# MECHANISM FOR DETECTING NAPL IN GROUNDWATER WITH RESISTIVITY


**Todd Halihan**
**Oklahoma State University**

**Valina Sefa - Oklahoma State University**
**Tom Sale – Colorado State University**


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# CONTAMINATED SITE CHARACTERIZATION

- Generally site characterization is done through two methods :

  1. Point Sampling : Monitoring Wells **(surgery)**
  2. Indirect subsurface measurements using surface or borehole geophysical techniques **(scan)**

# How do you do that?

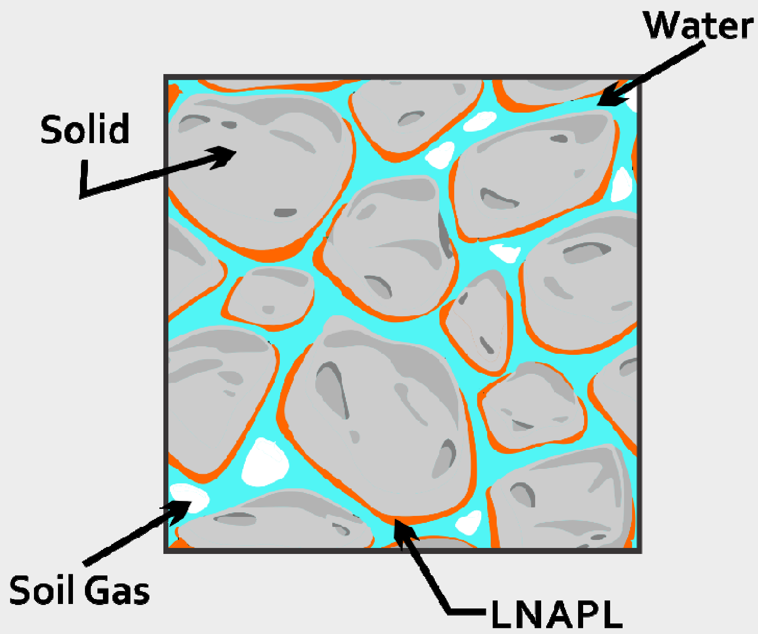
- Electric Resistivity Imaging (ERI) can be used in fresh water environments to detect petroleum at ppm concentrations (Halihan et al., 2005)

- The results can be extrapolated to interpret ERI results in field settings that detected NAPL in ppm quantities

- We don’t have data evaluating the mechanism for the detection of low concentrations of LNAPL in the subsurface

# MECHANISM

- Archie (1942) saw a simple relationship for the bulk resistivity of sand when all the pores are filled with water ($R_o$), resistivity of the pore fluid ($R_W$), and the formation resistivity factor ($F$)



Pore-Network (Newell,1995)

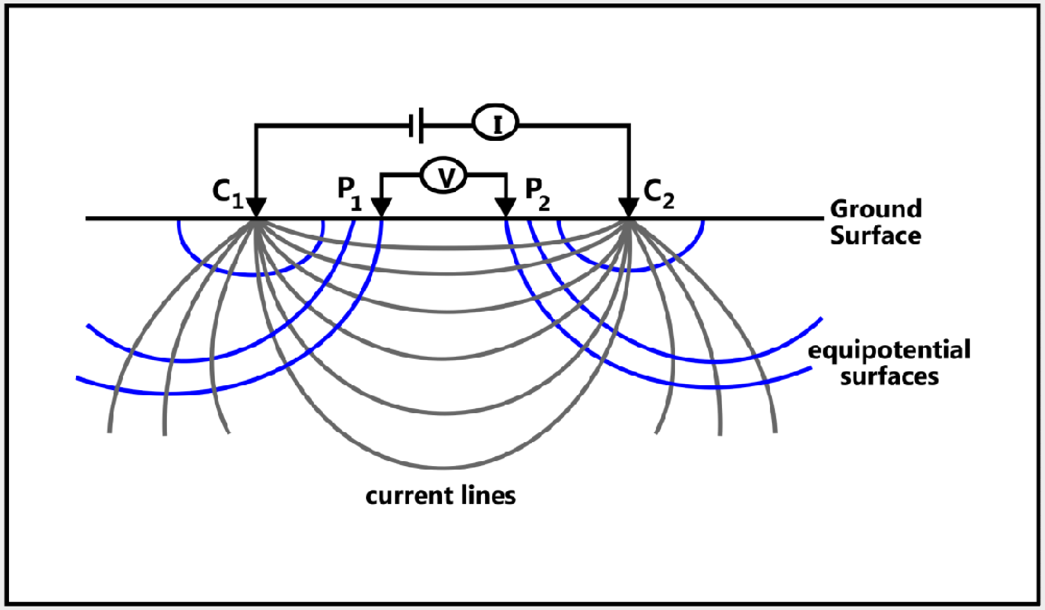
$$\rho = a\phi^{-m} s_w^{-n} \rho_w$$

*ρ [ohm-m] - bulk resistivity*
*$S_w$ - saturation percent*
*$\rho_w$ [Ohm-m] -resistivity of the pore fluid*
*$\phi$ - porosity*
*n - saturation exponent*
*m - cementation factor*

# MECHANISM

- Electric Resistivity imaging (ERI) is a geophysical technique which measures the difference in subsurface resistivity utilizing an array of electrodes.

- Models of apparent resistivity measurements provide estimates of true subsurface bulk resistivity



# HYPOTHESIS

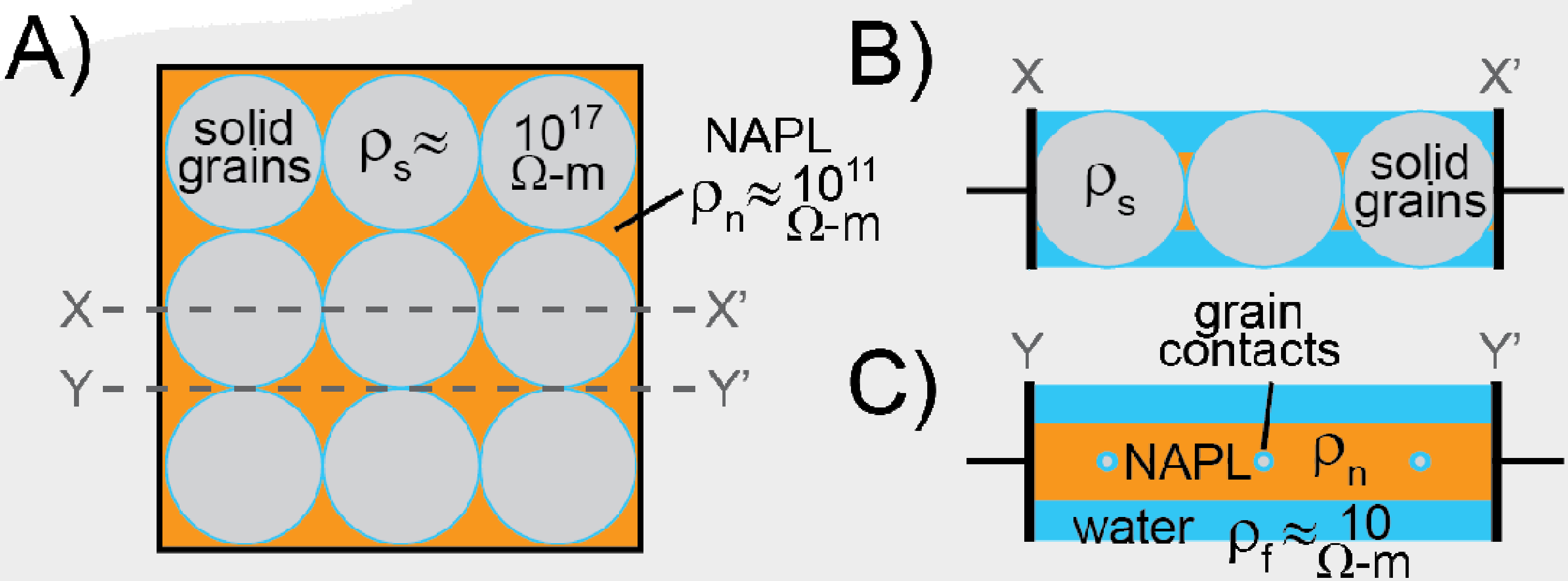
- How do you detect small quantities of NAPL in subsurface environments with electrical resistivity?

- The hypothesis is that small quantities of NAPL create a barrier that decrease the current flow resulting in an increase of bulk resistivity of the media

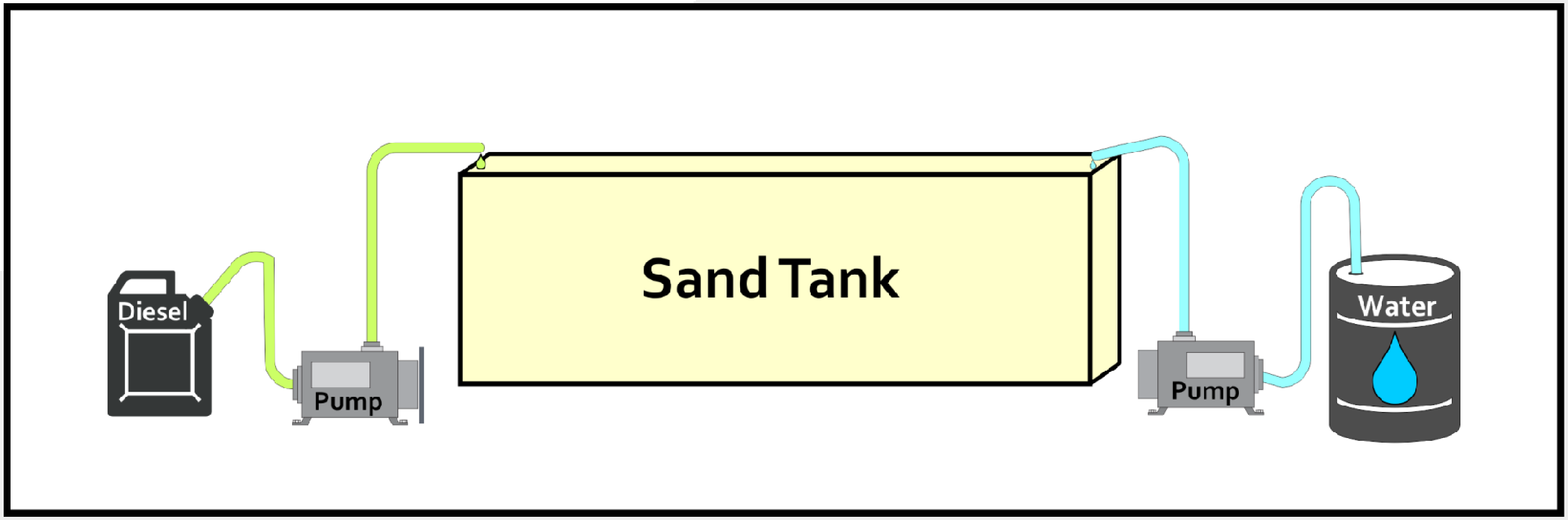
- This hypothesis was tested by:
    1. Developing a theoretical model
    2. Conducting a Laboratory tank experiment
    3. Building forward resistivity models

# NAPL Resistive Barrier Mechanism

NAPL creates an insulating layer with sufficient saturation which leads to the high resistivity signal without requiring significant mass

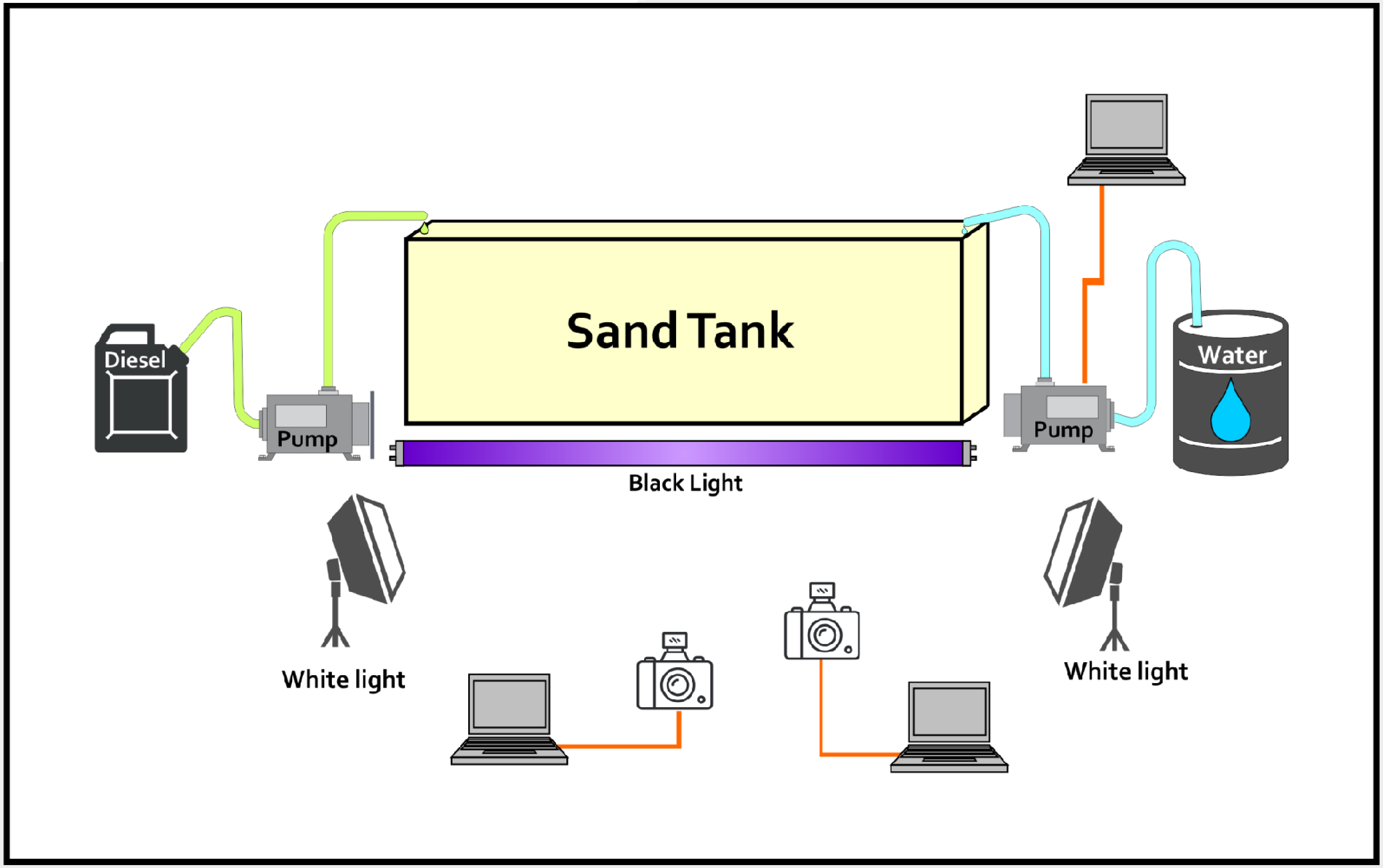


# EXPERIMENTAL SETUP

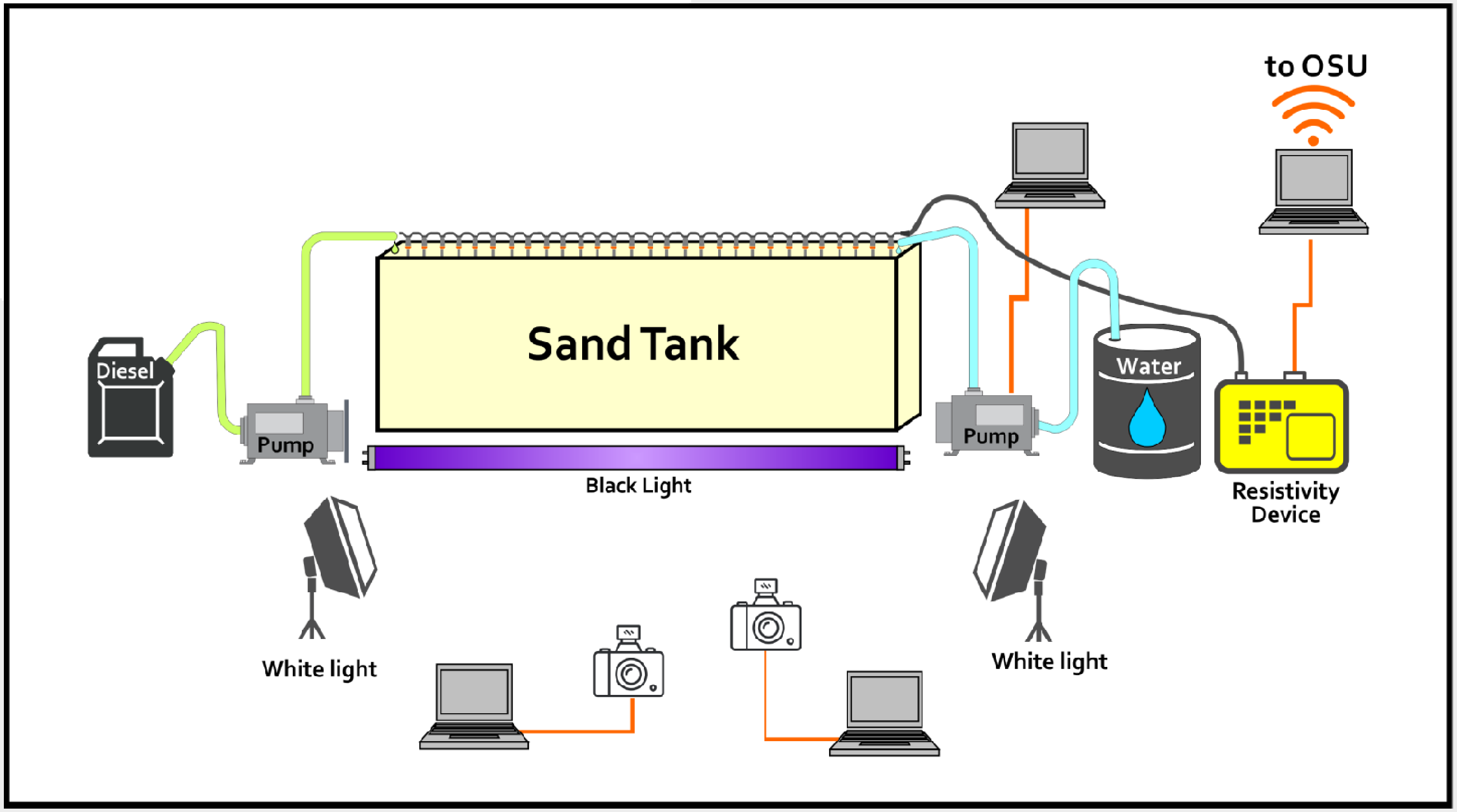



- Water level of steady 28 cm, followed by tidal movements after spill
- Diesel spilled at 1.9 ml/hr for 14 days a total of 642 ml
- The LNAPL (diesel) was treated with fluorescent dye to enhance visualization of NAPL behavior

# EXPERIMENTAL SETUP

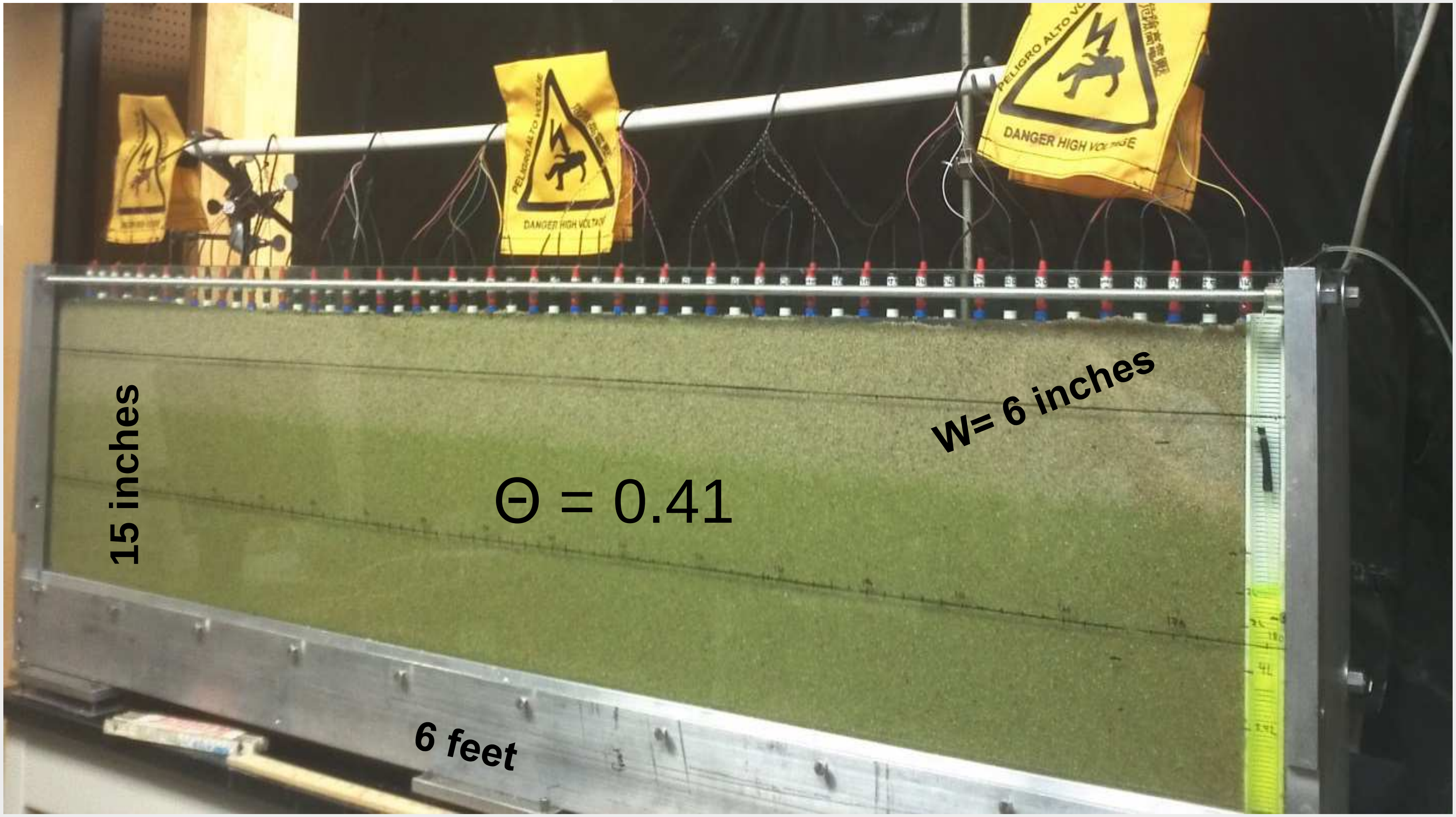


# EXPERIMENTAL SETUP




- 56 electrodes connected to AGI SuperSting
- Electrode spacing 3.175 cm apart, 1.6 cm resolution
- ERI line 1.75 m long, 35 cm depth of investigation

# EXPERIMENTAL TANK



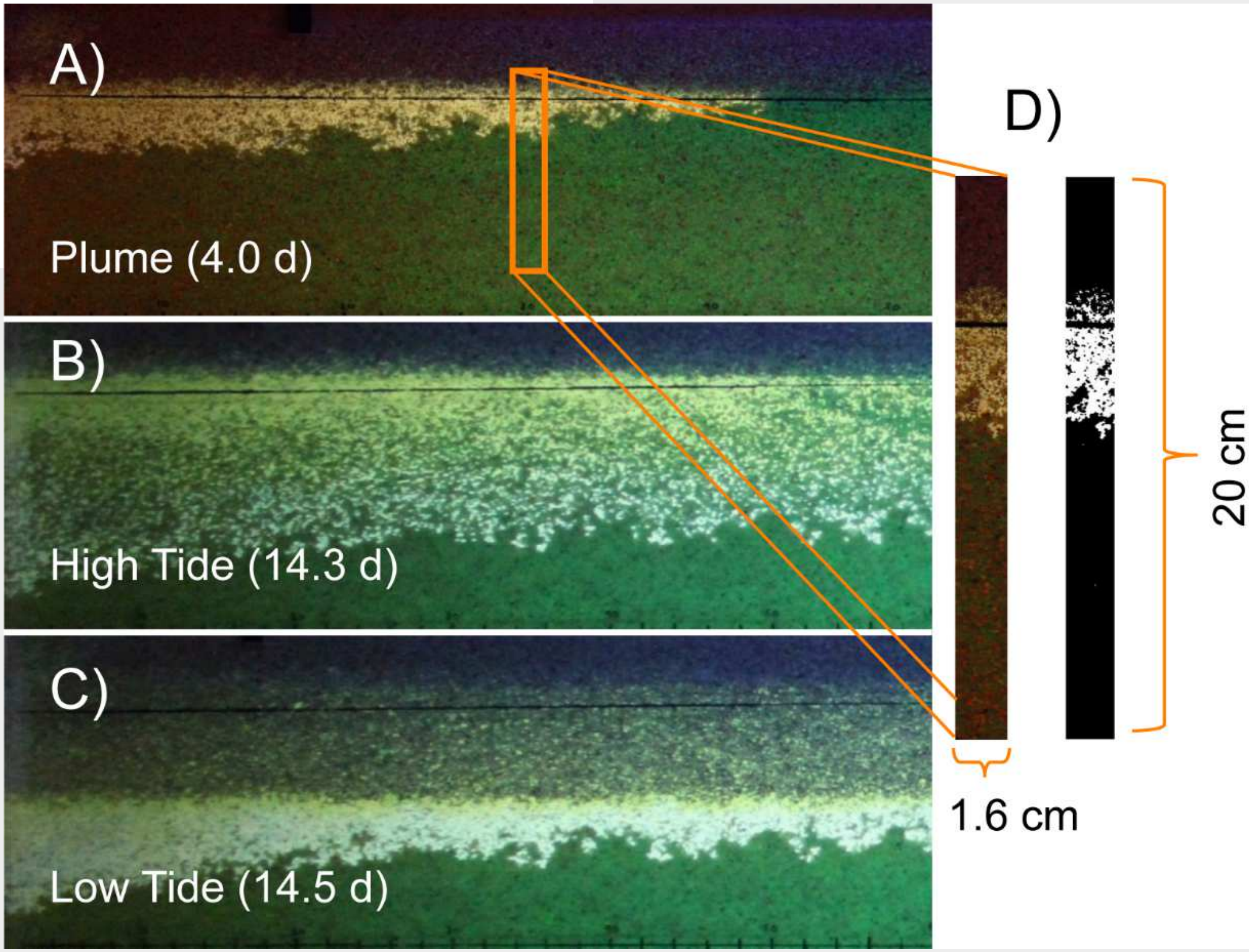
# Data Acquisition

17 days, 2 phases:

1. Steady water table (14 days)
   - Diesel was spilled continually
   - Data were collected daily

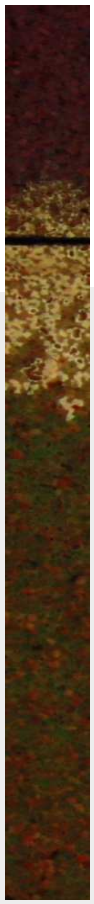
2. Tidal/smearing simulations (2 days)
   - Water table was cycled
   - Data were collected every 6 hours

# DIGITAL IMAGES OF DIESEL DISTRIBUTION



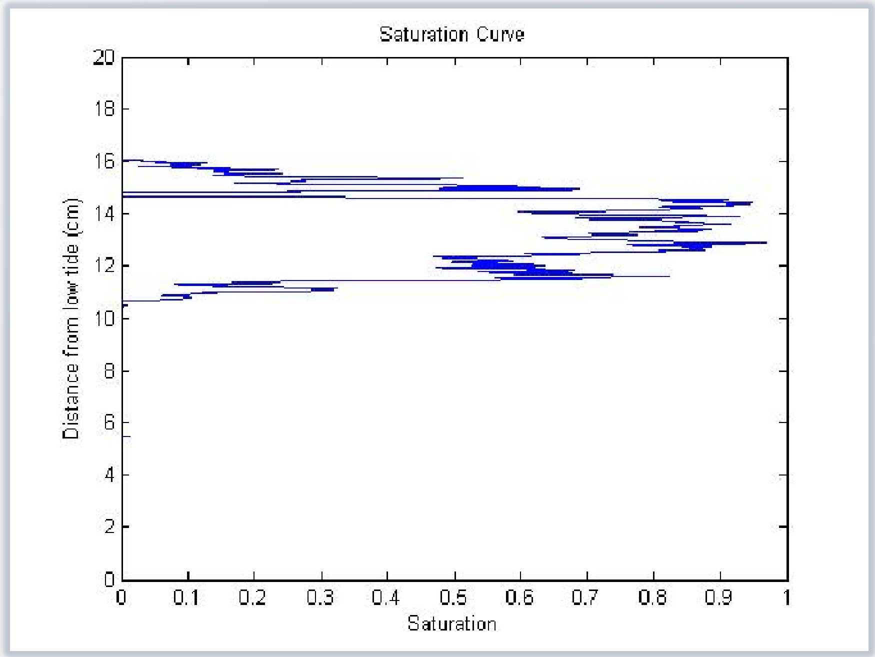
# Saturation Data Processing

a)



b)

c)



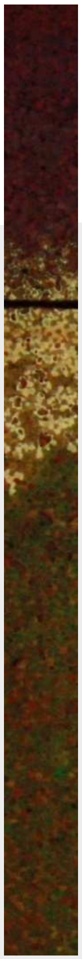

*a) Element volume*

*b) Element volume after MatLab*

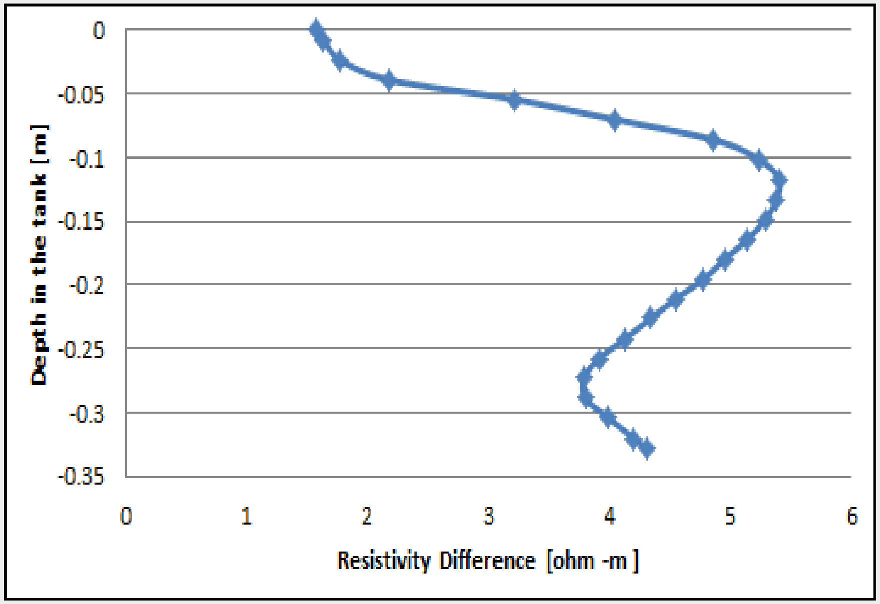
*c) Saturation curve produced by MatLab*

- Mass was calculated from saturation profiles

# Resistivity Data



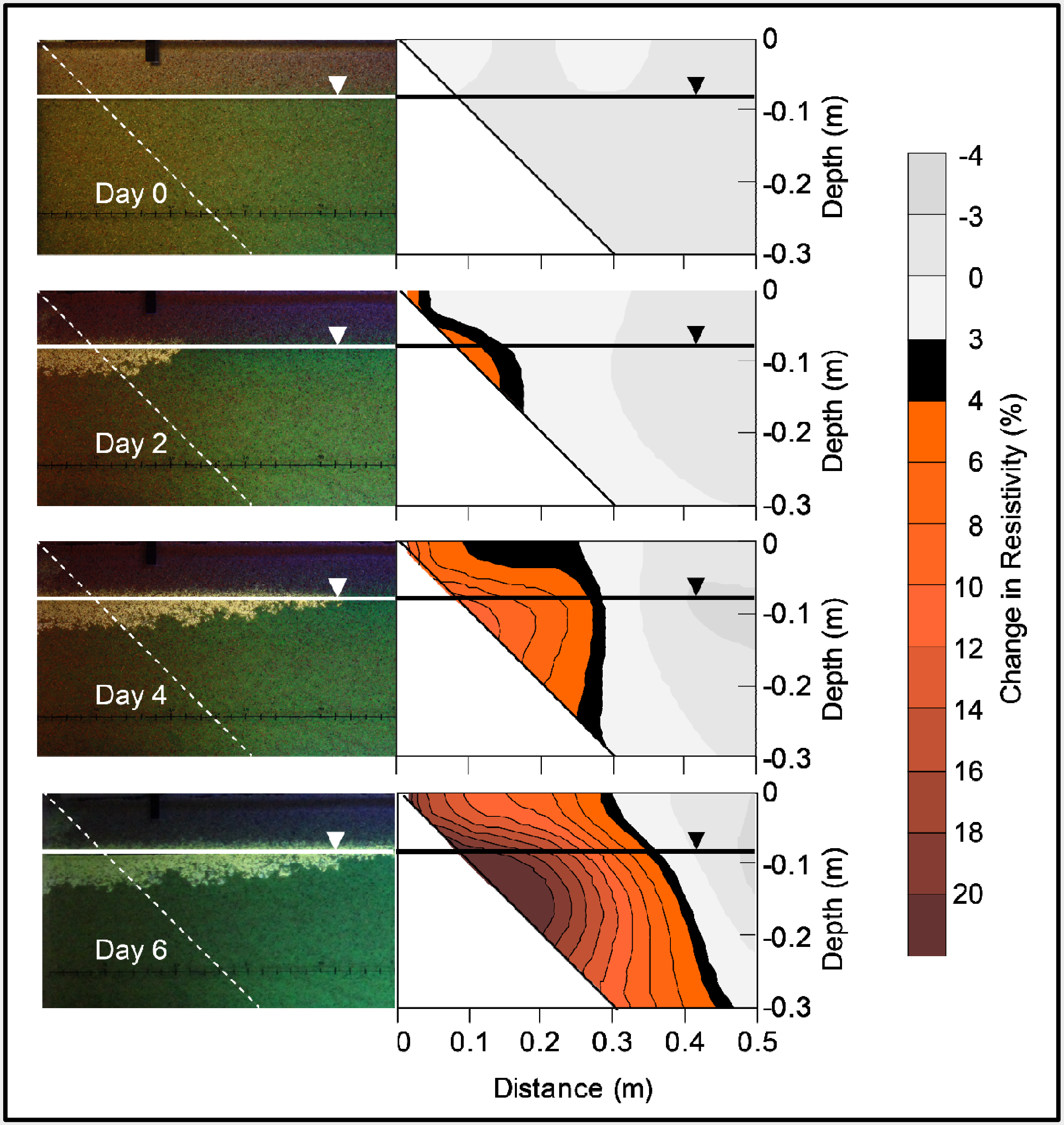
a)




b)

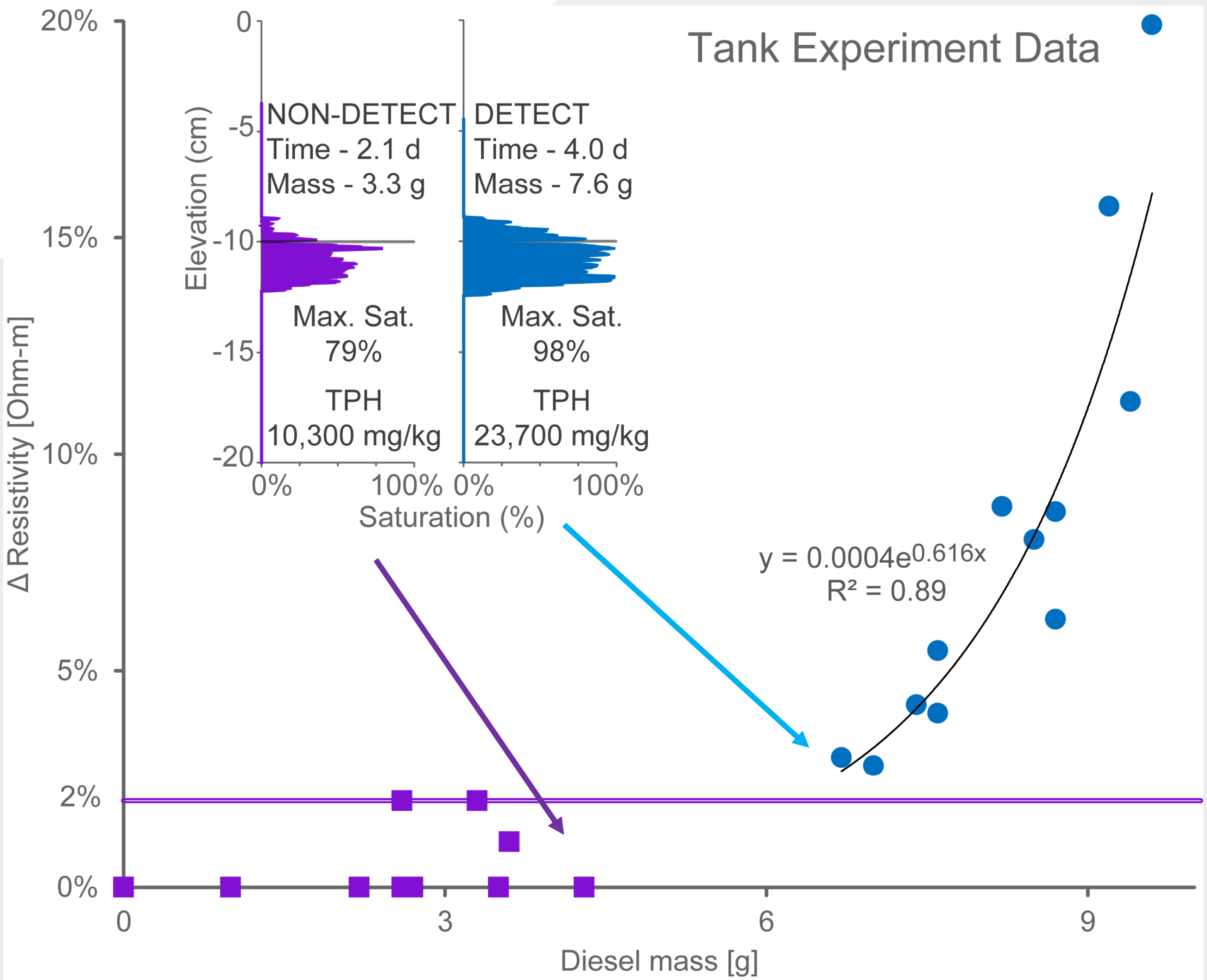
*a) Element volume*

*b) Change in resistivity with depth*



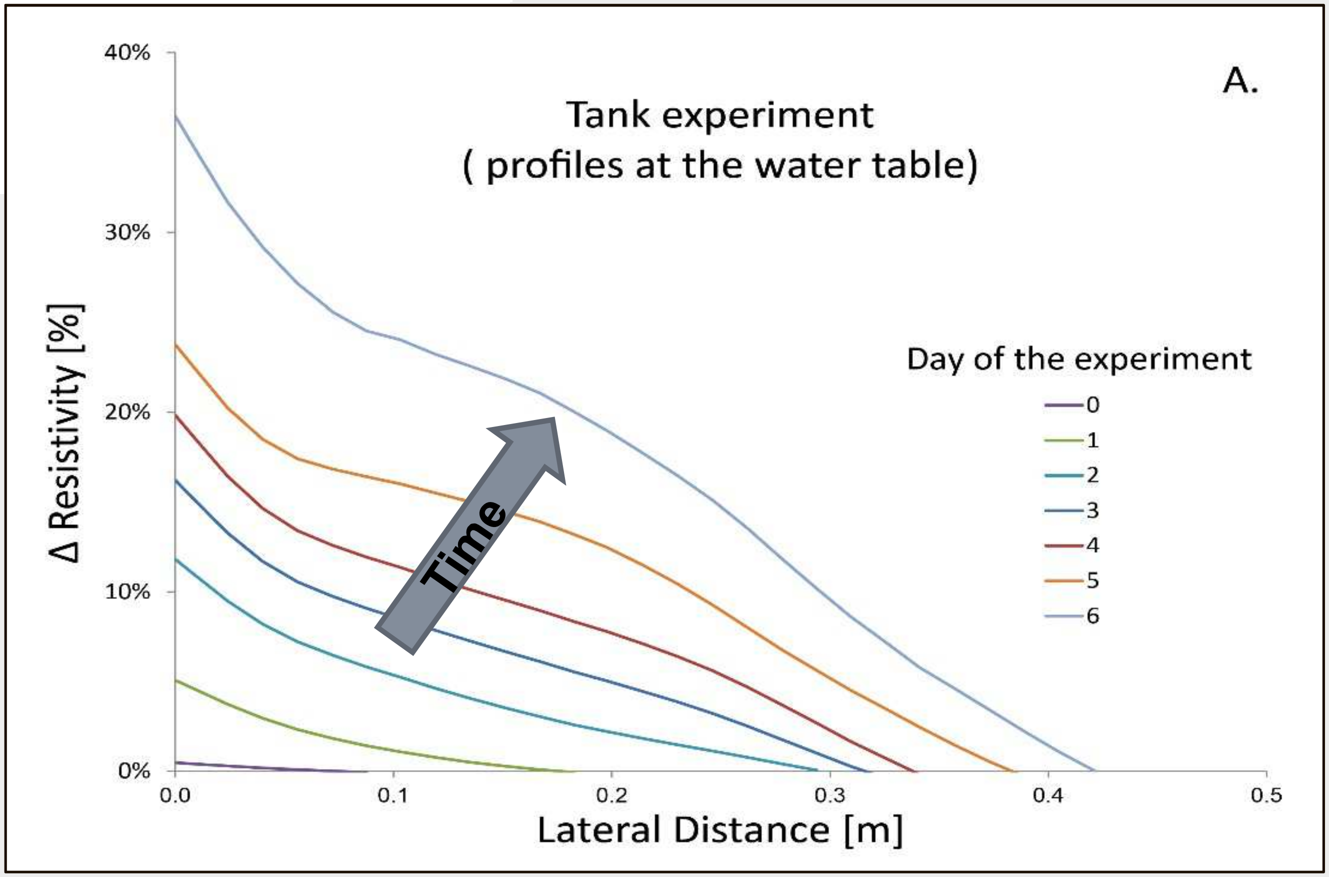
Day 0
Day 2
Day 4
Day 6
0
-0.1
-0.2
-0.3
Depth (m)
0
0.1
0.2
0.3
0.4
0.5
Distance (m)
-4
-3
0
3
4
6
8
10
12
14
16
18
20
Change in Resistivity (%)

# DATA CORRELATION



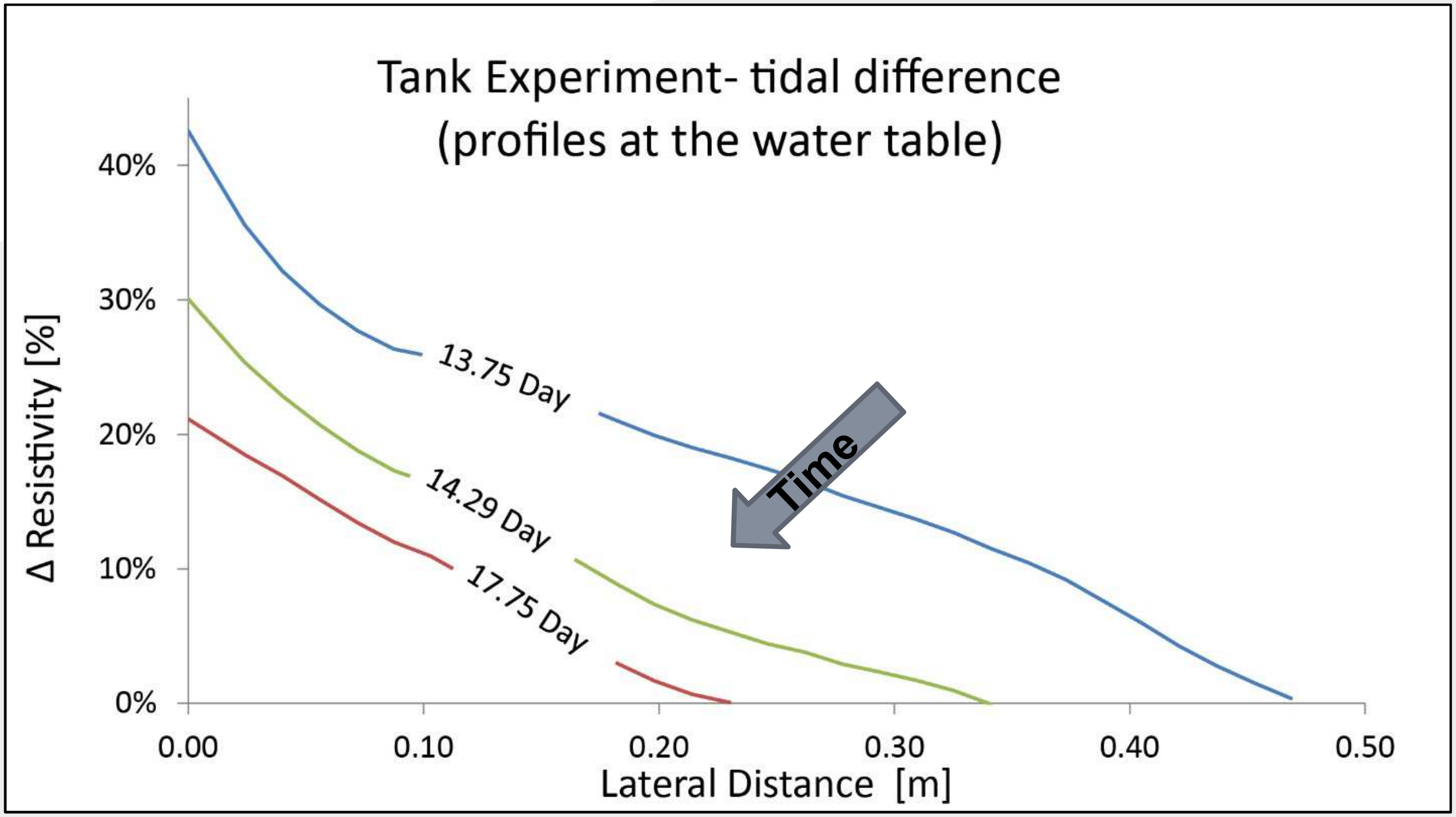
# Δ RESISTIVITY AT WATER TABLE

The ERI profiles reflect the NAPL migration observed optically



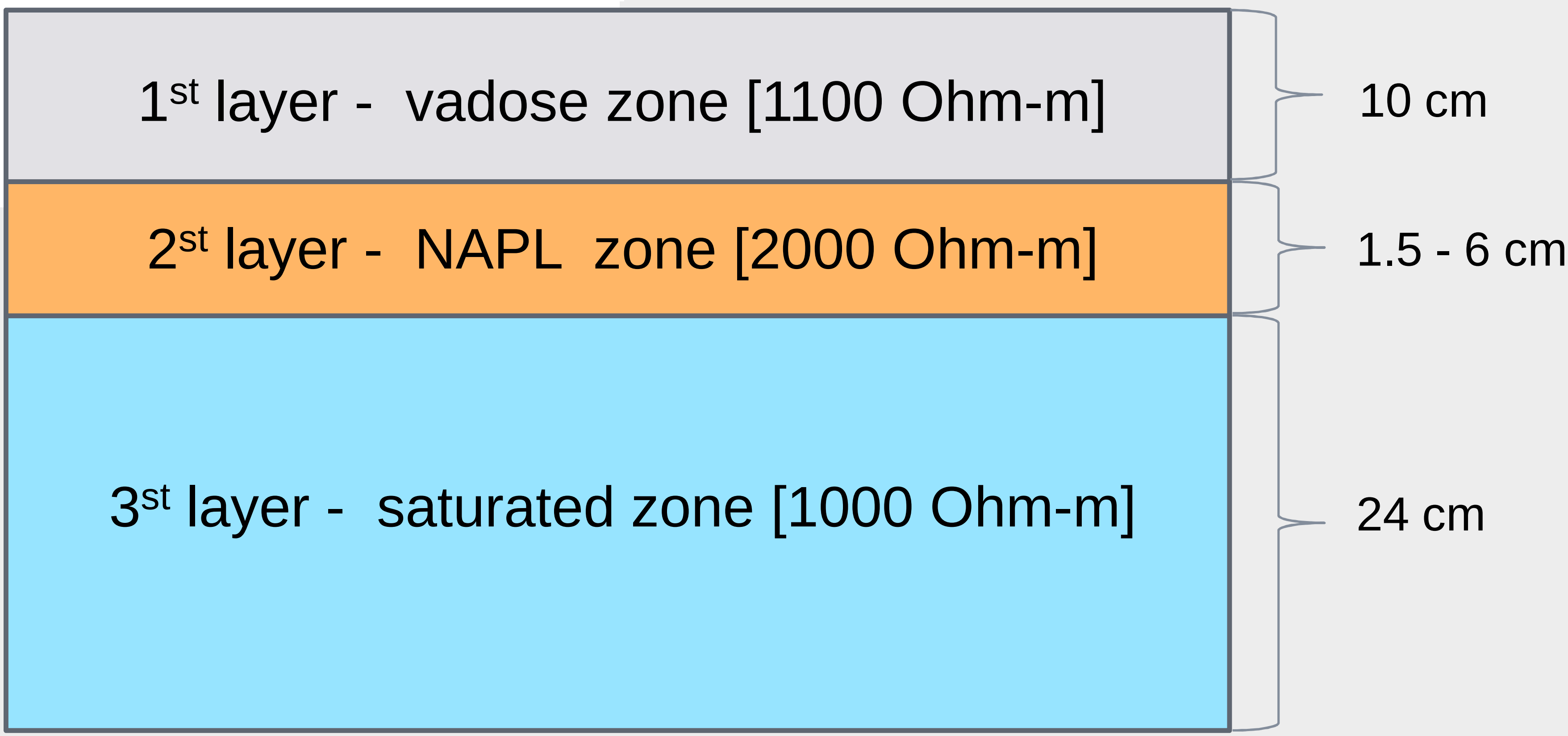

Noise determine at ~2%

# Δ RESISTIVITY AT WATER TABLE

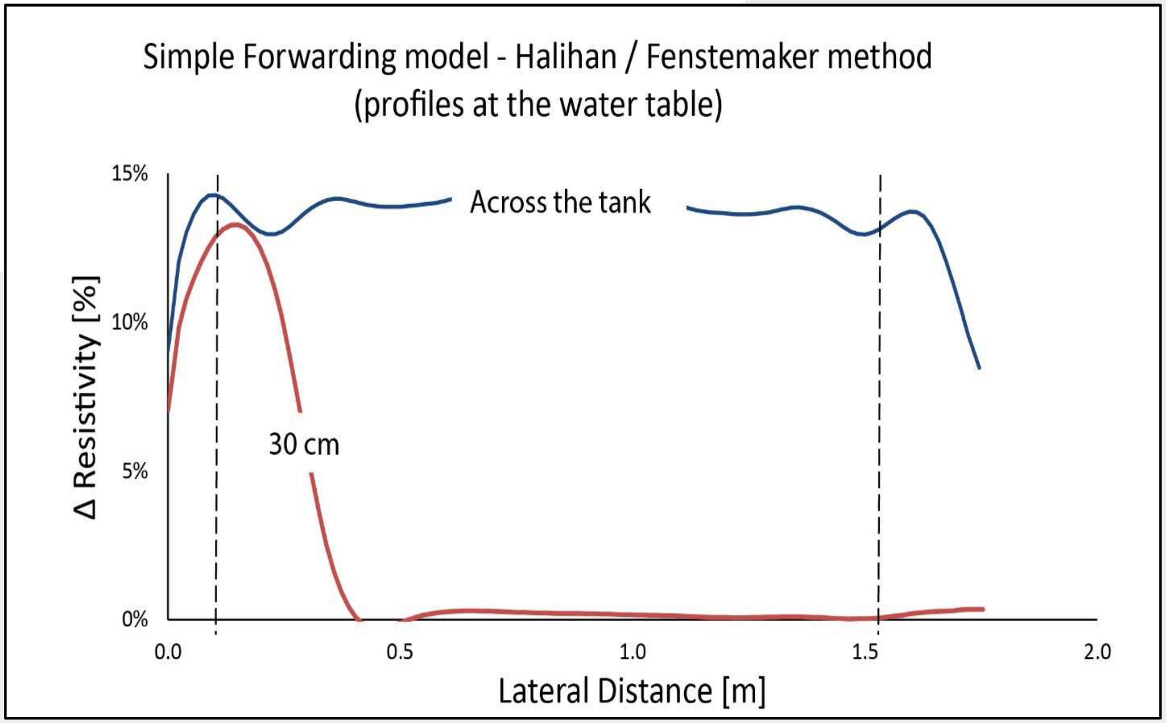



**Low Tide Profiles -** have Δ resistivity higher than 300%

# Resistivity Forward Model



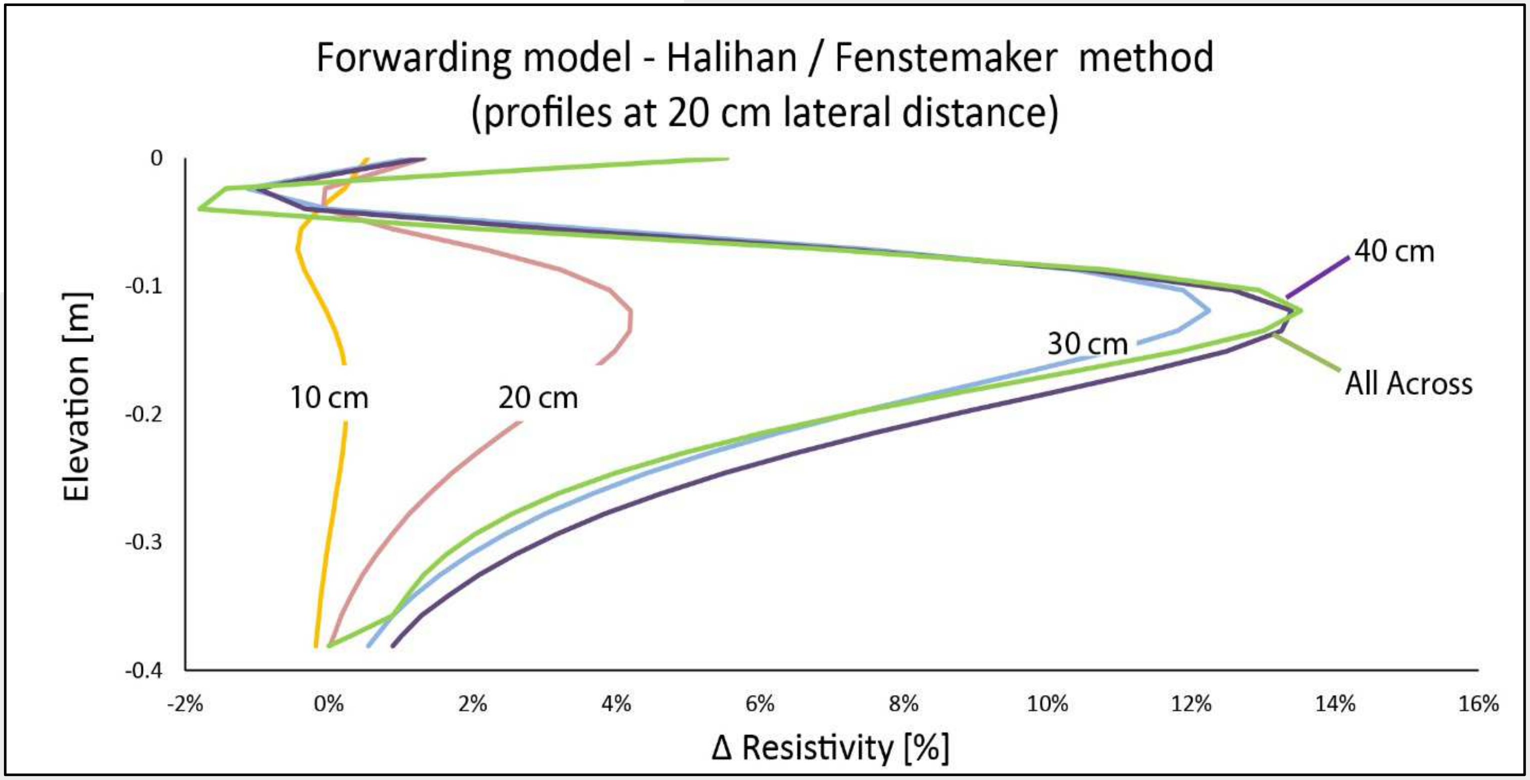
# SIMPLE FORWARD MODEL




- Single resistive layer 1.5 cm thick
- The dashed line represent the trapezoid boundaries.
- The model was able to predict the edge of the "plume"

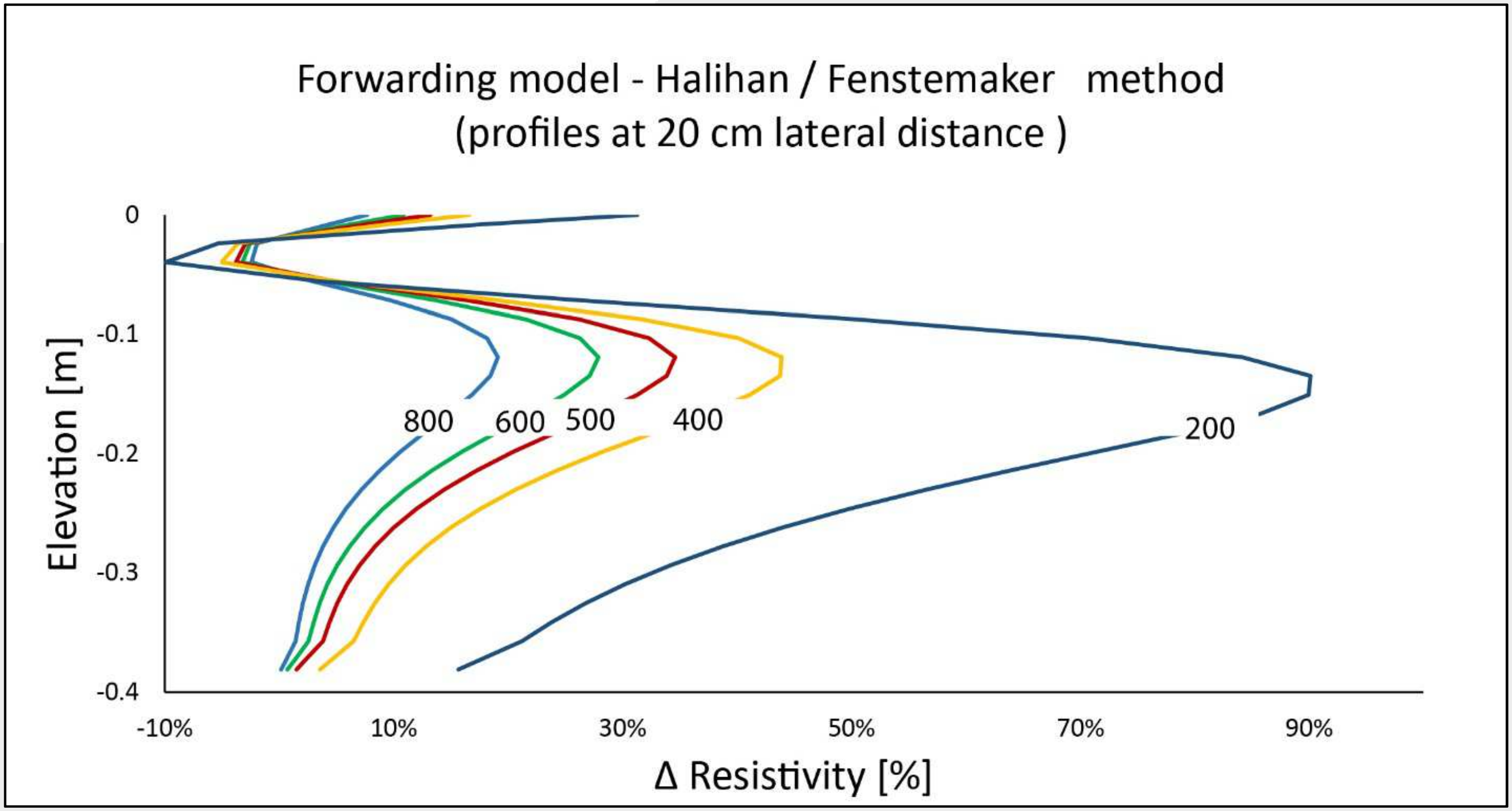
The tank boundary was a resistive boundary acting as a no flow boundary where the models are assuming an infinitely wide half space

# FORWARD MODEL–VARYING PLUME LENGTH




- 10 and 20 cm long plume generated Δ resistivity < 2% ( noise)
- Contrary to the tank experiment Δ resistivity did not increase with increase in the plume length

# Forward Model–Various Background Resistivity




Background resistivity [Ohm-m] reduced relative to the NAPL layer.

# CONCLUSIONS

- Geometric distribution of phase separate hydrocarbon controls the NAPL detection electrically, not bulk concentration
- Theory available that signal can be generated by part per million NAPL concentrations acting as electrical barrier
- Tank illustrates signal when NAPL blocks pores, signal reduction when smeared to break barrier
- Forward model illustrates signal can be stronger with larger electrical contrasts

# ACKNOWLEDGMENTS/QUESTIONS?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