# PLEASE HOLD THE SALT

# Authors

- Reed Jackson and Randy Brunatti , AMEC Earth & Environmental
  - Combined assessment and remediation experience of more than 20 years and 200 sites
- Gary and Maureen Johnston, Cosmic Ventures
  - Combined geophysical assessment experience of more than 50 years and 1000 sites

# What's the Big Deal ?

- Sodium chloride is essential for human and animal biochemistry
- We need salts for deicing and industrial production
- Tastes good on potato chips and peanuts
  - However
- Too much salt causes harm to land and water receptors and human consumers

# Natural Salts in Alberta

- Significant salt concentrations in soil and water can be naturally occurring
  - solonetzic soils in the Southern Prairies
  - groundwater discharge areas
  - evaporative concentration
  - bedrock of marine origin

Naturally Saline Soils Around a Prairie Slough

# Salts From Human Actions

- Road deicing in Canada uses 5 million tonnes / year - diffuse impacts
- Transportation yards with outdoor pickled sand storage areas - intense impacts
- Upper Lotsberg Formation mining provides salts for table use, industrial production and creates storage caverns
- Oil and gas drilling and production

# Seawater and Produced Water

| Source | Chloride (mgL) |
|---|---|
| Seawater | 19,000 |
| Medicine Hat PW | <500 |
| Cold Lake PW | 5,000 |
| Redwater PW | 65,000 |
| Rainbow Lake PW | 120,000 |

# Who Cares About Salt Releases

- General Public – perception and visual impacts
- Landowners – land use limitations, loss of production, water supply for drinking, livestock water and irrigating
- Regulators – protection of environment and the principal of equivalent land use

# Regulatory Guidelines & Criteria

- AENV: Soil and Surface Water Guidelines
- AB Agriculture: Soil Quality and Salt Tolerance
- CCME: Soil and Water Quality Criteria
- Env. Canada: Environmental Management of Road Salts

# Soil Criteria

- Conductivity:
  - 2 dS/m topsoil / 3 dS/m subsoil
  - 4 dS/m industrial
- SAR
  - 4 agricultural
  - 12 industrial
- Chloride: 370 mg/kg B.C. [draft]

# Water Criteria

- Groundwater Criteria - aesthetic objectives
  - sodium: 200 mg/L
  - chloride: 250 mg/L
- Surface Water Chloride:
  - 35 mg/L no observed effects - Fathead Minnow
  - 140 mg/L no observed effects - Daphnia
  - 230 mg/L four day average
  - 500 mg/L runoff water release criteria
  - 860 mg/L one hour every three years

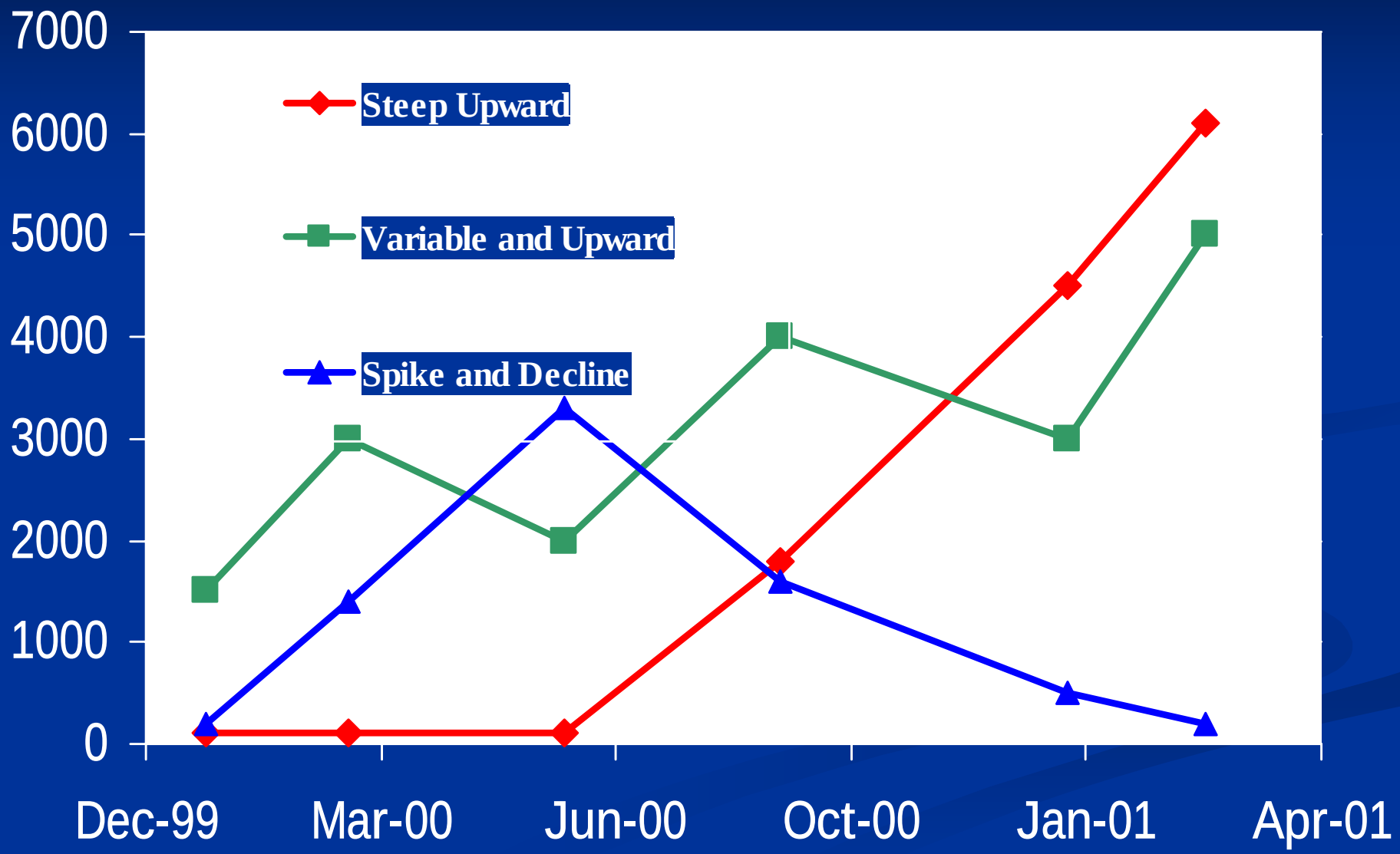
# Salts Relative to Background

- Naturally saline soils may have limited or no potential to mitigate added salts
- Due to sensitive receptors, remediation to close to background may be necessary to restore equivalent land use

# Migration of Salts

- Overland flow and surface water
- Vertical movement downward in soil – varies with soil texture and permeability
- Groundwater
  - density driven flow and segregation
  - horizontal flow

# Chloride (mg/L) Trends in Groundwater



# Adverse Effects

- Vegetation stress / death, poor crop yield
- Impaired and hardened soil structure
- Aquatic ecosystem stress
- Poor water quality for human or animal use

# Salt Tolerant Plants [EC > 8]

- Barley
- Wheat
- Bromegrass
- Alfalfa
- Spinach
- Lilac
- Willow

# Salt Sensitive Plants (EC < 2 dS/m)

- Timothy
- Red Clover
- Peas
- Raspberry
- Spruce
- Aspen
- Birch

# Tools to Delineate Salt Impacts

- Historical records - often poor or incomplete
- Vegetation stress assessment - seasonal
- Soil sampling and analysis
- Hydrogeologic investigation with groundwater sampling and analysis
- Geophysical tools - EM and / or Resistivity

# Stressed Trees

# Surficial Salt Crust

# Salt Spill Geophysics

- Release of salt changes the electrical characteristics of the ground affected
- Salt will increase conductivity
- Salt will lower resistivity

# Background Conductivity

- Lower values found:
  - mountain glaciated areas
  - sands and gravels
- Higher values found:
  - in clayey continental glaciated areas
  - shale bedrock
  - naturally saline areas (sulphate rich)

# Geophysical Techniques

- Electromagnetic (EM) - radio portion
  - EM 38 measures to shallow depths
  - EM 31 measures to intermediate depths
  - deeper measurements are possible with wider coil spacing or inside a borehole/monitor well
- Ground Conductivity Meters or Resistivity Meters

# EM 31 Survey

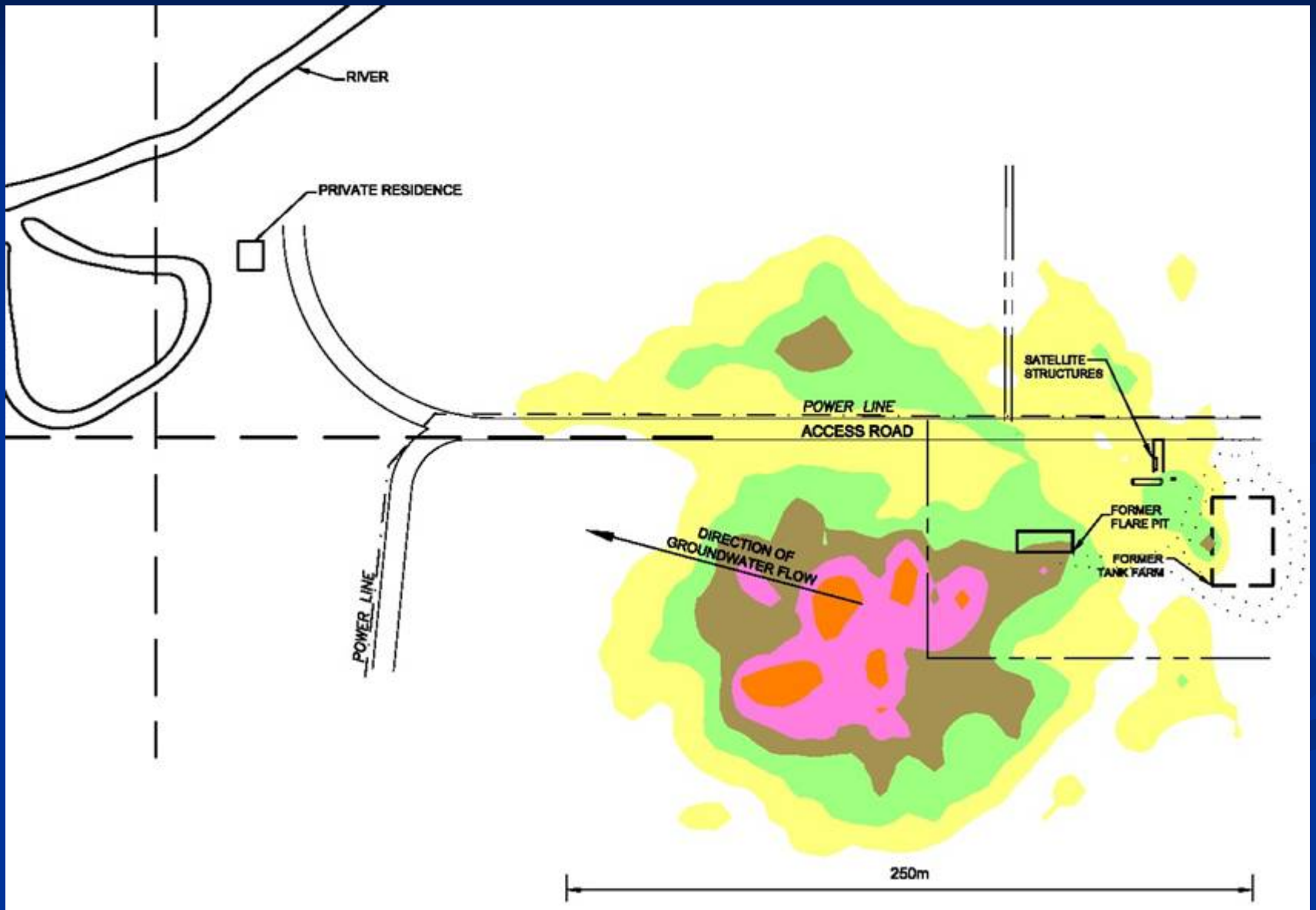
# EM Advantages

- Rapid mapping of approximate extent of spill
- Using EM 38 and 31 provides crude depths
- Can be used in industrial areas
- Averaging rotational readings can reduce or eliminate interference
- Age of spill may be apparent
  - recent spill has sharp edges
  - old spill has diffuse edges

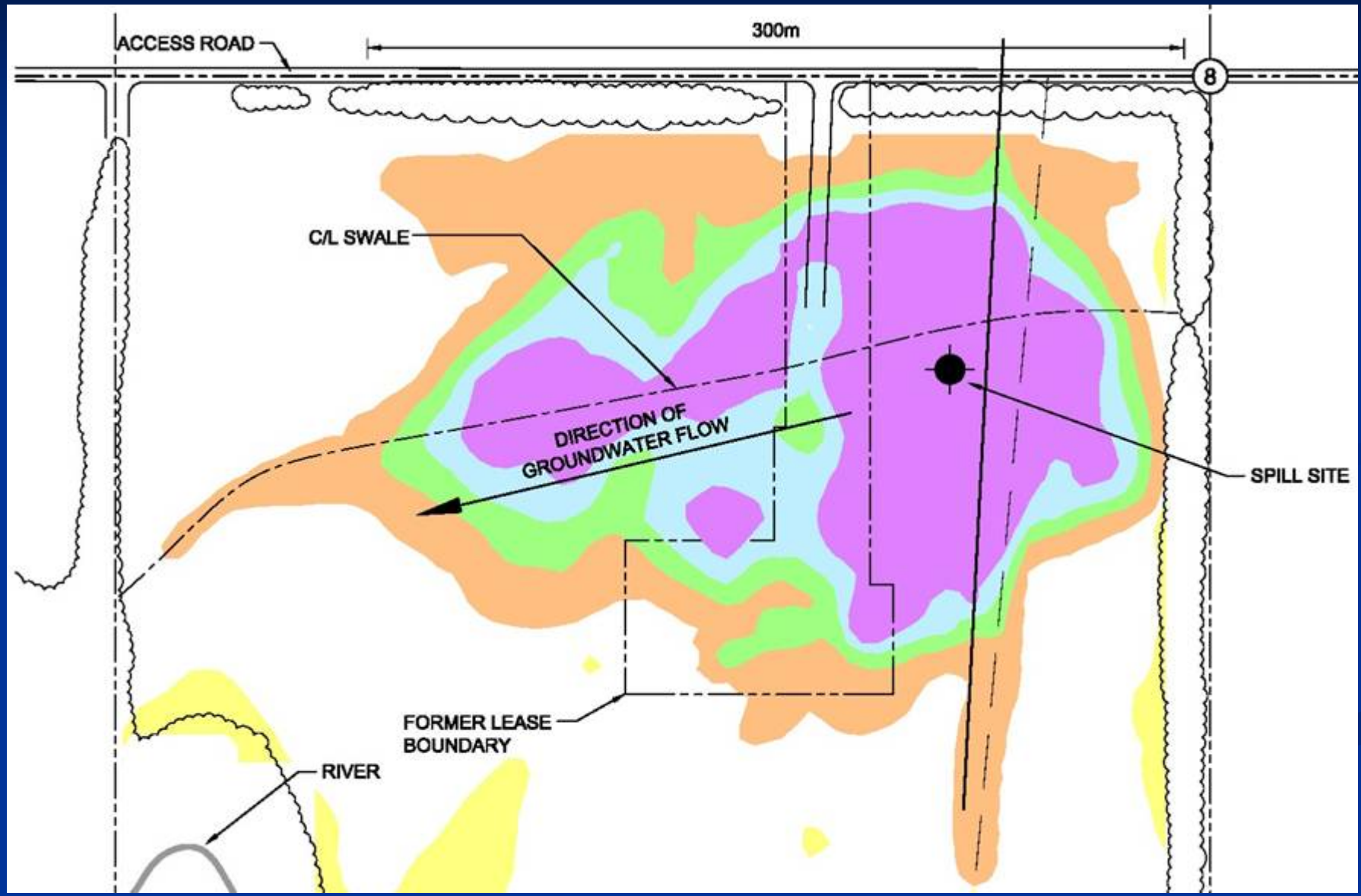
# EM Limitations

- Must be sufficient contrast to background
- Shallow penetration if surface is saline
- Depth information is crude
- Interference may limit value
  - e.g. pipeline ROW or under power lines
- Is not sensitive to thin saline zones

# EM 31 Anomaly - Deep



# EM 38 Anomaly - Shallow



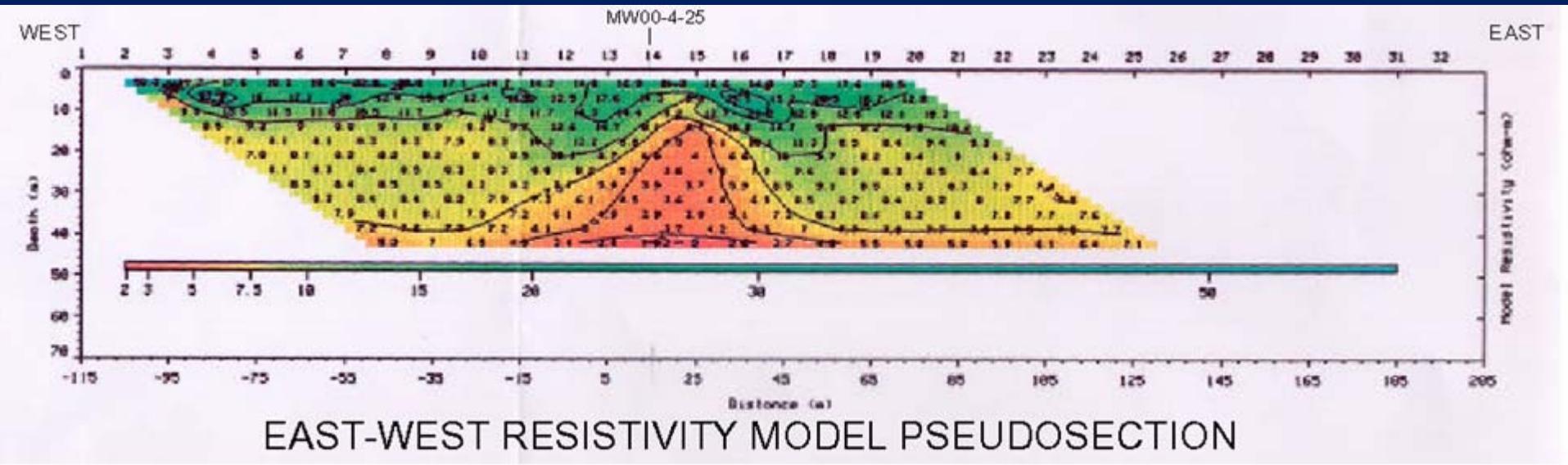
# Resistivity Advantages

- Better depth information
- Sounding provides higher quality depth data as compared to profiling (ERT)
- Can produce 2D and 3D sections
- Near surface conductive layers enhance penetration

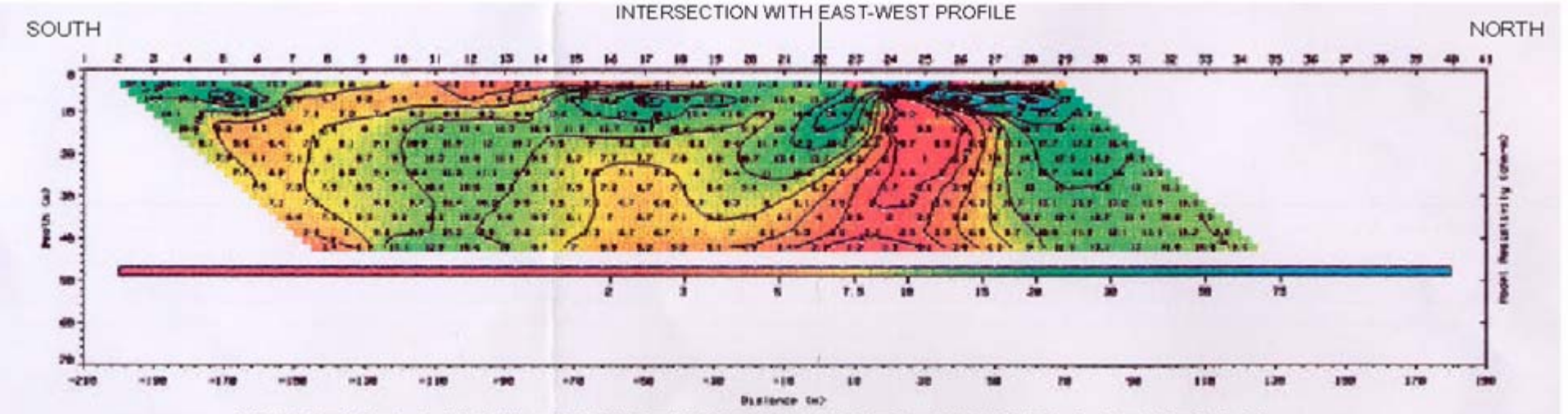
# Resistivity Limitations

- Higher cost to map same area
- Difficult to inject current in hard ground
- Equipment is not intrinsically safe
- Not sensitive to thin layers or slow changes in conductivity with depth
- Requires wide areas without interference

# Resistivity Profiles




EAST-WEST RESISTIVITY MODEL PSEUDOSECTION




NORTH-SOUTH RESISTIVITY MODEL PSEUDOSECTION

# Spill Response - High Value

- Contain extent on land with berms or ditches
- Recover fluids as soon as possible
- Minimize subsequent infiltration
- Remove source quickly
- Provincial reporting is required

# Surface Water

- Divert spills away from water bodies
- Protect from subsequent runoff
- Check for density segregation
- Provincial and Federal reporting is required

# Dig and Dump

- Quickly remove spill affected soil to landfill
- Likely cheapest option for highly saline soil
- Can use EC and Cl as field delineation tools

# Soil Amendments

- Deep till and add organic matter to improve permeability

- Add calcium to protect clay soil structure
  - calcium nitrate for fast action (nitrate risk)
  - calcium sulphate (gypsum) for slow release

# GW Recovery - Open Trench

- Shallow ditching through spill area
- Collect saline runoff and flush water
- Unless salt mass is small, this is an ineffective method to reach closure for most releases

# Shallow Tile Field

- Need shallow salts and shallow water table
- Parallel rows of perforated tile drain to sump
- Plow or dig in tile
- Usually seasonal operations

# Plowing in Drainage Tile

# Linear Interceptor Trench

- Deeper salt containment and recovery
- Usually installed by backhoe with tie in to sump
- Can provide a hydraulic barrier to groundwater flow
- Can operate year round

# Linear Interceptor Trench

# Bored Recovery Well

- Effective for deep salt impacts and highly permeable aquifers
- Often use bored wells to optimize screen diameter and yield
- Year round operations

# Bored Recovery Well

# Produced Water Equivalents

- For Oil & Gas Production related releases, salt recovery and system performance can be related back to the produced formation water

- Produced water equivalents =

  (chloride concentration of recovered water / chloride concentration of the produced water) x the recovered volume

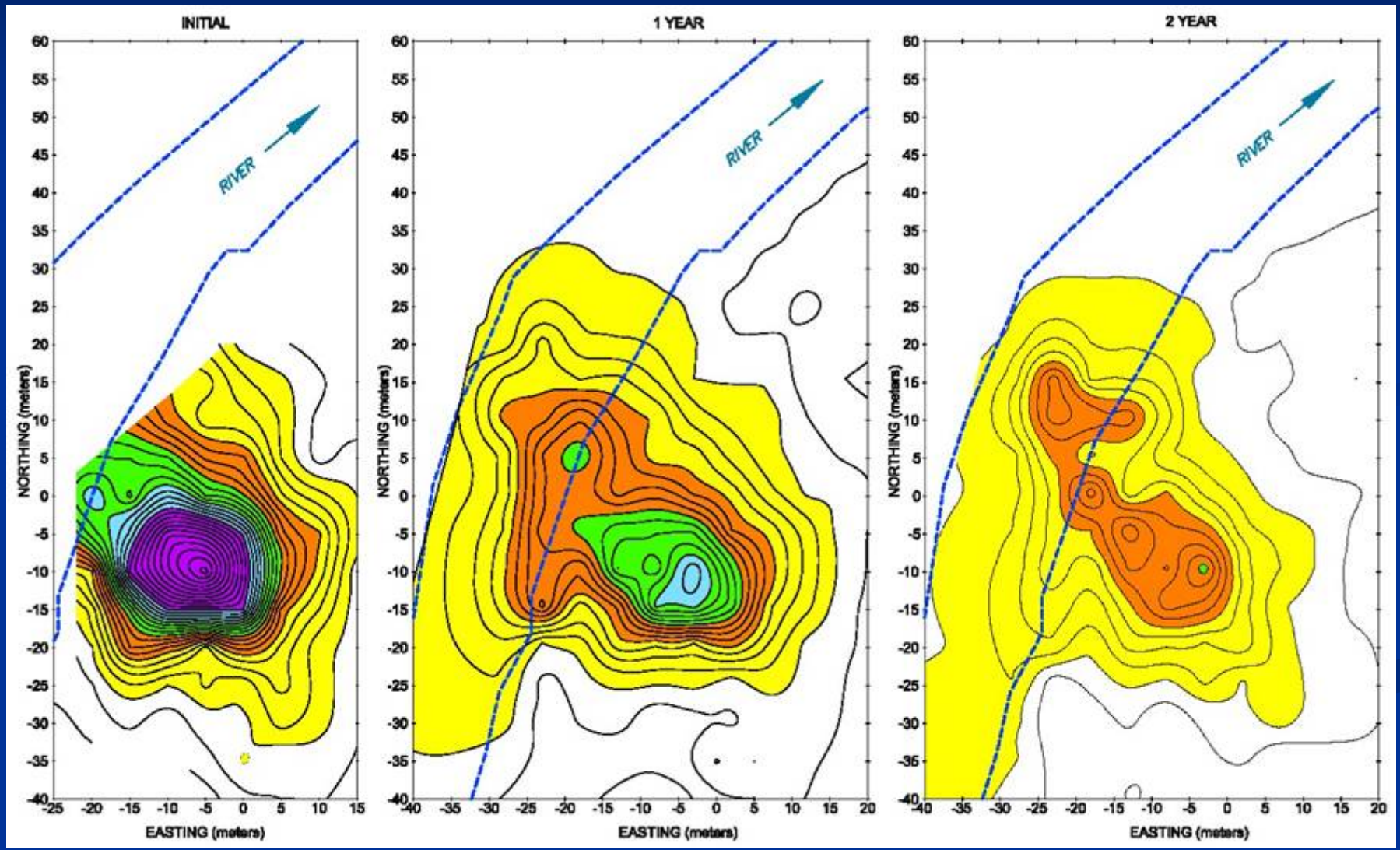
# Saltwater Recovery Summary

| Geology | Start | Chloride Concentration (mg/L) | | Recovered Water ($m^3$) | Average Annual Recovery ($m^3$) | Produced Water Equivalents ($m^3$) |
|---|---|---|---|---|---|---|
| | | Initial | 2005 | | | |
| Clay till | 1996 | 2,300 | 2,800 | 1,200 | 130 | **270** |
| Silt | 2000 | 2,240 | 690 | 7,300 | 1,460 | **112** |
| Sand | 2001 | 19,200 | 2,900 | 8,300 | 1,850 | **920** |
| Sand & Gravel | 2001 | 21,000 | 1,100 | 1,220 | 300 | **118** |
| Bedrock | 2003 | 24,000 | 1,700 | 1,115 | 450 | **107** |

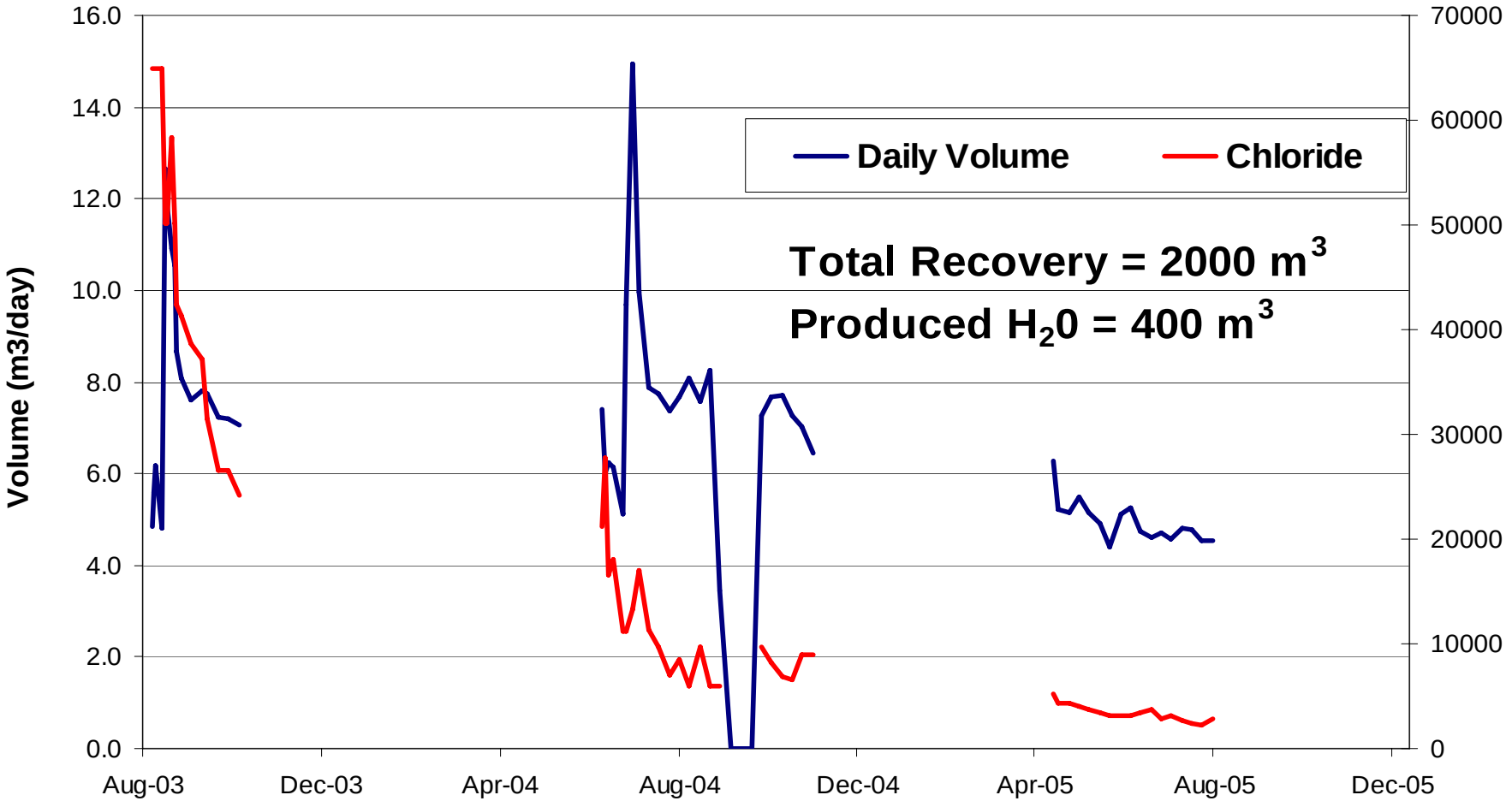
# Tough to Estimate % Recovery

- Usually the mass of salt released is unknown
- Spill reports are often one to three orders of magnitude low – corroded pipelines can leak slowly for a long time before discovered
- Salt is partitioned in soil, soil porewater, and groundwater

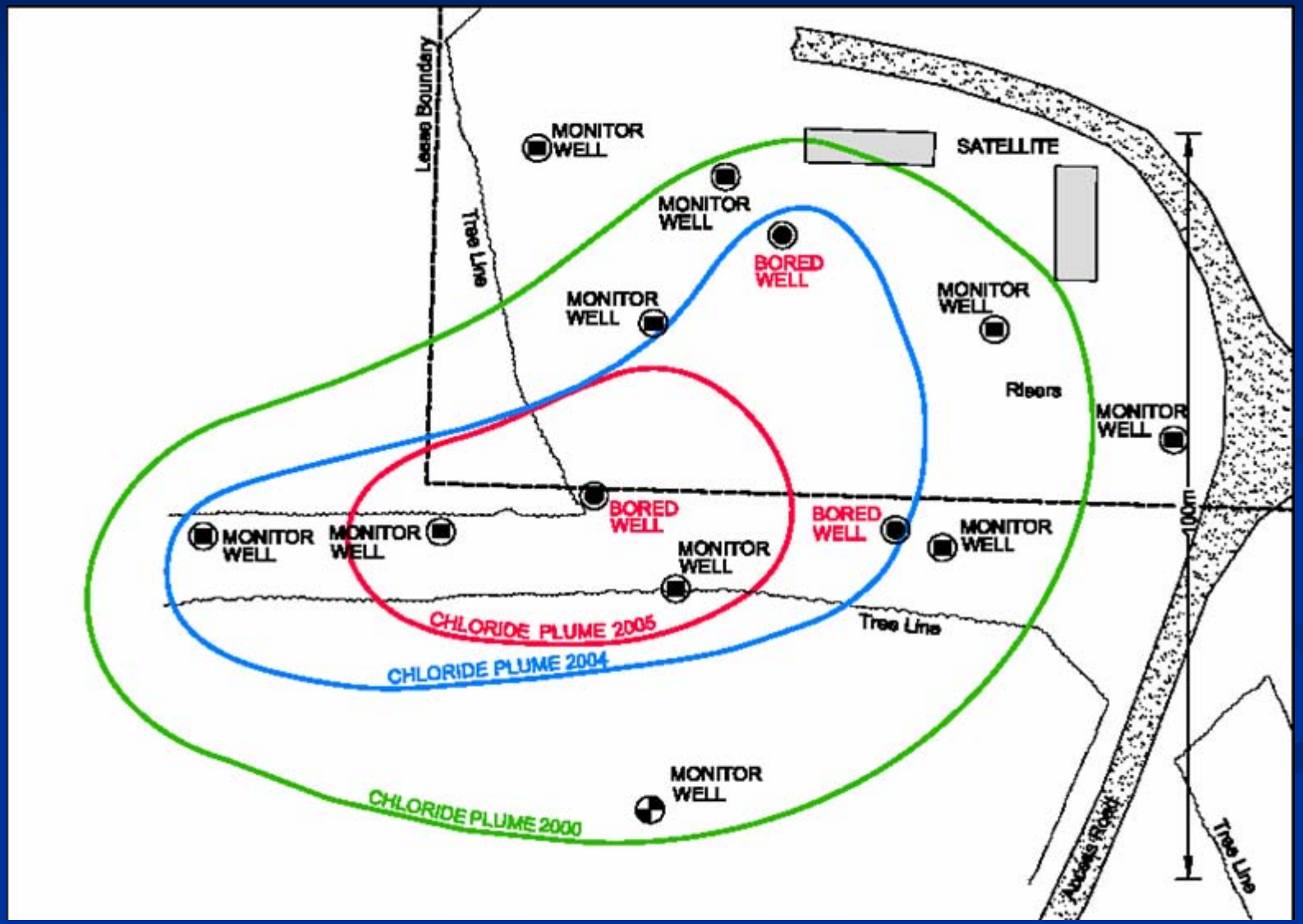
# Decreasing EM Intensity



# Groundwater Recovery Record



# GW Plume Reduction



# Operating GW Recovery Systems

- Pipeline to disposal well is lowest cost
- Year round operation preferred, frost protection is necessary
- Water Act Approval is required
- Maintenance and monitoring is crucial

# Plugged Tile

# Scale Problems

# Other Remediation Methods

- Phytoremediation – harvest and remove crop
- Soil washing for coarse soils or small salt mass
- Natural attenuation for diffuse low intensity impact areas
- New research areas

# Closure Issues

- Many priorities for industry managers
- Long term funding and management
- Landowner interactions
- Changing regulatory expectations

# Site Closure - Moving Targets

- *C & R* - Reclamation Certificate for specified land (well leases, pipelines, roads, mines, etc.)
- Remediation Certificate not yet available
- How to measure equivalent capability
- Land use changes - more sensitive receptors

# Risk Assessment / Site Management

- Contain impacts and perhaps recover salts
- Exclude or protect sensitive receptors
- Manage the site
  - engineering controls
  - limit land uses
  - monitor effectiveness

# Conclusions

- Every site is unique and needs assessment
- Accurate information about the site is crucial
- Rapid response pays big dividends
- Salt recovery or removal is usually required

# More Conclusions

- Good records are invaluable to assess remediation progress and performance
- Deal effectively and consistently with landowners and regulators - keep promises
- Try to get buy-in for closure before you start


QUESTIONS ?