DE-ICER (NaCl) SALT IMPACTED SOIL: 22X REMEDIATION FEASIBILITY STUDY

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Introduction: Relevance

- **Sustainable Re-development:** Contaminated Sites/Brown fields decontamination and land use via **SRA** (sustainable remediation alternatives) encompassing triple bottom line
- **Regulations:** Canadian Environmental Protection Act (CEPA) concluded Road (de-icer) Salts 'Toxic" & AENV Soil & Water Quality and CofC Water Discharge Bylaws
- **Usage:** Alberta used121,035 t of de-icer salt and Calgary used an estimated 20,428 t of salt (winter 97-98)[1]
- **Salt Management**: Excellent Resources; BMP, (TAC) & SMP (CEPA) for de-icer salt
- **Salt Remediation:** No pragmatic, **SRA** for existing de-icer impacted sites; The 22X case study - remediation feasibility

[1] Environment Canada/Health Canada (2000), Canadian Environmental Protection Act, 1999- Priority Substances list- Assessment Report -Road Salts. Report Released for Public comment August 12, 2000. Tables 6 and 8; Commercial Chemicals Evaluation Branch, Environment Canada, Hull, Quebec.

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22X Case Study

22X Road Maintenance Yard &Salt Storage Site, Calgary, Alberta

- Background/Regional Information
- Site Layout, History, Geology & Hydrogeology,
- Environmental Investigation Summary
- Contaminant Distribution Soil and Ground Water
- Test Locations & Site Characterization Summary
- Remedial Feasibility Study, Results and Next Steps

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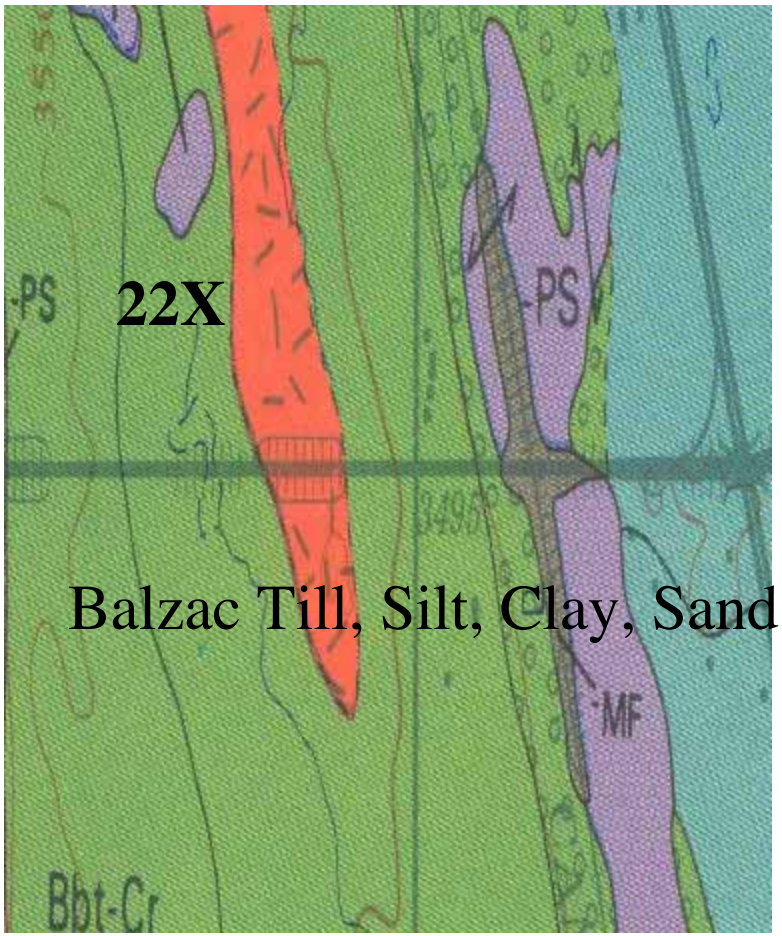
Background/Regional Information

Site Location

Surface Geology (Moran, 1986)



Balzac Till, Silt, Clay, Sand

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22X Site Layout and History

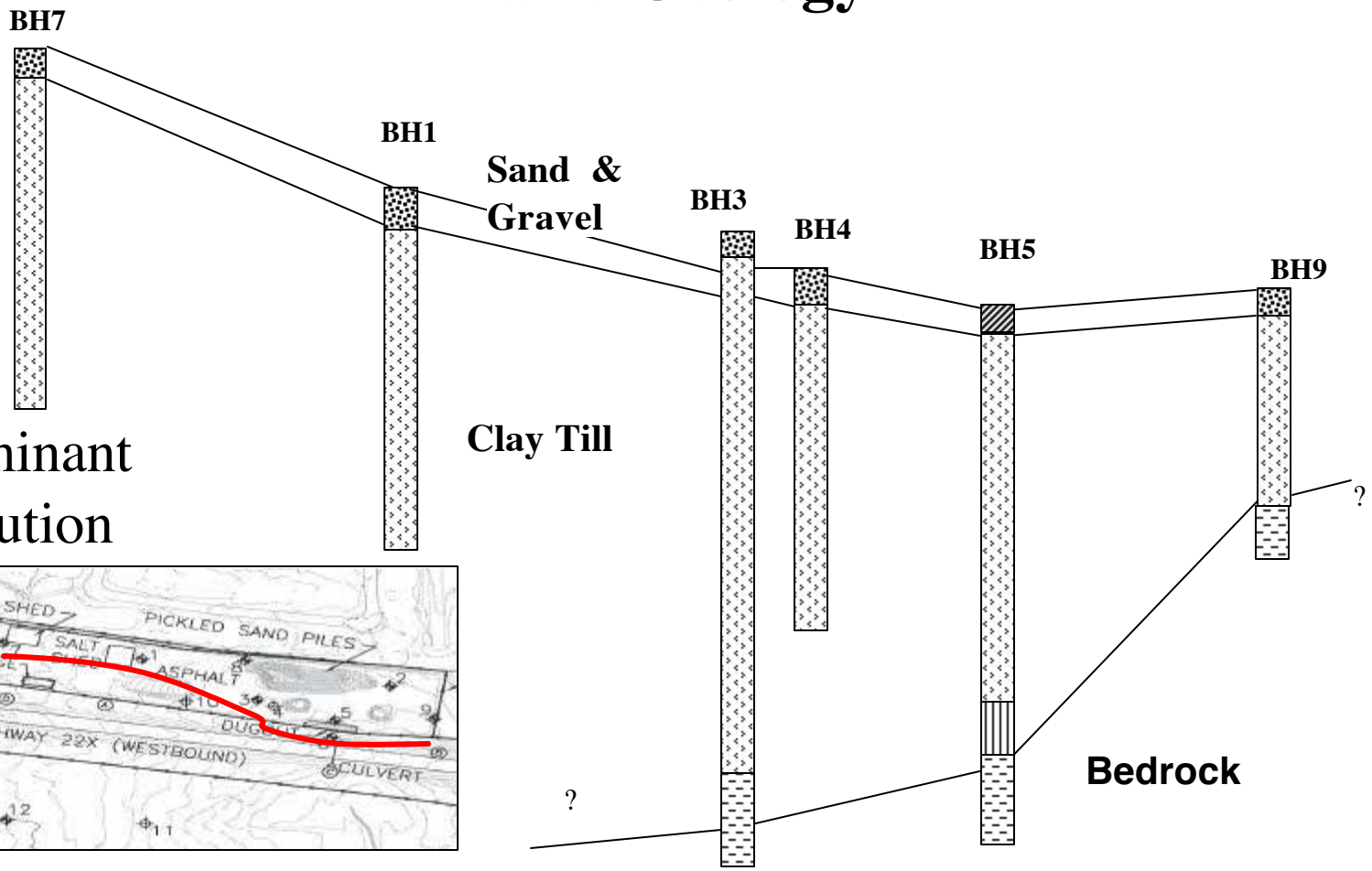
Environmental Investigative Program

- 13 Boreholes Drilled
- 10 Monitoring Wells Installed
- 6 Shallow Sample Areas
- Groundwater Monitoring and Sampling
- Hydraulic Conductivity Testing

  Phase-I, II & III Environmental Site Assessment

  Remedial Feasibility Study
- Three Remedial Technological Simulations
- 6 Test Pits Excavated 3.0m dbgs
- Desalination (leachate) Testing
- Post Remedial Testing (for Potential Soil Reuse)

Site Geology



Contaminant Distribution

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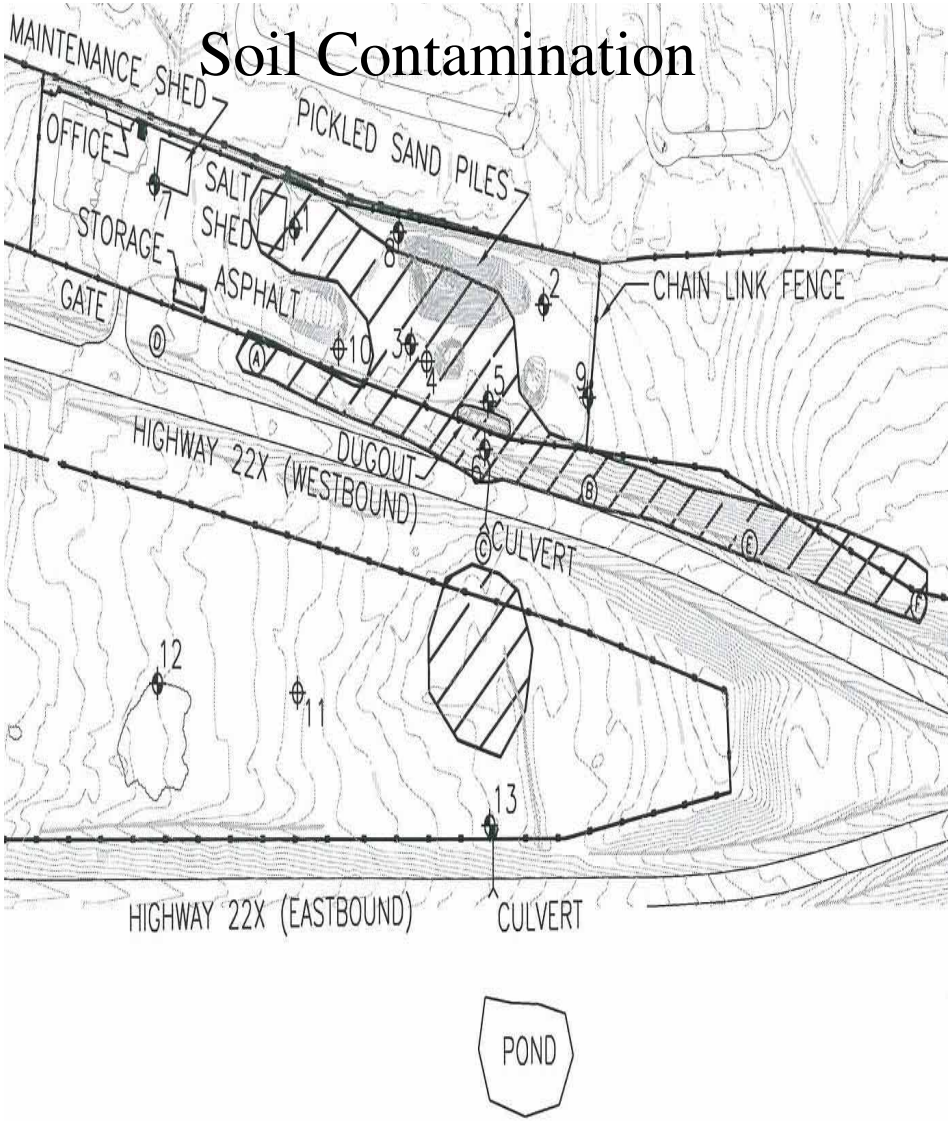
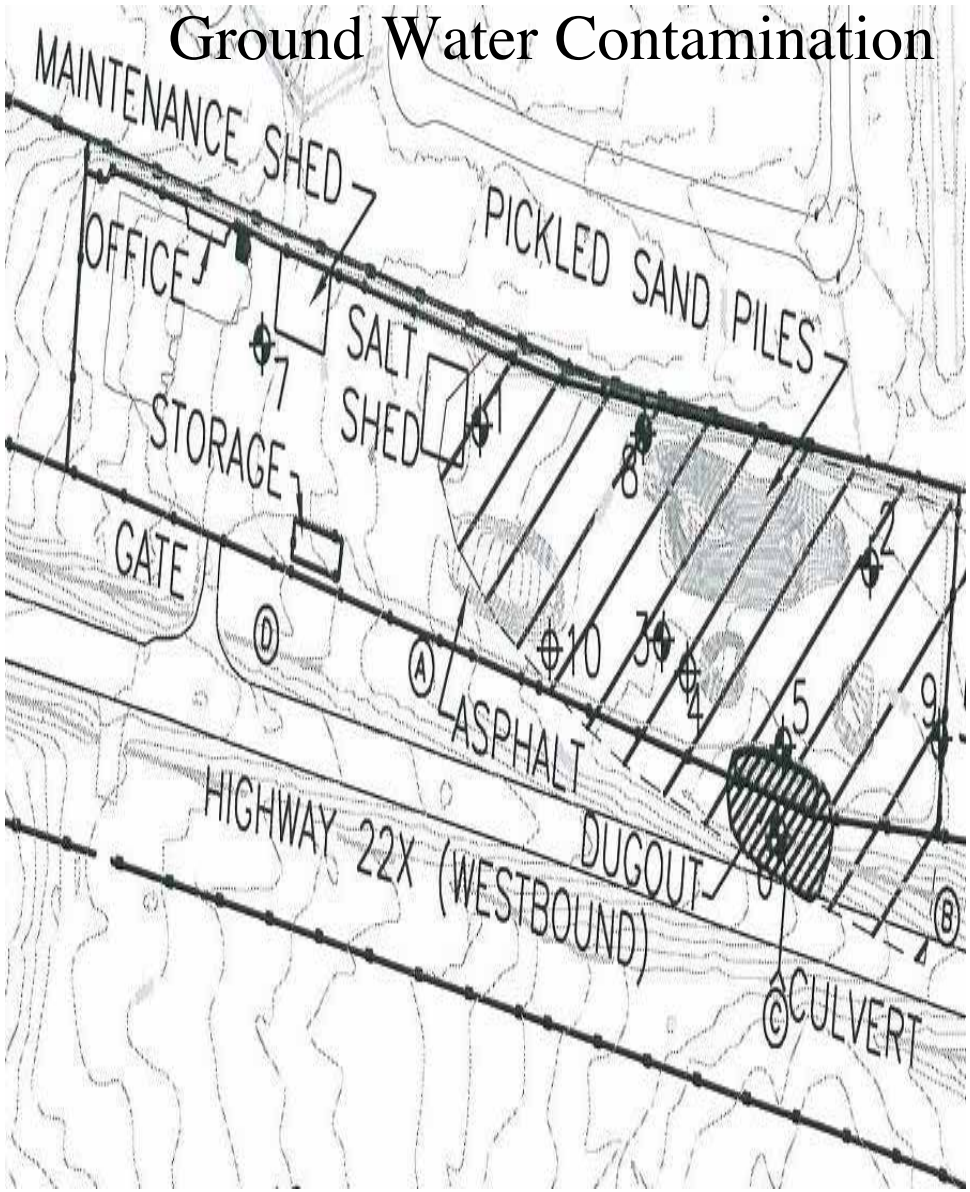
Soil Contamination



Ground Water Contamination



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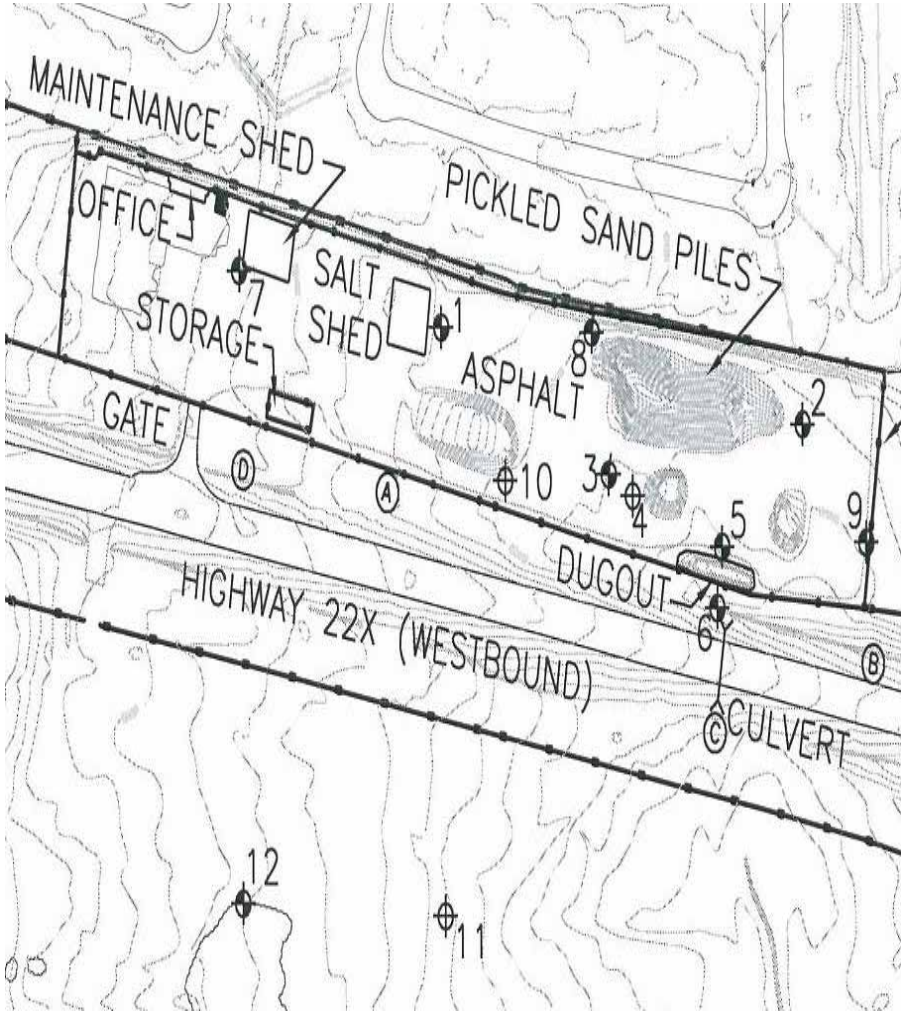
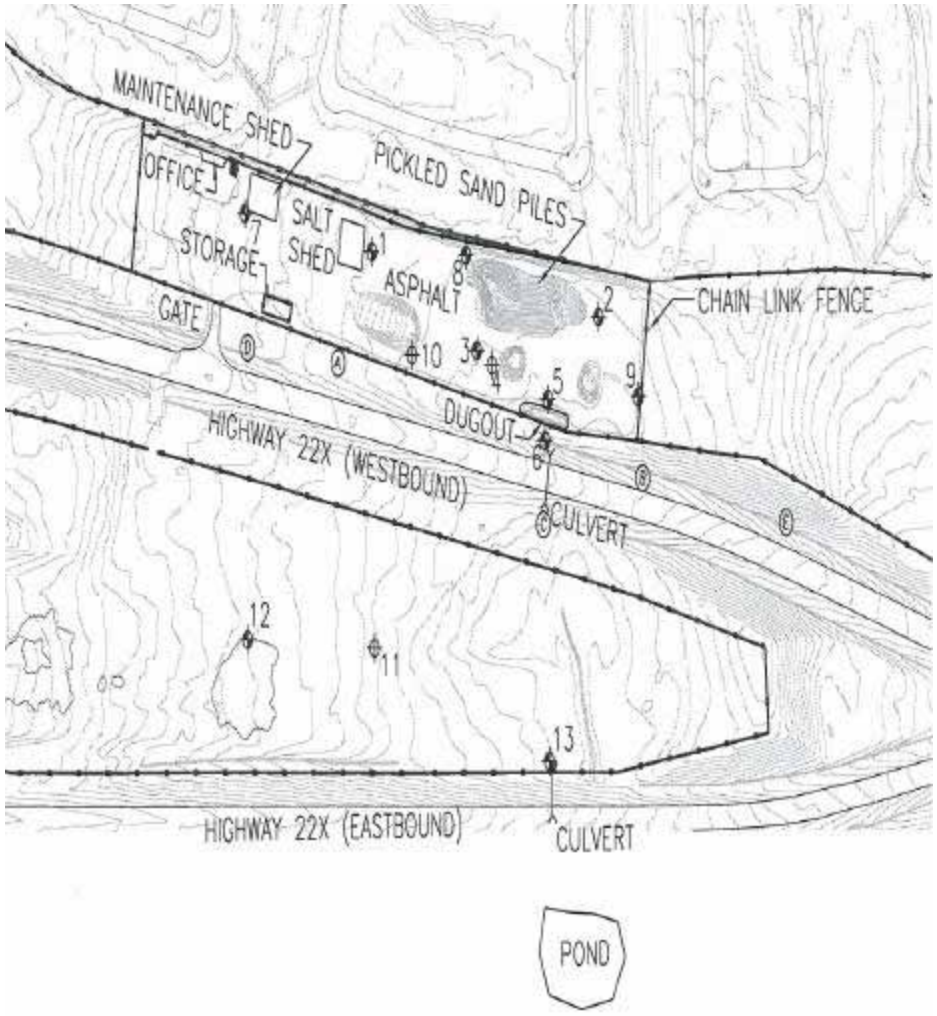
Borehole Location Plan



Shallow Sample Location



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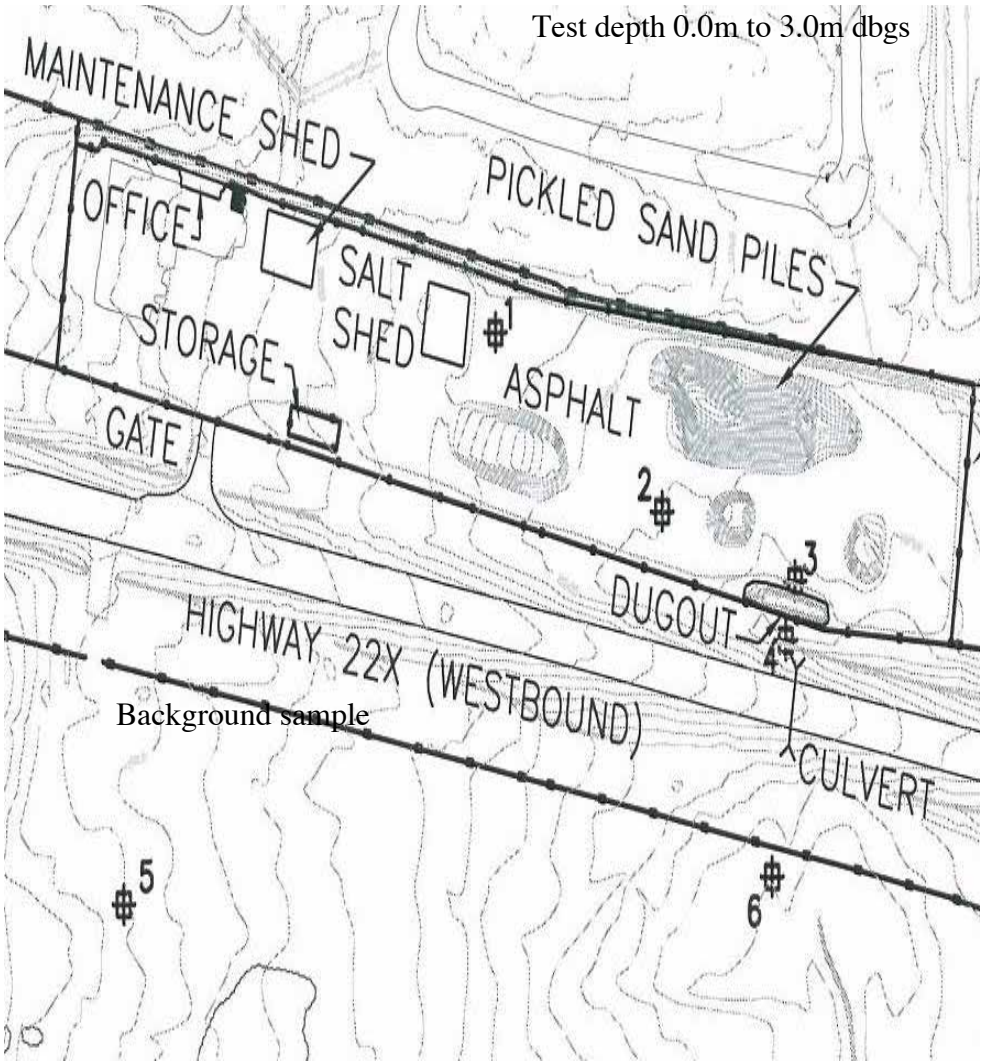
Remedial Feasibility Test Pit Location



Site Characterization

- Geology - Clay Till Overlain by Sand and Gravel
- Hydrogeology - Not Straight Forward
- Clay Till - Grain Sieve Analysis and soil engineering tests
- Site Hydraulic Conductivity - Very Low soil permeability, ***K*** from 10^{-8} m/s to 10^{-10} m/s
- Salt Impact Greatest < 1.5 m. On site handling and associated site run-off
- Groundwater Impacts over half the site. Mean concentration of GW composites Na=2090 mg/L and Cl= 4730 mg/L

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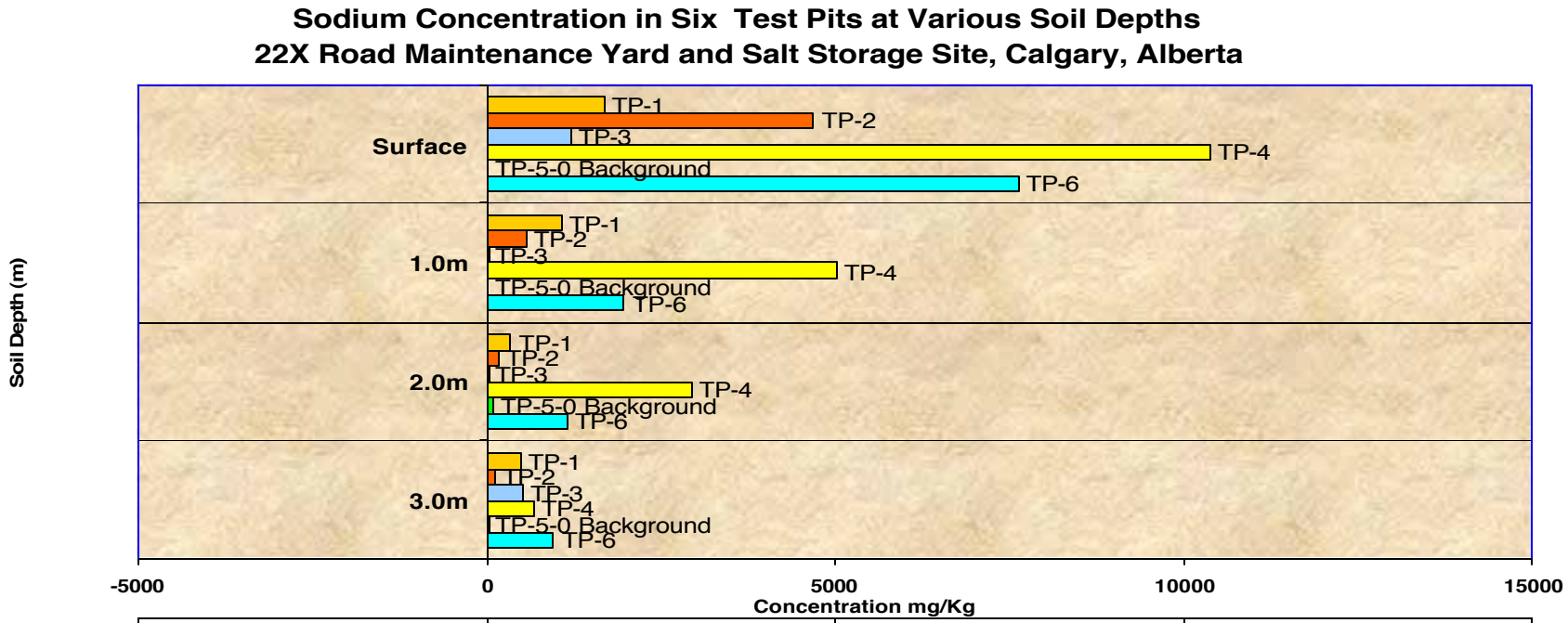
Pre-Remediation Sodium Concentration



	3.0m	2.0m	1.0m	Surface
TP-1	488	356	1065	1702
TP-2	136	178	573	4704
TP-3	526	50	44	1225
TP-4	695	2947	5038	10373
TP-5-0 Background	45	85	23	15
TP-6	954	1168	1976	7621

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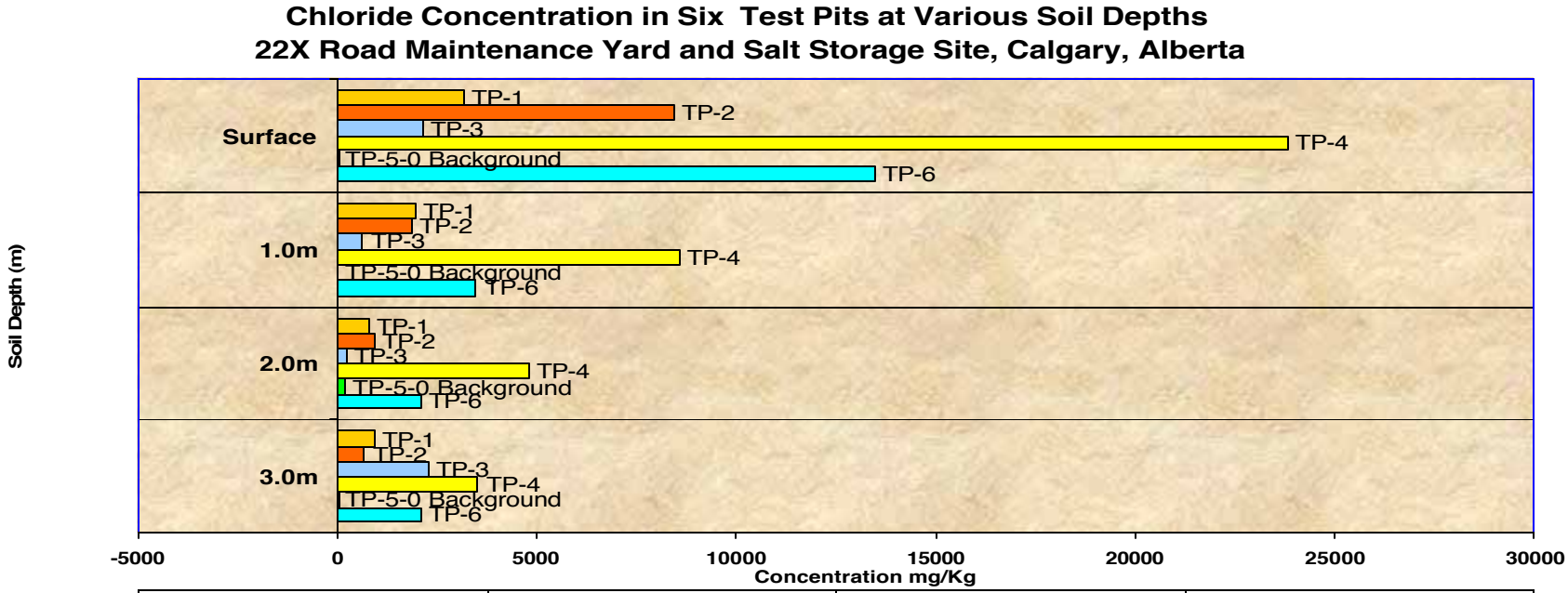
Pre-Remediation Chloride Concentration



	3.0m	2.0m	1.0m	Surface
TP-1	937	789	1984	3197
TP-2	693	916	1871	8433
TP-3	2306	227	646	2133
TP-4	3545	4818	8556	23801
TP-5-0 Background	69	220	21	32
TP-6	2119	2110	3468	13502

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22X Soil Quality Characterization Summary

Background Surface Soil

1. Sodium-Na *(15 mg/kg or 27 mg/L)*
2. Chloride-Cl *(32 mg/kg or 57 mg/L)*
3. EC *(0.7 dS/m)*
4. SAR *(0.7)*

Salt Impacted Surface Soils

1. Sodium -Na ranging from *(1225 mg/Kg or 4710 mg/L to 10, 373 mg/Kg or 20,700 mg/L)*
2. Chloride-Cl ranging from *(2133 mg/Kg or 8200 mg/L to 23, 801 mg/Kg/ 47, 600 mg/L)*
3. EC *(21 to 92.7 dS/m)*
4. SAR *(57.3 to 137)*

Alberta Environment * Soil Quality Guidelines

1. Sodium-Na *(Not specified)*
2. Chloride-Cl (*Not Specified)*
3. EC *(4 dS/m)*
4. SAR *(12)*

**For unrestricted land use*

In soils at 1.0m, 2.0m and 3.0 dbgs salt concentrations ranged from 5038 mg/Kg to 50 mg/Kg for sodium and 8556 mg/Kg to 227 mg/Kg for chloride

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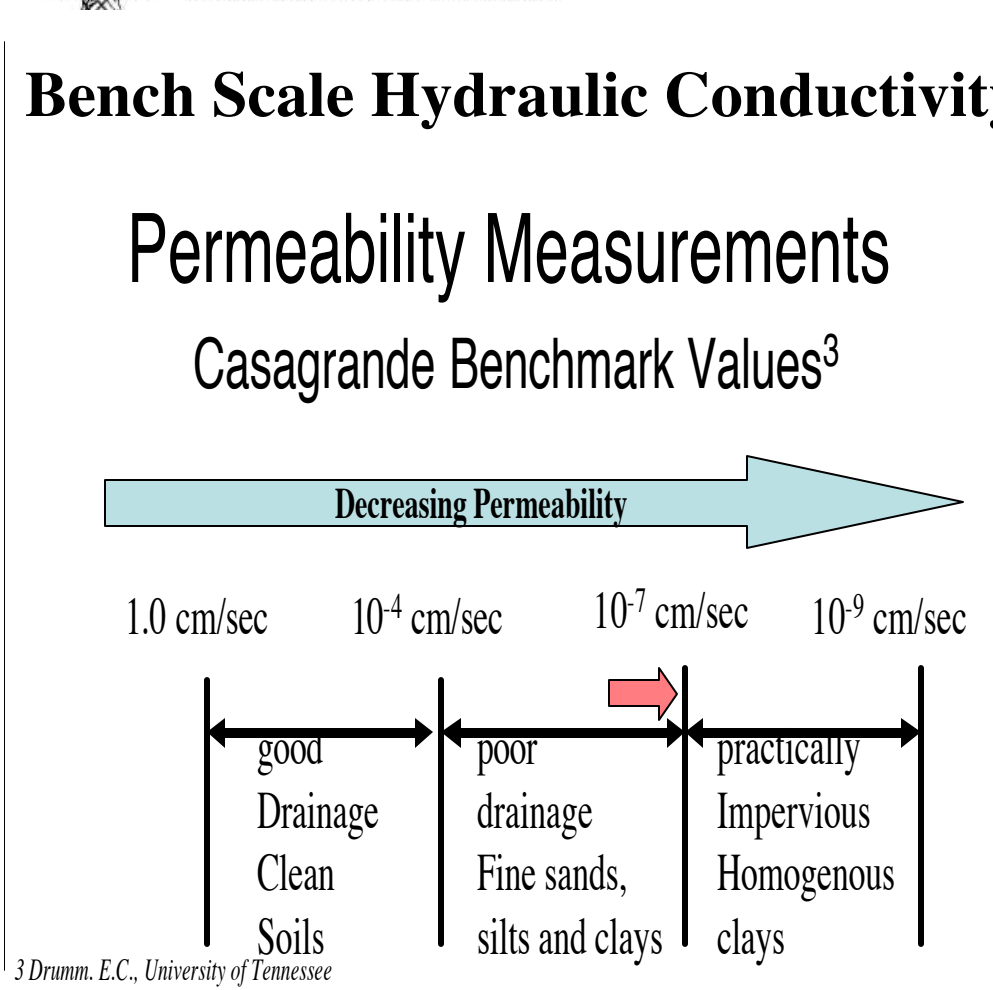
Bench Scale Hydraulic Conductivity



3 Drumm. E.C., University of Tennessee

Summary of Challenges

To clean up difficult clay soils presenting

- a) Low Permeability K ($< 1x10^{-6}$ cm/s)
- b) High De-icer Salt (Na^+) and (Cl^-) Contamination
- c) High EC and SAR that exceed Alberta Environment Guidelines

To find potential re-use for NaCl free remediated soils

To clean-up waste (leachate) waters

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Objective

Overall: Sustainable Remedial Alternatives **(SRA)** versus problem transfer (dig and dump)

Primary: Conducting a feasibility study (22X soils)

- *to evaluate three remedial (in-situ) technologies for NaCl reduction*
- *meet soil quality compliances*

  Desalinating post remediation waste water
- *to recover brine and produce clean permeate*
- *meet water quality compliances*

Associated: Conducting tests on remediated *(22X soils)*

Toxicity testing (using F. Candida), phyto-toxicity testing and leachate control to explore potential soil reuses

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Methods and Results Overview

Technology Simulation and Result Summary

1)Soil Flushing Remediation *(0.0m, 1.0m and 2.0m soils)*

2)Soil Chemical Amendment *(0.0m, 1.0m and 2.0m soils)*

3)Electro-kinetic Remediation *(0.0m soils)*

4) Comparison of three soil NaCl results

5) Comparison of three soil quality results

6) Desalination: water quality results

Post Remediation Test Result Summary

7) Acute and Chronic Toxicity Testing

8) Plant bio-assay & Leachate Control

Technology SFR, SCA & EKR Evaluation Summary

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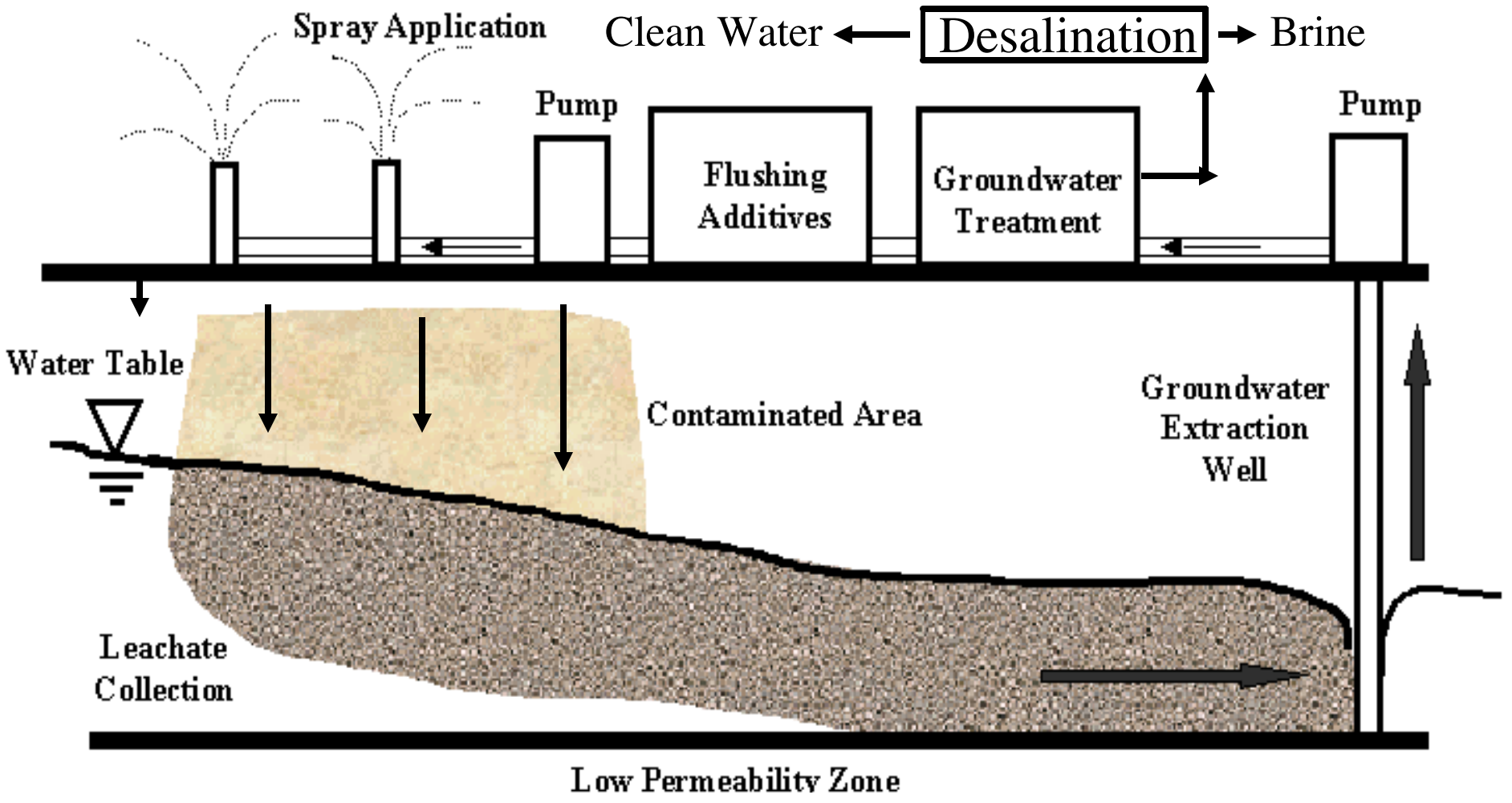
1) In-Situ Soil Flushing Remediation



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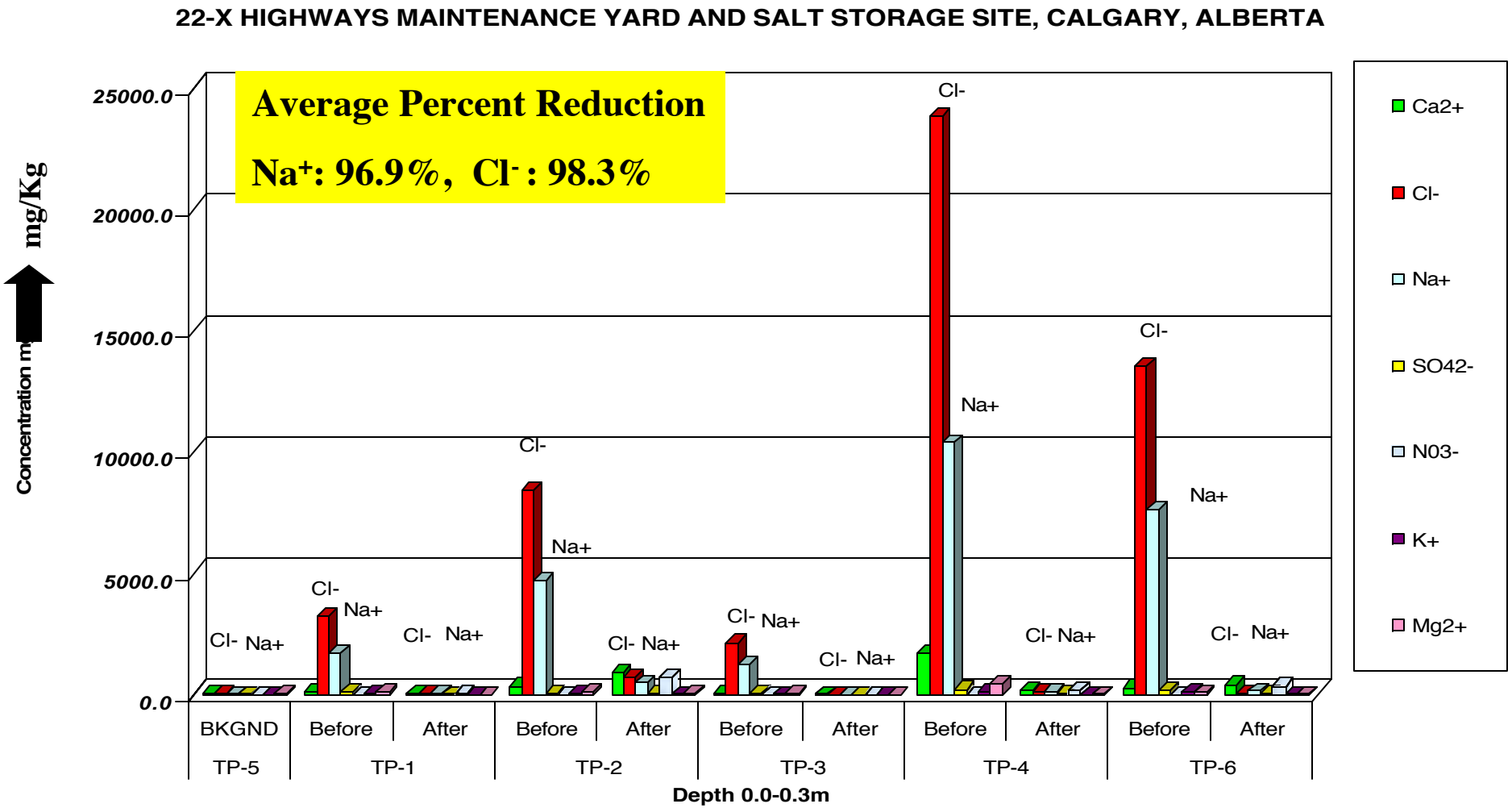
1) Post Remediation SFR Results



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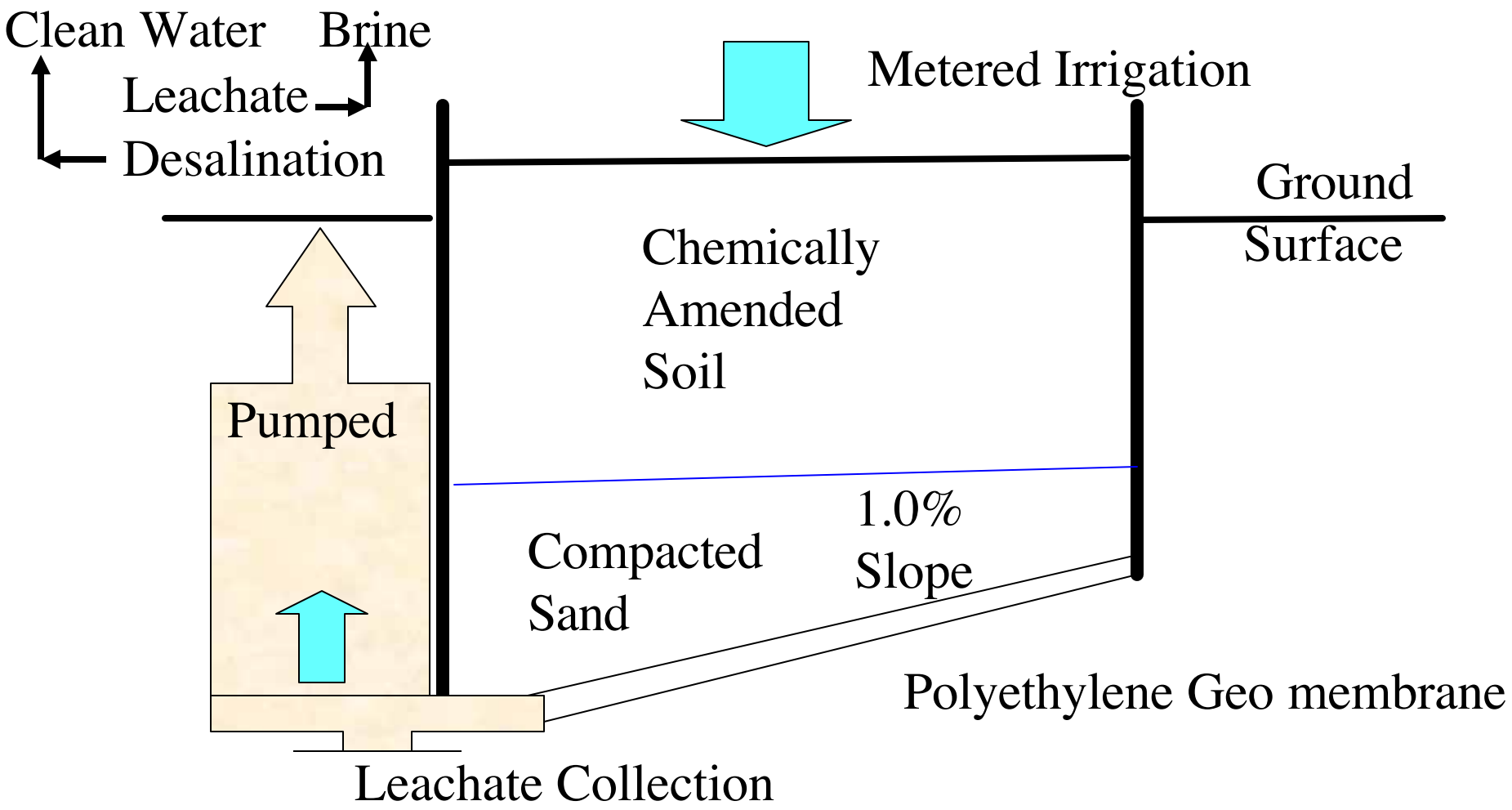
2) In-situ Soil Chemical Amendment



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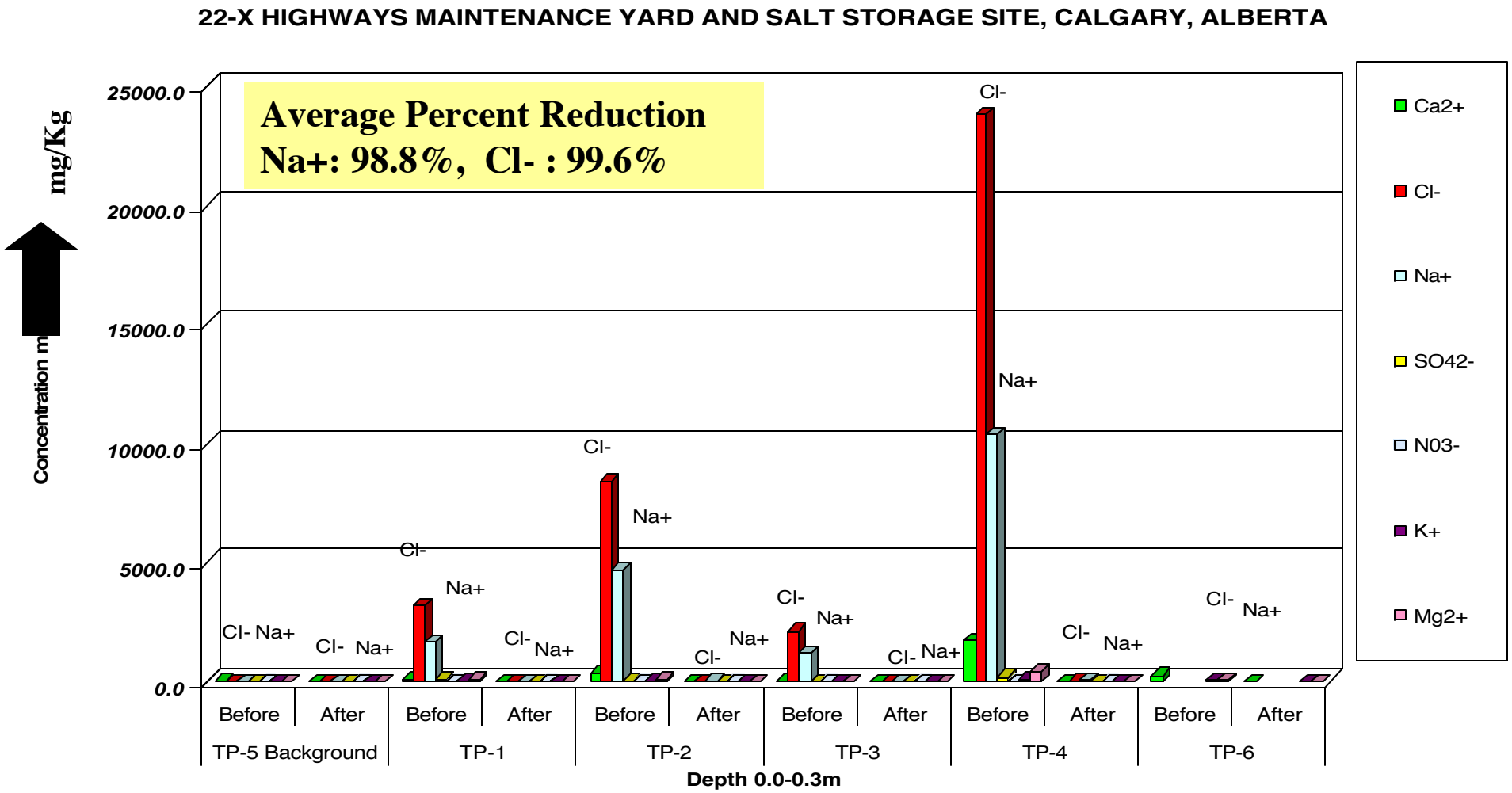
2) Post Remediation SCA Results



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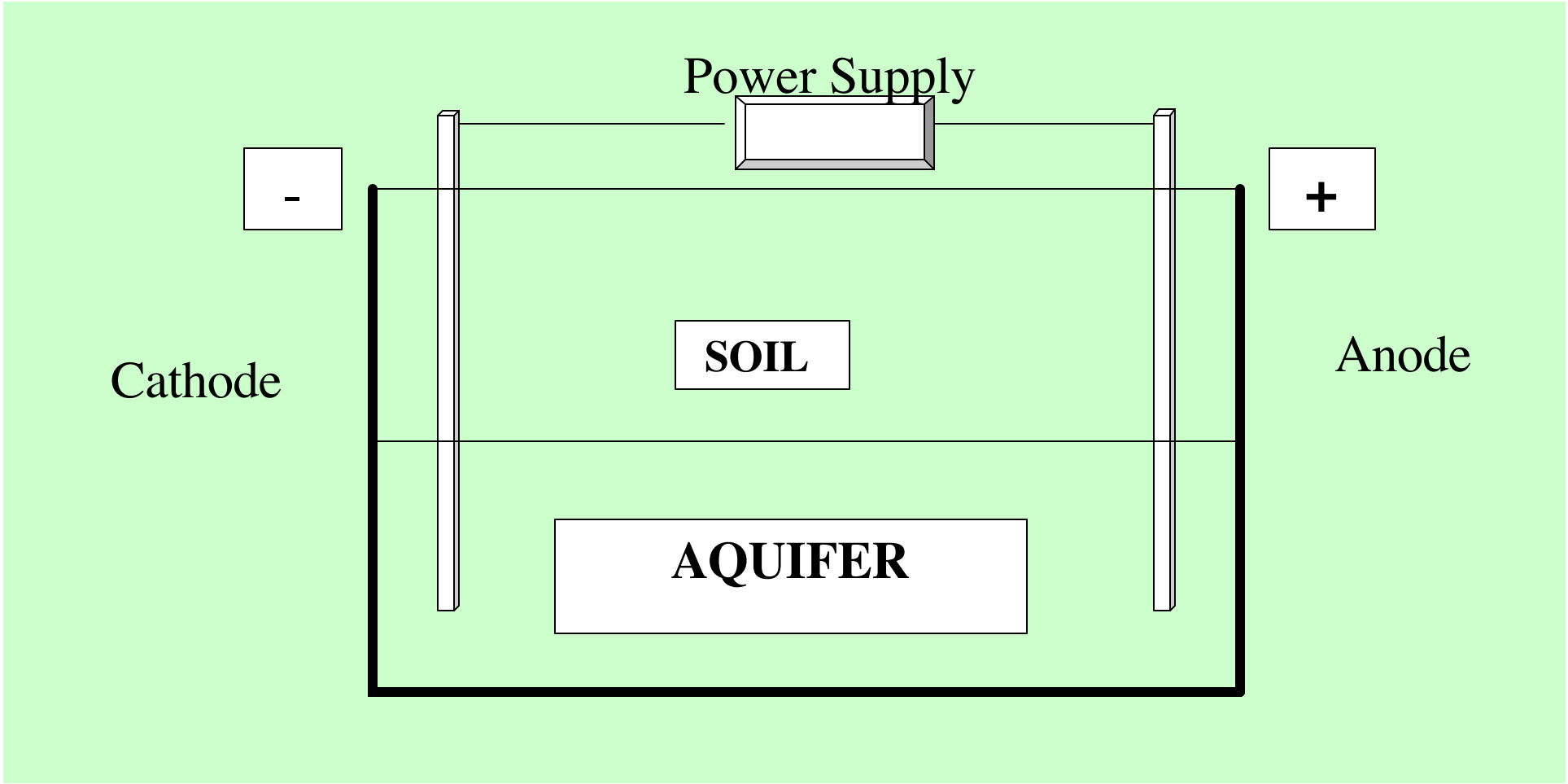
3) In-situ Electro-kinetic Remediation



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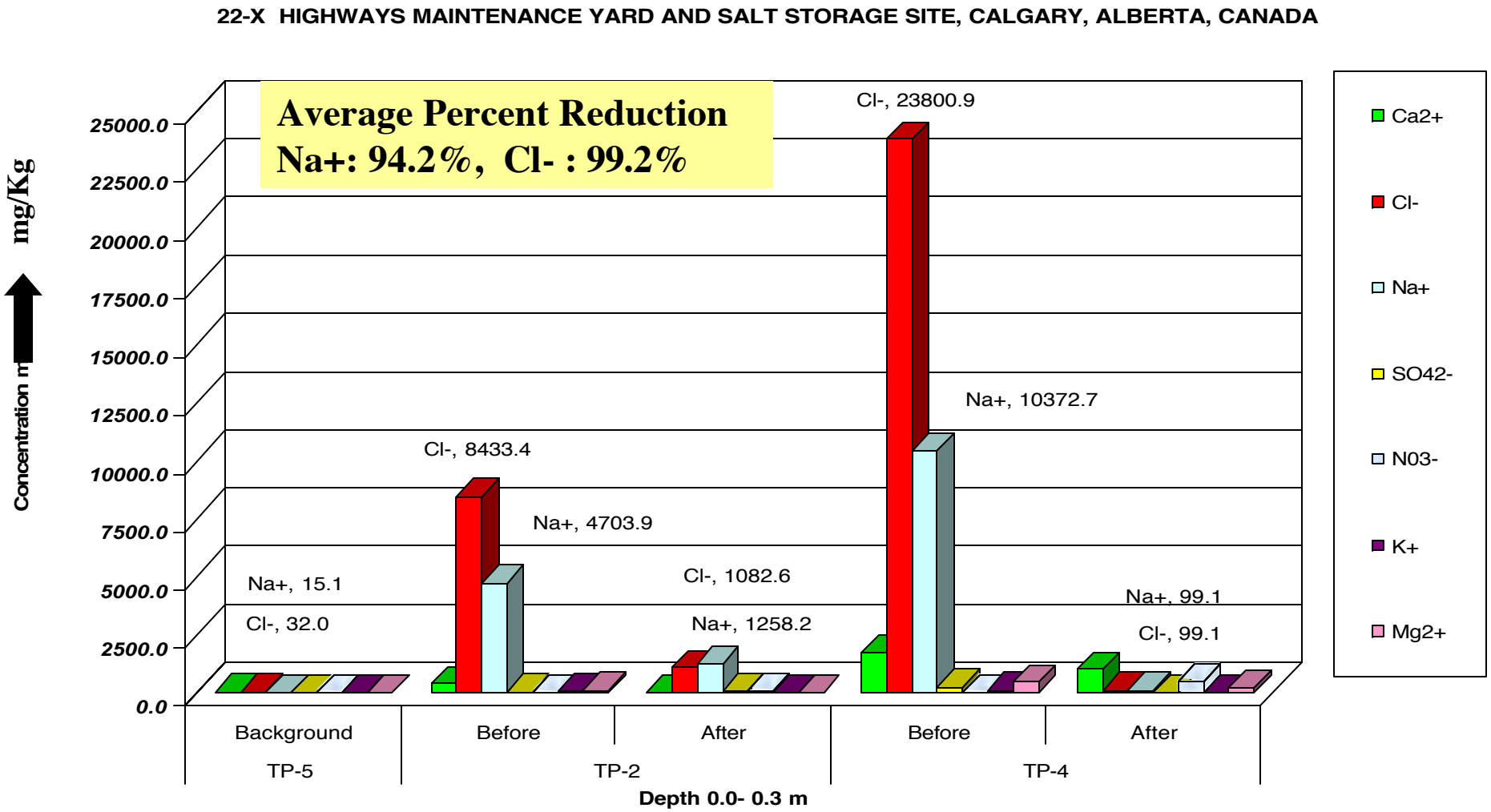
3) Post Remediation EKR Results



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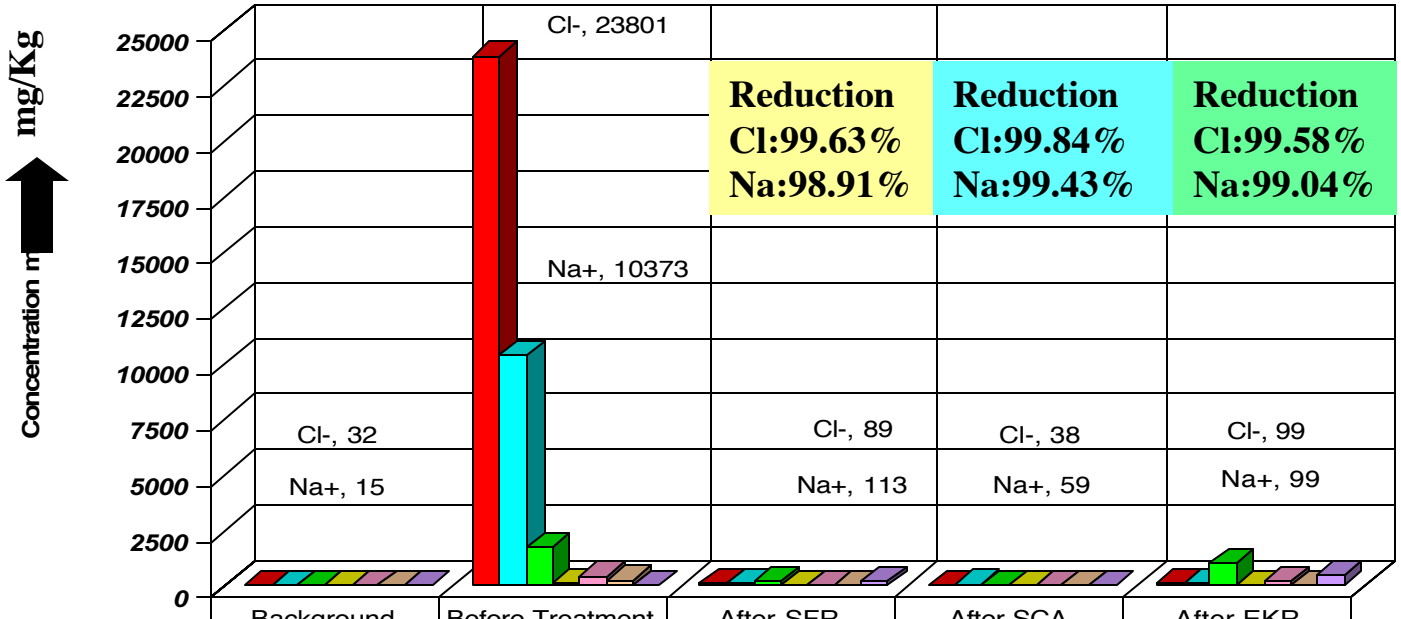
4) Comparison of Three Soil NaCl Results

REDUCTION OF DE-ICER NaCl IN SURFACE SOILS, AFTER SFR, SCA & EKR TREATMENT
22-X ROAD MAINTENANCE YARD AND SALT STORAGE SITE, CALGARY, ALBERTA



	Background	Before Treatment	After SFR	After SCA	After EKR
Cl-	32	23801	89	38	99
Na+	15	10373	113	59	99
Ca2+	36	1738	186	15	989
K+	2	106	8	2	9
Mg2+	21	433	11	3	210
SO42-	10	224	31	15	25

Depth 0.0- 0.3 m

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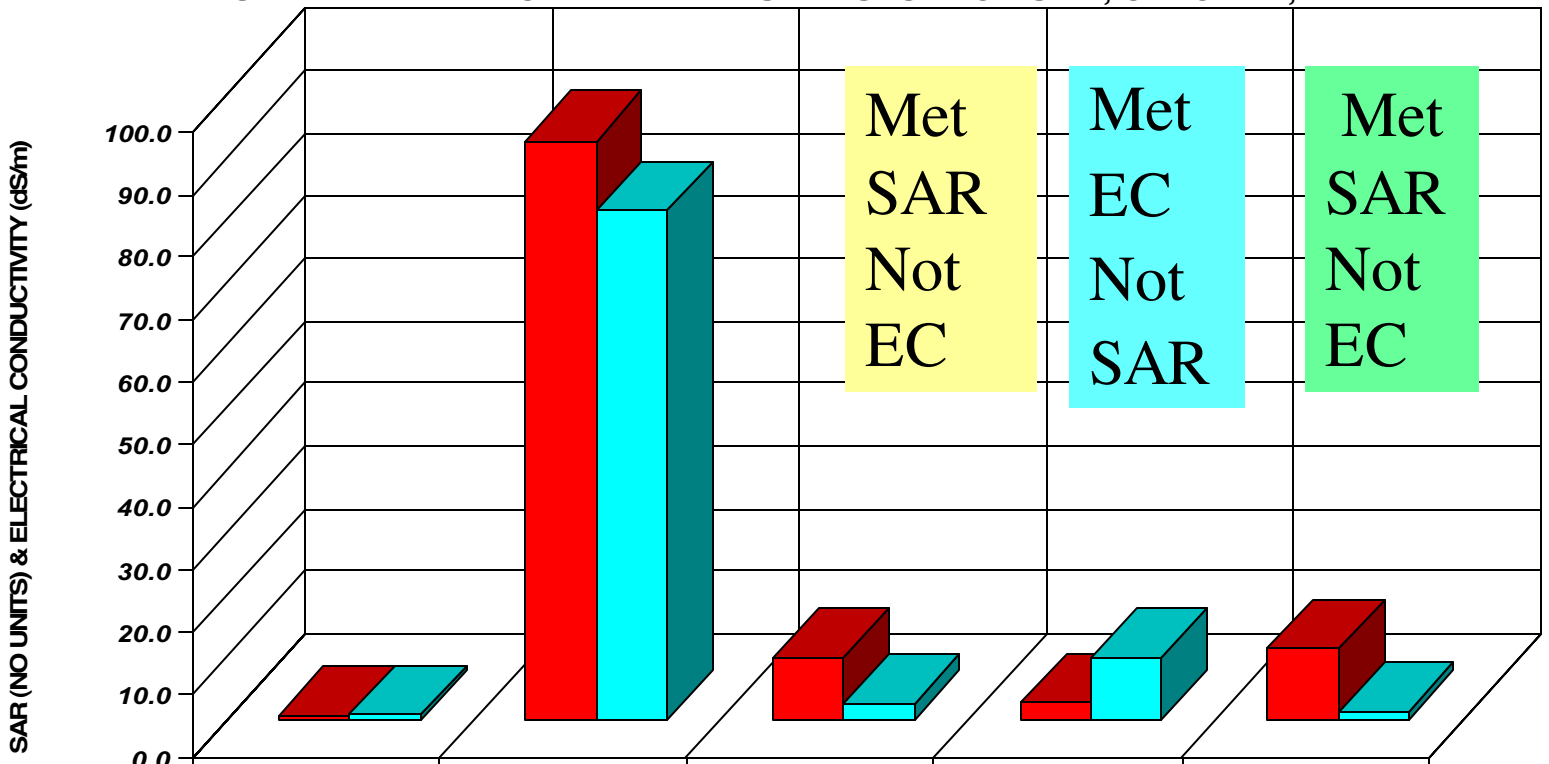
5) Comparison of Three Soil Quality Results

REDUCTION OF SODIUM ABSORPTION RATIO AND ELECTRICAL CONDUCTIVITY IN SURFACE SOILS, AFTER SFR, SCA & EKR TREATMENTS
22-X ROAD MAINTENANCE YARD AND SALT STORAGE SITE, CALGARY, ALBERTA



	Background	Before Treatment	After SFR	After SCA	After EKR
EC (dS/m)	0.7	92.7	9.9	2.8	11.4
SAR	0.7	81.6	2.7	9.8	1.3

Depth 0.0- 0.3 m

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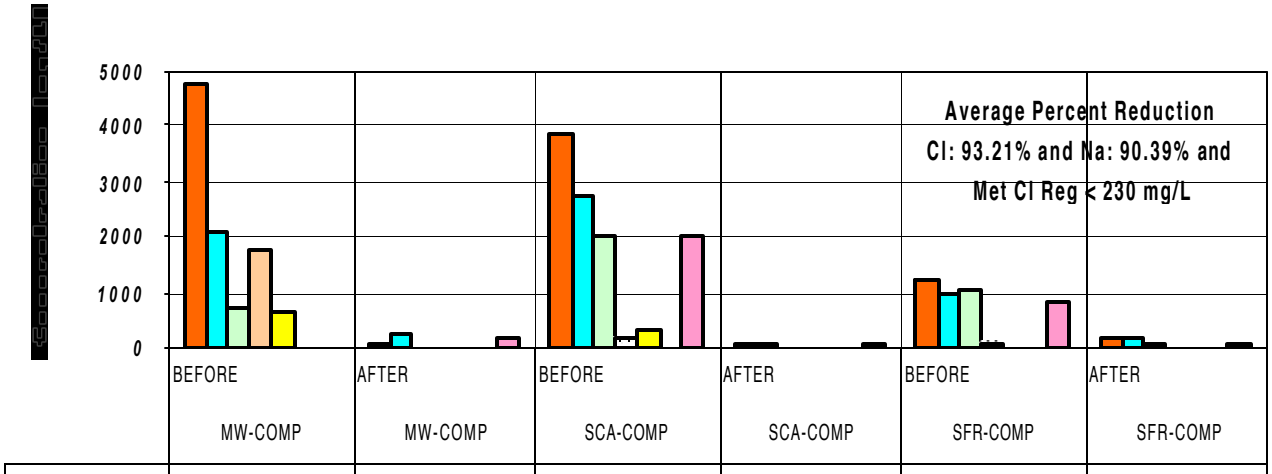
6) Desalination: Water Quality Results

DESALINATION OF MONITORING WELL COMPOSITES, CHEMICAL AMENDMENT LEACHATES AND SOIL FLUSHED EXTRACTS.
22-X ROAD MAINTENANCE YARD & SALT STORAGE SITE, CALGARY, ALBERTA

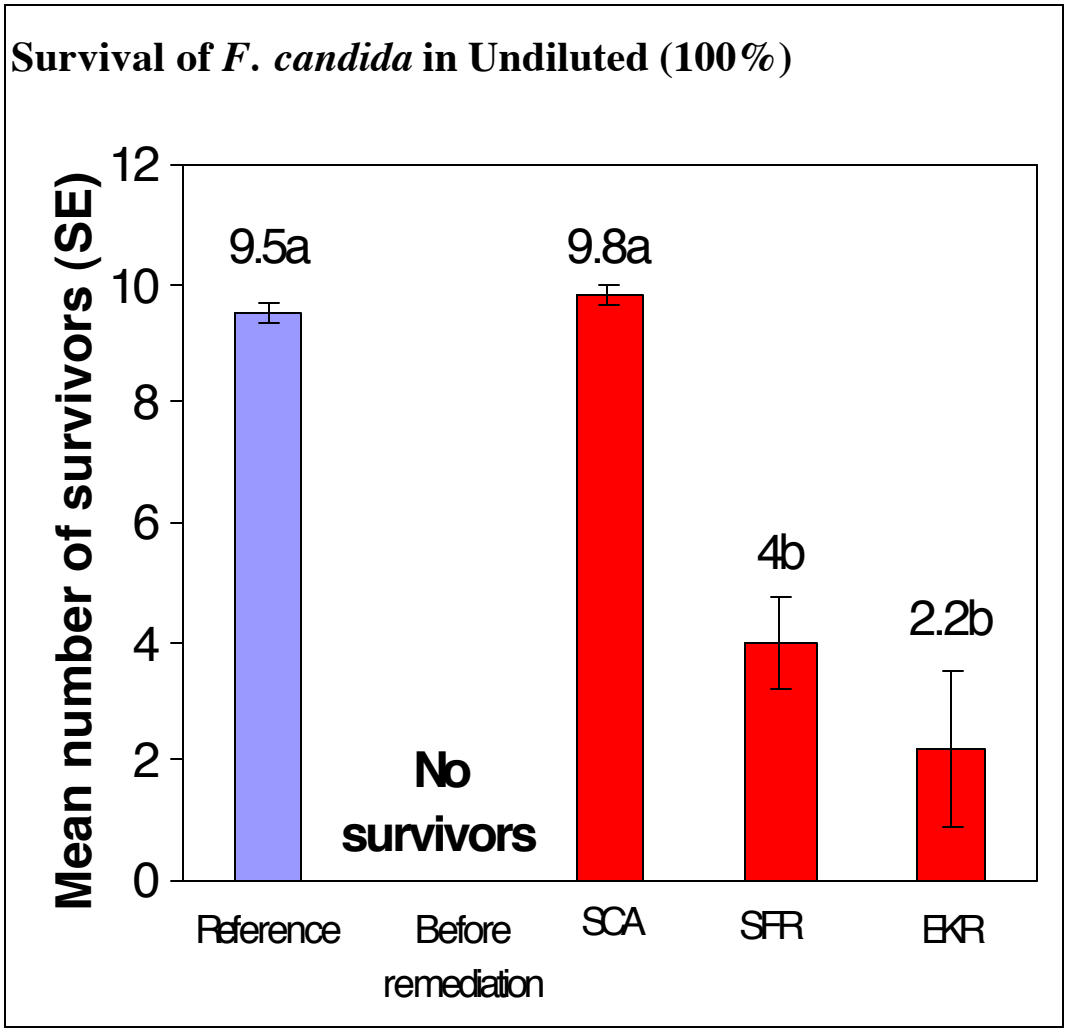


	BEFORE MW-COMP	AFTER MW-COMP	BEFORE SCA-COMP	AFTER SCA-COMP	BEFORE SFR-COMP	AFTER SFR-COMP
Chloride (Cl)	4730	86.4	3880	86.3	1200	196
Sodium (Na)	2090	207	2770	90	950	149
Calcium (Ca)	709	12.4	2010	38.1	1030	97.6
Sulphate (SO4)	1770	6.1	138	2.9	47.2	4.6
Magnesium (Mg)	632	2.6	350	8.7	38.3	5.4

Water Composites

- Surface Water quality parameters Cl-, Alkalinity as CaCO3 and pH were under the applicable Alberta Environment Surface Water Quality Guidelines for aquatic life.
- Na^+ and Cl^- in leachate water were reduced by >90.0%

7) Summary of Toxicity Results



- No survival in the contaminated soil before remediation
- Very high survival in both the reference soil and in the SCA soils. **SCA Soil Non-toxic**
- Significantly lower survival in soils treated by SFR or EKR
- A 20% reference soil and up to 80% remediated soil mixture of either SFR or EKR soil was Non-Toxic
- Soil structure appeared to be impacted by the SCA treatment, and formed hard chunks on drying, a factor that may be important under field conditions.

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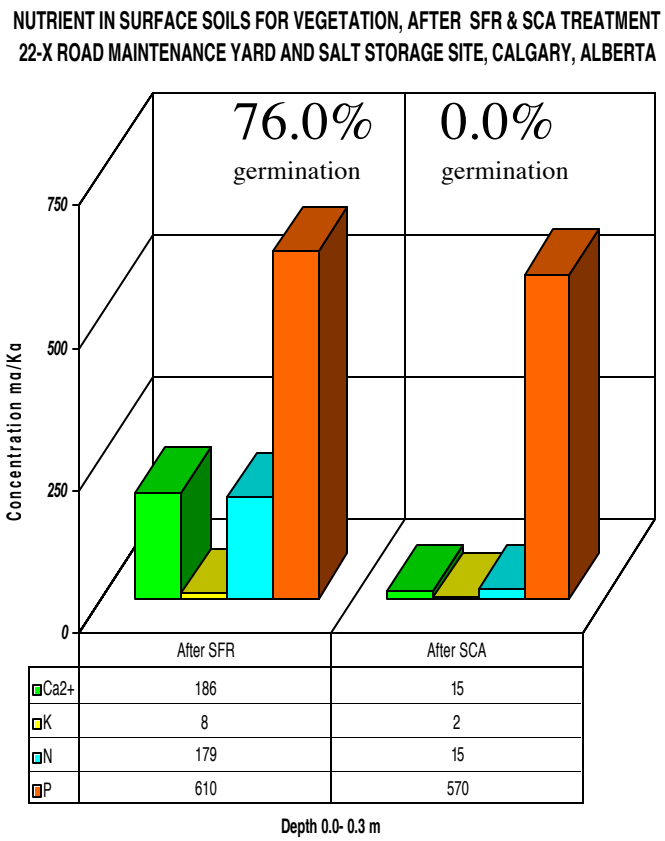
8) Summary of Phytotoxicity &Leachate Results



Phytotoxicity Prelim Result

1) TP-4 **SFR** Germination 76.0%. No evidence of phyto-toxicity
2) TP-4 **SCA**: Germination 0.0%. Evidence of phyto-toxicity
3) TP-4 **50:50 SCA diluted with reference soil**: Germination 44.0%. Evidence of phyto-toxicity. Further investigation?

Leachate Control Result

Na^+ 98.0%

Cl^- 99.3%

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SFR, SCA and EKR Evaluation Summary

Benefits

SFR: Rapid mass reduction of NaCl & other cation and anion contaminants (< 1week), Improves SAR, prelim test Not phyto-toxic

SCA: Mass reduction of NaCl (30 days) Prevents soil dispersion, improves EC, prelim post remedial test Not Toxic

EKR: Demonstrates major chlorine depletion with minimal water usage ~5.0L (30 days)

prelim test for potential sub-grade reuse good

Overall: (potential field application)

- Permanency in NaCl Decontamination
- Technology (in-situ) functionality high, provides remedial reliability and could be adapted for ex-situ clean-up as well.
- Provides impetus to conduct sustainability focused cost and benefit analysis
- Decontamination efforts would minimize potential environmental liabilities
- Land use freed up for redevelopment
- Sustainable in the long term

Limitations

SFR: Copious water use and secondary water treatment. High Soil EC.

SCA: Dependant on efficient drainage and leachate recovery. Presents high soil SAR

EKR: Presents pH imbalances, secondary precipitates, off-gas emissions, high soil EC

Overall: (potential field application)

- Soil Quality (EC and SAR) not consistent
- Technology bugs: Downstream migration, sequestering off gas emissions, and caustic soil pH not researched pilot scale on site.
- Initial technology development and performance testing costs high
- Status-quo could enhance potential environmental challenges
- Land use restricted
- Status quo is not sustainable due to long term liability

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Conclusions

NaCl target contaminant clean-up from clay soils

SOIL QUALITY

- *All three Remedial Technologies evaluated reduced Na Cl from soils > 98.0%;*
- *SFR and EKR met guidelines for SAR <12. SCA exceeded SAR Guidelines.*
- *SCA met EC<4 dS/m. SFR & EKR exceeded EC Guidelines.*

WATER QUALITY

- *Desalination permeate < 230 mg/L Cl, Alk as in $CaCO_3$ <20 mg/L and pH between (6.5-9.0). Met CCME 1999; Surface Water Quality Guidelines and Storm Sewer Discharge-26M98; Sanitary Sewer Discharge- 24M96*

POST REMEDIATED SOILS

- *Toxicological tests (SCA soil non-toxic), plant bio-assay (SFR soil not phyto-toxic) and leachate control (>98% for NaCl)*

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Next Steps?

De-contamination (DC) or Risk Management (RM)?

Pilot Scale Remedial Feasibility at 22X versus Long term maintenance & management

Sustainable Re-Development Approach

Environmental aspects:

- sustainable remediation versus dig and dump
- improved environmental health and safety versus maintaining status-quo

Social aspects:

- potential greening of site versus vacant Brownfield
- quality of life, higher property values versus lower property values

Economic aspects:

- added investment value from redevelopment versus restricted land use
- reduced liability versus long term liability
- high clean-up costs versus lower monitoring and maintenance costs

Requires:

- Sustainability focused Cost and Benefit Analysis (DC or RM?)
- Stakeholder participation, joint decision, resource contribution & implementation

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Questions ?

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