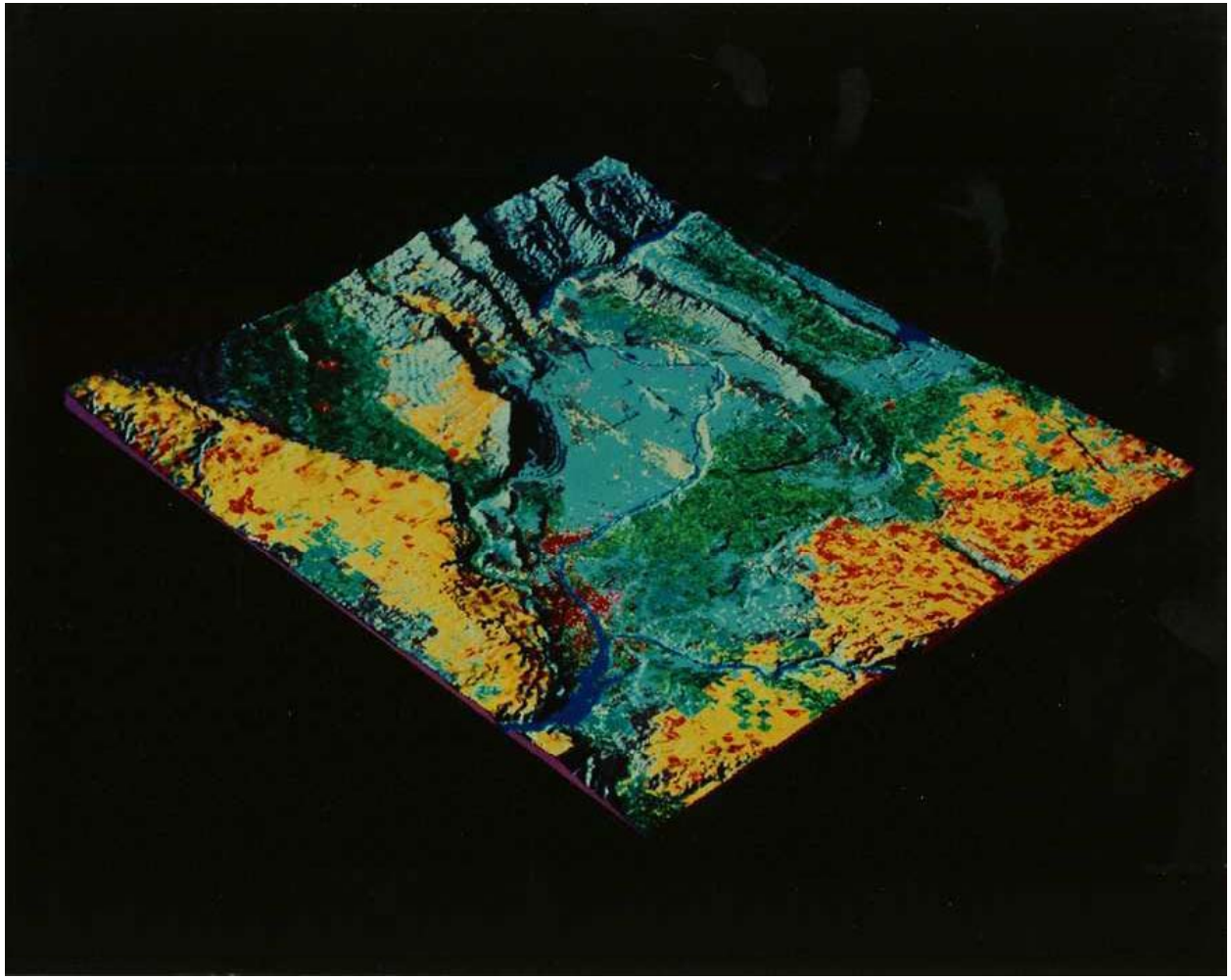
Hanford Groundwater Overview - Challenges to Cleanup

DOE-RL Groundwater Project

NAS Committee on Development and Implementation of a Cleanup Technology Roadmap

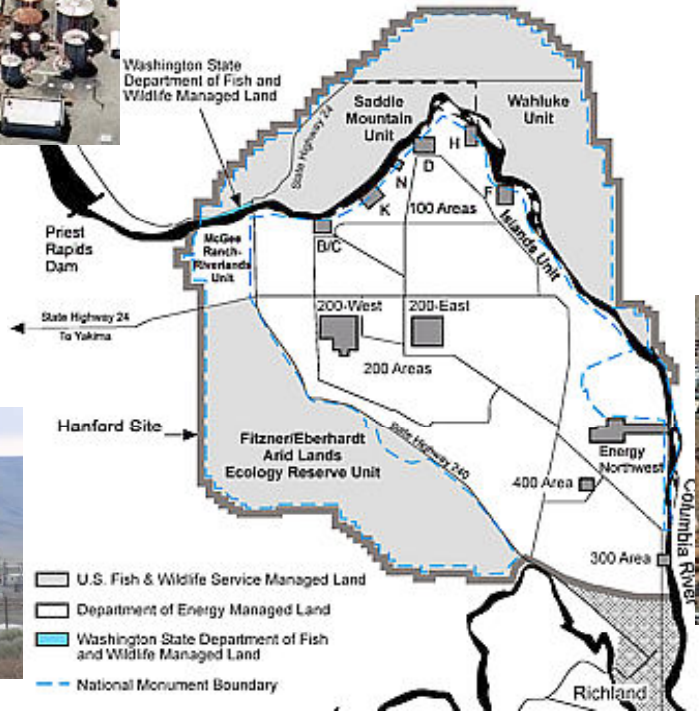
October 31, 2007



Nuclear Fuel Cycle

Irradiate Fuel Elements

Chemical Separations

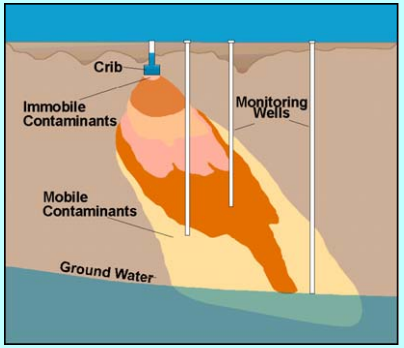


Plutonium Finishing

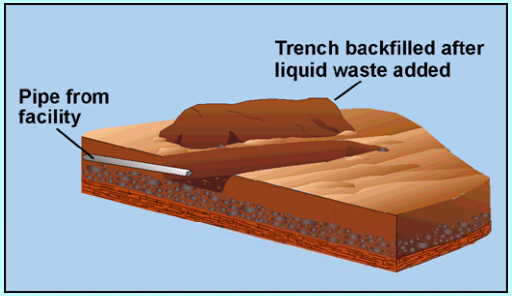
Manufacture Fuel Elements

Methods of Planned Liquid Releases to the Ground

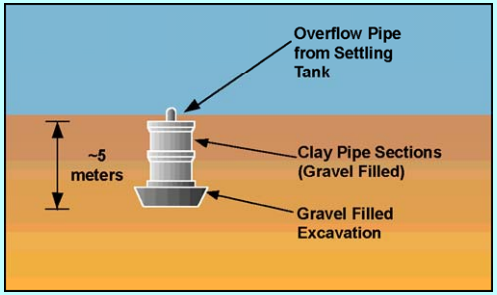
Cribs
1944-1990s



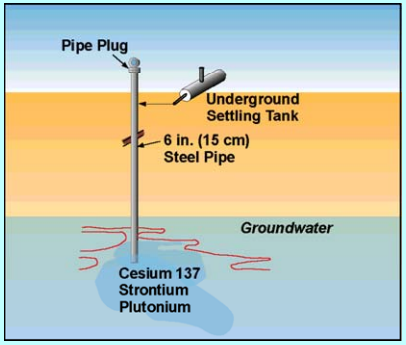
Specific Retention Trenches
1944-1973



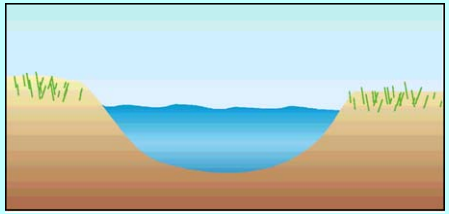
French Drains
1944-1980s



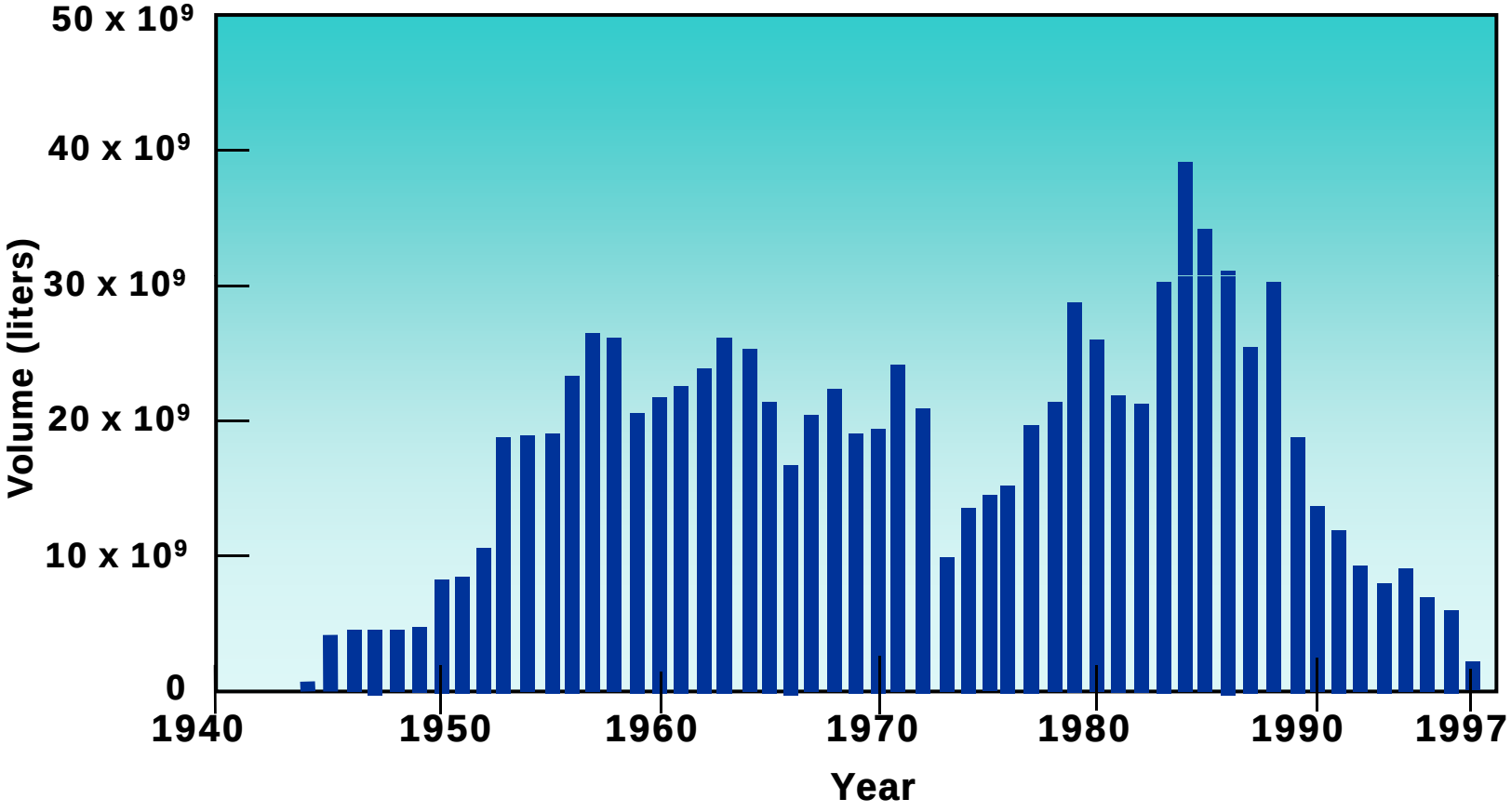
Reverse Wells
1945 - 1955
(one to 1980)



Ponds
1944-1990s

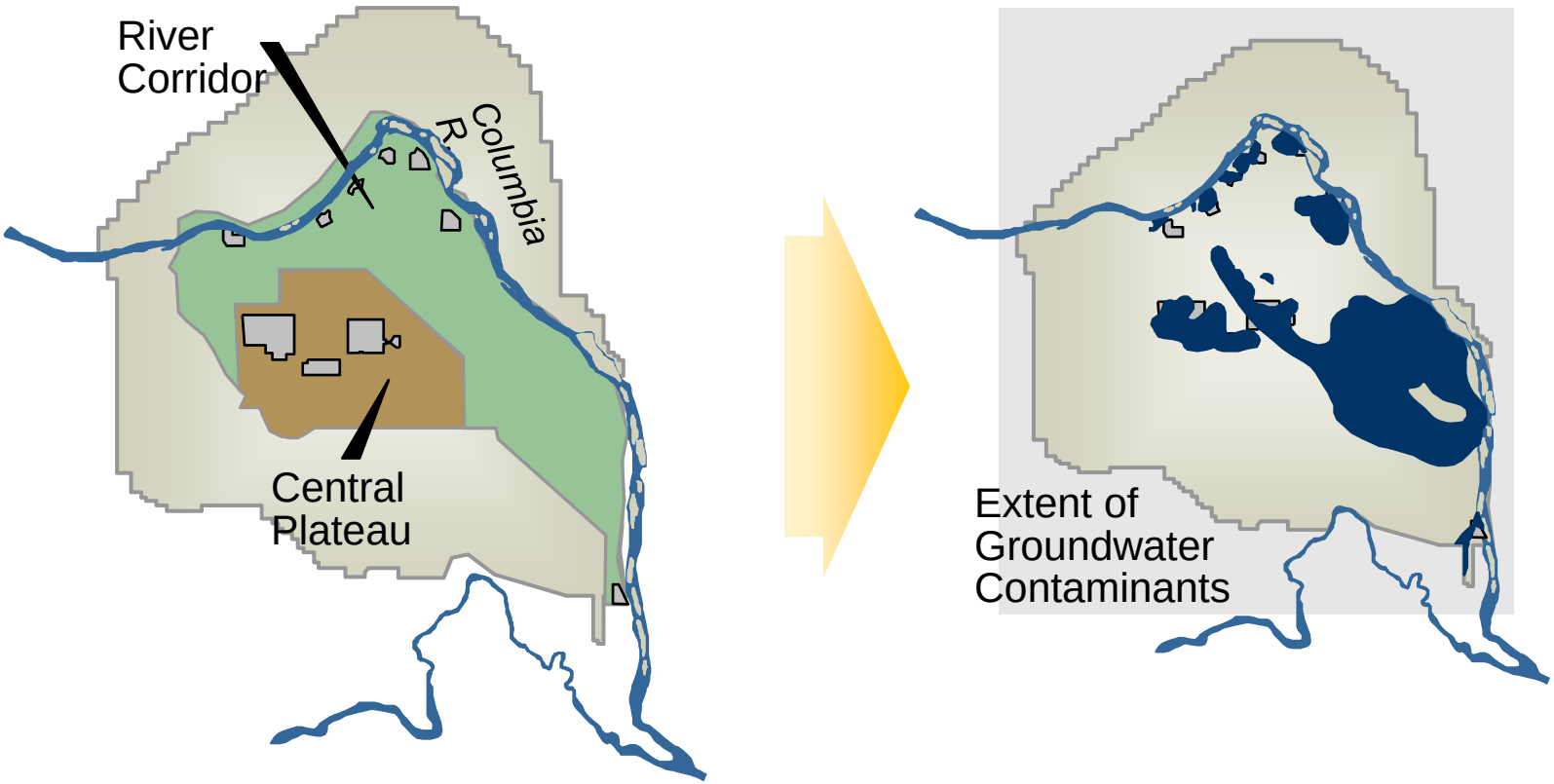


Liquids Discharged to Ground (450 billion gal)



Hanford Site Groundwater Overview

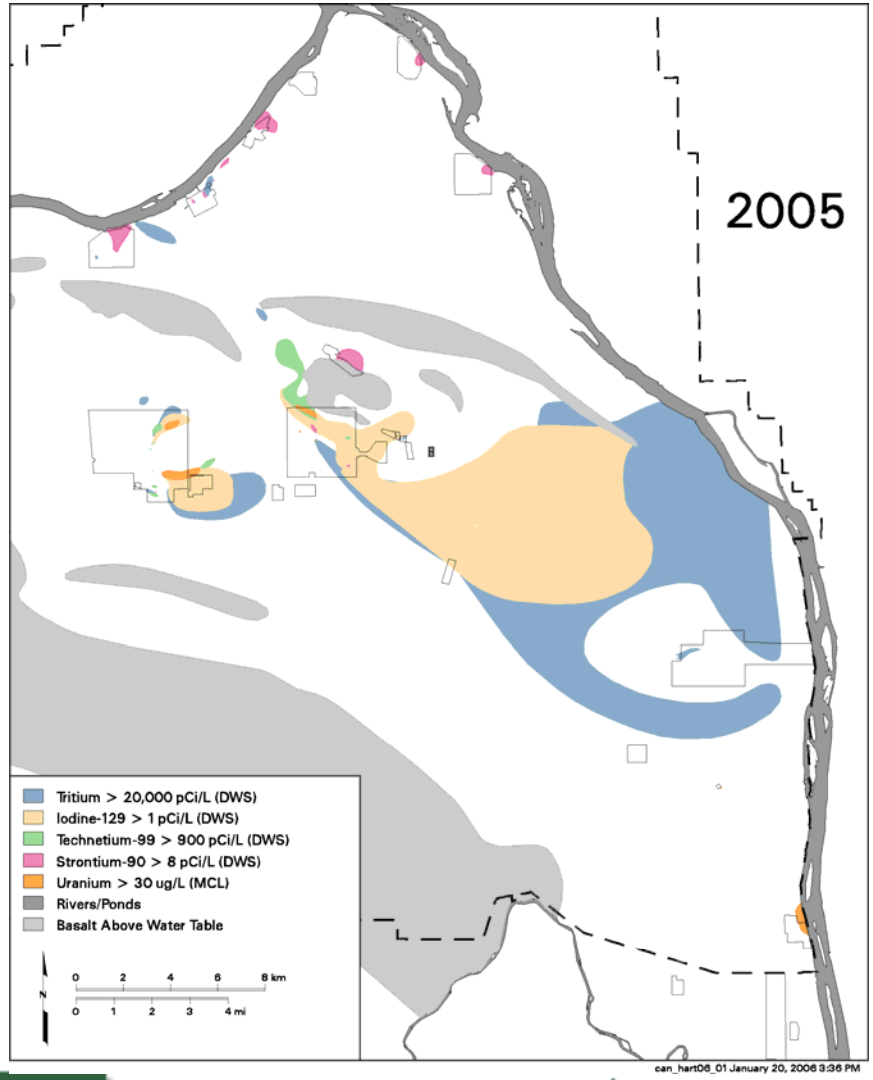
Extent of Groundwater Contamination



- Approximately 80 square miles of groundwater contaminated above drinking water standards
- Contaminants from 100/300 Areas and 3H from PUREX reach Columbia River

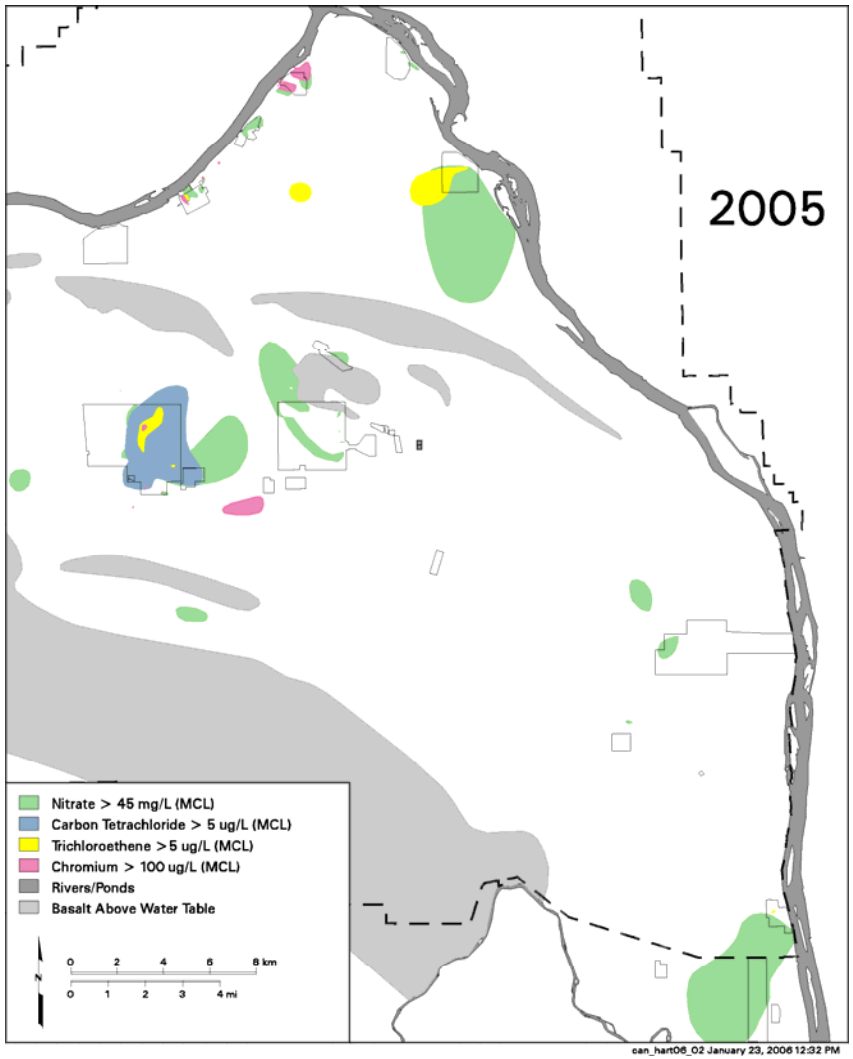
Radioactive Contaminants

- Tritium
- Iodine-129
- Technetium-99
- Uranium
- Strontium-90

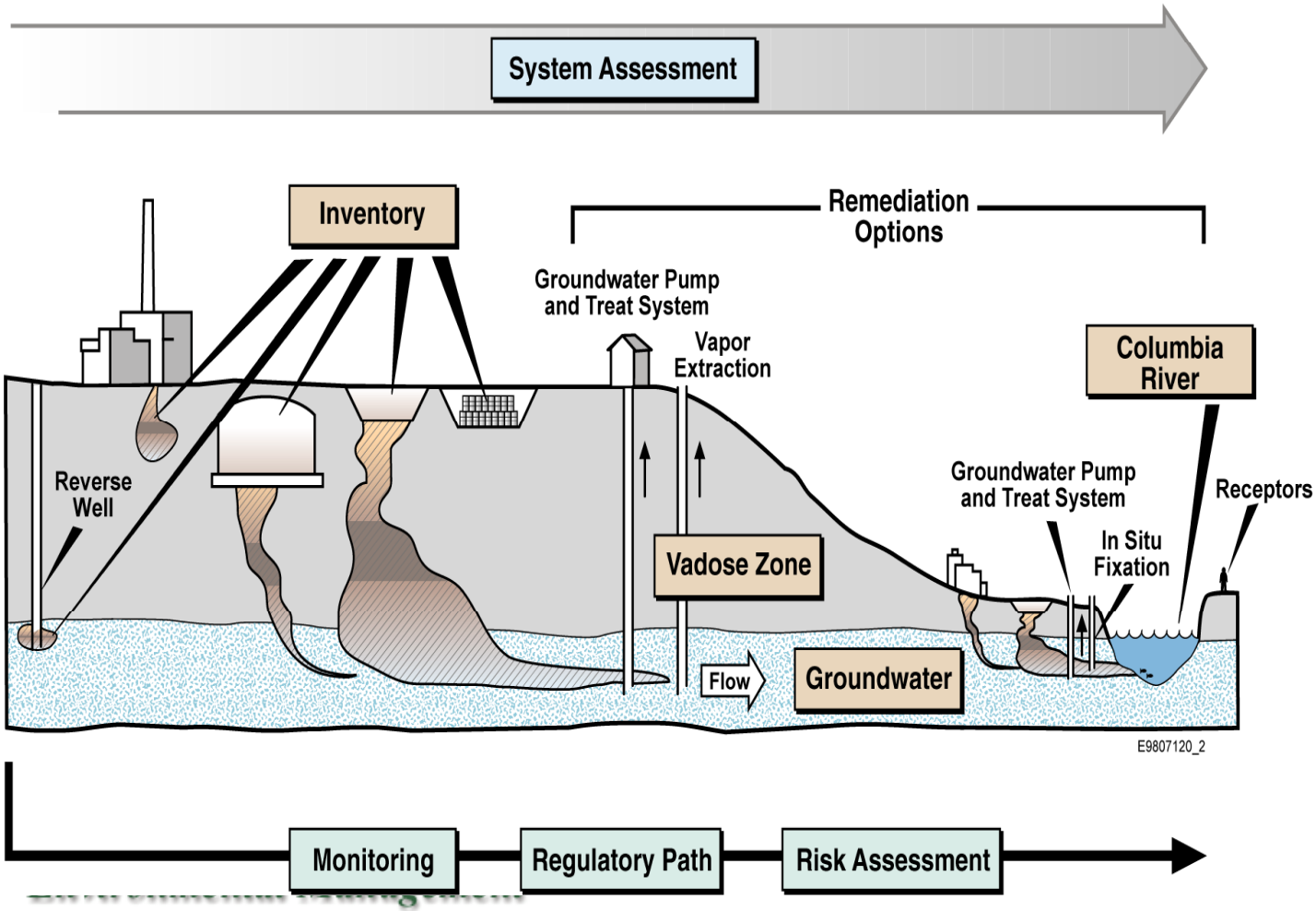


Chemical Contaminants

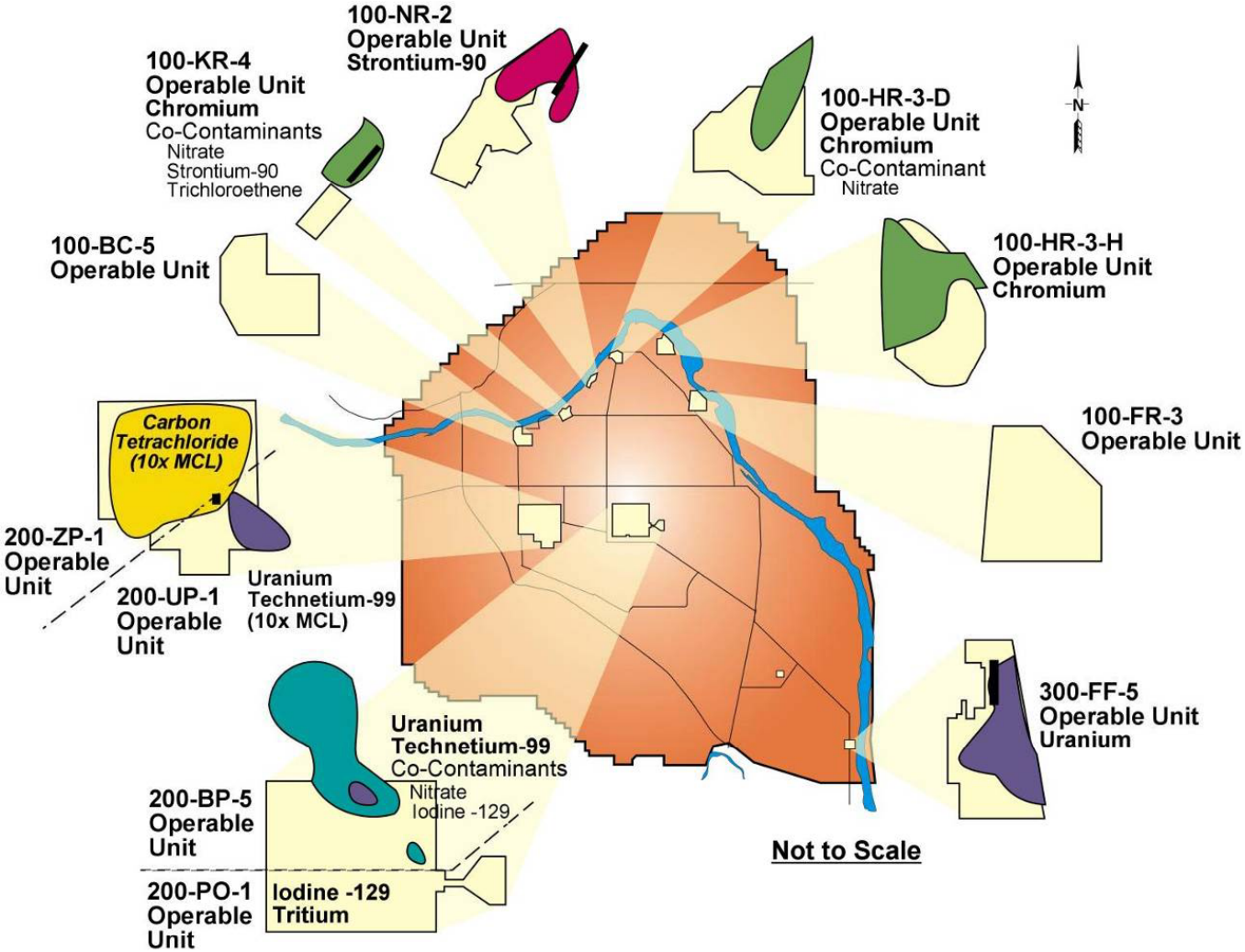
- Nitrate
- Carbon tetrachloride
- Trichloroethene
- Hexavalent chromium



System Model



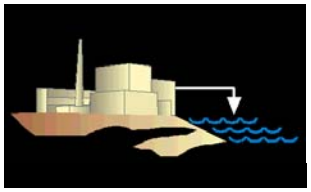
Remediation of groundwater plumes and protection of the Columbia River

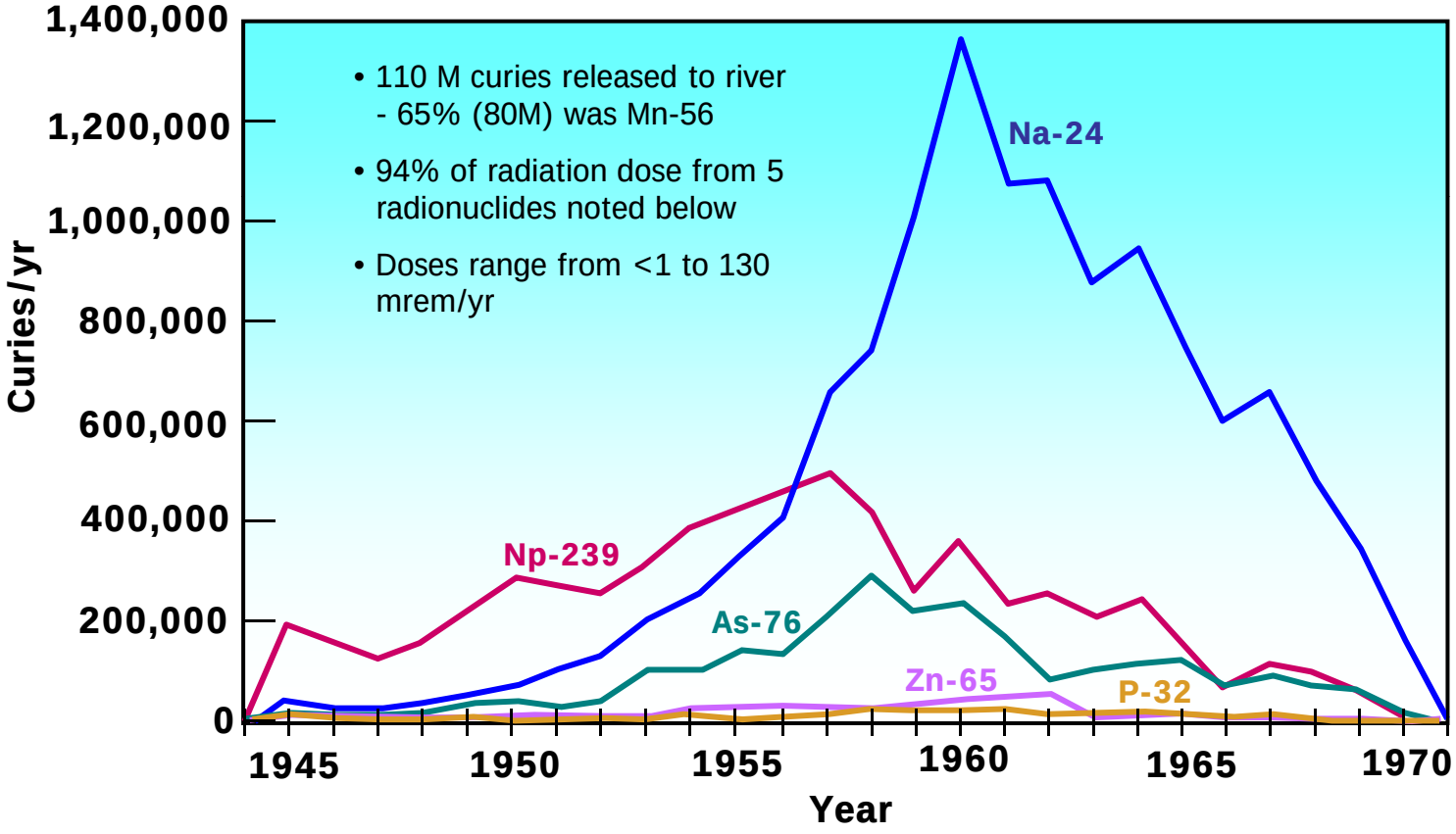


Columbia River

- 2nd largest river in the Continental United States (120,000 CFS average flow).
- WA State Designation of Water Quality is “Class A Excellent” for the Hanford Reach.
- H-3, Sr-90, I-129, U-234, U-238, Pu-239/240 are generally measured in the Hanford Reach mainstream above minimum analytical detection techniques; all well below DWS, all have Hanford and non-Hanford sources.
- In general, only H-3, I-129 and occasionally U are measured at a statistically higher concentration below Hanford as compared to above Hanford in the mainstream of the river.
  - Hanford is the largest source of H-3 and I-129
  - Largest source of U is from irrigation returns
- Current potential impacts occur where receptors are exposed to contaminated groundwater - contaminated groundwater “upwells” into the river gravels and seeps from the shoreline springs during low river stages in the riparian habitat. Mainstream of the river is not adversely impacted.

Key Radionuclides Released to Columbia River From Past Reactor Operation Discharge





RADIONUCLIDES IN COLUMBIA RIVER

Source: State of Oregon Radiation Protection Services

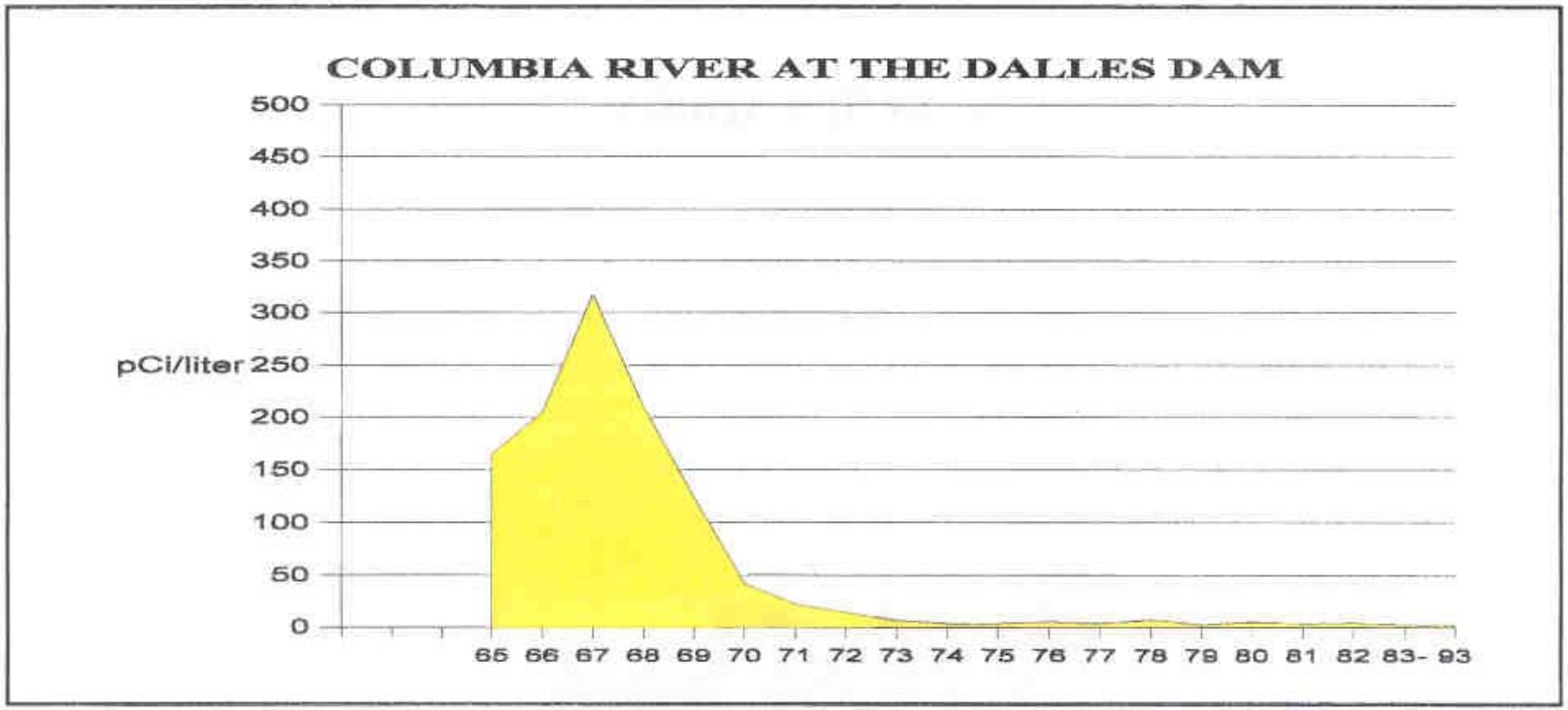
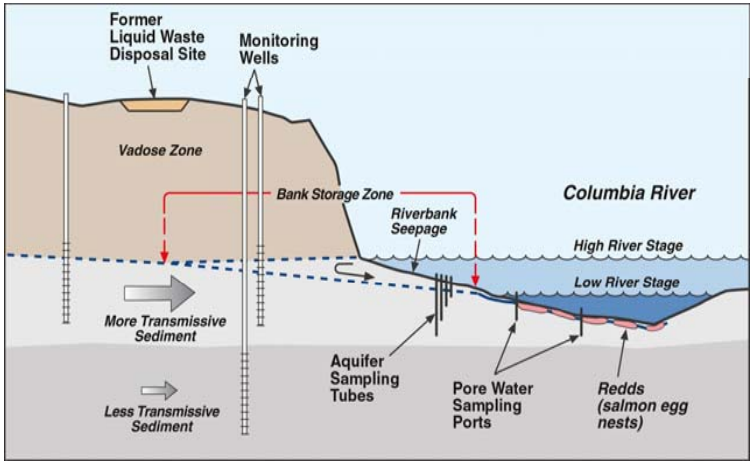


Figure 8. Average gross beta activity in surface water in pCi/liter at The Dalles Dam, 1965-1993.

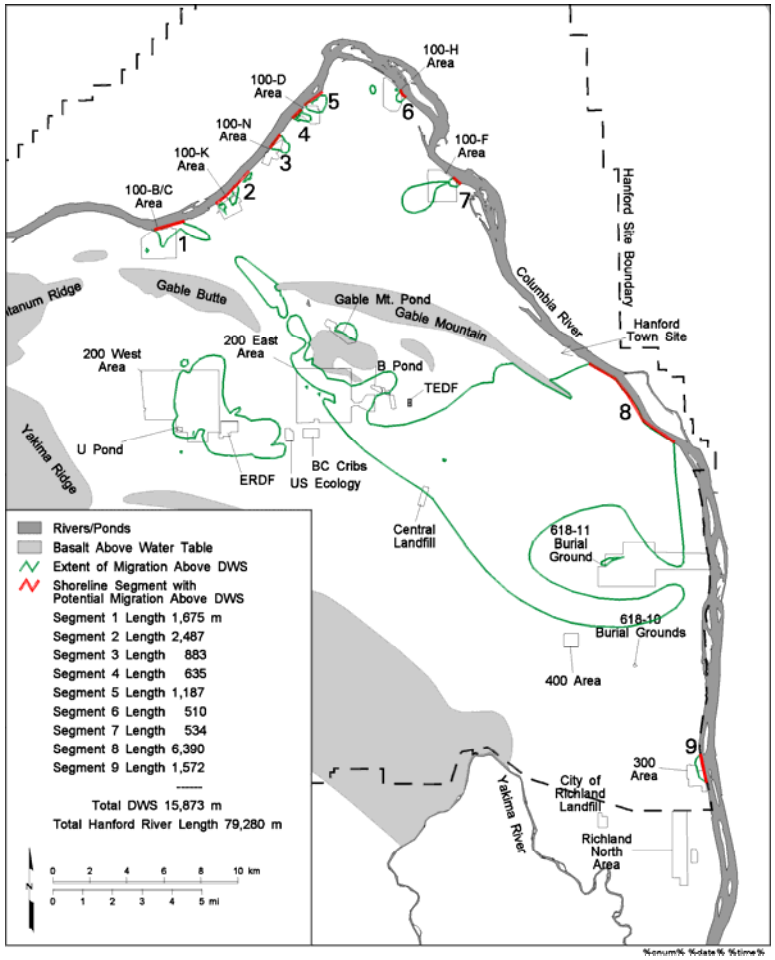
Past Direct Discharges During Reactor Operations
KE Reactor Retention Basins and Crib During Operations

Current Exposure at the Columbia River From Hanford-Derived Contaminants to Humans and Other Biota is localized

- Hyporheic Zone - groundwater upwells into the gravel bed of the river
- Riparian Zone - seeps containing a mixture of river water and groundwater



Approximately 16,000 meters of Columbia River shoreline receive contaminated groundwater



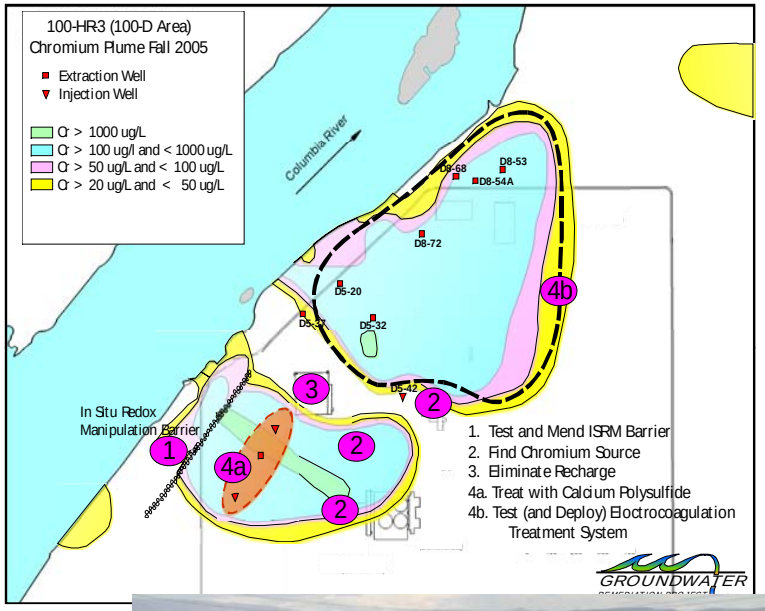
2006 GAO Audit

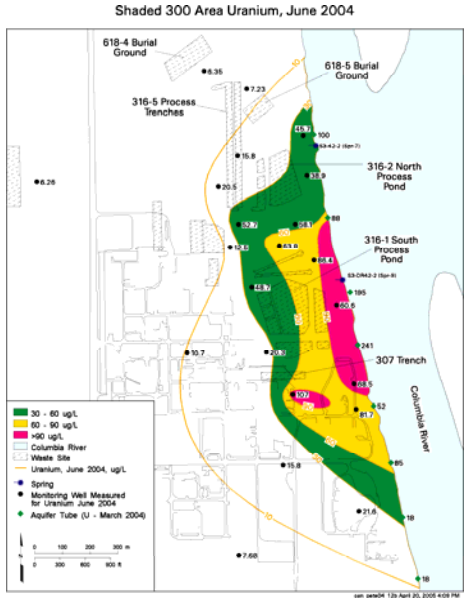
The conferees are concerned about DOE's efforts to protect contaminants from reaching the Columbia River. Technology used in several remedies is not performing satisfactorily, and there is a lack of new technologies to address contamination issues.

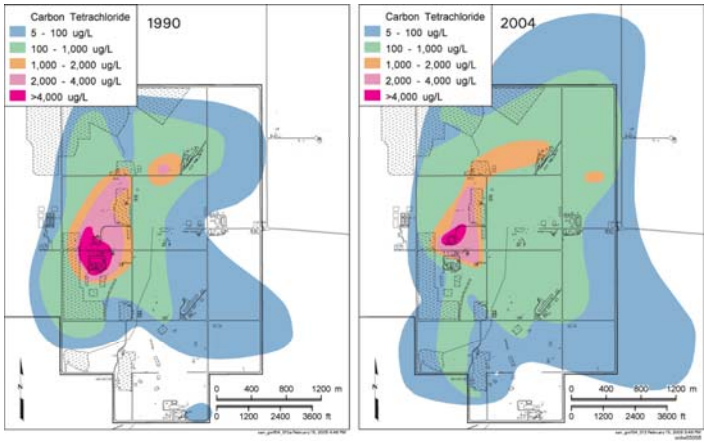
Key Hanford Contaminants Relevant to Congressional Concerns in CY 2006

- Contaminants Currently Entering the River
  - Hexavalent Chromium in the 100 Area reactor sites & the “Horn” of the river
  - Strontium-90 at 100-N
  - Uranium at the 300 Area
  - Tritium from 200 East Area (PUREX)
  - Iodine-129 from 200 East Area (PUREX)
- Contaminants that may reach the River in the future from the 200 Area (Based on mobility, half-life & inventory)
  - Technitium-99
  - Uranium
  - Carbon Tetrachloride

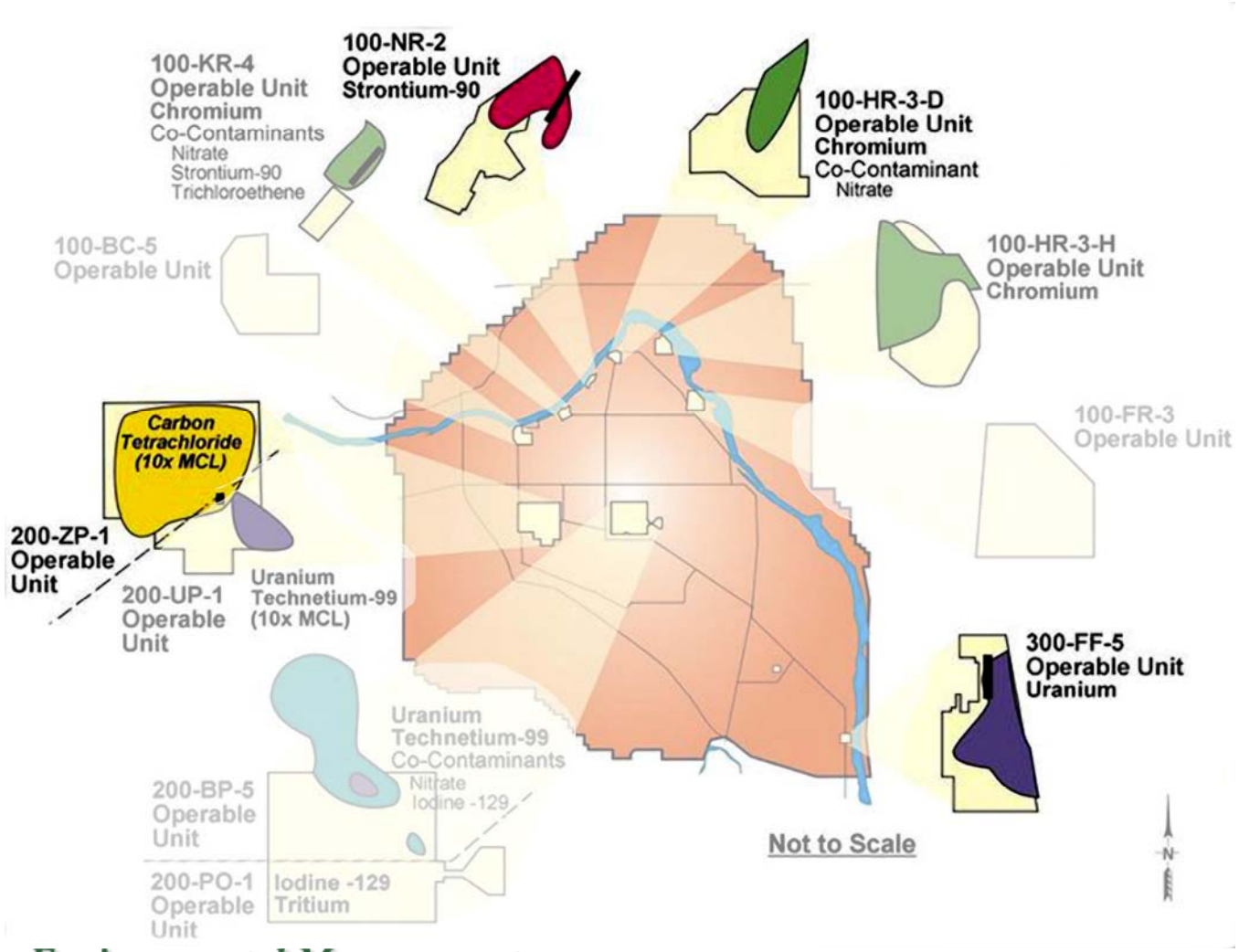
Columbia River Protection Projects
Four Areas of Focus – FY 2006/2007







CERCLA Operable Units Impacted by the Nine Projects Funded in FY 2006 & Supplemented in FY 2007 by RL and DOE-HQ



FY 2006 Columbia River Protection Projects Funded by $10M Directed Funding

Hexavalent Chromium in the 100-D & 100-K Areas

- Inject Micron-size Iron into Deteriorating Portions of the In Situ Redox Manipulation (ISRM) Barrier
- Field Test Electrocoagulation for Accelerated Cleanup of the Northeastern Plume in the 100-D Area
- Accelerated Bioremediation (Biostimulation)
- Geochemical/Mineralogical Study of Chromium in the Vadose Zone
- Refine Location of the Chromium Source at the 100-D Area

Strontium-90 in the 100-N Area

- Sequestration of Sr-90 Subsurface Contamination in the Hanford 100-N Area by Surface Infiltration of an Apatite Solution
- 100-N Area Strontium-90 Treatability Demonstration Project: Phytoremediation along the 100-N Columbia River Riparian Zone

Uranium in the 300 Area

- 300 Area Uranium Plume Treatability Demonstration Project: Uranium Stabilization through Polyphosphate Injection

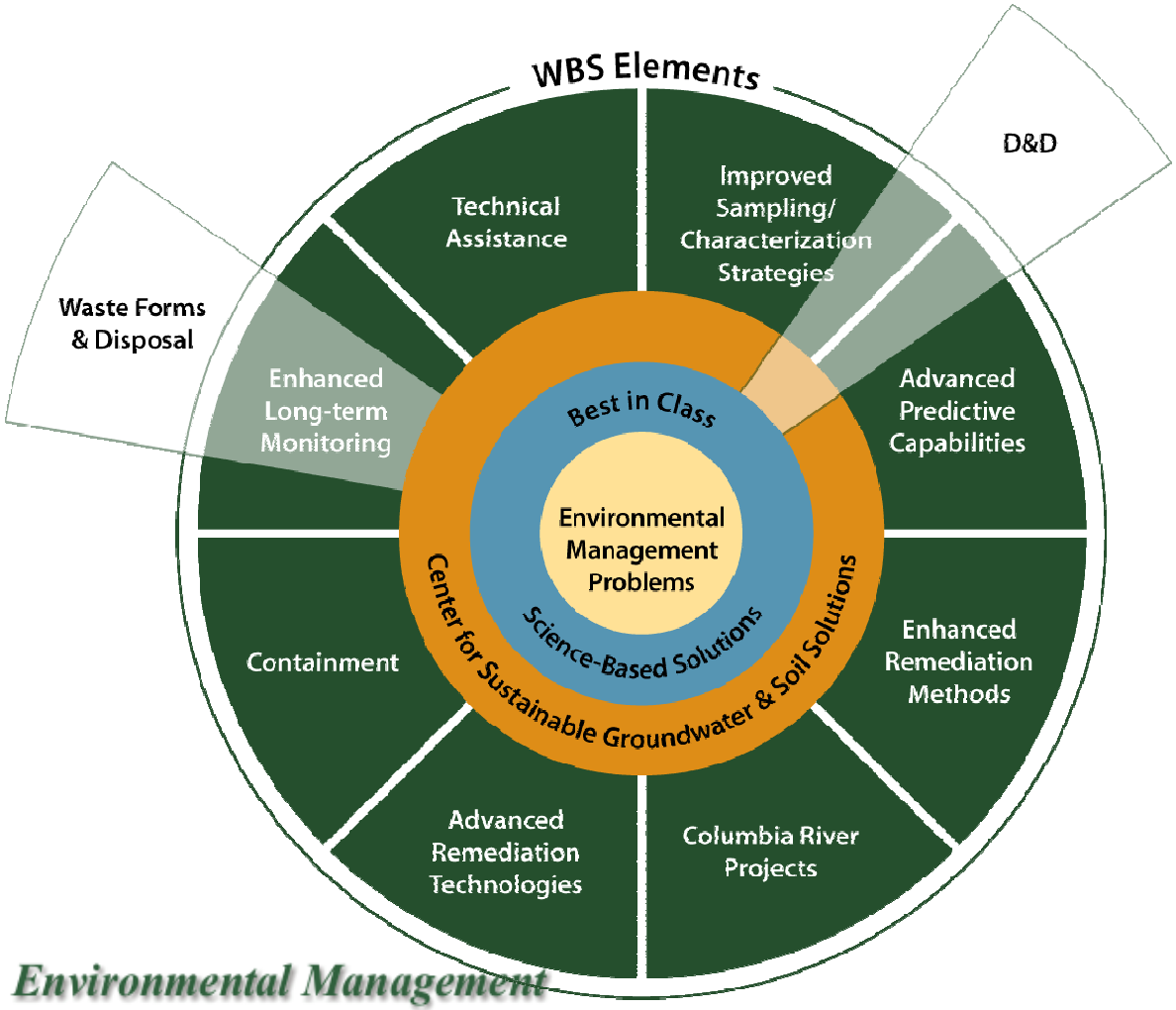
Carbon Tetrachloride in the 200 Area

- Carbon Tetrachloride and Chloroform Attenuation Parameter Studies: Heterogeneous Hydrolytic Reactions

FY 2007 Columbia River Protection Projects $2M Funded by EM-20 (DOE-HQ)

- **Hexavalent Chromium in the 100-D & 100-K Areas**
  - Additional source Investigation at 100-D
  - 4 additional characterization wells funded by RL
  - 12 wells to characterize chromium in the "Horn" between 100-D and 100-H - funded by RL
- **Strontium-90 in the 100-N Area**
  - Laboratory tests for biologic uptake
- **Uranium in the 300 Area**
  - Laboratory tests supporting vadose zone application of polysulfide sequestration

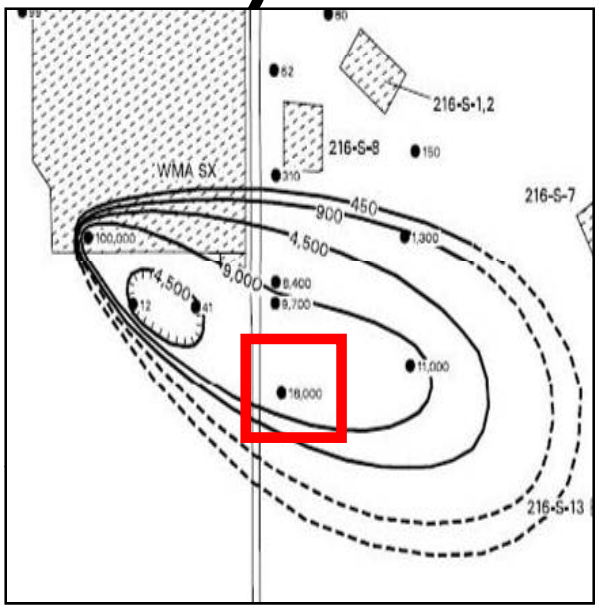
WBS Element Integration
Soils and Groundwater Remediation Program

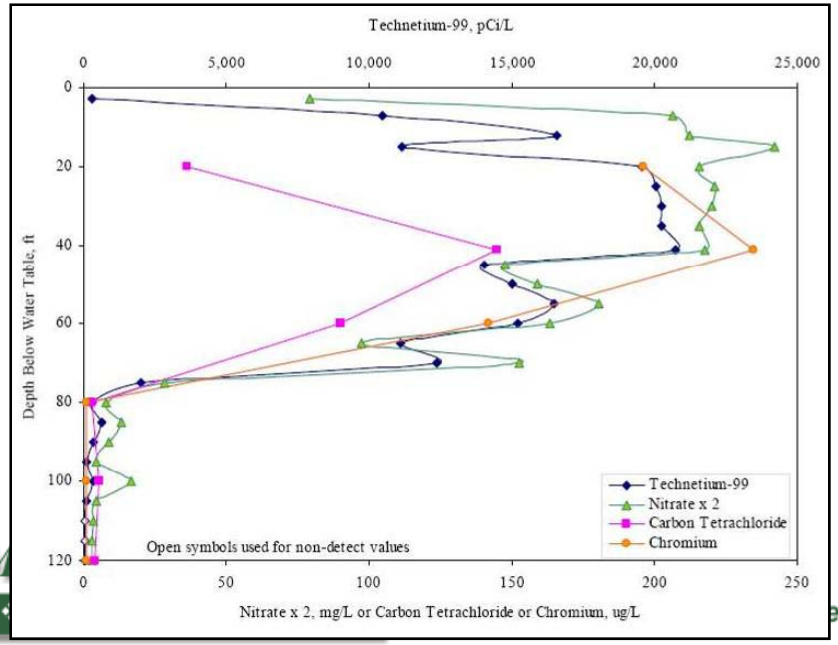


ART Project (200-UP-01)

Arcadis

- Key constituents of concern are technetium-99, nitrate, chromium
- Three injection wells and four new monitoring wells planned
- Planned reagents molasses and ferrous sulfate
- 5Yr Project $3.6M





ART Project Objectives

- Demonstrate effective distribution of reagents to the Ringold formation gravels
- Demonstrate that reducing biogeochemical conditions can be induced and sustained for a treatment period (i.e., 18 months to 2 years)
- Demonstrate that the concentration of key COCs in the groundwater can achieve treatment goals in 2 years or less in the reactive zone:
- Demonstrate that the precipitated technetium and chromium remain in insoluble forms. Note: we expect a continued flux of these radionuclides from upgradient.
- Show that secondary water quality impacts of the EARP technology are limited spatially downgradient of the reactive zone

Tank Farm Scope

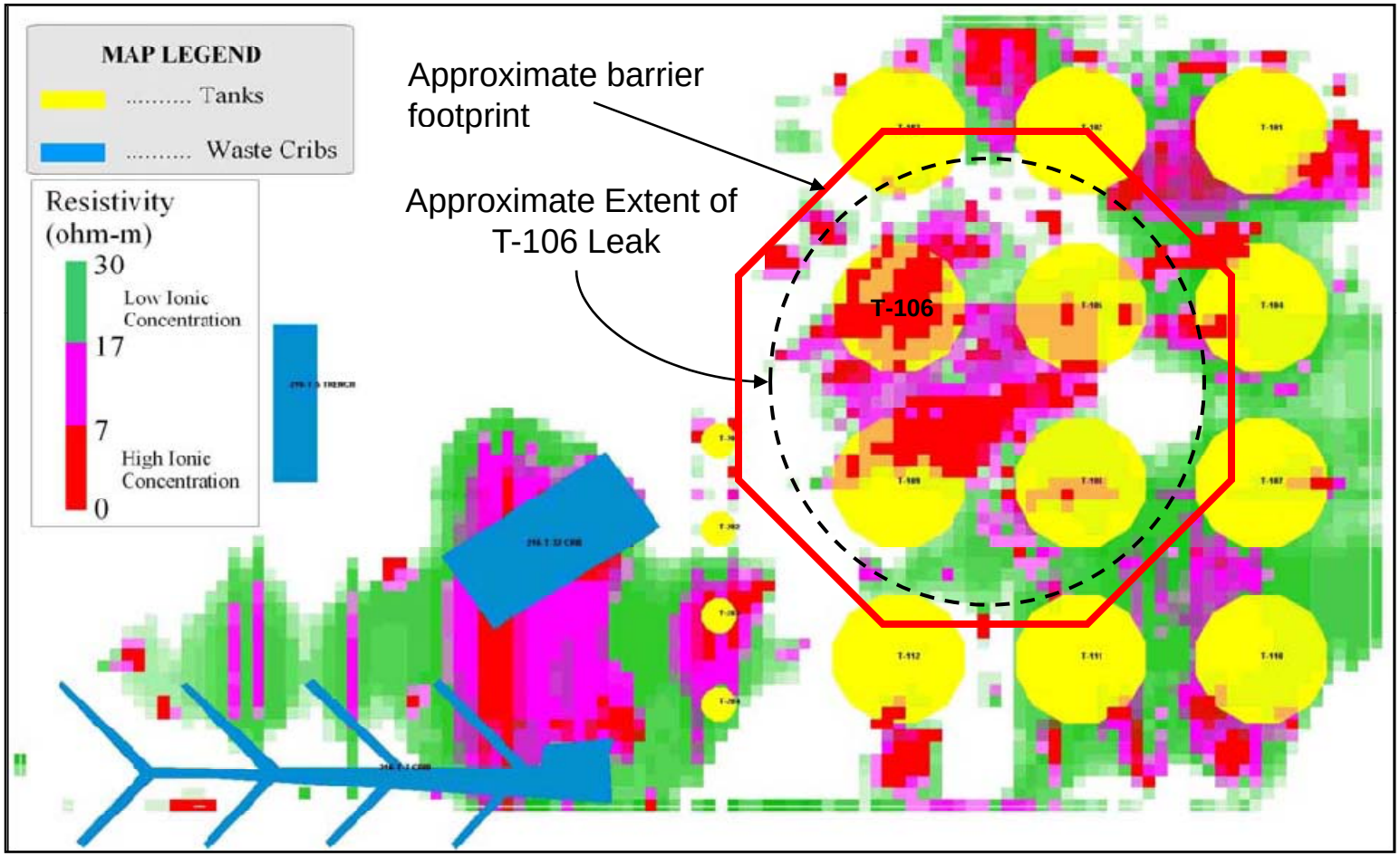
- 149 Single-Shell Tanks (SST) and 28 Double-Shell Tanks (DST)
- SSTs organized into 12 farms and 7 waste management areas (WMA)
- 67 SSTs are known to or are assumed to have leaked (~1 million gallons) (HNF-EP-0182)
- Over last 9 years, the Tank Farm Vadose Zone Program has
  - characterized the largest plumes,
  - implement surface water control measures
  - researched past knowledge,
  - developed new science and technology, and
  - estimated future impacts.

Advanced Science and Technology

- Science
  - Understand cesium mobility
  - Made progress on uranium mobility

- Technology
  - Used Advanced Photon Source to characterize radioactive samples
  - Developed direct push probeholes to > 100 feet bgs
  - Extended HRR/SGE to areas with large amounts of infrastructure and to areas with co-mingled plumes from nearby cribs and trenches.

Tank T-106 Plume



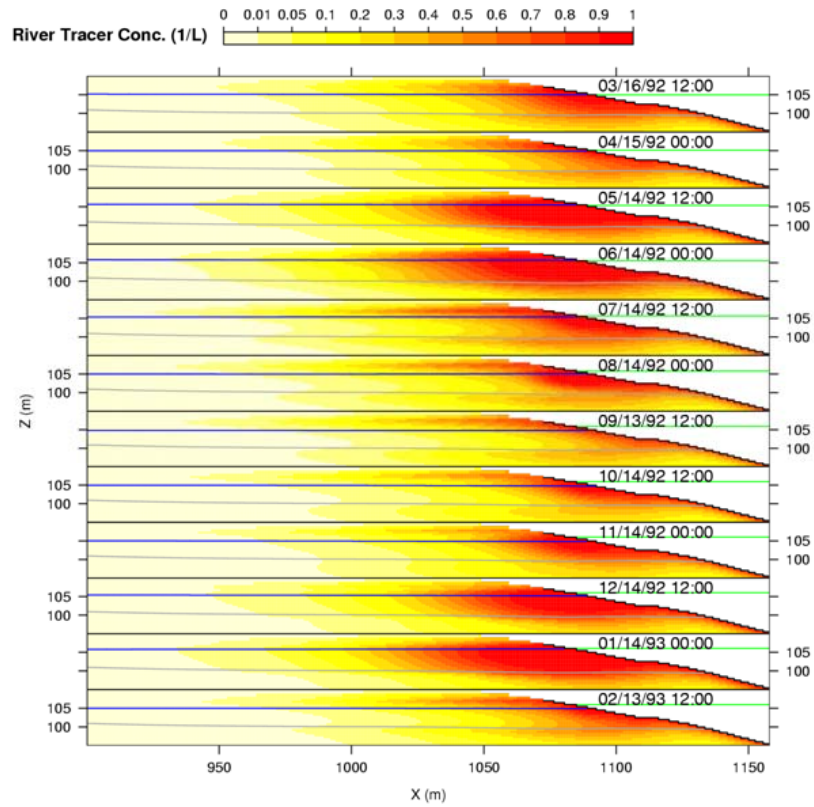
Well-to-Well Resistivity taken from Figure ES-1, RPP-RPT-28955, Rev 0, *Surface Geophysical Exploration of T Tank Farm at the Hanford Site*)

Approximate extent of T-106 Leak based on RPP-23752, 2005, *Field Investigation Report for Waste Management Areas T and TX-TY*, Figure 3-12

Technology Challenges for Hanford Soil and Groundwater Remediation

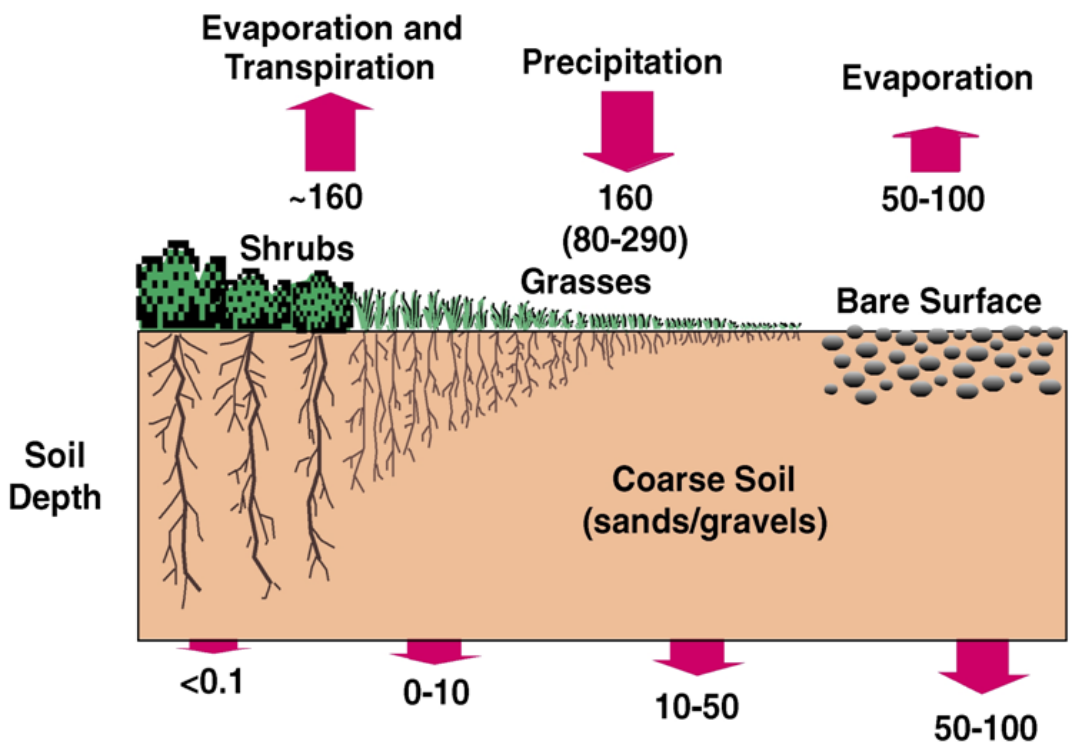
Groundwater and Vadose Zone Challenges

- Develop Numerical Models of Groundwater and Vadose Zone Chemical Reaction and Transport
  - Reactive transport models are needed to evaluate detailed conceptual models and to provide input for records of decision for in situ remediation as well as monitored natural attenuation.



Groundwater and Vadose Zone Challenges

- Determine Groundwater Recharge Through the Vadose Zone
  - Determine moisture flux through representative waste sites, including vegetated and graveled surfaces, accounting for seasonal variations in precipitation and heating.



Groundwater and Vadose Zone Challenges

- Develop Cost-Effective, In-Situ Remediation of Carbon Tetrachloride in the Vadose Zone
  - needed to meet an overall remediation goal of source reduction and control of groundwater concentrations below regulatory limits
- Develop and Test Cost-Effective, In Situ Remediation Technologies for Radionuclides in the Deep Vadose Zone
  - primary radionuclides of concern include uranium, technetium-99, plutonium, cesium, cobalt, and strontium-90.

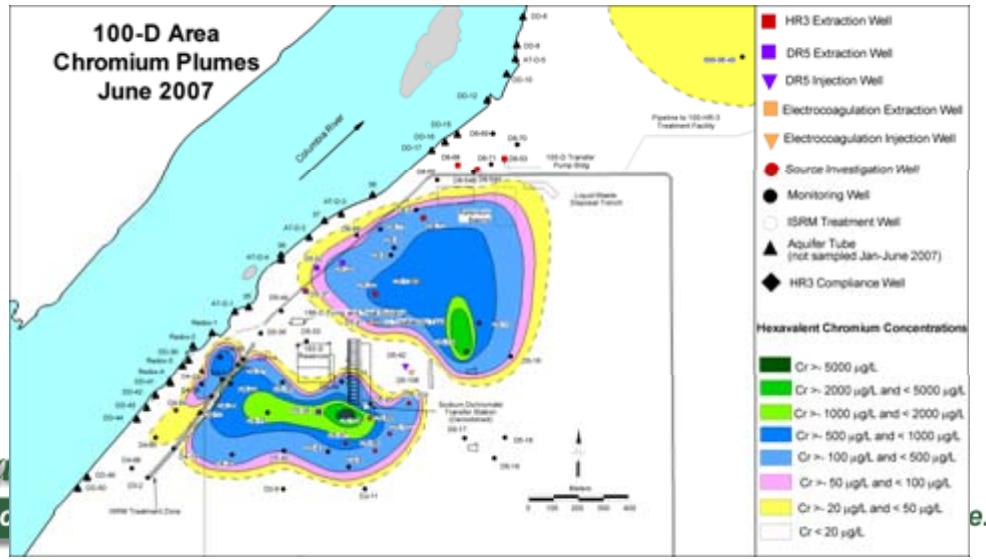
Groundwater and Vadose Zone Challenges

- Develop improved, Cost-Effective Methods for Subsurface Access to Support Characterization and Remediation
  - Subsurface access challenges include deep groundwater table, near-surface objects such as buildings or underground tanks, and a vadose zone consisting of unconsolidated silty sand, gravel, and cobbles

Enhanced Access Penetration System

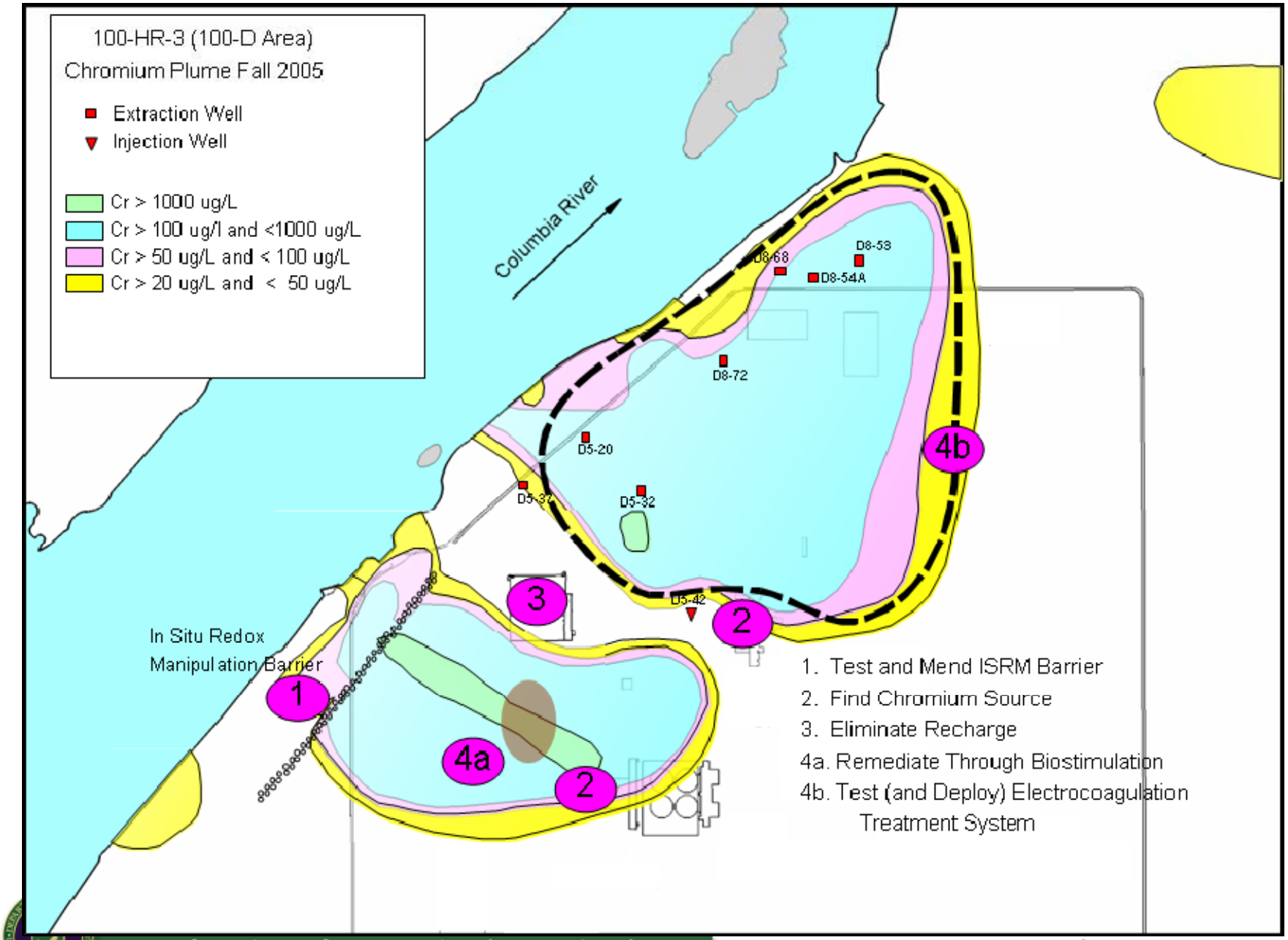
Groundwater and Vadose Zone Challenges

- Improved, Remote, In Situ Detection of groundwater constituents (e.g., Sr-90, Cr^{6+})
  - Will be needed to support cost effective performance monitoring of plume remediation and to support monitoring associated with long-term stewardship of the plume.
- Cost-Effective, In Situ Remediation of Hexavalent Chromium in the Vadose Zone
  - Will be required to remove or immobilize chromium contamination that is likely occurs deep in the vadose zone



BACKUP SLIDES

VR

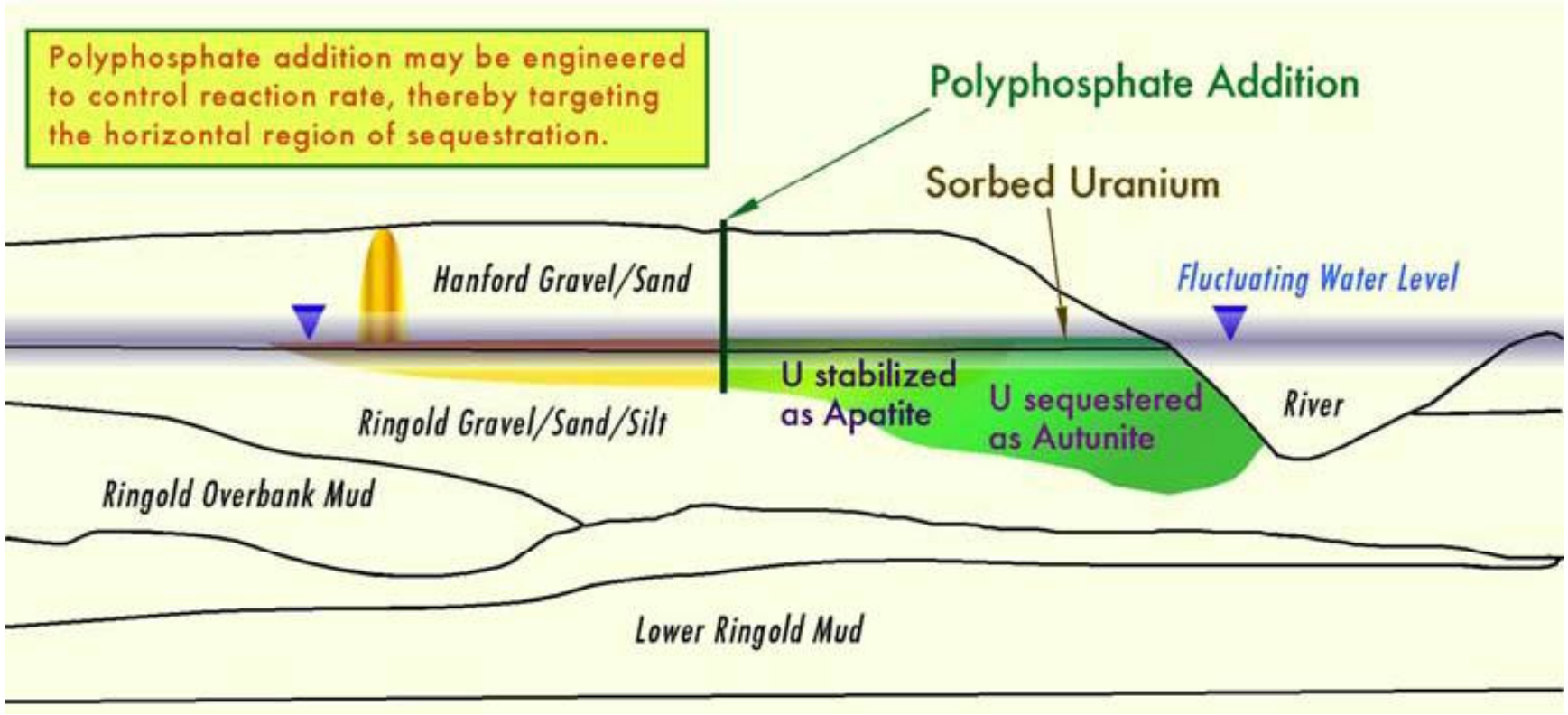

100-HR-3 (100-D Area)
Chromium Plume Fall 2005
Extraction Well
Injection Well
Cr > 1000 ug/L
Cr > 100 ug/l and <1000 ug/L
Cr > 50 ug/L and < 100 ug/L
Cr > 20 ug/L and < 50 ug/L
Columbia River
D8-53
D8-68
D8-54A
D8-72
D5-20
D5-32
D5-42
In Situ Redox
Manipulation Barrier
1
2
3
4a
4b
1. Test and Mend ISRM Barrier
2. Find Chromium Source
3. Eliminate Recharge
4a. Remediate Through Biostimulation
4b. Test (and Deploy) Electrocoagulation Treatment System

Slide 36

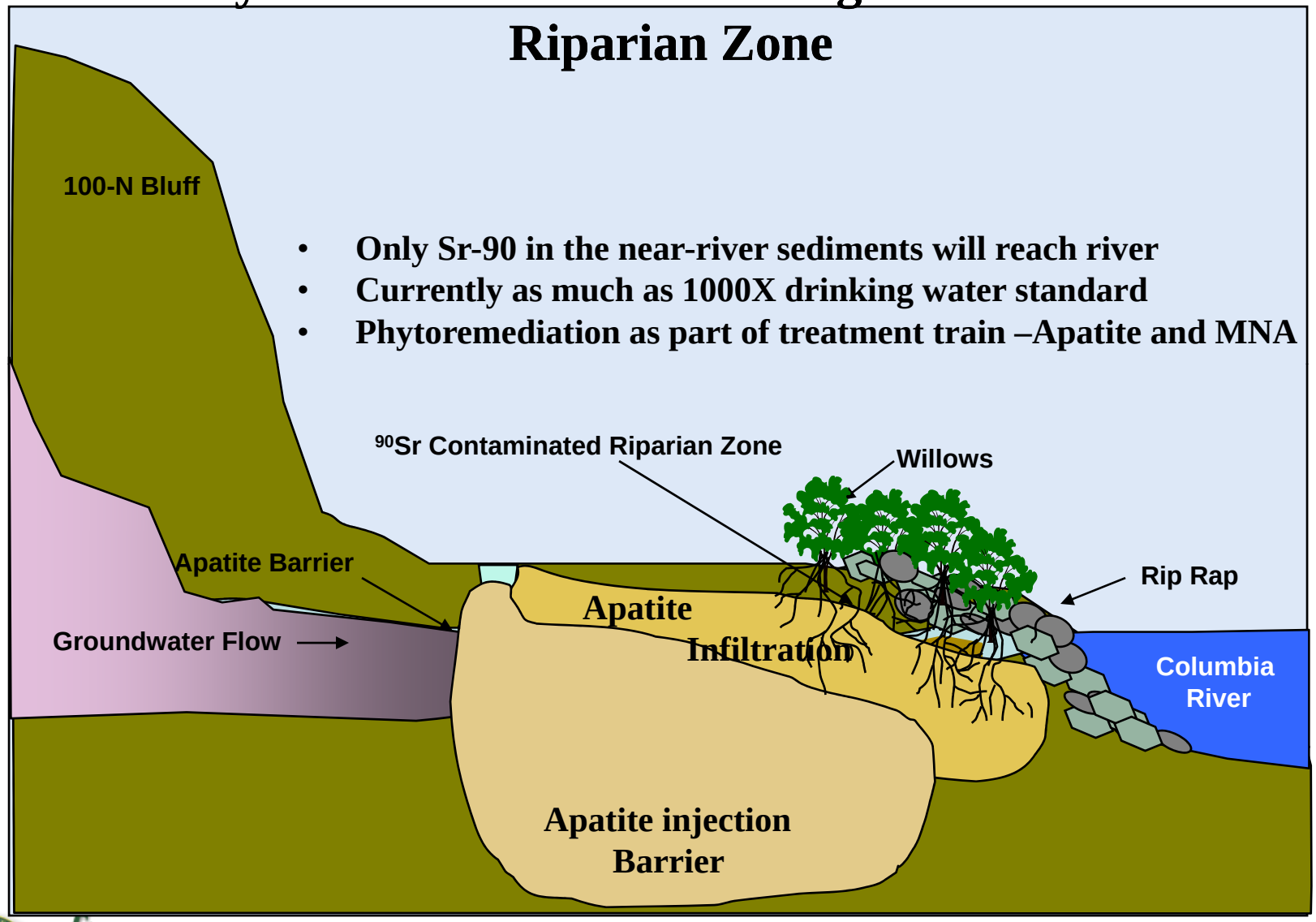
VRV1 This figure should be updated to remove the reference to calcium polysulfide and the identified injection and extraction well locations. If you want to indicate where the biostimulation treatability test will be conducted, the 4a location should be moved farther upgradient (just downgradient of teh southern two #2 location indicators.

Vince Vermeul, 9/14/2006

Conceptual Sequestration Process



100-N Phytoremediation of ^{90}Sr along the Columbia River Riparian Zone



- Only Sr-90 in the near-river sediments will reach river
- Currently as much as 1000X drinking water standard
- Phytoremediation as part of treatment train –Apatite and MNA

CT and CF Attenuation Parameter Studies: Heterogeneous Hydrolytic Reactions

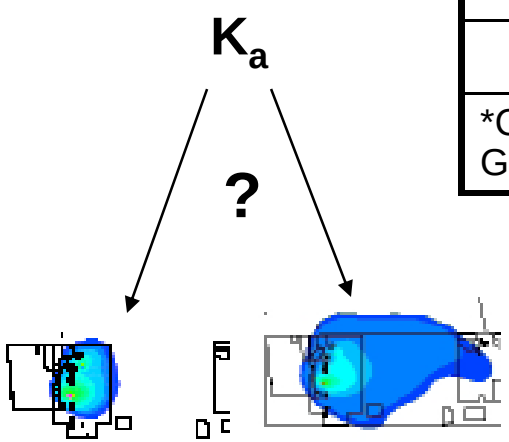
Large uncertainty in abiotic degradation rates (K_a) limits the ability to predict fate and transport and to develop cost-effective remediation plans for CT and CF plumes in 200 West Area

Project will provide critical physical-chemical data for CT and CF hydrolysis reactions under groundwater conditions (T, surfaces)

Type of Hydrolysis	CT		CF	
	Hom	Het	Hom	Het
Neutral	X*	?	X	?
Basic			X	?

*Currently funded by Hanford Groundwater Project

- First determination of K_a(Het) for CT and CF
- Maximum increase for K_a from Het could be 8x for 1000 ppb CT
- Clarification of K_a(Hom) for CF
- Improved K_a's will strengthen technical basis for remediation decision

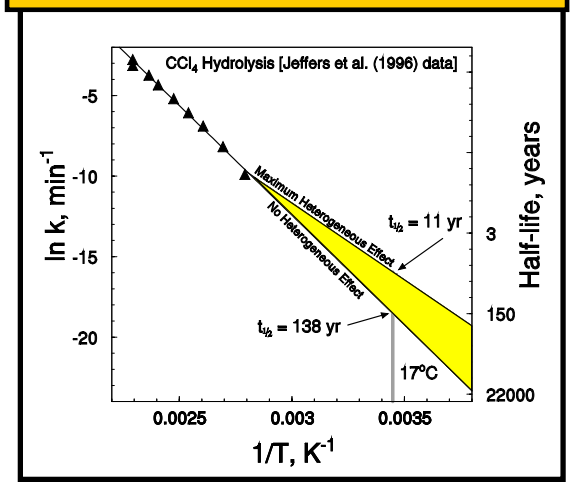


Homogeneous (Hom)—Occurring in solution phase only

Heterogeneous (Het) —Involves interface between solution and solid phase

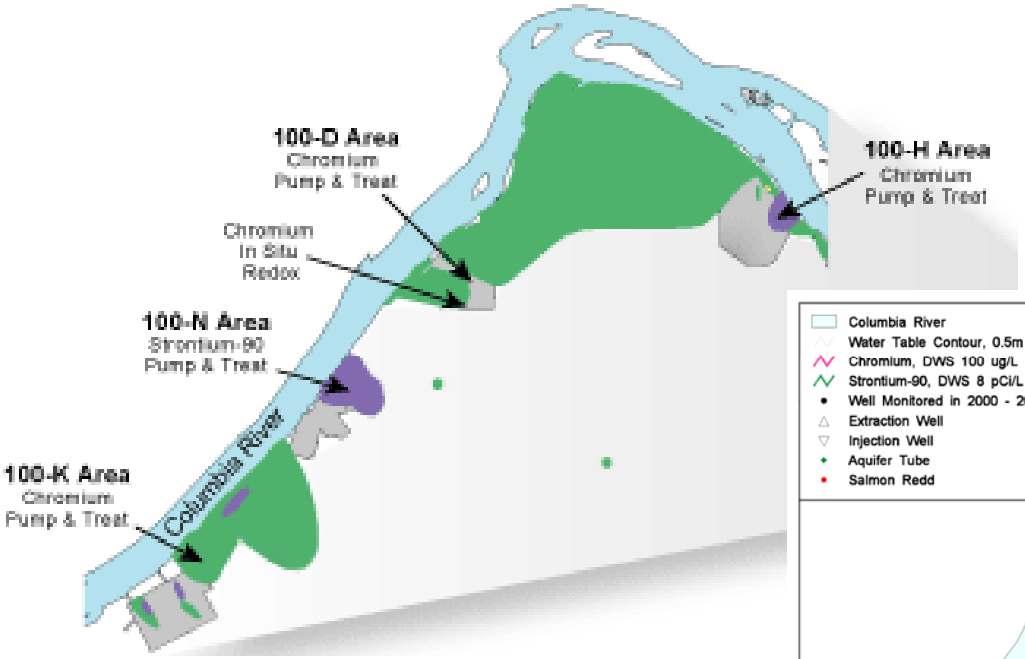
Neutral—Insensitive to pH (H_2O is active agent)

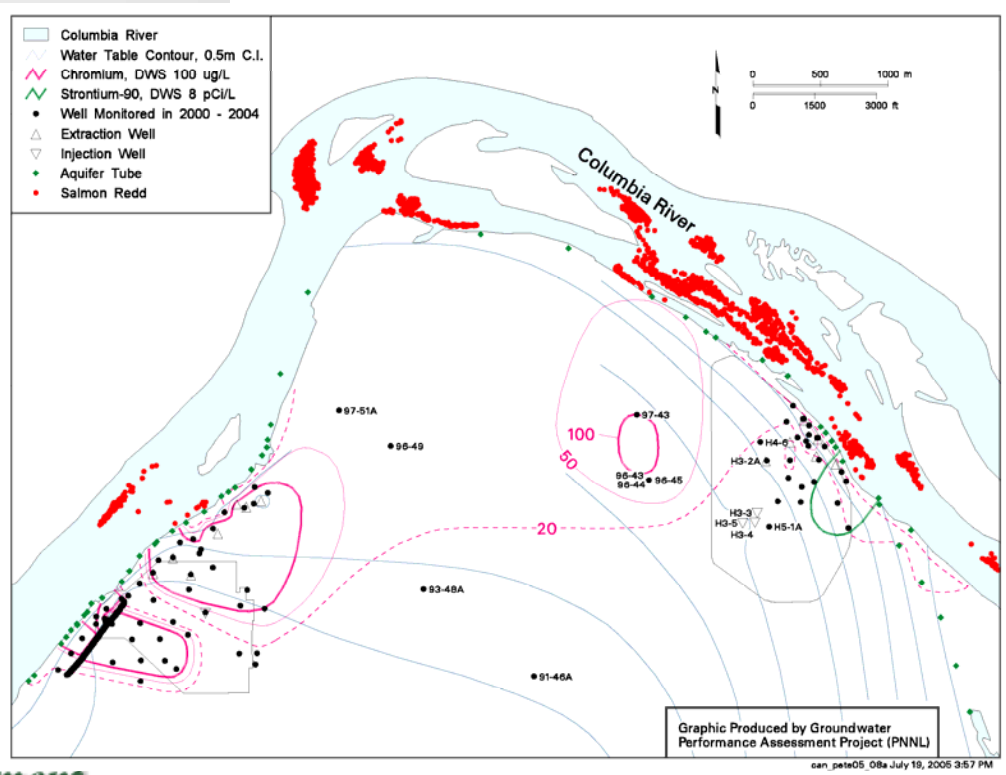
Base-catalyzed—Rate increases with pH (OH^- is active agent)



Problem → Project Approach → Potential Impact

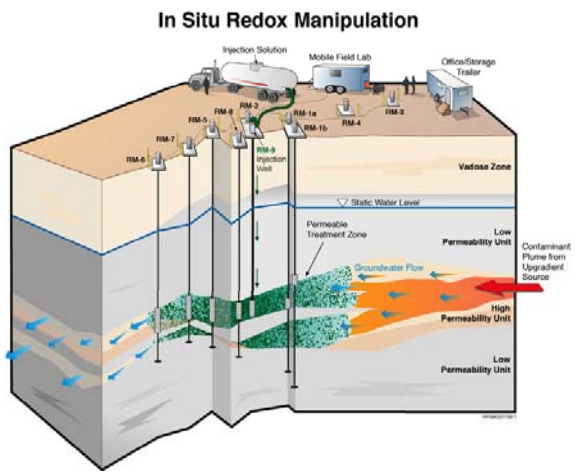
100 Area Hexavalent Chromium





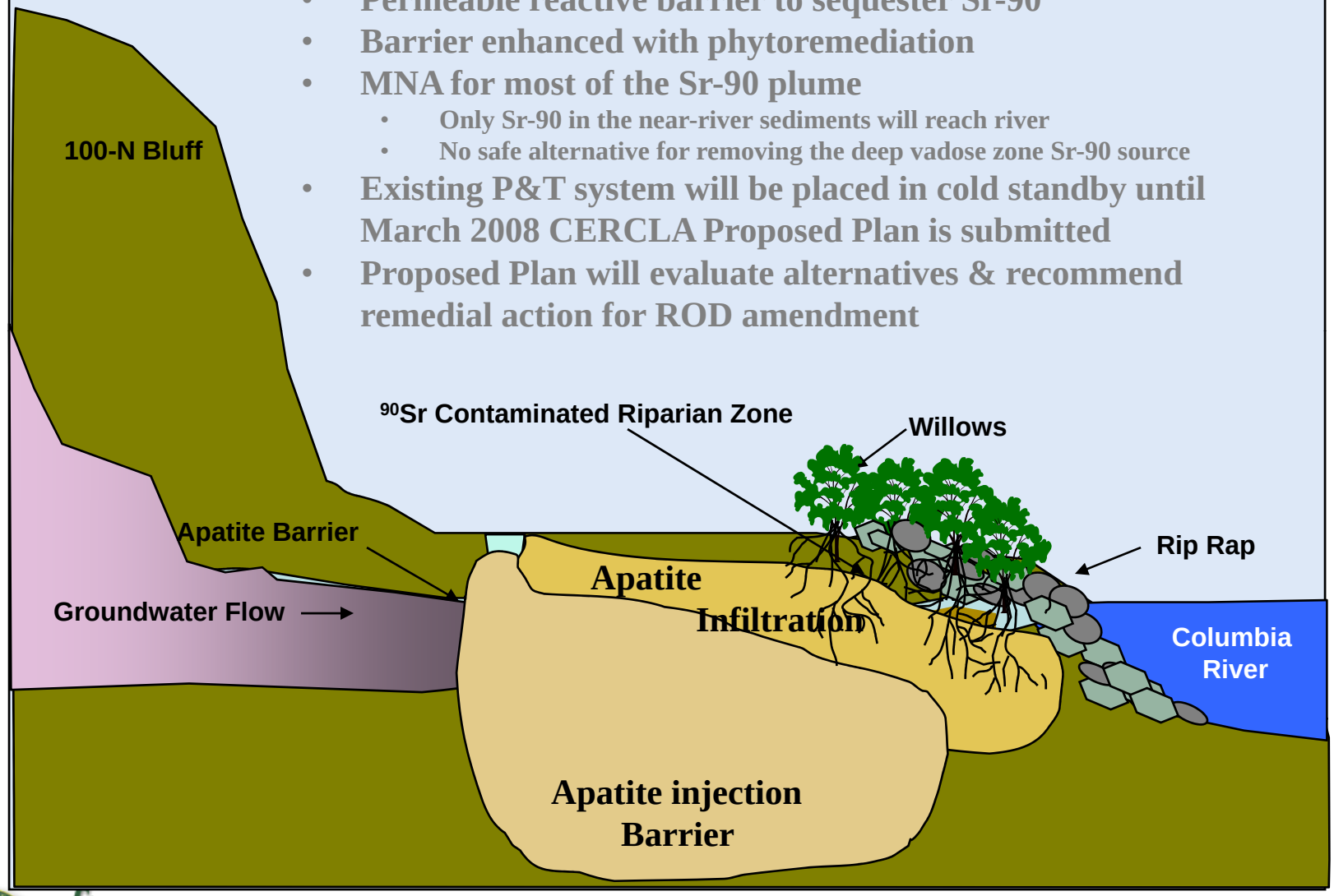
Progress - Hexavalent Chromium

- Inject Micron-size Fe into ISRM Barrier
  - Lab tests & modeling completed at MSE
  - More tests deemed necessary
  - July 2007 field demo on hold
- Field Test EC
  - 50 GPM system test complete
  - Technology successfully removes chromium
  - Injection well plugging challenges
- Accelerated Bioremediation
  - Wells drilled
  - Molasses test in 2007; Vegetable Oil Test in 2008
- Geochemical/Mineralogical Study of Cr in the VZ
  - Samples collected; Leaching studies underway, preliminary data on Cr aging effects
- Refine Location of the Chromium Source at the 100-D Area
  - Drilling of 7 wells complete
  - Data indicates we are close to a significant VZ source of Cr



Systems Approach to Address 100-N ^{90}Sr

- Permeable reactive barrier to sequester Sr-90
- Barrier enhanced with phytoremediation
- MNA for most of the Sr-90 plume
  - Only Sr-90 in the near-river sediments will reach river
  - No safe alternative for removing the deep vadose zone Sr-90 source
- Existing P&T system will be placed in cold standby until March 2008 CERCLA Proposed Plan is submitted
- Proposed Plan will evaluate alternatives & recommend remedial action for ROD amendment



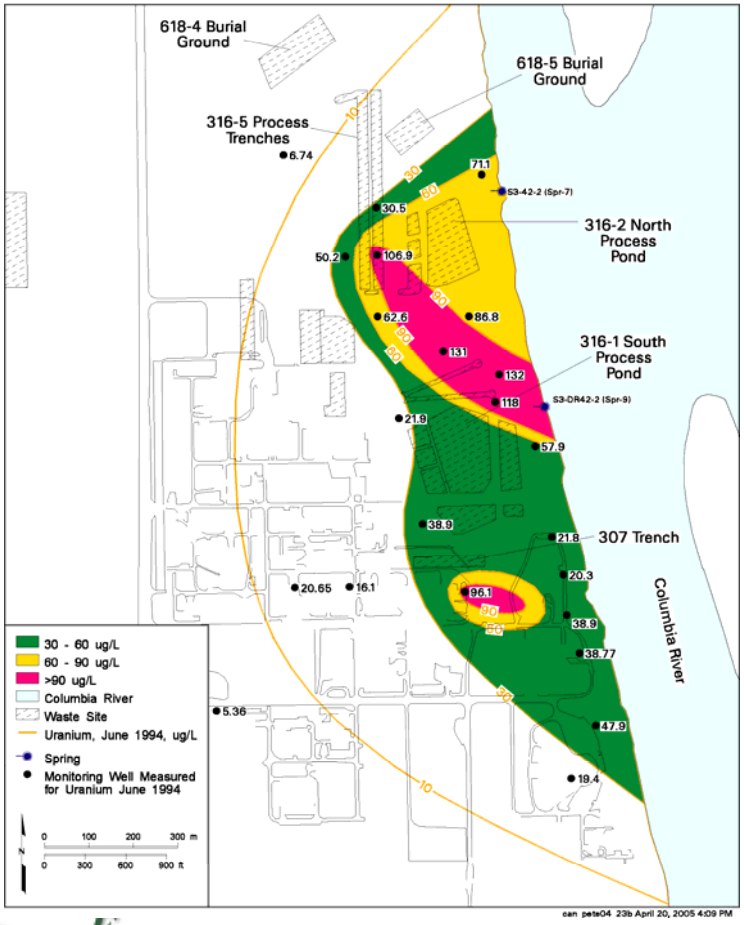
Progress - Strontium-90 in the 100-N Area

- Site-Funded initial 300 Ft barrier completed
  - CY 2008 higher-concentration injection campaign(s) to add robustness to the barrier
- Lab tests underway to support VZ application of apatite barrier – favorable initial results
- Field tests at “cold” 100-K location underway to determine biomass potential of coyote willows – phytoremediation as a polishing step to the apatite barrier
- Laboratory tests funded for food-web (insect) studies

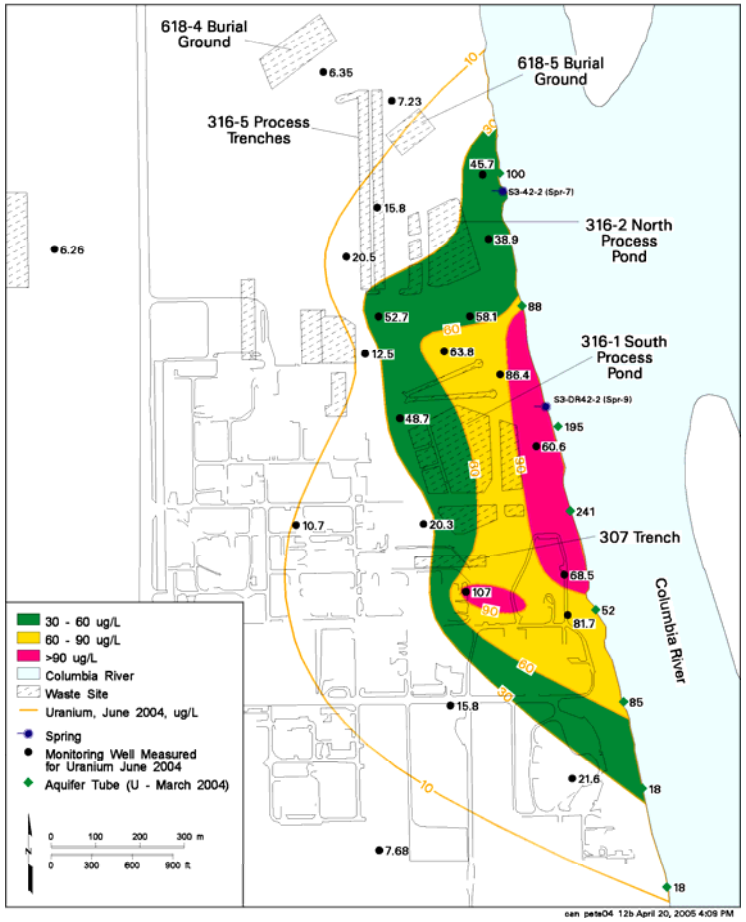
300 Area Uranium Plume

Exceeding Current Drinking Water Standard 1994 & 2004

Shaded 300 Area Uranium, June 1994



Shaded 300 Area Uranium, June 2004



300 Area Groundwater Conceptual Model

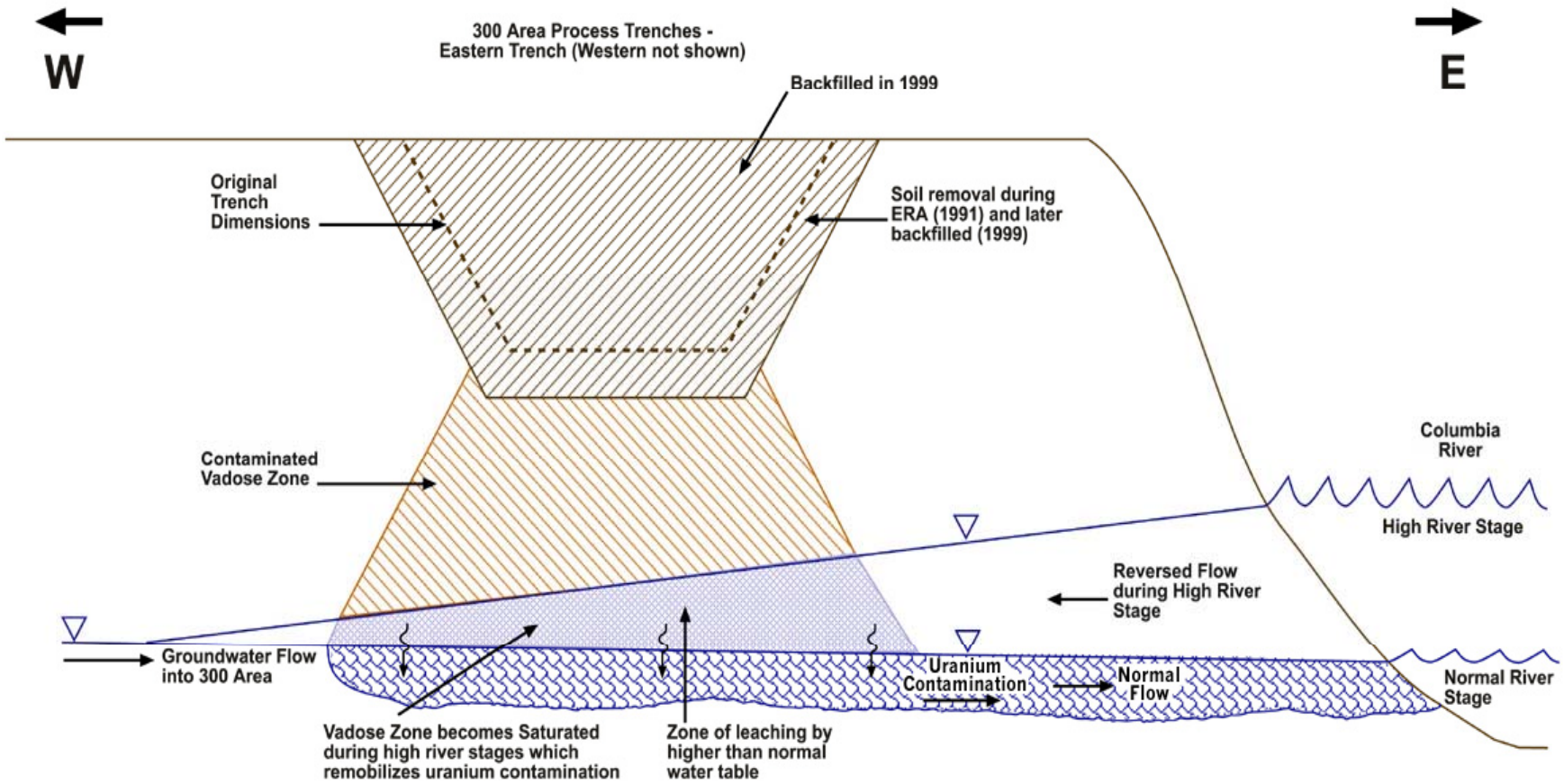
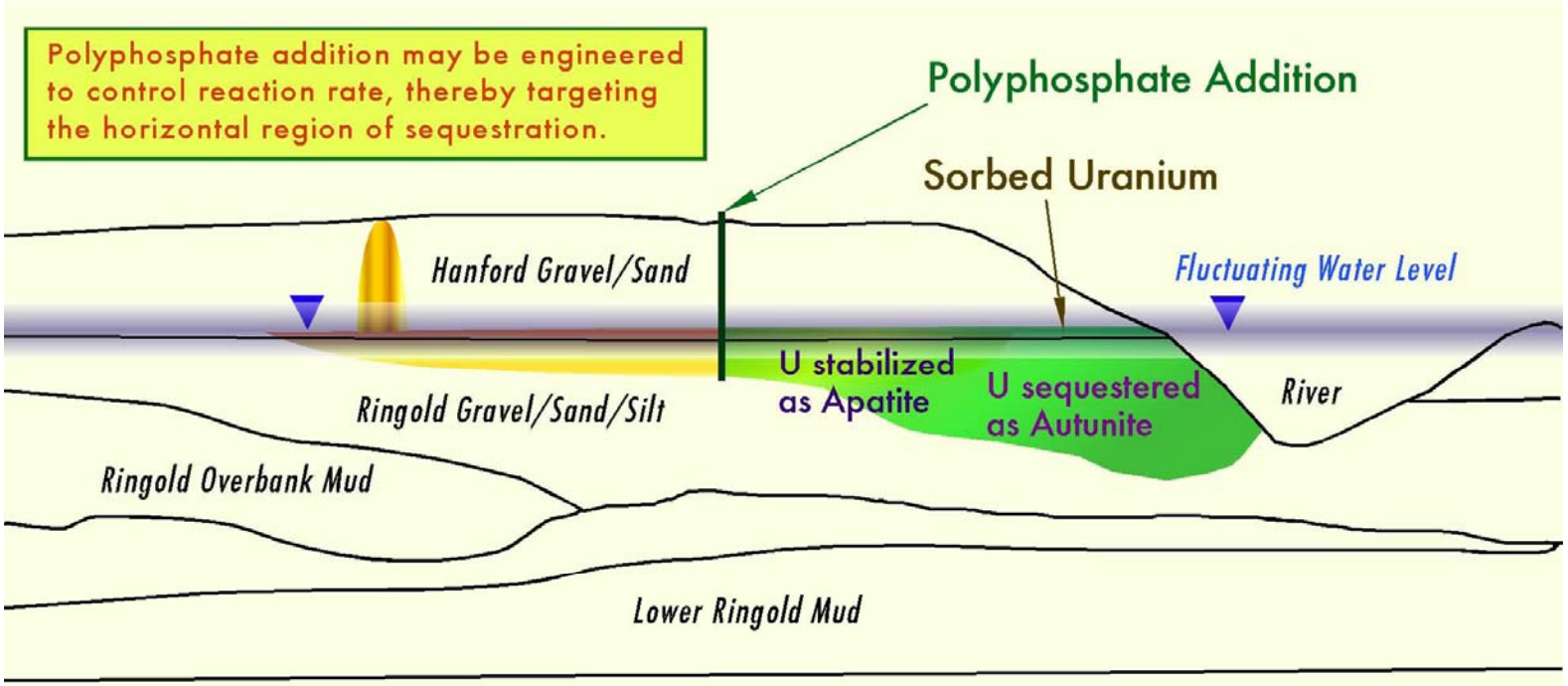


Figure Source: Lindberg 2002

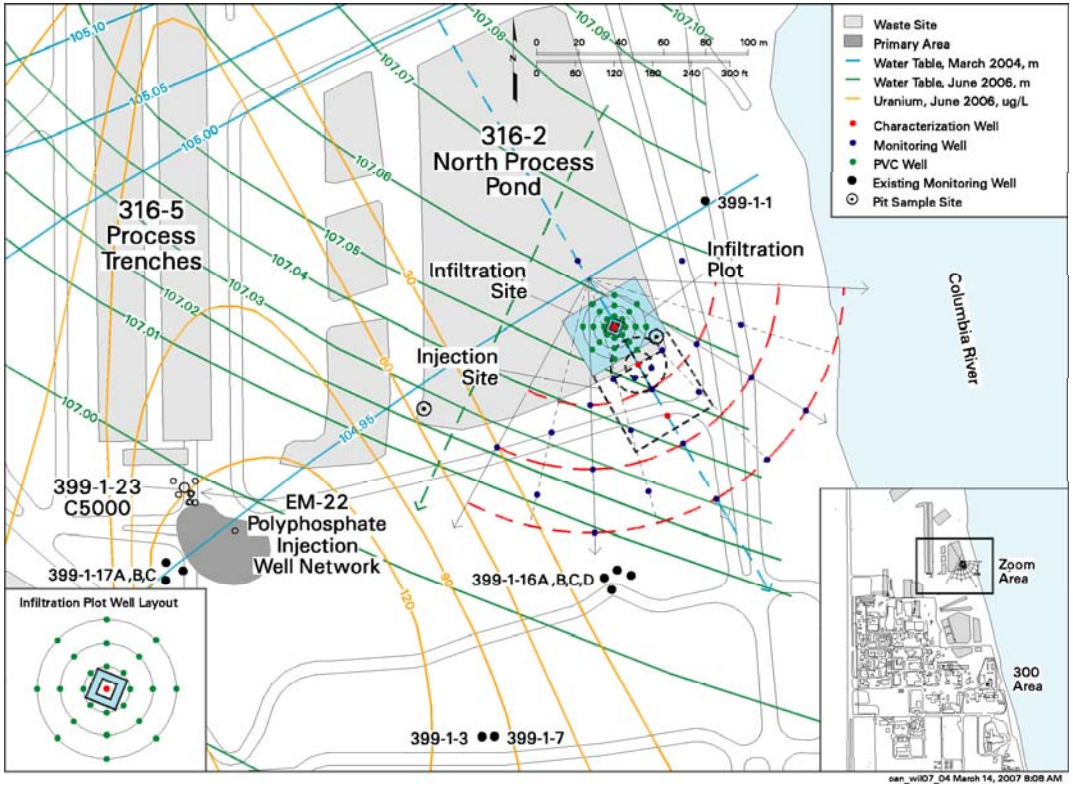
300 Area Uranium Plume Deployment of Polyphosphate



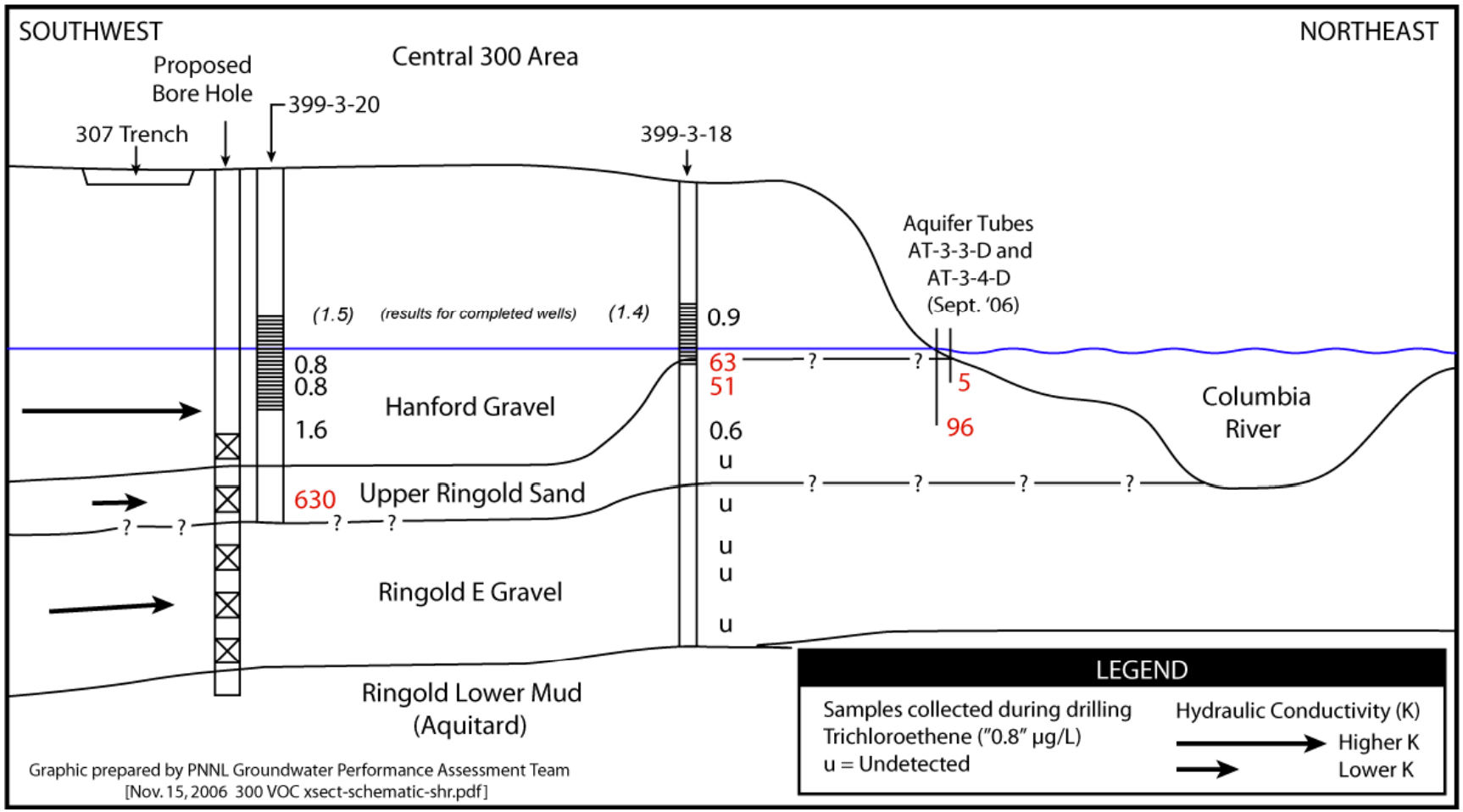
- Injection of soluble polyphosphate
- Lateral plume treatment
- Uranyl phosphate mineral (autunite) formation
  - Immediate sequestration
- Apatite formation
  - Sorbent for uranium
  - Conversion to autunite
- Enhancement of MNA

Other 300 Area GW Progress

- Limited Field Investigation
  - LFI Report complete
  - Includes preliminary remedial technology evaluation
  - 618-2 BG Pu transport resolved
  - TCE characterization wells planned
- 300 Area Risk Assessment Update complete
- 300 Area Multi-Year Field Investigation funded by Office of Science – U Geochemistry
- 300 Area Workshop August 29, 2007

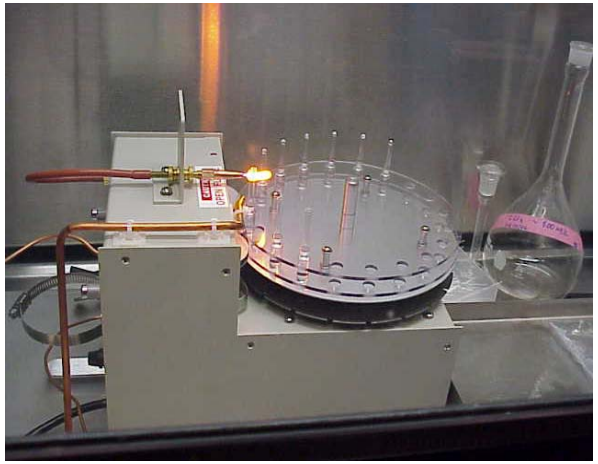


300 Area TCE


SOUTHWEST
NORTHEAST
Central 300 Area
Proposed Bore Hole
399-3-20
307 Trench
399-3-18
Aquifer Tubes AT-3-3-D and AT-3-4-D (Sept. '06)
(1.5)
(results for completed wells)
(1.4)
0.9
0.8
0.8
1.6
63
51
5
96
0.6
u
u
u
u
u
630
Hanford Gravel
Upper Ringold Sand
Ringold E Gravel
Ringold Lower Mud (Aquitard)
Columbia River
LEGEND
Samples collected during drilling
Trichloroethene ("0.8" µg/L)
u = Undetected
Hydraulic Conductivity (K)
Higher K
Lower K
Graphic prepared by PNNL Groundwater Performance Assessment Team
[Nov. 15, 2006 300 VOC xsect-schematic-shr.pdf]

Progress - Carbon Tetrachloride in the 200 Area

- Lab test initiated
- Collaboration with Dr. Peter Jeffers (SUNY Cortland)
- Multi-Year experiment

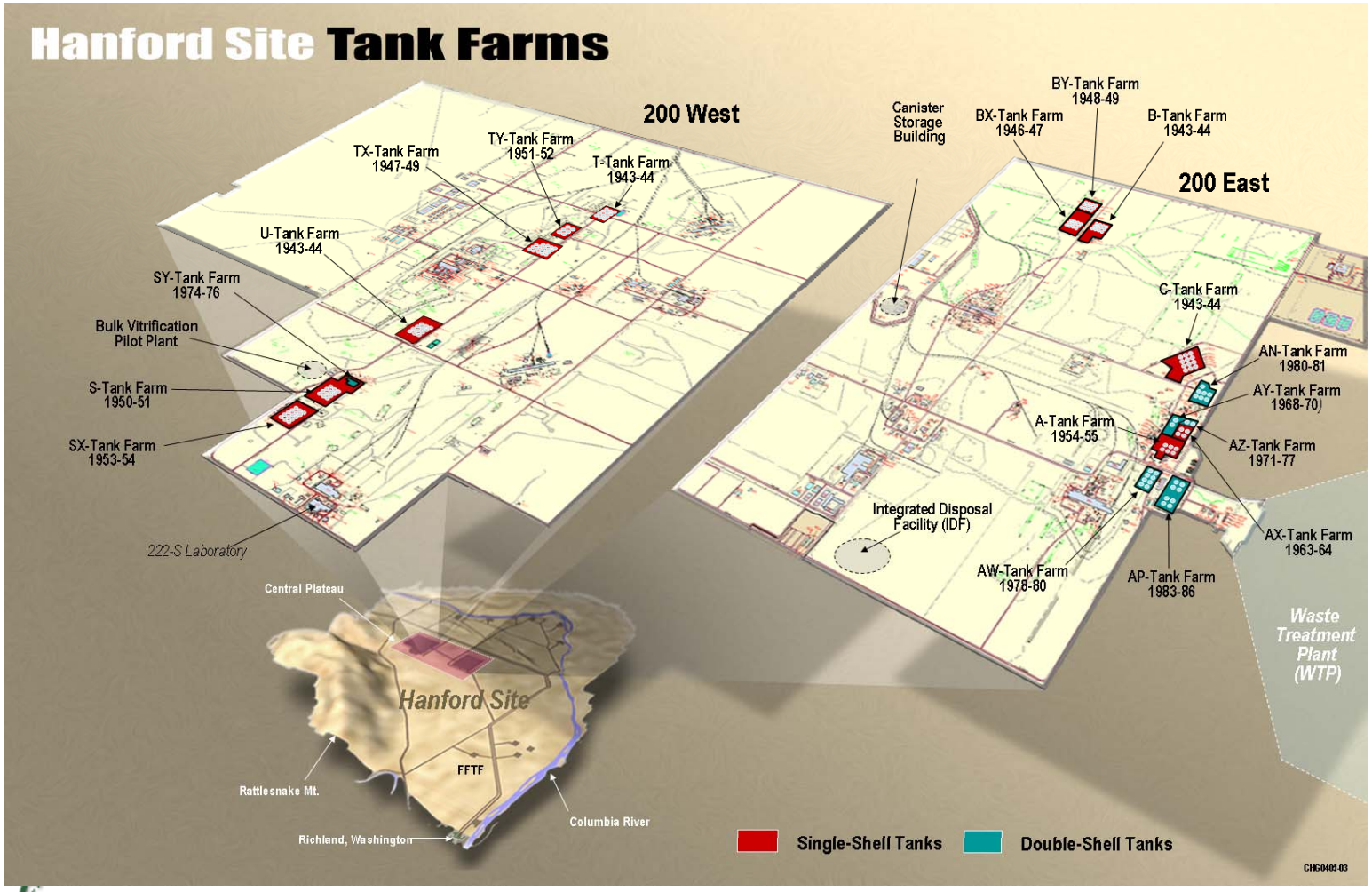


Tank Farm Additions to Mike Thompson's NAS Talk

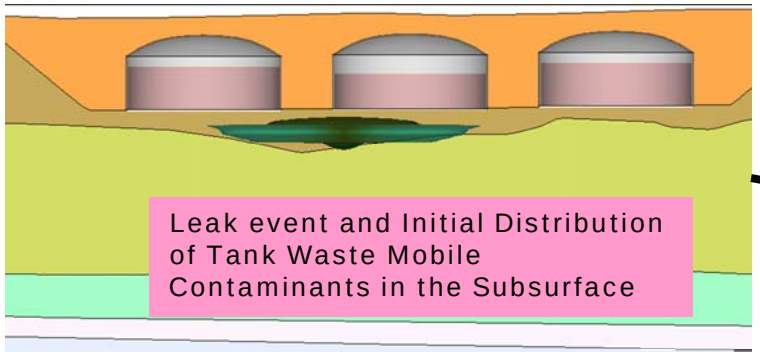
Tank Farm Scope

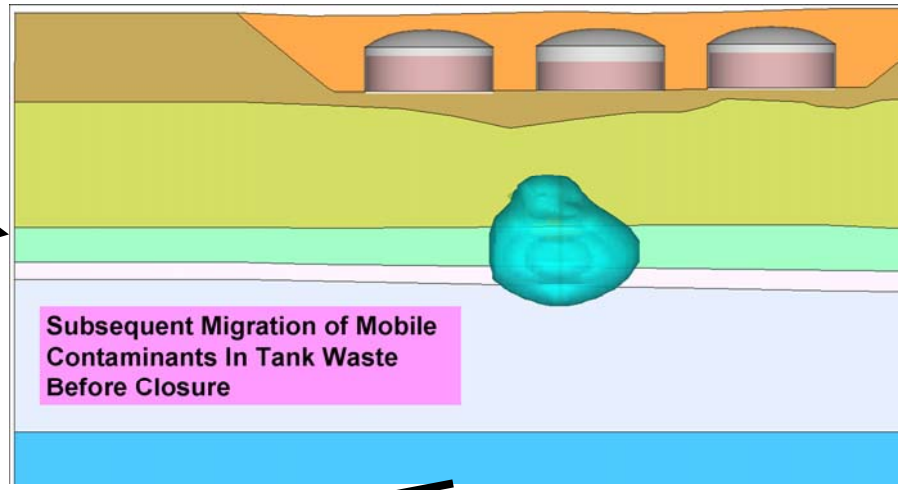
- 149 Single-Shell Tanks (SST) and 28 Double-Shell Tanks (DST)
- SSTs organized into 12 farms and 7 waste management areas (WMA)
- 67 SSTs are known to or are assumed to have leaked (~1 million gallons) (HNF-EP-0182)
- Over last 9 years, the Tank Farm Vadose Zone Program has
  - characterized the largest plumes,
  - implement surface water control measures
  - researched past knowledge,
  - developed new science and technology, and
  - estimated future impacts.

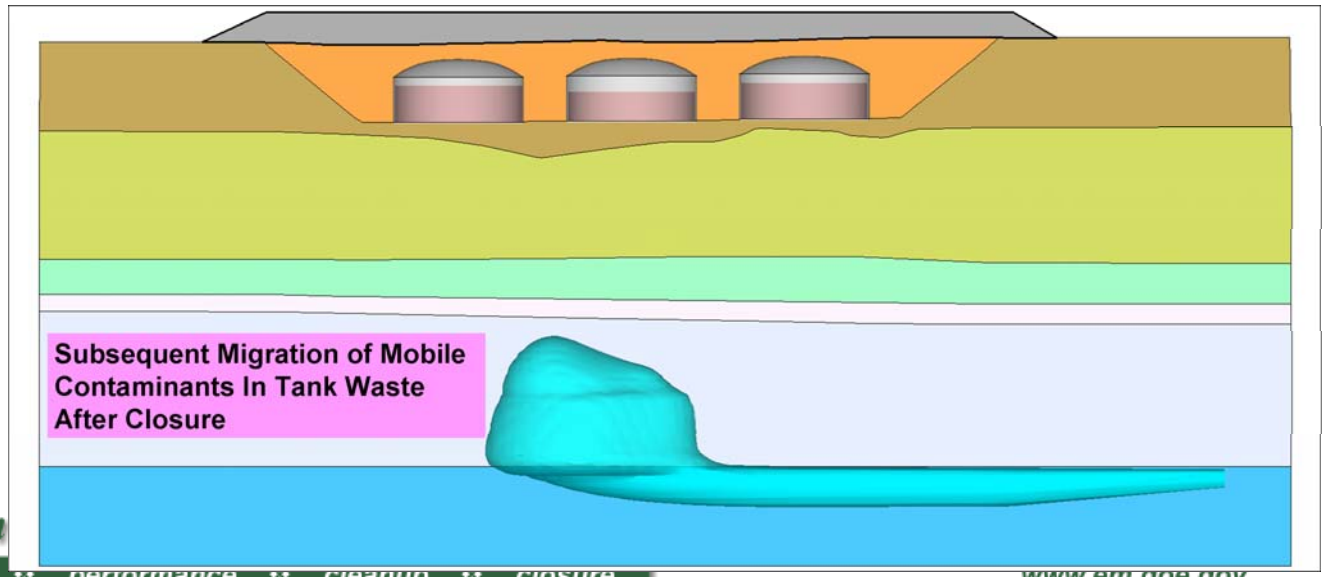
Location Map



Conceptual Model







Future Impacts from the SST PA (DOE/ORP-2005-001)

Performance Objective	Maximum Contaminant Level [a]				Exposure Scenarios [b]		
	Beta-Photon 4 mrem/yr	Tc-99 900 pCi/L	I-129 1 pCi/L	Cr 0.10 mg/L	All-Pathways Farmer 15 mrem	Radiological ILCR Industrial 1.0E-4 to 1.0E-5	WAC 173-340 Hazard Index Method B 1.0
WMA	***Tank Residuals***						
S-SX	◆	◆	◆	◇	◆	◆	◇
T	◆	◆	◆	◆	◆	◆	◆
TX-TY	◇	◇	◆	◆	◆	◇	◆
U	◇	◇	◆	◆	◆	◇	◇
C	◆	◆	◆	◆	◆	◆	◆
B-BX-BY	◆	◆	◆	◆	◆	◆	◆
A-AX	◆	◆	◆	◆	◆	◆	◇
WMA	***Past Releases***						
S-SX	●	●	◇	●	◇	●	●
T	●	●	◇	●	◇	●	◇
TX-TY	●	●	◇	●	◆	◇	◇
U	●	●	◆	●	◆	◇	◇
C	◇	◇	◆	◇	◆	◇	◇
B-BX-BY	●	●	◆	●	◆	◇	◇
A-AX	●	●	◆	●	◆	◇	◇

Below Performance Objective:

◆ Greater than a factor of 10

◇ Less than a factor of 10

Above Performance Objective:

● Greater than a factor of 10

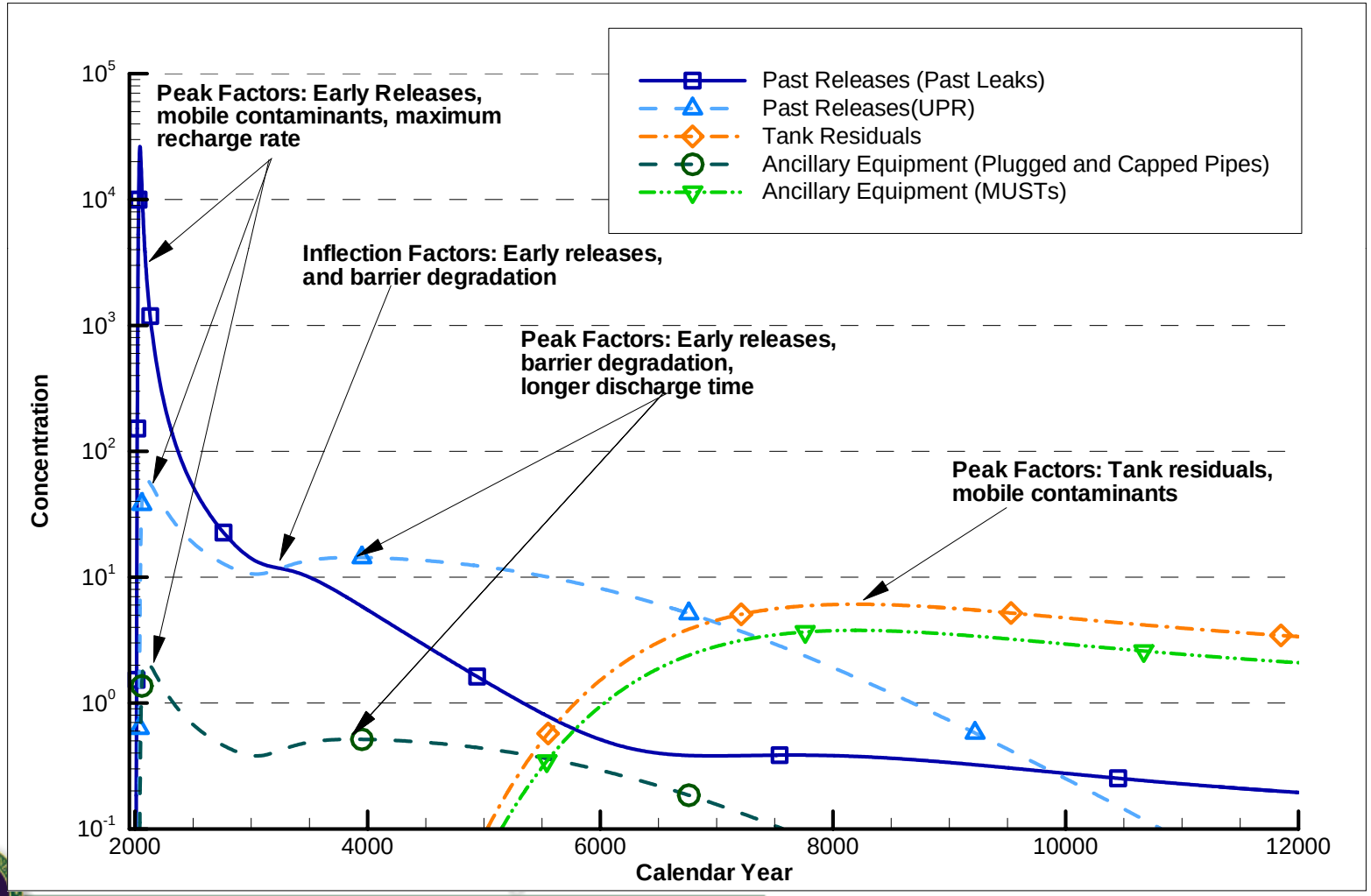
● Less than a factor of 10

[a] Evaluated from year 2000 to 12032.

[b] Evaluated from year 2332 to 12032.

ILCR = incremental lifetime cancer risk

Typical Future Impacts as Function of Time



Characterization Efforts

- 10 Boreholes drilled in the most contaminated plumes
- Over 125 Direct Push Boreholes
- High Resolution Resisitivity (HRR) Measurements Done in 7 Farms (2 more in progress)
- Detailed Laboratory Analyses
- Science using advanced DOE facilities designed to address transport of Cs, U, …

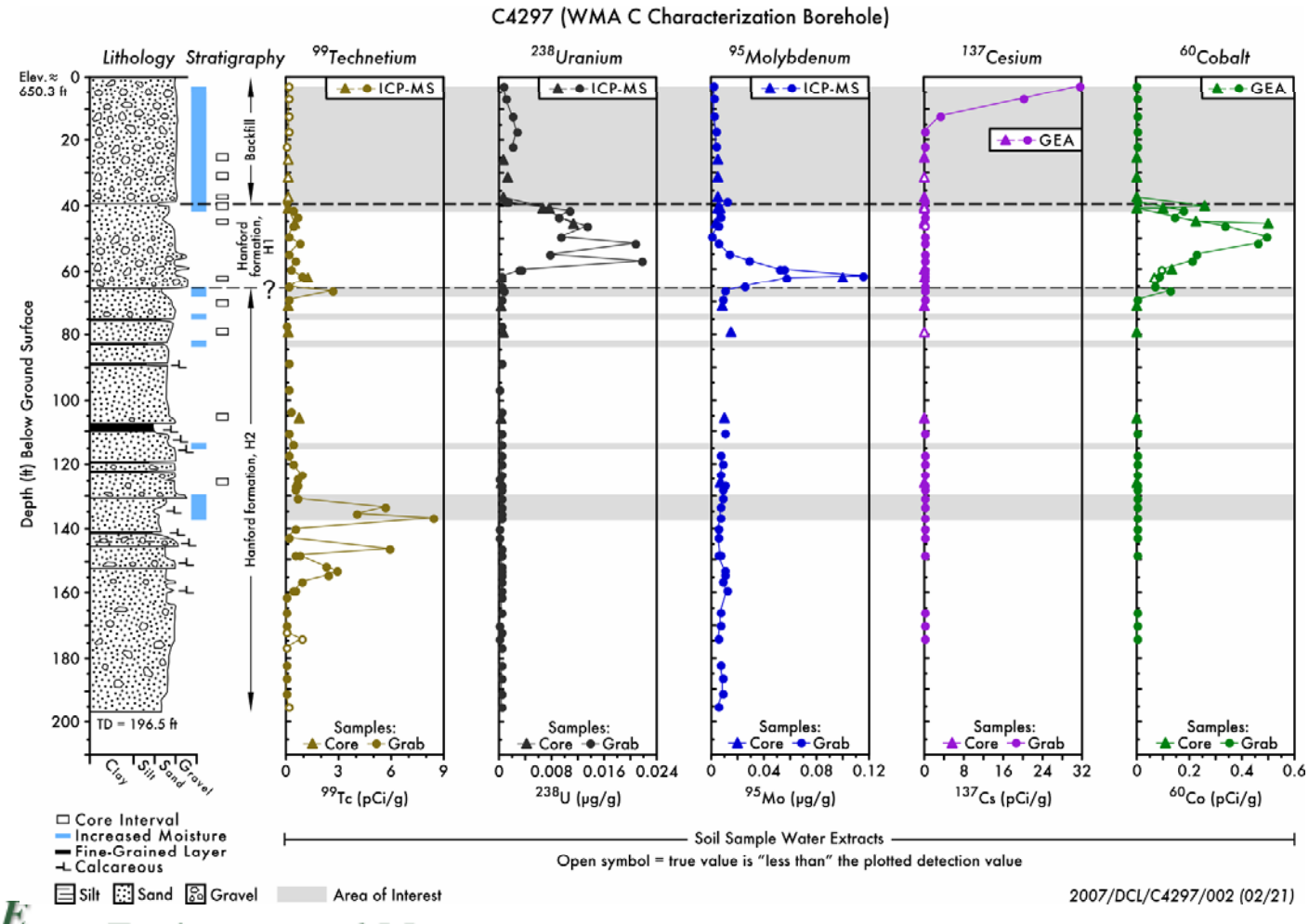
Advanced Science and Technology

- Science
  - Understand cesium mobility
  - Made progress on uranium mobility

- Technology
  - Used Advanced Photon Source to characterize radioactive samples
  - Developed direct push probeholes to > 100 feet bgs
  - Extended HRR/SGE to areas with large amounts of infrastructure and to areas with co-mingled plumes from nearby cribs and trenches.

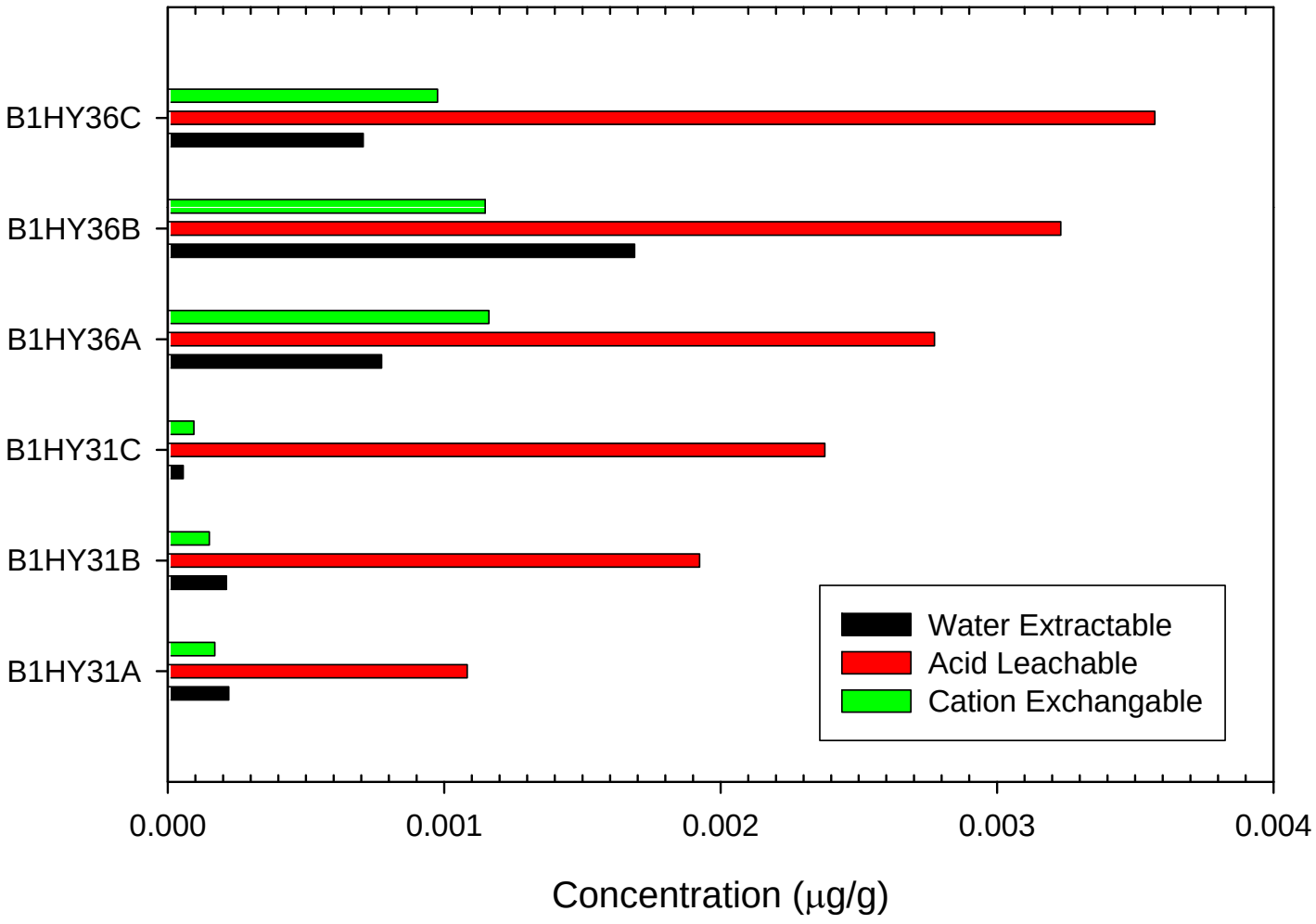
Tank SX-108 Slant Borehole

Tank C-105 Borehole Results

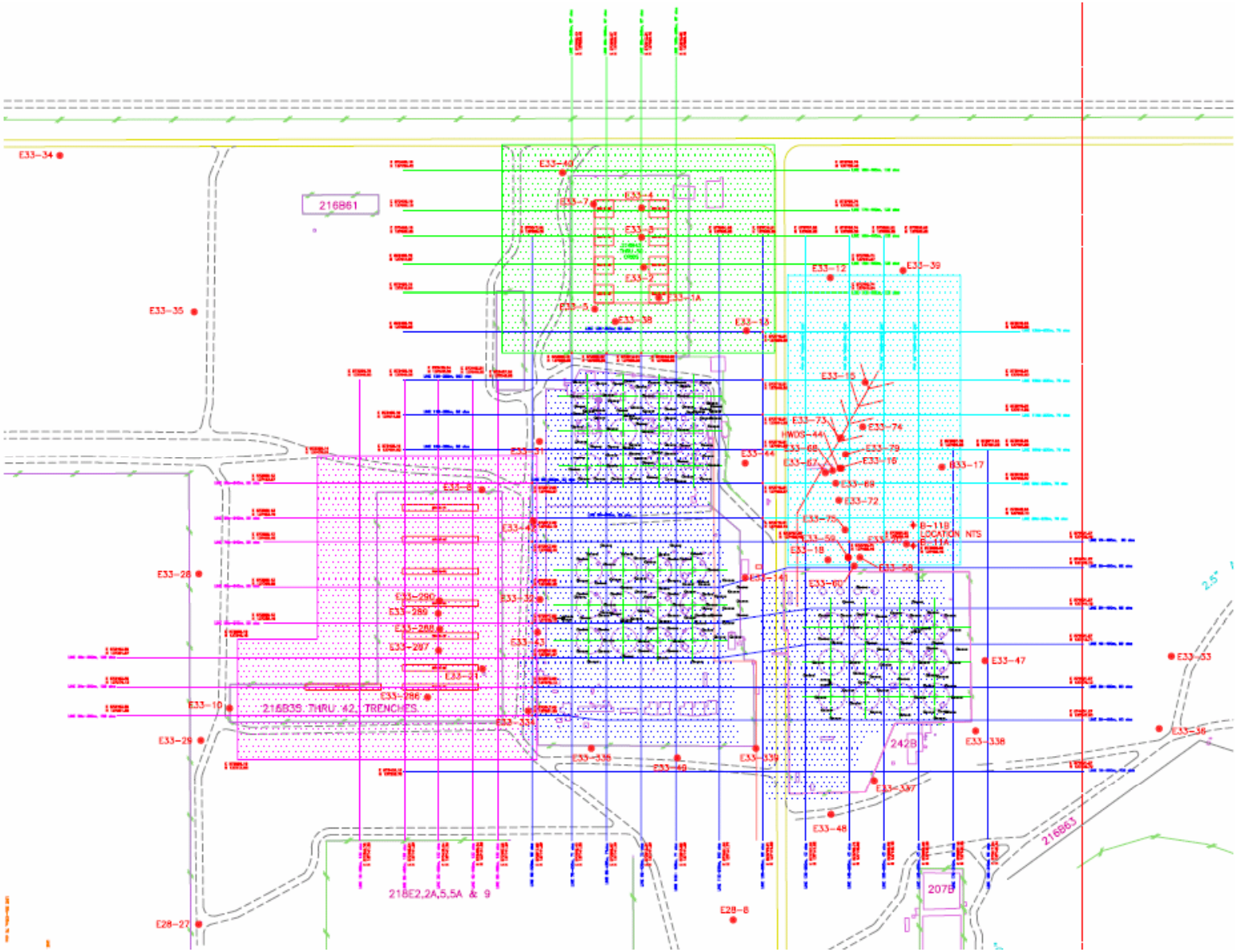


Direct Push Unit

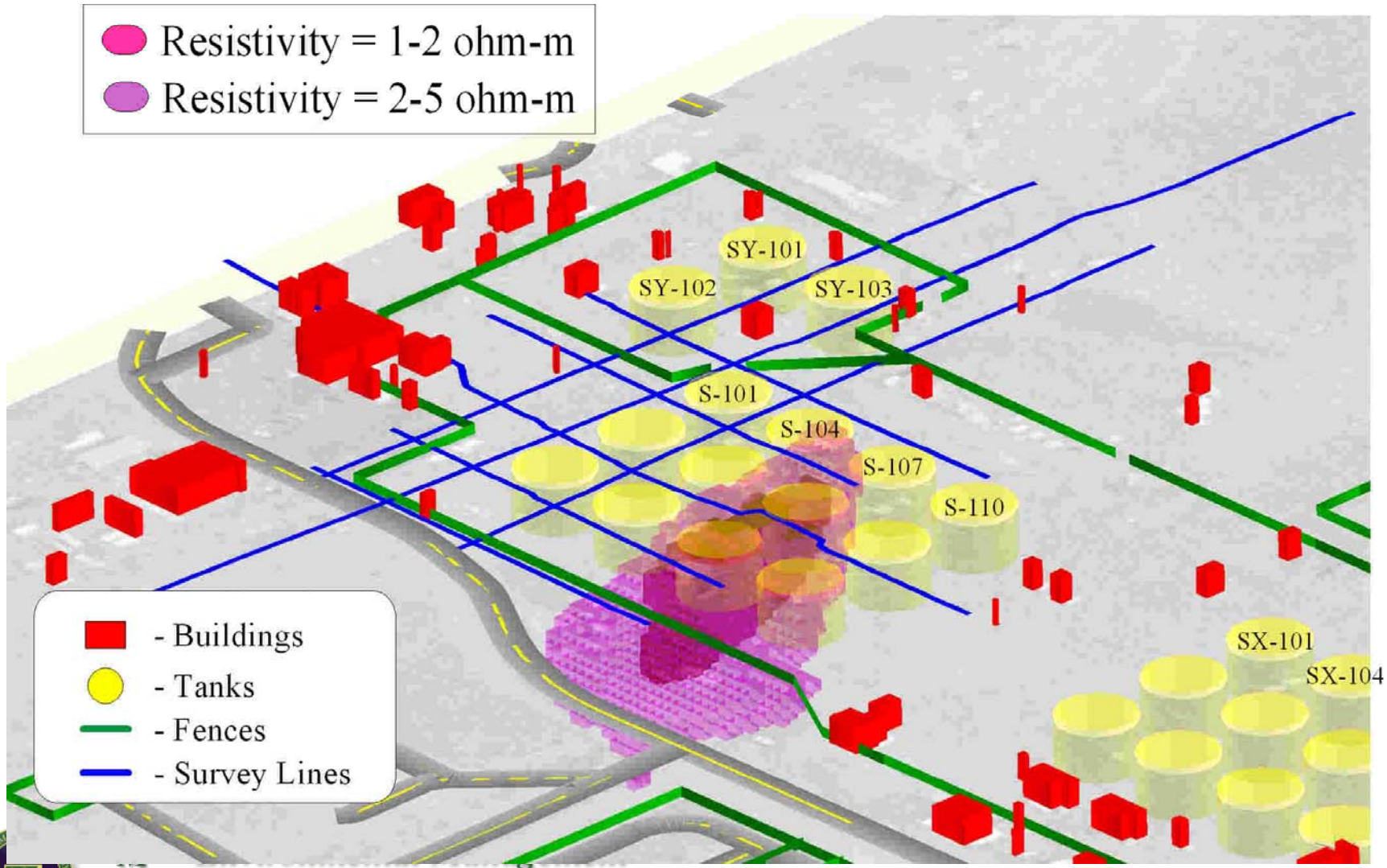
C Farm Slant Probehole Results



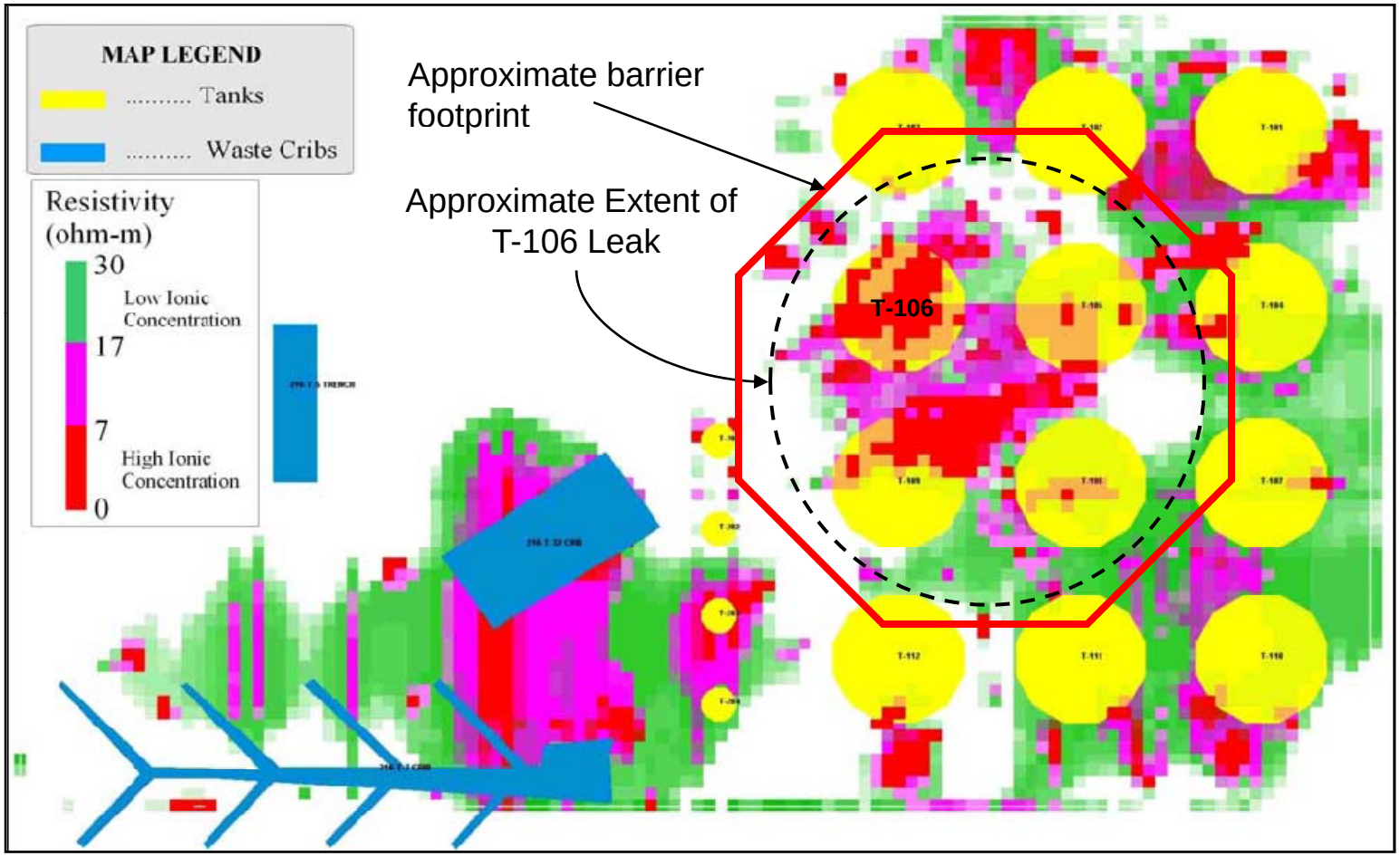
Resisitivty Layout in B/BX/BY



Resistivity Results (S Farm)



Tank T-106 Plume



Well-to-Well Resistivity taken from Figure ES-1, RPP-RPT-28955, Rev 0, *Surface Geophysical Exploration of T Tank Farm at the Hanford Site*)

Approximate extent of T-106 Leak based on RPP-23752, 2005, *Field Investigation Report for Waste Management Areas T and TX-TY*, Figure 3-12

Long Term R & D Needs

- **Remediation**
  - Deep vadose zone (>100 feet bgs) treatability [Tc, U, I, Cr]
  - Tools to convince public and regulators of long-term performance

- **Characterization**
  - In-situ vadose zone contaminant detector
  - Small, light-weight deep vadose zone sediment sample collection device capability of >10^3 pCi/g Cs-137
  - Tank waste residual waste release studies
  - Contaminant mobility studies based on basic chemistry, geology, physics, etc.
  - Large-scale inversion of geophysical measurements
  - Improved petrophysical measures to support resistivity interpretation