Re-Evaluating Remedial Objectives and the Conceptual Site Model at a Diesel Impacted Fractured Bedrock Aquifer in the Alberta Foothills

RemTech 2015

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Waterline Resources Inc.

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Timeline

- ~1998: Diesel impacts identified in a domestic use aquifer
- 19 years of groundwater monitoring
- 50+ piezometers
- Remedial trials: MPE, SVE, pump and treat, nutrient amendment, etc.
- 2010 to Present: Pump and treat remediation system operation and refinement, source characterization

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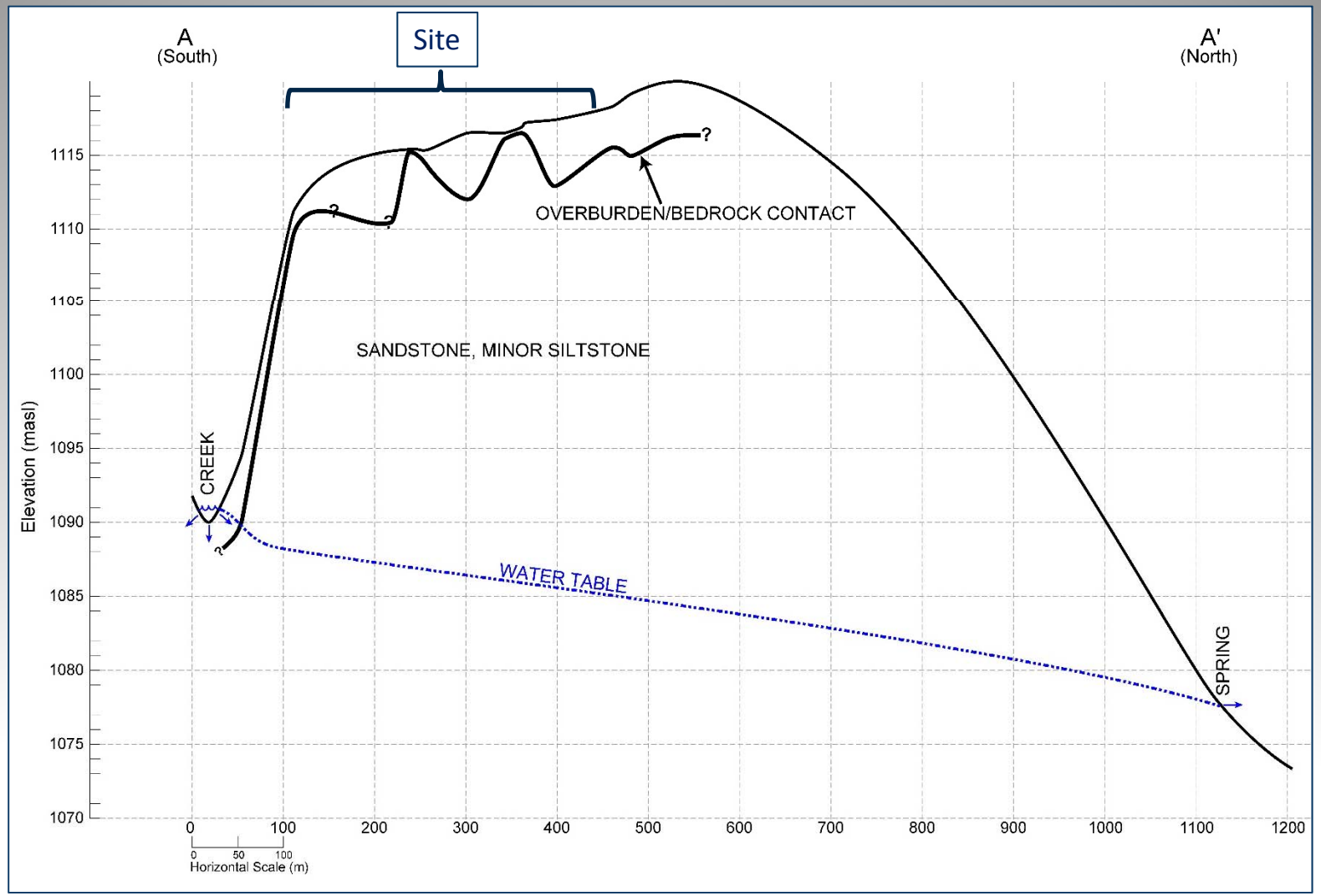
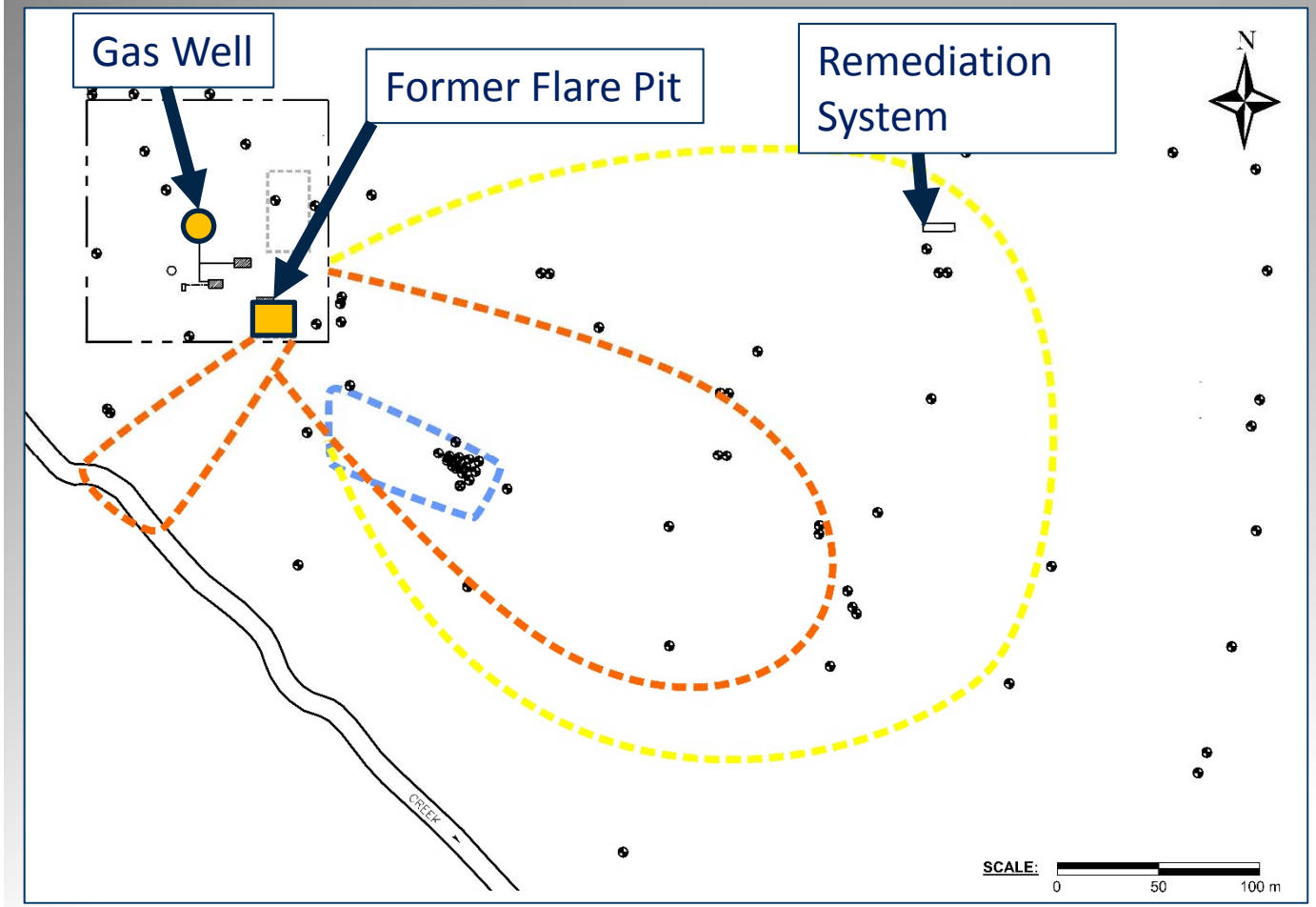
Site Setting



Potential Sources: Drilling Event



Orange: Heavily Contaminated (Anecdotal) (1982)
Yellow: Lightly Contaminated (Anecdotal) (1982)
Blue: Trees Cleared (1985)

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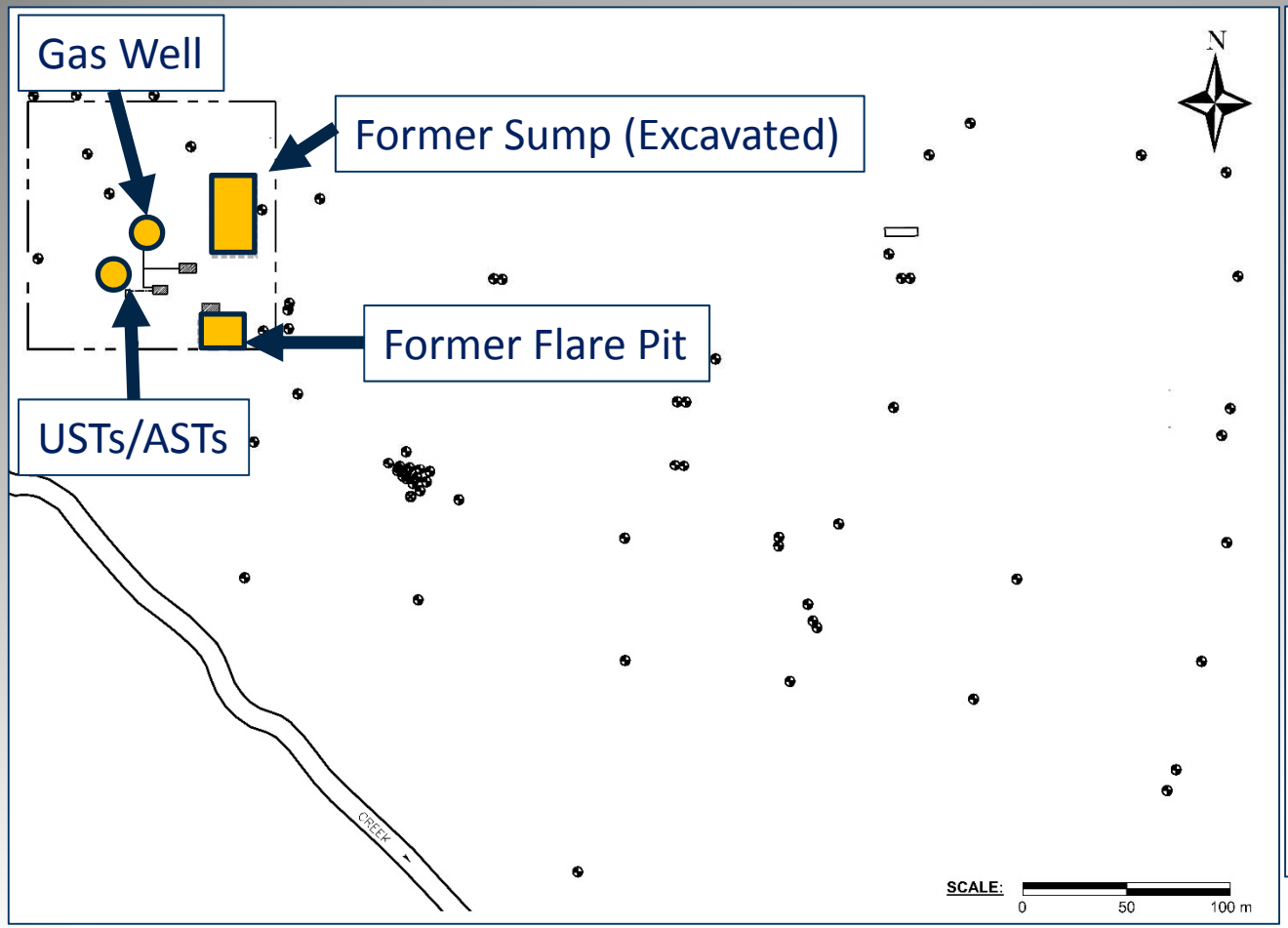
Potential Sources: Other



Estimated Hydrocarbon Volumes

Drilling Events
First Event: 157 m^3
Second Event: 298 m^3
Total: 455 m^3

Sump:
Portion of Drilling Events

Former Flare Pit:
Likely Low Volumes

USTs/ASTs: ????

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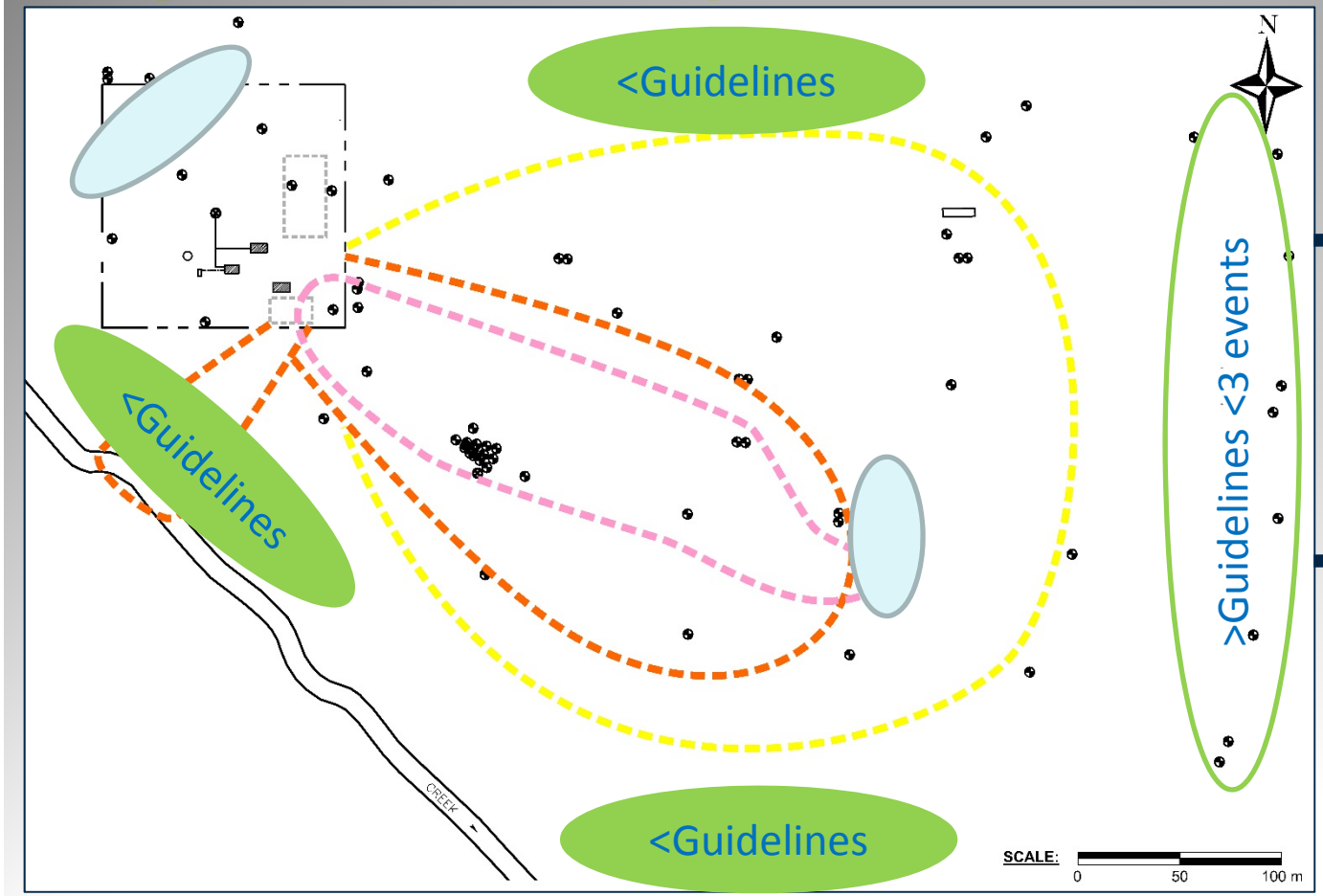
Hydrocarbon Impact Extent in Groundwater



Orange: Heavily Contaminated (Anecdotal)
Yellow: Lightly Contaminated (Anecdotal)
Pink: Interpreted LNAPL Extent

Dissolved Hydrocarbons

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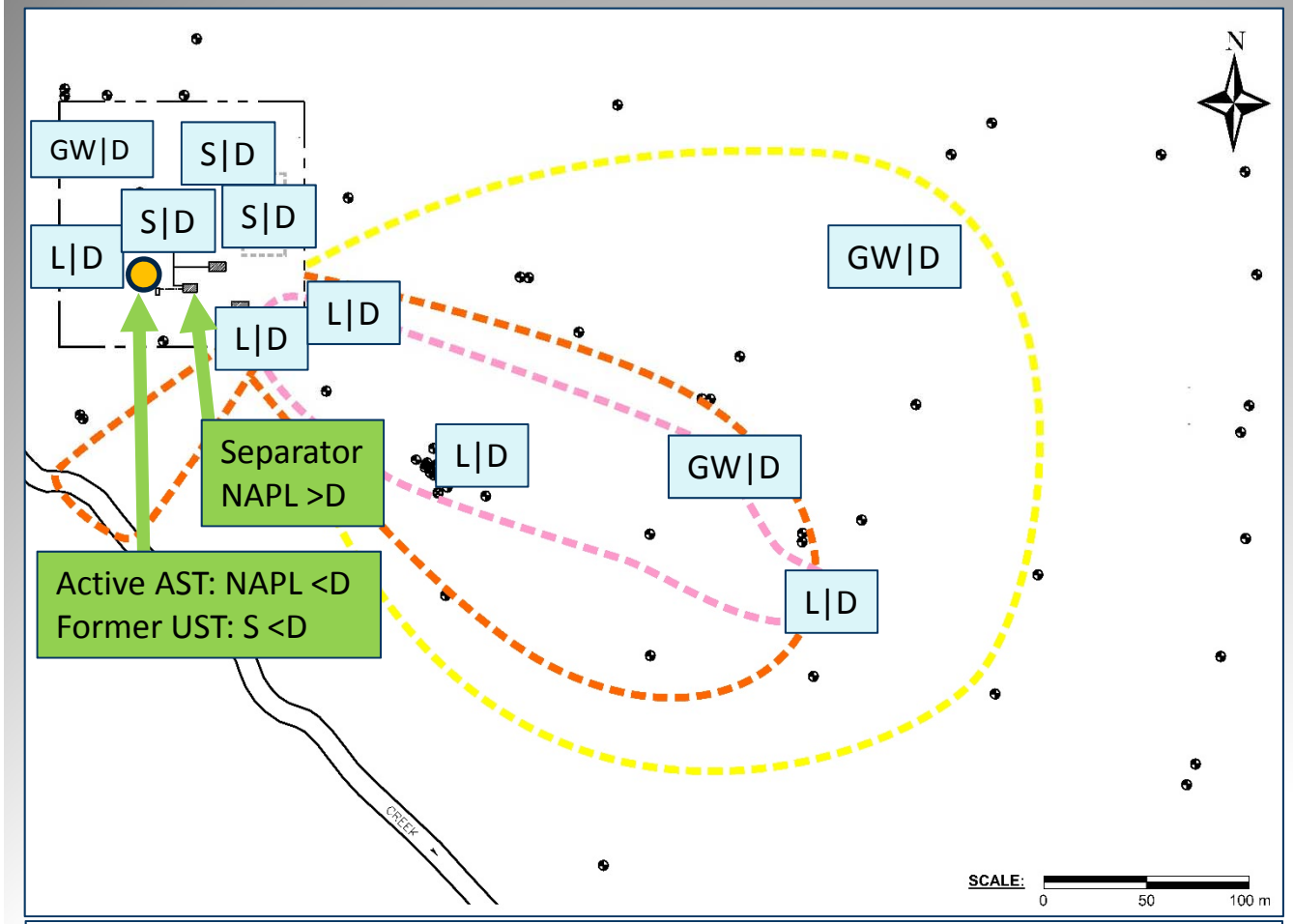
Hydrocarbon Characterization



- Generally diesel impacts identified (D), aside from ASTs/USTs and Separator

L: LNAPL, GW: Groundwater, S: Soil or rock

L|D: Diesel type hydrocarbon

< or > D: Lighter or heavier than diesel type hydrocarbons

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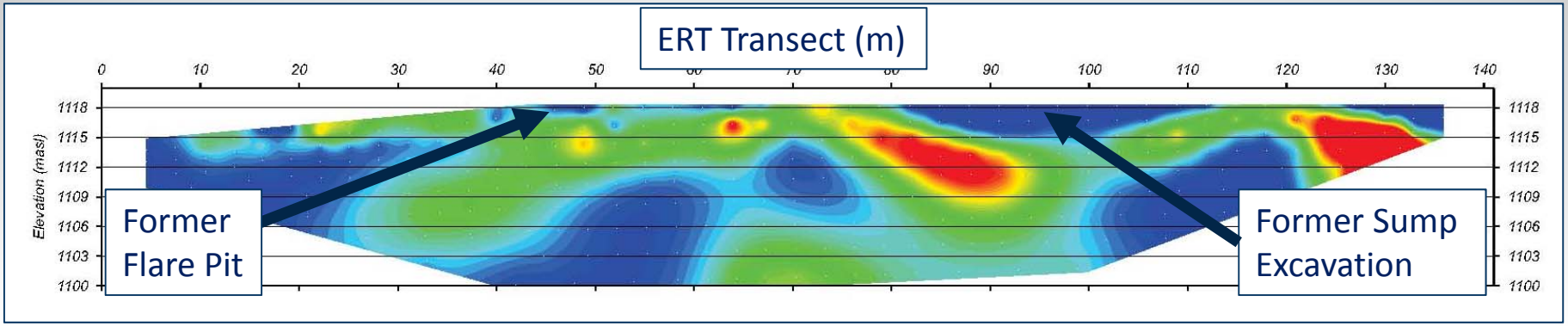
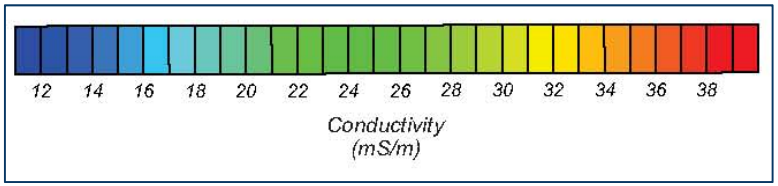
Salinity and Metal Source Indicators

- Phase I indicated that barium and salinity parameters would be of concern based on the drilling materials that were used
- Low chloride and barium concentrations in groundwater at the lease (good for the environment but not good for source characterization!)





Credit: AKS Geoscience

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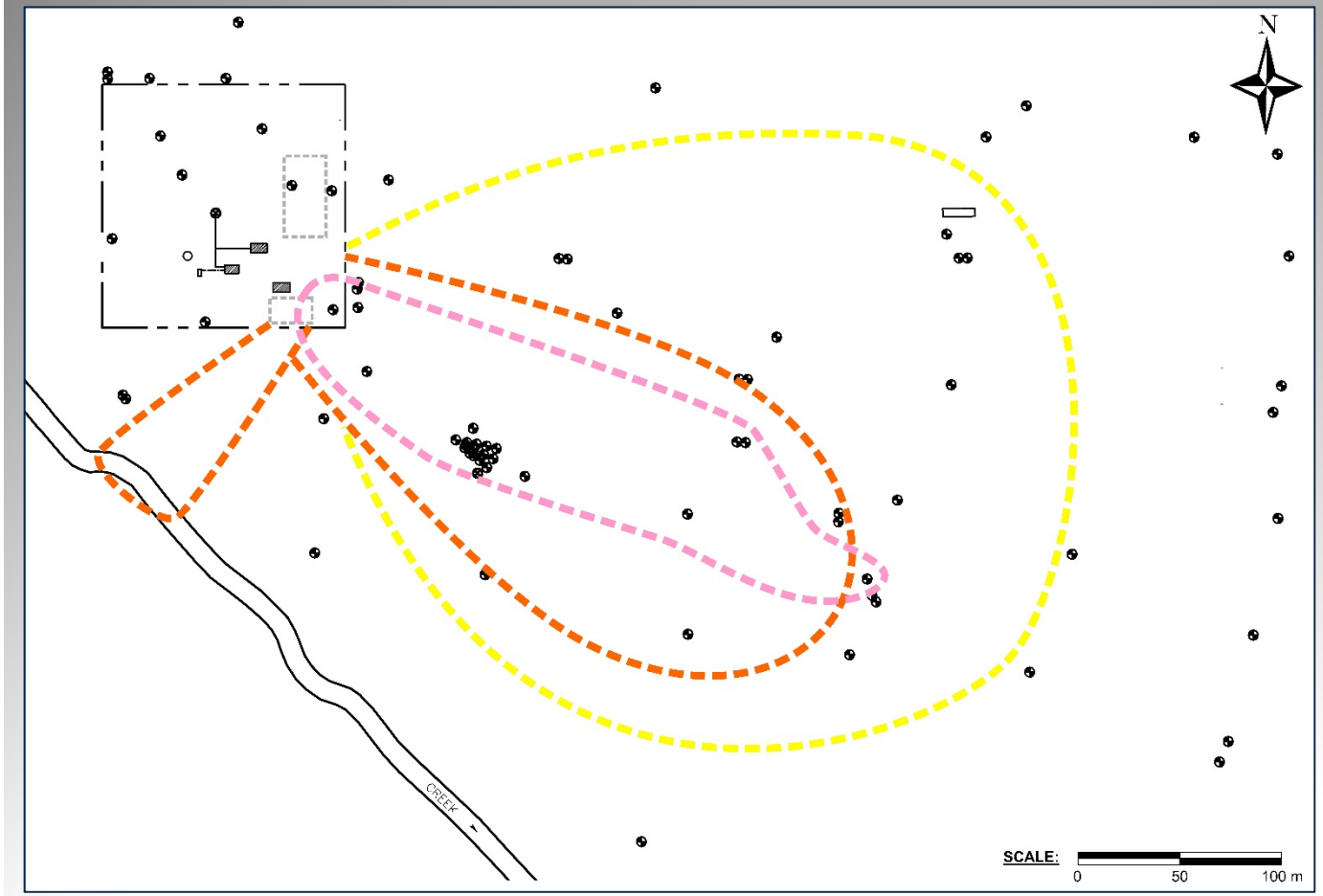
Sources: Summary



- LNAPL plume
- Limited dissolved hydrocarbon impacts
- Diesel

Orange: Heavily Contaminated (Anecdotal)
Yellow: Lightly Contaminated (Anecdotal)
Pink: Interpreted LNAPL Extent

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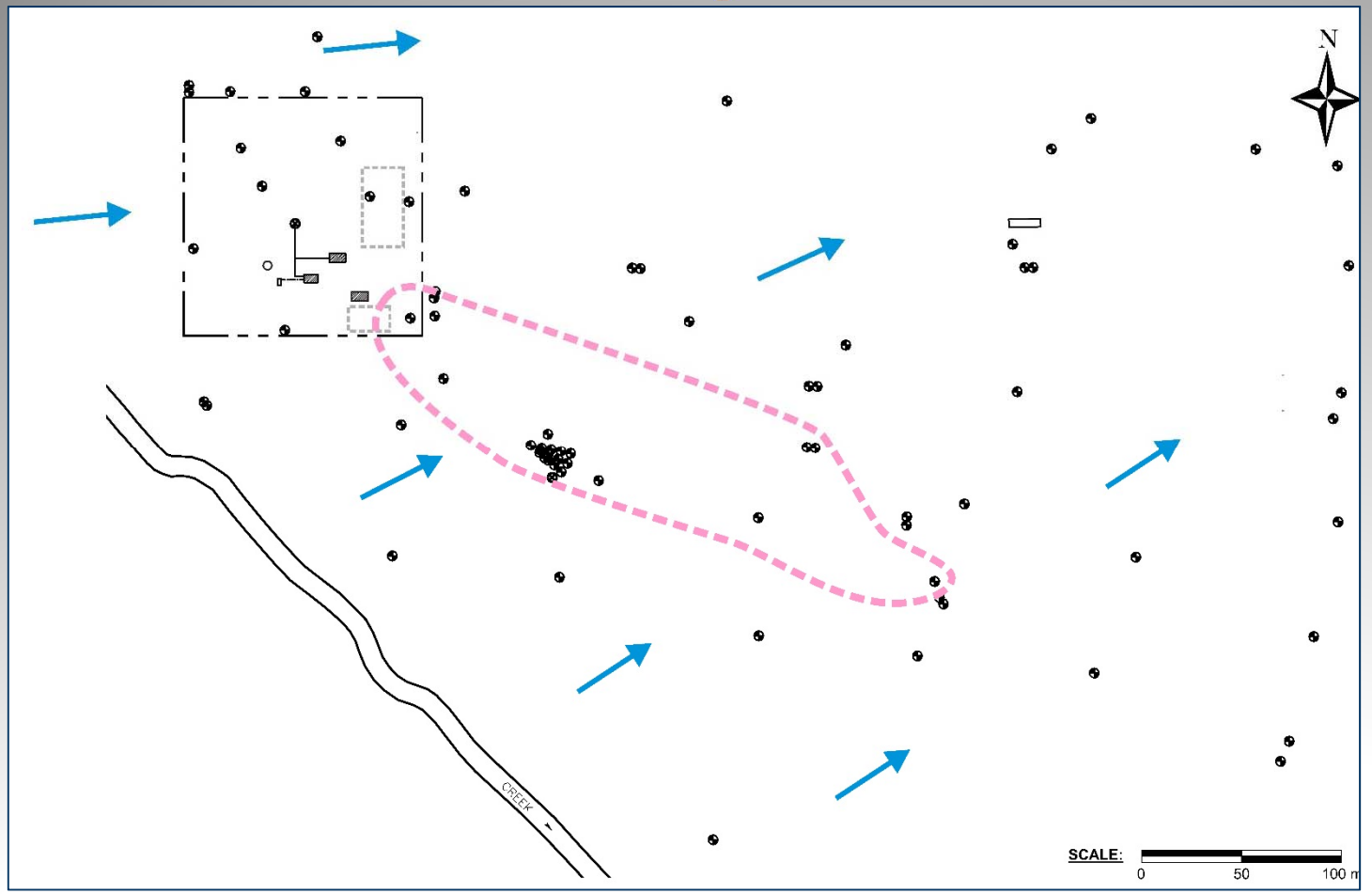
Pathway: Groundwater



- Generally NE flow direction, while LNAPL plume has a southeast orientation
- Fracture controlled flow?

Blue Arrows: Typical Groundwater Flow Direction
Pink: Interpreted LNAPL Extent

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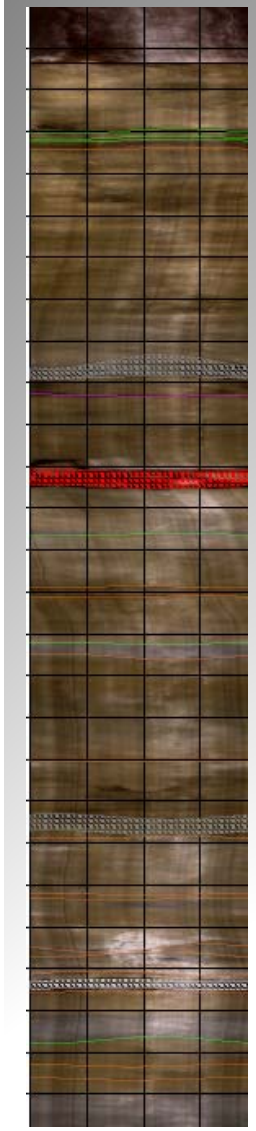
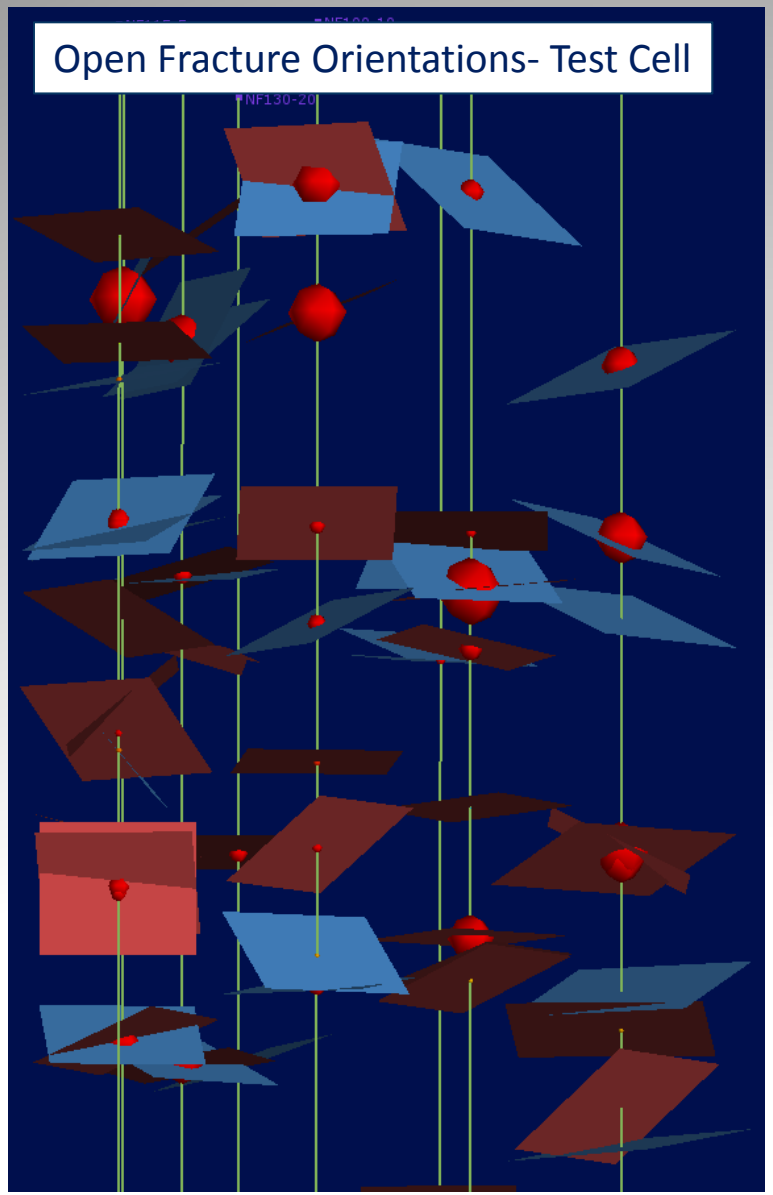
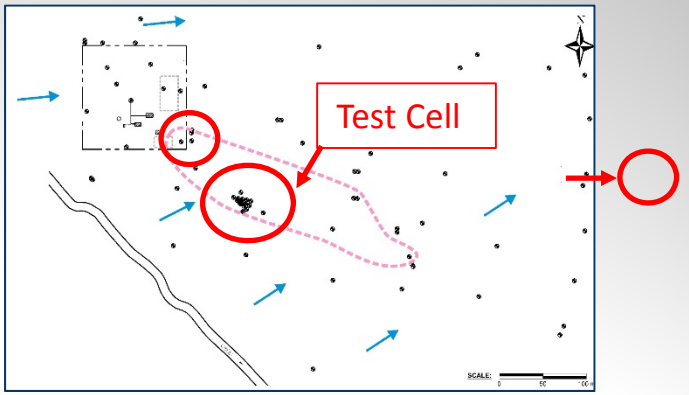
Pathway: Unsaturated Zone



Credit: DMT



- Optical televiewer used to spatially map fracture orientations and apertures in the unsaturated zone
- On a local scale, the fracture orientations are complicated and difficult to interpret



Investigated Area

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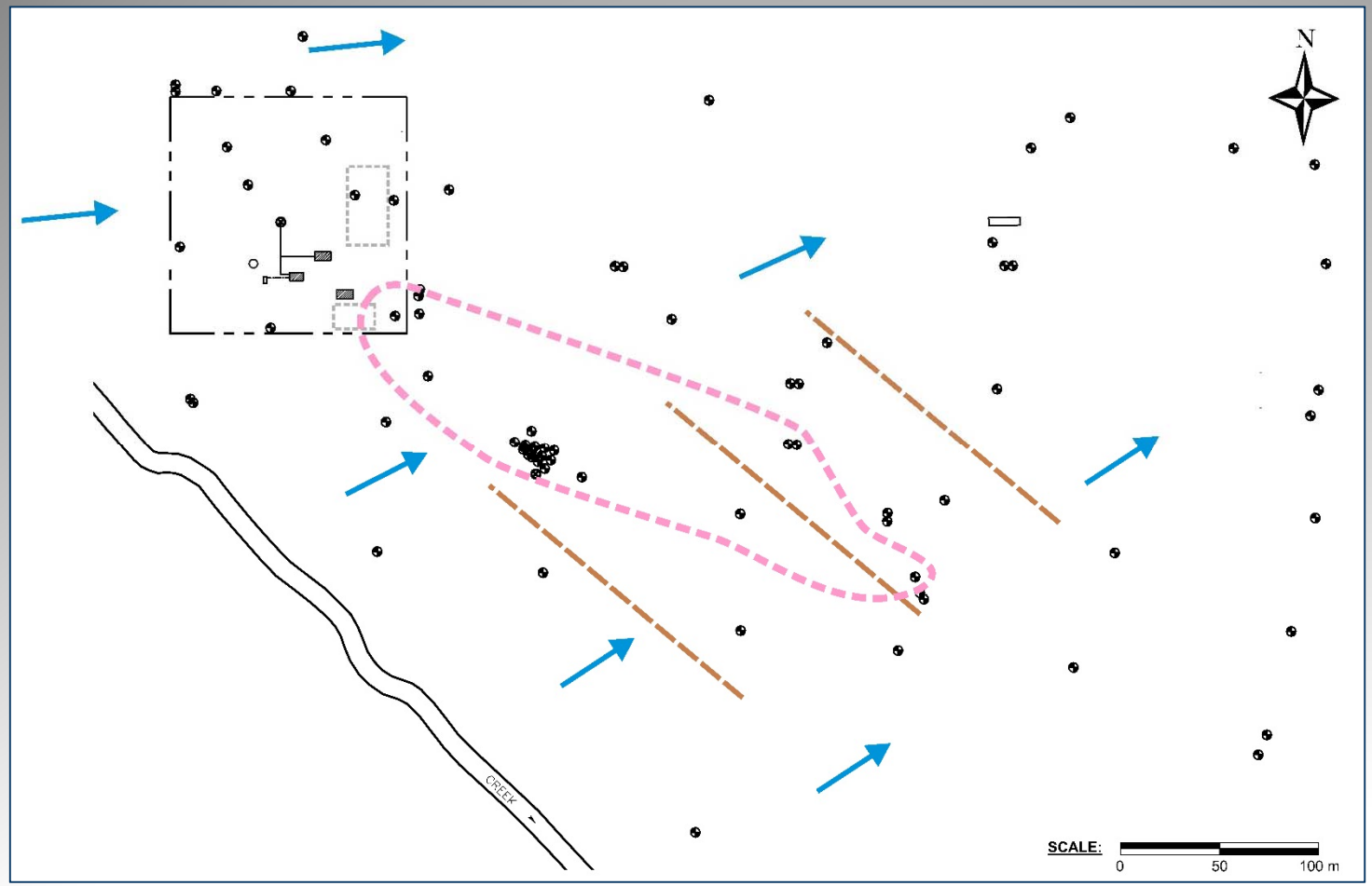
Pathway: Unsaturated Zone



- Dip direction to SE
- Dips generally <40° (bedding)

Blue Arrows: Typical Groundwater Flow Direction
Pink: Interpreted LNAPL Extent
Brown: Average Fracture Dip Direction

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Pathway: Downhole Camera

- Jetting tool used to gently clean borehole walls
- Downhole camera with fisheye lens used at the lease
- Vertical fractures generally had greater fracture apertures than subhorizontal fractures
- UV attachment also used to observe potential fluorescence of hydrocarbons (but no hydrocarbons were observed in normal and UV light)
- Average open fracture aperture of 9 cm (optical televiewer)

Raw Footage of Downhole Camera
https://youtu.be/QDqO_7i2Wa4

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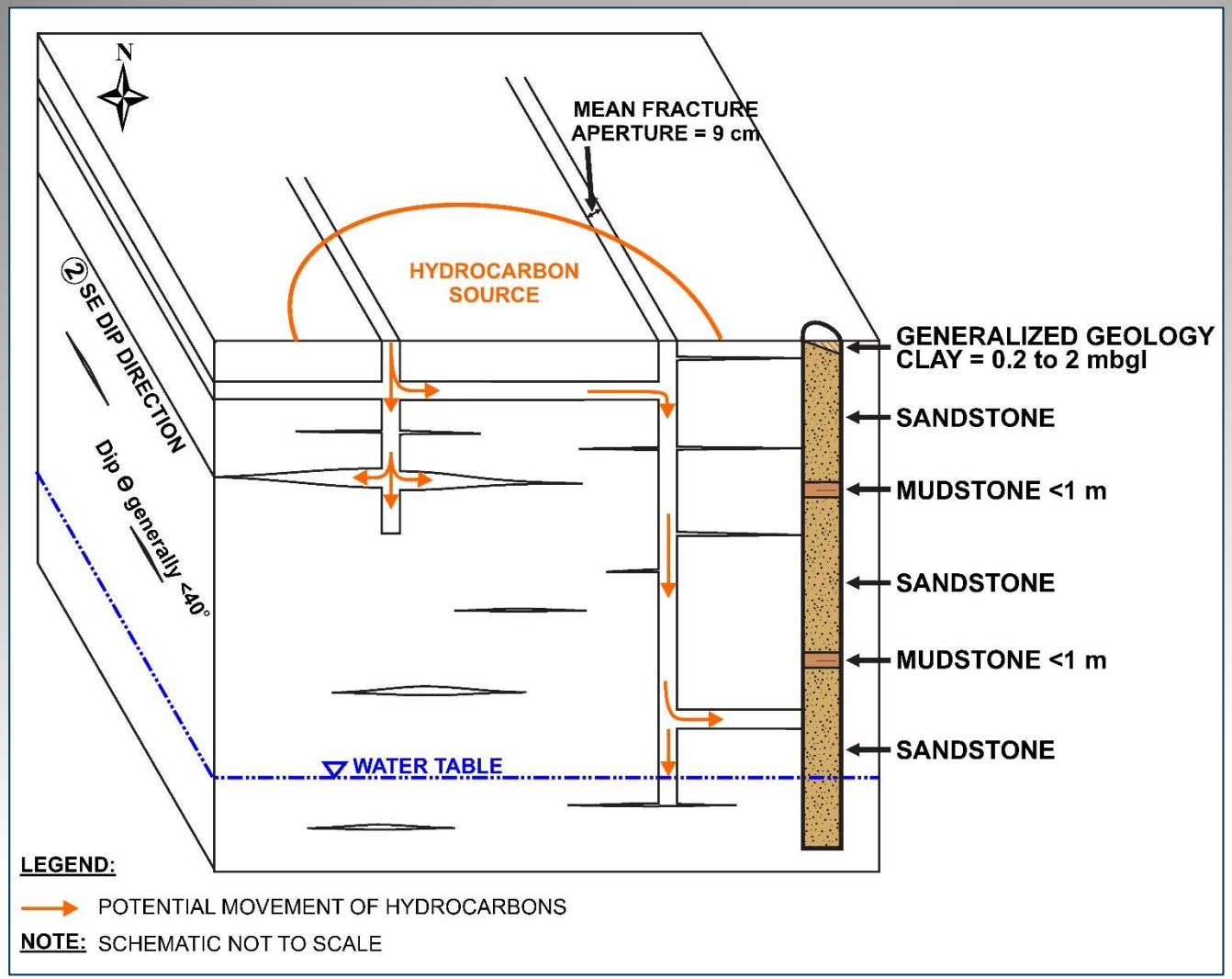
Pathway: Summary



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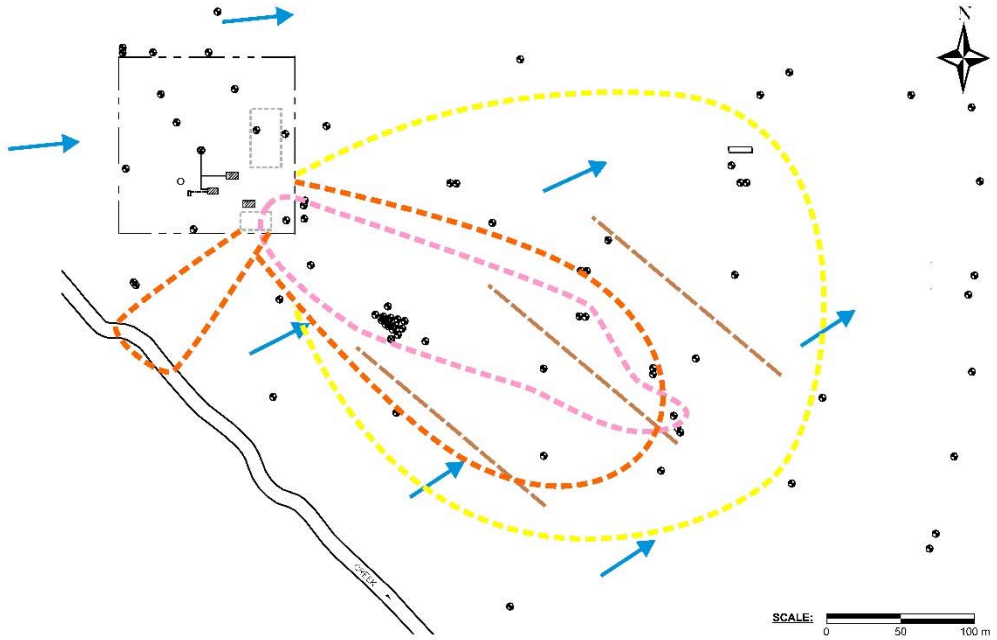
Pathway: Groundwater, Overland or Air?



- Orientation of anecdotal information appears to fit best with available information
- Orientation of fractures also likely have an influence

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Blue: Trees Cleared (1985) Pink: Interpreted LNAPL
Brown: Average Fracture Dip Direction
Blue Arrows: Typical Groundwater Flow Direction

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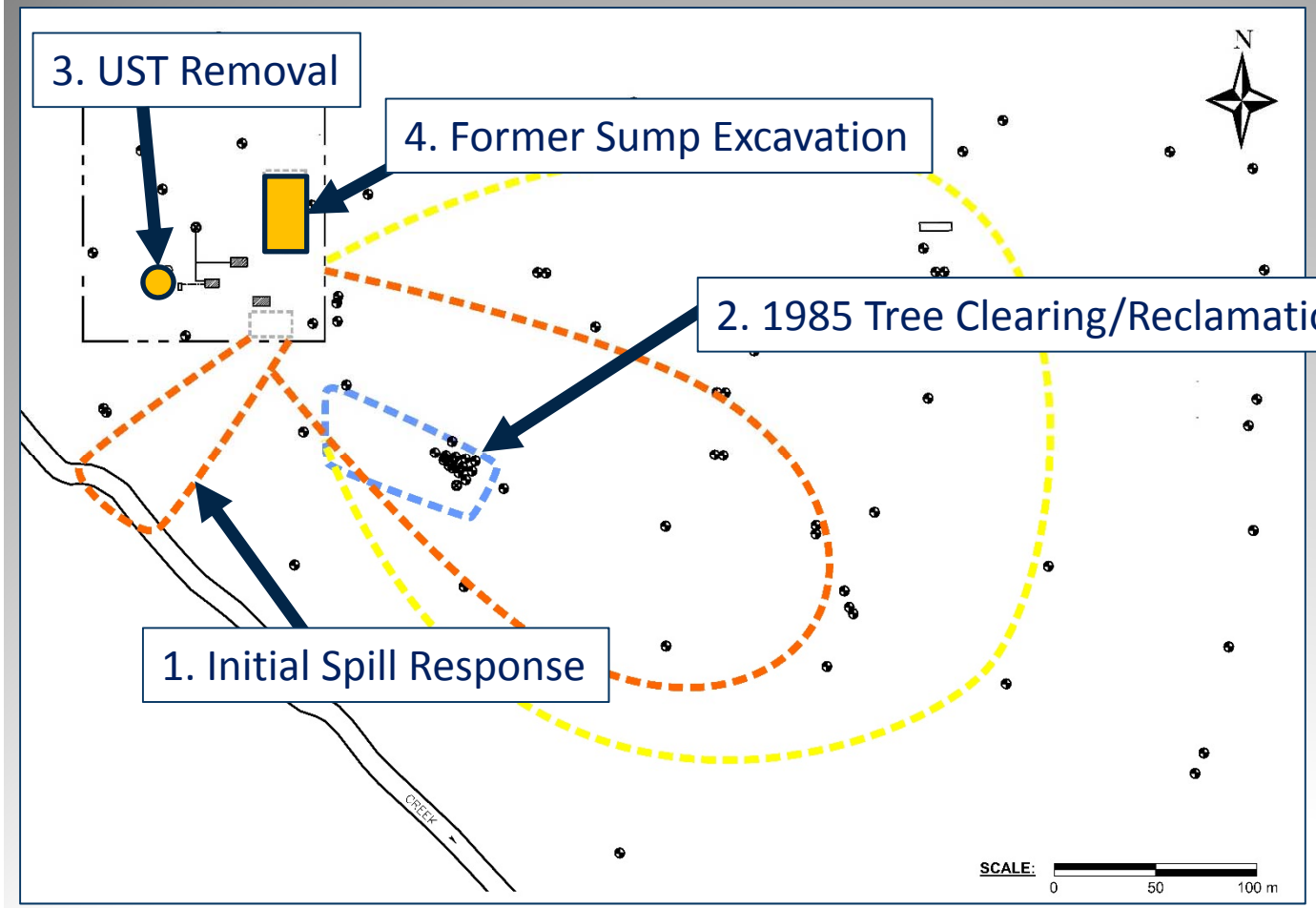
Remediation: Source Removal



- Estimated Hydrocarbon Remediation Volumes
  - Sump Remedial Excavation: 47 m^3
  - UST Removal: ????
  - 1985 Tree Clearing ????

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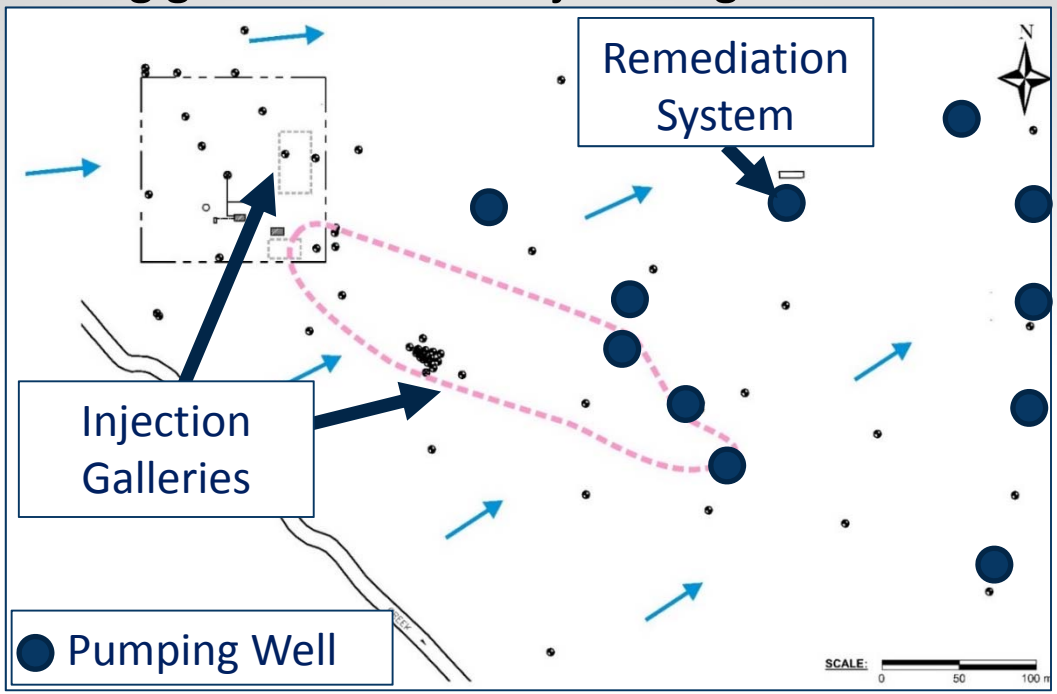
Remediation: Pump and Treat

- System Optimization: Pumping tests, partial pumping well abandonment, used different well configurations
- ~0.1 m^3 of hydrocarbon equivalent volume removed using pump and treat methods from 2010 to 2014
- No measurable change in water quality when system turned off
- Useful from containment and risk management perspectives and for oxygenating groundwater at injection galleries



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Manual LNAPL Recovery

- Passive bailers, manual bailing, and sorbent socks used to recover LNAPL on an annual to quarterly basis
- 0.07 m^3 hydrocarbon equivalent volume recovered during a similar time period to the pump and treat system
- LNAPL monitoring done opportunistically when on-site for other activities

Photo Credit: New Pig

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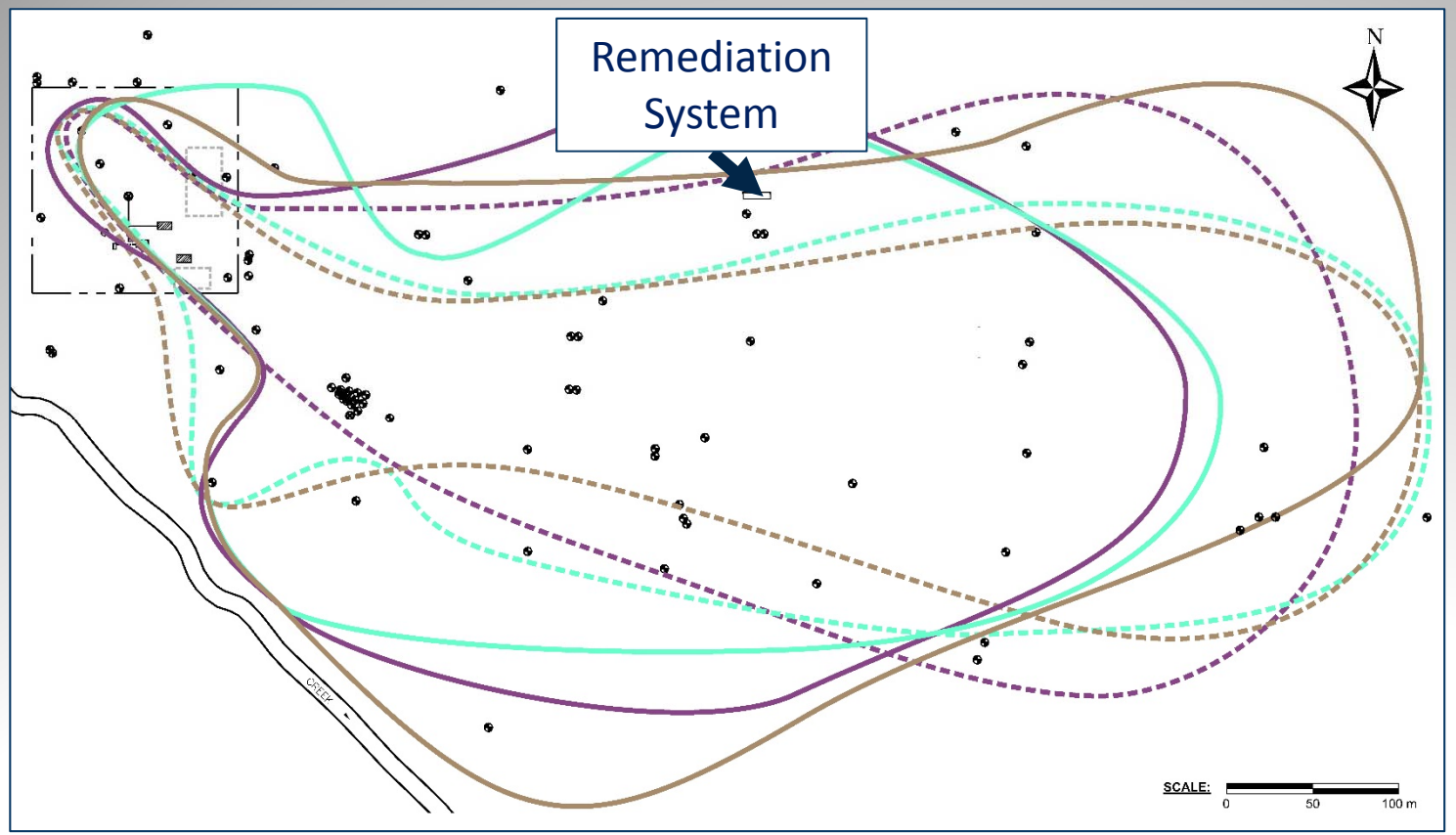
Natural Attenuation

- Natural attenuation of hydrocarbons is occurring
- Steady state plume



Blue/Green: Elevated Manganese

Purple: Negative ORP

Brown: Depleted Nitrate&Nitrite

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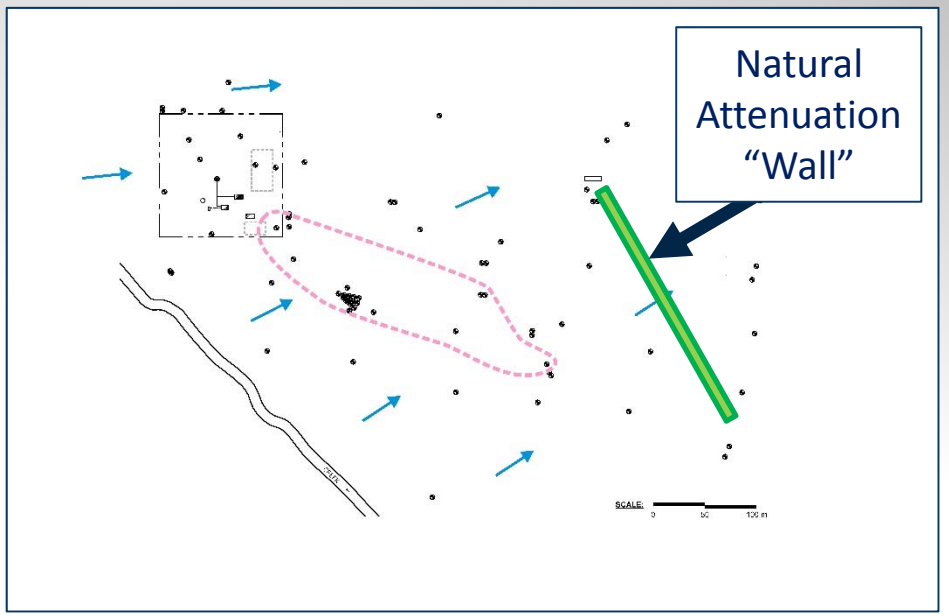
Natural Attenuation: Volume Estimate

- Assumed a natural attenuation front or "wall" on the downgradient portion of the plume keeps the hydrocarbon plume at steady state (i.e., not growing)
- Using conservative parameters for calculating the advective flux (i.e., Darcy flux*concentration)
- Estimated removal of 53 m^3 hydrocarbon equivalents/year, 530 m^3/10 years
- Uncertainty regarding length of "wall" and time
- Ballpark estimate, lots of variables with uncertainty



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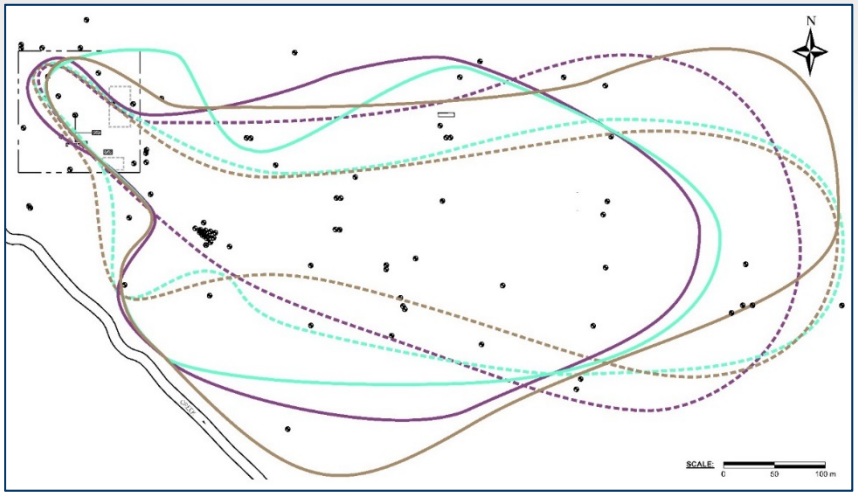
Natural Attenuation: Volume Estimate

- Used stoichiometry to very roughly estimate natural attenuation via the primary biodegradation mechanisms at the site (nitrate and manganese reduction)

Mechanism	Estimated Hydrocarbon Equivalents (Toluene) (m^3)
Nitrate Reduction	205
Manganese Reduction	265
Total	470



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Estimated Source and Remediation Volumes

Source	Estimated Hydrocarbon Volume (m^3)
First Drilling Event	157
Second Drilling Event	298
ASTs/USTs	????
Total	455 to ????

- Impacts not remediated to date, discrepancy likely related to uncertainty regarding natural attenuation estimate

Remedial Activities	Estimated Hydrocarbon Volume Remediated (m^3)
Remedial Activities in 1980s Related to the Drilling Events	????
UST Remedial Excavation	????
Sump Remedial Excavation	47
Pump and Treat Remediation	0.1
Manual LNAPL Recovery	0.07
Natural Attenuation	470 to 530
Total	517 to 577

Remediation: Summary

- Based on the steady state plume and long-term groundwater monitoring, natural attenuation and manual LNAPL recovery appears to be the most effective long-term remedial approach for this site

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Questions?

Thank You

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http://www.waterlineresources.com