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Development of Field-Wide Risk Based Remediation Objectives for An Aging Oilfield

Devon Canada Swan Hills Field

RemTech 2006

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Swan Hills Facilities

- Original discovery well 1956
- Major development in 1950s and 1960s
- Miscible injection in 1980s
- Currently 385 operational oil wells
- About 25 abandoned wells
- CO₂ injection pilot undertaken in 2005





- Sequential completion of Phase 1 and 2 investigations for approximately 400 sites
- Implementation of remediation for high risk and abandoned sites
- Construction of a purpose-built landfill to service the field







The Challenge !

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To develop a risk-based closure strategy for well sites.

- 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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Two Stage Approach:

1) Field Wide Background "Framework"

- define areas of common physical and ecological setting
- develop appropriate exposure scenarios
- 2) Site-specific risk assessment(s)
- adjust for site-specific conditions
- early demonstration project to prove concept



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Used a GIS approach to identify areas of common physical and ecological setting:

- Physiography
- Surface water
- Land use (town, forestry management areas, trap lines)
- Vegetation ecozones
- Surficial and bedrock geology
- Water well use

Compiled species lists for:

- vegetation
- terrestrial wildlife (mammals, birds, amphibians),
- aquatic species (fish and invertebrates)



Physiography







Geology and Vegetation





Risk Assessment Zones

- Four Natural Area "A" Zones:
- A1 = River valley
- A2 = Tertiary Sands and Gravels
- A3 = Moraine Blankets
- A4 = Organic Deposits (bogs and fens)
- One Residential "B" Zone:
- B = Town of Swan Hills







Swan Hills Natural Area Conceptual Exposure Model





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Swan Hills Residential Area Conceptual Exposure Model





10-18 Site Specific Risk Assessment

- Former Oil Well and Battery Site
- Drilled in 1960 and abandoned in 1963
- Former battery with 2 ASTs and a flare pit noted in 1966 airphoto
- All infrastructure removed by 1971
- Phase 2 investigations in 2003 and 2005.





1994 Aerial Photo





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WorleyParsons Komex

Major Contaminant Sources

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Problem Formulation

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Risk Zone A3

Morainal Blanket

Land Use

 Natural Area, within Blueridge FMA

Contaminants of Concern

- ▶ BTEX, PHC F1 to F4
- Arsenic, boron







Exposure Pathways - Soil

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Operable Pathways

- plant and invertebrate soil contact
- wildlife ingestion
- protection of potable groundwater

Inoperable Pathways

- protection of groundwater for:
 - aquatic life
 - wildlife ingestion
 - livestock





Petroleum Hydrocarbon Fraction 3 Eco-Contact Guideline

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Issues:

- •F3 guideline tends to be a remediation driver for crude oil contamination
- •Often not achievable through bio-treatment
- Hypothesis for guideline re-evaluation:
- •Boreal forest plant species may be less hydrocarbon sensitive
- •Weathered hydrocarbons may be less bioavailable and less toxic

Pathway	Fine Soil (mg/kg)	Coarse Soil (mg/kg)
Soil Contact	800	400
Wildlife Soil Ingestion	17,000	17,000
Subsoil Management Limit	3,500	2,500



Conventional Test Species	Endpoints
Northern wheatgrass	▶emergence
Perennial rye	►root length
Alsike clover	►shoot length
	►shoot and root mass (wet/dry)
Env Canada Boreal Species	Endpoints
Trembling Aspen	▶emergence
Black spruce	►root length
White spruce	►shoot length
Bluejoint reedgrass	►shoot and root mass (dry)
Canada goldenrod	



Test Species	Endpoints
Earthworm (<i>Eisenia andrei</i>)	Survival, reproduction, progeny mass
Springtail (Folsomia candida)	Survival, reproduction, fecundity







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Bioassays

 Screening level test using 100% "strength", PHC F3 ~ 7,000 mg/kg or 10,000 mg/kg

Definitive tests:

- Geometric series of concentrations:
- 0% (background reference soil)
- ▶ 1%, 2.5%, 5%, 10%, 20%, 40%, 60%, 100% "strength"
- ▶ Used to identify LOAEC, NOAEC, EC₂₅, EC₅₀



Black Spruce Emergence





Black Spruce Definitive Test

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artificial, background, 1%, 2.5%, 5%, 10%, 20%, 40%, 60%, 80%, 100%





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Guideline Data Requirements:

- CCME guideline minimum requirement:
- 10 endpoints from 3 species
- This study: 10 species providing up to 52 endpoints

Eco – Contact Guideline:

- ► 25th percentile of the EC₂₅
- Endpoints screened for validity (statistically and biologically relevant, monotonic etc).



Rank Sensitivity analysis of EC/IC All "Acceptable" Datapoints



Rank Sensitivity analysis of EC/IC Boreal Forest and Invertebrates Only

- Remediation ongoing at a second site using the same site-specific F3 guideline
- Screening level bio-assays will be completed on "clean" samples from excavation perimeter to validate F3 guideline
- Testing will be limited to 2 boreal plants and 1 invertebrate species

- Field wide review and development of "risk zones" completed
- Site-specific risk assessment completed for demonstration site
- Regulatory review underway
- Foundation for Field Wide Risk Assessment
- Application to other fields / regions

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