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Groundwater Monitoring Optimization for a Long Term, Large-Scale Program in Swan Hills, Alberta

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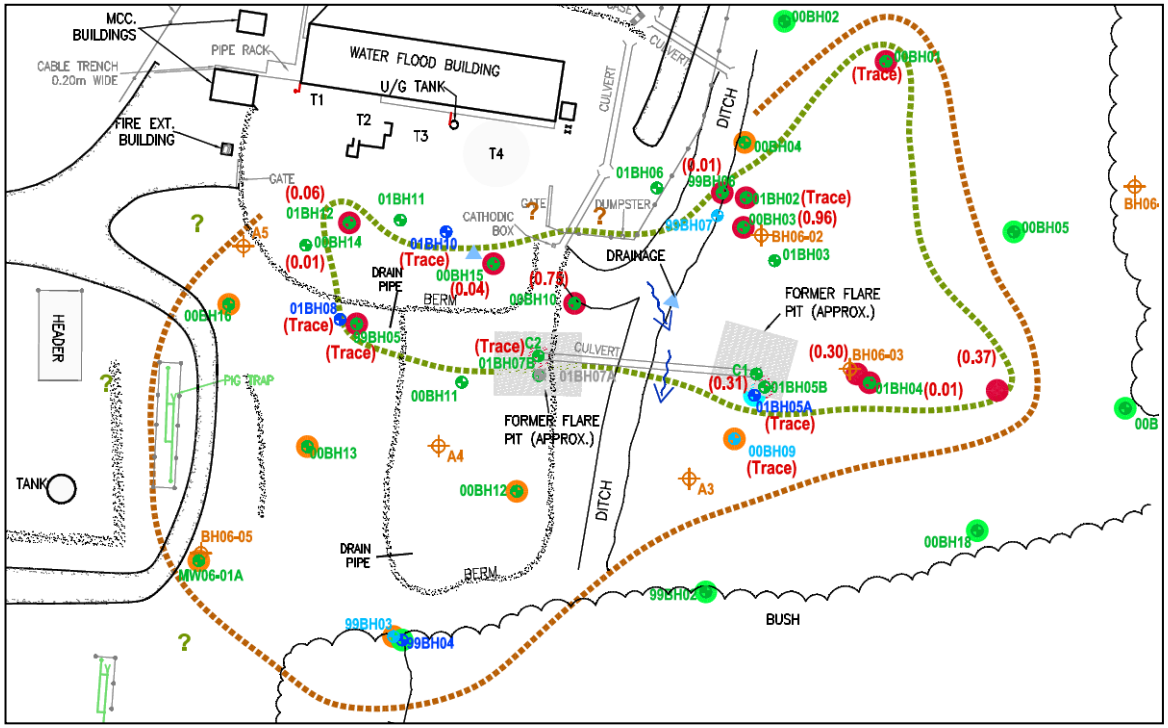

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Presentation Outline

- Introduction to field
- Environmental risk strategy
- Monitoring program
- Results to date
- Cost optimization
- HC in the soil phase vs. the dissolved phase
- Summary and moving forward

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Field Location

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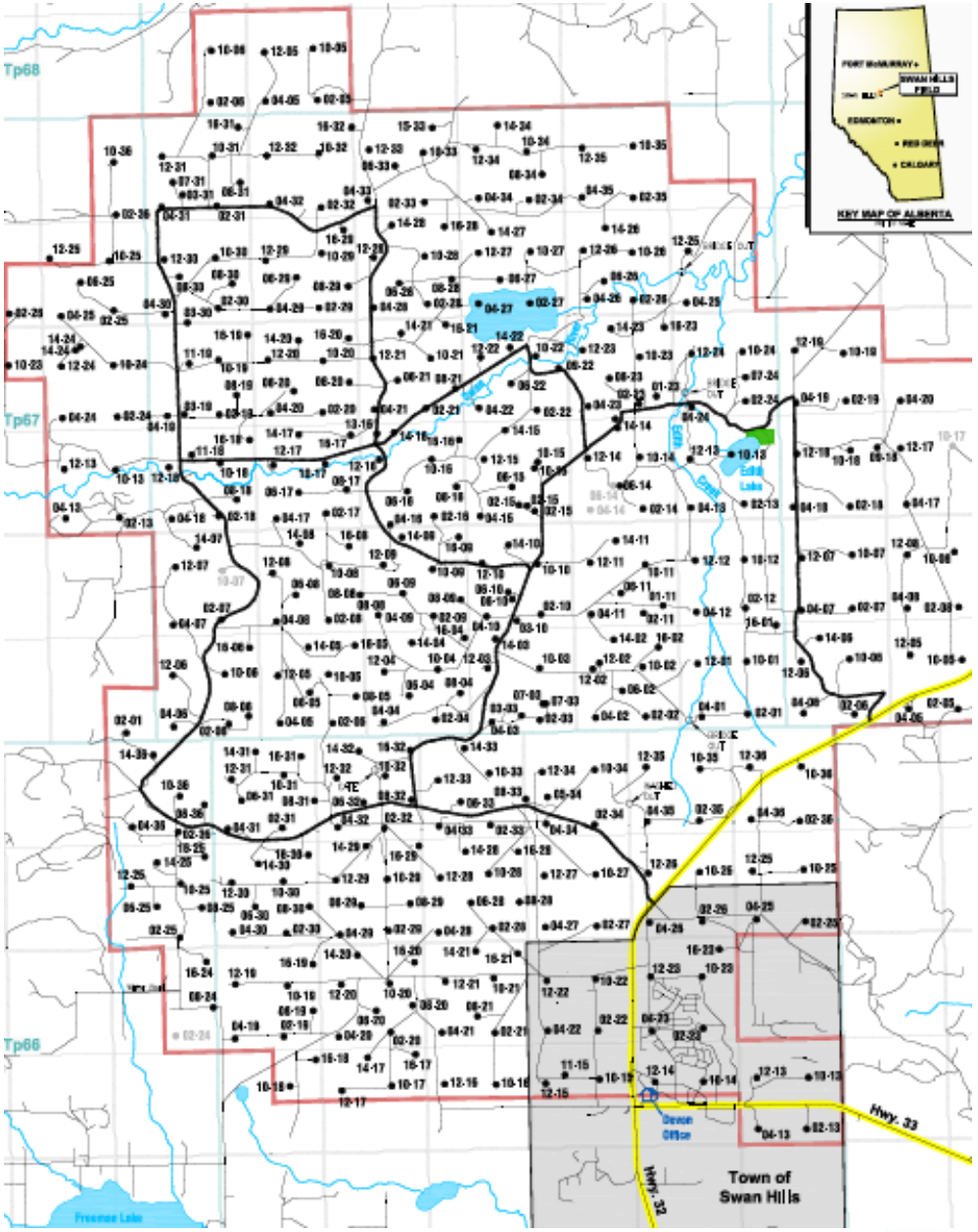
Swan Hills Field

- Approximately 420 km^2
- Devon operates on behalf of more than 20 production companies
- 400+ operating or suspended sites
- Initial development in 1950s, peak production in mid-1970s



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Flare Pits and Drill Sumps

Flare Pits – Contaminant Migration

Sumps – Limited Migration

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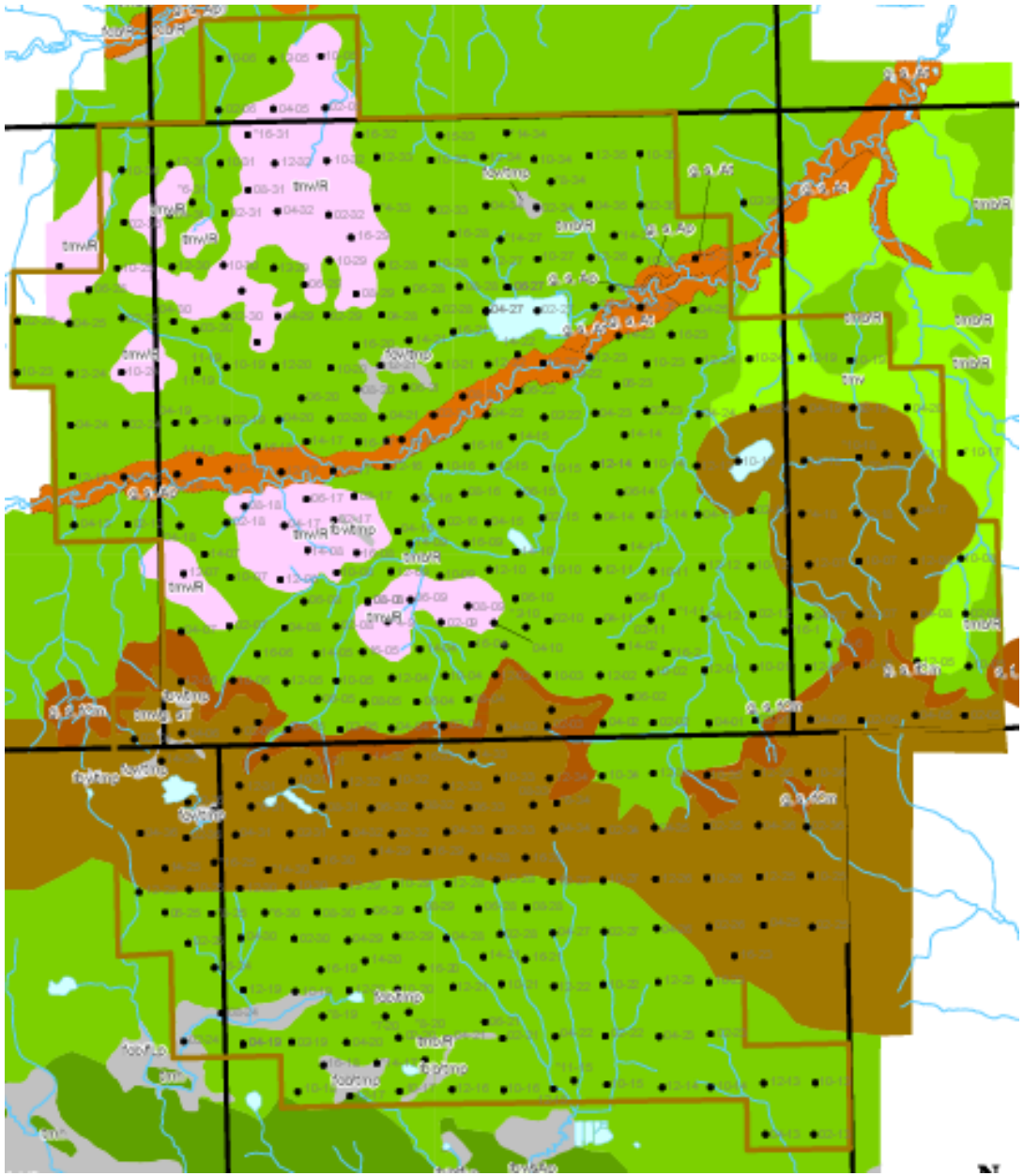
Surficial Geology

- Morainal till deposits
  - Pink – thin till (<1m)
  - Green – thicker till (≥3m)
- Brown – Sands and gravels
- Orange - Alluvial sands and gravels along the Swan River
- Grey – Peaty/mossy deposits



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Regulatory Framework – Swan Hills Field

- Compliance with AEW Tier 1 - most straightforward way to achieve closure

- Developing site-specific criteria to provide reachable alternatives, if necessary

Environmental Risk Strategy – Swan Hills Field

- The assessment and remediation program consists of three main activities:
  - environmental site assessments (ESAs);
  - source material management; and
  - post-remediation monitoring, if required

Groundwater assessment and monitoring

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Risk-Based Closure

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Key components of closure strategy:

1. Source removal to the extent practical
2. Long term (but not perpetual) monitoring
3. Achievable risk-based remedial objectives appropriate to the remote boreal forest setting of the Swan Hills field

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Groundwater Monitoring Program - Overview

109 sites instrumented (87 monitored in past 5 yrs)

Contaminants of concern: weathered petroleum hydrocarbons

Focus on natural attenuation (NA) and status of dissolved plumes (shrinking, stable or increasing)

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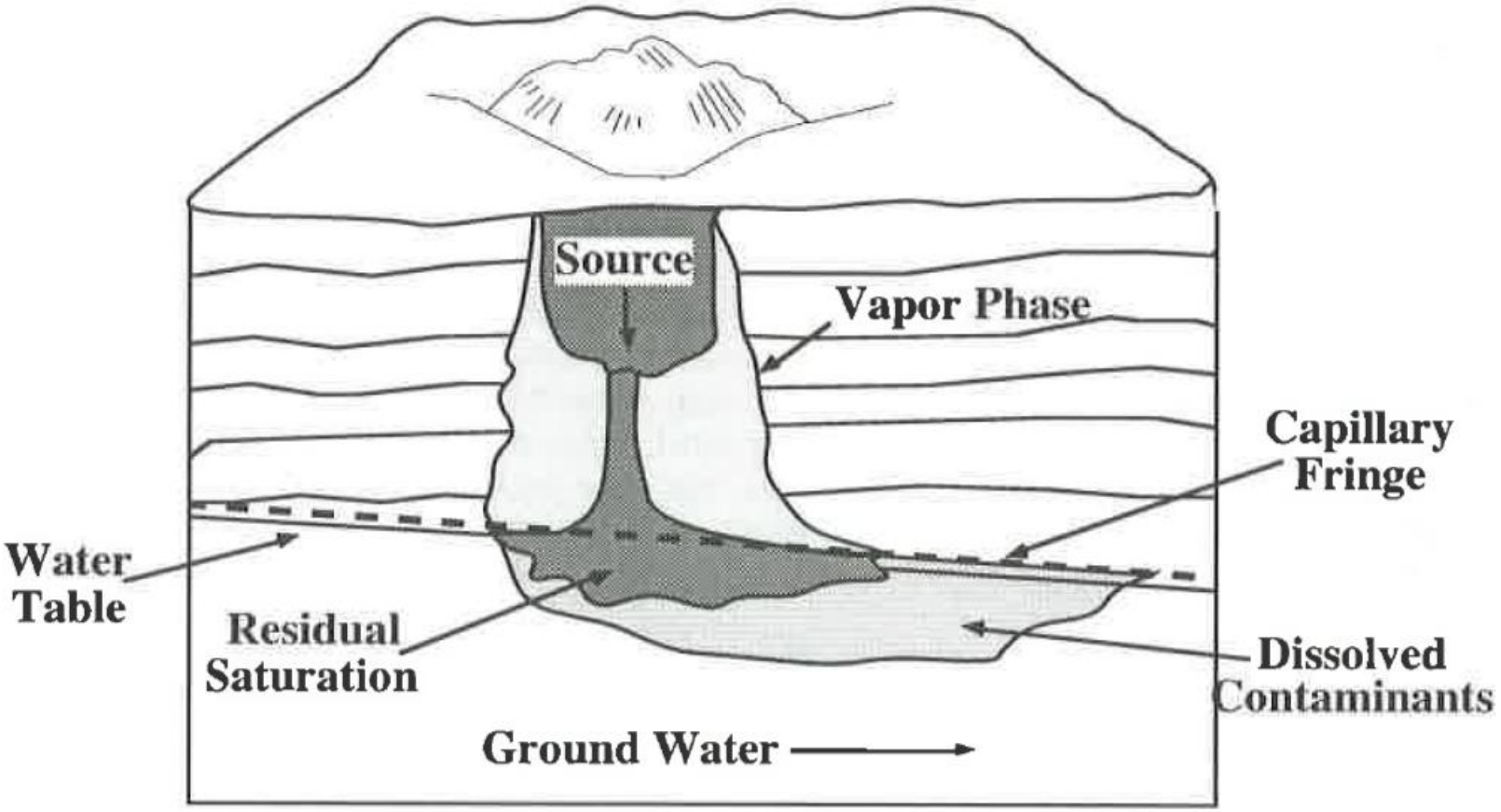
Natural Attenuation



From Norris et al. 1994

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Sampling Frequency

- 3 monitoring events for gw characterization
  - Routine, HCs, metals and PAHs
- Discontinue seasonal monitoring - no seasonal variability observed for dissolved phase at 109 sites
- Ongoing sampling where risk to off-site receptors

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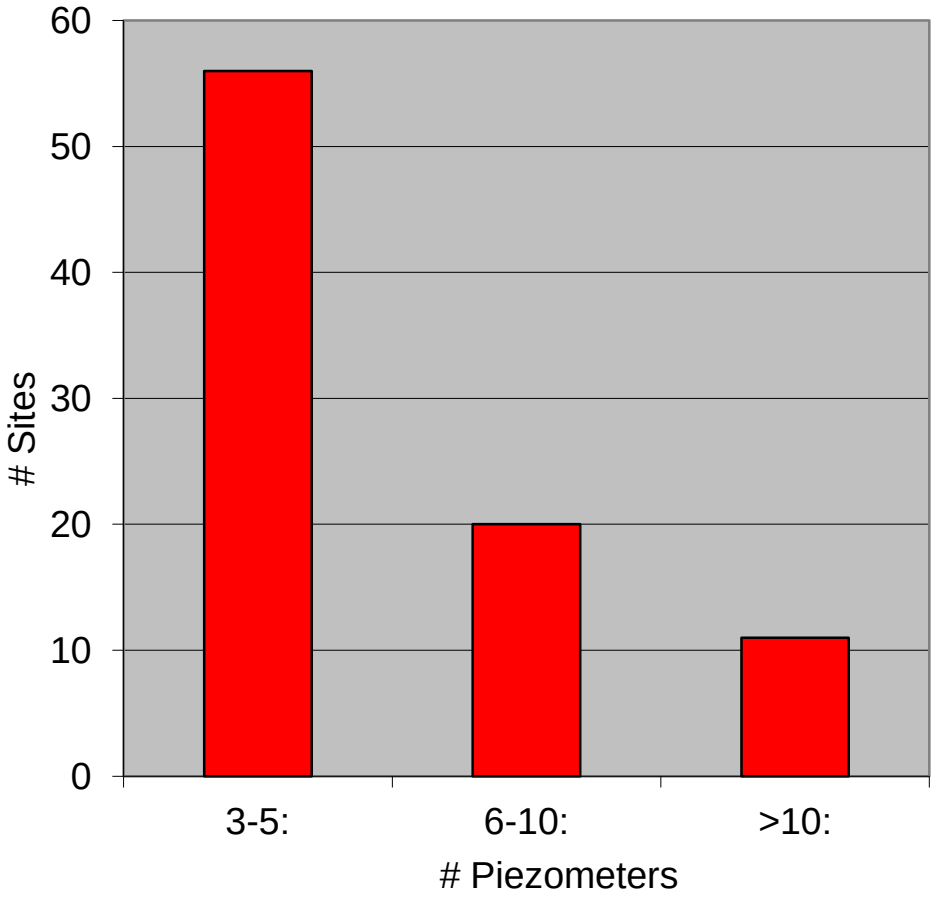
Number of Piezometers Per Site

- Range – 3 to 43
- Median – 5



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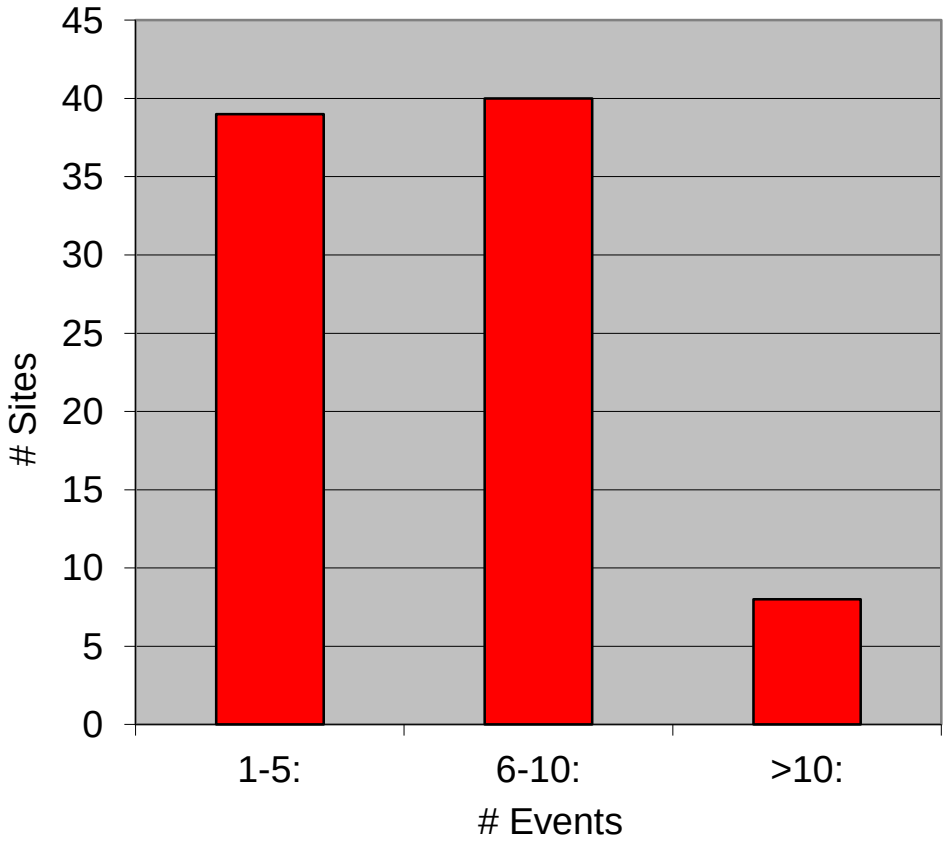
Number of Monitoring Events Per Site

- Range – 1 to 18
- Median – 6



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Results – Number of Plumes Identified

HC Phase	No. of Multi-Point Plumes	No. of Single Point Plumes	Total No. of Plumes
Free	8	9	17
Dissolved	19	25	44

- Encompasses BTEX compounds and HC F1 and F2
- Free phase excluded detections of trace free product or hydrocarbon sheen (1 cm minimum thickness)
- Dissolved phase plumes = concentrations of at least one component exceeded the AEW Tier 1 groundwater remediation guideline

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Results – Plume Trends

Plume Trend	Free Phase	Dissolved Phase
Increasing	0 (0%)	1 (2%)
Decreasing	3 (18%)	6 (14%)
Stable	14 (82%)	37 (84%)

- Free phase trends based on thickness
- Dissolved phase based on concentrations

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CORONA Research Project

- COnsortium for Research On Natural Attenuation
- Reviewed monitoring data from 124 Alberta upstream oil and gas facilities for evidence of NA
- Included sites in Swan Hills Field

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Plume Trends – CORONA vs. Swan Hills

- CORONA - 102 HC plumes; Swan Hills – 44 HC plumes

Dissolved Plume Trend	CORONA	Swan Hills
Increasing	6%	2%
Decreasing	26%	14%
Stable	47%	84%
Variable	21%	0%

- No correlation between plume classification and geologic setting, geographic location, permeability and flow velocity

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Groundwater Monitoring - Costs

Year	# of Sites	Lab Costs ($)	Total Costs ($)
2007	55	116,000	355,000
2008	54	68,000	343,000
2009	17	18,000	101,000
2010	56	82,000	394,000
2011	32	49,000	224,000
2012	2	2,000	12,000

Cost optimization:

- Fall 2007 – implemented no-purge sampling
- Spring 2008 – critical review of frequency and analytical
- 2011 – less frequent sampling for low impact sites
- 2012 – reduced monitoring

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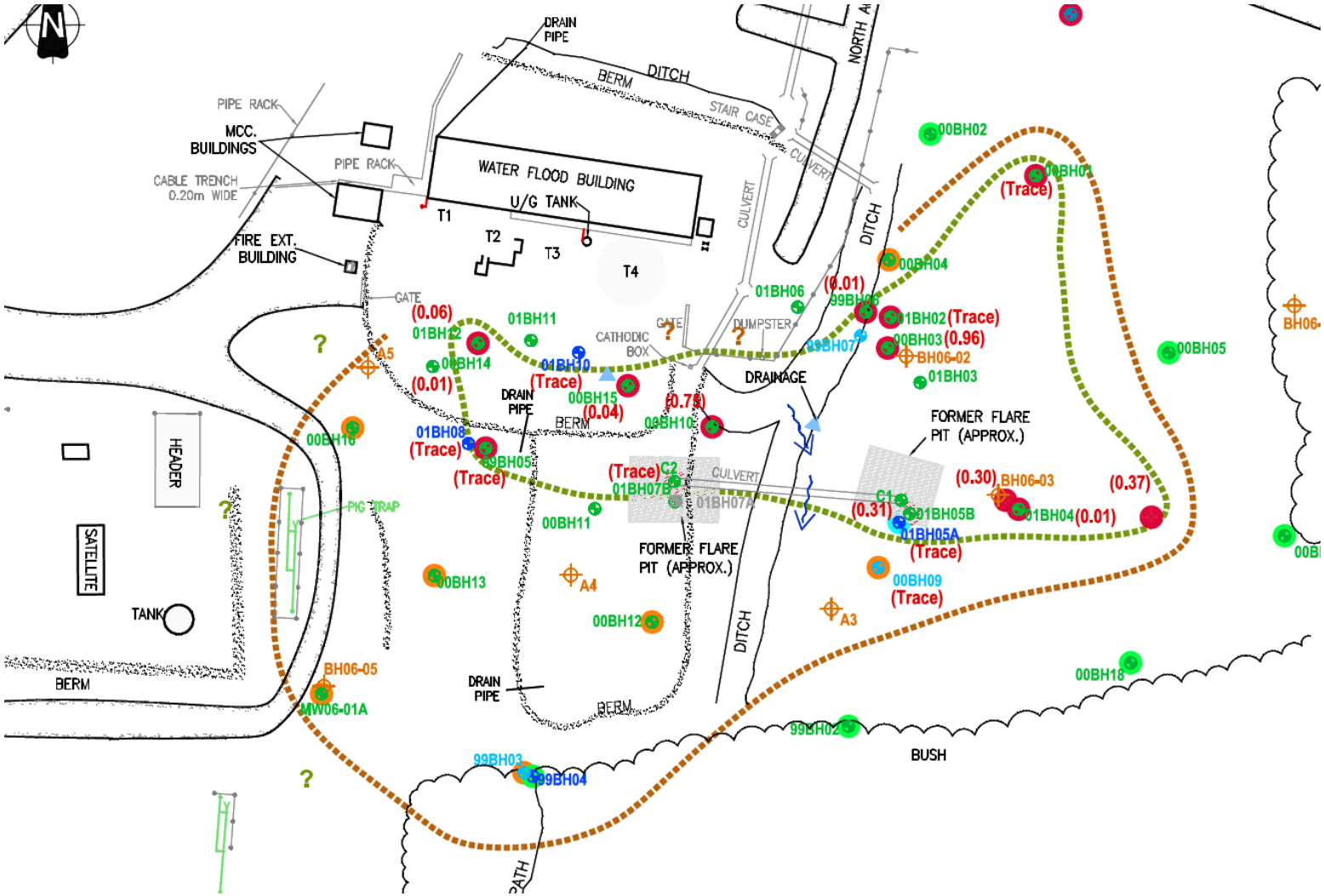
Heavily Instrumented – Traditional Approach



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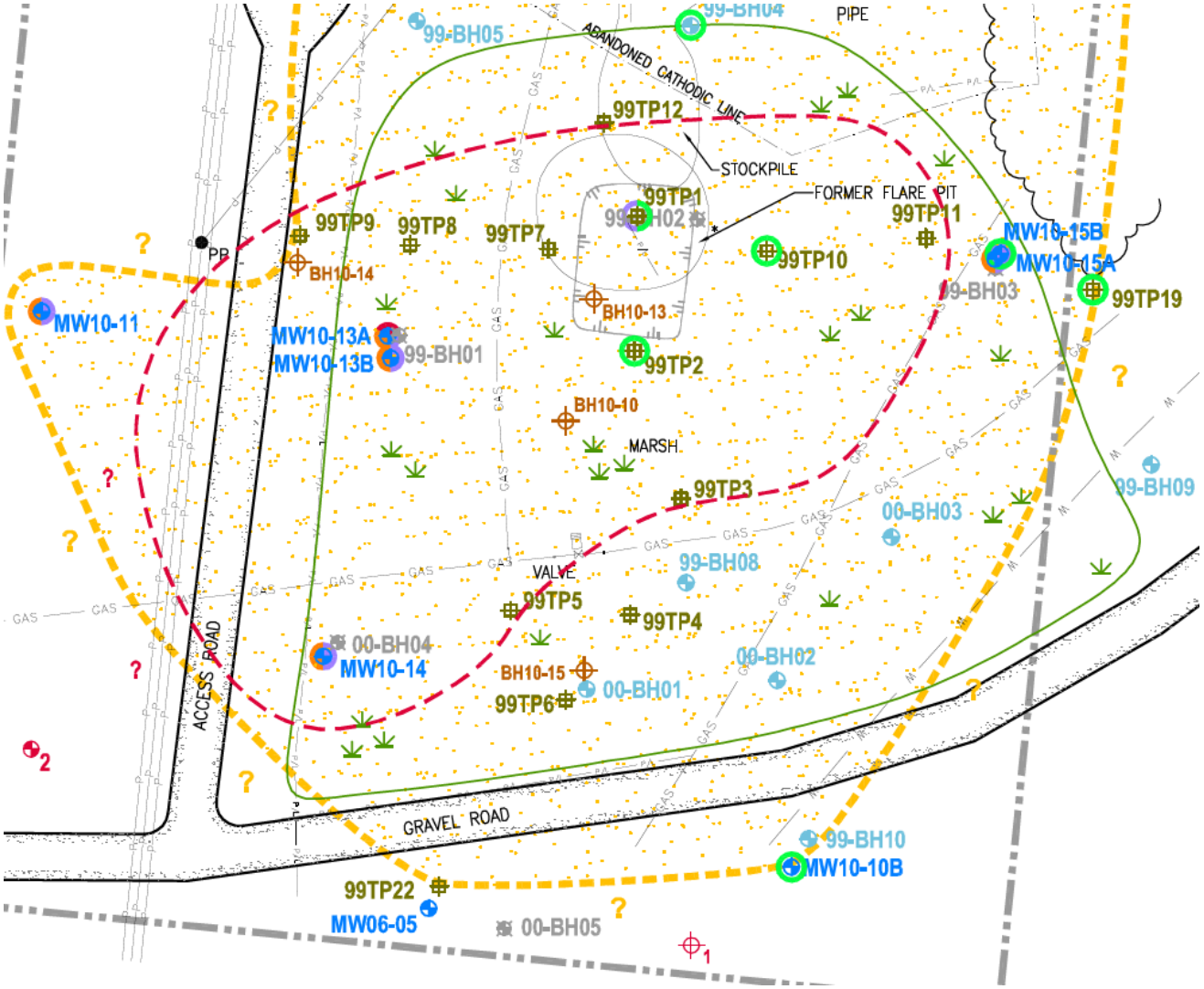
How Many Piezometers Required for Delineation?



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Soil HC vs. Dissolved HC Concentrations

- What dissolved HC concentrations result from soil HC impacts?

- Is there a “threshold” concentration where the need for groundwater investigation could be reduced or perhaps eliminated?

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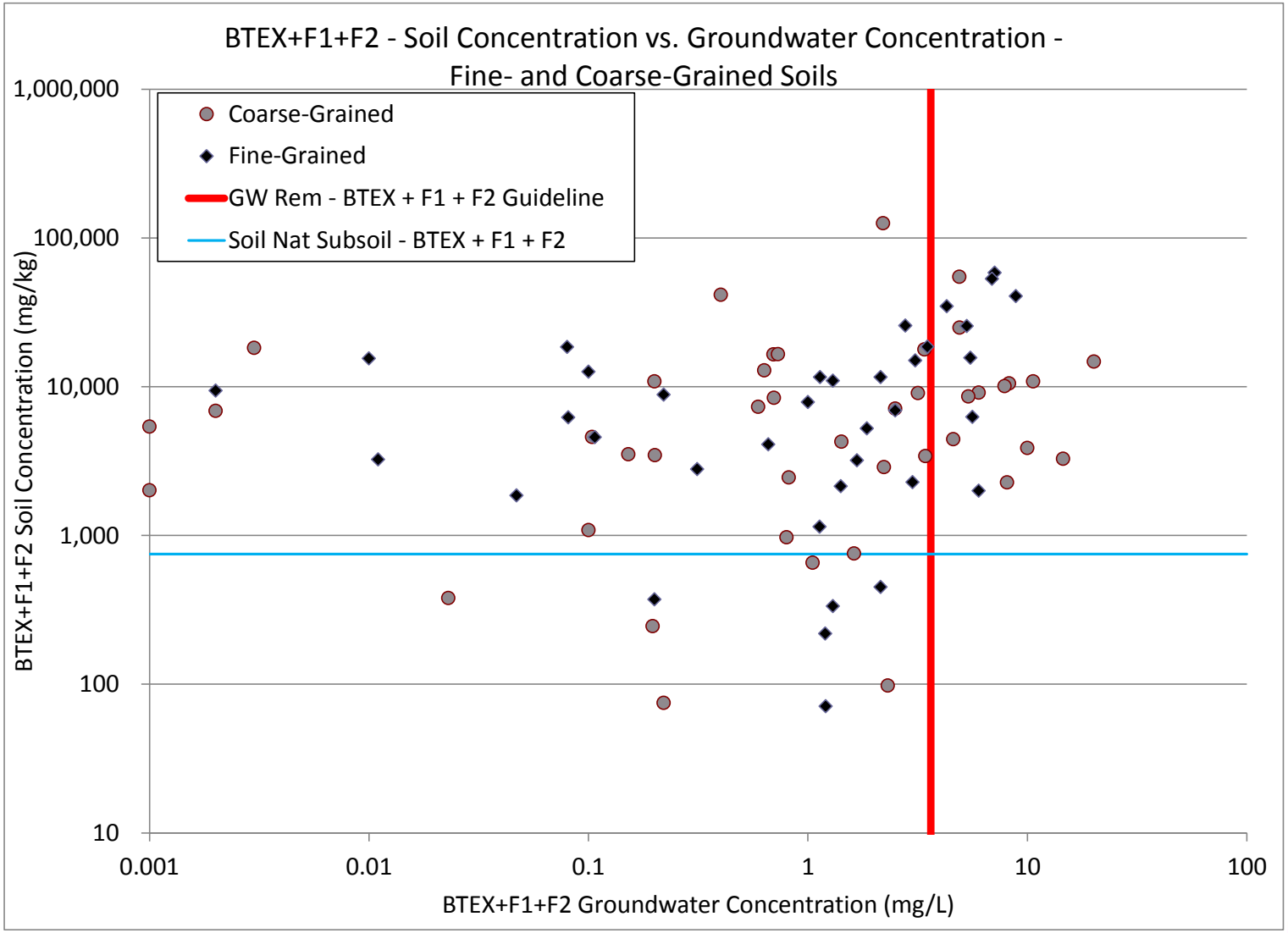
Soil HC vs. Dissolved HC Concentrations



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Summary

- 88 sites - 16% free phase, 40% dissolved plumes
- 98% of HC plumes in field are stable or decreasing (agrees with literature)
- Monitoring frequency reduced due to steady-state conditions
- Supplemental delineation has had limited benefit
- No dissolved phase concentrations exceeding guidelines at soil concentrations <2,000 mg/kg (88 sites)

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Moving Forward

- Critically review the need for **a)** ongoing monitoring and **b)** complete plume delineation
- Determine what the protocol/requirements are for monitoring to support site closure
- Develop a standardized, results-based protocol for ongoing/future monitoring