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Examination of a Groundwater Remediation Pilot Test to Remove Organic By-Products from Natural Gas Processing

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Safety Moment – Summer BBQing

- **Gas Grill / Charcoal Grill Safety Tips:**
- Check grill hoses for cracking, brittleness, holes, and sharp bends.
- Move gas hoses as far as possible from dripping grease or hot surfaces.
- Keep propane gas containers upright.
- Never keep a filled container in a hot car or car trunk.

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Outline

- Characterization of Sulfolane as groundwater contaminants;
- Water treatment process design, implementation and optimization;
- Pilot system results summary;
- Transition from pilot to full scale – requirements and approach; and
- Hydrogeology related to groundwater extraction and re-injection into the formation.

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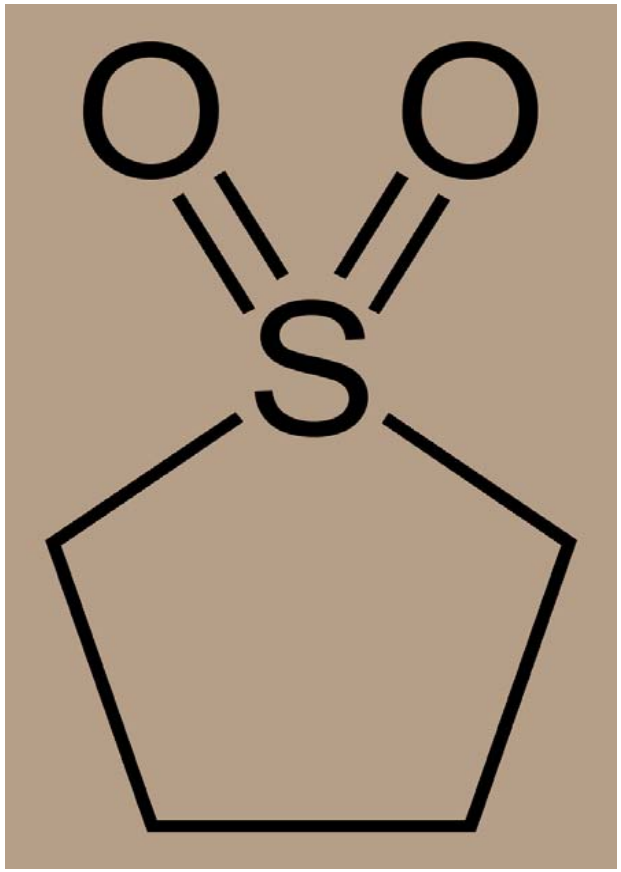
Sulfolane



- Degrades aerobically NOT anaerobically

Characterization of Sulfolane as Groundwater Contaminants

- 1985: Sulfolane and DIPA were first detected which initiated a detailed monitoring program
- 1986: tanks, water and drain lines were removed or replaced
- 1991: groundwater monitoring detected offsite Sulfolane
- Between 1985-2007, 42 monitoring wells were installed to characterize the site.

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Remediation Driver

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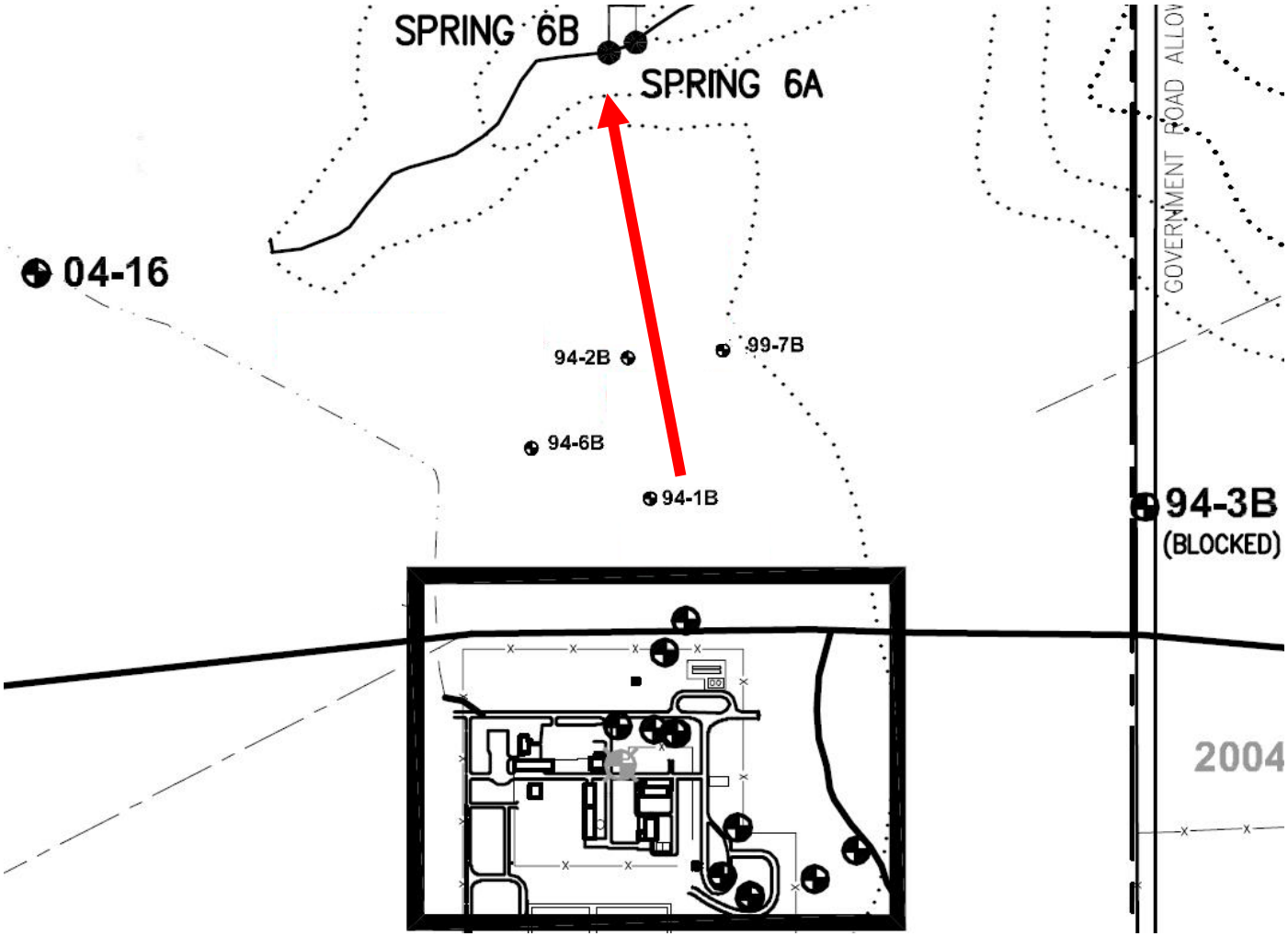
Key Locations



History of Sulfolane Remediation

- Originally studies completed on biodegradation of Sulfolane in industrial wastewaters.
- Research studies were completed by University of Alberta in the mid 1990's focusing on soil/groundwater remediation.
- Stoichiometry of Sulfolane oxidation under ideal conditions:

$$C_2H_8O_2S + 6.5O_2 \rightarrow 4CO_2 + 3H_2O + 2H^+ + SO^{-4}$$

- Surface Water Quality Guidelines, 2010 provides the primary criteria for Sulfolane remediation (0.09 mg/L).

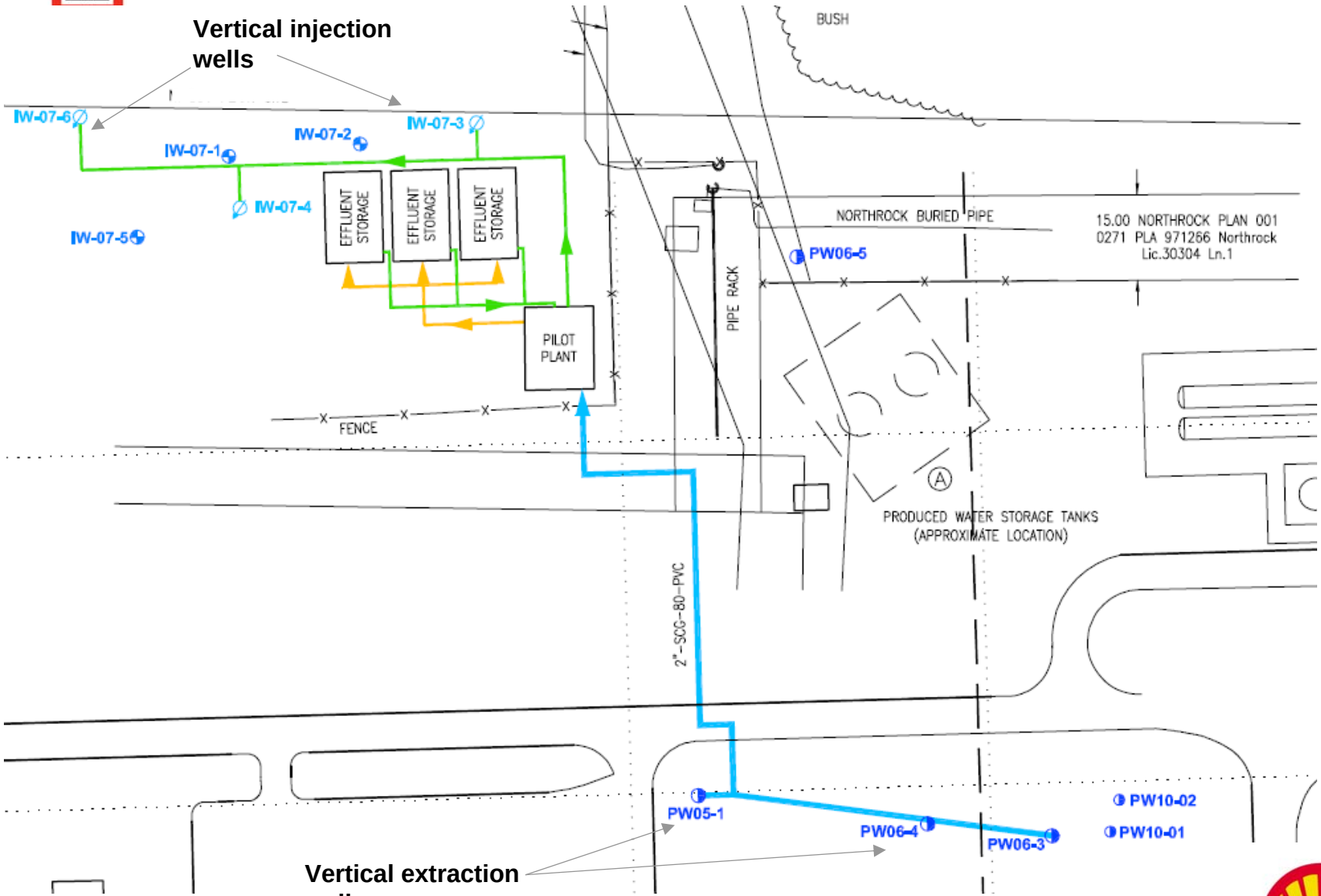
Characterization of Sulfolane as Groundwater Contaminants

- 2006-2007: Investigated the treatability of Sulfolane-impacted groundwater, including:
  - Groundwater recovery
  - Lab scale In-situ remediation
  - Lab scale biodegradability testing
- 2008-Present: Operate pilot system and observe effect on contamination plume

Water Treatment Process Design

- An aerobic biological system with activated sludge and clarifier
- Uses activated sludge from a municipal wastewater treatment plant
- Treatment effective to <0.001 mg/L
- Treatment capacity 150m^3/day
- Effluent stored, sampled and discharged to formation

Water Treatment Process Design



Water Treatment Process Design

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Pilot System Results Summary
Analytical Results

	Benzene	Toluene	Ethylbenzene	Xylenes (t)	PHC F1 (C6-C10)	PHC F2 (C10-C16)	DIPA	Sulfolane
RW05-1	0.0020	0.0008	0.0050	0.072	0.11	0	<0.05	3.4
RW06-4	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	0	<0.05	11.0
RW06-3	<0.002	<0.002	0.1900	2.400	220.00	0.0	0.54	12.0
Effluent	<0.0004	<0.0004	<0.0004	<0.0008	<0.1	<0.1	<0.3	<0.001

*Sampling date: 22 Oct 2010

*All concentrations in mg/L

- Treated effluent was below detection limits for all treatment objectives
- This demonstrates the ability of the pilot system to treat the recovered water with a single pass through the system

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Pilot System Results Summary

	2008	2009	2010
Operation Interval	September to October	May to September	June to September
Water Recovered	315 m^3	2200 m^3	1780 m^3
Treated Water Injected	315 m^3	2300 m^3	1770 m^3
Sulfolane Removed	5 kg	31 kg	14 kg
Treatment Success	Below detection limits; multiple pass	Below detection limits; single pass	Below detection limits; single pass
Highlights	Established system effectiveness	Single pass	New wells drilled, no significant process interruptions

Implementation and Optimization

- Pump screen fouling
  - Water is very hard
  - Scale is effecting flowrates
  - Pulling pumps periodically is necessary
- Sludge recycle
  - Calcite may make sludge “heavy” and difficult to recycle
- Minor mechanical issues
  - Some piping and valves replaced to improve flow control

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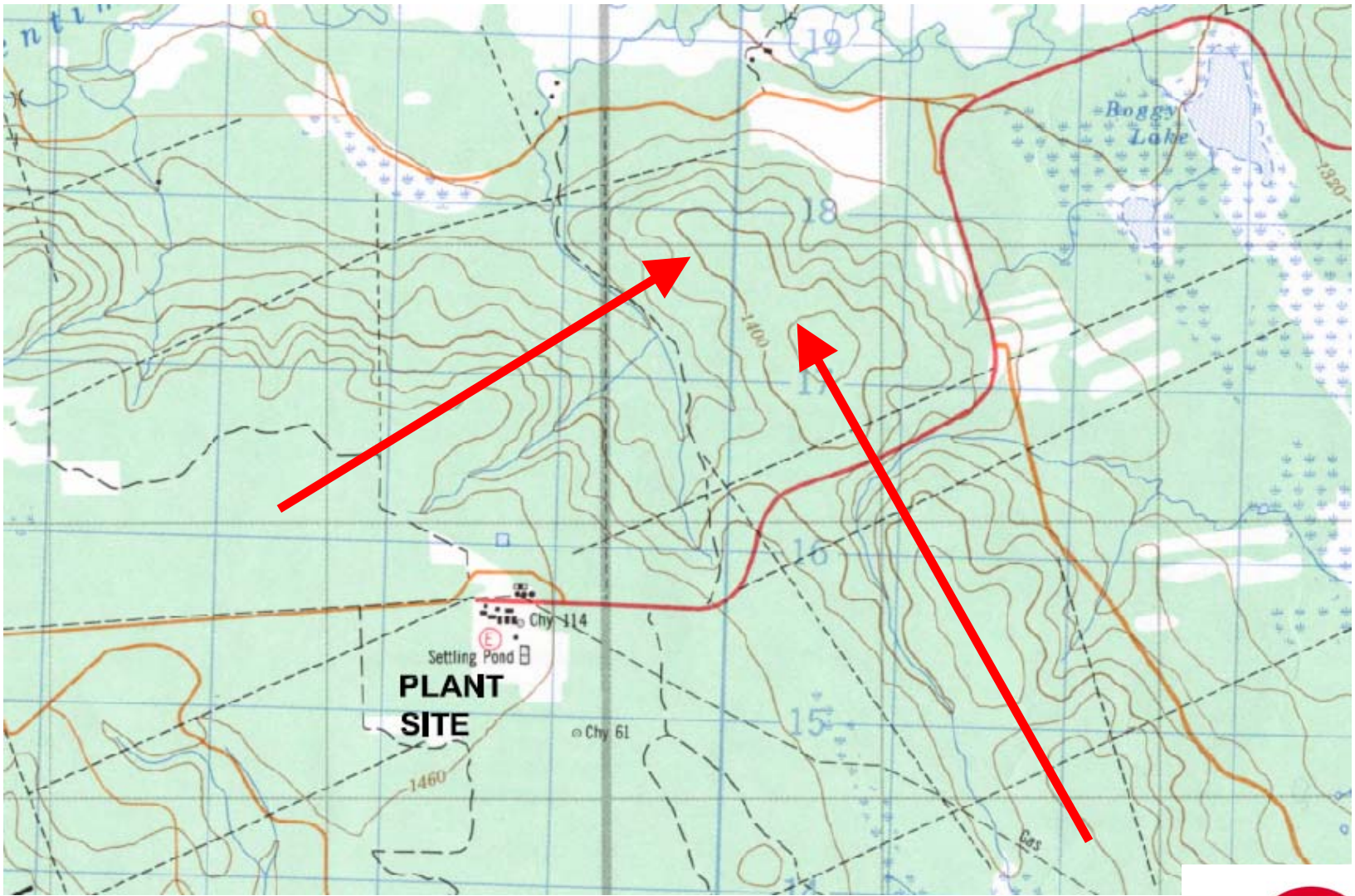
Surface Water Monitoring

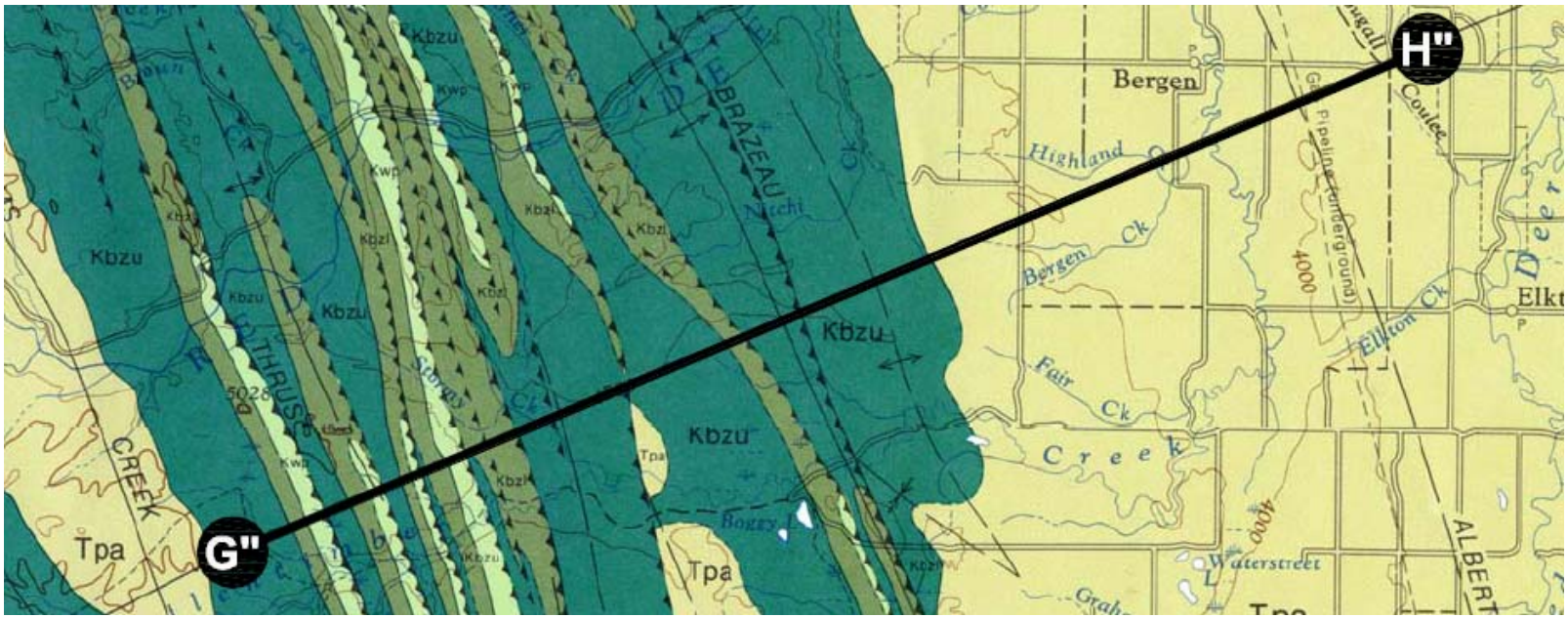
Transition from Pilot to Full Scale

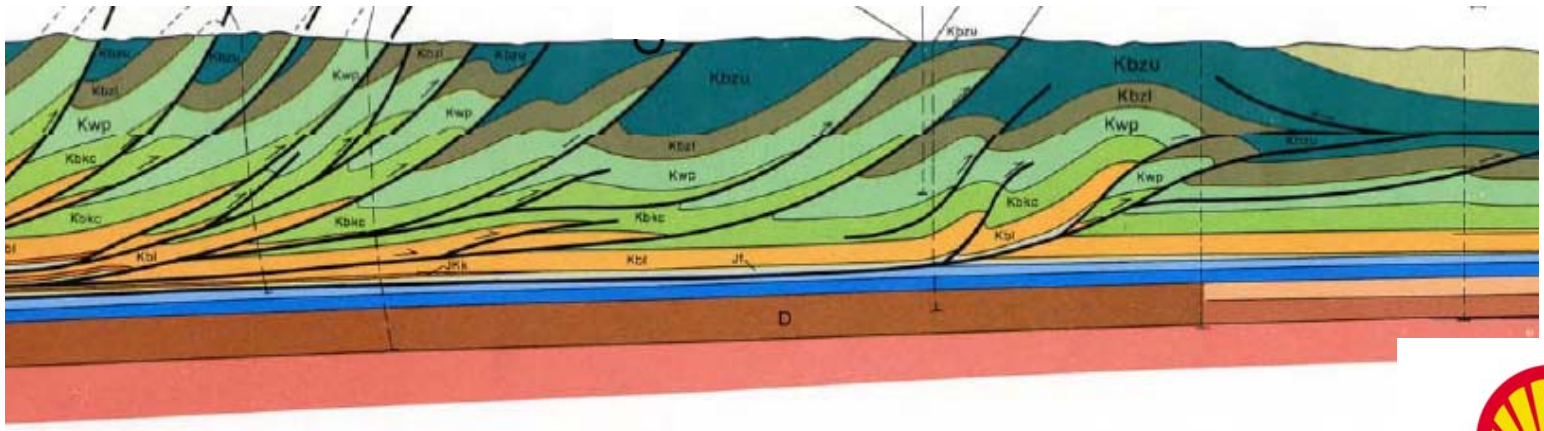
- Process Optimization
  - Apply computer modelling software (PetWin)
  - Define HRT with enhanced testing strategy
  - Define SRT by measuring and controlling sludge waste/recycle
- Effluent Handling
  - Propose direct injection of treated effluent to AENV
- Hydrogeology
  - Install data loggers to track groundwater elevation with better resolution
  - Continue characterization of the fractured bedrock to define optimum capture strategy.

Hydrogeology – Bedrock Characterization



Hydrogeology – Regional Geology

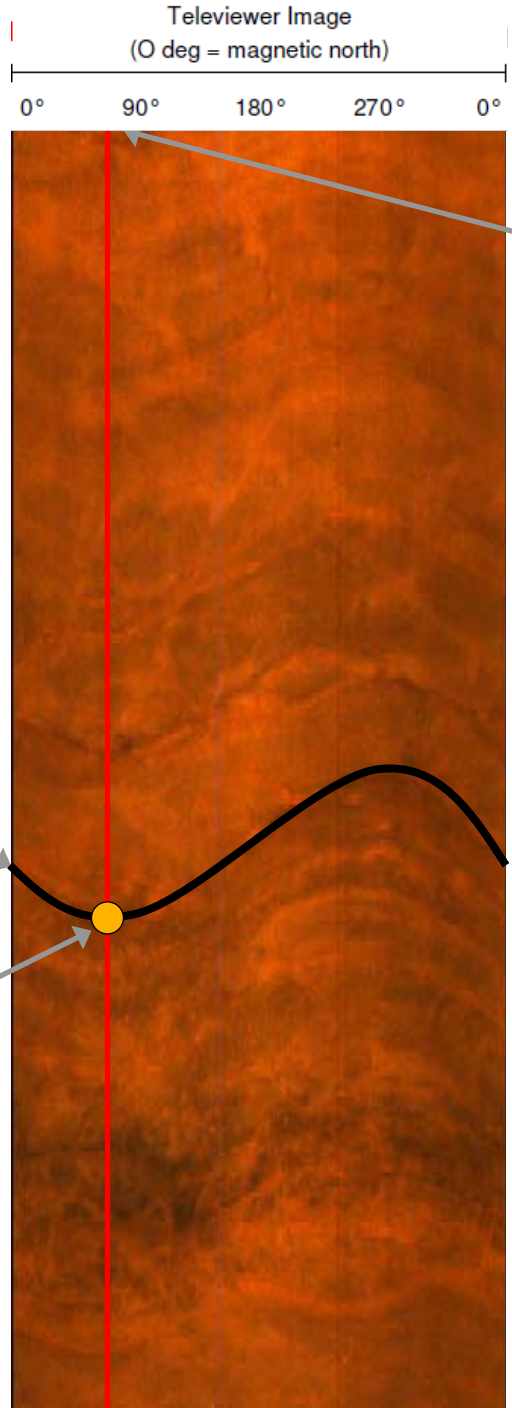




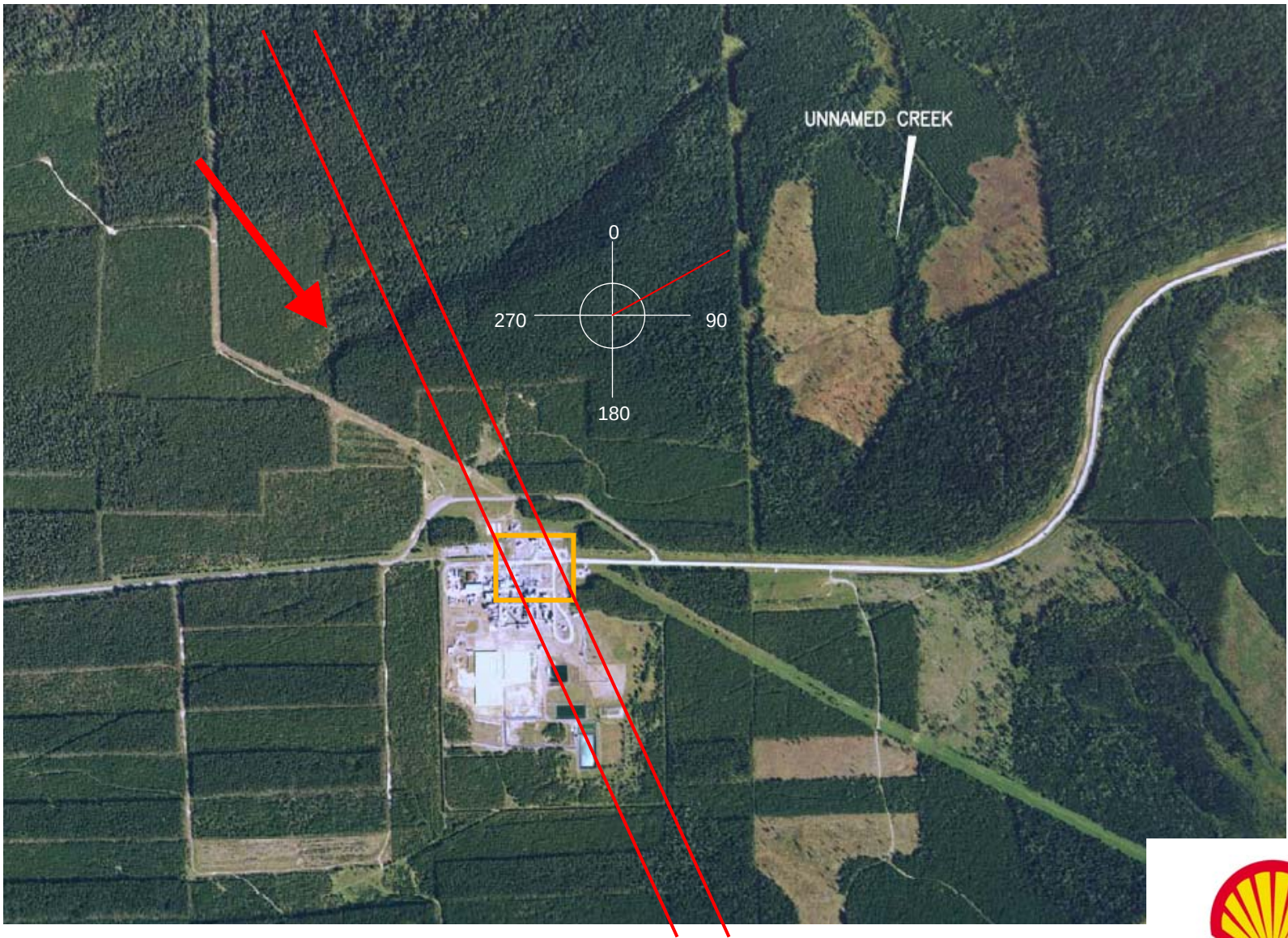
Hydrogeology

Depth Interval:

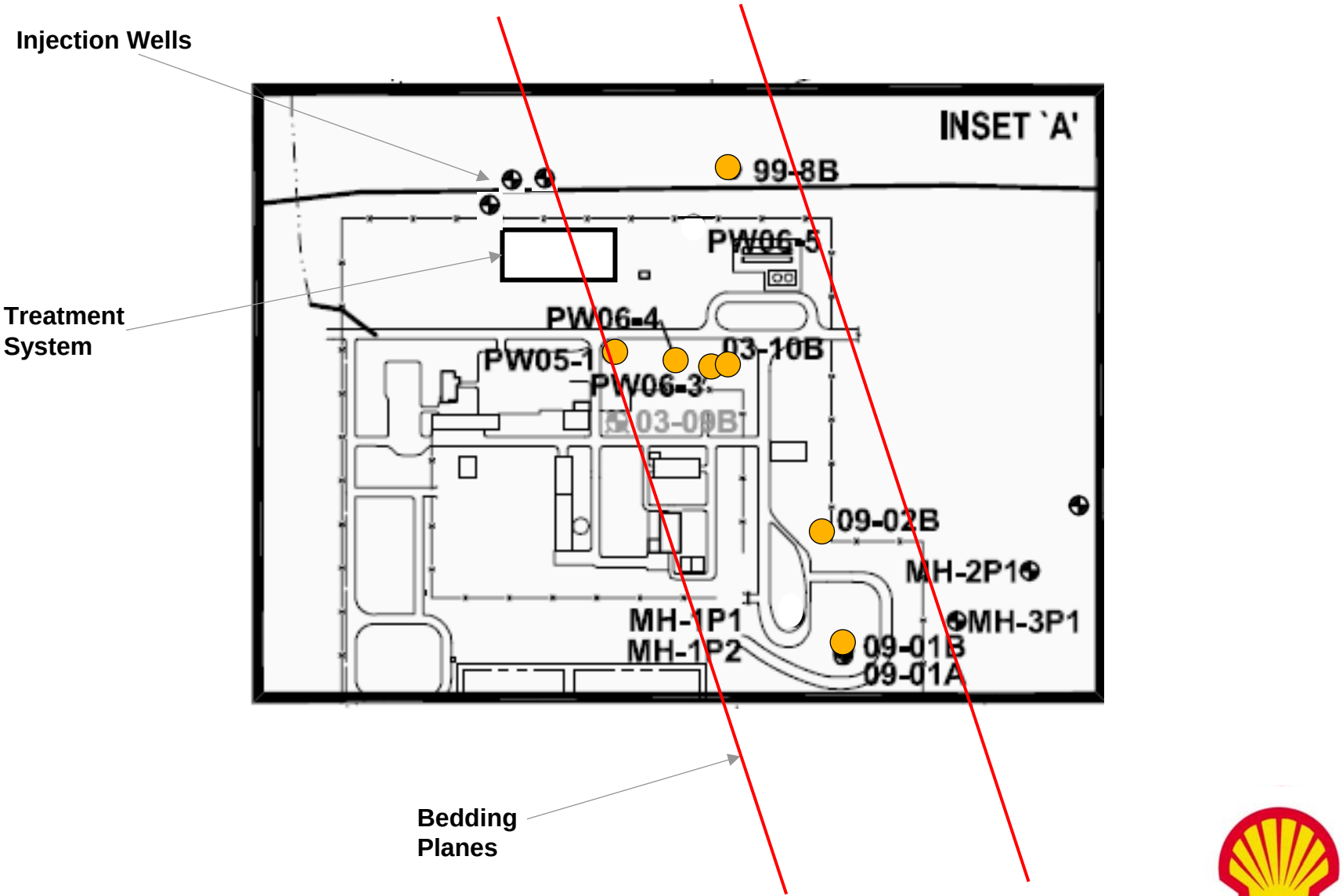
21.20 – 22.10 m



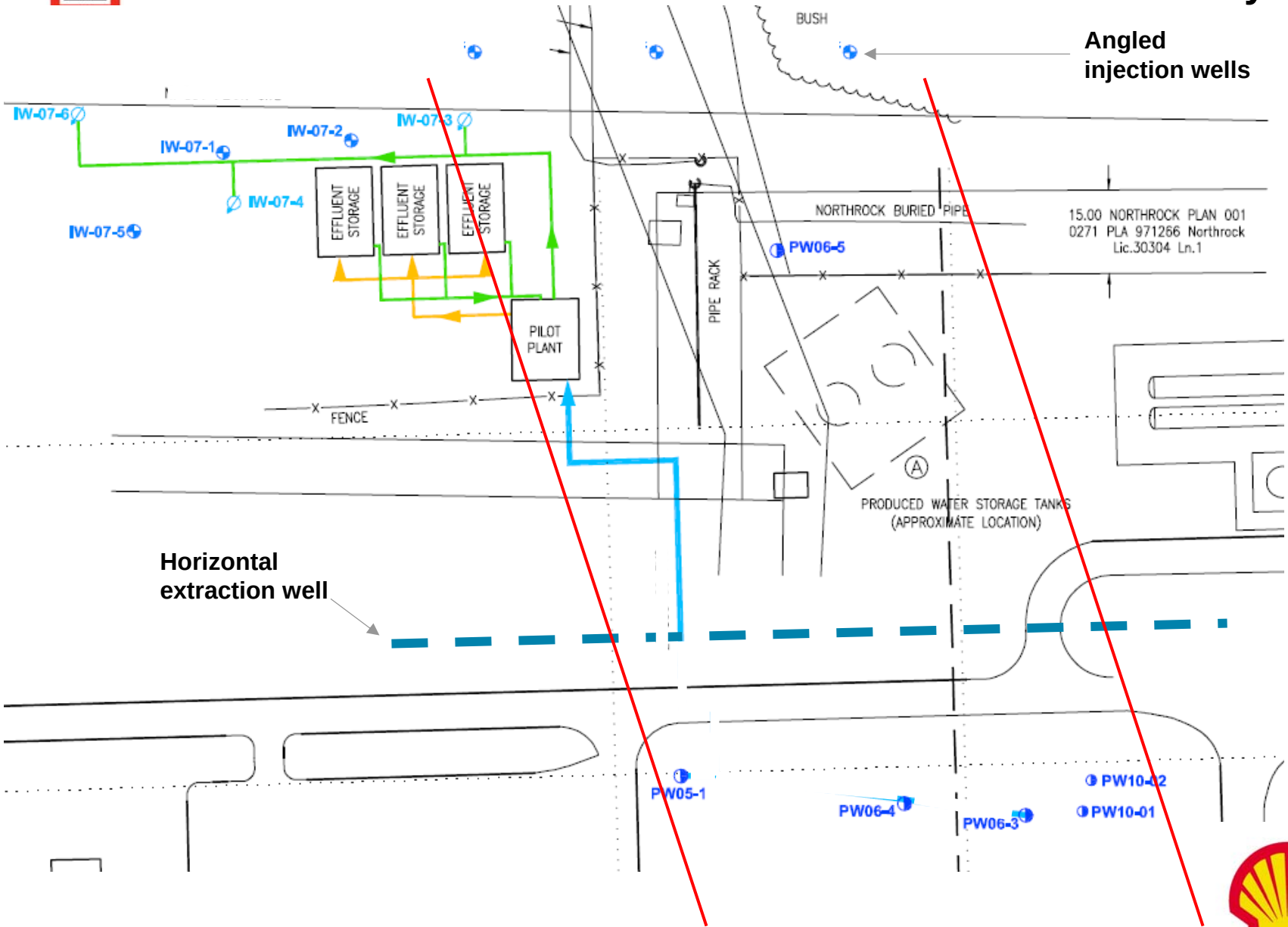
Hydrogeology – Surficial Geology



Hydrogeology – Bedrock Characterization



Full Scale Treatment System



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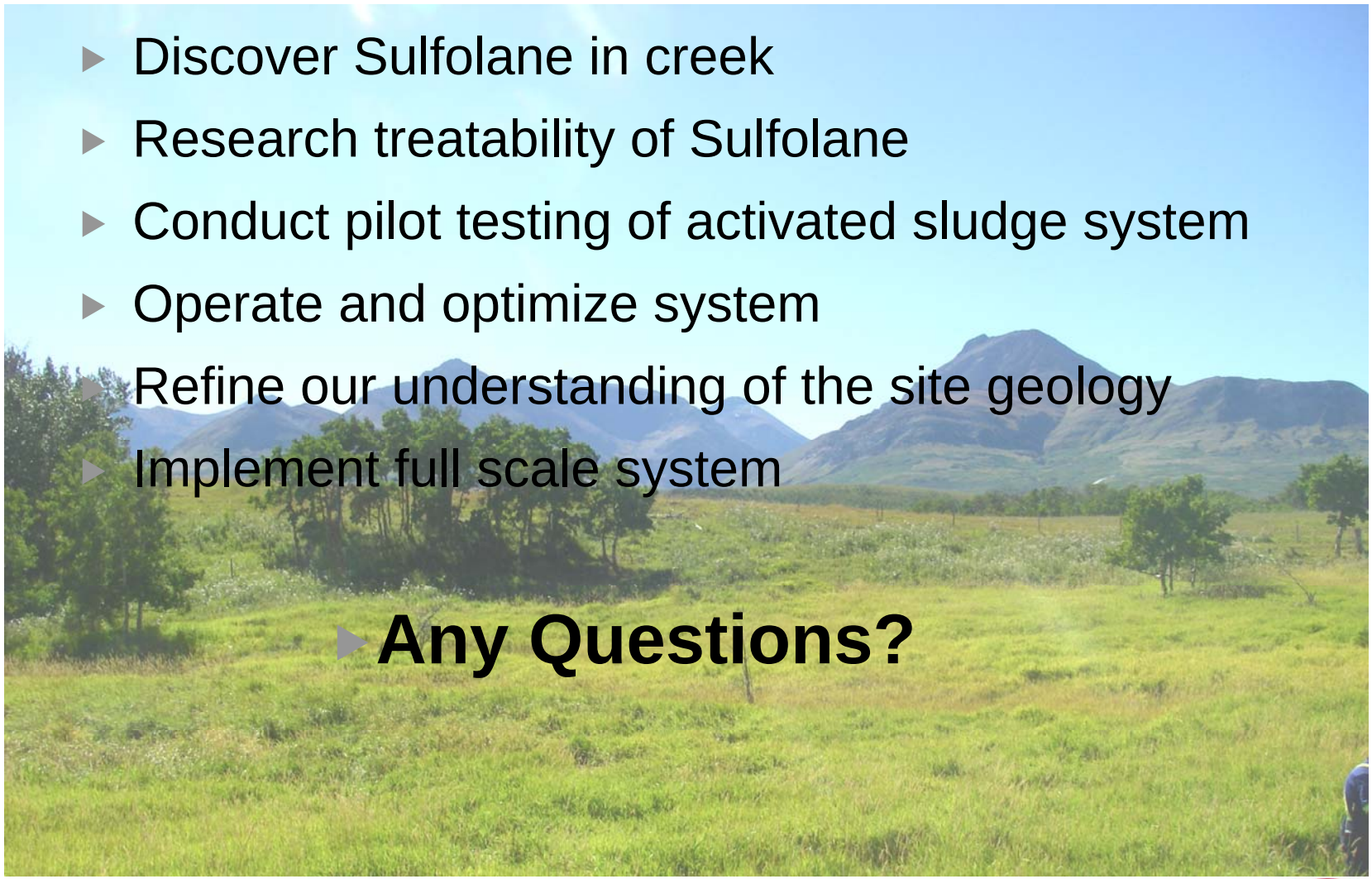
Summary



- Discover Sulfolane in creek
- Research treatability of Sulfolane
- Conduct pilot testing of activated sludge system
- Operate and optimize system
- Refine our understanding of the site geology
- Implement full scale system

- **Any Questions?**