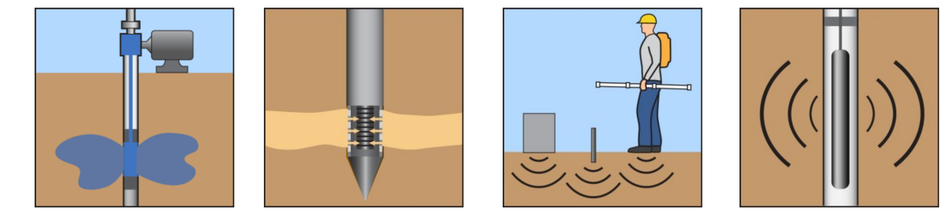
A method selection tool to improve geophysical and hydraulic characterization on the Hanford Site

Judy Robinson, Fred Day-Lewis, Rebecka Iveson, Klaudio Peshtani, Inci Demirkanli, Rob Mackley
Pacific Northwest National Laboratory

DEEP VADOSE ZONE PROGRAM @PNNL

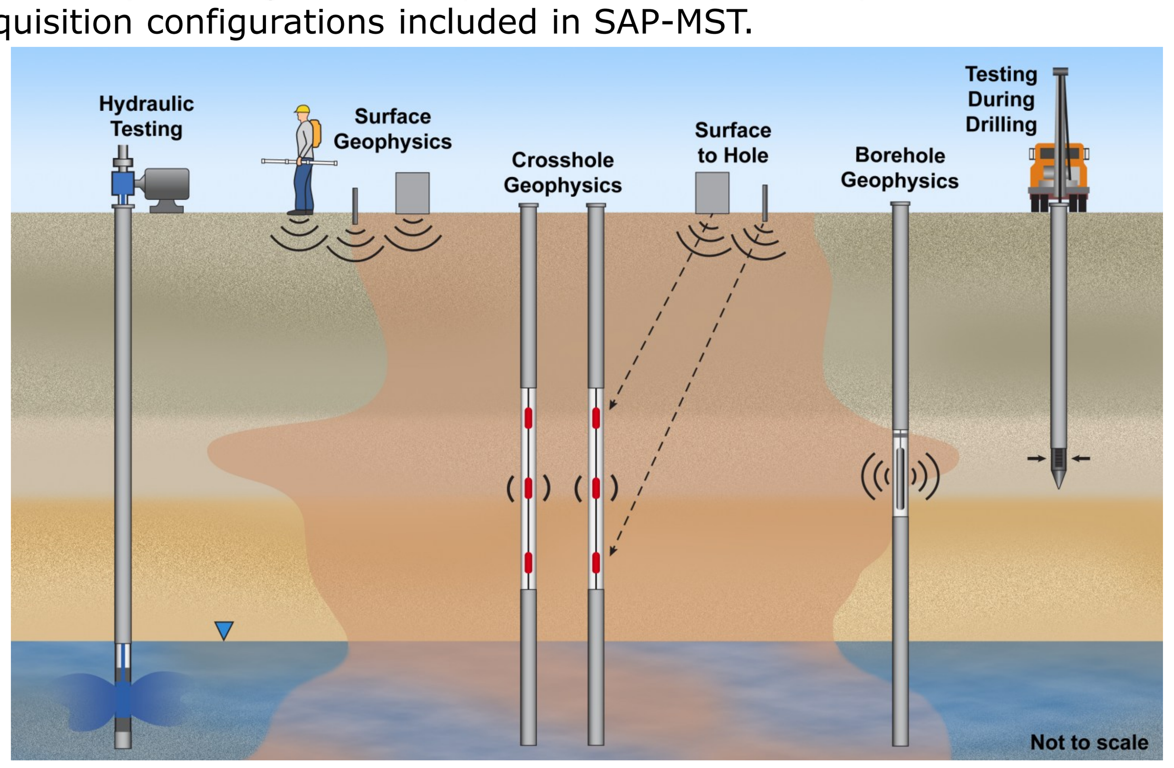


Summary: A geophysical and hydraulic method-selection tool, named the **Sampling and Analysis Plan – Method Selection Tool (SAP-MST)** has been created to support integrated site characterization and/or monitoring. Environmental remediation at complex sites, such as the Hanford Site in southeastern Washington state and other radionuclide-contaminated sites within the U.S. Department of Energy complex, requires careful planning that considers and weighs the complementary and competing goals of site characterization. SAP-MST has been designed to meet these needs.

Introduction

Site characterization and/or monitoring activities involve a set of technical interrogation methods to address the specific data needs related to these characterization components. At the Hanford Site, a suite of geophysical, hydraulic, and other field methods have been used for subsurface characterization, remedy monitoring, and parameter estimation.

SAP-MST is an Excel tool designed to help select geophysical and hydraulic methods based on specific data needs and site conditions. Methods are separated into geophysical and hydraulic categories and grouped by data acquisition configuration (e.g., surface, single-well, cross-well). The figure below provides a simplified representation of the methods and data acquisition configurations included in SAP-MST.



A Data Quality Objective (DQO) framework (EPA 2006) was adopted for defining site-specific investigation objectives. The initial steps in the DQO workflow are to identity the problem and study goals to address data gaps. In SAP-MST, the user selects DQOs relevant to their specific objectives. These are divided into generalized themes (left column).

Vadose Zone	
Contaminant Source and Behavior	Determine spatial distribution of contaminant source
	Determine downward flux of a contaminant source to groundwater
Geology	Determine subsurface structure (stratigraphy, soil type, lithology)
Hydrogeologic Conditions	Estimate hydrogeologic properties [e.g., unsaturated conductivity (K_{unsat})]
Monitoring	Monitor vadose zone system dynamics (e.g., moisture content changes, contaminant migration)
	Monitor the spatial and temporal distribution of an amendment (e.g., delivery and transport of an injected chemical amendment, changes in moisture or porewater saturation during soil flushing)
Subsurface Detection	Detect/delineate subsurface targets (e.g., archaeology, tanks, pipes)
Saturated Zone	
Contaminant Distribution and Behavior	Characterize the spatial distribution of contamination
	Determine vertical contaminant concentration profile
Geology	Characterize the extent of specific geologic units
Hydrogeologic Properties	Characterize spatial distribution and heterogeneity of hydrogeologic properties (e.g., preferential flow pathways and boundaries, high K zones)
	Estimate well and aquifer properties that relate to groundwater flow (e.g., specific capacity, hydraulic conductivity, specific yield and/or storage, aquifer thickness)
	Estimate hydrologic properties that relate to contaminant transport (e.g., porosity, dispersivity, sorption, mass transfer rates)
Saturated Zone Monitoring	Monitor aquifer system dynamics (e.g., saturation change, water table fluctuation, contaminant migration)
	Monitor active remediation, such as extent of specific injectate (or amendment) as delivered (e.g., injected). This could be for a specific objective such as contaminant containment and/or source containment. Monitor contaminant migration in response to active remediation.
	Monitor post-active remediation conditions [e.g., monitored natural attenuation (MNA)]

SAP-MST Logic, Constraints and Workflow

The geophysical and hydraulic methods available in SAP-MST were selected based on their recognized, emerging, or potential utility at Hanford. An example of the details considered in SAP-MST for seismic and electrical geophysical methods are shown below.

Category	Method	Measurement	Application	Relative Scale	Relative Cost	Level of Effort	Considerations
Seismic	**Reflection**	Analysis focuses on reflection evens to extract surbsurface structures and interfaces.	Location of subsurface boundaries	m – km	$$$		• Small source-receiver offsets • Need many source-receiver locations • Processing is relatively expensive
	Refraction	Analysis focuses on of the first arrival times of the initial ground movement from seismic sources from different offset locations to extract the P-wave velocities	Correlated with lithology, porosity, saturation	m – km	$$		• Large source-receiver offsets • Need fewer source-receiver locations • Processing is relatively less expensive
	Surface Waves	Analysis commonly focuses on the dispersion of surface waves to extract the shear wave velocities	Correlated with lithology, porosity and used to investigate soil strength	m – km	$$		• Active (multichannel analysis of surface waves - MASW) and passive (microtremor survey method - MSM) are used • Landstreamers allow for rapid data collection
	Vertical seimic profiling (Surface-to-borehole)	Measures seismic arrivals from a surface seismic source with one or more receivers at depth in a borehole	Stratigraphic correlation with seismic velocities	m – 100m	$		Can be combined with surface measurements for more robust intepretations
Electrical	**Electrical resistivity tomography (ERT)**	Different 2D/3D combinations of current injections through electrodes and measurement of potential through receiving electrodes	Sensitive to lithology, porosity, temperature, grain size and sorting	m – km	$		Time lapse ERT can evaluate processes over time (e.g. remedial injection), removing the static effects of lithology/geology for a more robust interpretation
	Induced Polarization (IP)	Measures the temporary, reversible storage of charge that occurs after an ERT measurement	Sensitive to mineral/grain surfaces and can be used to identify finer layers/heterogeneity	m – km	$$		Can reduce ambiguity in static ERT images

SAP-MST workflow also considers site conditions and well construction to determine relevant geophysical and hydraulic methods.

#	Site Condition
1	Is the investigation during drilling (i.e., not post drilling)?
2	Are there nearby wells that can be used for hydraulic observation in the saturated zone?
3	Is the goal depth of investigation (DOI) > 30% of the length of a possible survey line on the ground surface?
4	Is there a large fluid conductivity contrast between native groundwater and target fluids (e.g., contamination, amendments)?
5	Is the target DOI within the top 5 m?
6	Is disturbance of the ground (e.g., installation of electrodes or geophones) prohibited?
7	Are there sources of EM interference (utilities, metal pipes, etc.)
8	Are there high electrically conductive shallow materials (fine-grained sediment, metallic content, reinforced concrete) in the near subsurface?
9	Is GPS signal problematic at the site?

#	Well Construction Criteria	Options
10	What is the well casing material?	• Steel [Default] • PVC (or non-metallic) • No wells
11	Are the screen(s) or open interval long relative to the length of the casing?	• No [Default] • Yes
12	What material is in the annular space, around the casing?	• Bentonite/conductive grout [Default] • Resistive grout • Native soil
13	If there's a pump in the well, is removal possible?	• Yes [Default] • No

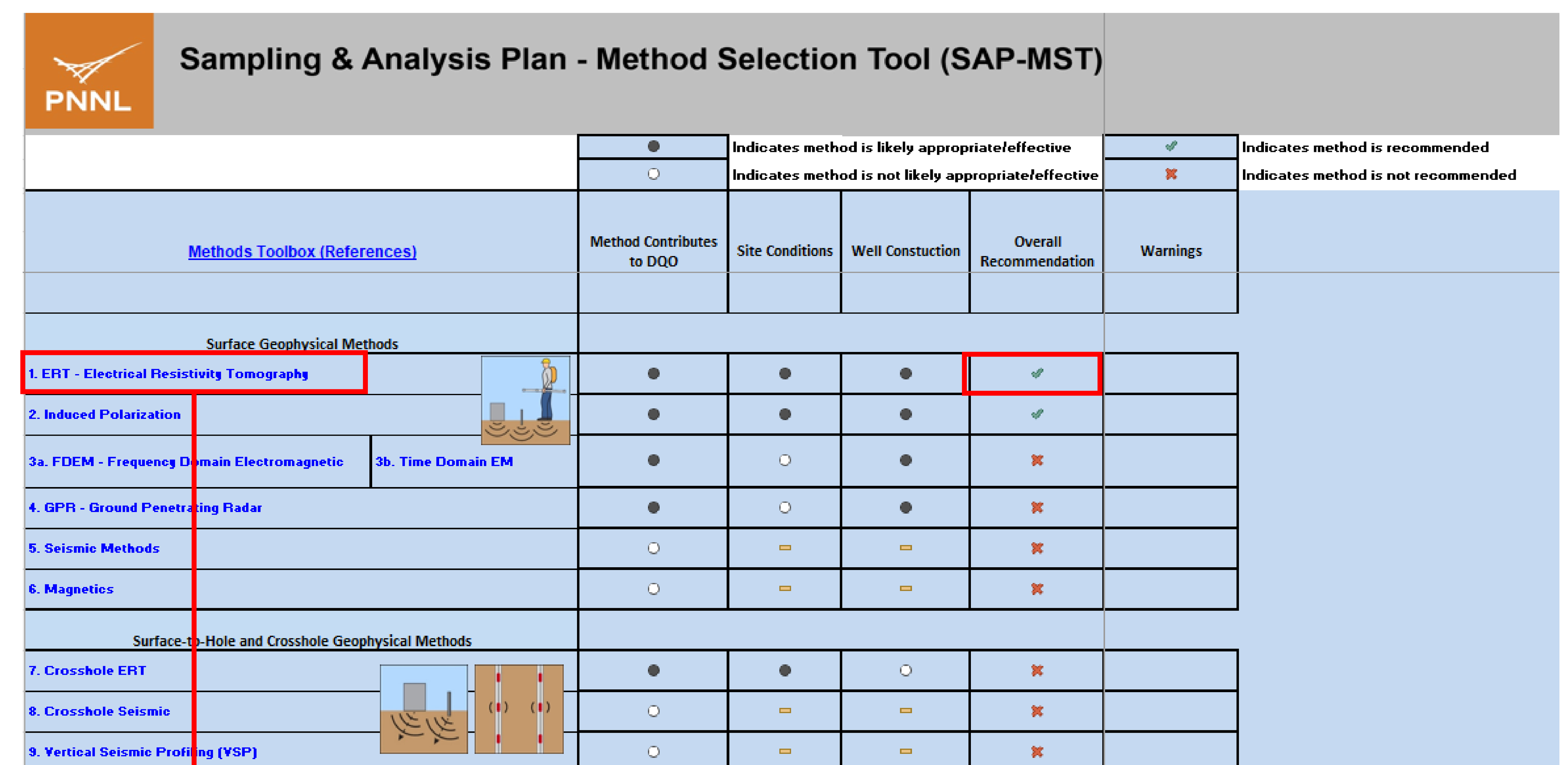
SAP-MST workflow

Select one or more Generalized DQOs → Specify the Site Conditions and Well Construction → Review the Methods Selected

If there are uncertainties in DQOs or site conditions, try different scenarios to determine sensitivities and impact on methods selected

Site-specific Method Selections

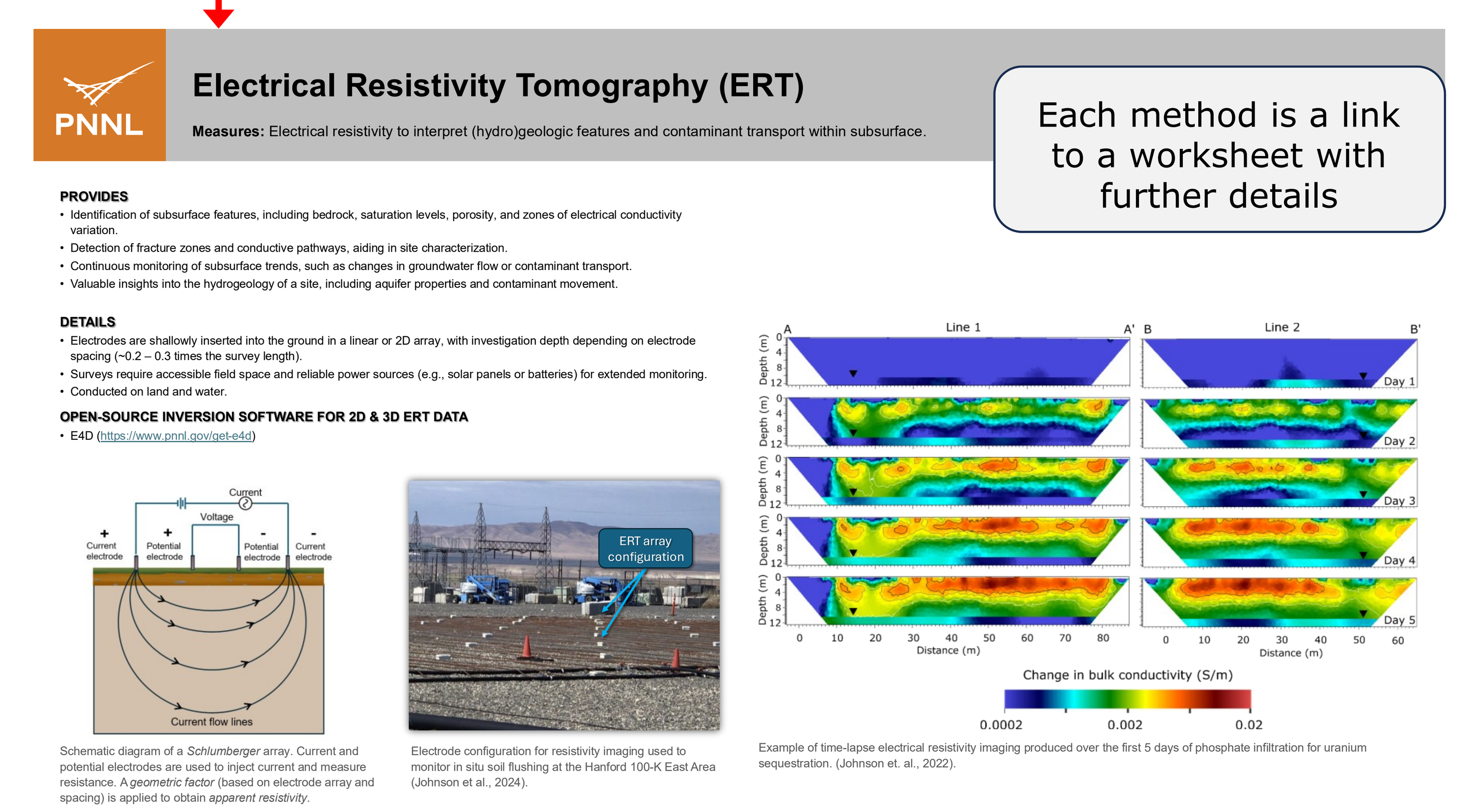
The Method Selections are provided as a Summary, which shows the overall recommendations and what criteria either ruled-in or ruled-out a method selection. Additional granularity is provided within the tool (not shown below) with information on the exact criteria that ruled-in or ruled-out a method selection.



Sampling & Analysis Plan - Method Selection Tool (SAP-MST)

● Indicates method is likely appropriate/effective
○ Indicates method is not likely appropriate/effective
✔ Indicates method is recommended
✖ Indicates method is not recommended

Methods Toolbox (References)	Method Contributes to DQO	Site Conditions	Well Constuction	Overall Recommendation	Warnings
Surface Geophysical Methods					
1. ERT - Electrical Resistivity Tomography	●	●	●	✔	
2. Induced Polarization	●	●	●	✔	
3a. FDEM - Frequency Domain Electromagnetic / 3b. Time Domain EM	●	○	●	✖	
4. GPR - Ground Penetrating Radar	●	○	●	✖	
5. Seismic Methods	○	–	–	✖	
6. Magnetics	○	–	–	✖	
Surface-to-Hole and Crosshole Geophysical Methods					
7. Crosshole ERT	●	●	○	✖	
8. Crosshole Seismic	○	–	–	✖	
9. Vertical Seismic Profiling (VSP)	○	–	–	✖	



Each method is a link to a worksheet with further details

Next steps

- Add geochemical site investigation methods and the additional DQOs that are applicable to these methods
- Engage SAP-MST with working technical professionals conducting site characterization at Hanford

References: EPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4. United States Environmental Protection Agency EPA/240/B-06/001. Washington, DC. https://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4.

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