





# Cleaning Up a Salt Spill:

#### Predictive Modelling and Monitoring Natural Attenuation to Save Remedial Costs

CONSULTING ENGINEERS AND SCIENTISTS

Edmonton • Calgary • Vancouver • Nanaimo • Kelowna • Inuvik



Lethbridge • Fort St. John • Whitehorse • Yellowknife





- Introduction
- Remedial Alternatives
- Alternate Approach: Site Assessment and Predictive Modelling
- Importance of Predictive Modelling for Remediation by Natural Attenuation





- Site located in central Alberta.
- Pipeline break on September 6, 2002 caused by corroded pipe.
- Approximately 5,250 m<sup>2</sup> affected area.
- Initial spill response (by others):
  - standing fluid (produced water and oil) removed by vacuum truck;
  - trenches excavated along and downslope of spill area;
  - limited soil and trench water quality data collected; and
  - geophysics survey (EM 38).
- Shallow groundwater table present.



## Site Plan

00







# Remedial Alternatives (16,000 m<sup>3</sup> in situ)

- Traditional dig and dump (\$2.1M to \$2.5M).
- Pump and deep well disposal (\$1.0M to \$1.3M).





# EM38 Survey (September 2002)





# EM38 Survey (September 2002, 2003)











- Electromagnetic (EM) survey 2004.
- Groundwater flow regime.
- Soil and groundwater quality data.
- Vegetation survey.
- Predictive modelling vs. observed water quality.



## Site Assessment: EM Survey (2003, 2004)

www.eba.ca









#### Site Assessment: Groundwater Flow Regime

www.eba.ca







#### Site Assessment: Groundwater Flow Net



HORIZONTAL SCALE: 1:800 VERTICAL SCALE: 1:100



www.eba.ca

- Fall 2002 (spill response info in source area):
  - maximum chloride (CI) concentration of 39,100 mg/Kg; and
  - maximum sodium adsorption ratio (SAR) of 49.7 dS/m and electrical conductivity (EC) of 29 dS/m.



# Site Assessment: Soil Chloride Concentration (Spring 2005)



# Site Assessment: Soil SAR Concentration (Spring 2005)



#### Spring 2005

- Spill Area:
  - chloride in shallow well (523 mg/L); and
  - chloride in deep (bedrock) well (27 mg/L).
- High EM38 Area:
  - chloride in shallow well (747 mg/L); and
  - chloride in deep (bedrock) well (6 mg/L).



# Site Assessment: Dissolved Chloride Concentration Profile Along Plume





- White spruce trees dying because of waterlogged conditions.
- Waterlogged conditions predate 2002 pipeline spill.
- Some regeneration occurring, but growth is inhibited because of salt water spill.
- Restoration plan for site reclamation provided to client.





# × 3



CREATING AND DELIVERING BETTER SOLUTIONS

000







00.0





00





ODAG





#### BASE: 1983 AERIAL PHOTOGRAPH







#### BASE: 1993 AERIAL PHOTOGRAPH















- Trees not killed by salt spill.
- Chloride concentrations not affecting bedrock aquifer.
- Chloride plume moving, but decreasing over time.
- What's the process? Can this be sustained and at what rate?





## Conceptual Salt Leaching Model



## Conceptual Transport Model





www.eba.ca

## Conceptual Transport Model



## Model Calculation Results









#### Groundwater Quality





www.eba.ca

# Model Calculation Results (Comparison to Analytical Data)

www.eba.ca





# Fate and Transport: What processes are occurring?

- Upward vertical groundwater flow direction (Vu):
  - salts not being transported deeper; and
  - enhances soil flushing.
- Horizontal flow 45 m/year (Vi):
  - provides natural flushing capacity.
- Infiltration rate (Vr):
  - provides groundwater recharge; and
  - enhanced by ponding (drainage course disrupted).



- Met remedial objectives within four years of the spill.
- Natural attenuation effective for remediating this salt spill.





- Traditional Dig and Dump (\$2.1M to \$2.5M).
- Pump and Treat \$1.0M to \$1.3M.
- Natural Attenuation:
  - \$50,000 for site assessment;
  - \$10,000 for predictive modelling; and
  - \$20,000 for ongoing EM survey and groundwater quality monitoring (3 years).
- Preferred Remediation Option?
  - cost Saving of \$900,000 to \$2.3M;
  - remediation complete within 4 to 6 year timeframe; and
  - minimal surface disturbance.



- Site Assessment: EM survey and attenuation with time (mass spreading with time).
- What's the process? Can this be sustained and at what rate?
- Impact of CI off site?



- Continue monitoring (EM survey, groundwater quality).
- Evaluate EC/SAR in soils and need for amendments.
- Engage stakeholders [Alberta Environment (AENV)/landowner].
- Implement restoration plan:
  - improve surface drainage after remediation goal achieved; and
  - revegetate area and weed control .



#### Questions??

www.eba.ca







www.eba.ca

EBA Engineering Consultants Ltd.