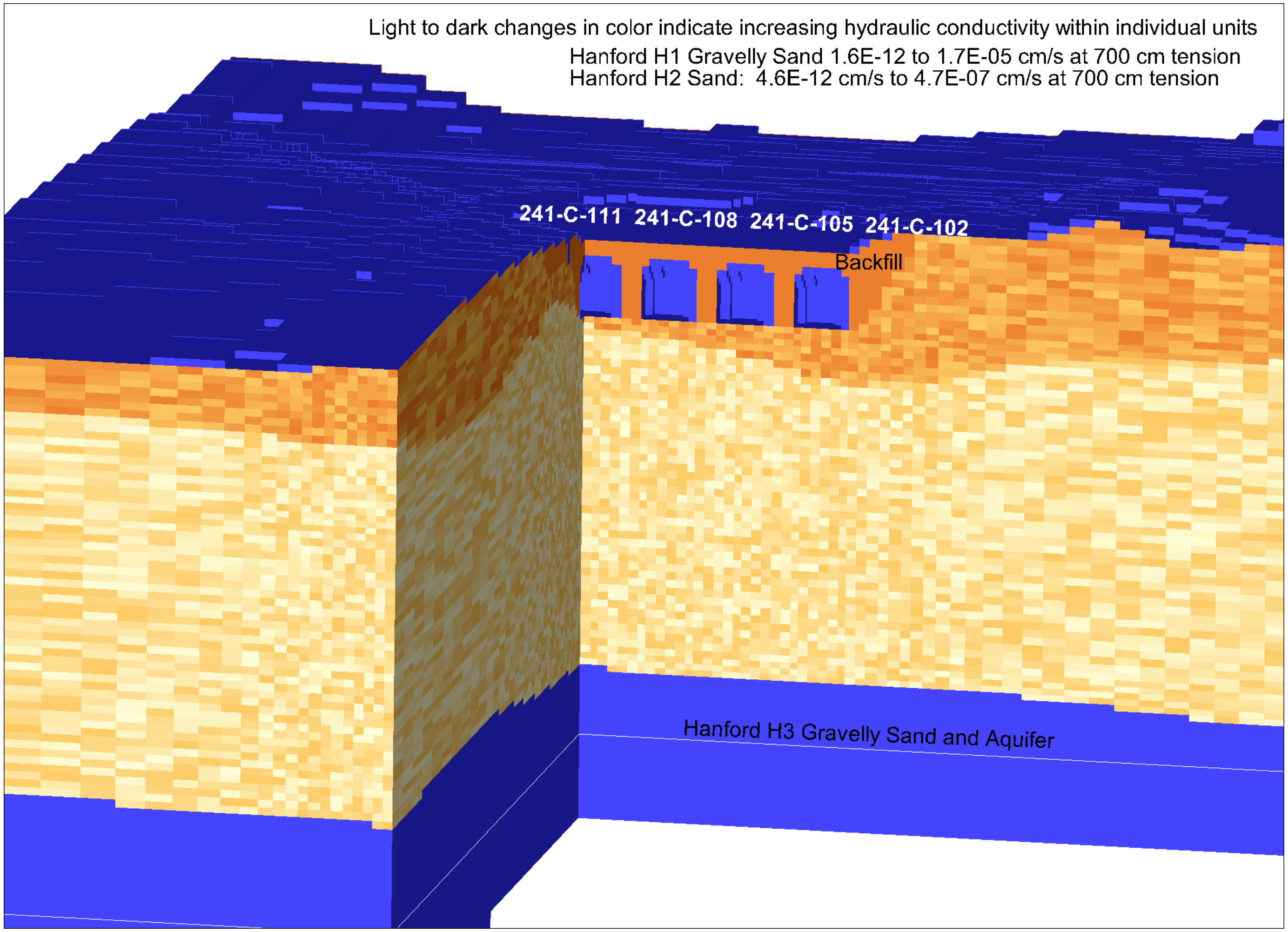
Potential Lateral Transport along Dip of H2 Unit in Vadose Zone at WMA C



Section B-B' Showing Soil Moisture Profiles

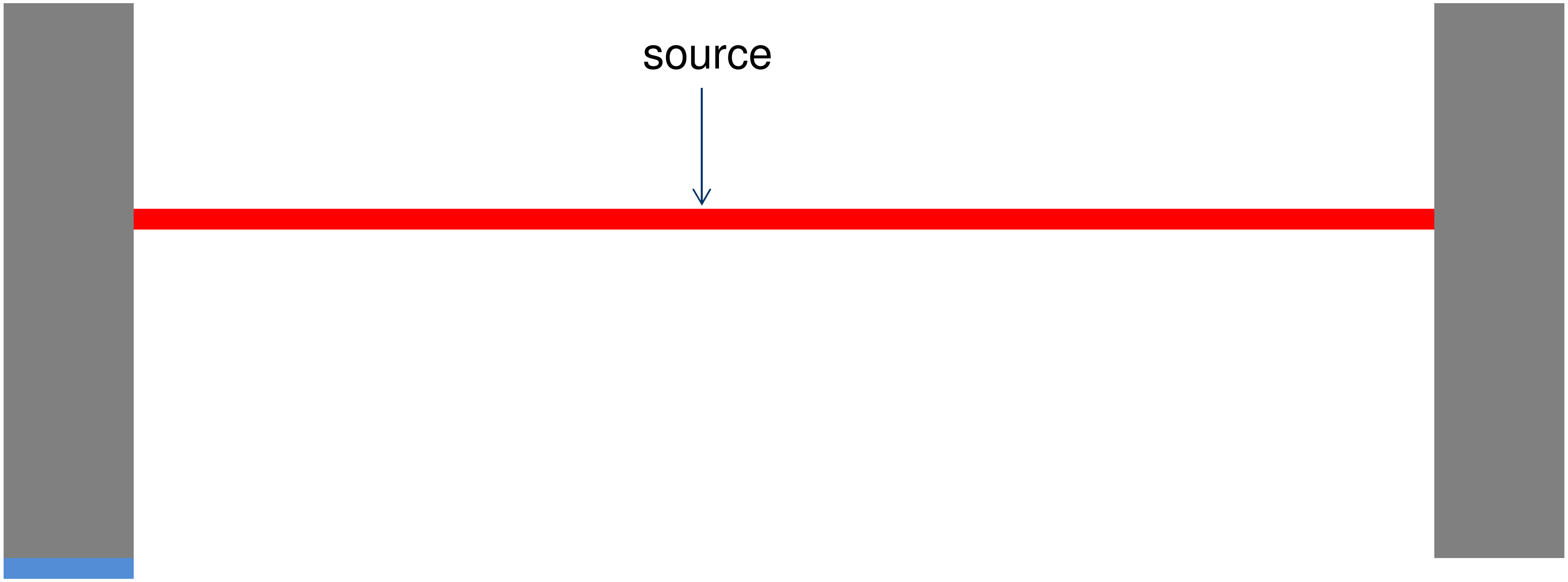


3D Model: Heterogeneous case

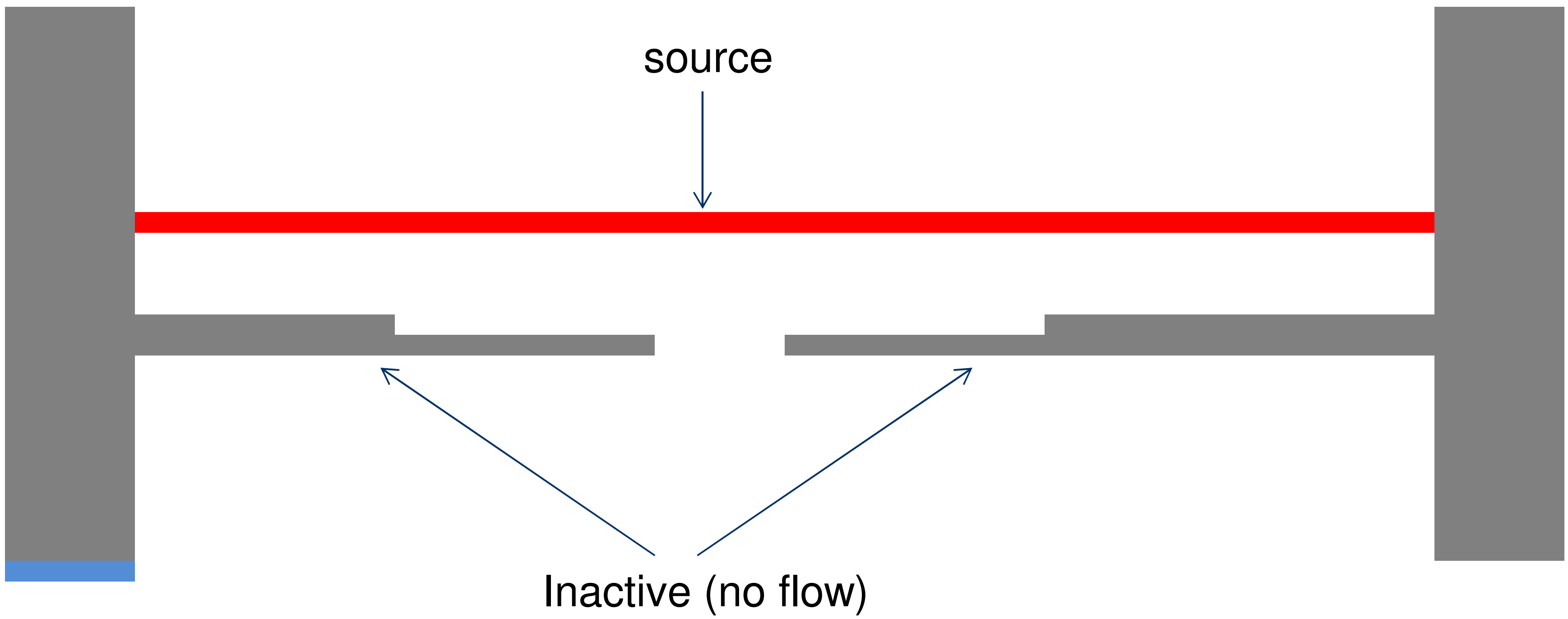


- Same Solid Model
- Random Assignment of Hydraulic Properties within each Unit

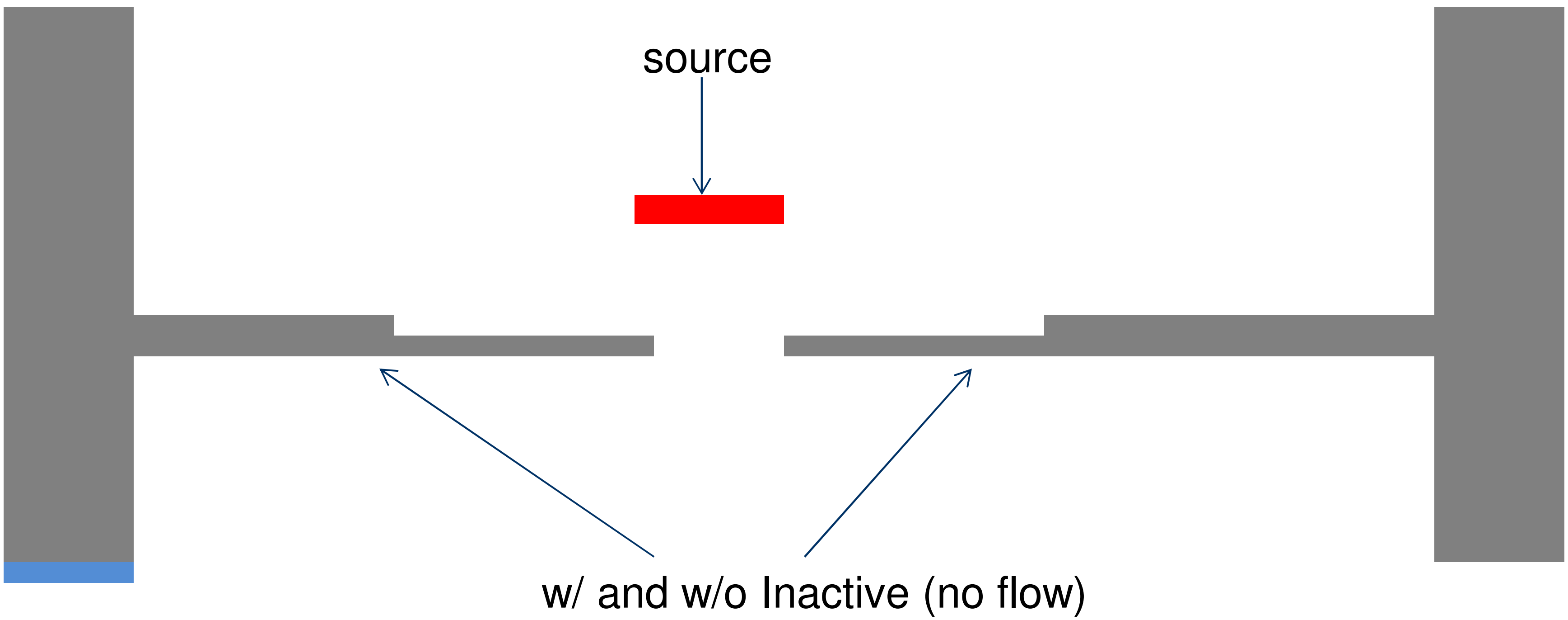
2D Test: Simple Setup



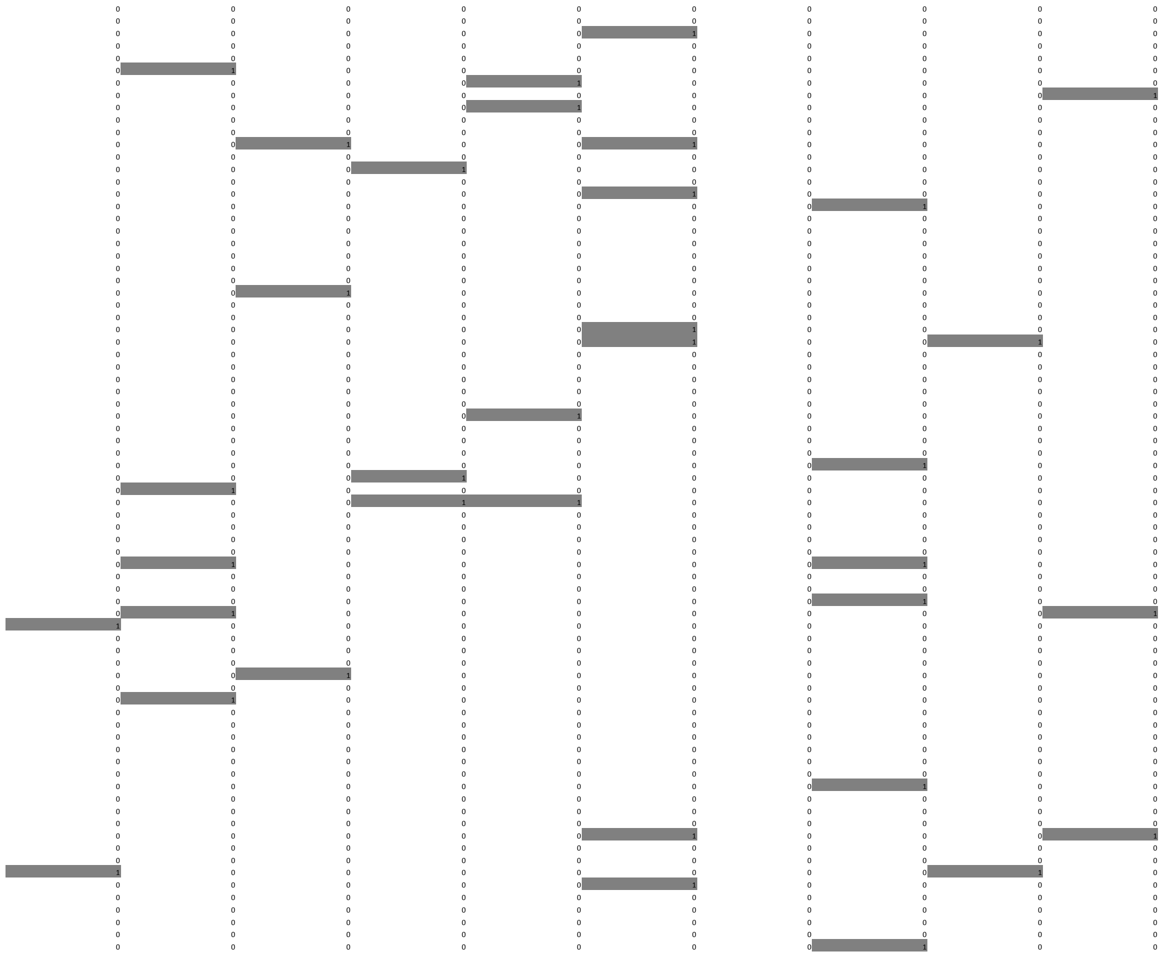
2D Test: Constricted Flow



2D Test: Constricted Flow



3D Test: Random Flat Lenses (2%, 5%, 10%)



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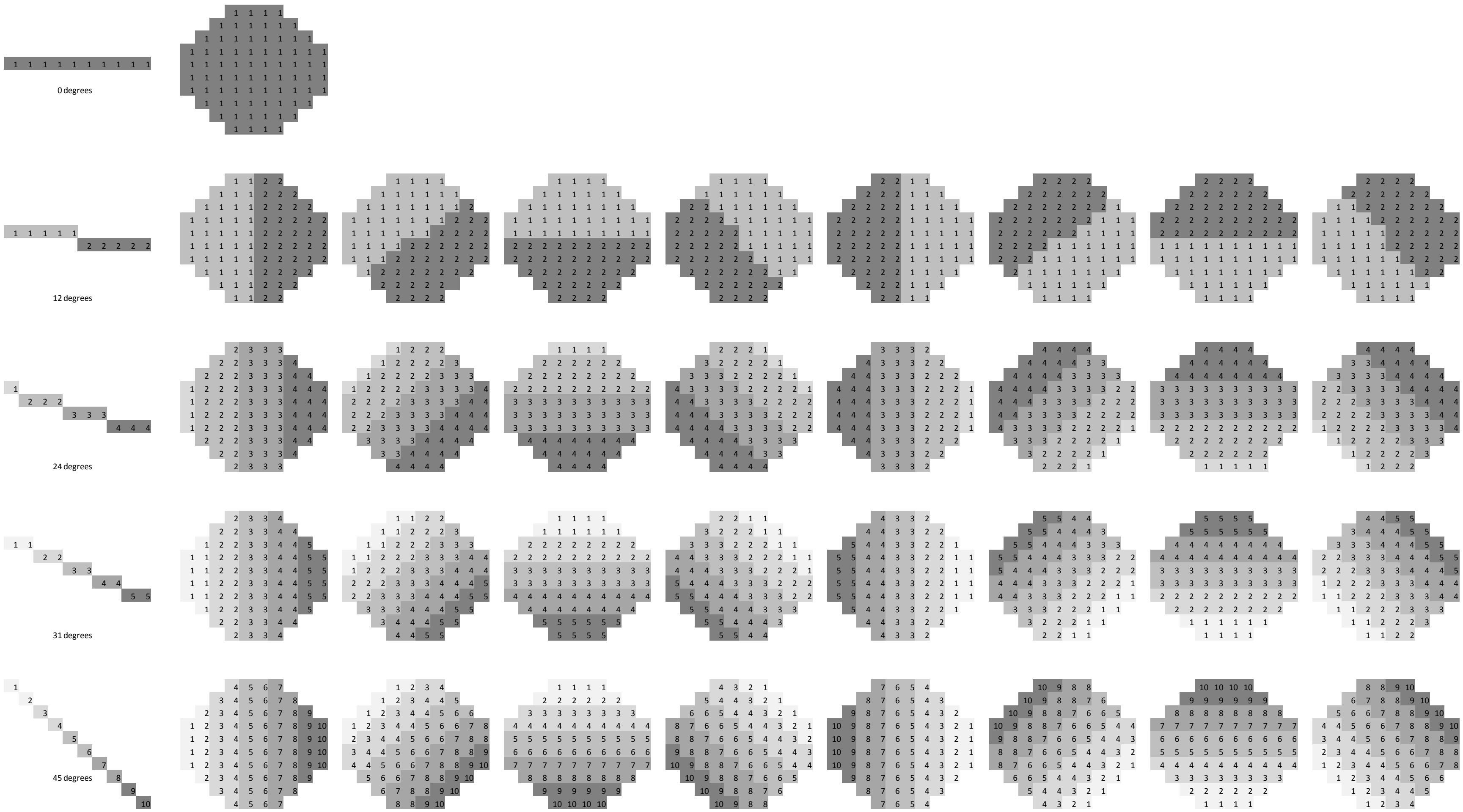
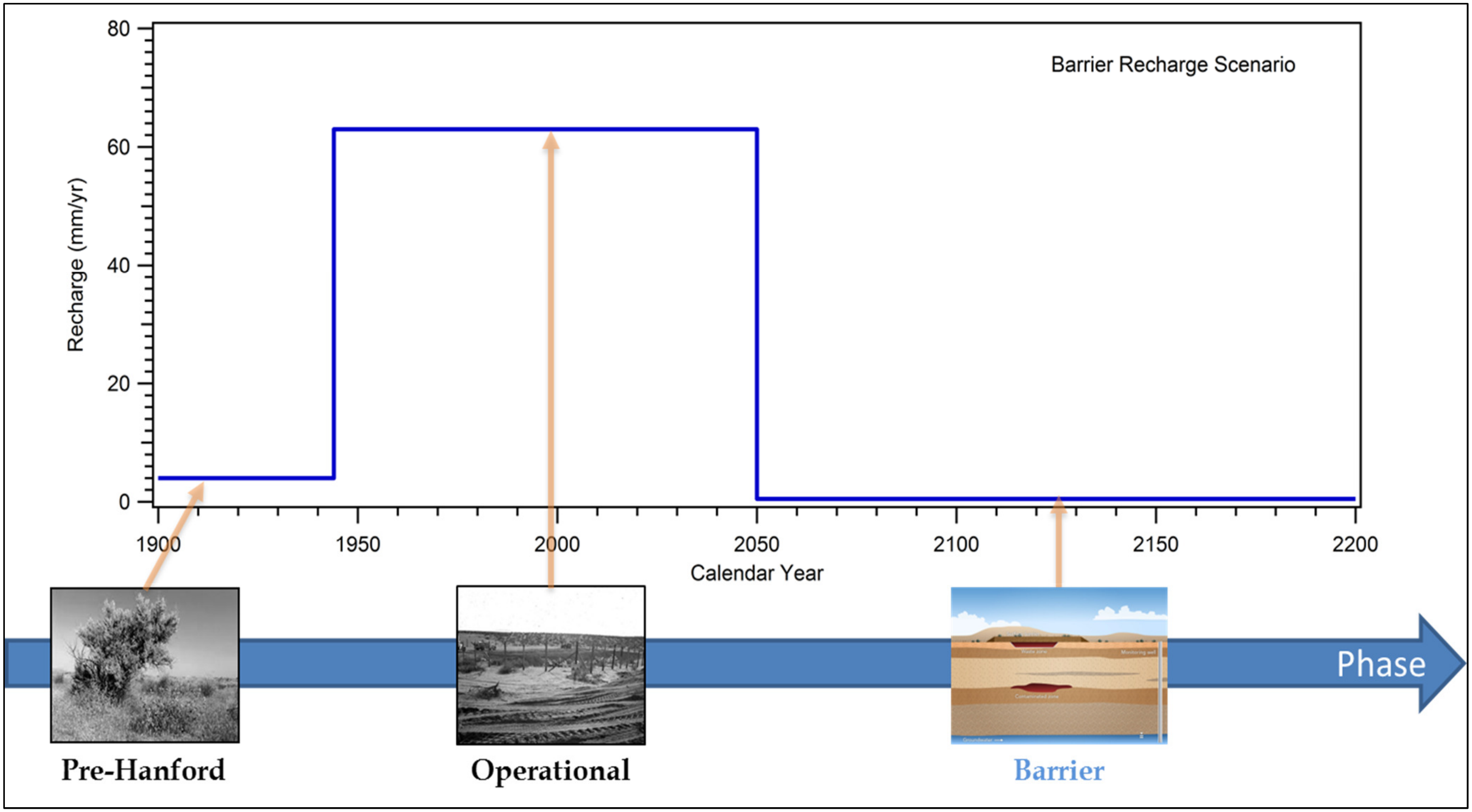
Proposed: 3D lenses varying slope and orientation randomly



Infiltration Scenario (1)

Inner Area Barrier Recharge Scenario - Recharge Rates (mm/yr)						
	Historic Simulation (pre-2015) (Initial hydraulic conditions)		Predictive Simulation (post-2015) (Calculation of peak groundwater concentration)			
Surface Soil Type	**Pre-Operational Phase (Before1944)**	**Hanford Operations Phase (1944-2014)**	**Bare Soil Phase (2015-2049)**	**Barrier Design Life Phase (2050-2549)**	**Barrier Degradation Phase (2550-3049)**	**Mature Shrub-Steppe (After 3049)**
Hanford sand, disturbed	4.0	63.0	63.0	0.5	Linear degradation from 0.5 to 4.0 over 500 yrs	4.0

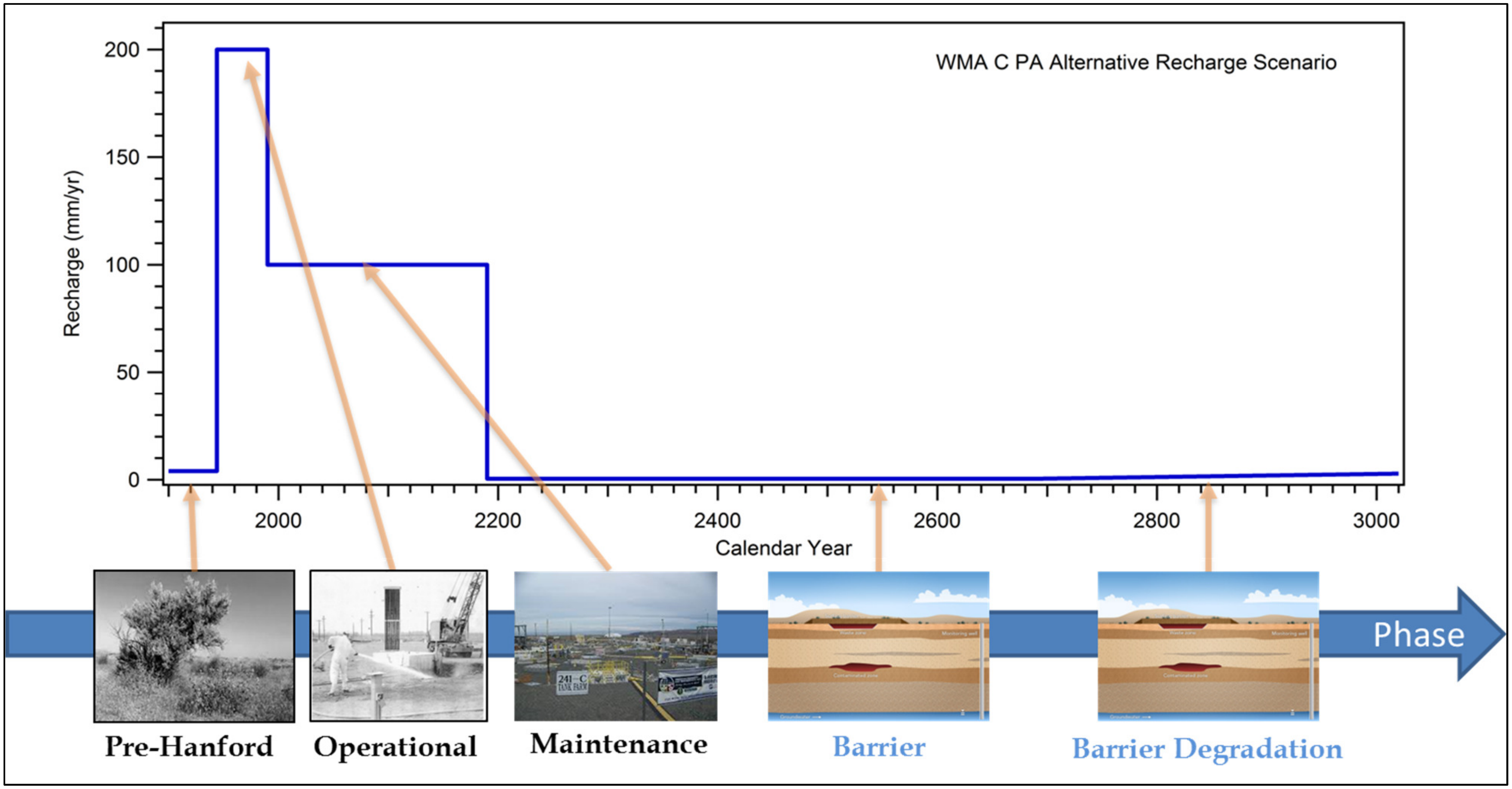
Infiltration Scenario (1)



Infiltration Scenario (2)

Alternative Barrier Recharge Scenario - Recharge Rates (mm/yr)					
Surface Soil	Pre-Hanford Phase (Before 1944)	Hanford Operations Phase (1944-1990)	Maintenance Phase (1991-2190)	Infiltration Barrier Phase (2191-2690)	Barrier Degradation Phase (After 2690)
Tank Area	4.0	200.0	100.0	0.5	Linear degradation from 0.5 to 4.0 over 500 years

Infiltration Scenario (2)



Description	Base Case (Full Source+ Infiltration = 63mm/yr)	With Clay (Full Source+ Infiltration = 63mm/yr)	With Clay (Partial Source+ Infiltration = 63mm/yr)	With Clay (Full Source+ Infiltration=Barrier Scenario)	With Clay (Full Source+ Infiltration=Barrier Scenario)
Base Case: Full Source and Constant Recharge of 63 mm/Yr	Base Case		3	4	5
Clay layers Below Source (Clay in layer H2)		2a	3a	4a	5a
Stair Step Clay Layers Below Source (Clay in layer H2)		2b	3b	4b	5b
5 % Random Clay Layers (Clay can be in any layer)		2c	3c	4c	5c
10 % Random Clay Layers (Clay can be in any layer)		2d	3d	4d	5d

Potential Tests to Consider

- Dry vs. wet conditions
- Clay lenses – no flow vs lower hydraulic conductivity
- Nonlinear sorption: saturation of sorption sites
- Other?

Questions…

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