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Utilizing Geophysical Methods in Remedial Decision Making at the Hanford Site

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2023 Global Summit
on Environmental Remediation
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U.S. DEPARTMENT OF ENERGY
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Soil and Groundwater Remedies

What information is necessary to select, implement and then monitor a subsurface remedy?

- Source of contamination
- Nature and extent of contamination
- Properties and structure of subsurface media
- How each of the above changes with time

Geophysics can be used in conjunction with other data collection and interpretation methodologies to “fill in the gaps” and reduce uncertainty in all of the above.

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Present and Future Threat to Groundwater

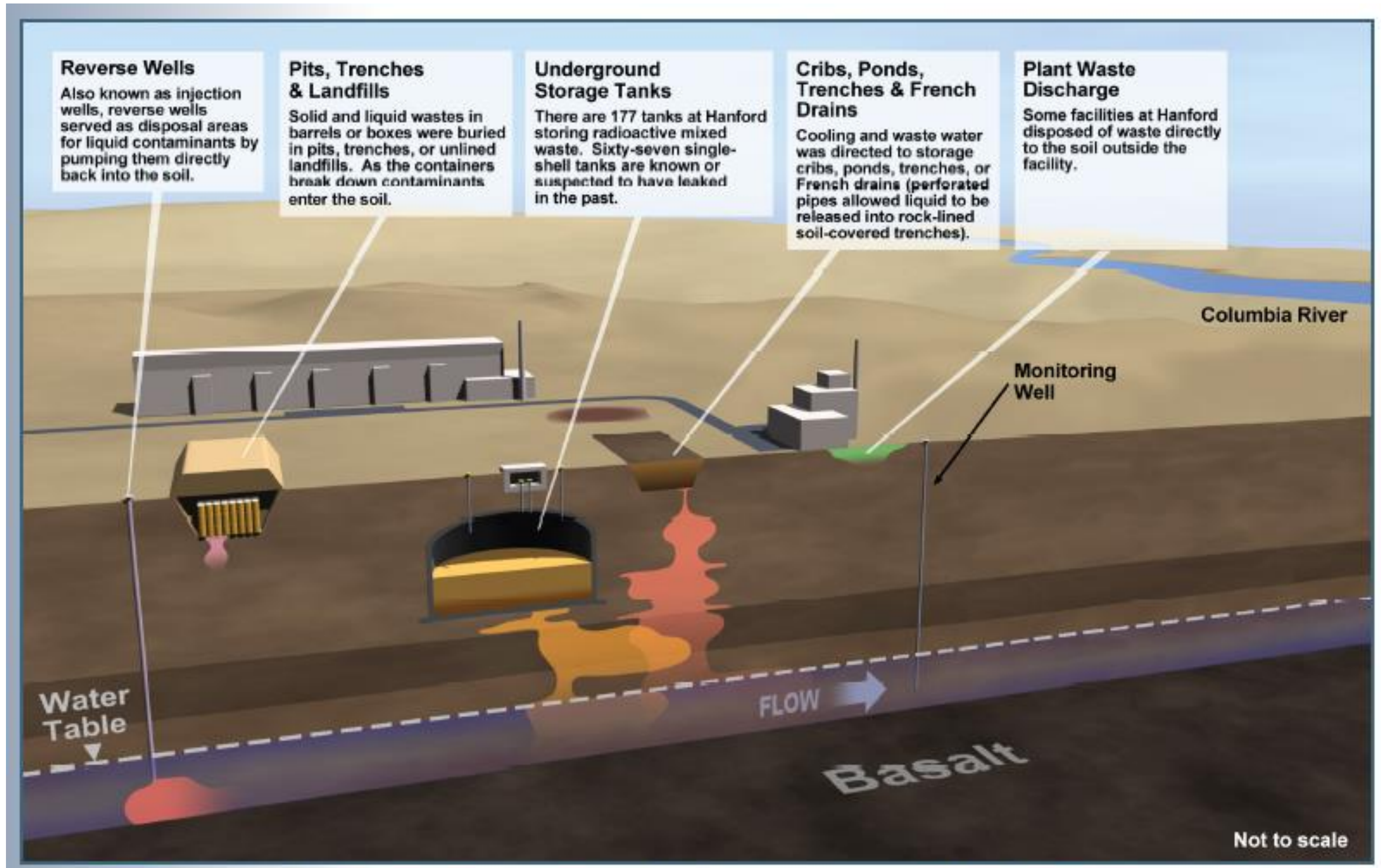

Figure 1.3. These are existing or potential sources of groundwater contamination on the Hanford Site. Processing facilities and waste tanks shown are located in the Central Plateau (200 Areas).

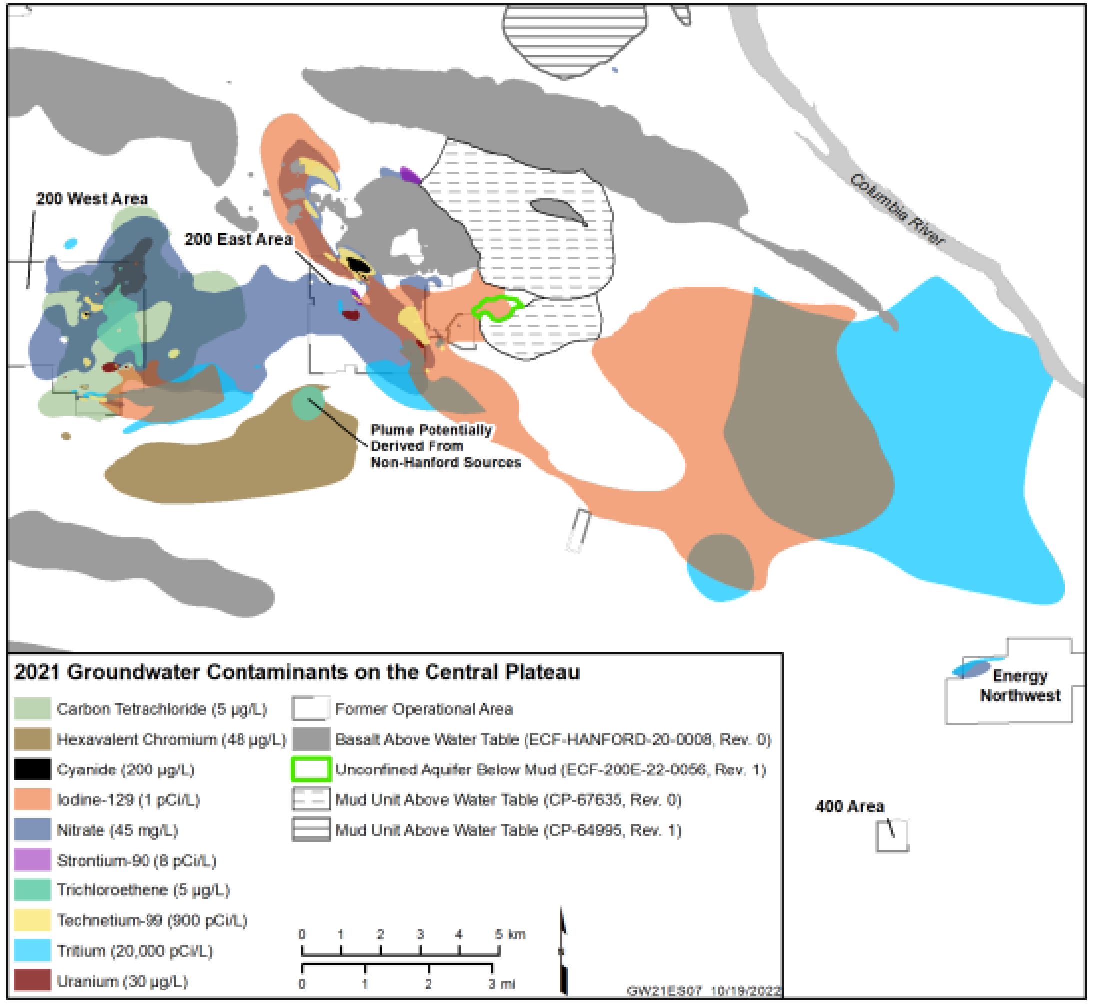

Figure ES-7. Groundwater Contaminant Plumes in the Central Plateau

Central Plateau: residual contamination in the 250-350’ thick vadose zone may be replenishing groundwater plumes for hundreds of years.

Geophysical Methods Employed

Broad categories commonly used at the Hanford Site:

- Ground Penetrating Radar
- Electromagnetics
- Borehole-Based Geophysical Logging
- Seismic
- Resistivity

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Ground Penetrating Radar/Electromagnetic

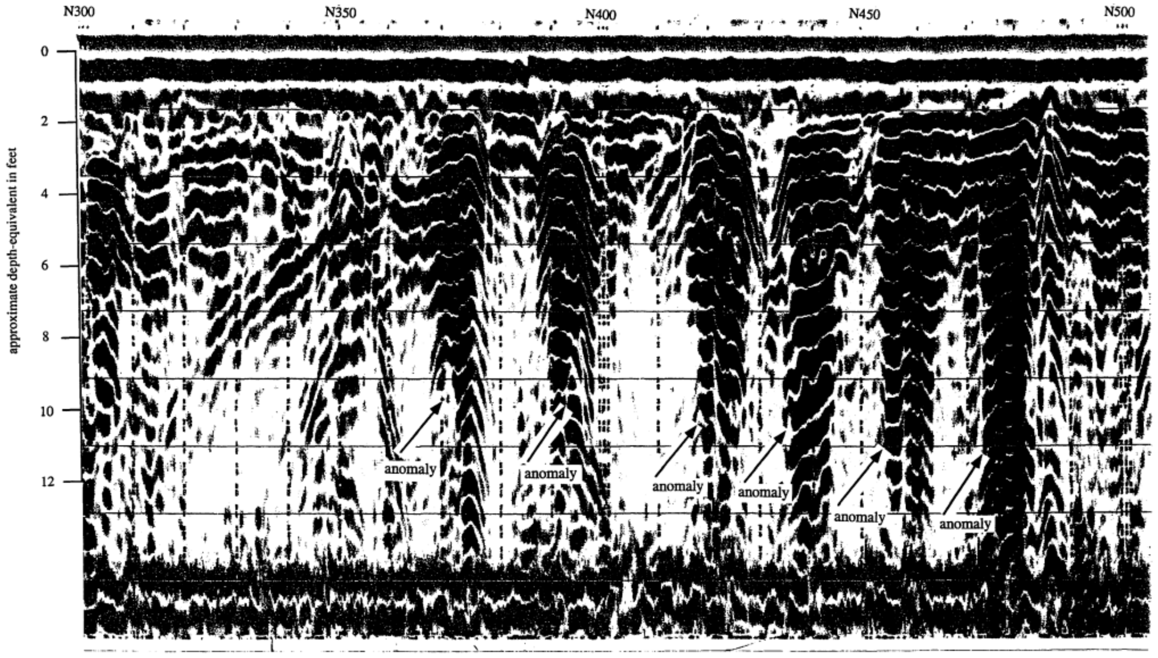
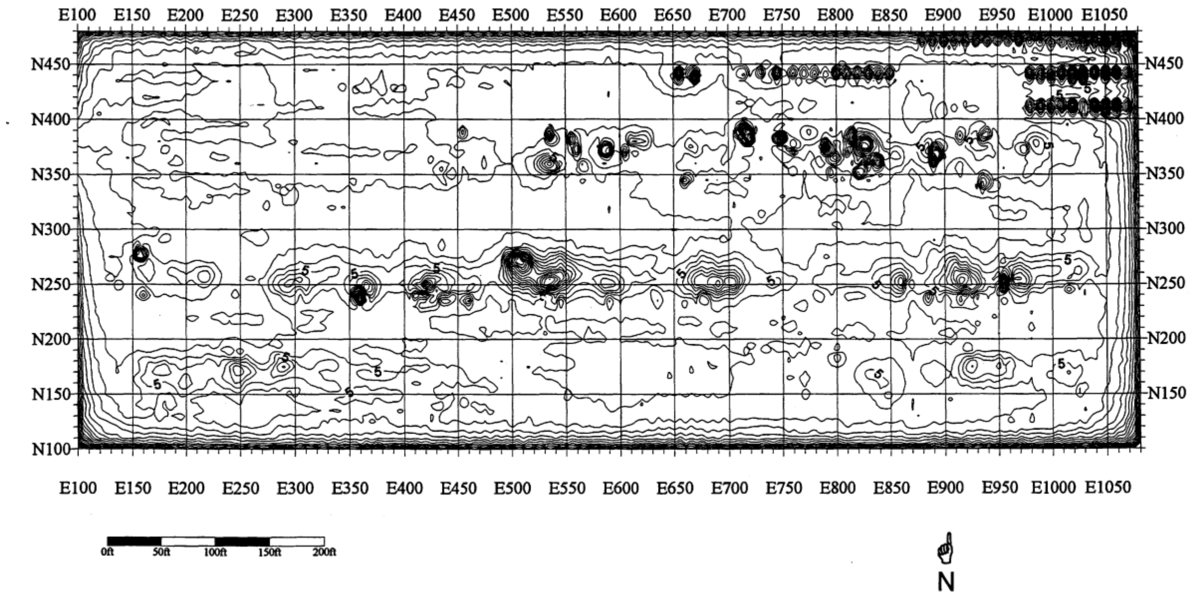


Figure 14. GPR Profile E420, N300 to N500, 618-10 Burial Ground.
(Cross-section shows series of anomalous reflecting horizons observed in northeastern portion of burial ground [300-MHz antenna,108-NS window, depth scale 2.3 ft/in.]).



GPR and EM surveys have been used at Hanford for identifying the location and sometimes the condition of

- Buried waste such as vertical pipe units, caisons and other solid wastes
- Disturbed soils to more precisely locate waste sites

Borehole Geophysics

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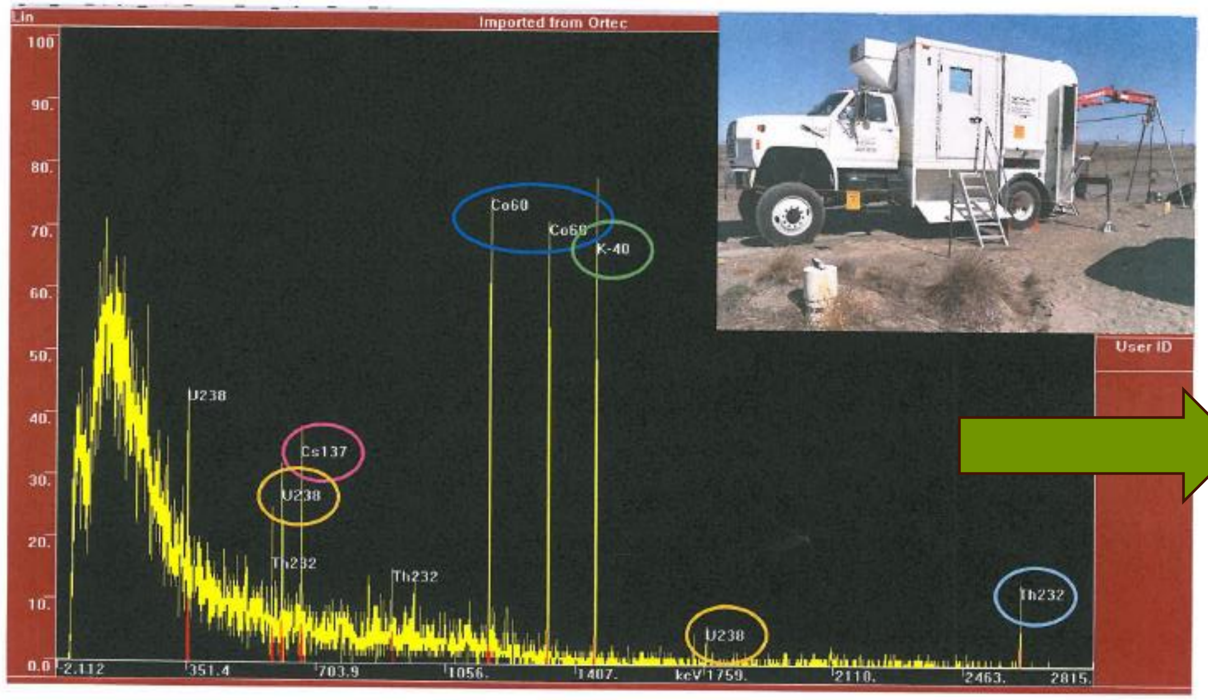
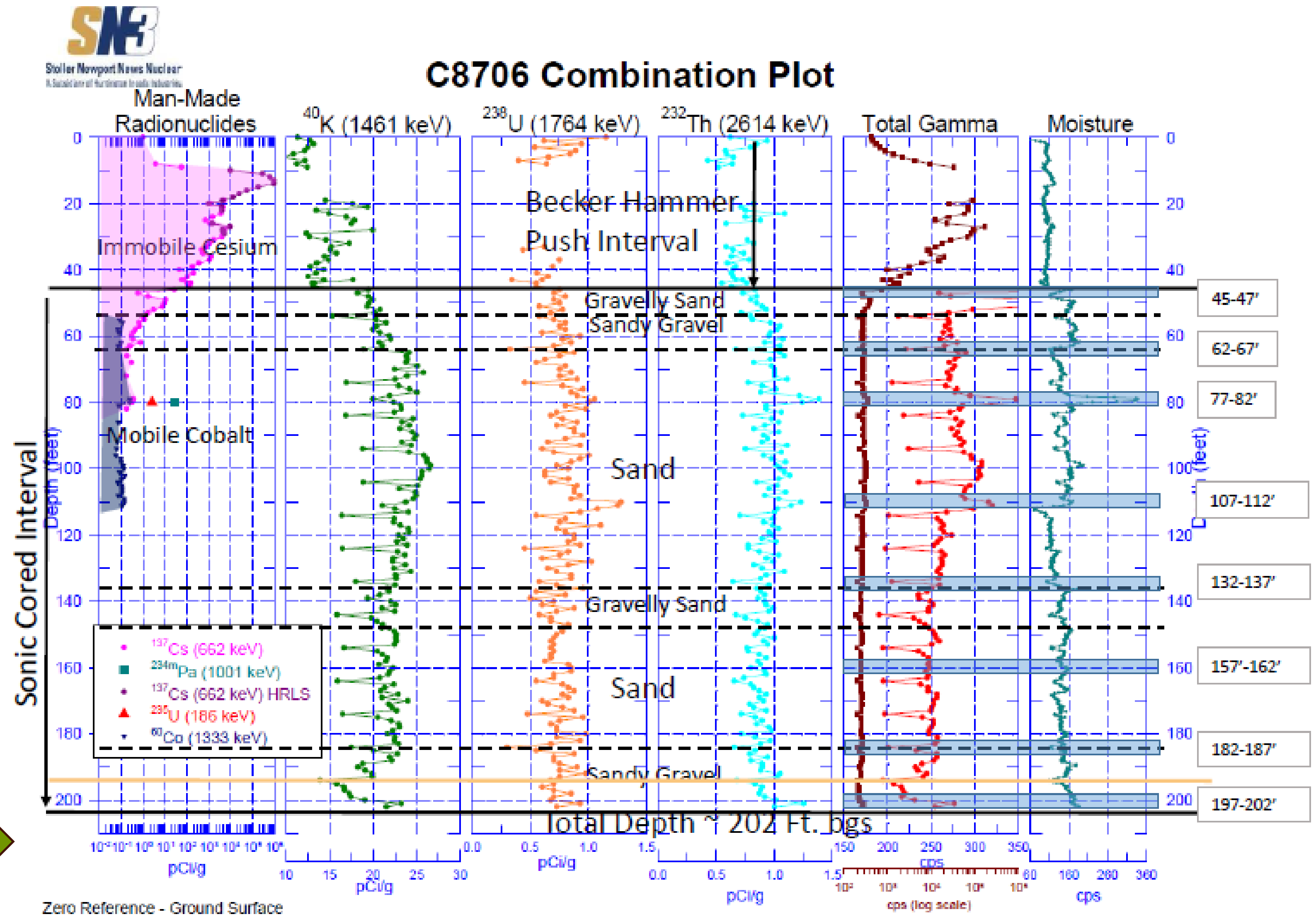
Borehole-based geophysical logging is used to understand nature and extent of contamination:

- Estimate depths and activity of gamma-emitting fission products
- Identify lower permeability layers that can control contaminant distribution
- Identify subtle stratigraphic changes not visible in cuttings





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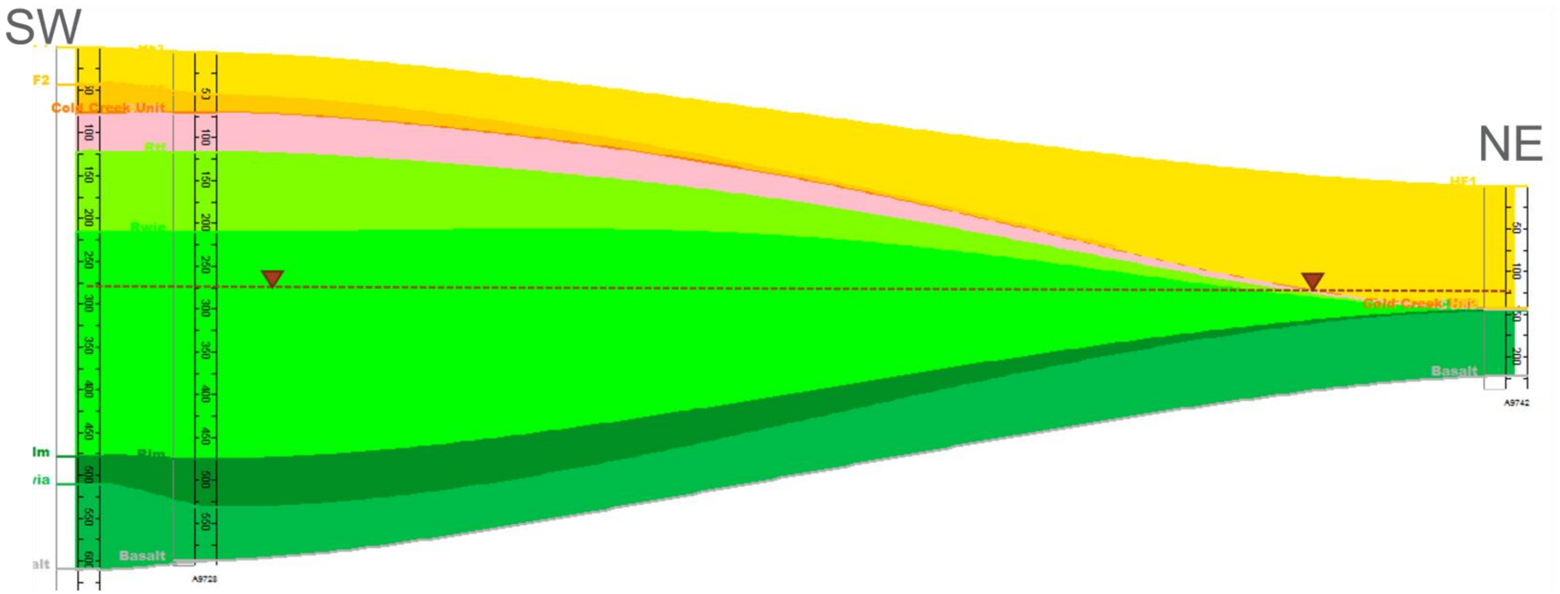
Seismic Surveys

Seismic data is used to fill in the interpretation between boreholes:

- Understand/predict thickness and therefore transmissivity of the unconfined aquifer
- Identify features that may focus the contamination
- Results have implications for cleanup timeframes



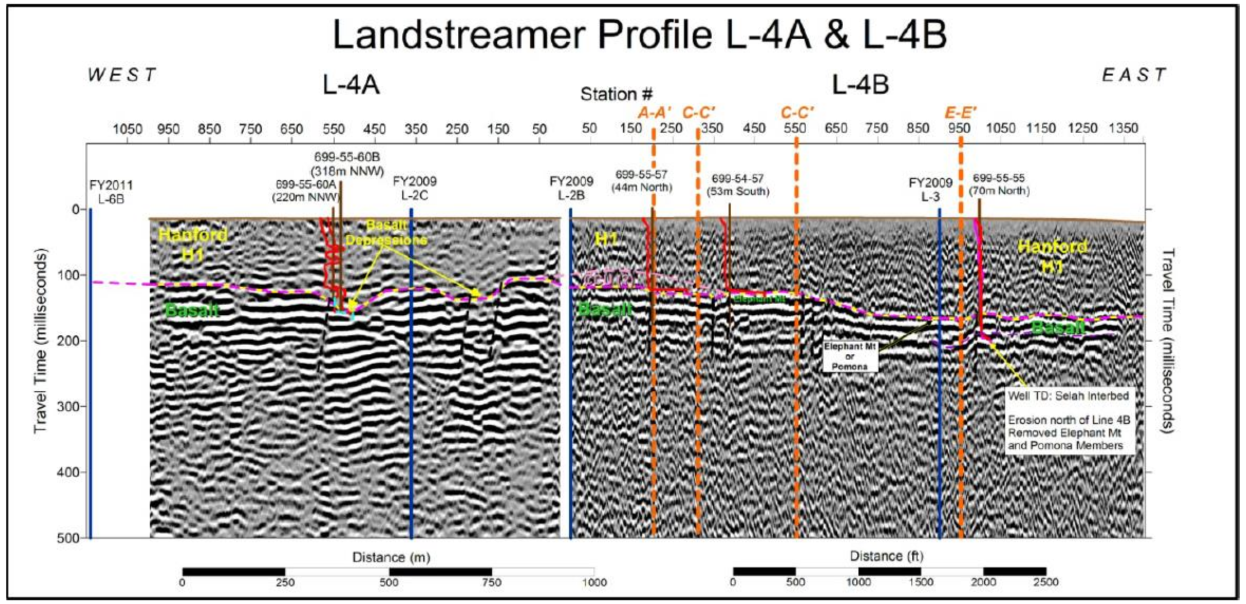
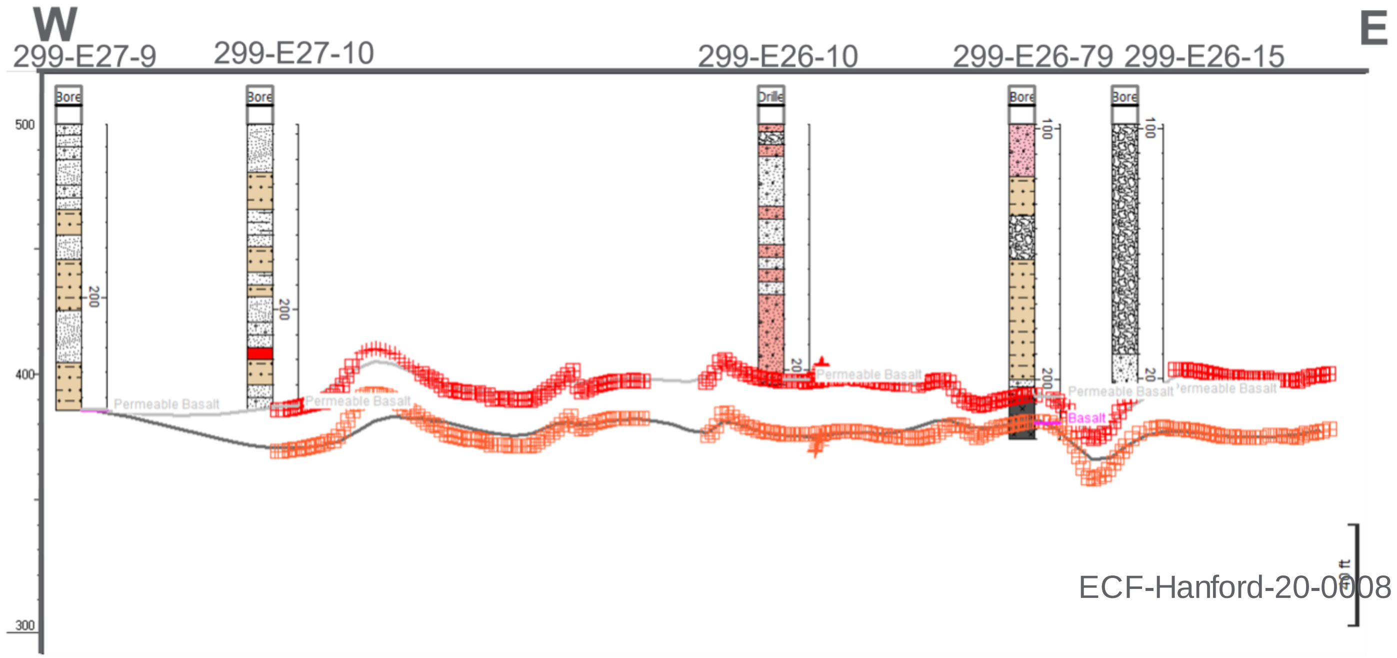


Figure 11. Landstreamer Profile L-4



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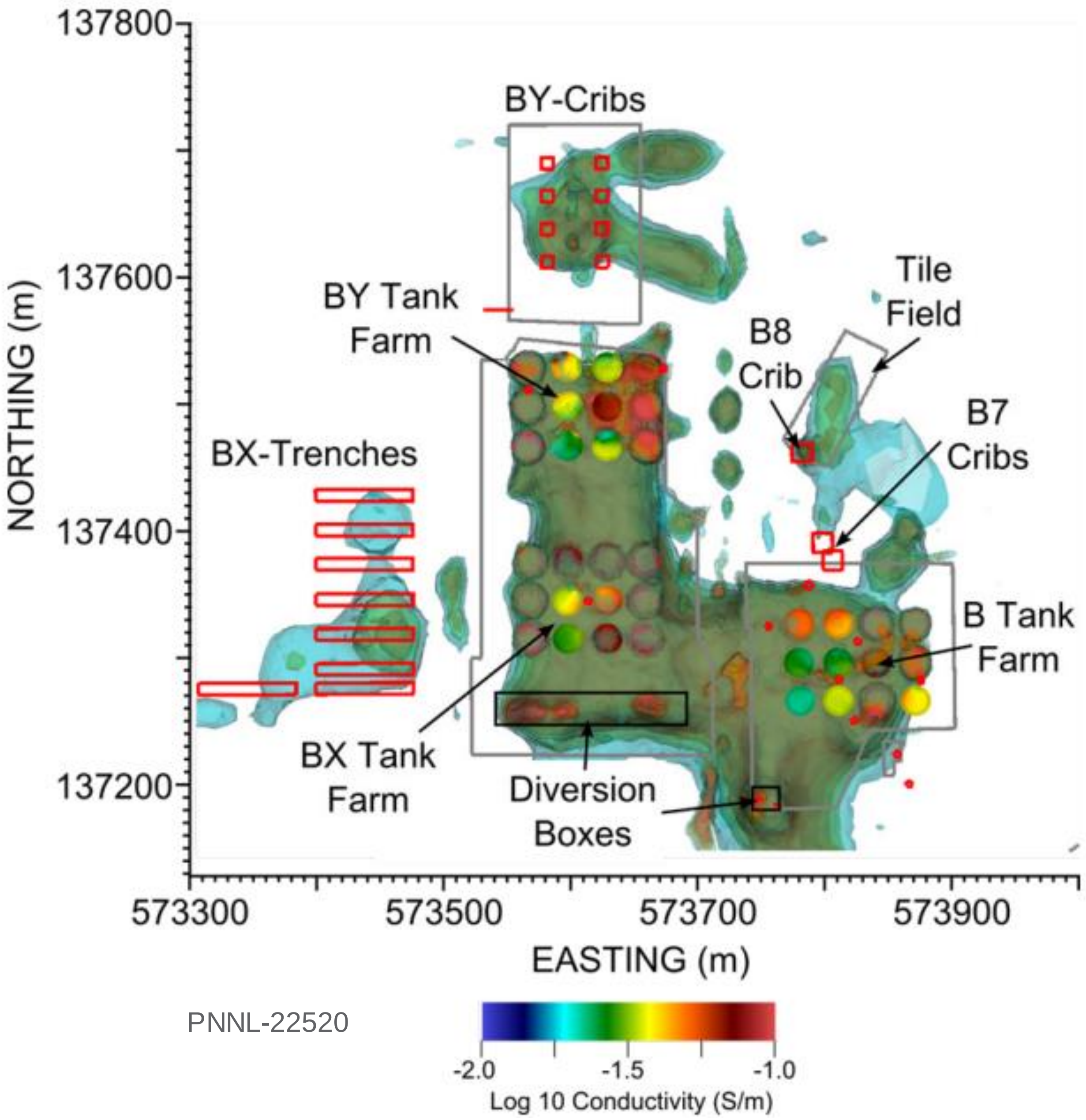
Resistivity Surveys



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Electrical Resistivity Tomography (ERT) is uniquely useful in some areas of the Hanford Site

- Semi-arid environment paired with high volume historical discharges
  - Slow recharge rates
- High-ionic strength of discharges
  - Nitrate a common contaminant

ERT can provide a 4D image of nature and extent of contamination

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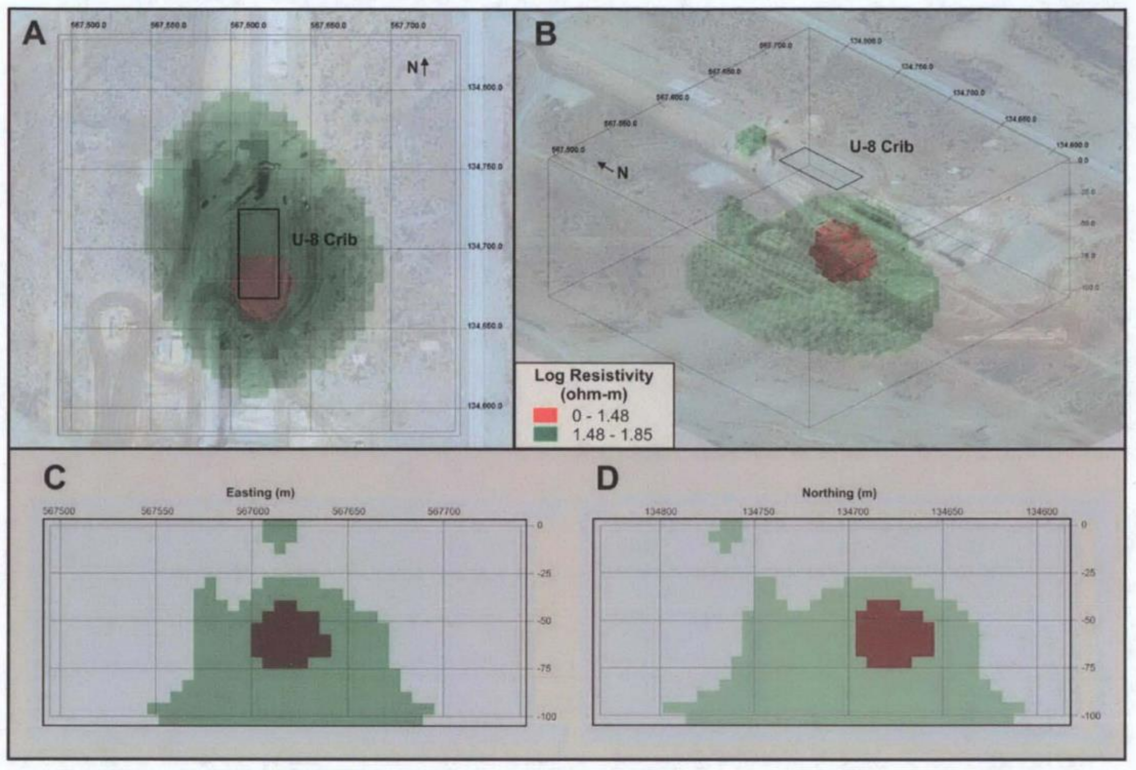
ERT to Characterize Nature and Extent

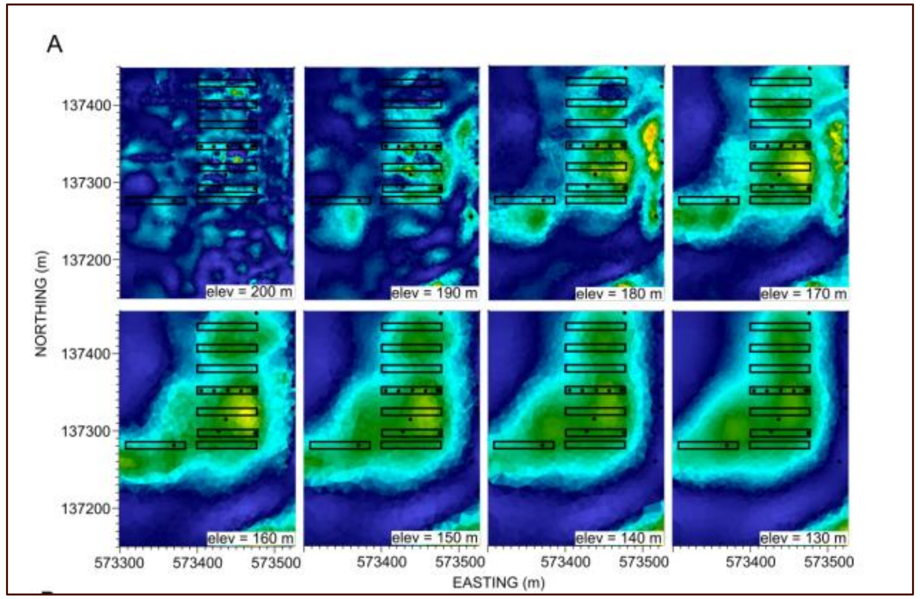
Use of ERT to plan characterization boreholes (B-Complex, U-8, etc.):

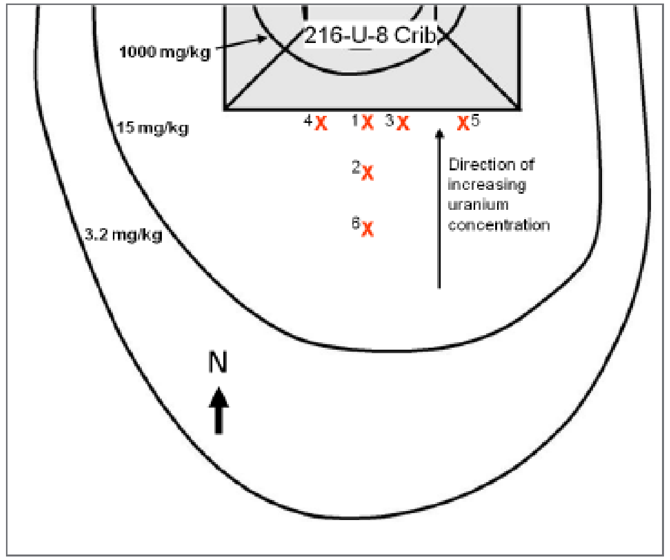
- ERT indicates “hot spots” to locate boreholes
- Soil samples from boreholes characterize contaminants
- Less boreholes necessary to establish nature and extent

U-8 Crib ERT Survey



BX Trenches ERT Survey





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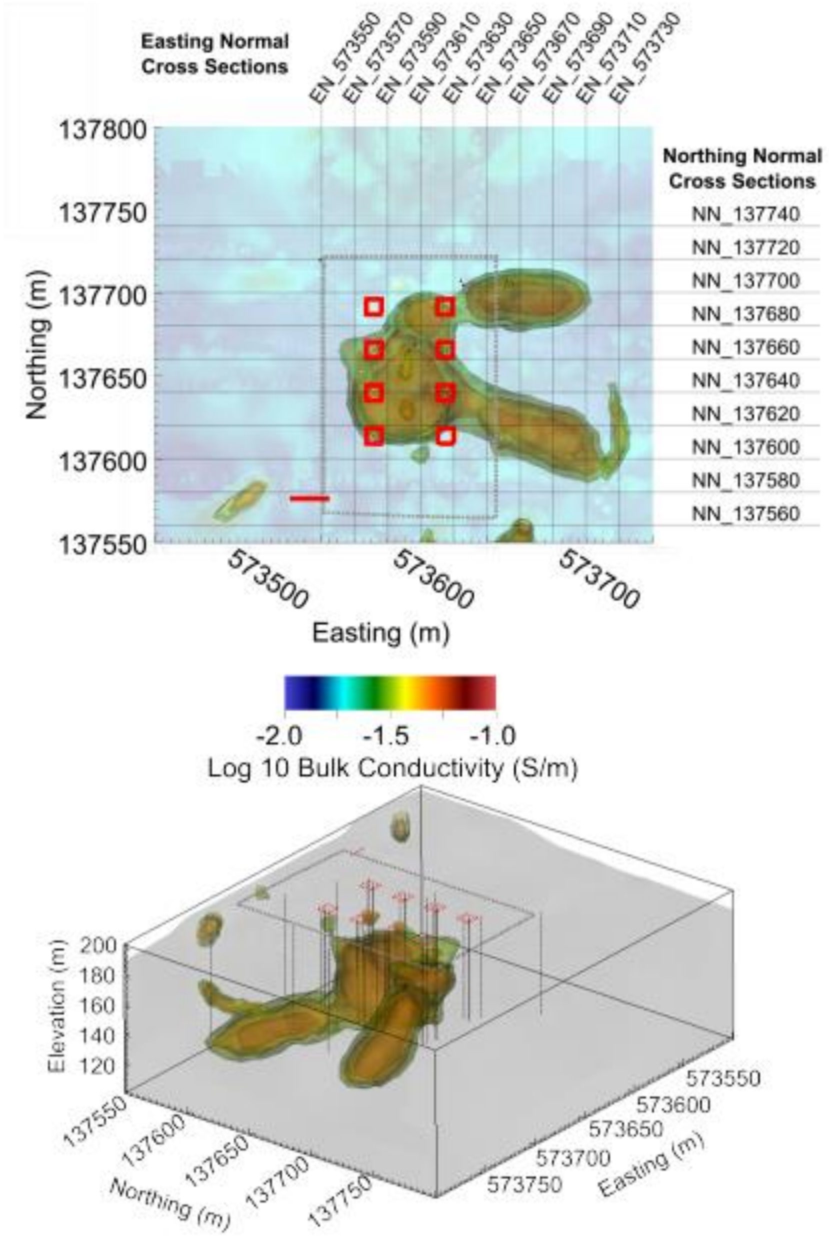
Nature and Extent Importance

Understanding nature and extent of contamination in the vadose zone is important to the remedy decision process:

- Delineates three-dimensional area requiring a remedy
- Provides a basis for the remedy selection and design
  - E.g. in-situ treatment, surface barrier
- Indicates the impact to groundwater

- ERT can provide an understanding of extent of contamination, but often other lines of evidence are necessary to understand the nature of the contamination



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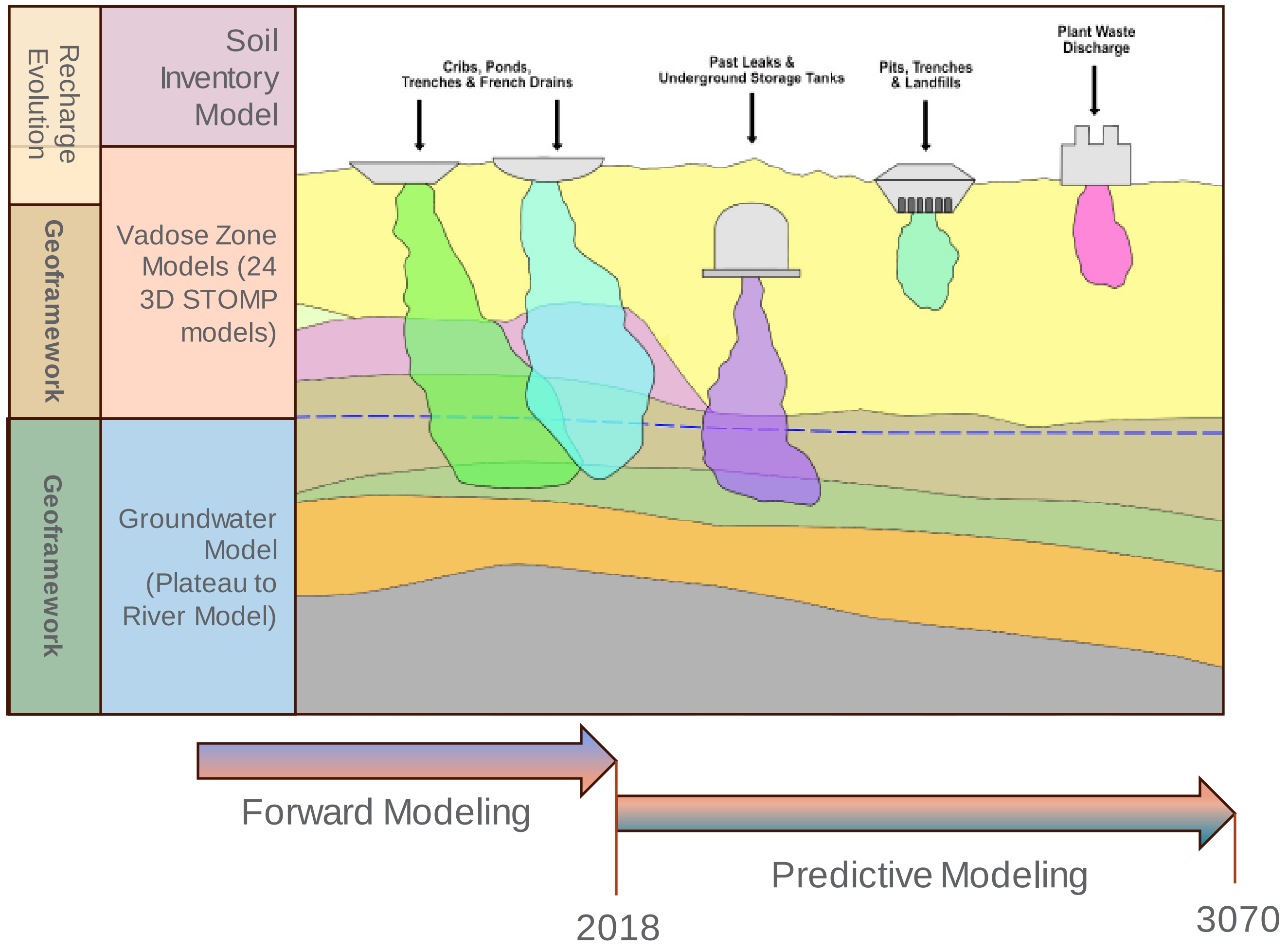
Central Plateau: Threat to Groundwater

- Final and Interim groundwater decisions in place on the Central Plateau
    - present status of groundwater contamination relatively well understood
- Continuing and future flux to groundwater less understood
- Solution: Cumulative Impact Evaluation Modeling Toolsets

Cumulative Impact Evaluation



CIE is designed to simulate future contamination migration from multiple sources to and within groundwater to support decision-making for the Central Plateau

Central Plateau: Threat to Groundwater

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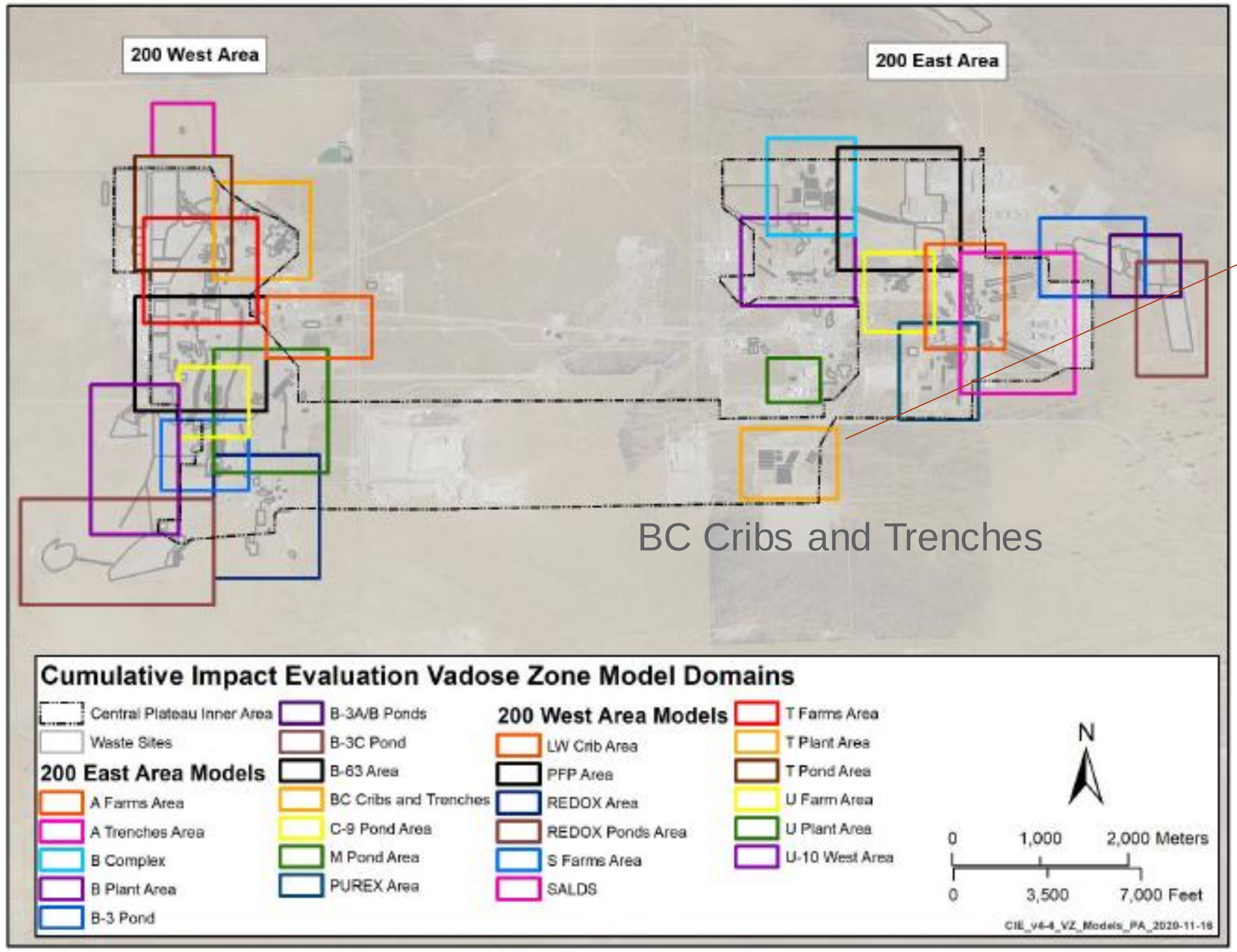
Forward modeling results can have high uncertainty in areas without current groundwater plumes



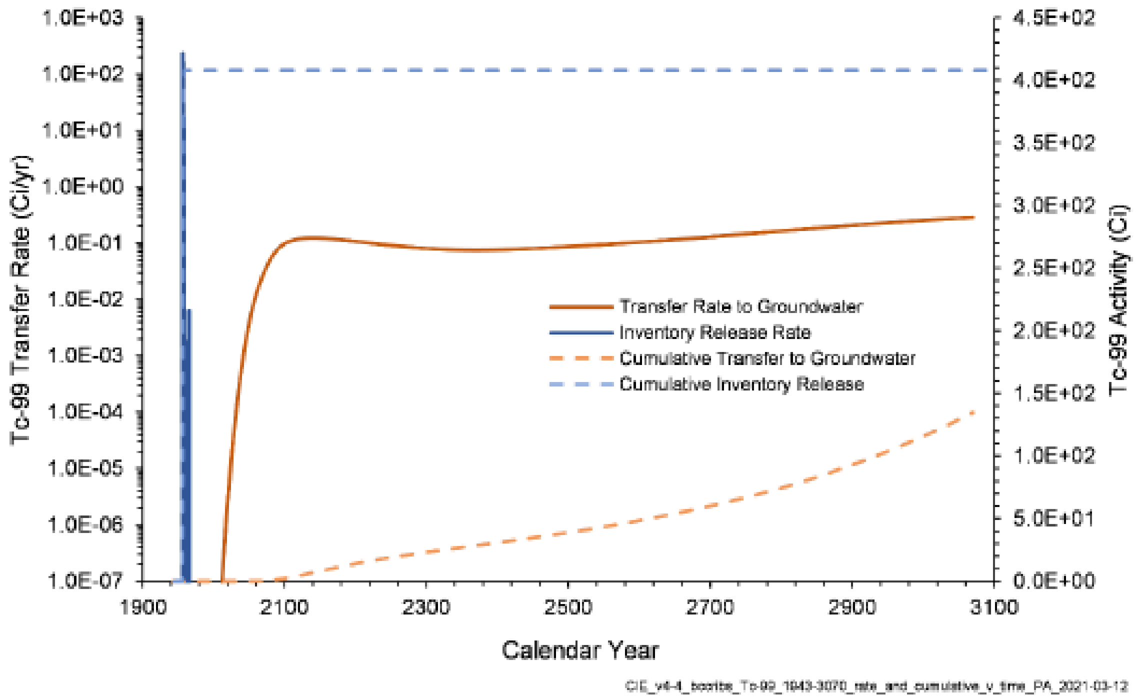


Figure 7-47. Tc-99 Inventory Released from Waste Sites and Transfer Rate to Groundwater for the BC Cribs and Trenches Model from 1943–3070

BC Cribs and Trenches: large volumes of tc-99 waste discharged but have not yet made it to the groundwater

Quantifying the plume in the vadose zone today will result in higher confidence predictions of when tc-99 will reach groundwater and how long it will persist

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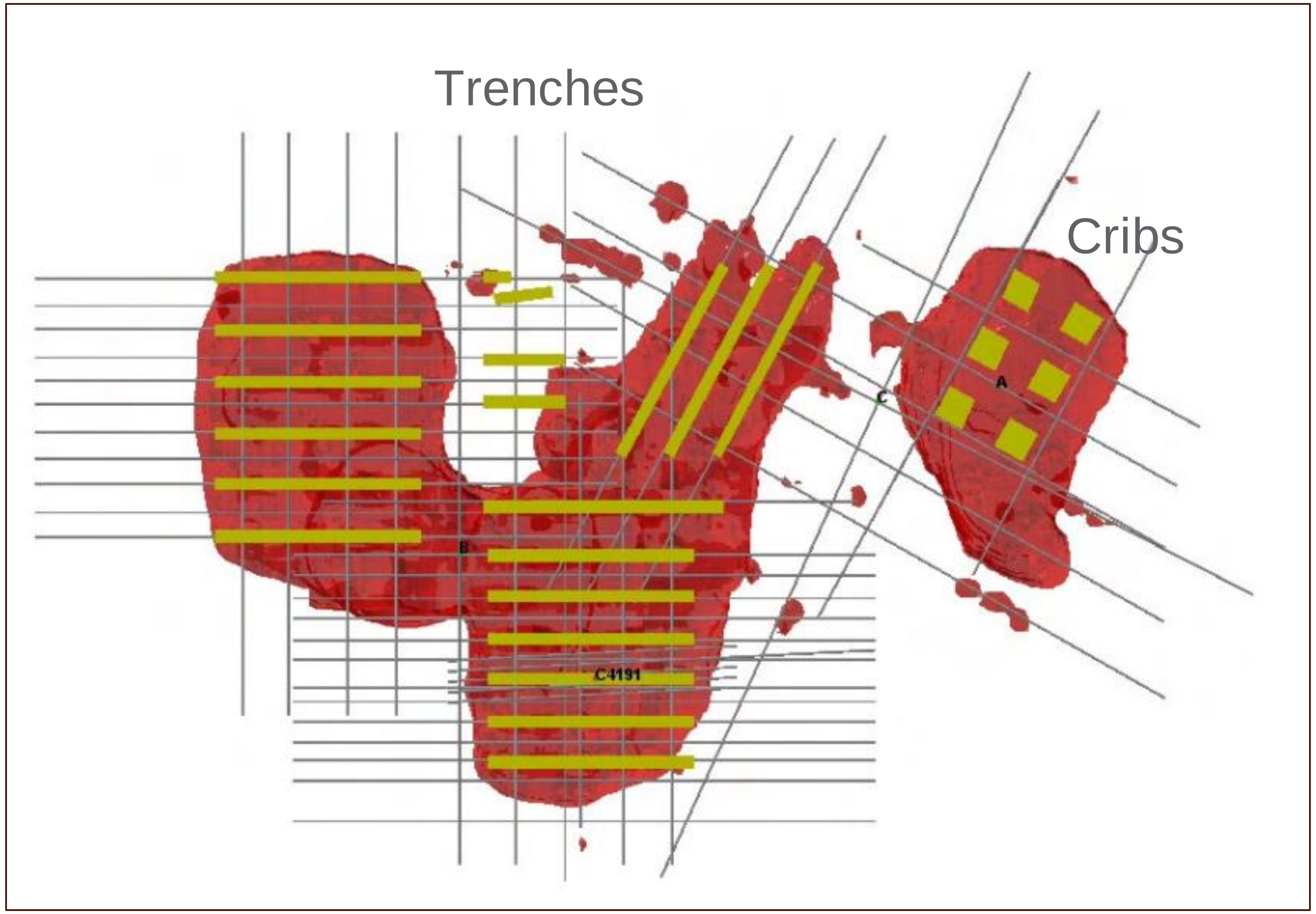
ERT to Characterize Future Impacts to Groundwater

Important considerations at the BC Cribs and Trenches Site:

- Relatively isolated from other disposal waste sites, less commingling
- Highly concentrated nitrate and tc-99 waste streams discharged
- Close to the “exit point” for the Central Plateau groundwater



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Vadose Zone Plume Mapping via ERT

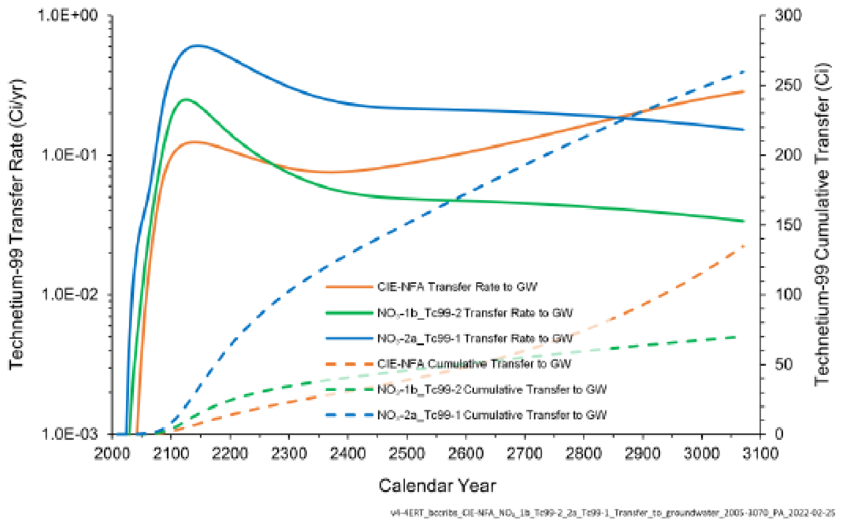
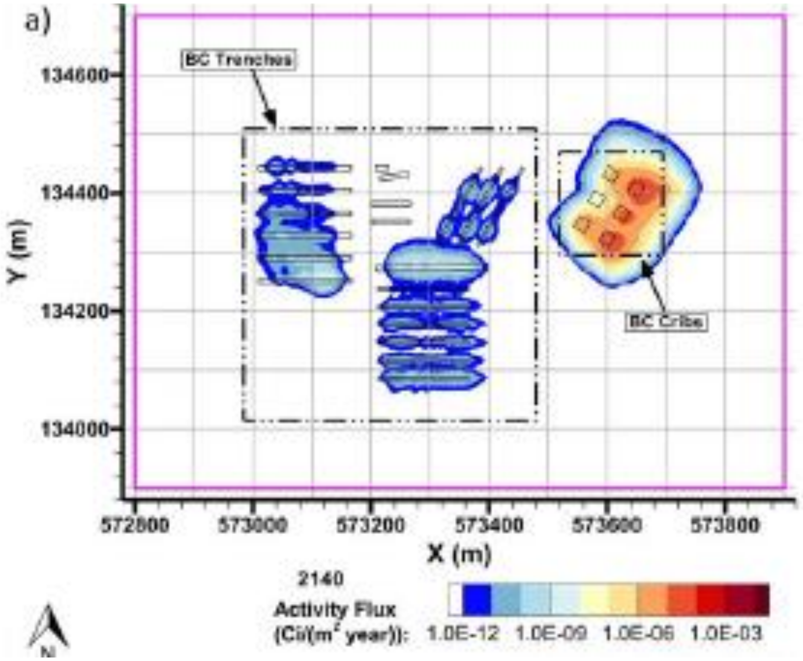


Figure 7-38. Transfer Rate and Cumulative Transfer Comparisons Between Cumulative Impact Evaluation No Further Action Scenario and Select Base Analysis Technetium-99 Distributions



Convert resistivity results to contaminant concentration plume:

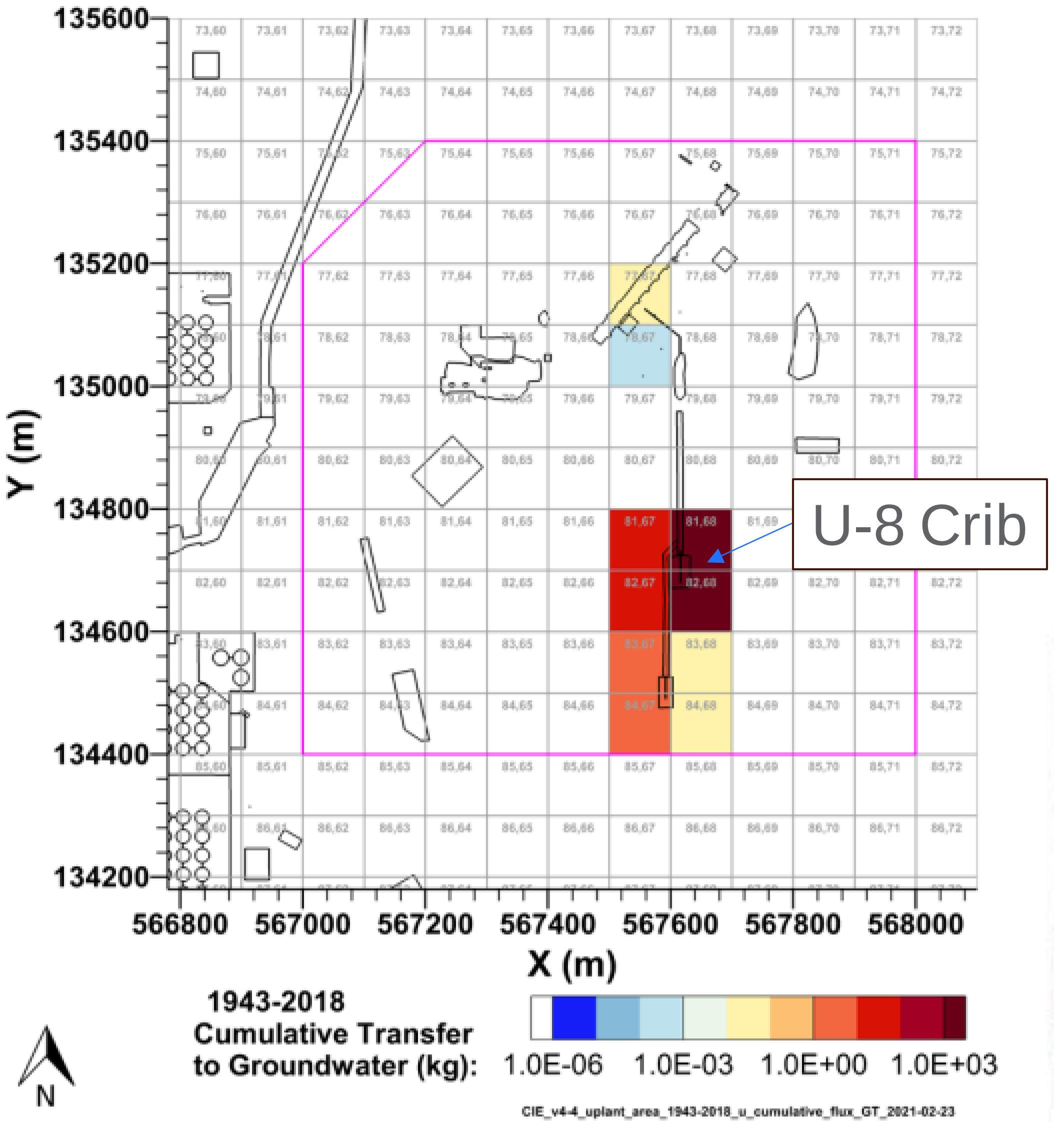
Bulk conductivity → fluid conductivity → porewater nitrate concentration → porewater tc-99 concentration

Nature and Extent Estimation Method	Peak Arrival to Groundwater	Amount of mass/activity remaining
Forward Modeling	2125-2145	20-23%
ERT-based vadose zone plume	2140	67%

ECF-Hanford-21-0136, Rev 1

All modeling methods show arrival first under BC Cribs
Indicating that ERT measurements roughly agree with the Soil Inventory Model

Vadose Zone Plume Mapping via ERT



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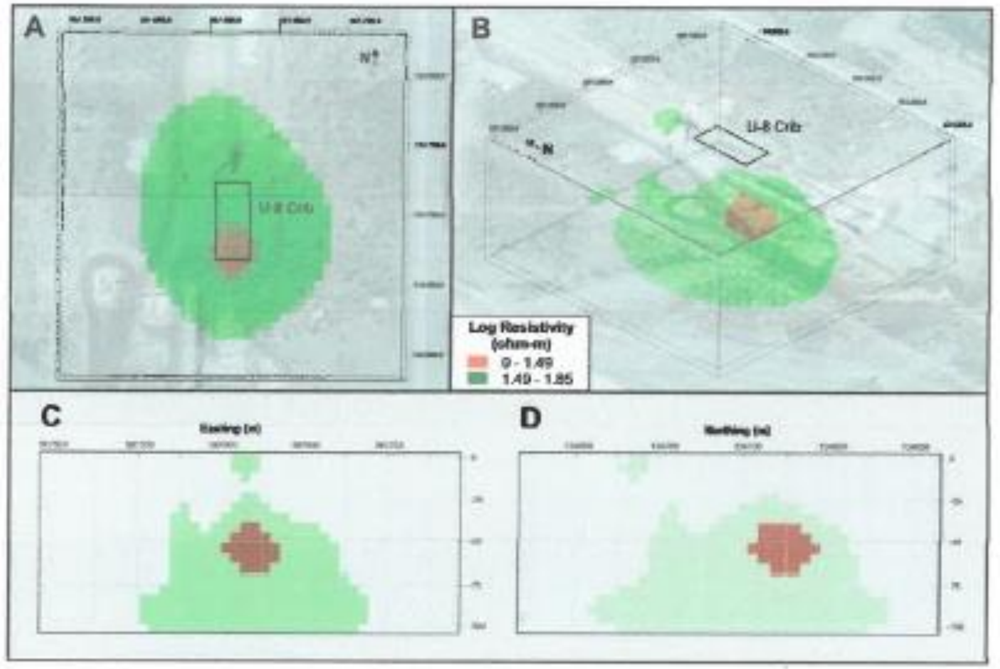
CIE forward modeling shows earlier arrival of uranium in groundwater than the monitoring well data indicates.

However, there is not a direct relationship to derive uranium concentrations from bulk conductivity



Resistivity data collected at U-8 crib

It is necessary to collect uranium mobility data to understand how the contaminants will migrate to the groundwater over time.

ERT to Monitor Remedy Implementation

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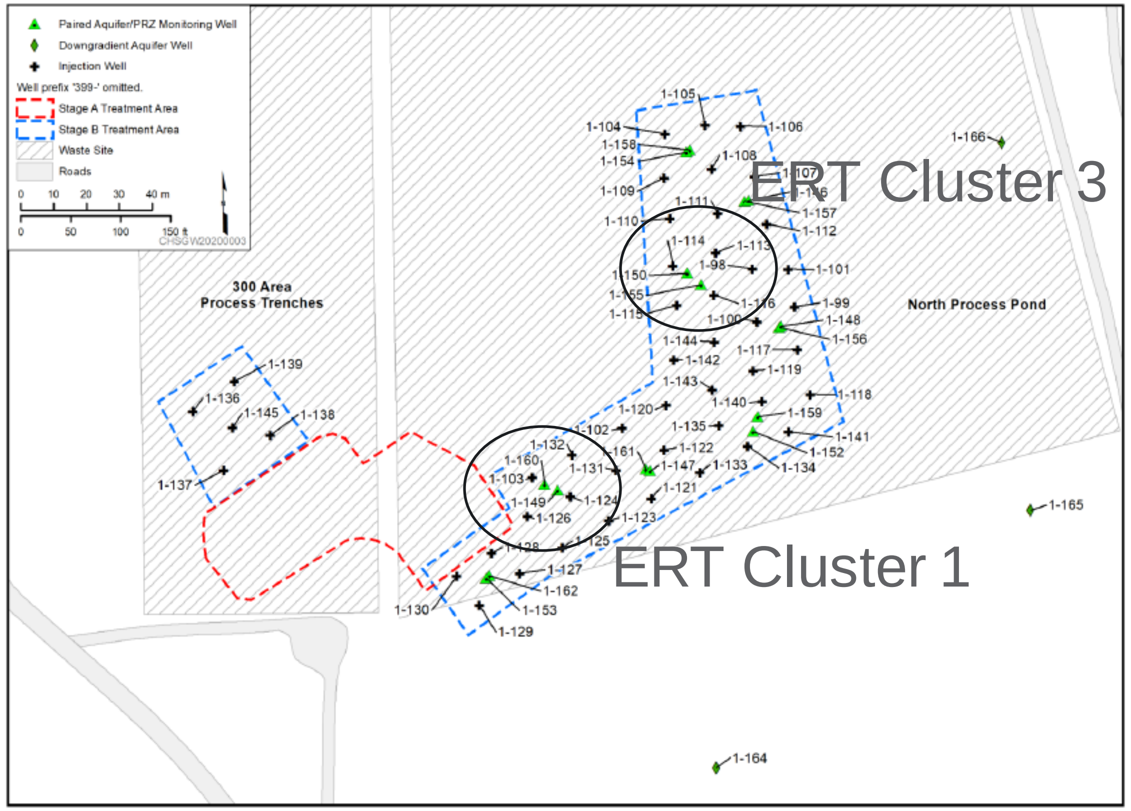
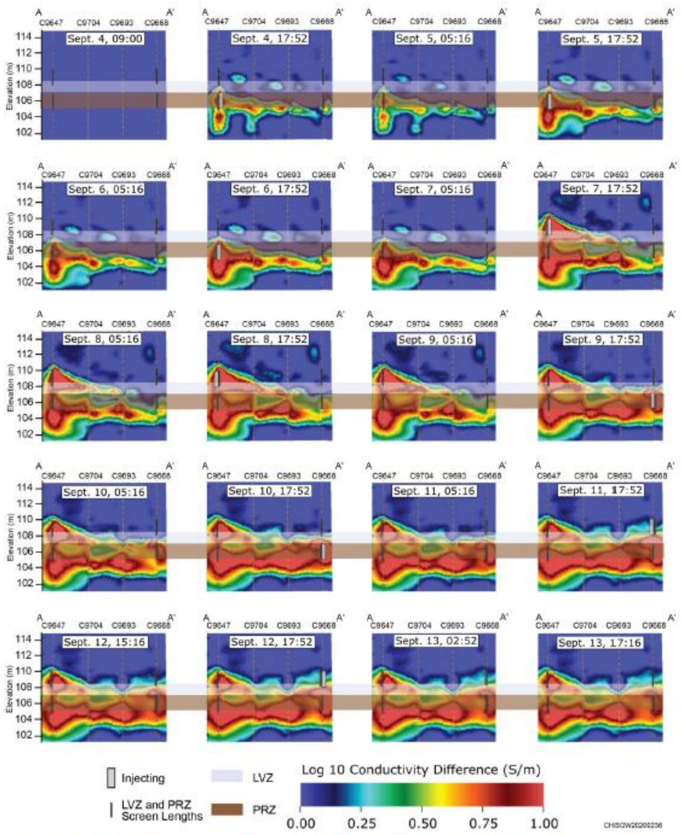
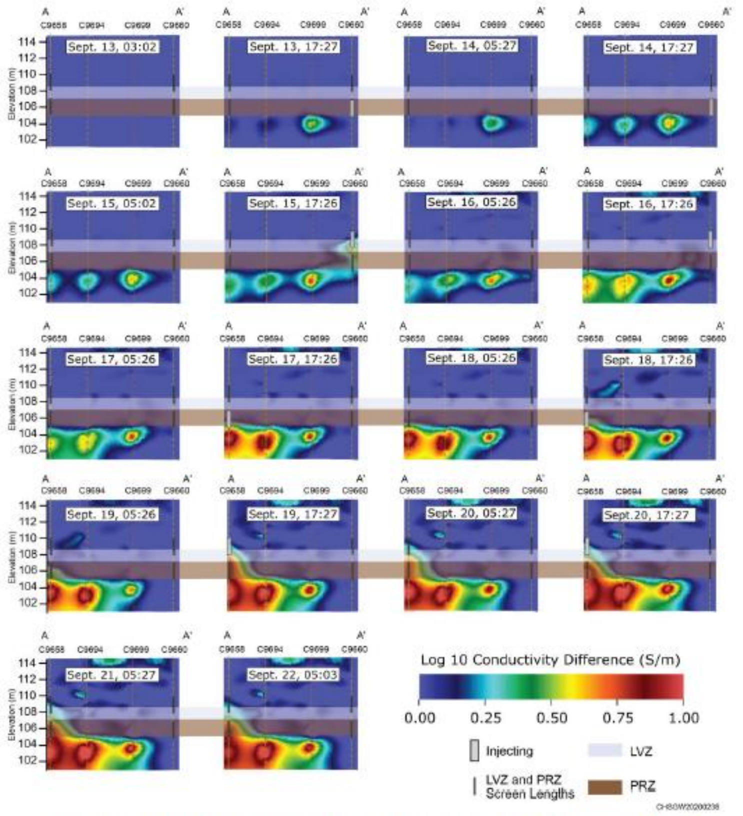


Figure 2-4. Forty-Eight Injection Wells and Nineteen Monitoring Wells Drilled for Stage B



Source: Modified from Figure 17 in PNNL-28619, *Stage B Uranium Sequestration Amendment Delivery Monitoring Using Time-Lapse Electrical Resistivity Tomography*.



Source: Modified from Figure 19 in PNNL-28619, *Stage B Uranium Sequestration Amendment Delivery Monitoring Using Time-Lapse Electrical Resistivity Tomography*.

ERT Cluster 1

ERT Cluster 3

Use of ERT to monitor the implementation of the selected remedy

- Real-time ERT can be another line of evidence ensuring the successful application of fluids in the subsurface

An outcome of the time-lapse ERT results in an in-situ treatment:

Demonstrates areas where injected solutions move anisotropically through the subsurface, which may not have been observable otherwise

Conclusions

- Geophysical methods are a useful tool in the remedy decision and implementation process, but they are not universally applicable
- Geophysical methods should be used in conjunction with other lines of evidence to interpret sources, nature and extent of subsurface contamination
- The characteristics of the Hanford Site and the unique nature of the contamination requiring remediation provide good opportunities for using a variety of different data collection and interpretation approaches.

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