Using High Resolution Site Characterization to Demonstrate Monitored Natural Attenuation

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23rd IPEC; Wednesday, November 9, 2016

Electrical Evaluation of MNA

1. MNA vs time and space
2. MNA vs electrical properties
3. Star City, AR
   - HRSC Process for CSM
   - Regulation
4. Questions/Discussion

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MNA vs Time – will it go away?

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DO
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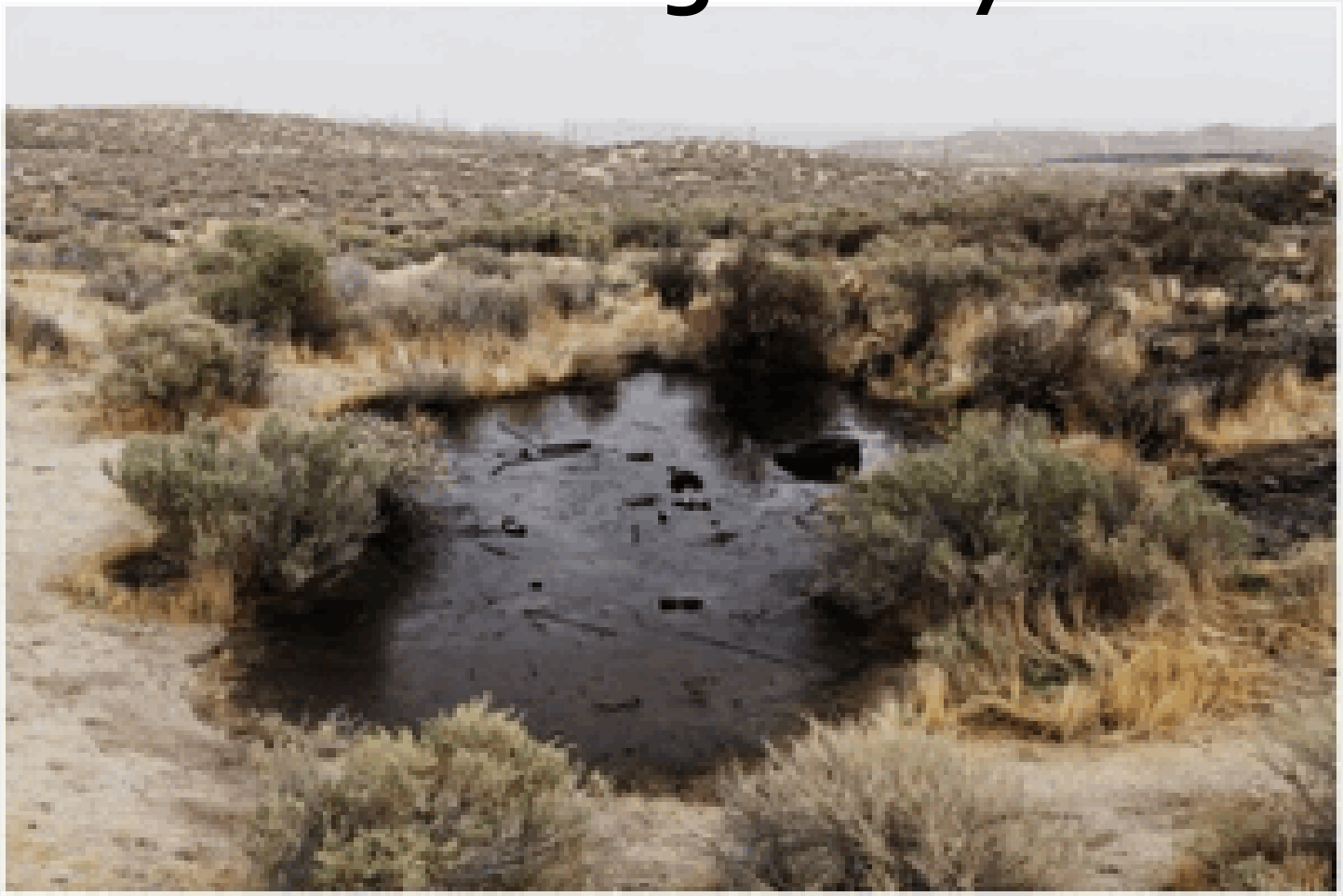

A natural oil seep near McKittrick, CA. (Photo: Todd D'Addario) (loe.org)

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MNA checklist

1. Source stopped?
2. Horz and Vert Extent
3. Ecology
4. Presence of degrading microbes

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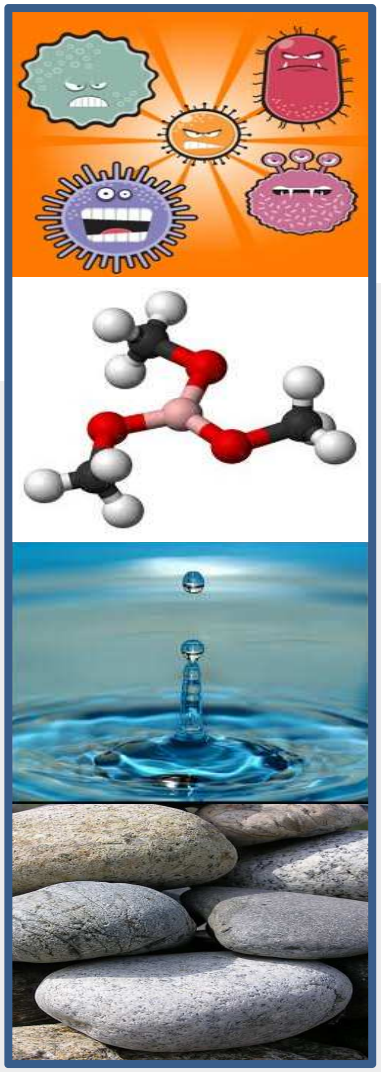
What do Electric Glasses See?



1. Biological activity
2. Contamination/ Injectates/etc.
3. Groundwater/Fluids
4. Soil/Bedrock

Higher

Signal Strength

Lower

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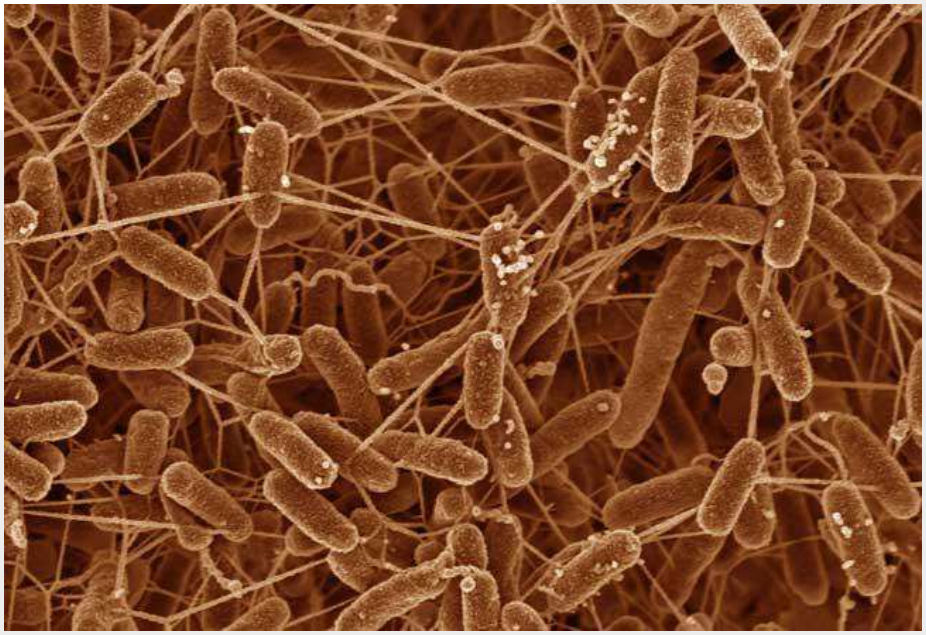
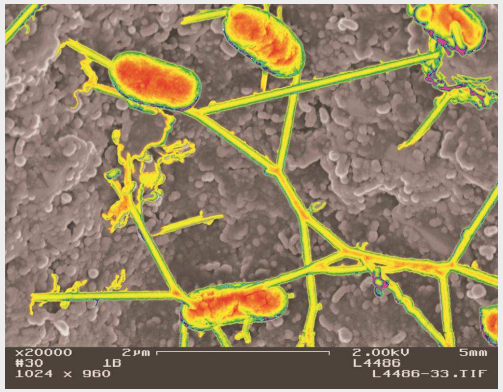
Electrical View of Microbes

"Nanowires" (Electron Microscopy)



bluetechblog.com/2010/06/15/make-electricity-not-sludge/



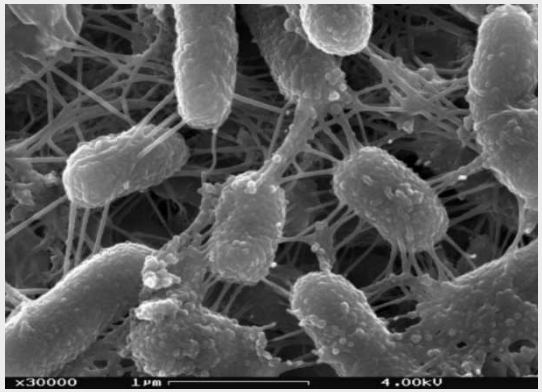


Image courtesy of Dr. Estella Atekwana

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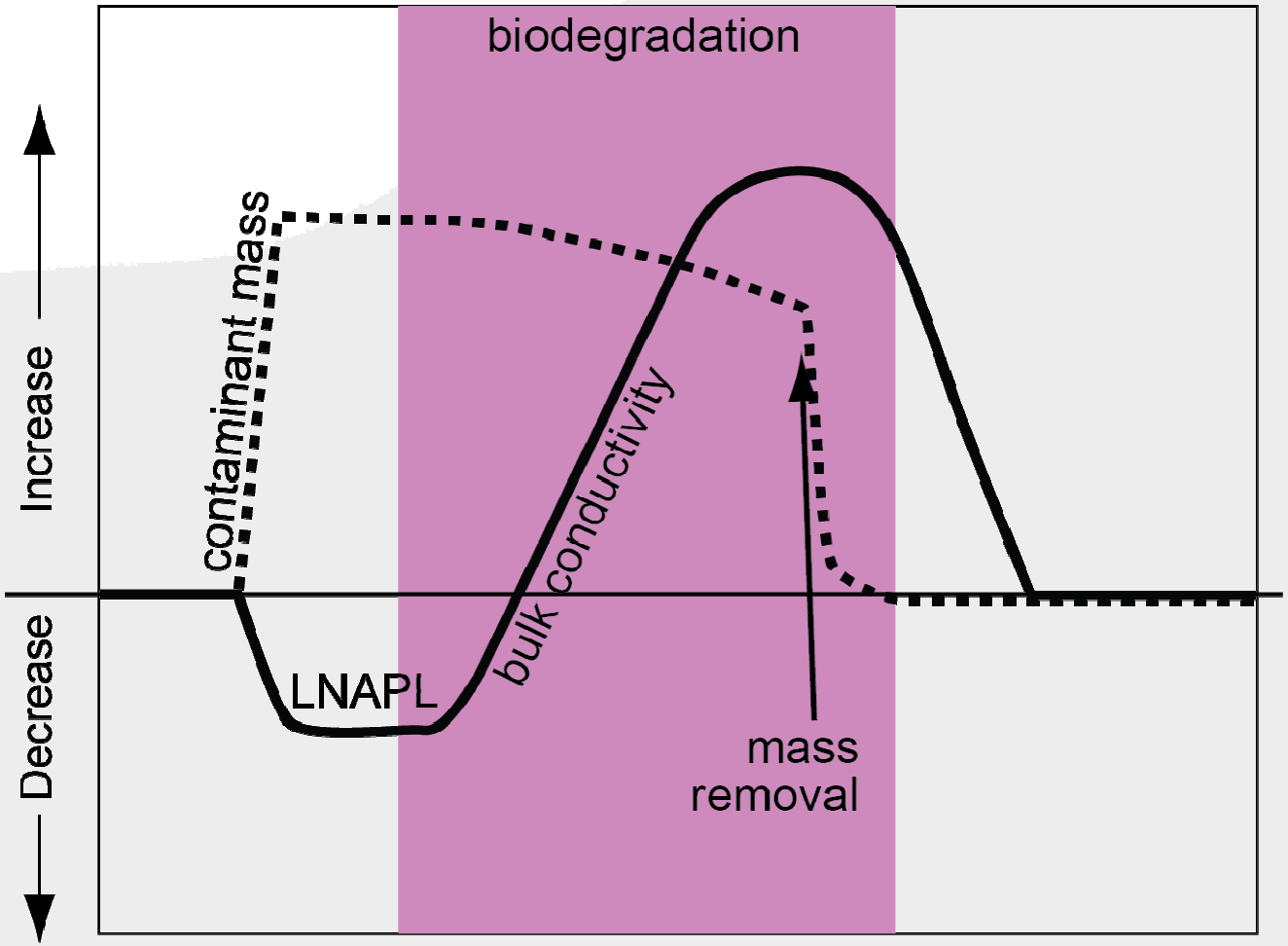
Electrical Properties of Microbes



Modified from
Che-Alota et al., 2009

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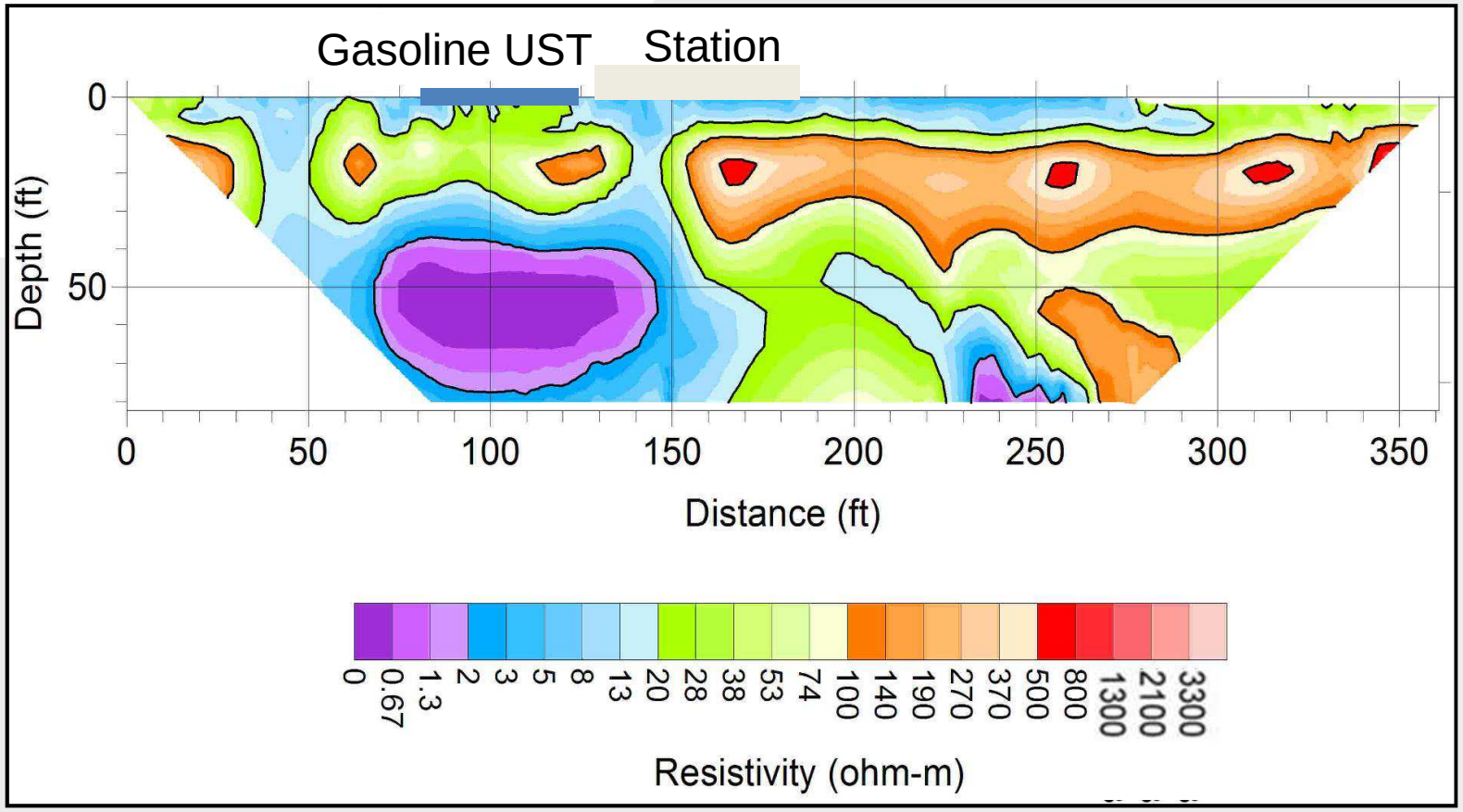
Small Microbe House – New Mexico



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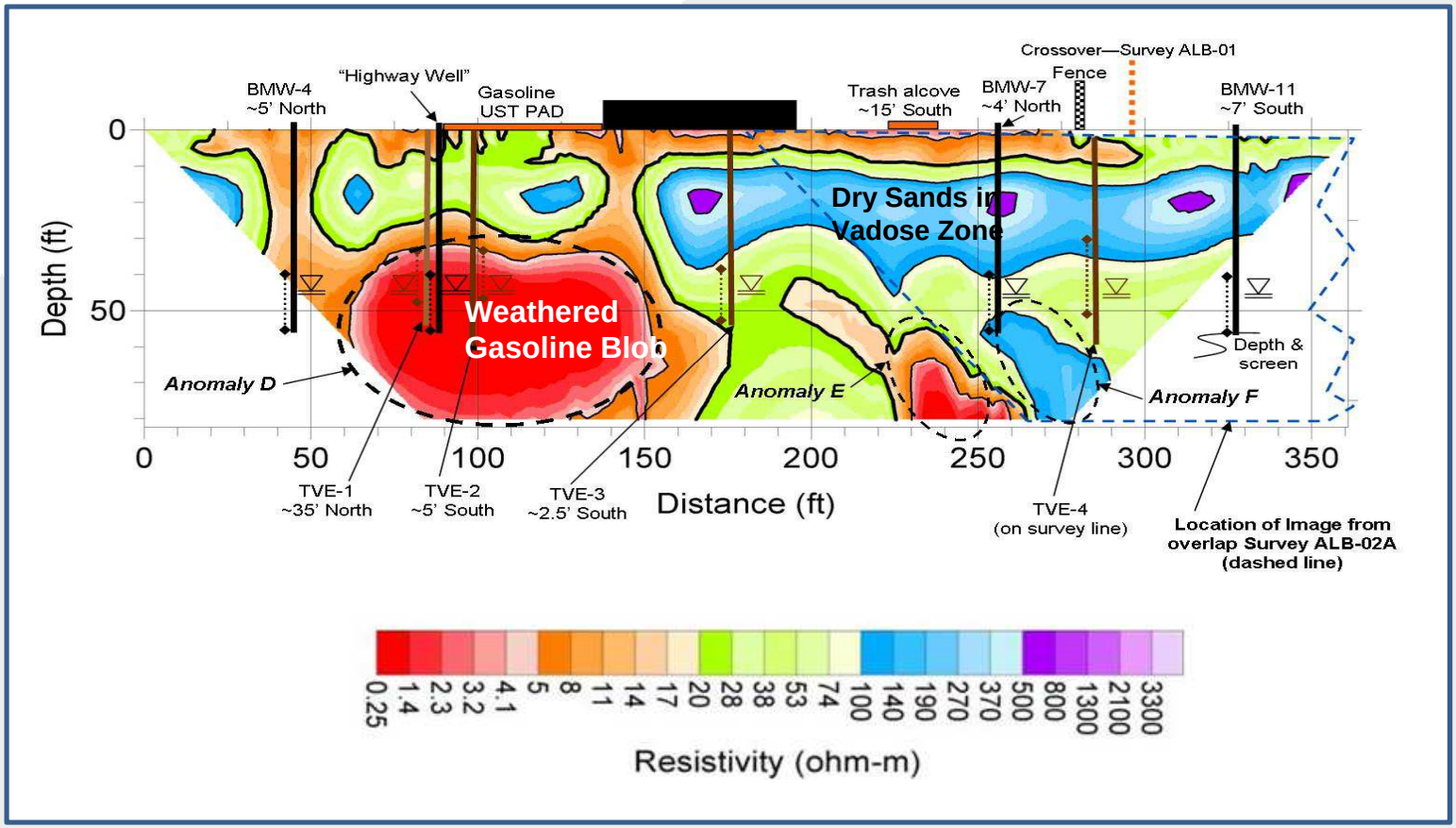

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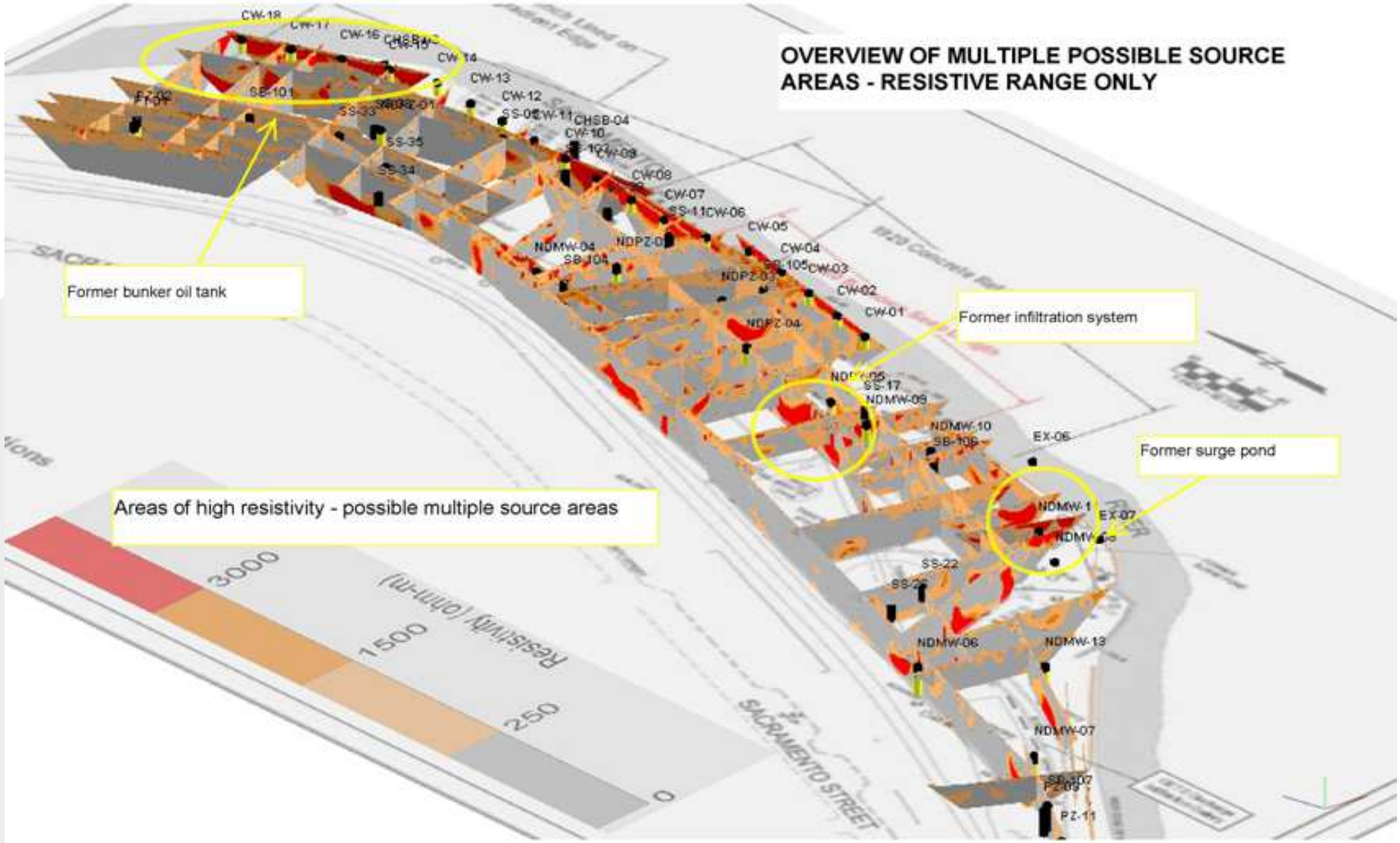
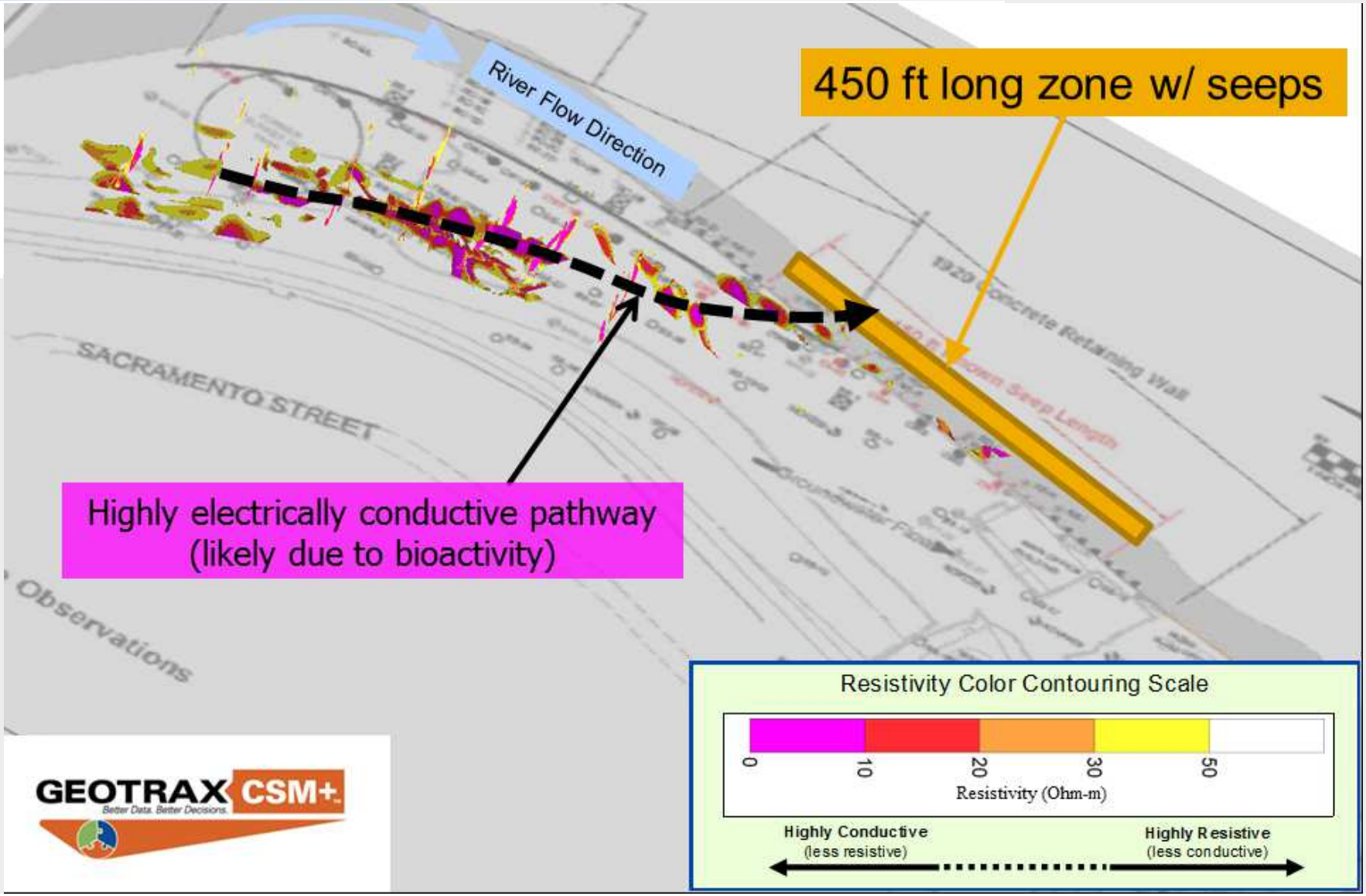
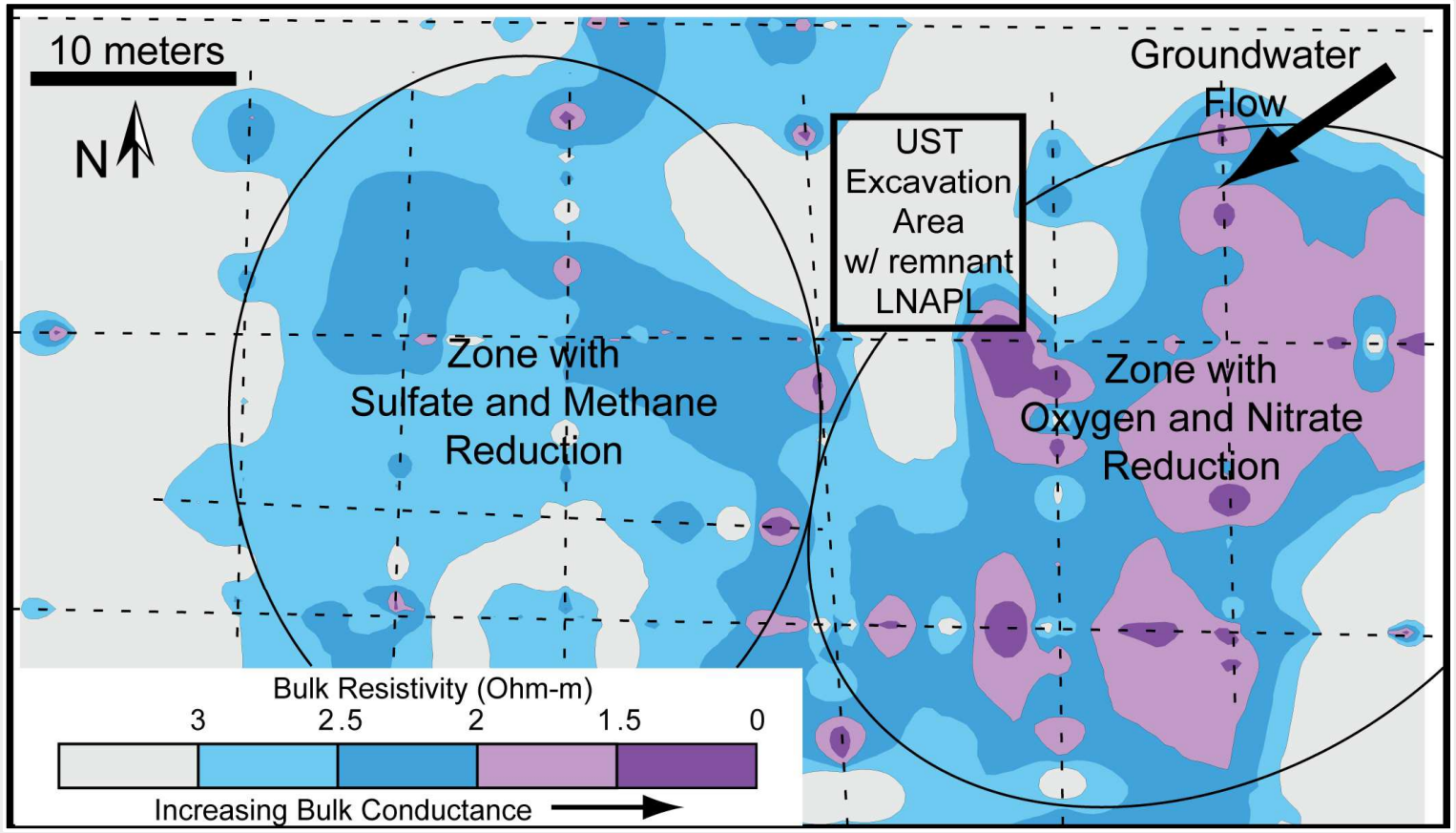
Microbial Subdivision - California



Microbial Subdivision - California



Microbial City - Colorado



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Case Study: Pipeline Break, AR

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Case Study: Pipeline Break, AR

- PSH related impacts generally in finer grained sediment below coarse grained layer
- PSH related impacts limited by lateral extent of coarse grained layer
- Electrical “blob” anomalies crossing the coarse grained layer are targets for PSH related impacts
- No evidence of deep PSH related impacts, just lignite

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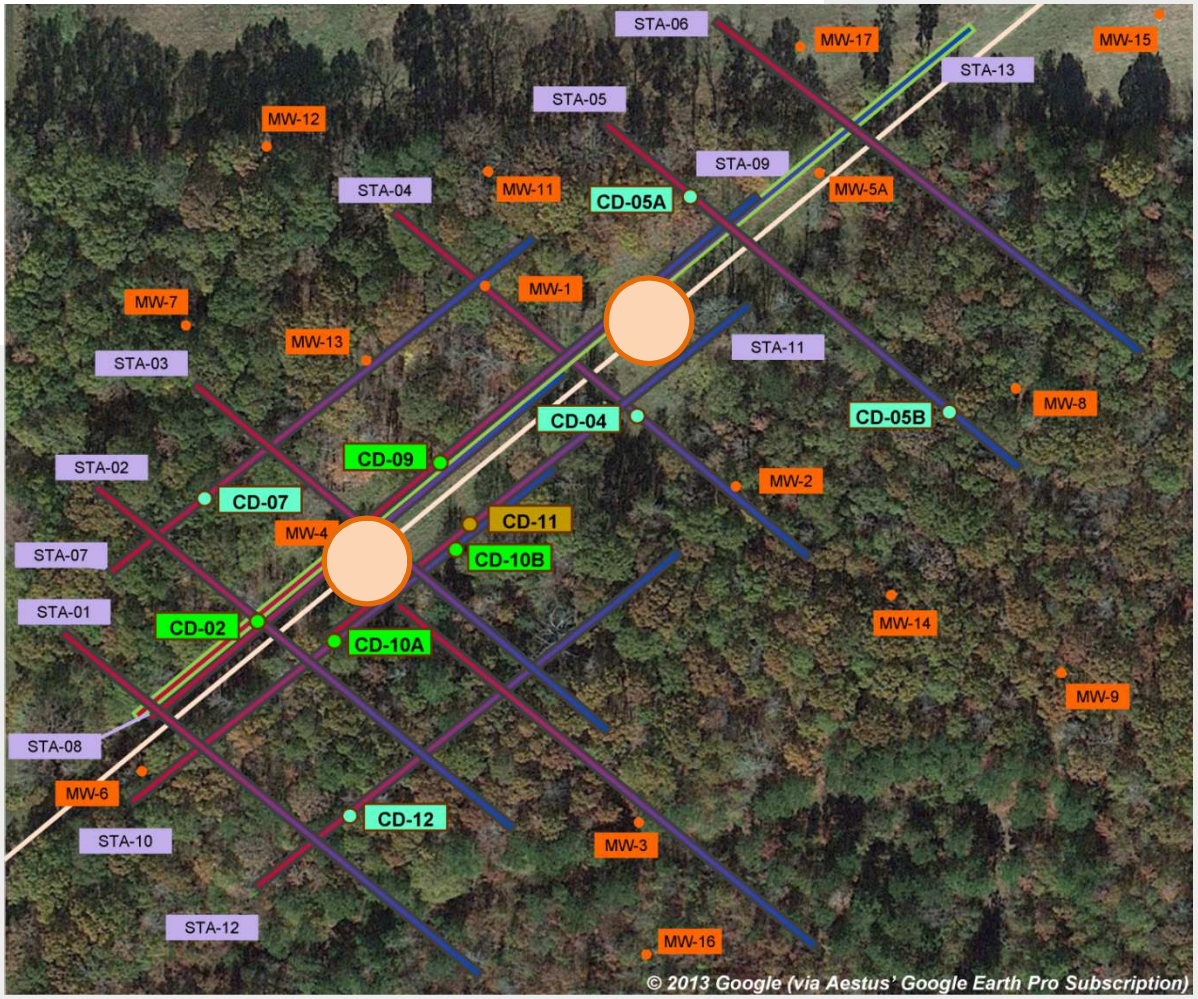
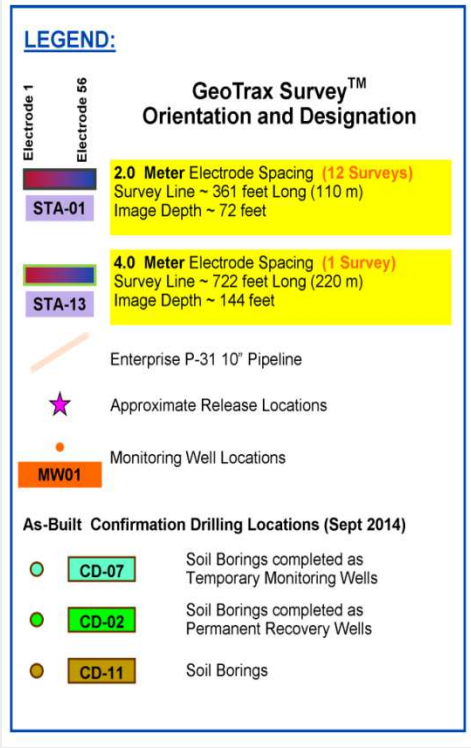
GeoTrax Survey™ Lines and Wells





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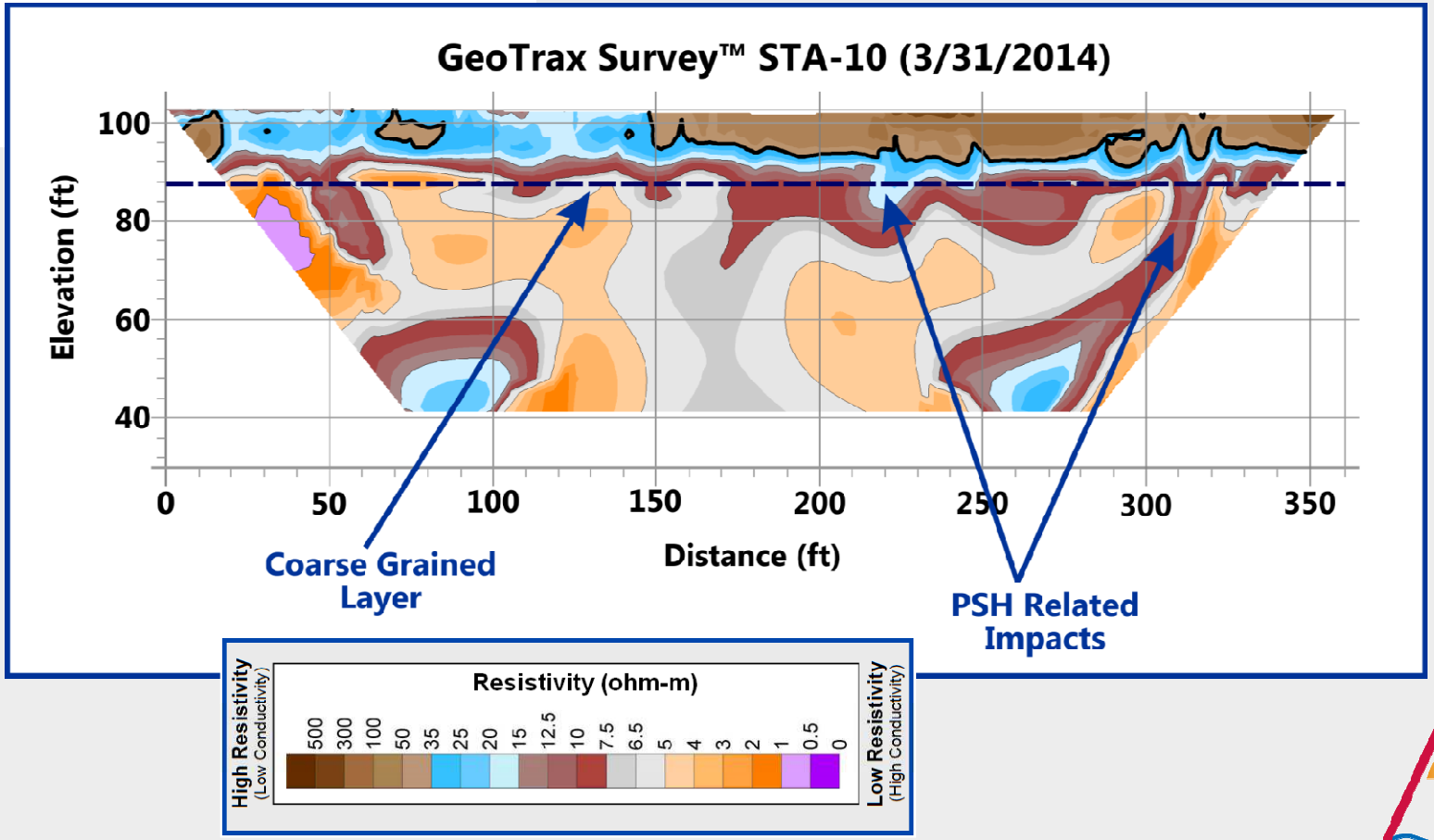
GeoTrax Surveys Highly Conductive

"Blob" anomalies crossing the coarse grained layer are targets for PSH related impacts



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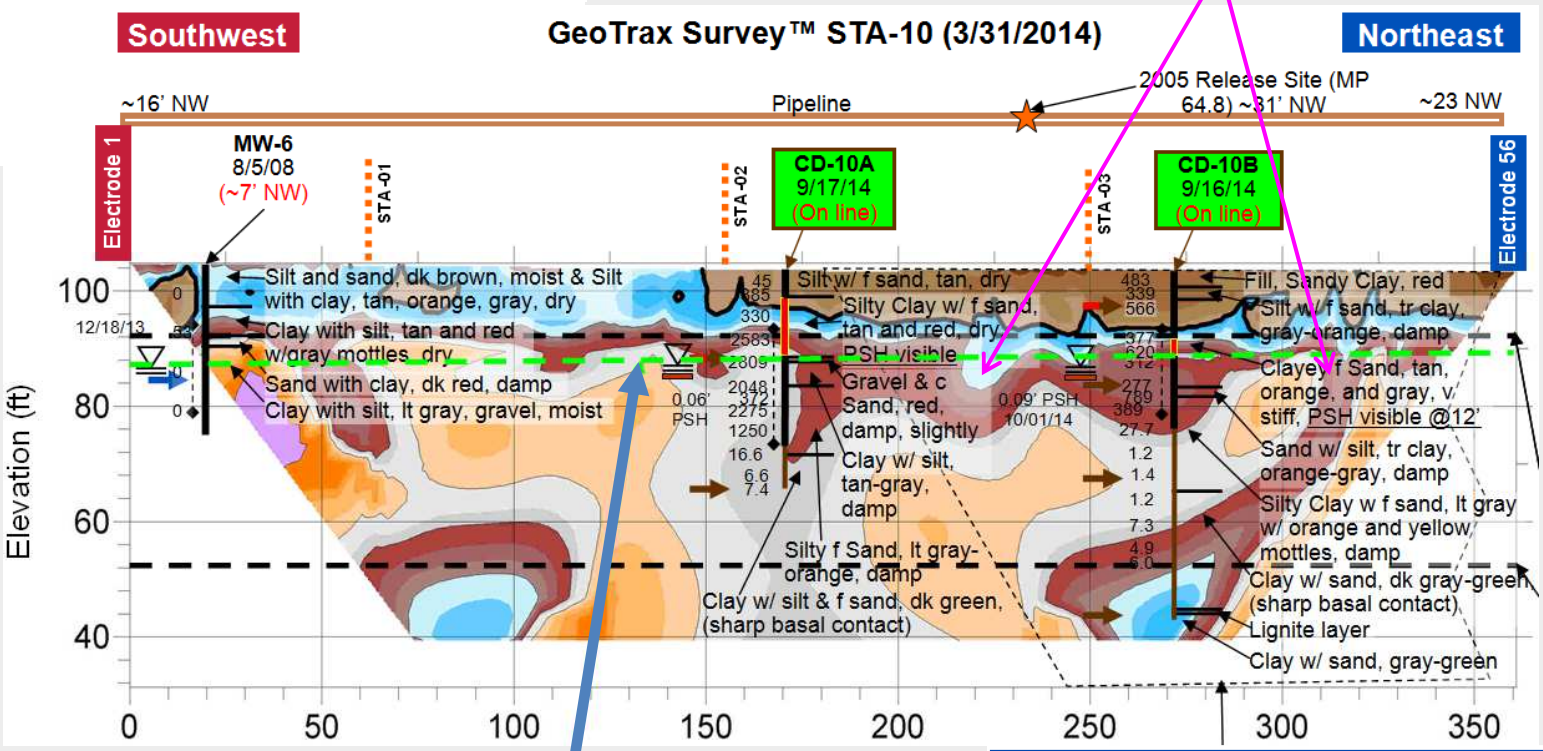
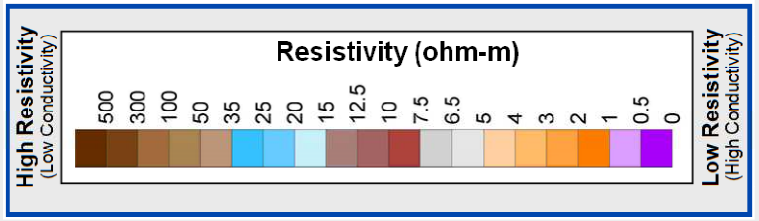
Data Integration Evaluating Targets

PSH related targets

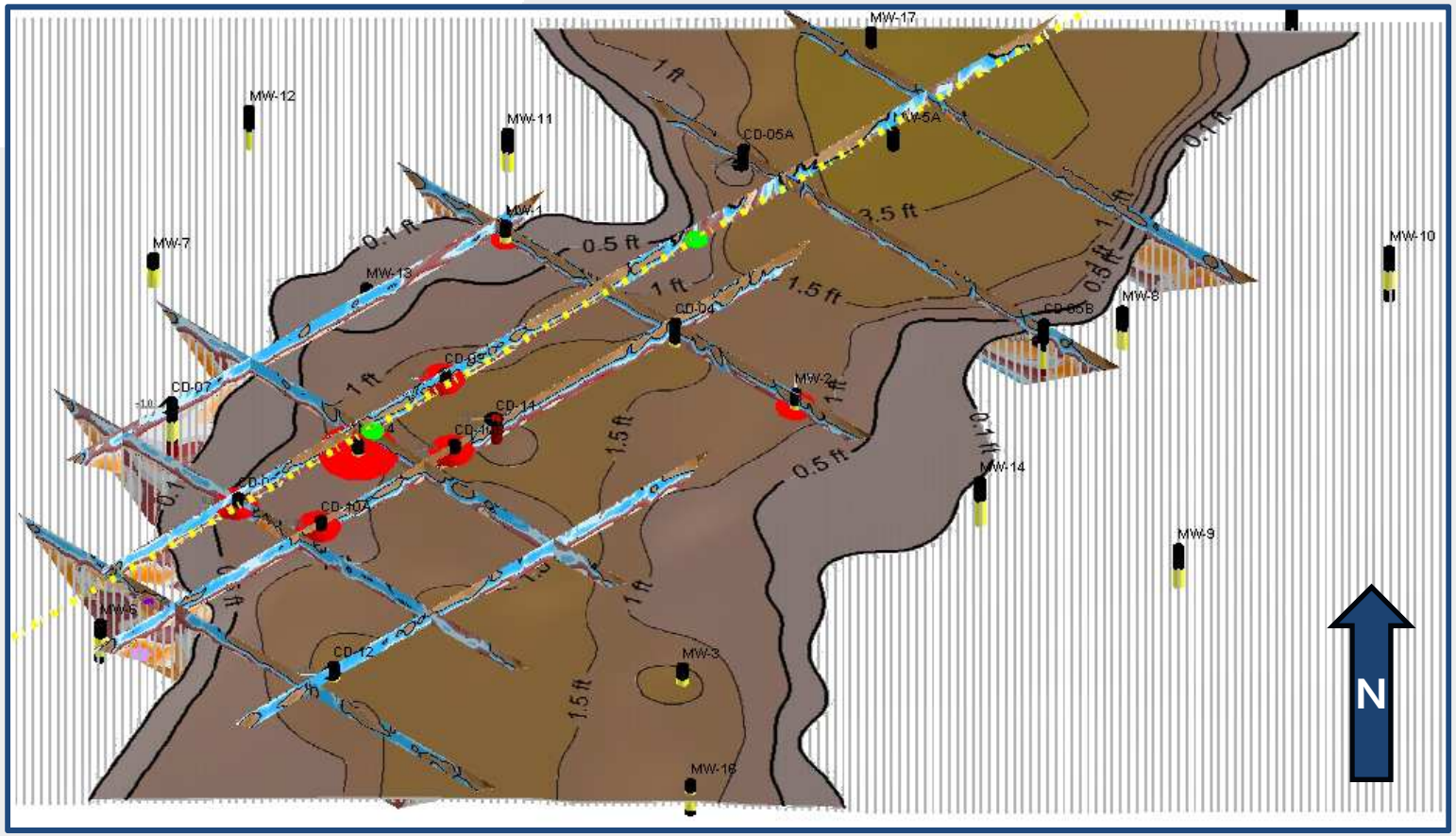


Coarse grained layer



Updated CSM (Graphical Explanation)

PSH related impacts bounded by lateral extent of coarse-grained layer



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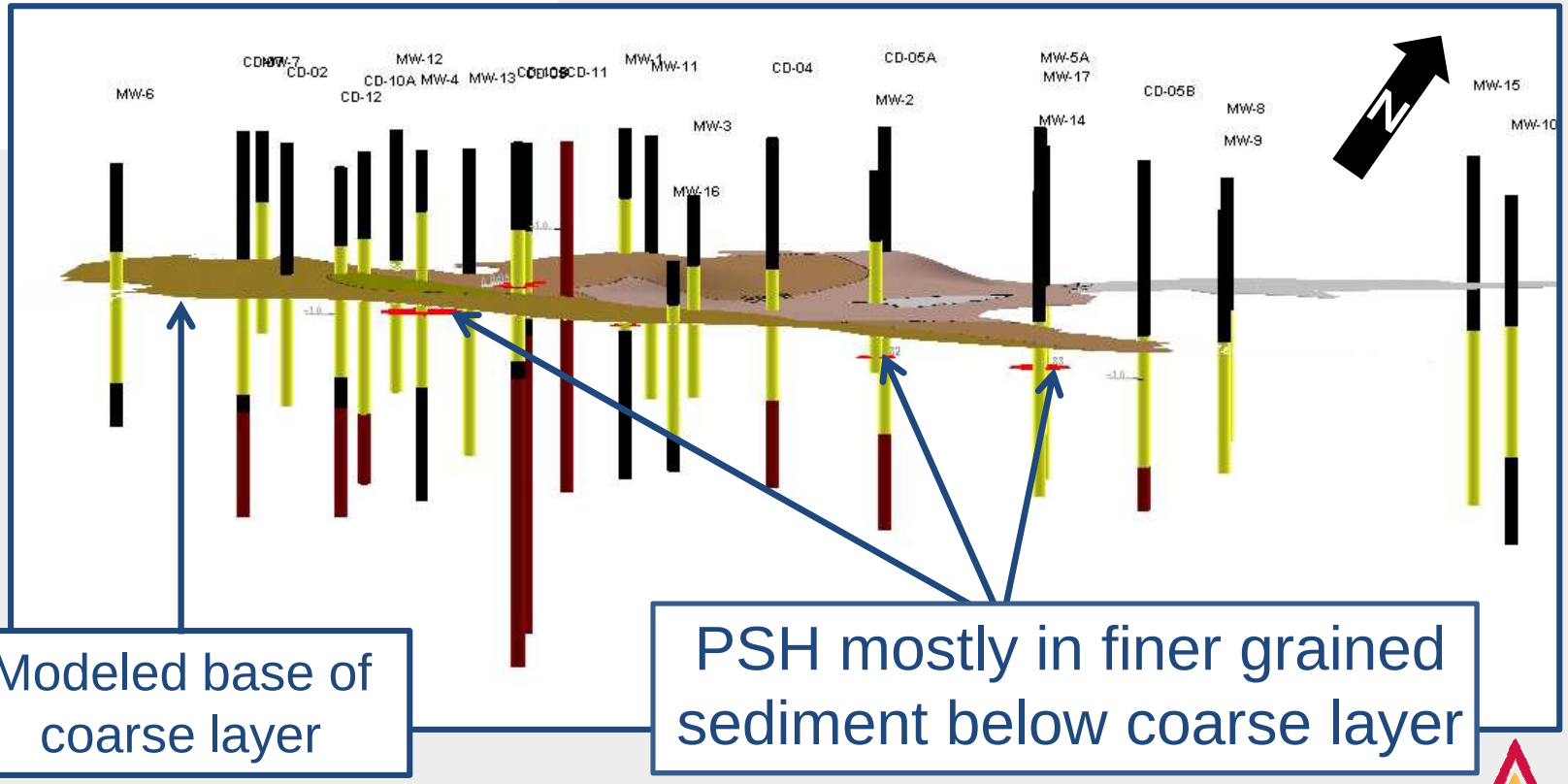

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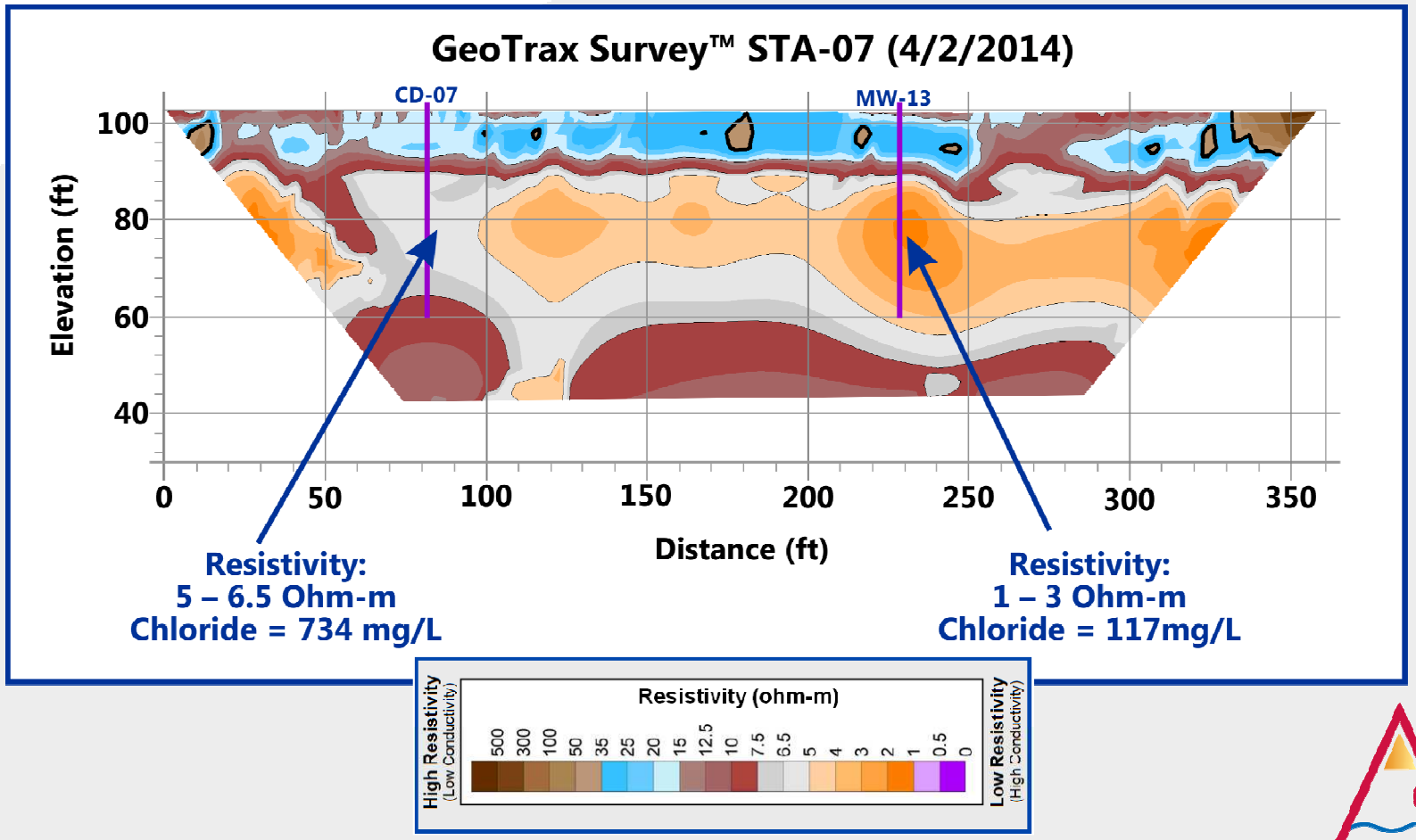
Low EC and Cl^- at Conductors

In general, low site resistivity w/ low chloride at impacted wells suggests widespread biological activity



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Biodegradation: multiple lines of evidence

- In general, low site ER (w/ low Cl^- at impacted wells) suggests widespread biological activity
- Coarse grained layer may act as natural horizontal "air sparge system" (positive ORP and DO values)
- Microbial activity confirmed with Microbial Insights Petroleum QuantArray

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Remedial Design Inputs

- "Blob" anomalies crossing the coarse grained layer are targets for PSH related impacts
- Multiple lines of evidence indicate PSH degradation likely ongoing
- Can material migrate easily?

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Key Factors for HRSC MNA

- Integrative Team looking for Technical Solution
  - Consultants
  - Regulators
  - Hydrogeophysicists
  - Microbiologists
- Microbial Patterns Highly Variable
- Iterative Process to Answer Questions

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Questions/Discussion

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