

# In-Situ Remediation of Brine Impacted Soils and Groundwater Using Hydraulic Fracturing, Desalinization and Recharge Wells

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**Wiebe Environmental Services Inc.**

*"Practical Solutions for Environmental Management"*

# The Problem

- Former oil battery established in 1940's, decommissioned in late 1960's with reclamation certificate issued in 1972
- Land owner reports poor vegetative growth in former Battery area
- Investigate cause of poor growth and delineate contaminants of concern
- Remediation of impacted soil and groundwater associated with a former Battery site





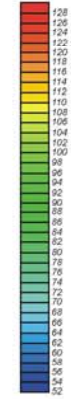
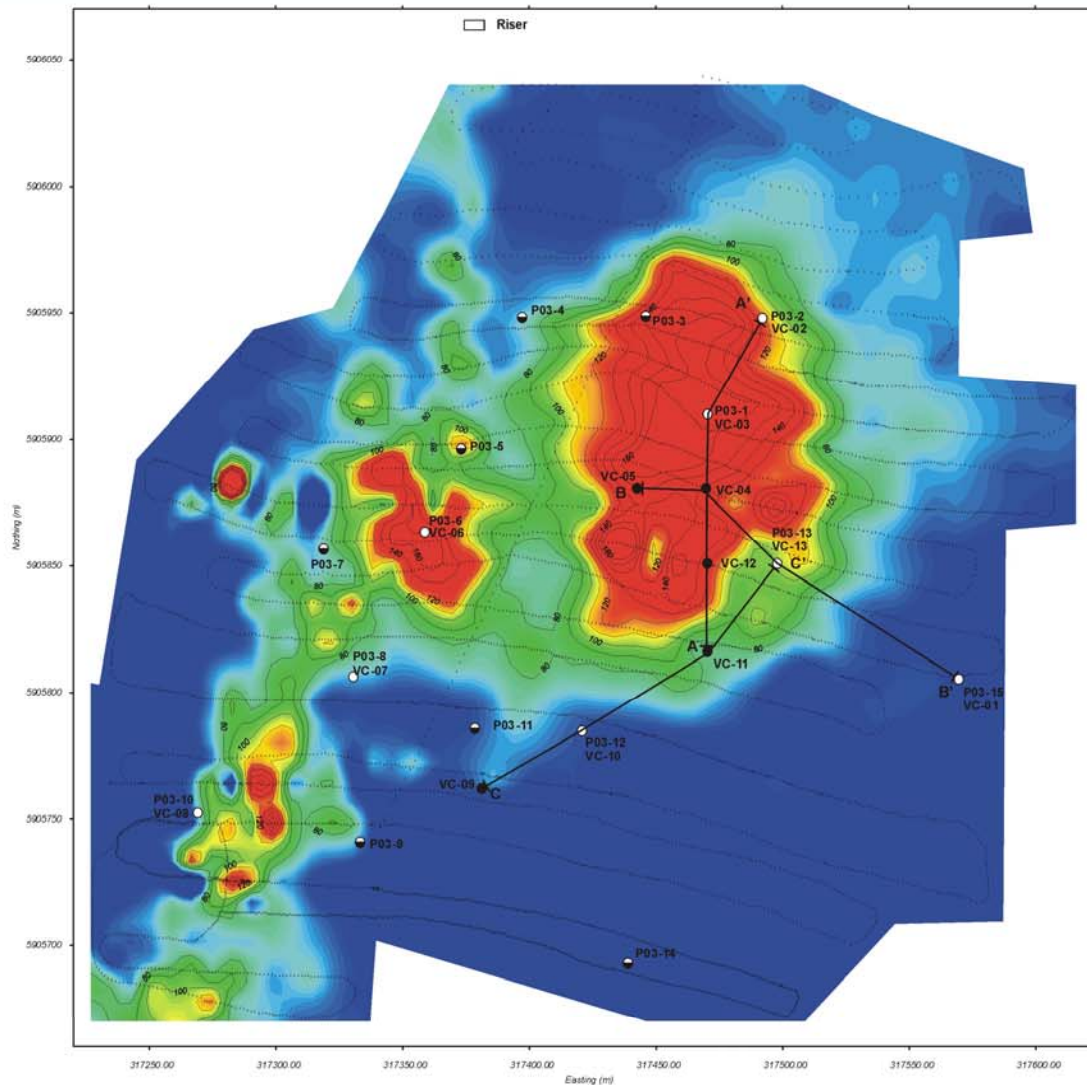
Former Battery Site 1962



# The Investigation

- Agrological, Geophysical and Hydrogeological investigation into extent of anthropogenic impacts
- Develop remediation options and plans to deal with issues of concern





Conductivity (mS/m)

**LEGEND**

- - Monitoring well and vertical conductivity locations
- - Monitoring well location
- - Vertical conductivity location
- | — - Vertical conductivity cross-section



**EM31 CONDUCTIVITY DATA**  
 7-33-49-26 W4M  
 CALMAR, ALBERTA

**JOB NO: 03177**

**DATE: JAN. 22, 2004**

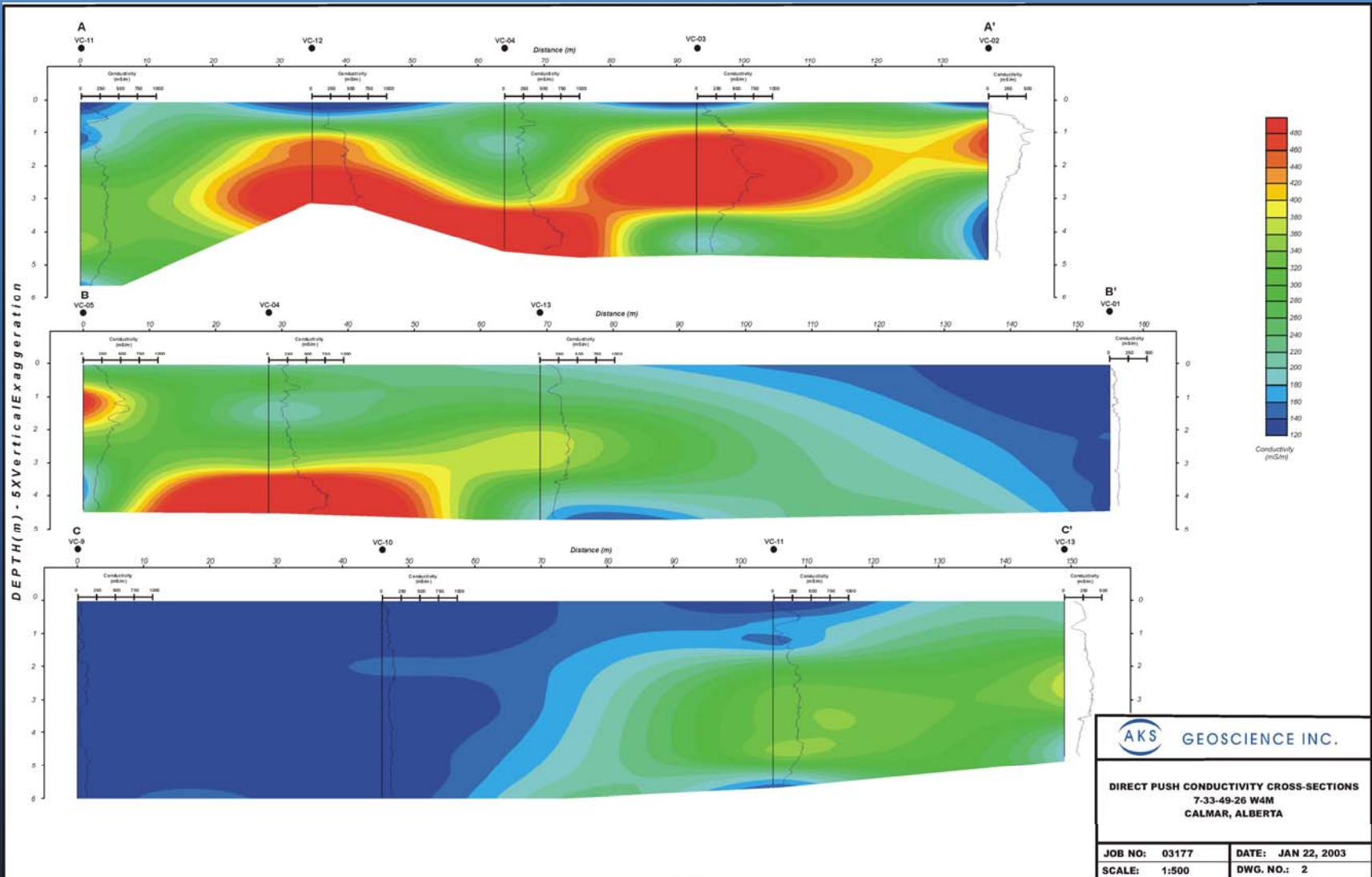
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**DWG. NO.: 1**



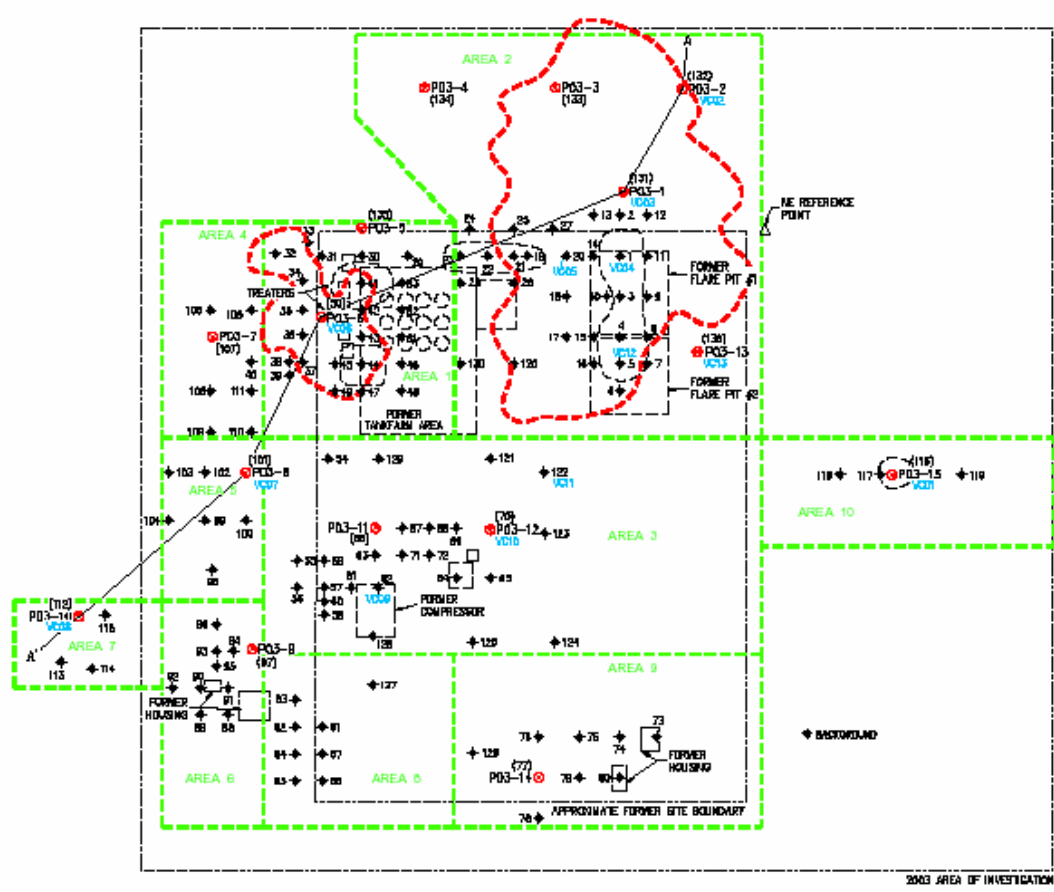
# EM31 Survey Results





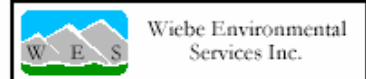
# Vertical Conductivity Survey Results





- LEGEND**
- 2003 MONITORING WELL LOCATION
  - ⊕ 2003 BOREHOLE LOCATION
  - VCO1 2003 VERTICAL CONDUCTIVITY
  - AREA 1 INVESTIGATION AREAS
  - A—A' CROSS SECTION LOCATION (SEE FIGURE B)
  - APPROXIMATE LIMITS OF BRINE IMPACTED PLUME
  - APPROXIMATE LIMITS OF HYDROCARBON IMPACTED PLUME

NOTE:  
ALL SITE FEATURES ARE APPROXIMATELY LOCATED.



**TITLE**  
SITE DIAGRAM SHOWING  
PHASE II SITE ASSESSMENT PROGRAM

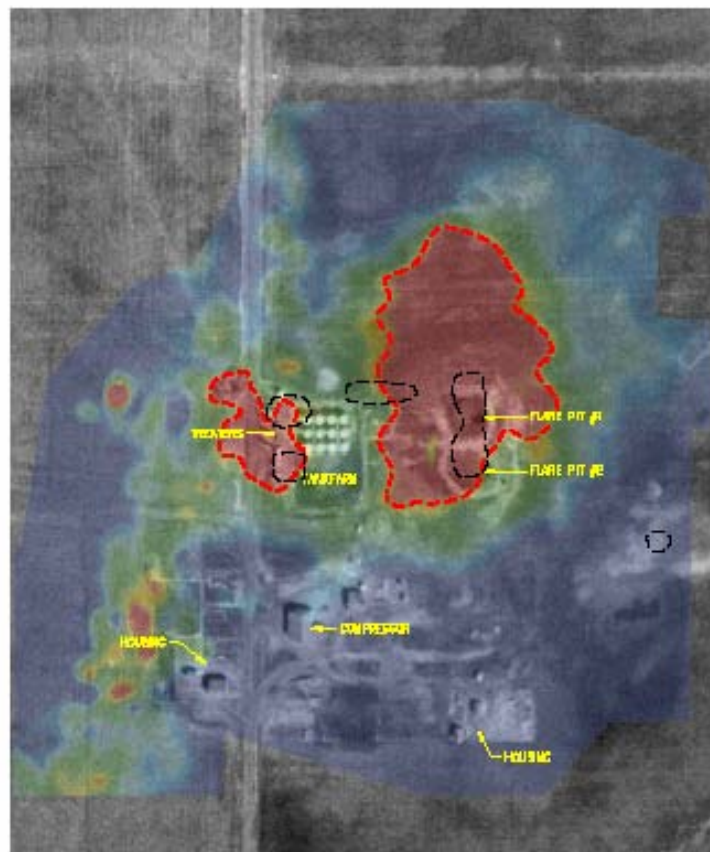
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SCALE	1:1500	CHG	W	
FILE	D:\02_04\env7-03-02-2003\4.dwg			

CALMAR  
07-33-49-26 W4M



# Phase II Site Assessment Program





**LEGEND**

- APPROXIMATE LIMITS OF BRINE IMPACTED PLUME
- APPROXIMATE LIMITS OF HYDROCARBON IMPACTED PLUME

NOTE:  
 DATA WAS OBTAINED FROM JACO SERVICES INC. AND DISPLAYED ON  
 AERIAL PHOTOGRAPH FOR INFORMATION PURPOSES ONLY. THIS IS NOT TO  
 BE TAKEN AS EXACT MEASUREMENT OR LOCATIONS DUE TO DISTORTION.



CALMAR  
 07-33-49-26 W4M



CLIENT:	ORL	DT:	1982
DATE:	08/05/82	SCALE:	1:2500
FIELD:	% 0000	OPER:	WES
FILE: C:\AKS\Calmar\07-33-49-26\0000.dwg			

AUGUST 5, 1982  
 AERIAL PHOTOGRAPH

FIGURE  
 2



Impacted Areas





## Results

- 137 boreholes and 100 test holes to a maximum depth of 7.5 m
- Approximately 8,000 m<sup>3</sup> of heavy end hydrocarbons, trace elements (metals), and heavily brine impacted materials was identified in the former tank farm and the buried flare pit areas
- Approximately 62,000 m<sup>3</sup> of brine impacted materials
- Approximately 1,000 m<sup>3</sup> of medium to light end hydrocarbon impacted materials
- groundwater flow is to the northwest at an average linear velocity of 3 mm/year to 6 mm/year



## The Options

- In-situ or on site treatment of heavy end hydrocarbons difficult and cost prohibitive. Best option to remove heavy hydrocarbons for off-lease disposal
- Light end hydrocarbons can be treated in-situ, on site or can be removed for treatment or disposal. Off site disposal was selected because the volumes were relatively small, other material was being shipped off lease and on site options would restrict reclamation efforts
- The large volume of salt impacted material made removal cost prohibitive. Other option was in-situ treatment



# Limitations on Salt Remediation

- Saline impacts cannot be reclaimed by chemical amendments, conditioners or fertilizers
- Salts cannot be volatilized or degraded
- Soils and groundwater can only be reclaimed by removing salt
- Volumes are too great to dig and dump and natural leaching, if feasible will take decades, especially in semiarid regions



# Treatment of Saline Soils

- Leaching Requirement
  - The amount of water needed to leach salts out of the soil profile
- Artificial Drainage
  - Enhanced removal of salty groundwater
- Artificial Recharge
  - Application of water to enhance leaching



# Solution

- Multi tasking approach to flush salts through the system and dispose off site
  - Sufficient recharge to move salts out of soil zone to water table
  - Sufficient drainage to move salts to collection point
  - Removal and Disposal of Waste Water



## How?

- Install artificial drainage and pump system to remove saline water, create a hydraulic gradient and lower water table
- Desalination of leachate water
- Blend treated water to meet soil chemistry requirements
- Leach salts from soil profile by applying treated water
- Dispose of process waste water



# The Plan

- Removal of remaining infrastructure including pipelines
- Excavation and off-lease disposal of hydrocarbon and major salt impacted soils
- Creation of buried sump for leachate recovery
- Hydraulic fracturing of brine impacted soils
- Installation of injection wells
- Operation of desalinization unit to treat water with injection of processed water





Excavated Pipelines

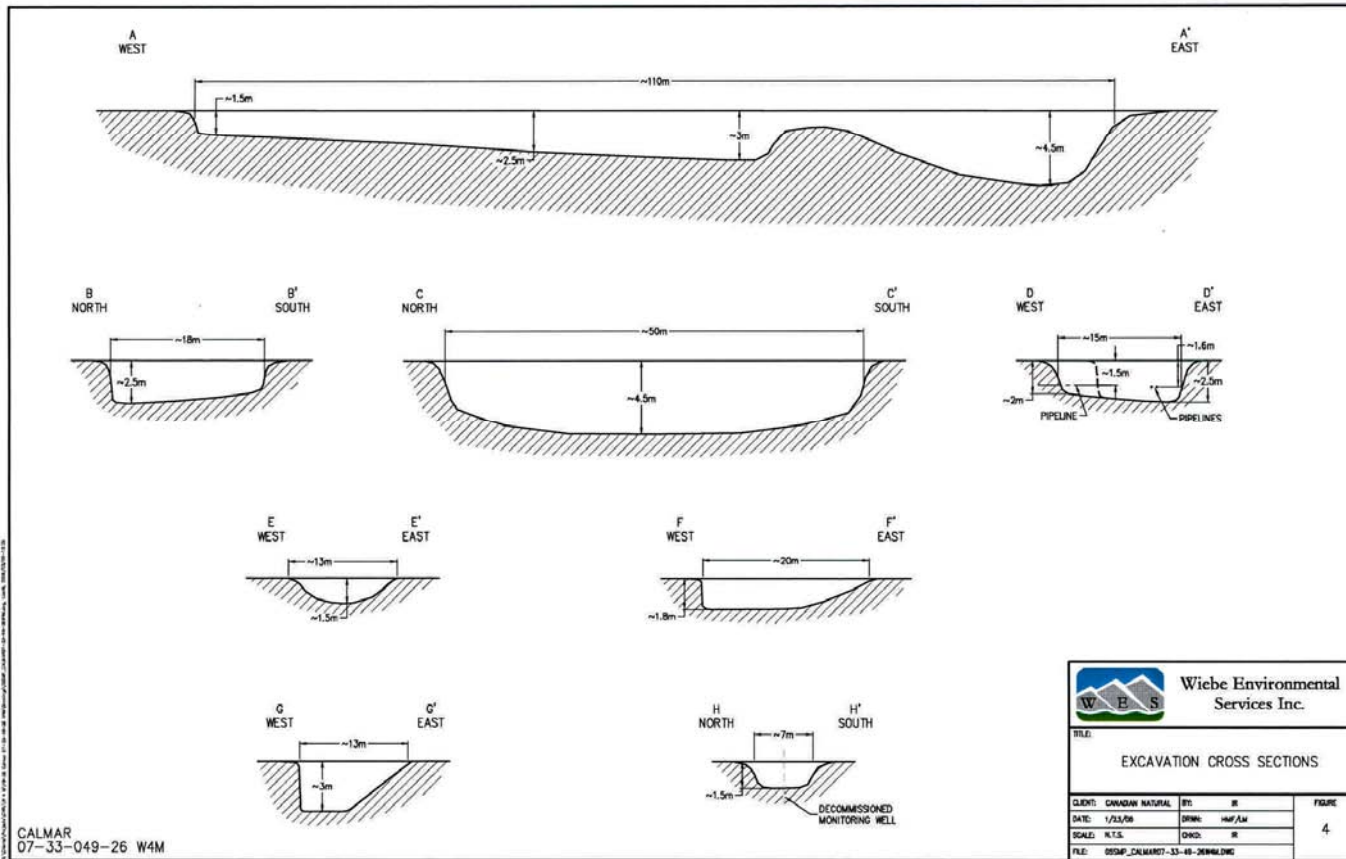







Former Flare Pit Excavation





CALMAR  
07-33-049-26 W4M

 <b>Wiebe Environmental Services Inc.</b>	
TITLE:	
EXCAVATION CROSS SECTIONS	
CLIENT: CANADIAN NATURAL	BY: JR
DATE: 1/23/09	DRAWN: JMF/JM
SCALE: R.T.S.	CHECK: JR
FILE: DESM_CALMAR07-33-049-26W4M.DWG	
FIGURE	
4	



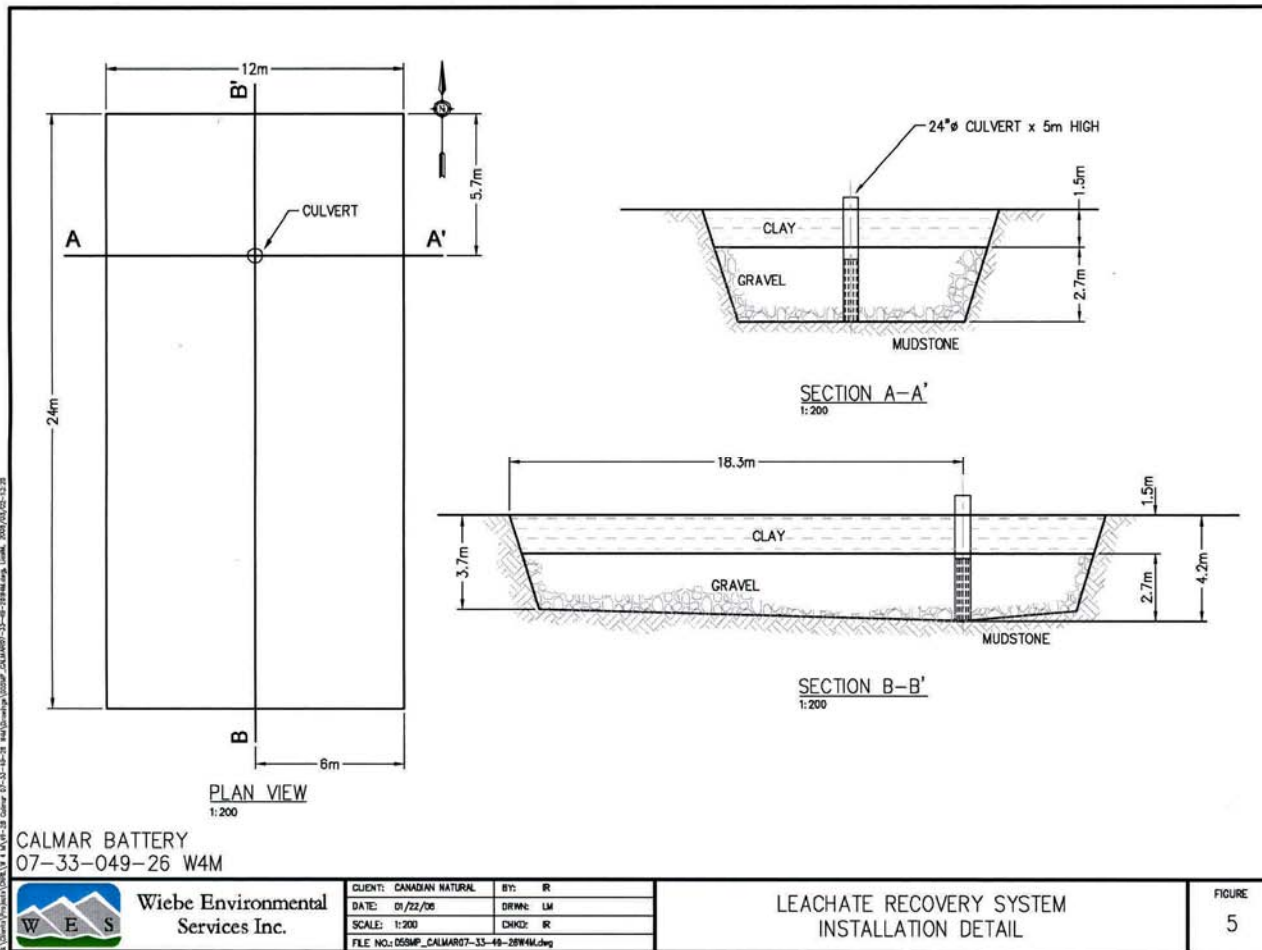
# Excavation Profiles





## Leachate Recovery System





## Leachate Recovery System Profiles





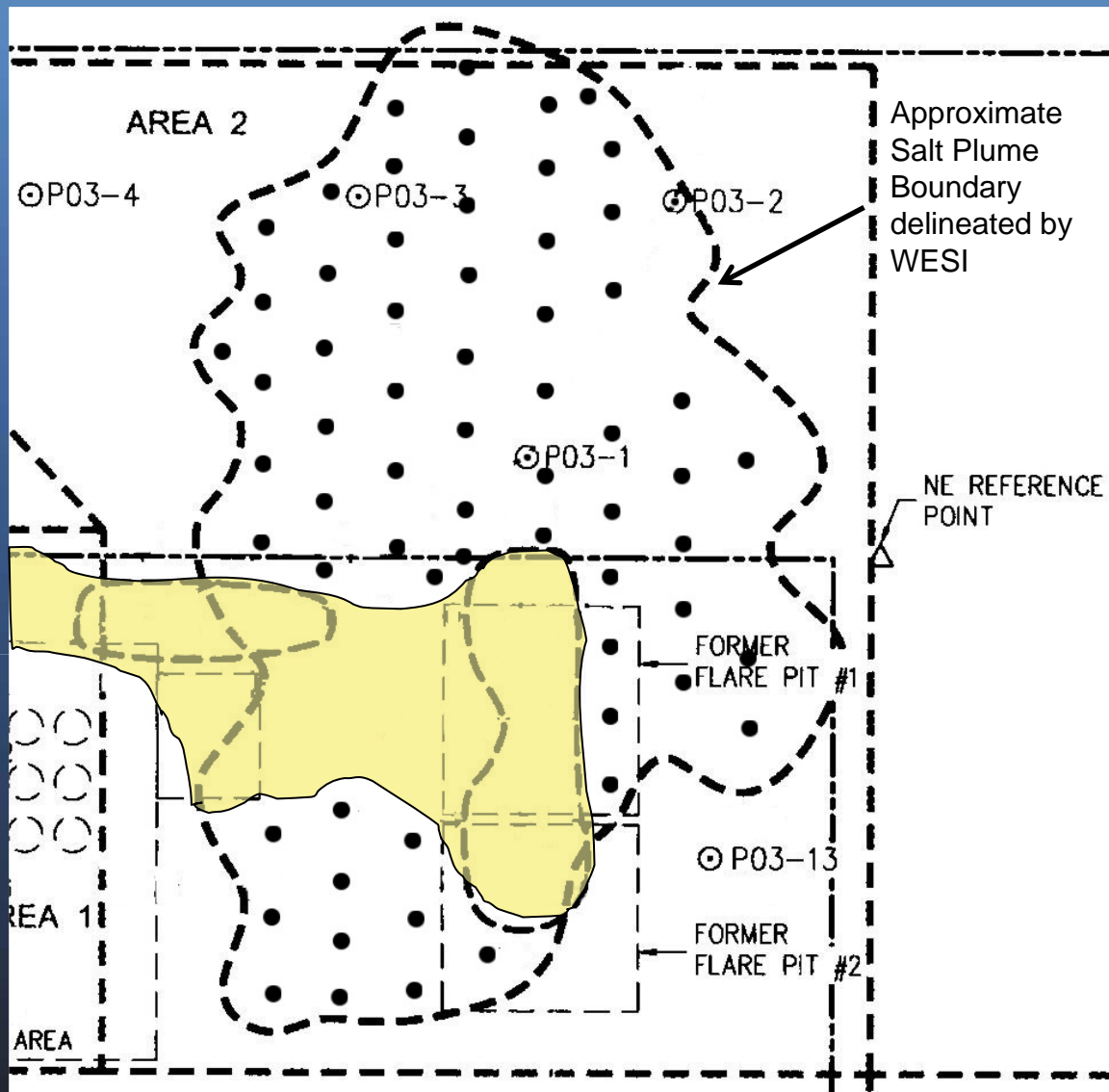
After Backfilling and Leveling



# Hydraulic Fracturing

- Fractures initiated using Direct Push Fractool and drilling string
- Fracture mapping with surface mounted tilt meters
- 65 fracture boreholes within the salt plume emplaced 221 drainage fractures containing 207.1 tonnes of sand
- Theoretical fracture radius was 6 m with fractures up to 11 m observed in the field
- Fracture break pressures ranged from 1,000 kPa to 1,500 kPa
- Fracture mapping conducted on 47 fractures to confirm placement and connectivity





Hydraulic Fracturing Injection Locations





## Fracture Emplacement of Sand Slurry

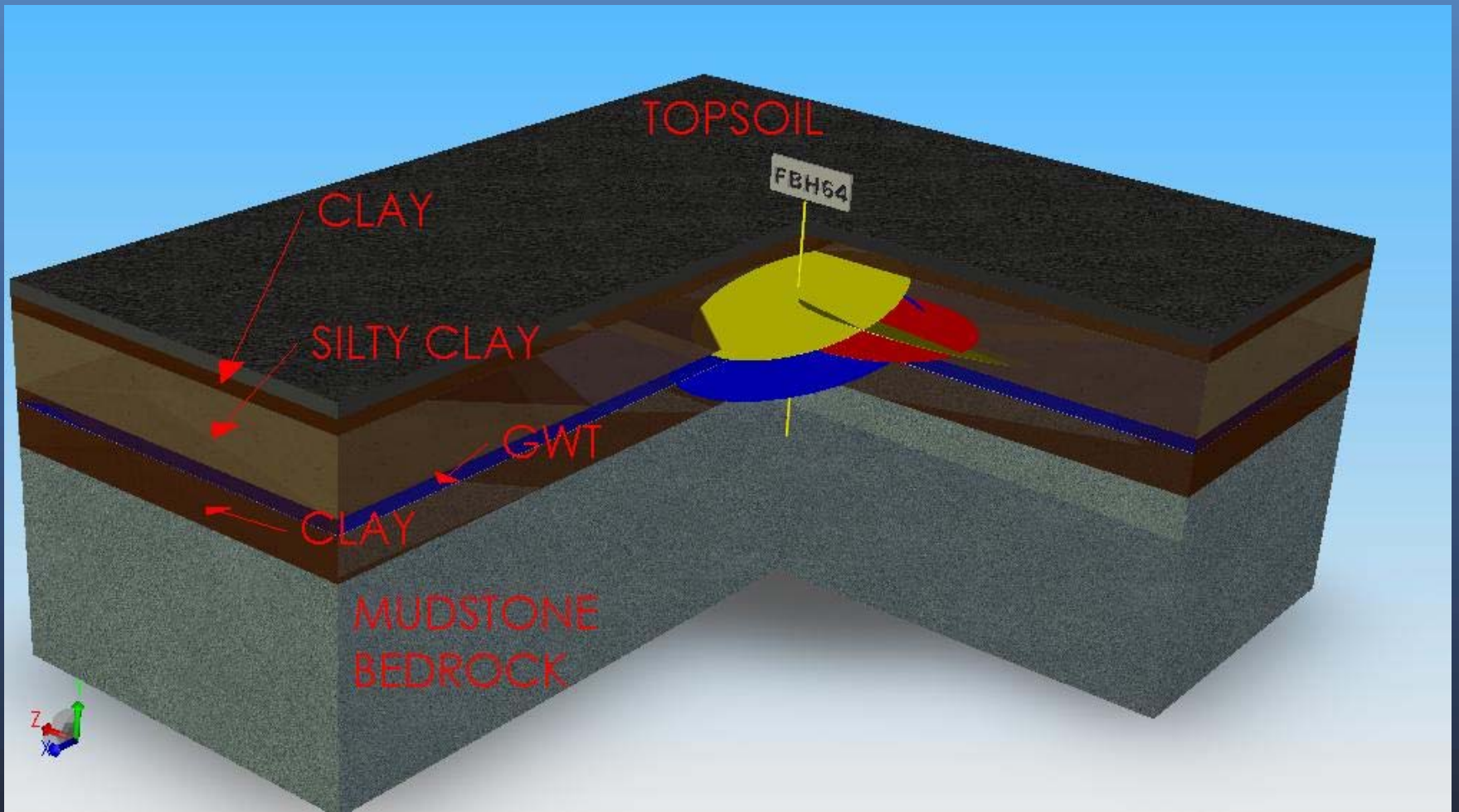






Environmental Fracturing Unit



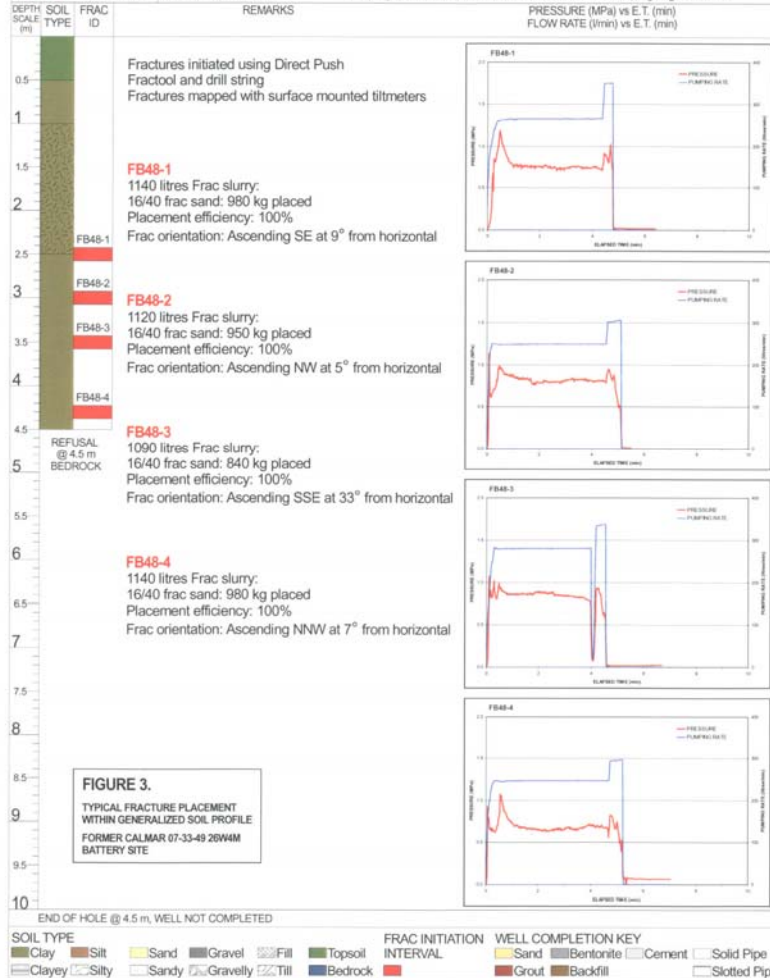


## Conceptual Model of Hydraulic Fracturing





Fracture Well Number : FB-48 Client : Canadian Natural Resources Limited Frac Supervisor : GB & GG  
 Date : 14 December 2005 Drilling Contractor : EarthProbe Technologies Drill Rig : Direct Push  
 Job number : 05FR09 Pumping Contractor : Frac Rite Environmental Pumping Rig : EF9300



FRAC RITE ENVIRONMENTAL LTD.



# Fracture Placement



# FRACTURES AT FBH48

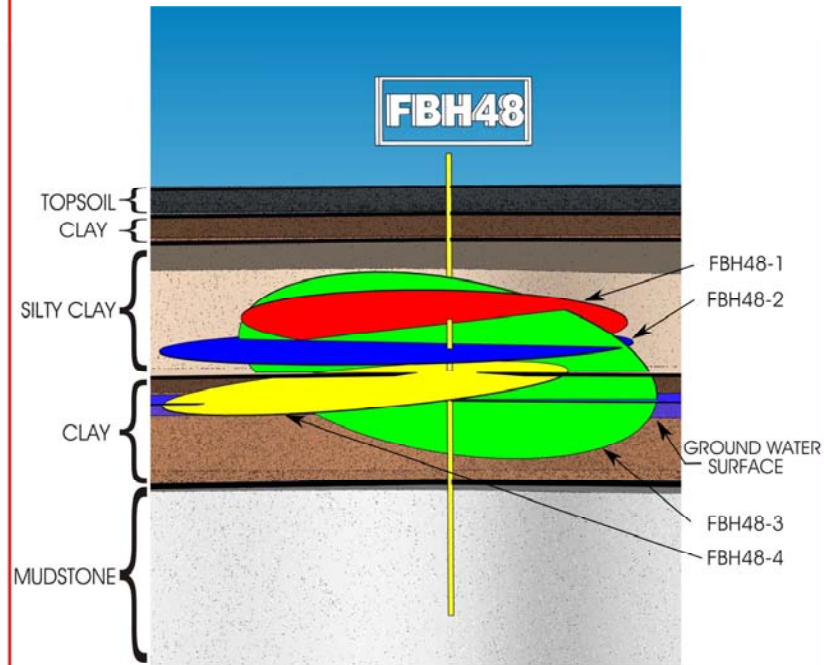


Figure III-9

Three-dimensional representation of sand drainage fractures at Fracture Borehole FBH48



## Sand Drainage Fractures





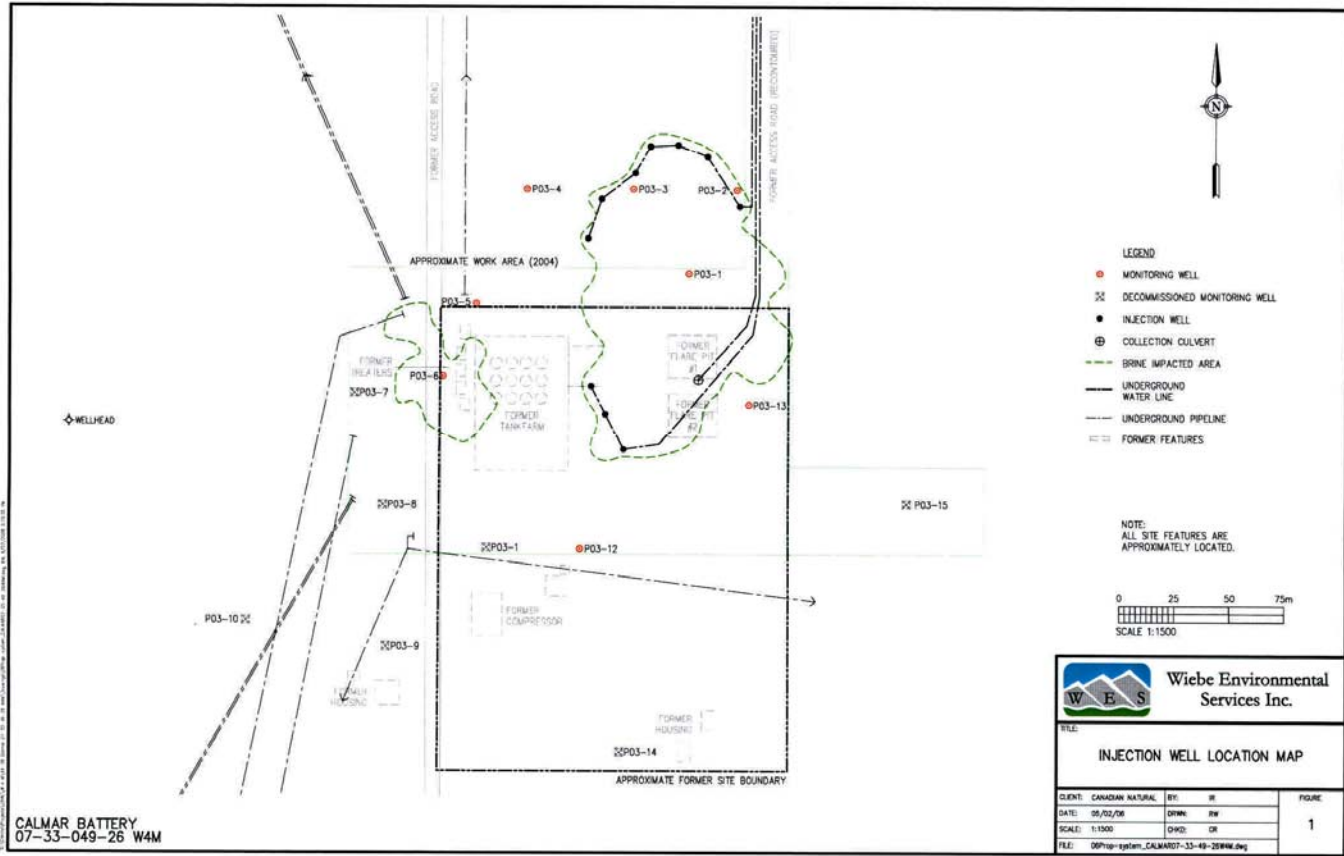
Fracturing Locations



# Injection Wells

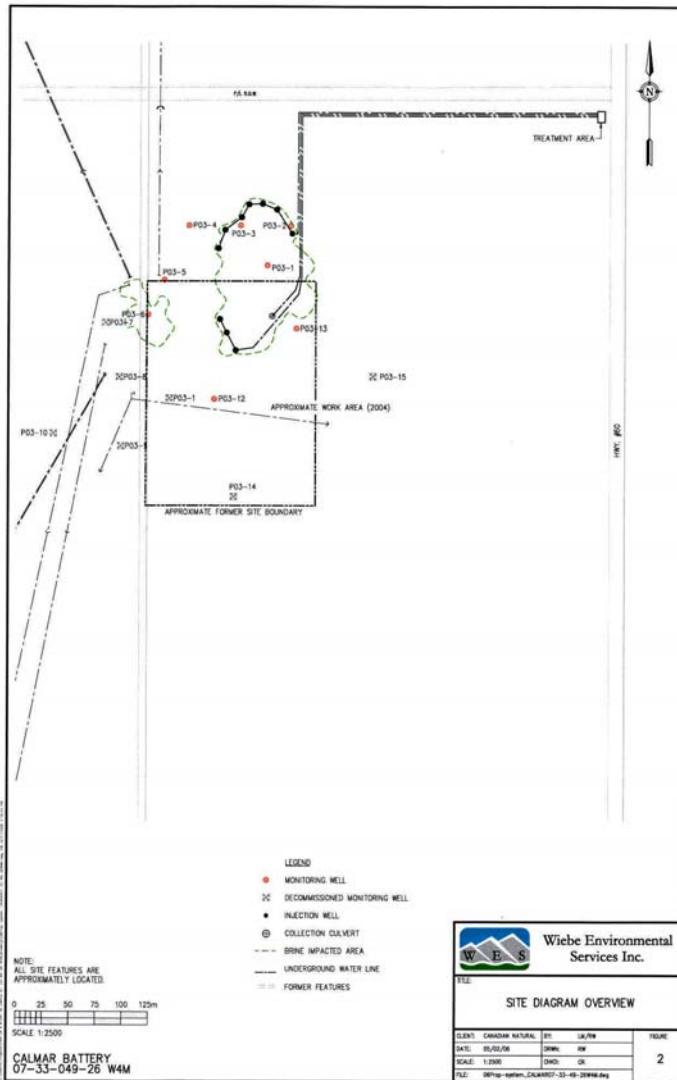
- Injection wells installed to re-circulate treated groundwater through the salt plume
- Wells placed to bypass the non impacted upper 1.5 m of the soil profile
- Wells completed within fracture boreholes for maximum effect
- Injection wells placed at upgradient perimeter of salt plume to maximize head differential and promote flow towards the leachate collection sump





# Injection Well Location Map

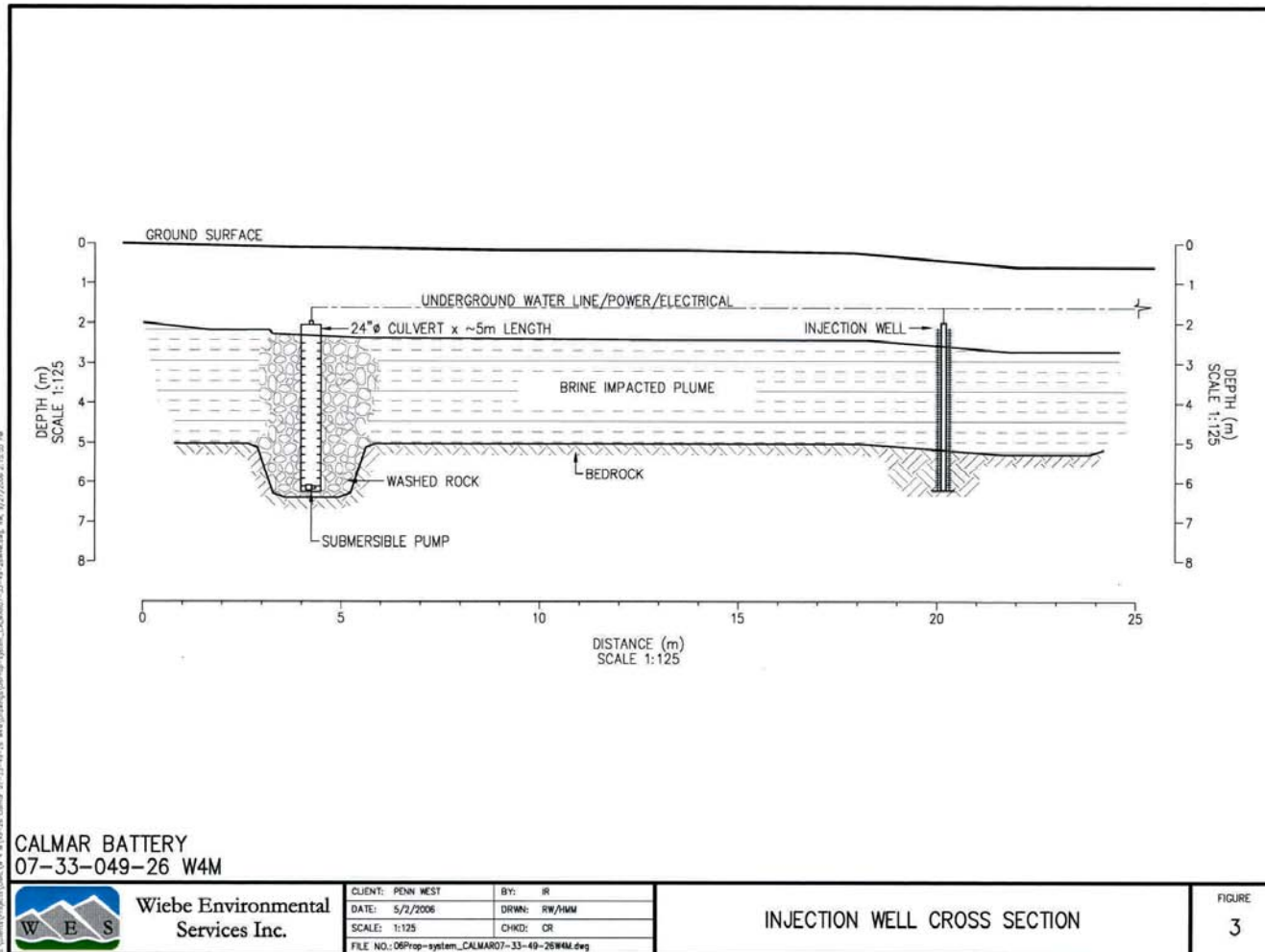




Treatment Site Overview







# Injection Well Installation Profile





Feed Lines for Injection Wells





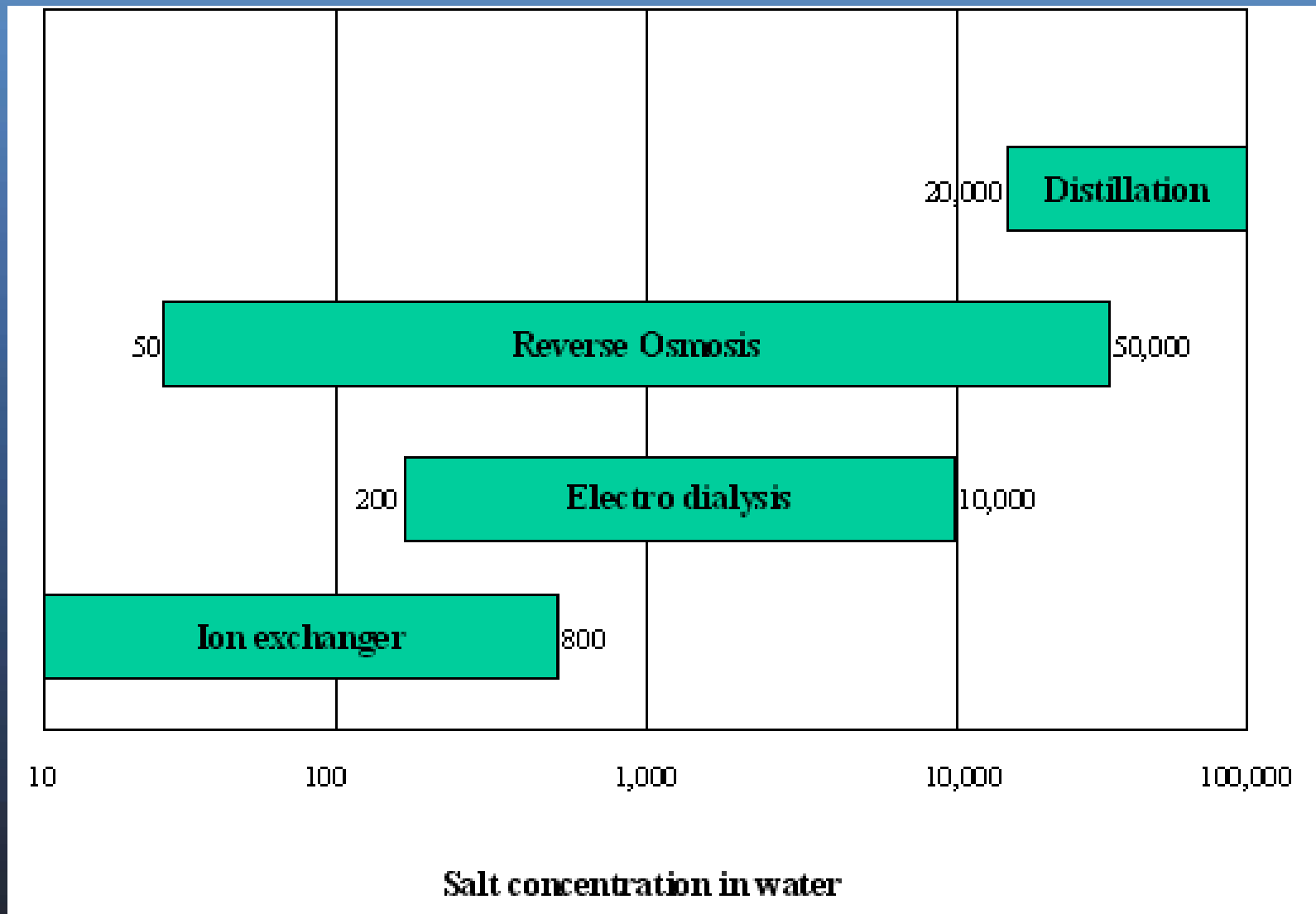
Pad Preparation



# Desalination Processes

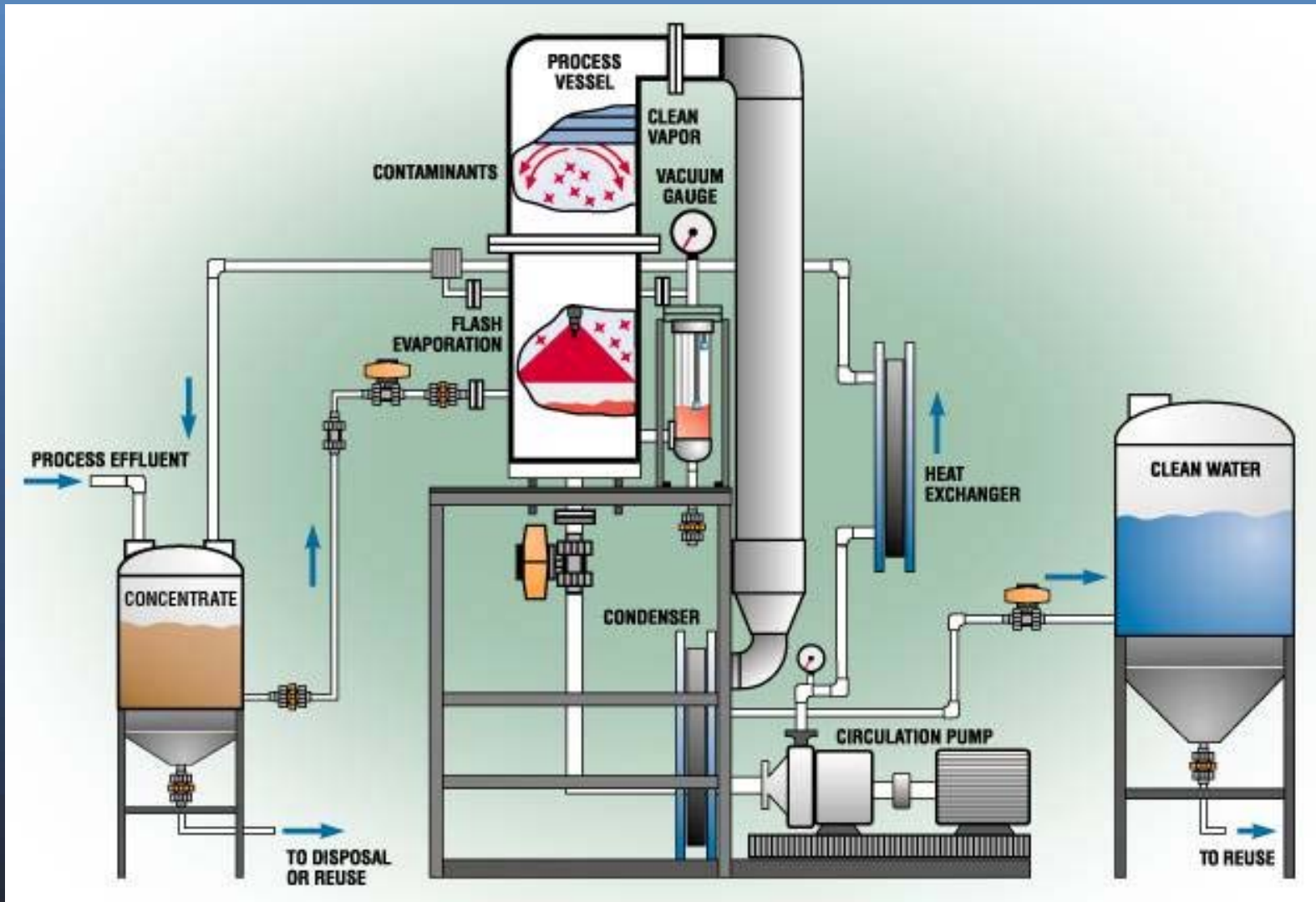
- Thermal
  - Multi-Stage Flash Distillation
  - Multi Effect Distillation
  - Vapour Compression Distillation
- Membrane
  - Electrodialysis
  - Reverse Osmosis





## Concentration Range of Effective Technologies





Flash Distillation Process





Some Assembly Required





Getting the Bugs Out





## What Next

- Optimise system to improve efficiency and track remediation results
- Track volumes and costs to determine cost effectiveness and break even threshold
- Develop site specific remediation alternatives for other sites
  - Flood irrigation
  - Surface water treatment



