CHPRC-03917 -VA
Revision 0

Cumulative Impact Evaluation Workshop 3(B): Vadose Zone Modeling

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

CH2MHILL
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Revision 0

Cumulative Impact Evaluation Workshop 3(B): Vadose Zone Modeling

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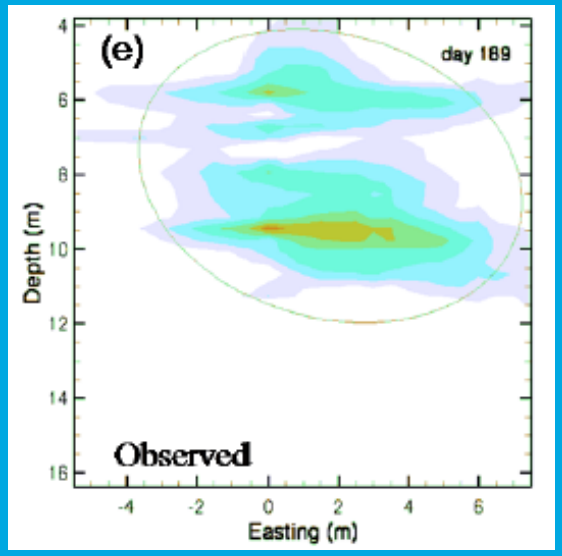
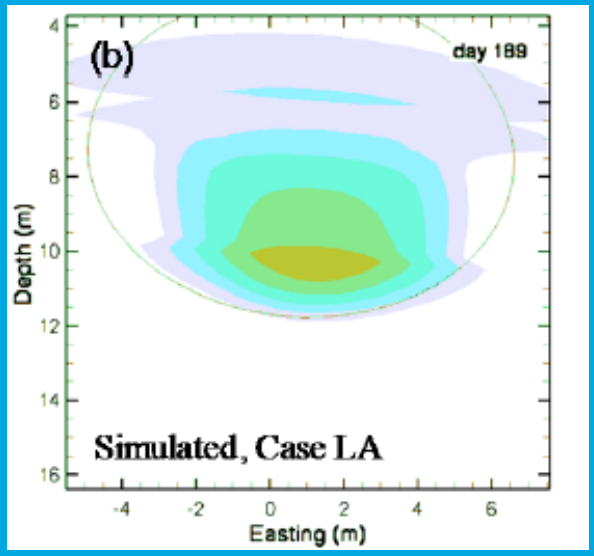
APPROVED
By Lynn M. Ayers at 9:07 am, Nov 26, 2018

Release Approval

Date

Cumulative Impact Evaluation - Workshop 3





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Vadose Zone Flow and Transport Modeling:

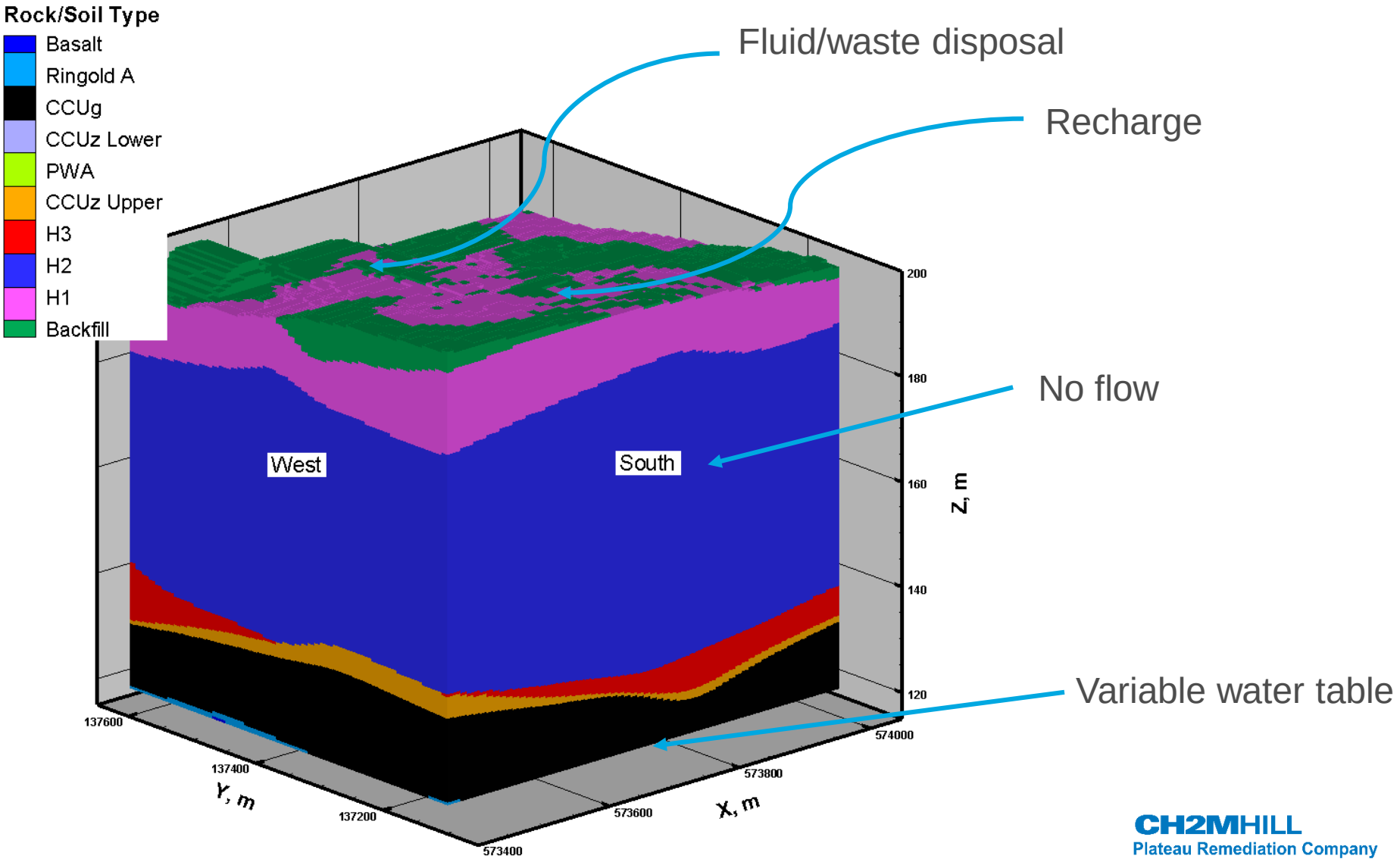
- Initial and Boundary Conditions

Questions to Address Regarding Vadose Zone Model Initial and Boundary Conditions

1. How to use existing analyses to define the time-varying recharge rates applicable during Hanford operations, planned/assumed remediation, and post-remediation?
2. How to define the time-varying water table location?
3. How to use inventory and liquid disposal information to describe model sources?

Note: Slide numbering reflects the earlier portion of this presentation was provided in Workshop 3 (9/18/2018); material beginning with slide 41 was presented in Workshop 4 (11/13/2018).

Boundary Conditions



Boundary Conditions: Recharge

- Recharge definition: Flux of water reaching (recharging) the water table.
- Vadose zone modeling: Flux leaving the evapotranspiration zone traveling to the water table → Top surface boundary condition
- Background on the various methods that have been used to determine natural recharge (e.g., lysimeters; tracer studies; modeling) is provided by Fayer and Keller (2007; PNNL-16688).

Boundary Conditions: Recharge

A GIS-based tool is needed to provide for spatial and temporal variation in recharge:

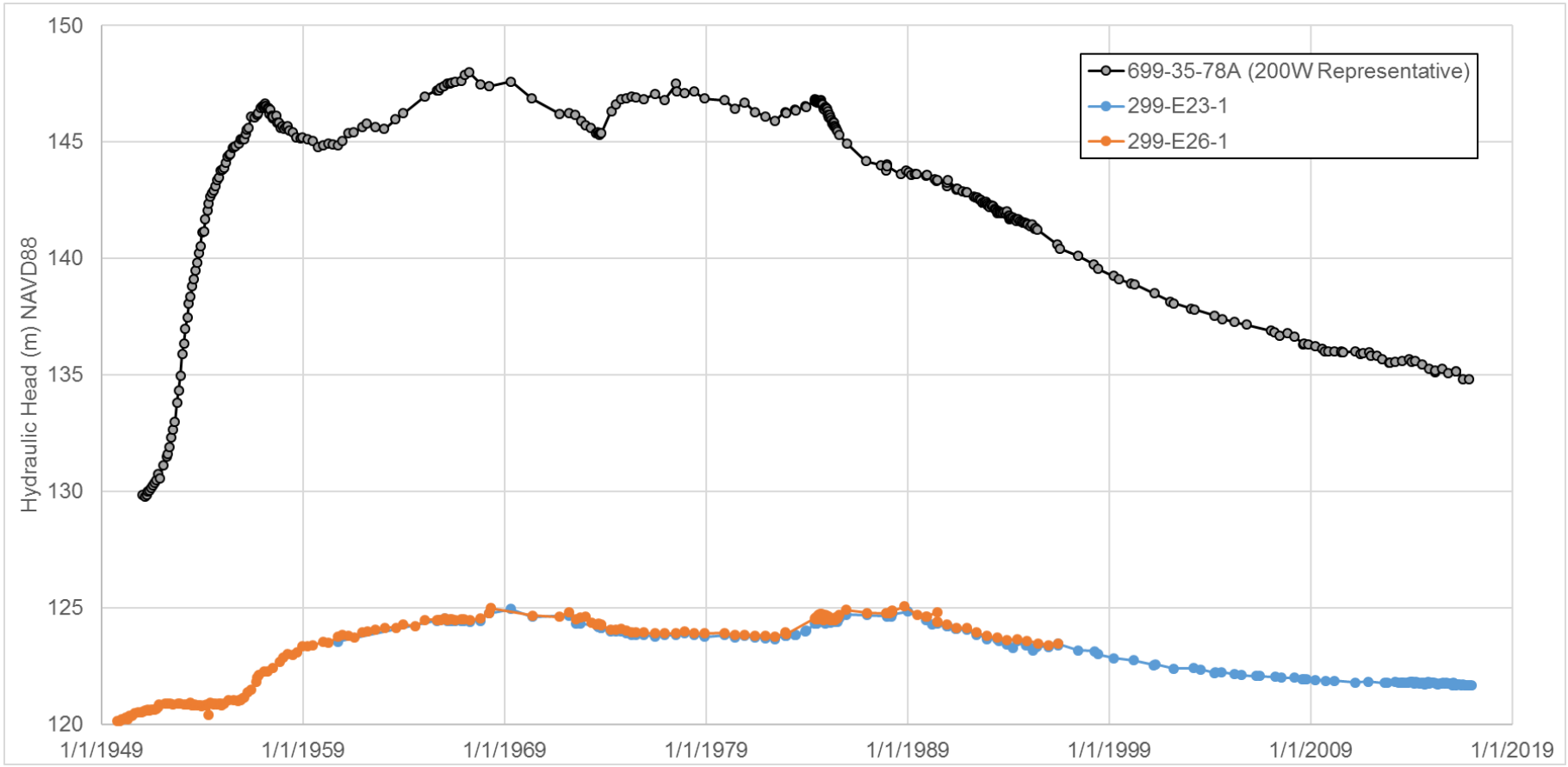
- Based on soil type, vegetation, disturbance, waste sites, and covers over time.
- Provides means to organize disposition baseline information for use in the vadose zone models.

Question 1: How to use existing analyses and field observations to define time-varying recharge rates?

A GIS-based tool will be developed to organize spatial and temporal recharge information consistent with disposition baselines and recharge rates provided in the graded approach document (DOE-RL-2011-50).

Question 2: How to use field observations to define the time-varying water table location?

Vadose Zone Boundary Conditions: Water Table Boundary Conditions



Water table levels at representative wells for the 200W and 200E Area.

Question 2: How to use field observations to define the time-varying water table location?

- Numerically evaluate how to use hydraulic head data from representative wells (and future predictions) to compute contaminant fluxes to groundwater.
- Select efficient method for computation of mass/activity fluxes to groundwater.

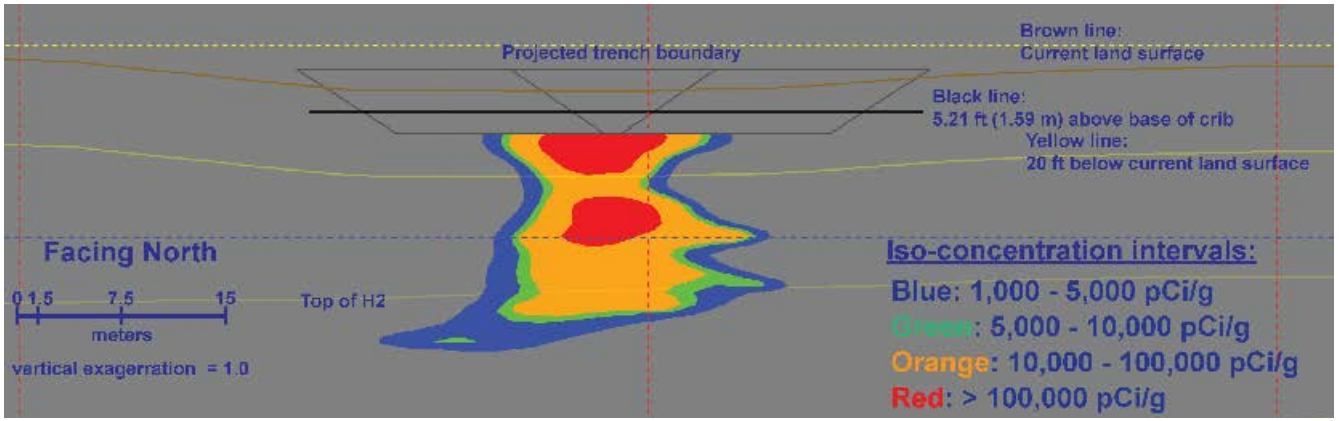
Question 3: How to use inventory and liquid disposal/leak information to describe model sources?

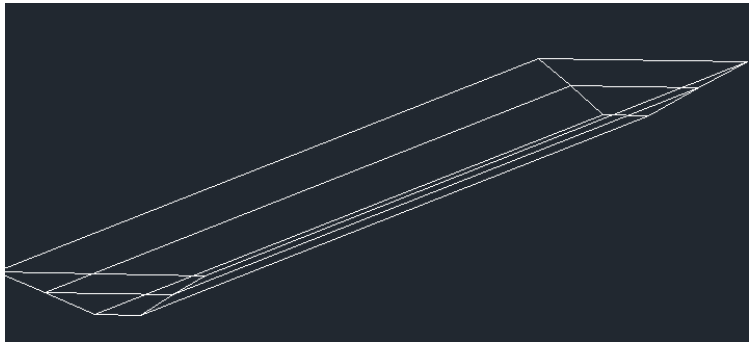
Boundary Conditions: Contaminant and Liquid Sources

- The inventory model SIM-v2 provides liquid volumes and contaminant inventory information.
- In combination with information on waste site geometry, the volumes and contaminants may be introduced into a vadose zone model through boundary conditions (liquid and contaminant sources).

Boundary Conditions: Contaminant and Liquid Sources

- Waste site geometry data availability:
  - ArcGIS® Coverage: Waste Site Footprints (2D)
  - Three-Dimensional Waste Site Models for the 200-PW-1/3/6 and 200-CW-5 Operable Unit Waste Sites, Central Plateau, Hanford Site, Richland, Washington. ECF-HANFORD-14-0054, Rev. 0





ARCGIS is a registered trademark of ESRI, Redland, California.

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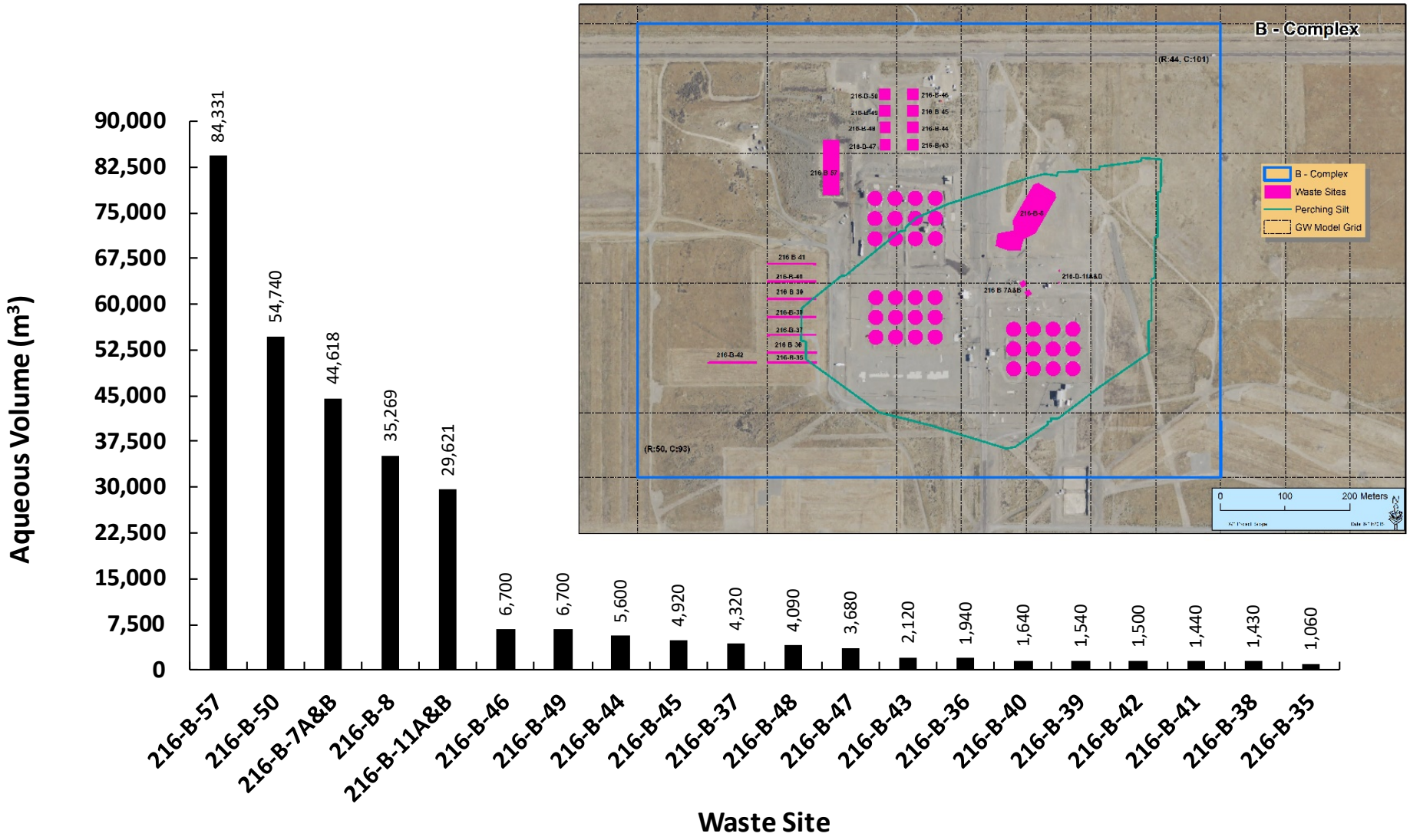
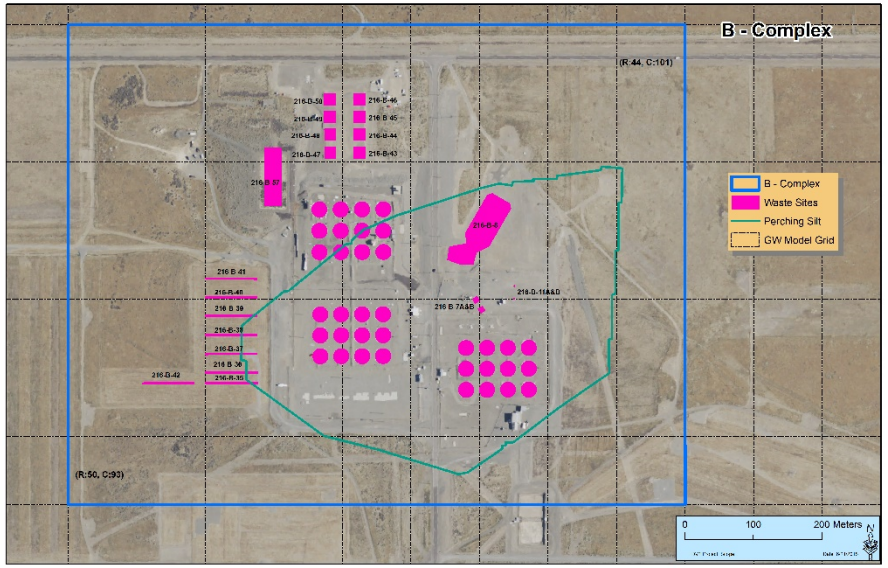
Boundary Conditions:
SIM v2 B-Complex 200-DV1-OU Example

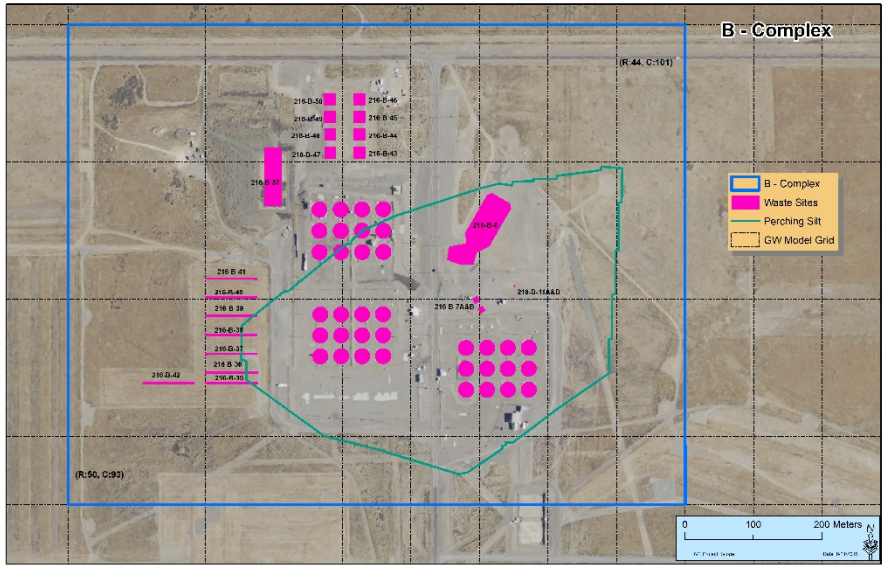


Boundary Conditions:
SIM v2 B Complex 200-DV1-OU Example

Pore volume = Waste site area * distance to water table * porosity



Boundary Conditions:
SIM v2 B Complex 200-DV1-OU Example



Forward Modeling Approach

1. Steady-state simulation to create 1943 flow field (initial conditions)
2. Flow and contaminant transport simulation
   - Use waste site liquid and contaminant inventory data from SIM-v2 and volumes from sites without radionuclide/chemical inventory as boundary conditions.
   - Use spatially and temporally variable recharge at the model top surface.
   - Obtain mass/activity fluxes at bottom boundary for transfer into groundwater model.

Boundary Conditions:
BY Cribs Tc-99 Flux to Groundwater

Note: a video was shown on this slide.

B43 – B49:

-33,800 m^3 liquid
-129 Ci Tc99
-1954-1955

B50:

-92,800 m^3 liquid
-0 Ci Tc99
-1965-1974

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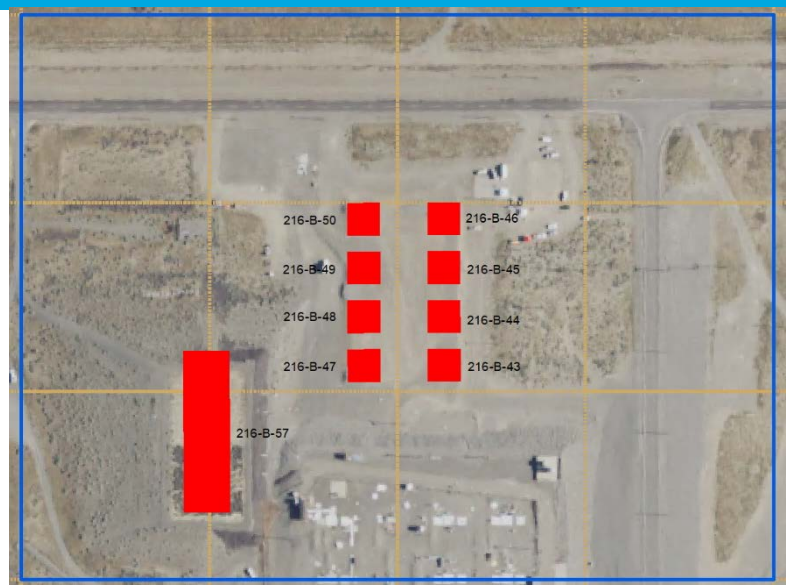
Boundary Conditions:
BY Cribs Tc-99 Flux to Groundwater

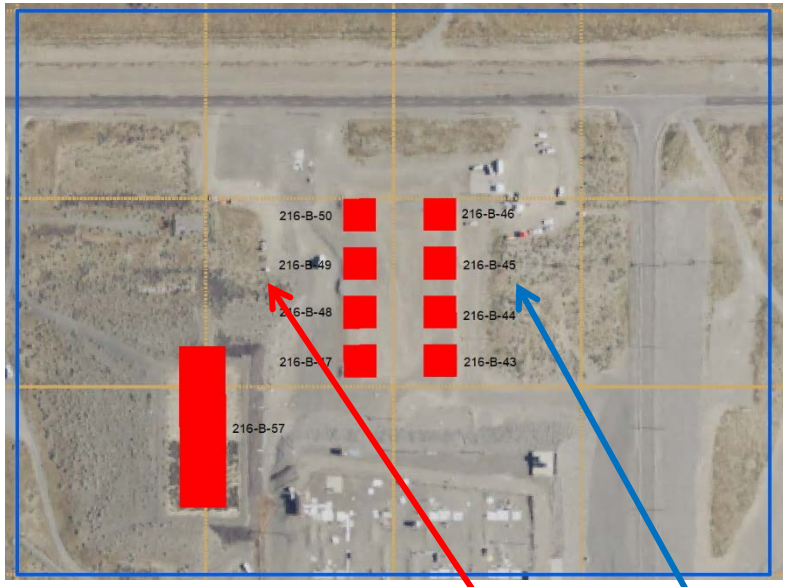


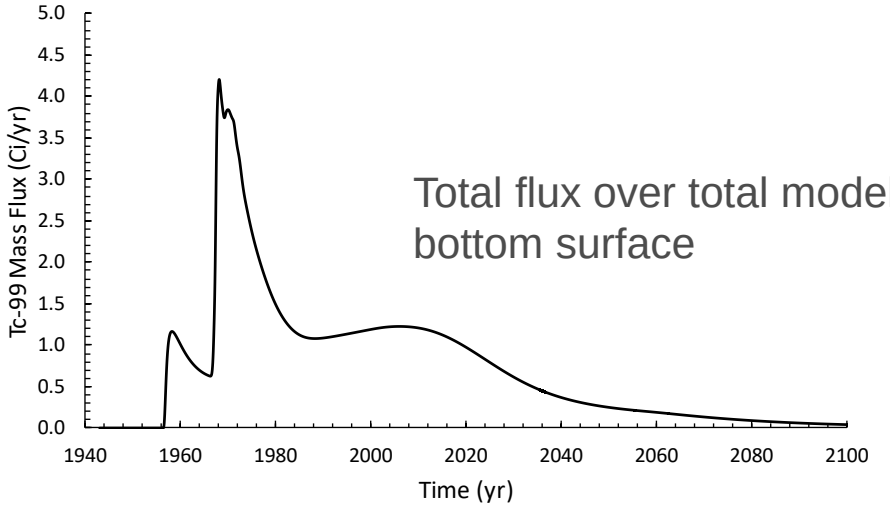
Transport due to increased recharge during operations

Rapid initial migration to groundwater after B-43 - B-49 disposal

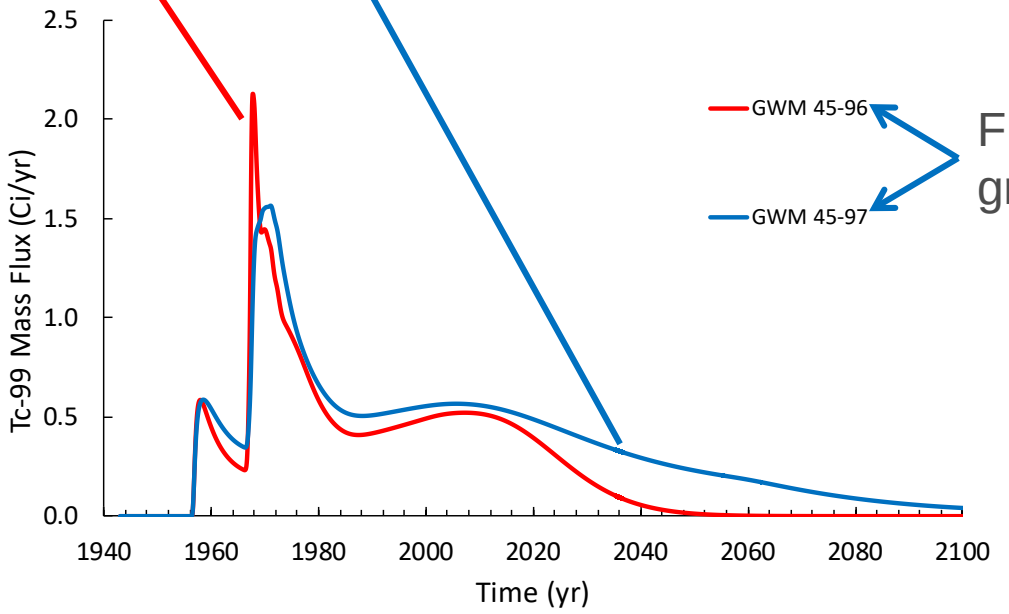
Flushing due to B-50 liquid disposal

Boundary Conditions:
BY Cribs Tc-99 Flux to Groundwater





Total flux over total model bottom surface



Fluxes forwarded to groundwater model

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Question 3: How to use inventory and liquid disposal/leak information to describe model sources?

- Use waste-site liquid and contaminant inventory data from SIM-v2 and non-radiologic site liquid volumes from site-specific literature (e.g., HNF-SD-LL-SP-001, 200 and 600 Areas Sanitary Waste Water Master Plan; Quarterly Discharge Monitoring Reports for TEDF and SALDS).
- Use waste-site geometry information from GIS Waste Site Footprints and ECF-HANFORD-14-0054.
- Use ‘forward’ modeling approach to simulation vadose zone flow and transport.

Cumulative Impacts Evaluation Workshop 3: Geologic Representation and Vadose Zone Modeling

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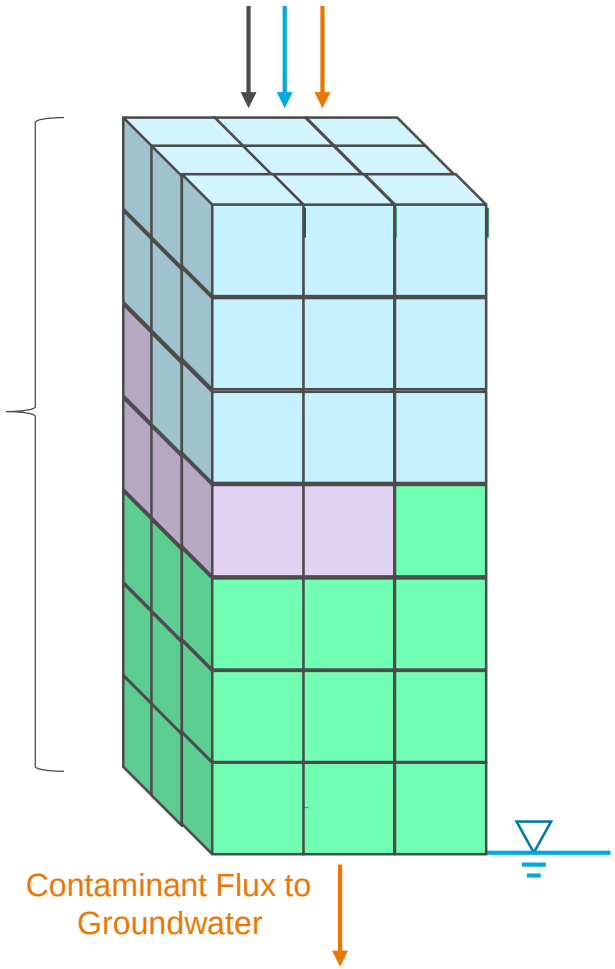
Summary

Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP©

Top Boundary Condition

Influxes of natural recharge, liquid effluent discharges, & contaminant



Geologic Representation
Hydrostratigraphic

Contaminant and Effluent Loading
SIM-v2

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

Dimensionality/Scale
3D

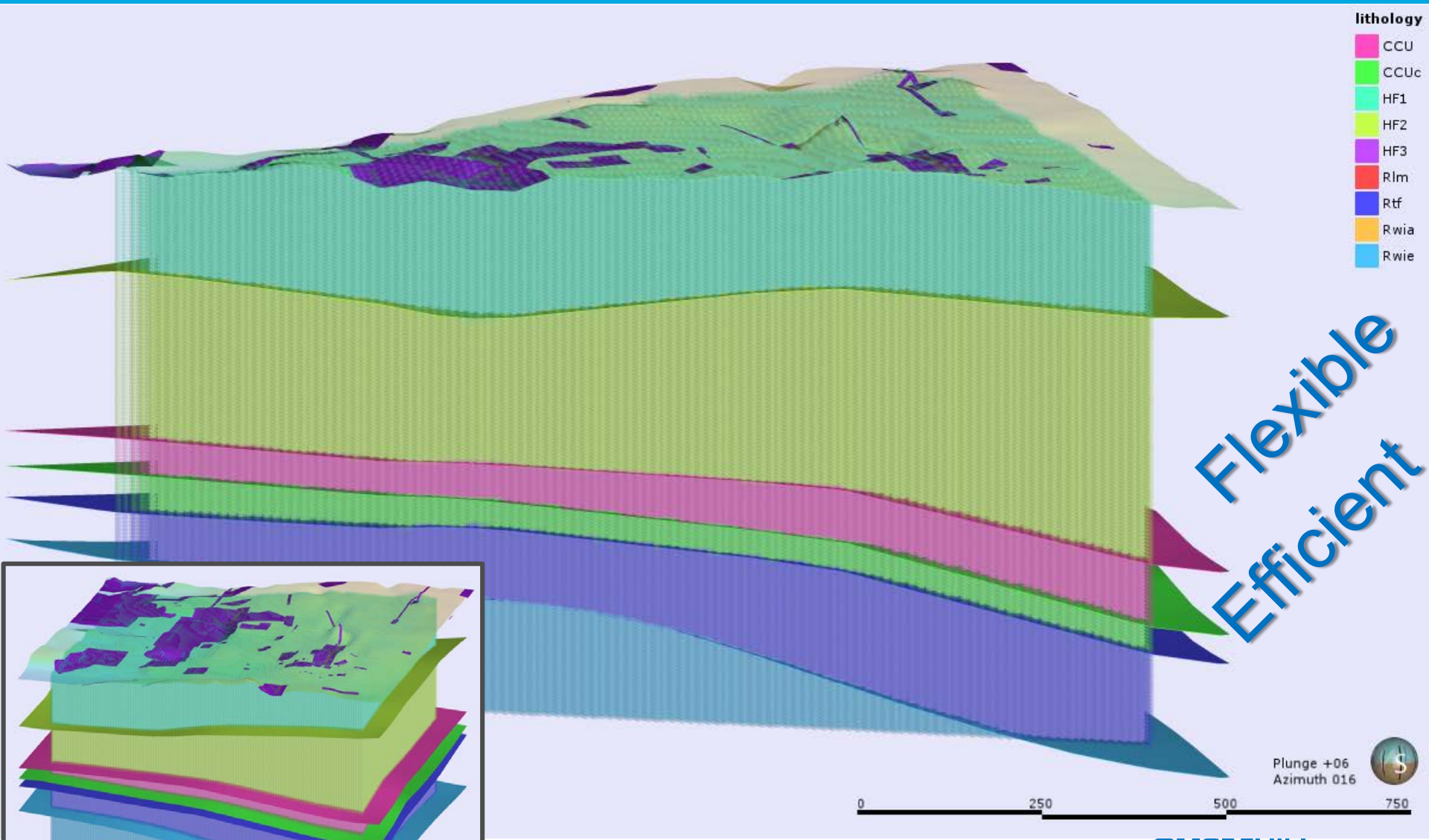
Initial Condition

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Remedial Actions
Disposition baseline to account for actions taken to date, decisions made, and reasonable anticipated range of actions for as-yet decisions.

Bottom Boundary

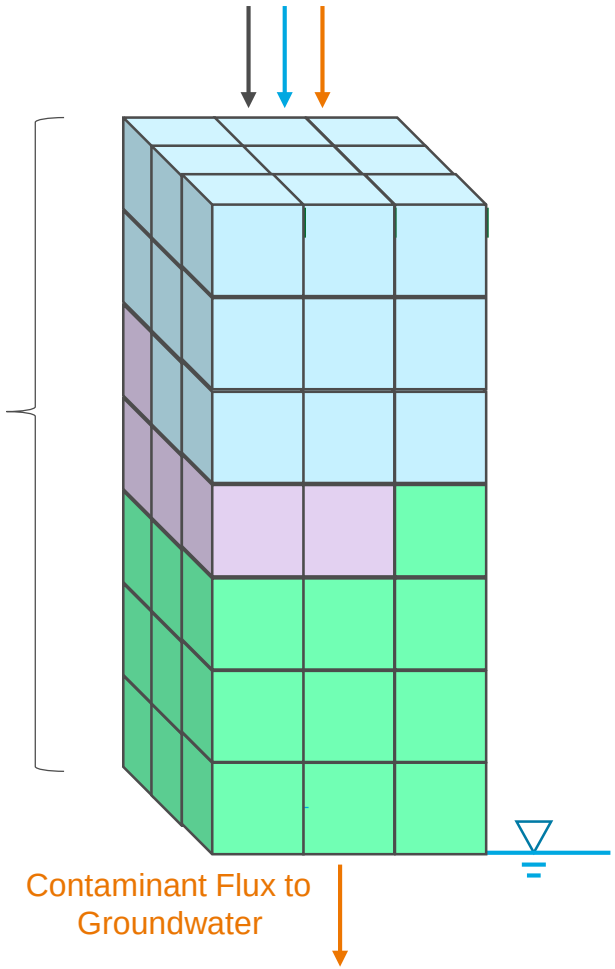
Aspect – Geologic Representation
Stratigraphic Approach (using CPVZGF)



Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

Influxes of natural recharge, liquid effluent discharges, & contaminant



Top Boundary Condition

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Contaminant and Effluent Loading
SIM-v2

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

Dimensionality/Scale
3D

Initial Condition

Impact of Adjacent Sites
Explicit –multisite models to simulate co-mingling of liquid effluent discharges

Remedial Actions
Bracket disposition baseline end states with no-further-action and lifecycle report range; fix actions to date, decisions to date, and TC&WM EIS ROD landfill closure of tanks

Bottom Boundary

Aspect – Hydraulic Parameters

Parameterization by stratigraphic unit using EHM with upscaling

- fluid properties, e.g., μ
- diffusion coefficient, D_o

Literature (CRC Handbooks, etc.)

- dry bulk density, ρ_d
- porosity, ϕ

Averaging data from Hanford literature

- tortuosity, τ

Millington and Quirk (1961)

- contaminant distribution coefficient, K_d

Hanford literature (site-specific values)

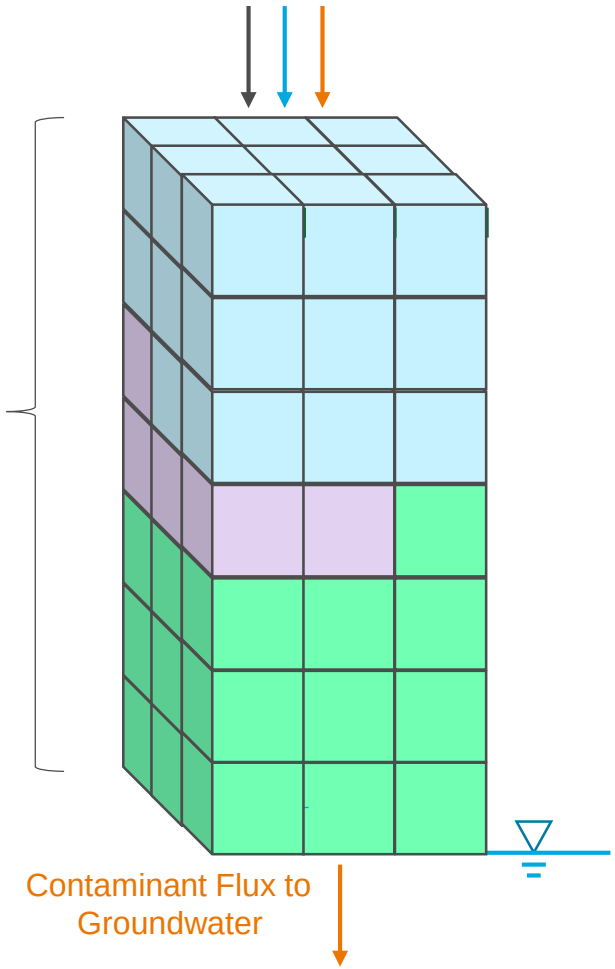
- sat. hydraulic conductivity, K_{sat}
- relative permeability, $k_r(\theta)$
- water retention, $h(\theta)$
- dispersivity, α_i

Upscaling methodologies appropriate for Hanford vadose zone and consistent with previous modeling

Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

Influxes of natural recharge, liquid effluent discharges, & contaminant



Top Boundary Condition

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Contaminant and Effluent Loading
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Hydraulic Properties
Equivalent homogeneous model
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Dimensionality/Scale
3D

Initial Condition

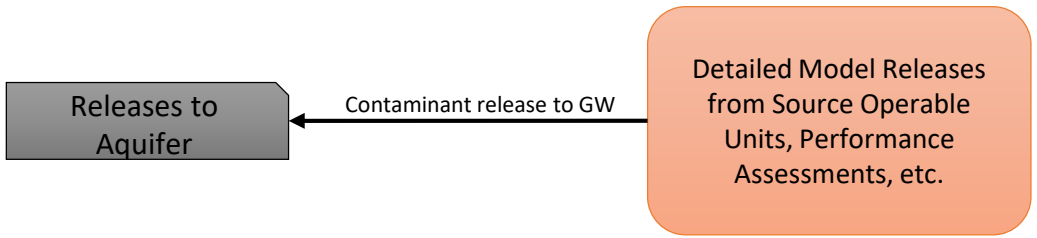
Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Remedial Actions
Bracket disposition baseline end states with no-further-action and lifecycle report range; fix actions to date, decisions to date, and TC&WM EIS ROD landfill closure of tanks

Bottom Boundary

Aspect – Initial Conditions

- Default for CIE Rev. 0 will be to use the “1940s-forward” approach, simulating contaminant distribution in the vadose zone from a clean condition prior to commencement of Hanford Site operations using process knowledge (SIM-v2 sources).
  - Vadose zone models will be developed to be representative
- As the OUs develop detailed models that use imposed initial conditions for contaminant distribution, these will be incorporated into the CIE.



Modular

Conceptualization for a CIE: aspects to consider for representative vadose models

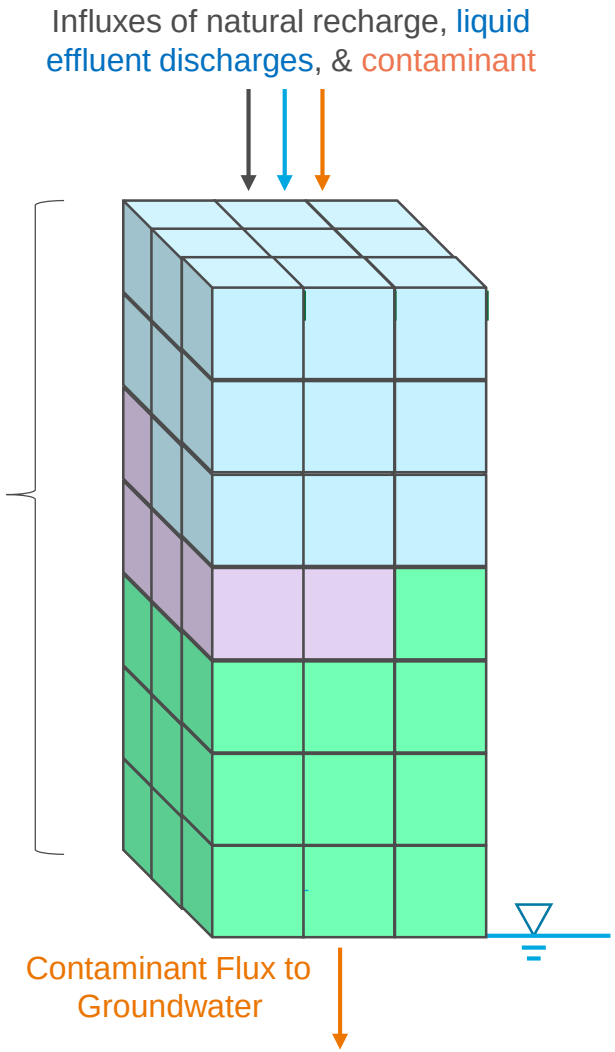
Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

Contaminant Initial Condition
Start at 1940s with no initial contamination present; incorporate characterization data to define initial conditions at present as made available in Operable Unit specific studies

Remedial Actions
Bracket disposition baseline end states with no-further-action and lifecycle report range; fix actions to date, decisions to date, and TC&WM EIS ROD landfill closure of tanks



Top Boundary Condition

Contaminant and Effluent Loading
SIM-v2

Dimensionality/Scale
3D

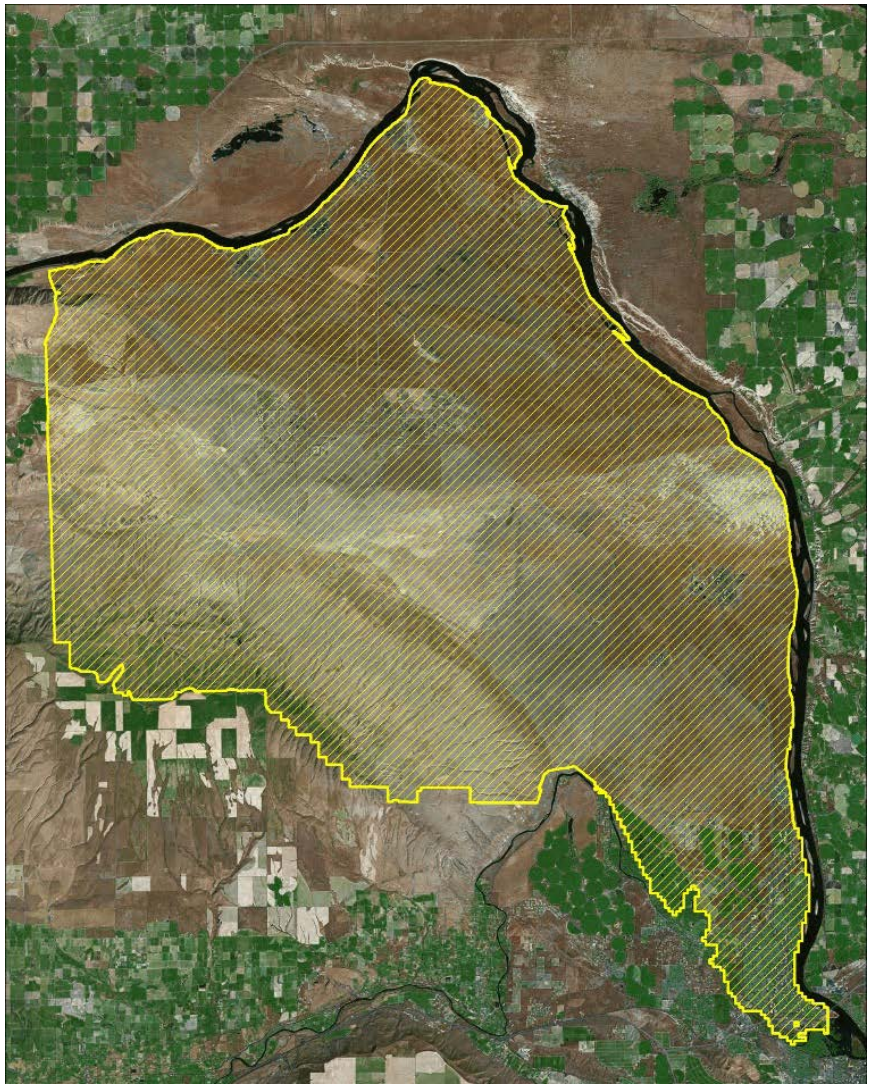
Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Bottom Boundary

Aspect – Boundary Conditions (Top)

A tool is needed

- GIS based to determine site-specific spatial-temporal variation in recharge for STOMP model simulations.
- Use spatial representation of waste sites, soils classifications, and documented remediation actions
- Develop a time series of surface disposition and recharge.



Flexible Efficient Representative

Aspect – Boundary Conditions (Top) Continued

- Propose a task as part of the CIE development to estimate future artificial deep percolation / recharge quantities for potential inclusion in vadose zone models:
  - Dust suppression water
  - Storm water management
  - Other potential sources

Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

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Remedial Actions
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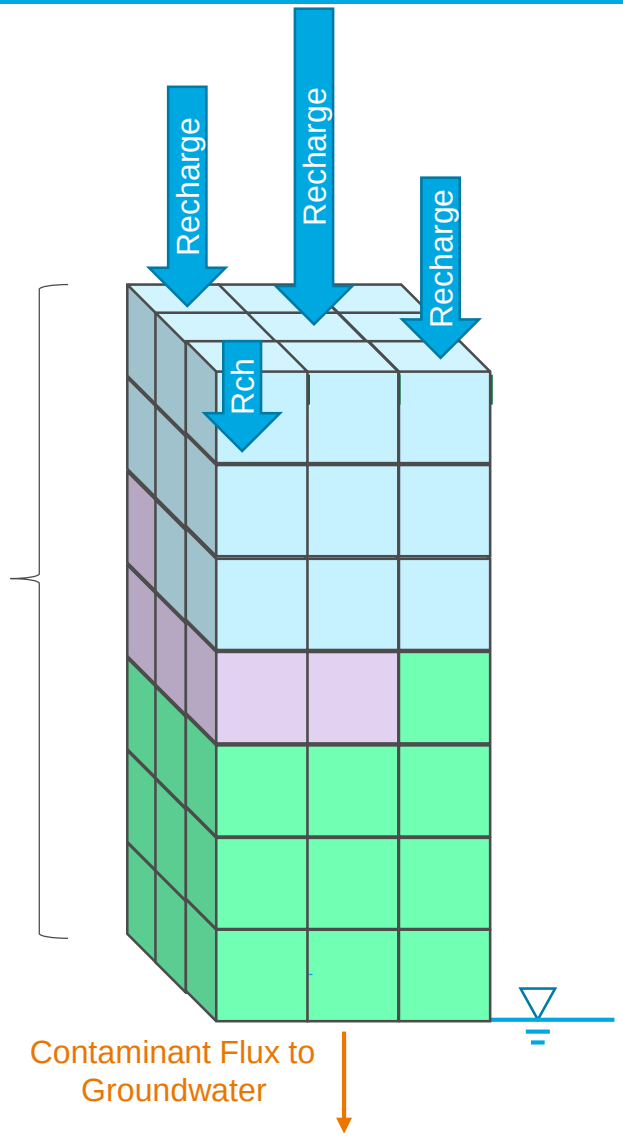


Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

Contaminant and Effluent Loading
SIM-v2

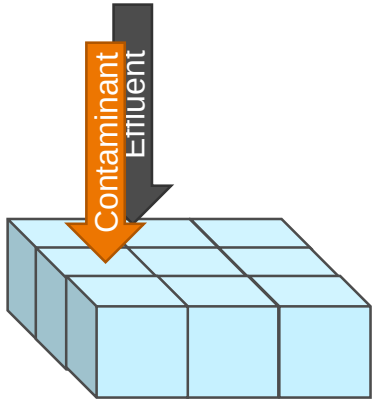
Dimensionality/Scale
3D

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Bottom Boundary

Aspect – Contaminant & Effluent Loading

- In CIE Workshop 2, the SIM-v2 was selected as the source for contaminant mass/activity and effluent volumes to use for the CIE.
  - Because of the selection of multi-site 3D modeling for the dimensionality aspect, sources of contaminant mass/activity and effluent volume must be distributed in time and space to appropriate elements of the top surface of the vadose zone models.



Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

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Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

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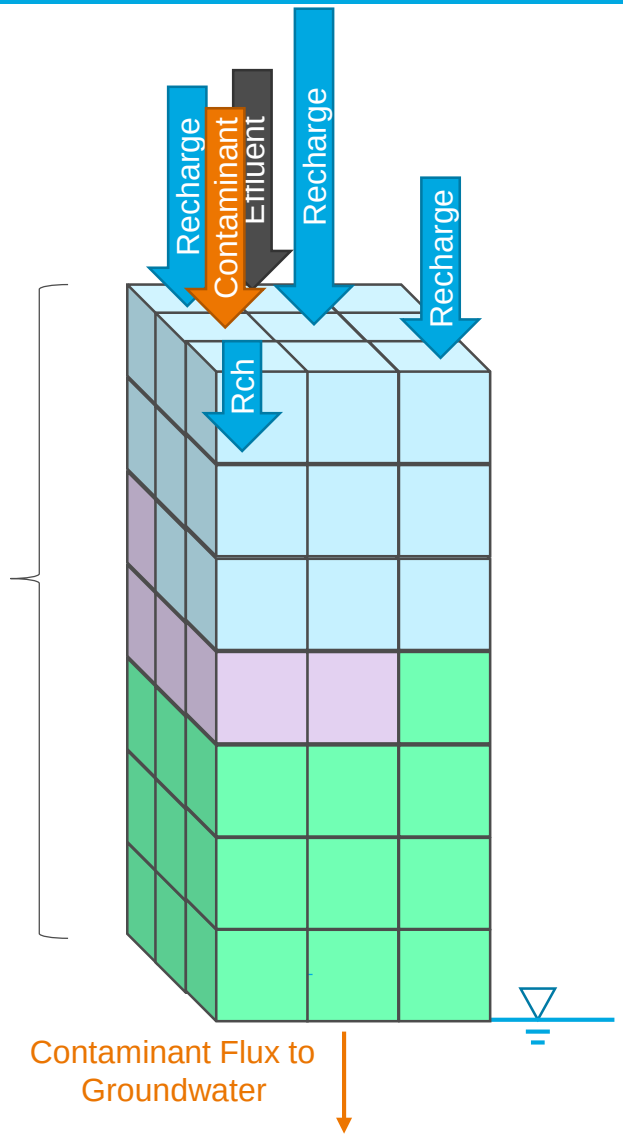


Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

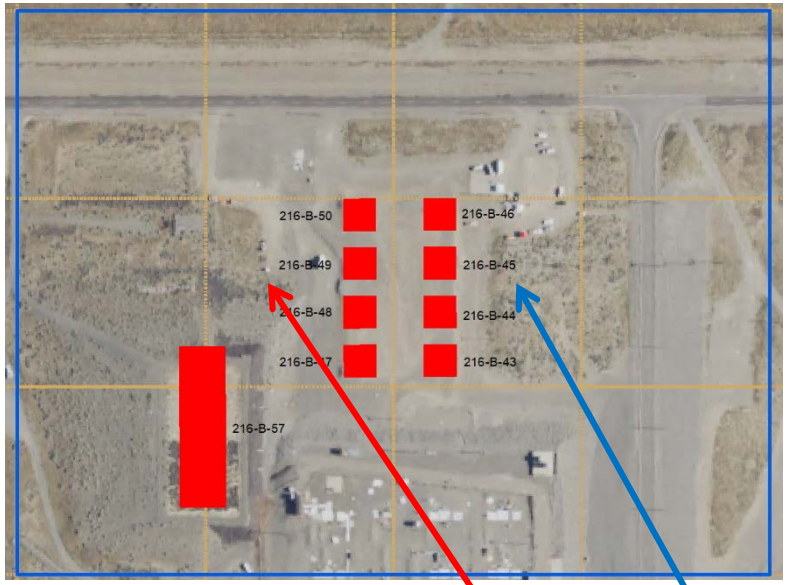
Contaminant and Effluent Loading
SIM-v2; time-varying waste releases of contaminant mass or activity and effluent volume specified as source terms for each waste site to the top layer of nodes (reflecting surface topography) at a specified depth from 1940s onward.

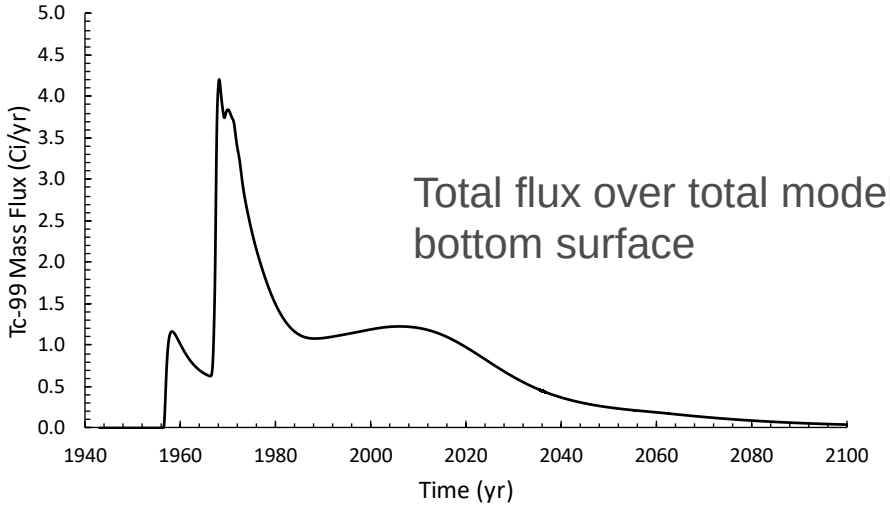
Dimensionality/Scale
3D

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

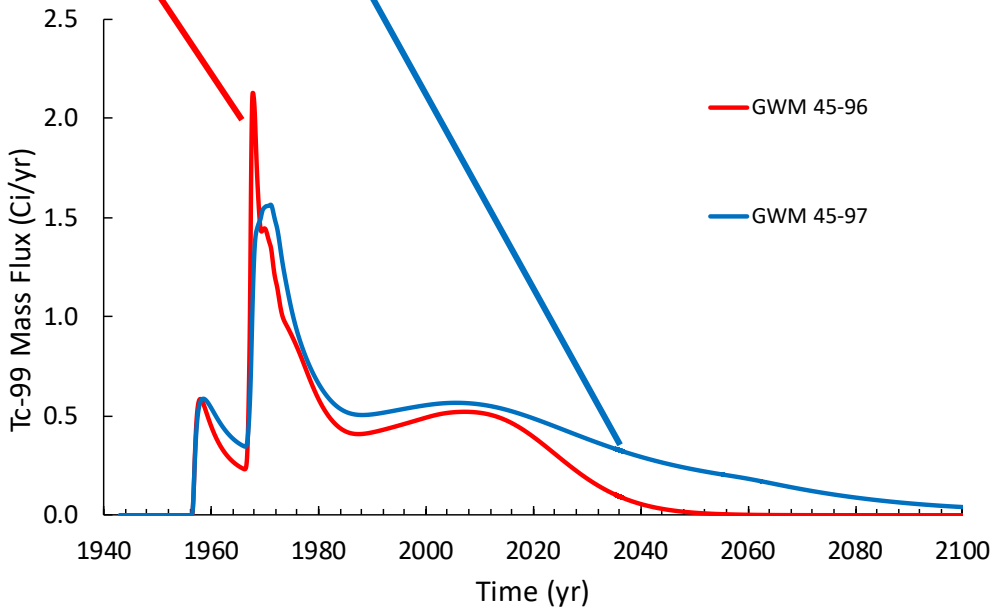
Bottom Boundary

Aspect - Dimensionality





Total flux over total model bottom surface



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Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

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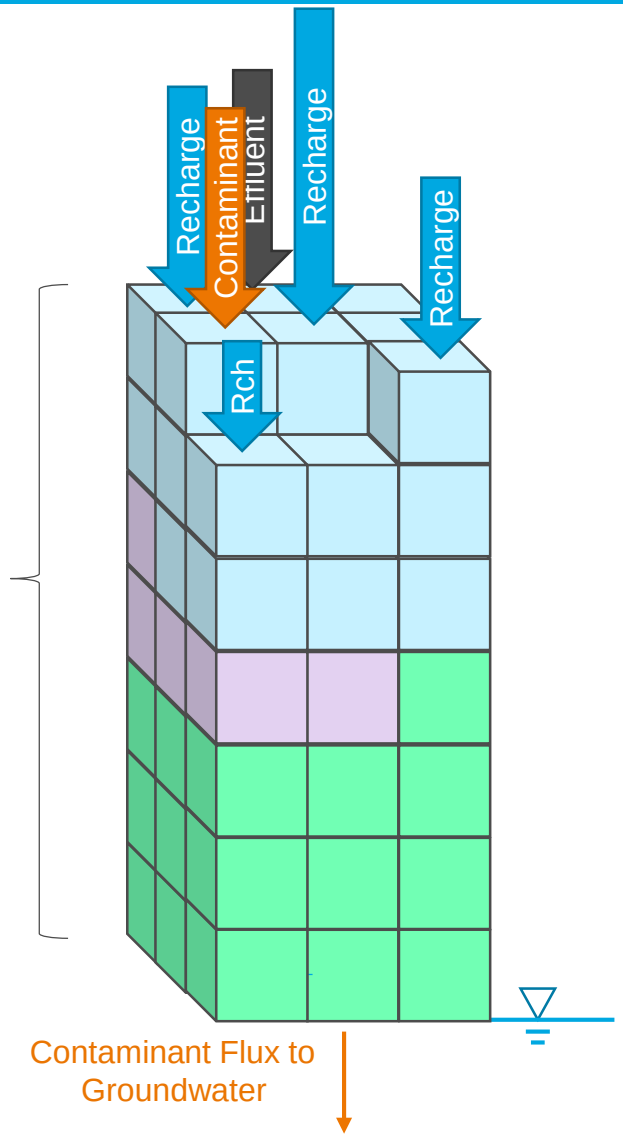


Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

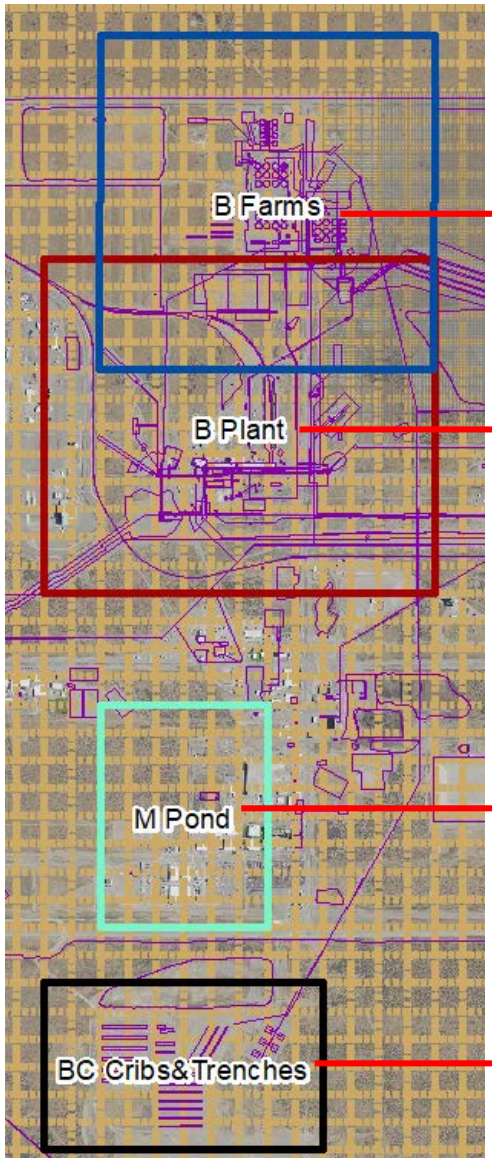
Contaminant and Effluent Loading
SIM-v2; time-varying waste releases of contaminant mass or activity and effluent volume specified as source terms for each waste site to the top layer of nodes (reflecting surface topography) at a specified depth from 1940s onward.

Dimensionality/Scale
3D; explicitly three-dimensional model of multiple waste sites grouped so as to address potential for effluent comingling in the vadose zone.

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Bottom Boundary

Multi-site Models to Explicitly Address Effluent Co-mingling Potential



43 Sites

31 Sites

3 Sites

23 Sites

Model domain size defined by:

- Computational limitations (~2-3M nodes)
- No flow (zero flux) vertical boundaries
- Consideration of plume co-mingling

Overlapping models will be needed, but contaminant inventories are only included in one of the models to maintain modular approach and avoid double-counting release to the groundwater facet.

Conceptualization for a CIE: aspects to consider for representative vadose models

Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

Initial Condition
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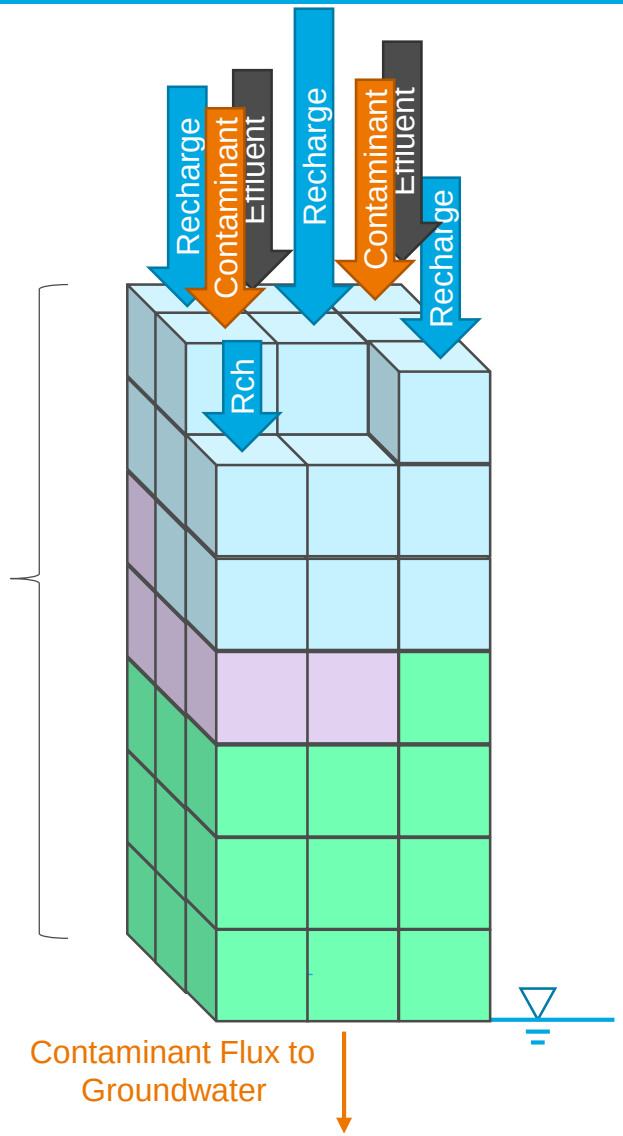

Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

Contaminant and Effluent Loading
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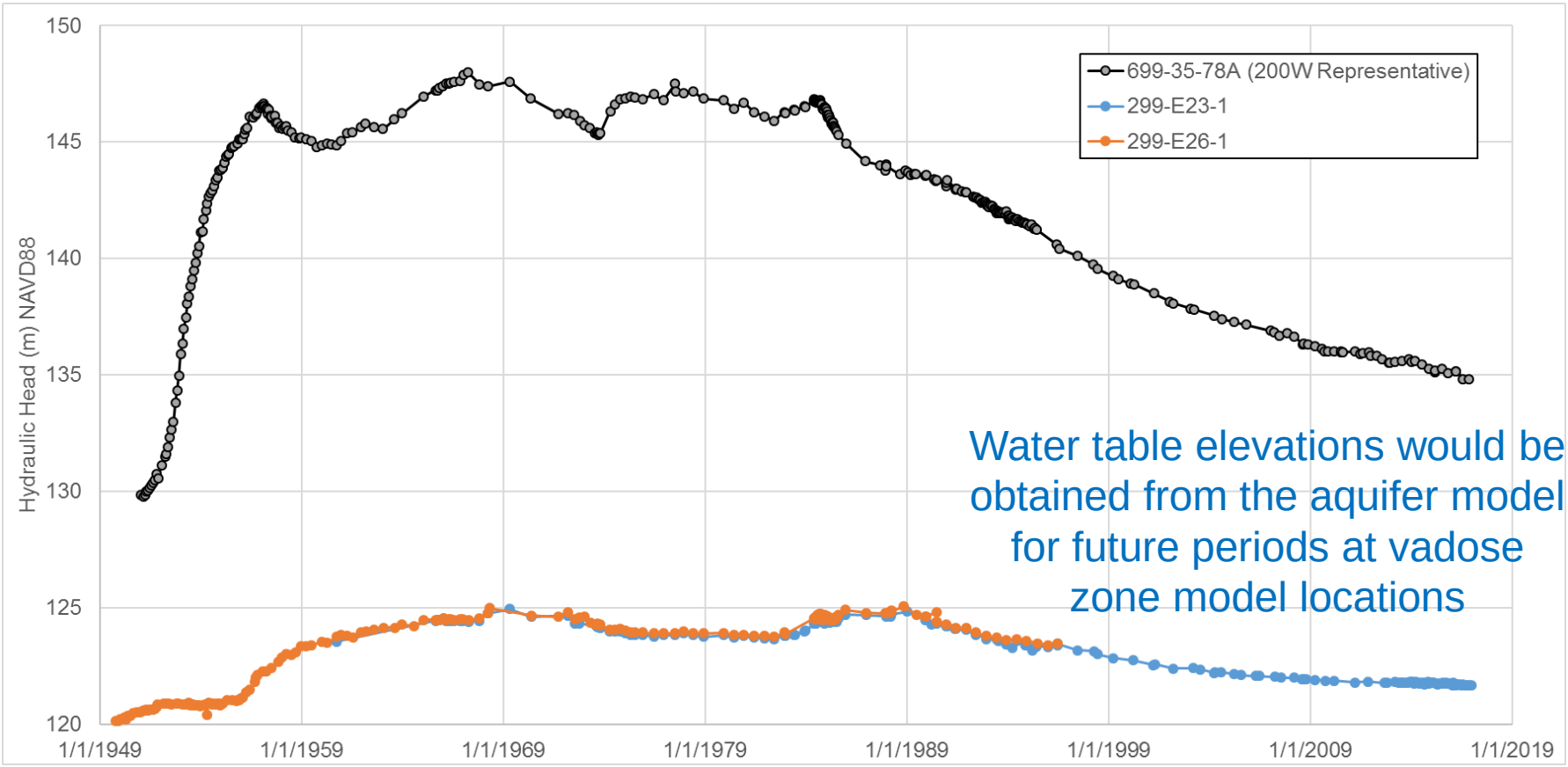
Dimensionality/Scale
3D; explicitly three-dimensional model of multiple waste sites grouped so as to address potential for effluent comingling in the vadose zone.

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Bottom Boundary

Aspect – Boundary Conditions (Bottom)



Hydraulic Head Measurements from representative wells for the 200W and 200E Area. Note Elevation is NAVD88.

Conceptualization for a CIE: aspects to consider for representative vadose models

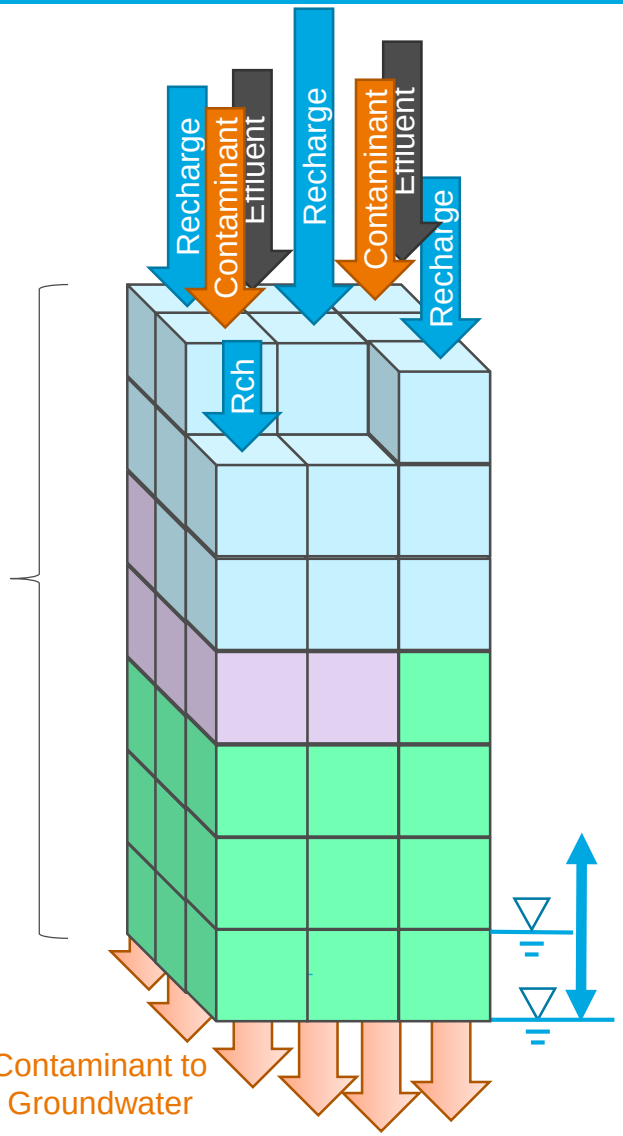
Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model
Parameter upscaling

Initial Condition
Start at 1940s with no initial contamination present; incorporate characterization data to define initial conditions at present as made available in Operable Unit specific studies

Remedial Actions
Bracket disposition baseline end states with no-further-action and lifecycle report range; fix actions to date, decisions to date, and TC&WM EIS ROD landfill closure of tanks



Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

Contaminant and Effluent Loading
SIM-v2; time-varying waste releases of contaminant mass or activity and effluent volume specified as source terms for each waste site to the top layer of nodes (reflecting surface topography) at a specified depth from 1940s onward.

Dimensionality/Scale
3D; explicitly three-dimensional model of multiple waste sites grouped so as to address potential for effluent comingling in the vadose zone.

Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges

Bottom Boundary
Evaluate and if significant treat water table as transient location (based on historic data for past and groundwater model for future).

Conceptualization for a CIE: aspects to consider for representative vadose models

Note: highlighted assumptions would be areas of with greater representativeness than in prior site-wide assessments

Models Implemented in STOMP

Geologic Representation
Hydrostratigraphic using the Central Plateau Vadose Zone Geoframework

Hydraulic Properties
Equivalent homogeneous model Parameter upscaling

Initial Condition
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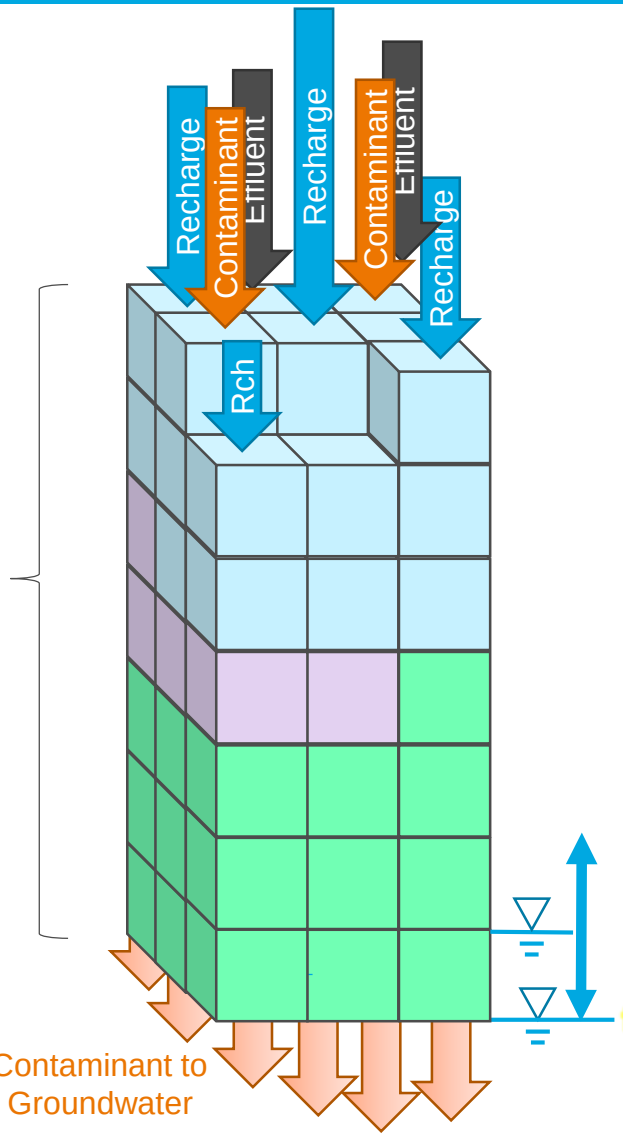


Top Boundary Condition
Recharge applied as temporally and spatially varying flux to account for changes in surface soil and vegetation type.

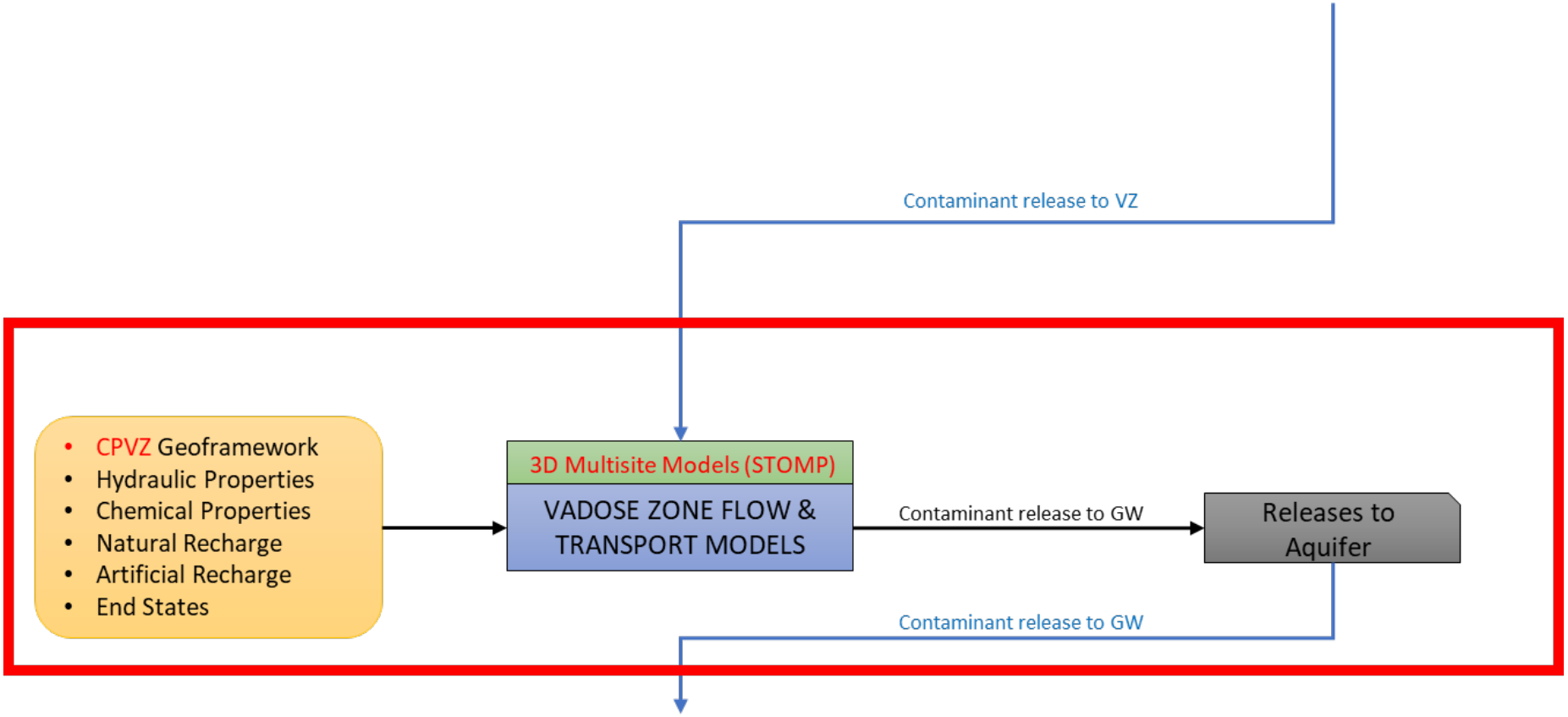
Contaminant and Effluent Loading
SIM-v2; time-varying waste releases of contaminant mass or activity and effluent volume specified as source terms for each waste site to the top layer of nodes (reflecting surface topography) at a specified depth from 1940s onward.

Dimensionality/Scale
3D; explicitly three-dimensional model of multiple waste sites grouped so as to address potential for effluent comingling in the vadose zone.

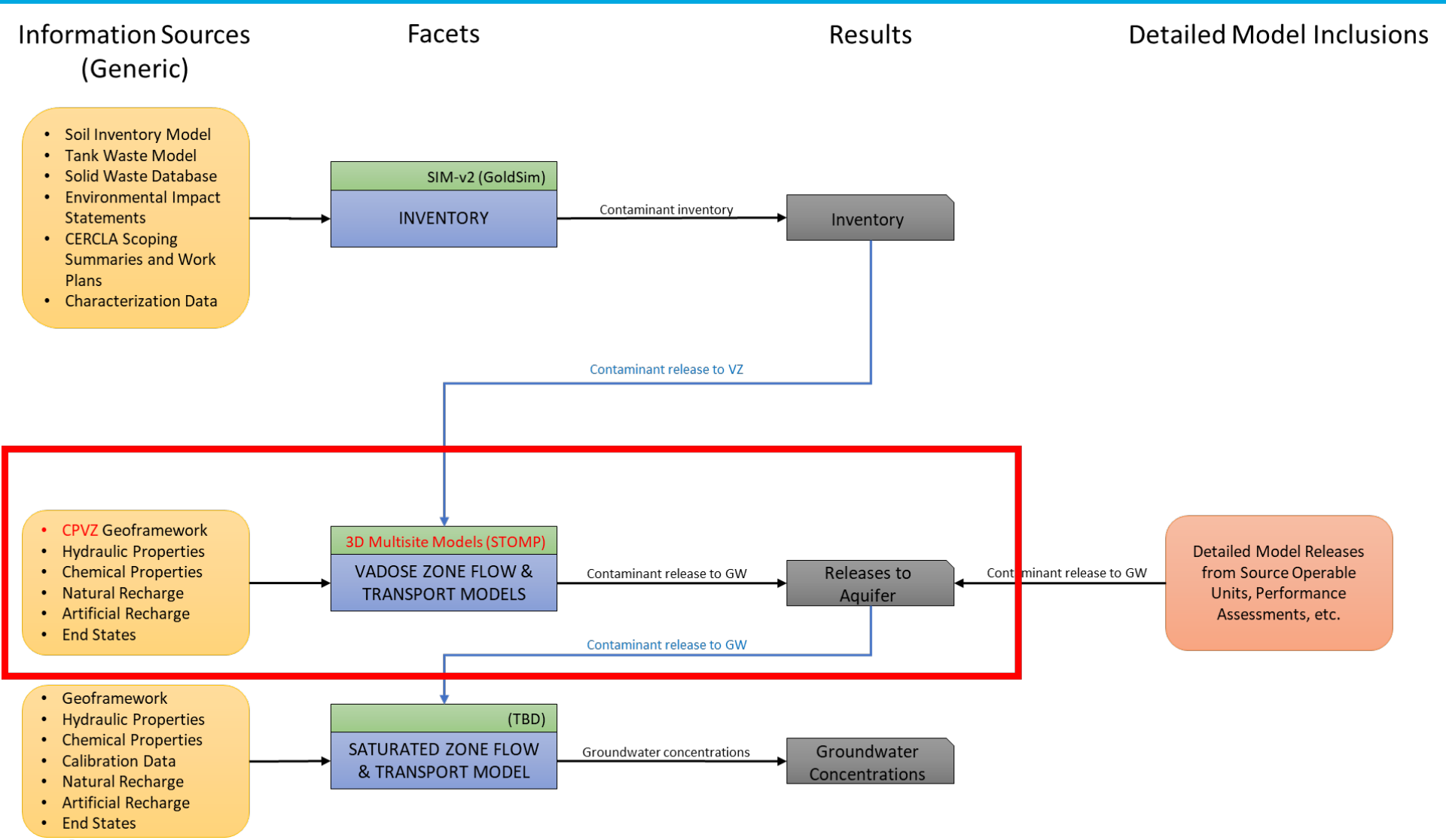
Impact of Adjacent Sites
Explicit – multisite models to simulate co-mingling of liquid effluent discharges.

Bottom Boundary
Evaluate and if significant, treat water table at transient location (based on groundwater model at waste site location).

Filling in the CIE Wiring Diagram for this Facet



Full Wiring Diagram (Updated)



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