washington river protection solutions

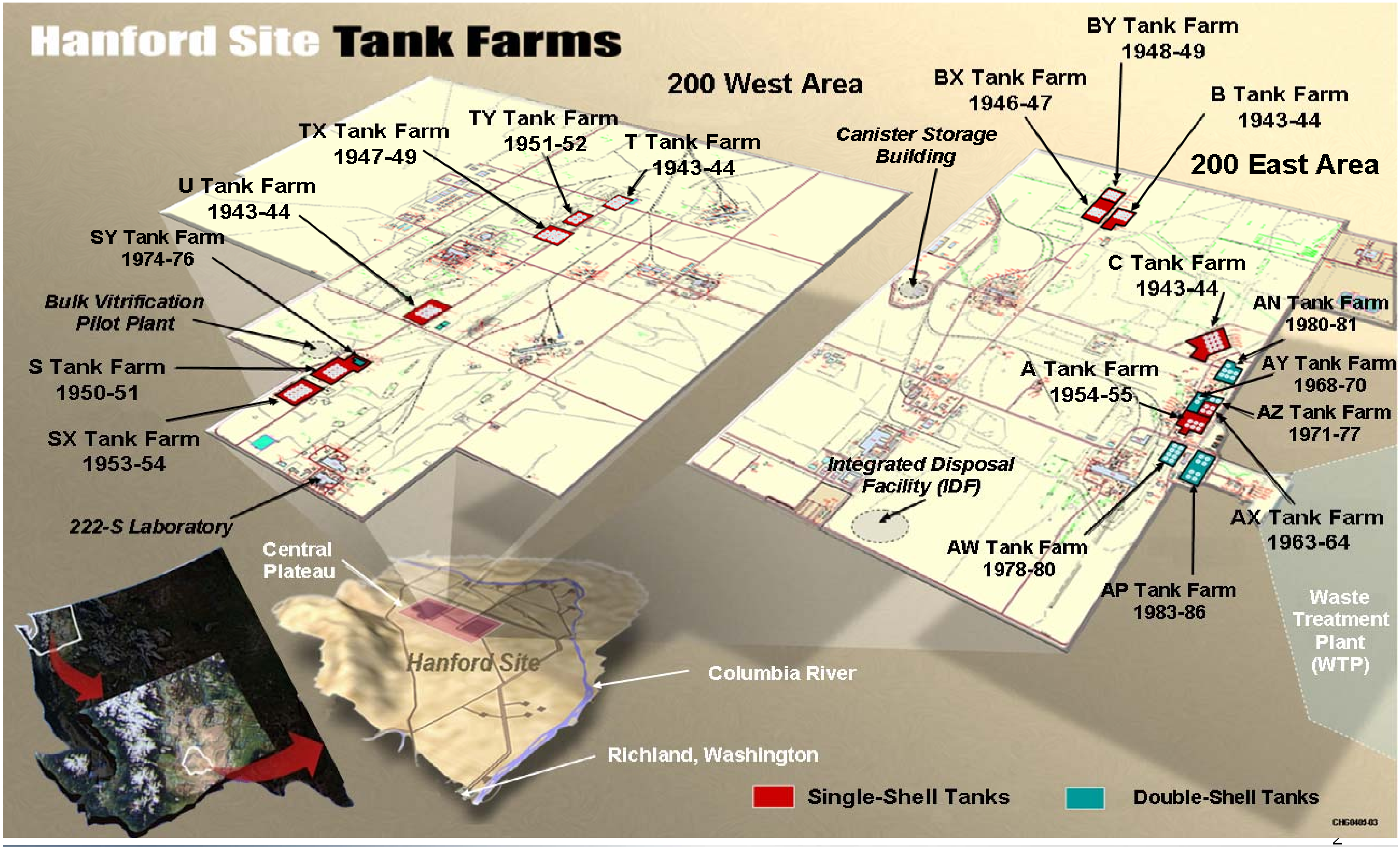
# Interfaces Involved in Modeling of Hanford Tanks

Modeling the Performance of Engineered Systems for Closure and Near-Surface Disposal
Salt Lake City, Utah

Michael Connelly (WRPS)
Marc Wood (CHPRC)

July 13 – 14, 2009

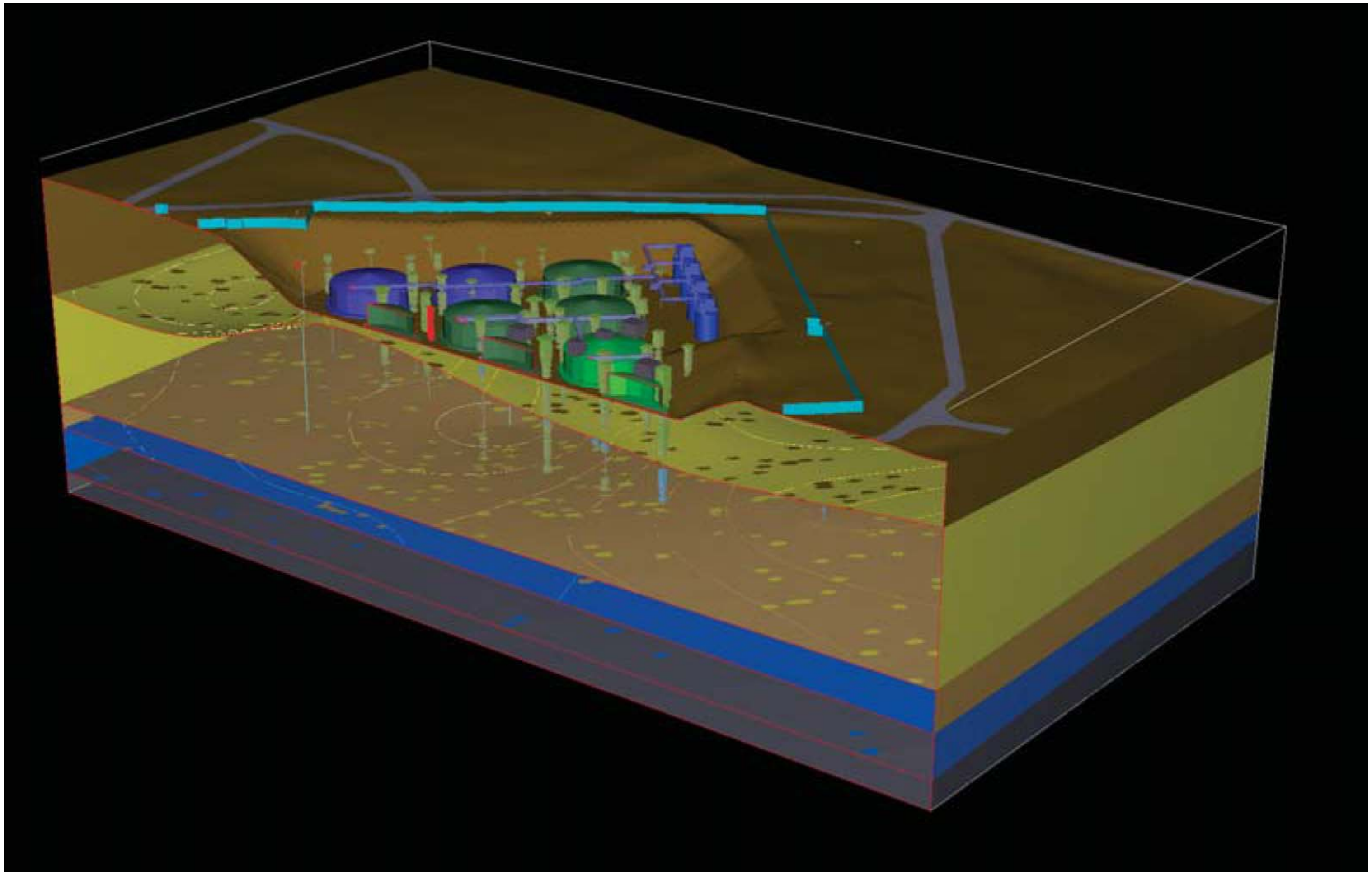
# Background: Hanford Site and Tank Farms



# General Conditions

- 149 ssts with waste from fuel reprocessing
- In the process of removing waste from tanks for vitrification
- Goal to remove as much waste as possible (99 % or better)
- Permanent closure includes grouting tank void volume and placing engineered barrier over tanks and nearby infrastructure
- Components being modeled are engineered cover, waste containment system, thick vadose zone and small portion of unconfined aquifer
- First version of a contaminant flow and transport analysis has been completed and scoping process is in place with decision makers and interested parties to refine the initial effort

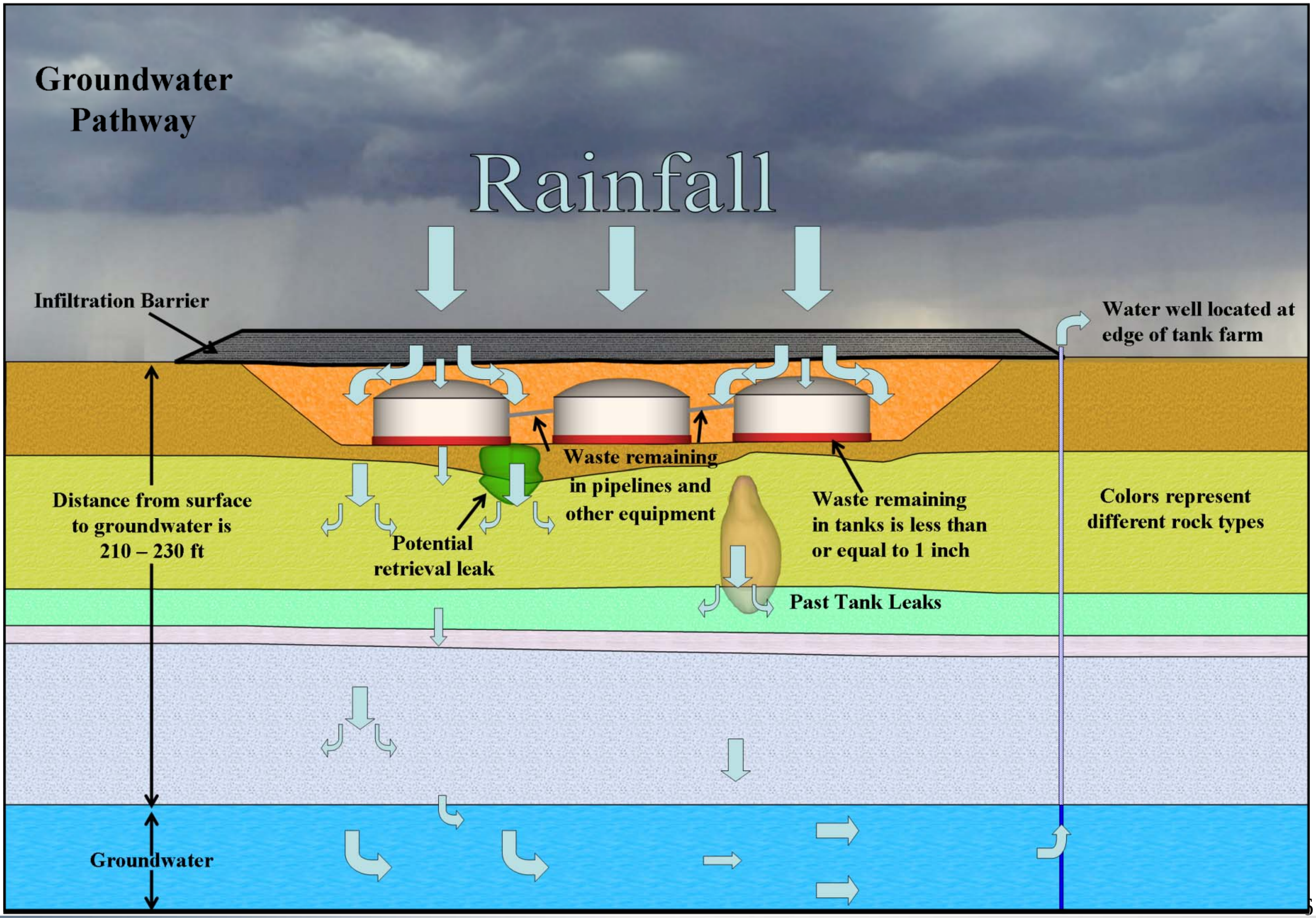
# Three-Dimensional Representation of WMA C



# NRC "Defense-in-Depth"

| Water Contacts Contaminants and Leaches into the Vadose Zone → | Contaminants in Vadose Zone Transported to Aquifer → | Contaminants in Aquifer Transported to Points of Use |
| --- | --- | --- |
| **Functioning Barrier / Feature**<br>• Surface Barrier<br>• Grouted Tank Structure | **Functioning Barrier / Feature**<br>• Surface Barrier<br>• Vadose Zone | **Functioning Barrier / Feature**<br>• Unconfined Aquifer |
| **Operating Properties and Processes**<br>• Evapotranspiration (low recharge rate)<br>• Grouted Tank Structure (diverted recharge)<br>• Minimum waste volume<br>• Diffusion through grout, tank liner, and shell | **Operating Properties and Processes**<br>• Low recharge rate<br>• Thick Vadose Zone ( > 200 ft)<br>• Water migration through layered geologic strata (variable hydraulic conductivity and anisotropy)<br>• Contaminant retardation (sorption)<br>• Radioactive Decay | **Operating Properties and Processes**<br>• Contaminant mixing with water leads to concentration dilution (hydraulic gradient, porosity, and conductivity)<br>• Dispersion over path length from aquifer entry location to point of use<br>• Contaminant retardation (sorption)<br>• Radioactive Decay |

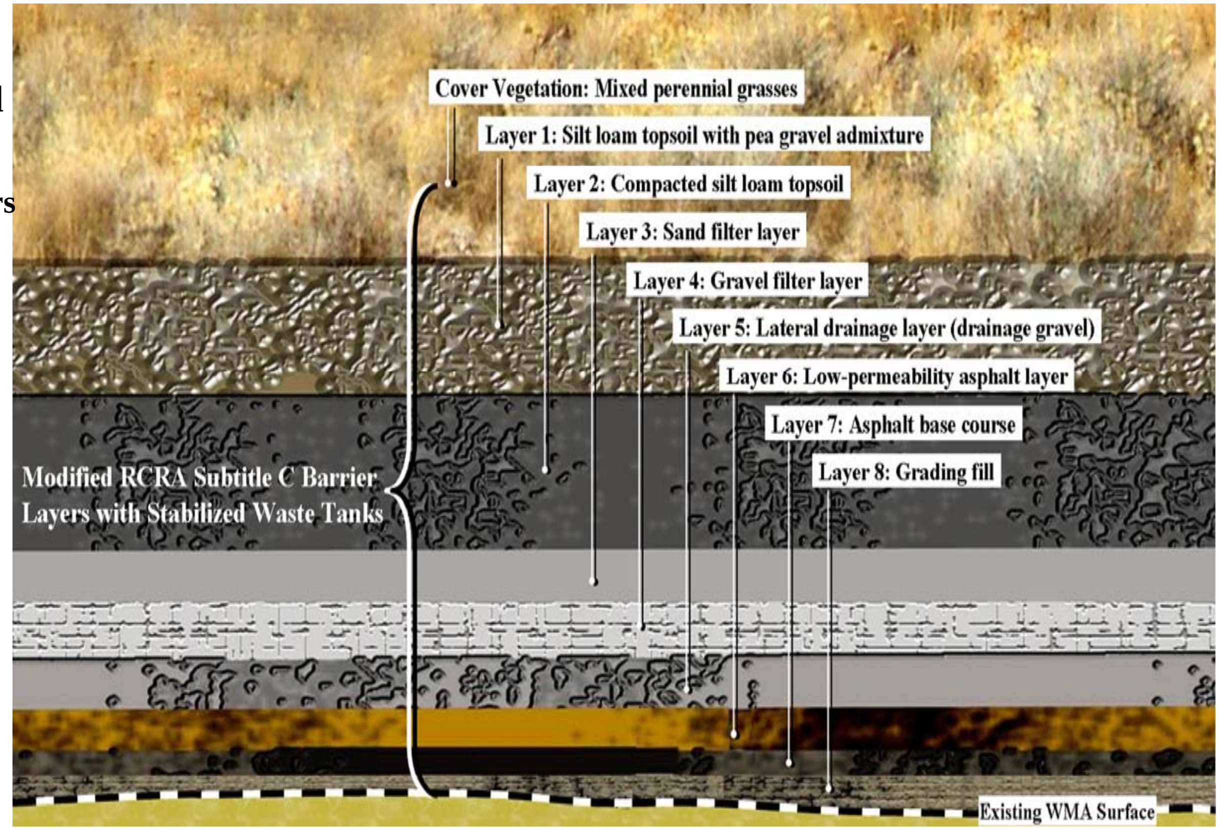
# Conceptual Model for Groundwater Pathway



# Engineered Surface Barrier: Modified RCRA C

## Engineered Cover Features

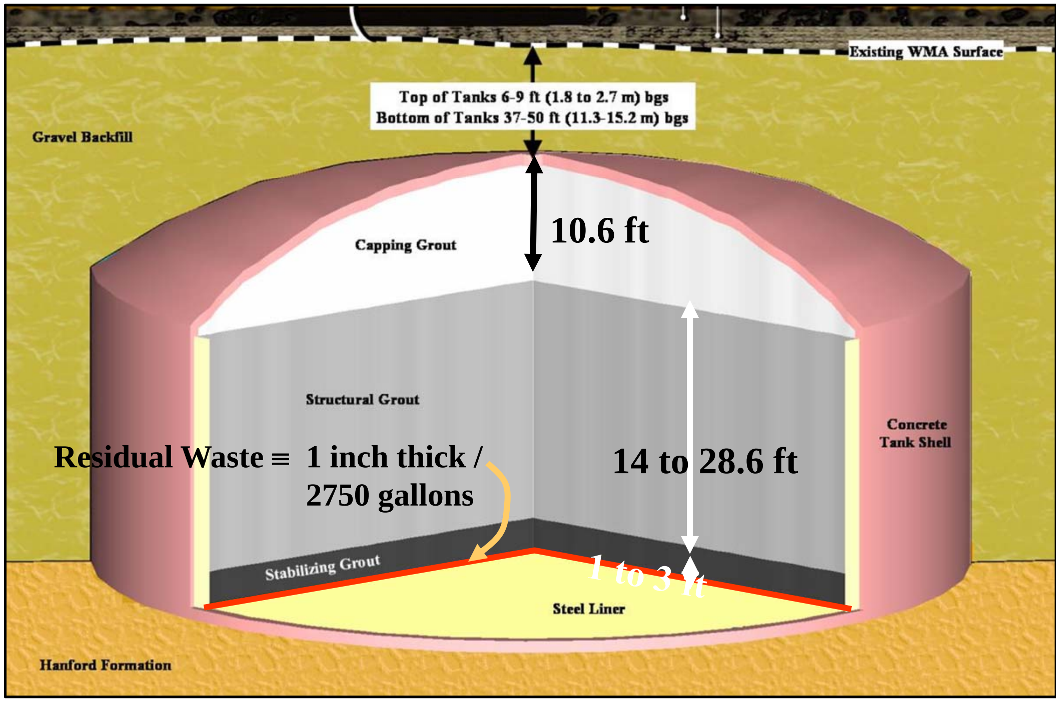
- Primary Purpose: Infiltration Control
- Supporting Performance Information
  - 20 + Years of Studying Infiltration/Barriers
  - Field Lysimeters
  - Prototype Barrier at B-57 Crib
  - Chlorine Studies
  - May Change Final Design to Mono-Layer
- Modeling Approach
  - Averaged Annual Infiltration Rate
  - Uses Design Goal of 0.5 mm/y
  - Measured a B-57 Prototype is < 0.1 mm/yr



# Barrier: Potential Grouted Tank Structure

## Waste Containment System

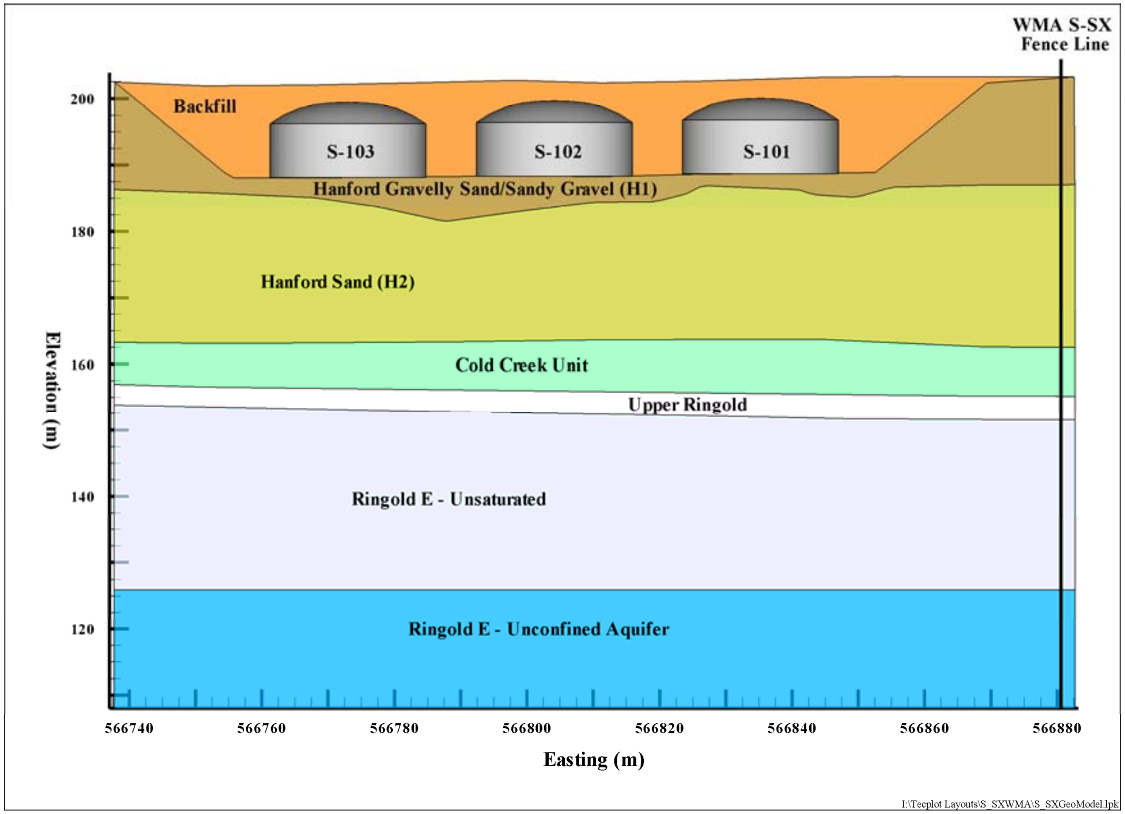
- Features (Waste inside liner, concrete shell, and grouted void volume)
- Primary Purpose: Limit water interaction with waste to slow release
- Supporting Performance Information
  - Generic diffusion release (SRL, Harbour et al. 2004 provided effective diffusion coefficients for Tc-99)
  - Durability of grout (SRL, Harbour et al. 2005 provided insights through consideration of ancient structures [Pantheon, Hadrian's Wall, and Roman Aqueducts)
  - Initiated Waste Release Studies at PNNL
    - Release of contaminants from residual waste
    - Interaction between residual waste and stabilizing grout
- Modeling Approach
  - Diffusional release at the structure bottom vadose zone interface
  - Assumes steel liner goes away at closure (conservative approach → no data for how the steel liner behaves)



# Natural Barrier: Vadose Zone

## Vadose Zone

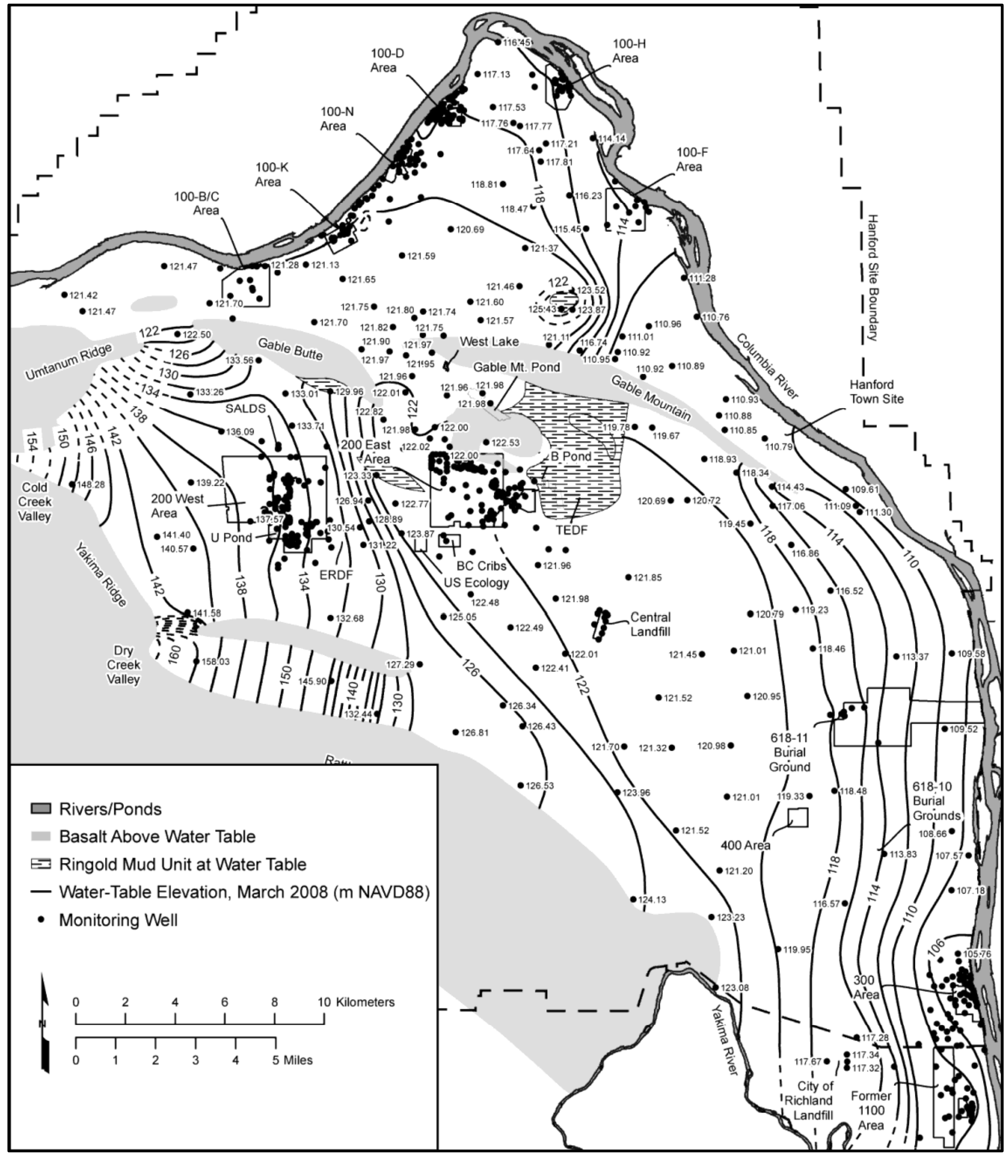
– **Features**
  - Greater than 200 ft thick
  - Three major stratigraphic units
  - Ubiquitous finer stratification of alternating particle size distribution, low moisture content (0.03 to 0.12 volumetric moisture content)
– **Supporting Performance Information**
  - Unsaturated/saturated hydraulic conductivity measurements on lab scale samples for major particle size distributions
  - Hanford site specific moisture characteristic curves (van Genuchten-Mualem Parameters)
  - Geophysical logging has provided volumetric moisture content
  - Hanford site specific sorption data for various contaminants (mostly radionuclide)
– **Modeling Approach**
  - Moisture-dependent hydraulic conductivity and anisotropy,
  - Two-dimensional simulation
  - Advective flow through porous media



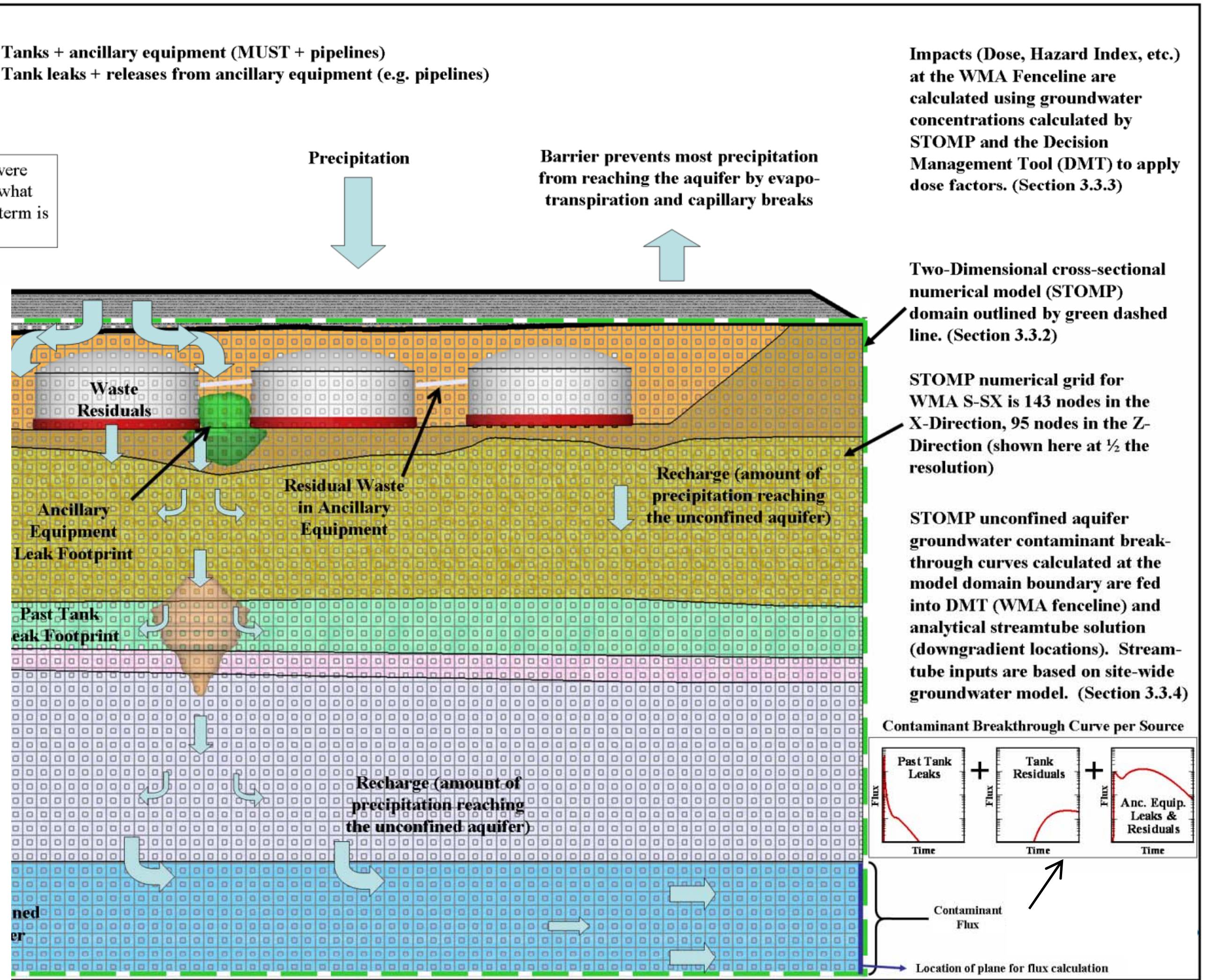
# Natural Barrier: Unconfined Aquifer

## Unconfined Aquifer

- **Features**
  - **Location dependent major unit**
  - **Hydraulic conductivity**
  - **Thickness**
  - **Gradient**
- **Supporting Performance Information**
  - **In -situ hydraulic conductivity measurements**
  - **Head data from monitoring well network**
- **Modeling Approach**
  - **Advective flow through porous media**



# Integrated Numerical Representation



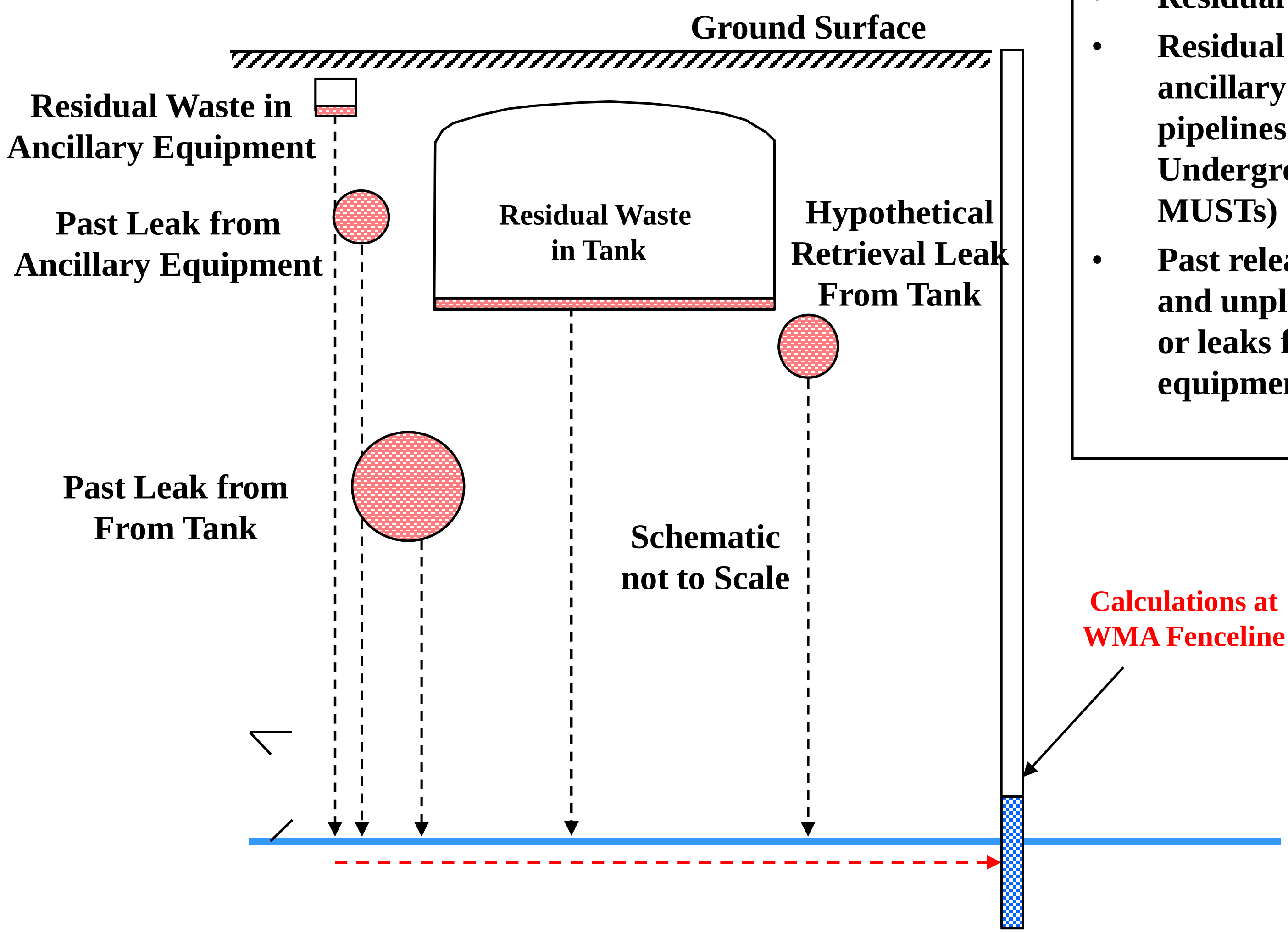

- **Numerical Code: STOMP (*Subsurface Transport Over Multiple Phases*)**
  - **Infiltration**
  - **Wste Release**
  - **Transport through the vadose zone**
  - **Unconfined aquifer out to the WMA Fenceline**
- **Approach uses 2-D Slice**
  - **Through tank structure**
  - **Reference Case and sensitivity off of reference case**
- **Interfaces**
  - **Infiltration rate boundary**
  - **Diffusional release across tank bottom**

# Reference Case

Post -closure conditions affecting flow and transport of tank residual contaminants

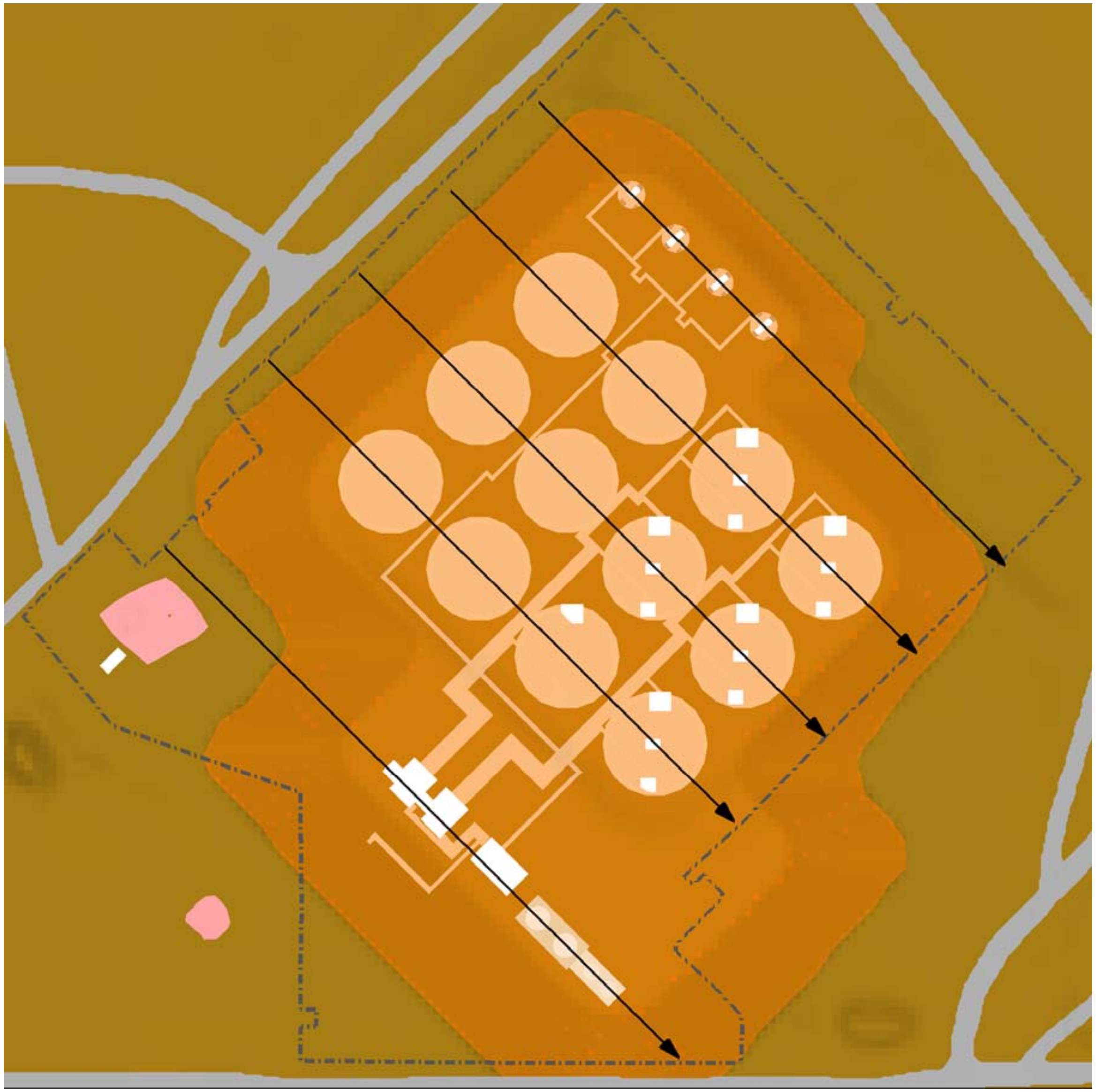
- Small residual inventory for mobile contaminants (e.g. ranges from ~0 to 12 Ci of Tc-99, at WMA C maximum = ~0.75 Ci
- Recharge History
  - Operational Period: 2000-2032: 100 mm/yr
  - Functional Surface Barrier: 2032-2532: 0.5 mm/yr
  - Degraded Surface Barrier: 2532-12,032: 1.0 mm/yr
- Diffusion release from tank bottom (1E-9 $cm^2/s$)
- Vadose zone > 200 ft thick
- Contaminant sorption bins in vadose zone and unconfined aquifer (0, 0.2, 0.6 mL/g)
- High groundwater flux in local unconfined aquifer (200 East Area)

# Schematic Diagram of Subsurface Contaminant Migration Under an SST WMA

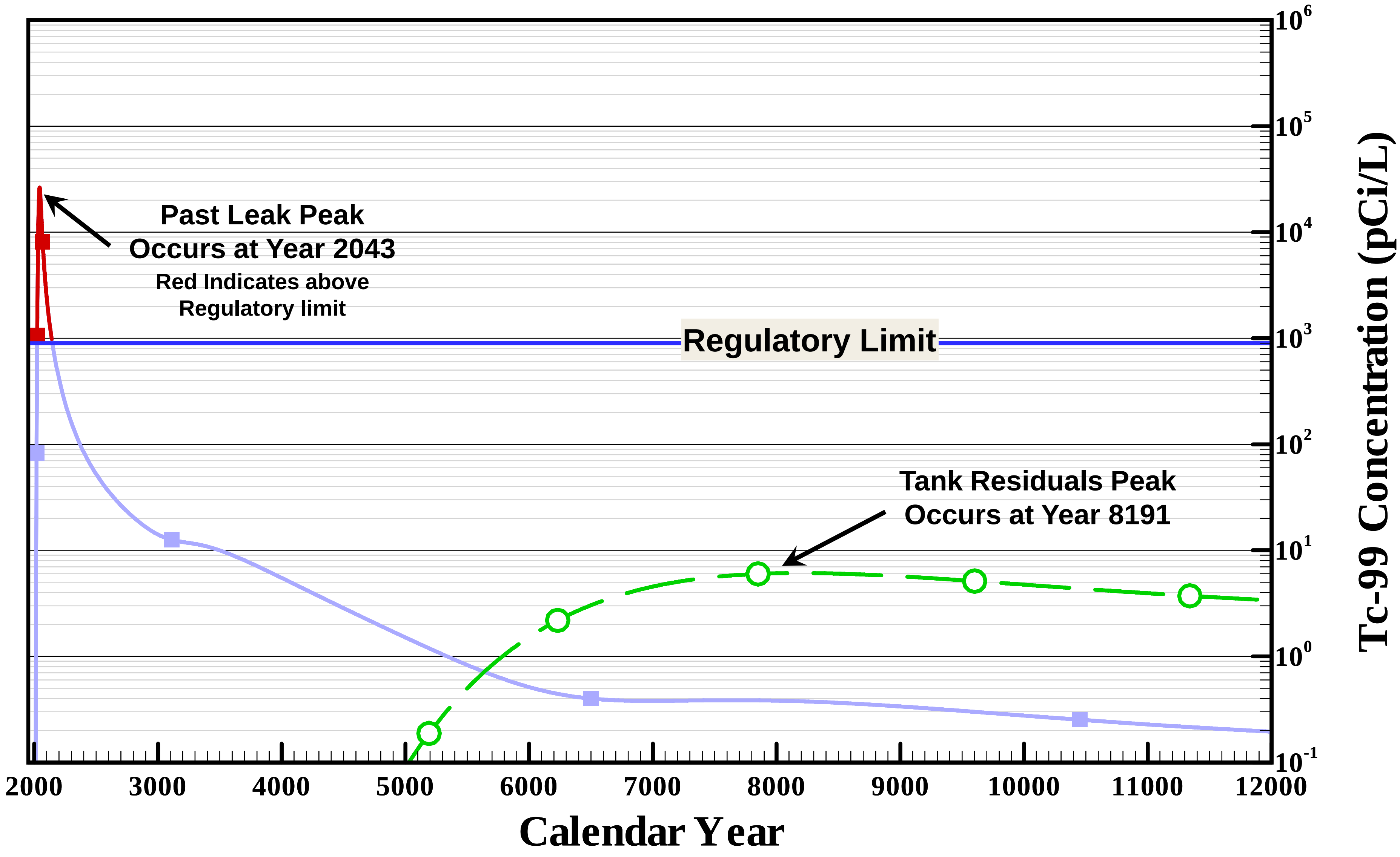



- Residual waste in tank
- Residual waste in tank ancillary equipment (i.e., pipelines and Miscellaneous Underground Storage Tanks or MUSTs)
- Past releases (i.e., tank leaks and unplanned releases (UPR) or leaks from ancillary equipment)

# Plan View of WMA C Showing 5 Pathlines



# Typical Result at WMA Boundary Groundwater Pathway



# Primary Reference Case Results for the WMA C Tank Residual Source Term

- Within 10,000 yr post-closure, non negligible radionuclide groundwater concentrations from tank residuals come only from completely mobile (Kd = 0 mL/g) contaminants
- Contamination levels are proportional to inventory and only Tc-99 has sufficient estimated inventory (< 3 Ci per pathline row) to generate non negligible groundwater concentrations
- Peak concentrations are more than 2 orders of magnitude below the MCL of 900 pCi/L at the fenceline