An Investigation of Natural Attenuation and Plume Geochemistry at an Oil Sands Mining Facility

Prepared for Remtech 2006

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Acknowledgements

- Analytical Support: Marianne vanderGriendt (University of Waterloo) & Shirley Chatten (UW)
- Co-Authors: Francoise Gervais (UW), Drs Jim Barker (UW), Uli Mayer (University of British Columbia), Carol Ptacek (UW & National Water Research Institute) and Dave Rudolph (UW)
- Syncrude Canada Ltd: Barry Esford, Grey Kampala, Mike MacKinnon, Lori Cyprien, Karen Chovan, Steve Carroll
- Field and Lab Assistance: Mike Gunsinger (UW), Rich Amos (UBC), Ed Cey (UW), Bill Marsh (University of Alberta), Naoki Yasuda (UW), Lindsay Oiffer, Wayne Noble (UW), Matt Lindsay (UW), Jeff Bain (UW)
- Funding from: The Canadian Foundation for Innovation, The Canada Water Network, NSERC and Syncrude

Outline

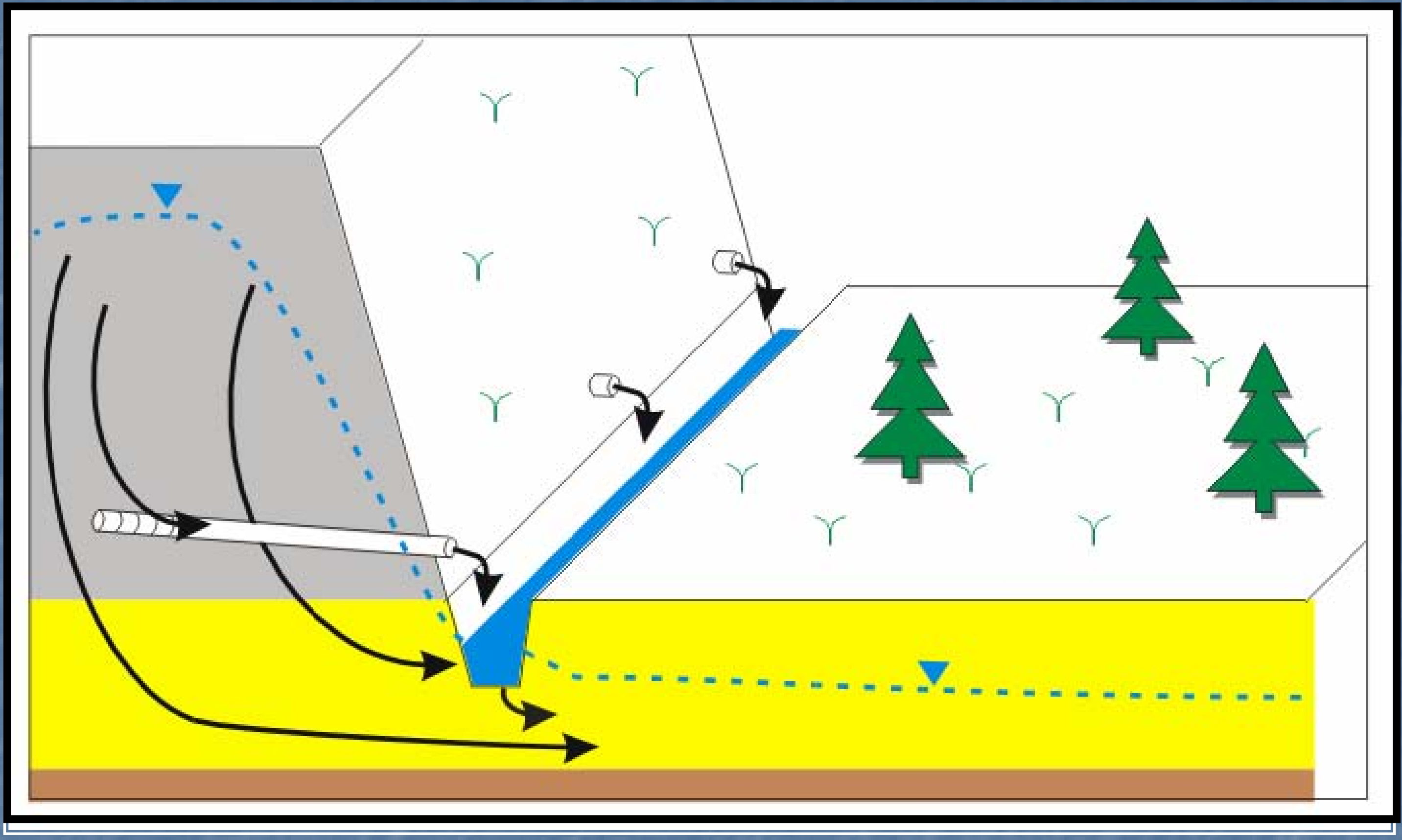
1. Objectives
2. Plume Dynamics
3. Sampling Network
4. General Plume Composition
5. Naphthenic Acid Attenuation Mechanisms
6. Trace Metals Release Mechanisms

Objectives

1. Identify the groundwater fate and transport properties of constituents of concern of seepage waters (Primary Effects)

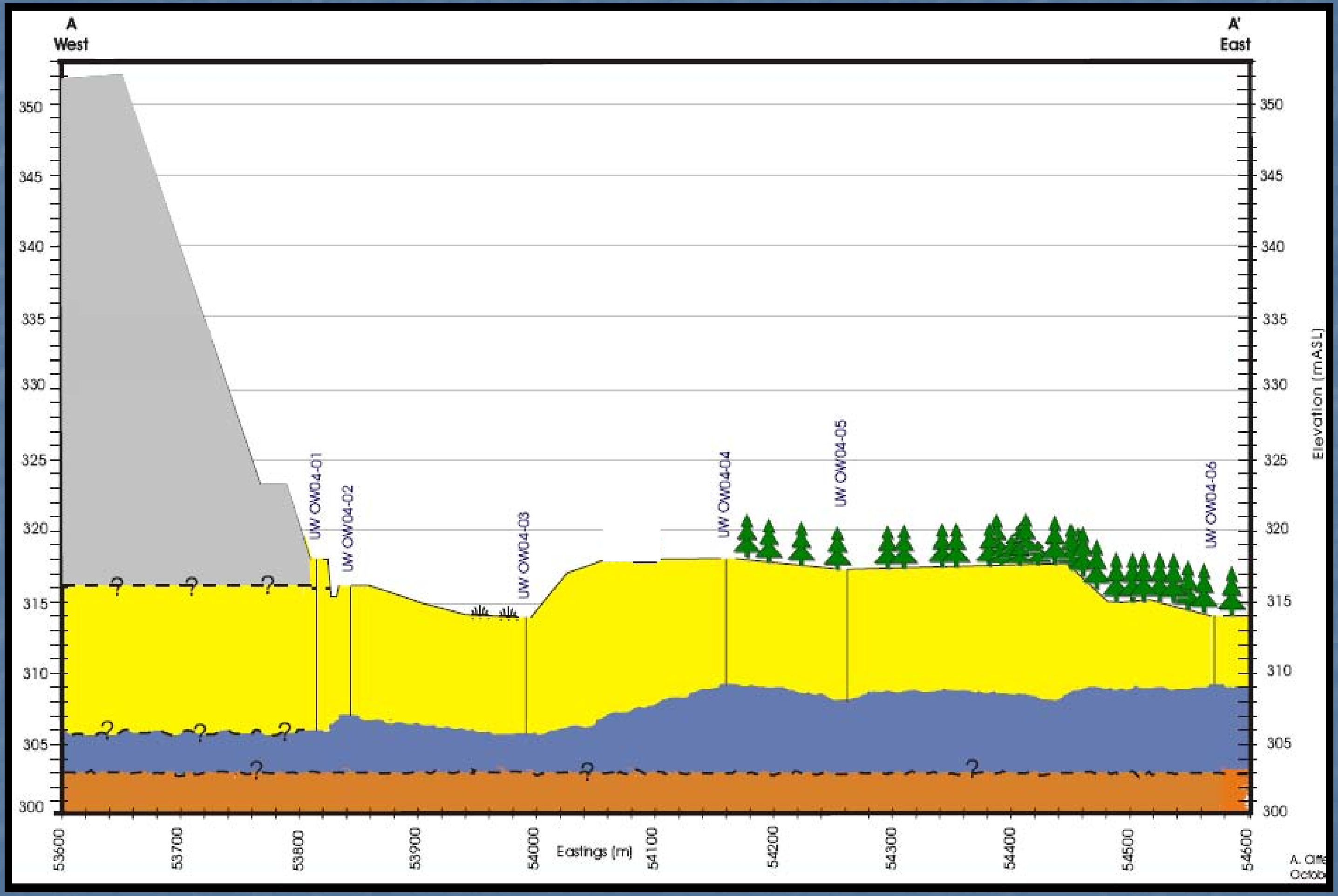
2. Determine the potential for trace metal release from the solid phase (Secondary Effects)

Plume Dynamics



- Objectives
- Plume Dynamics
- **Sampling Network**
- General Plume Composition
- NAs Introduction
- NAs Attenuation
- NAs Biodegradation
- NAs Sorption
- NAs Conclusions
- TMs Introduction
- TMs Dissolved Concentrations
- TMs Release Mechanisms
- TMs Controls for Release
- TMs Solid Phase Content
- TMs Reductive Capacity of Plume
- TMs Conclusions

Sampling Network



Objectives

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NAs Biodegradation

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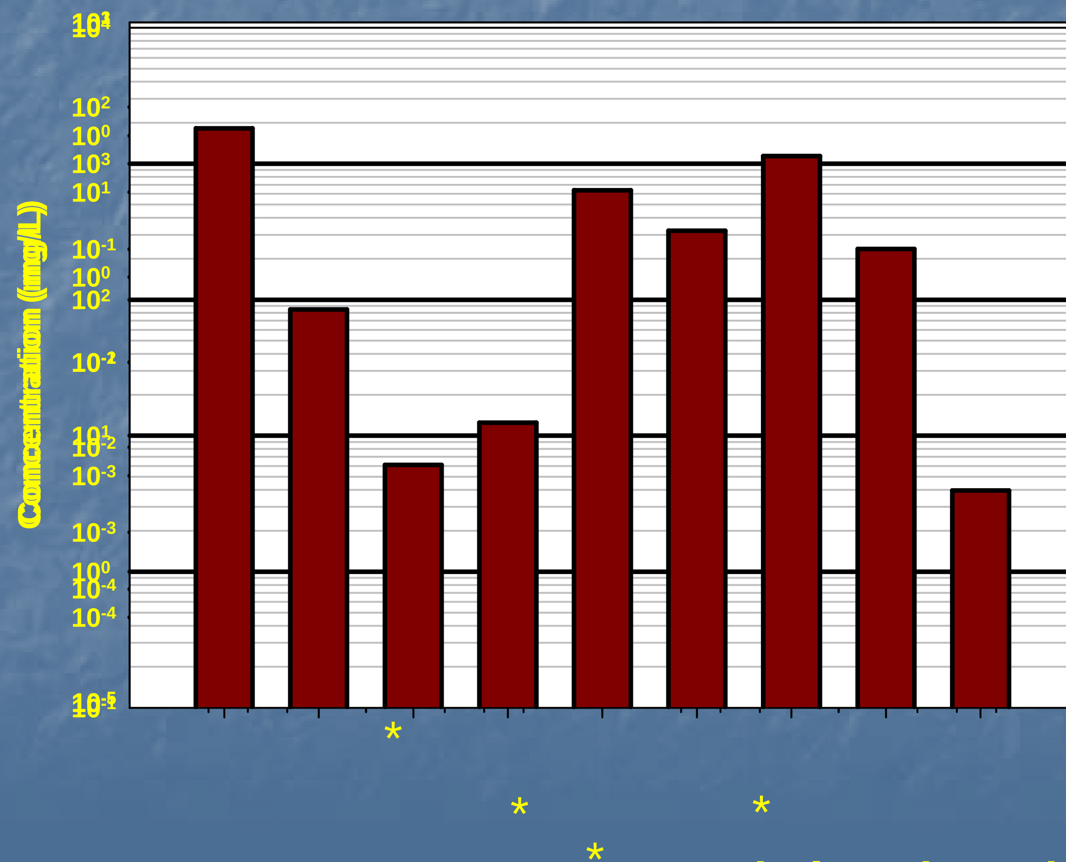
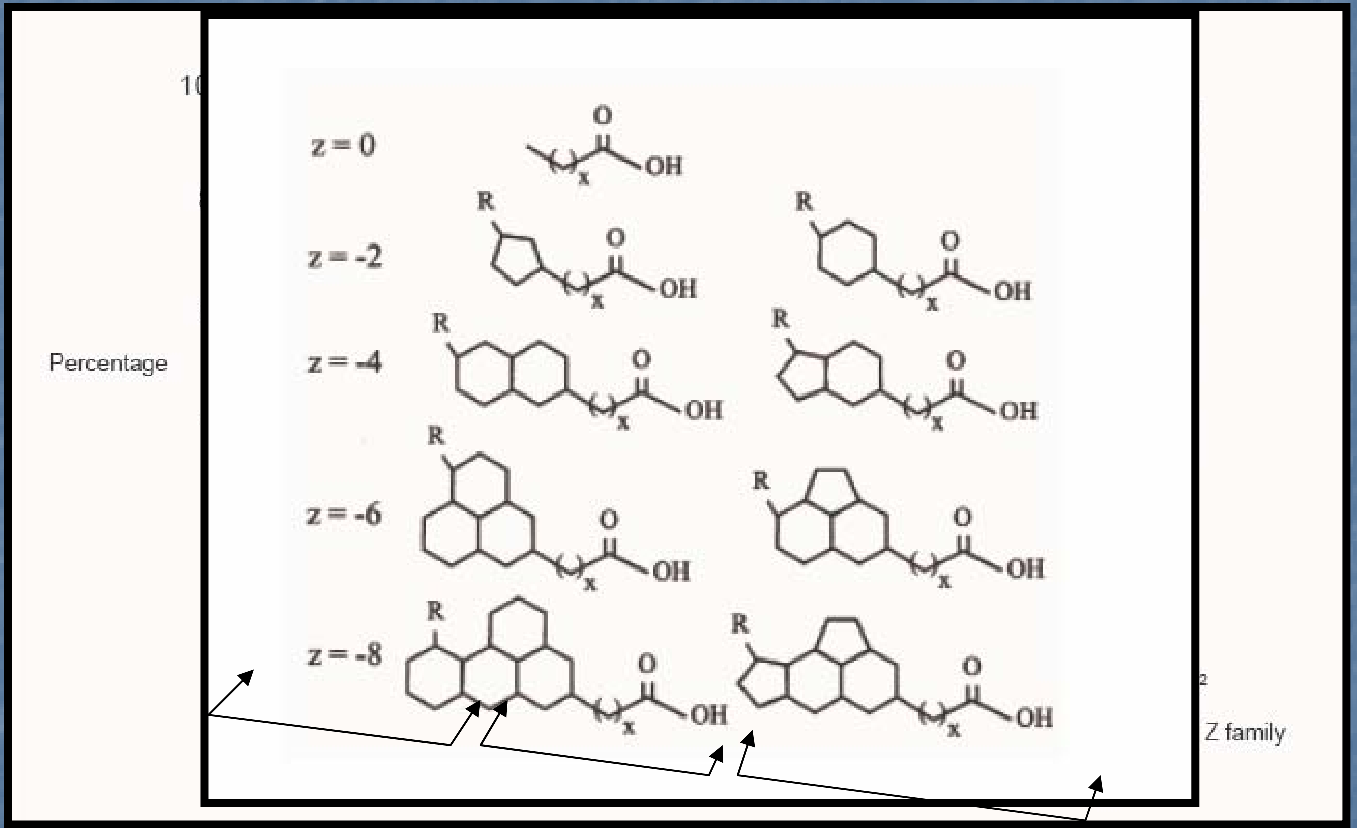
General Plume Composition

- **Maximum Concentrations Near Source (Adjacent to Tailings Dyke)**



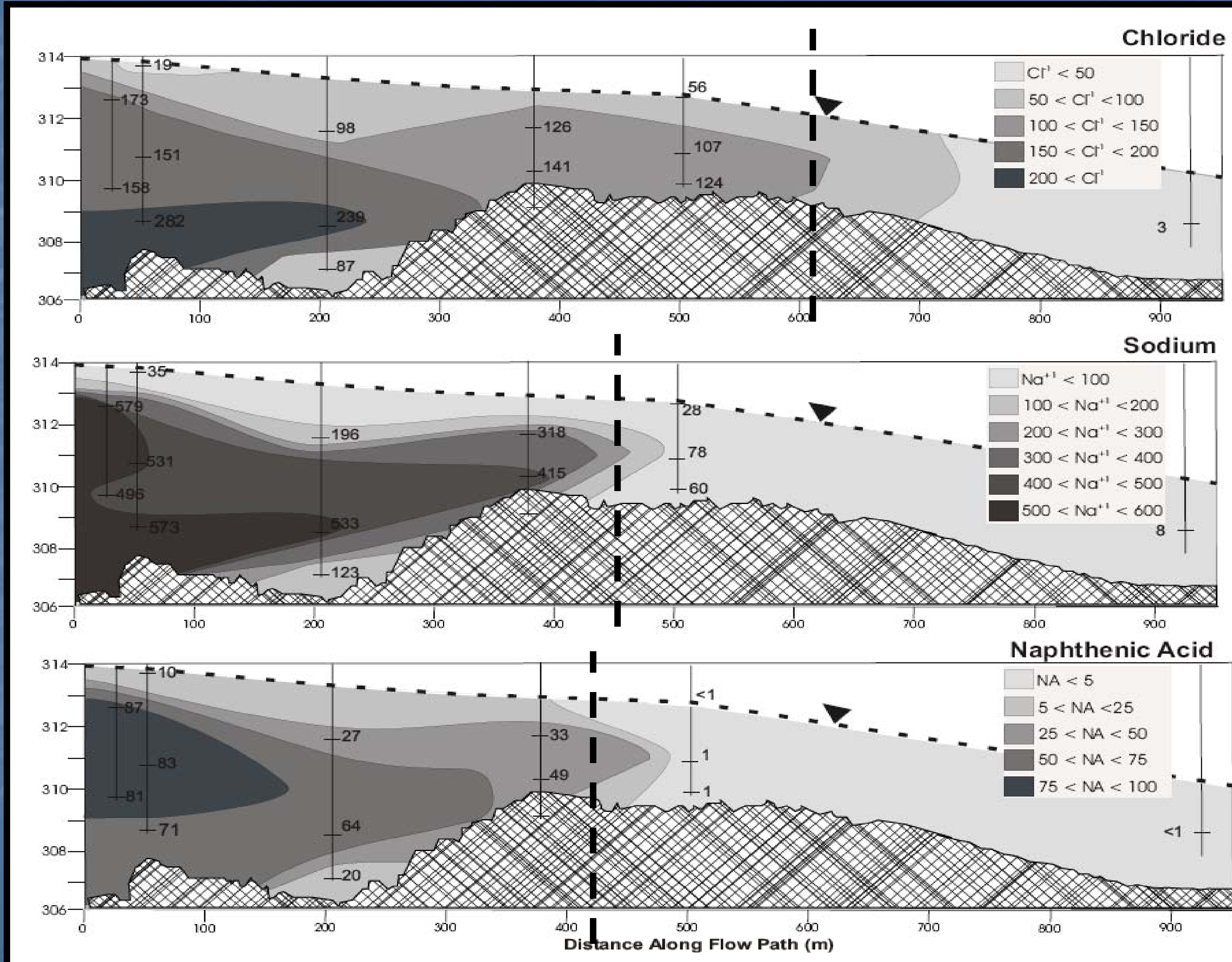
*** below detection limit**

Naphthenic Acids - Introduction

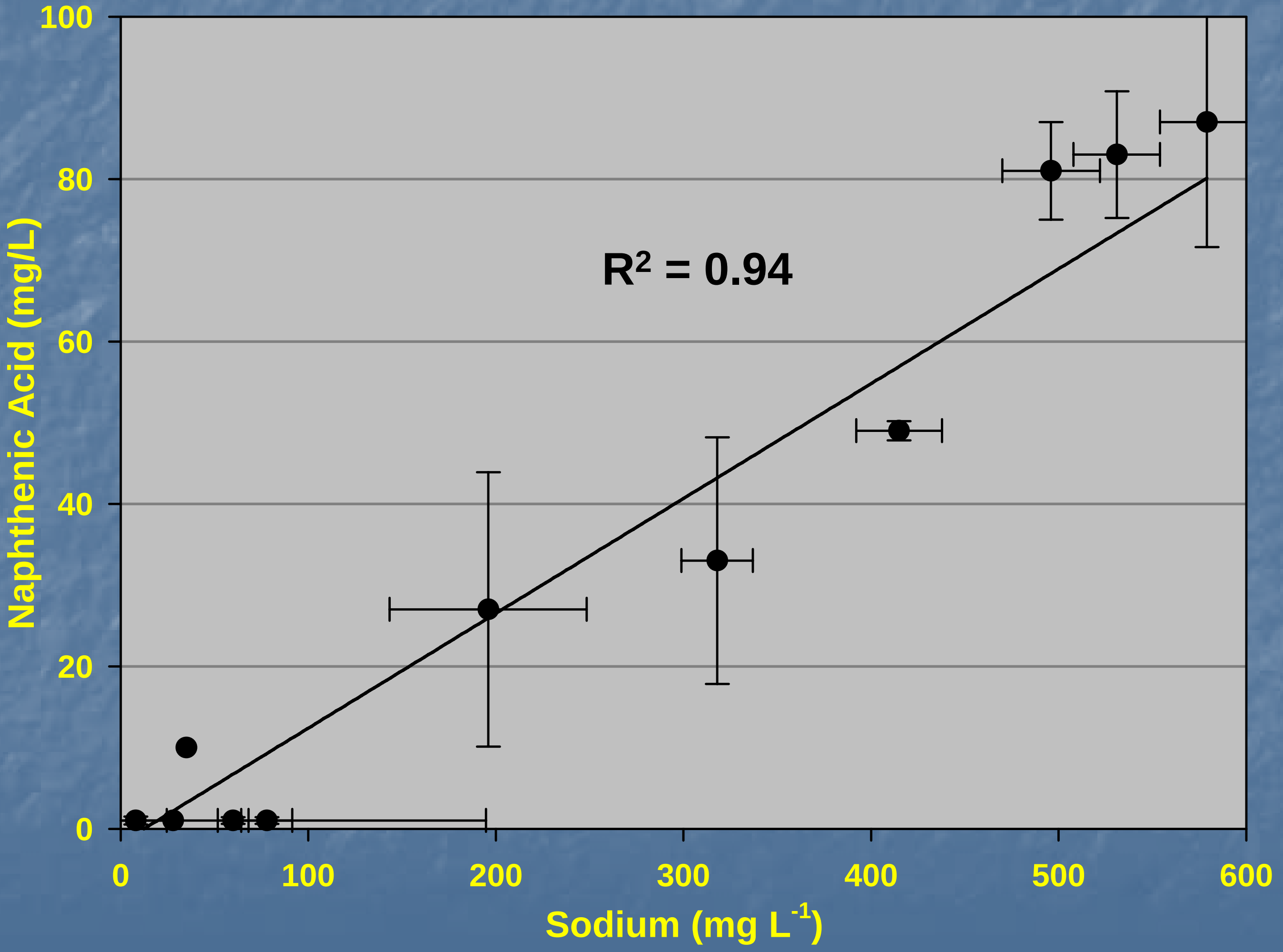


Gervais (2004)

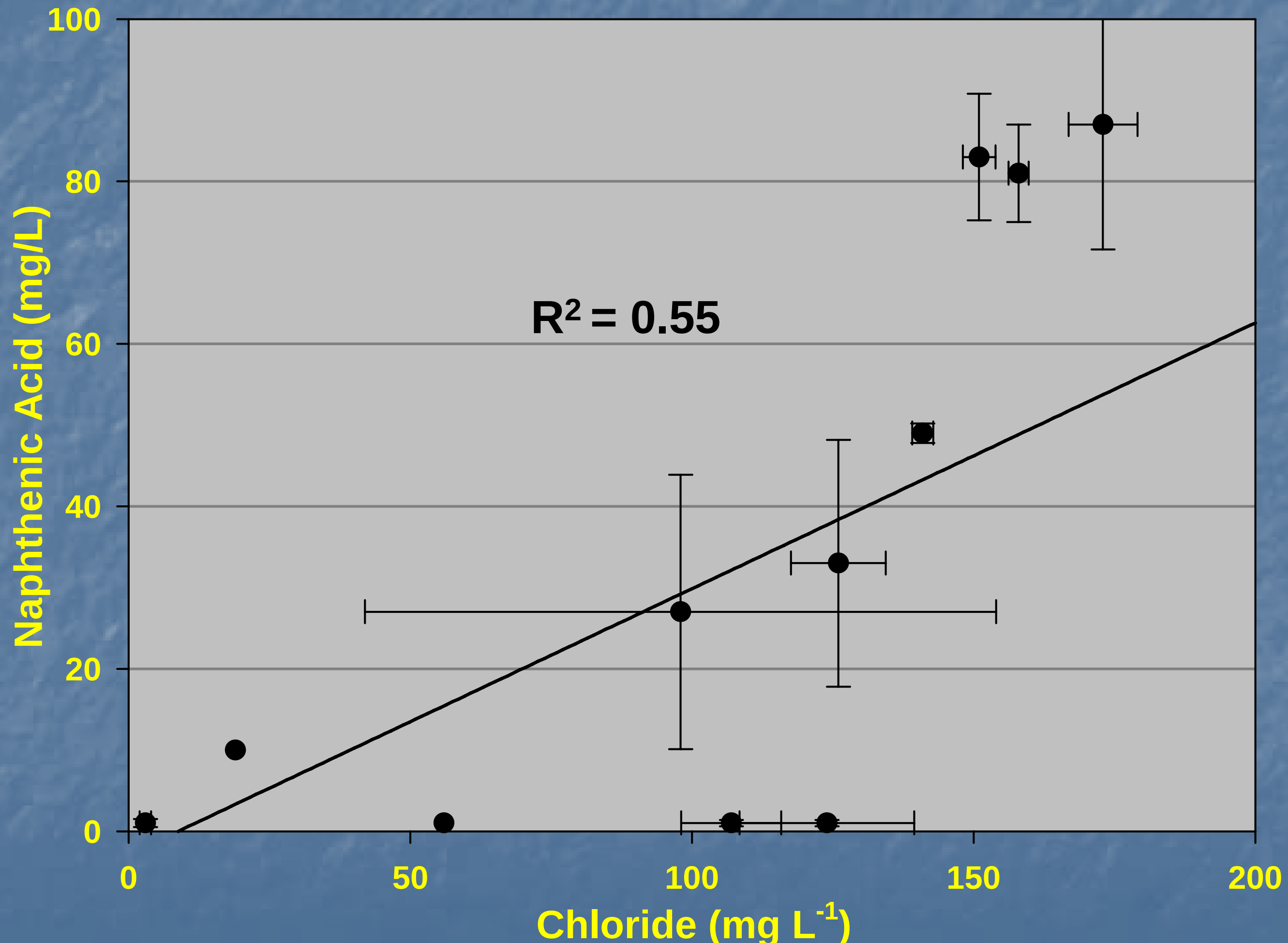
Naphthenic Acids - Attenuation



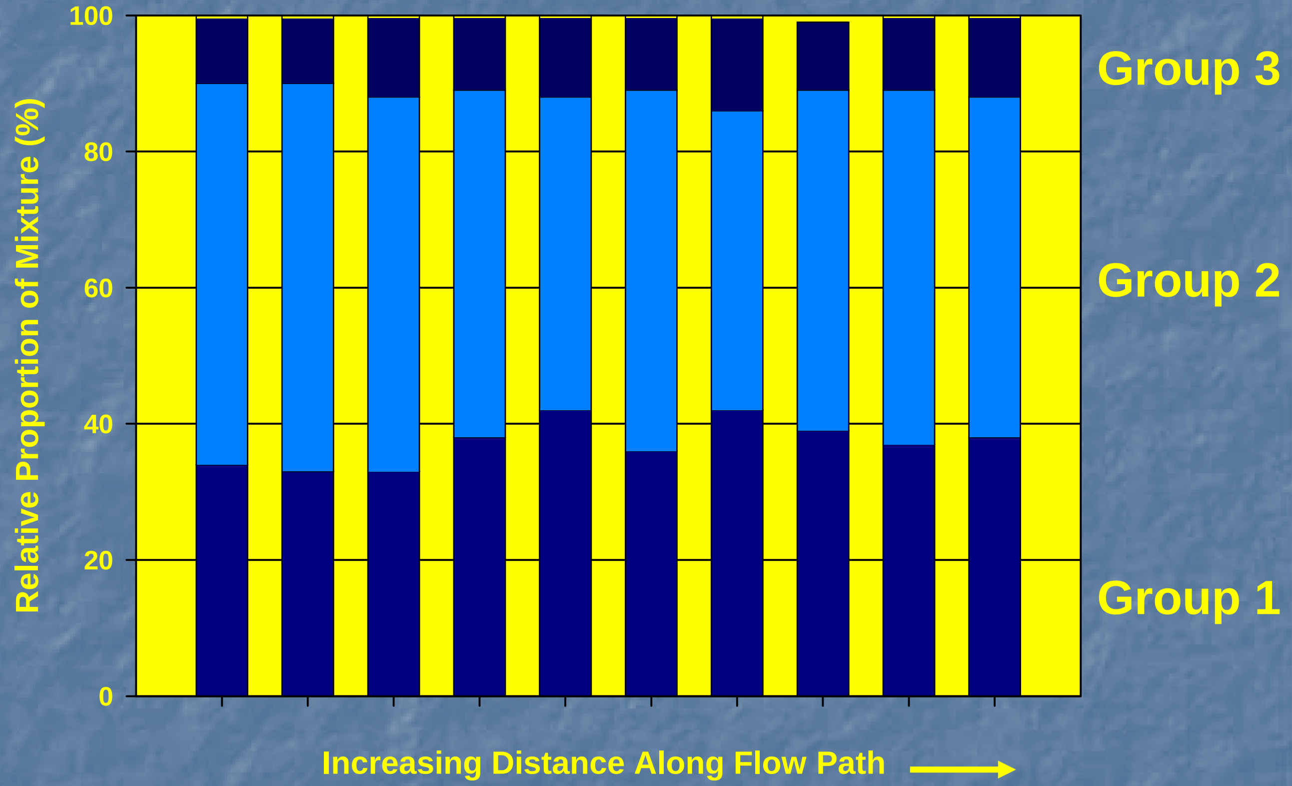
Naphthenic Acids - Attenuation



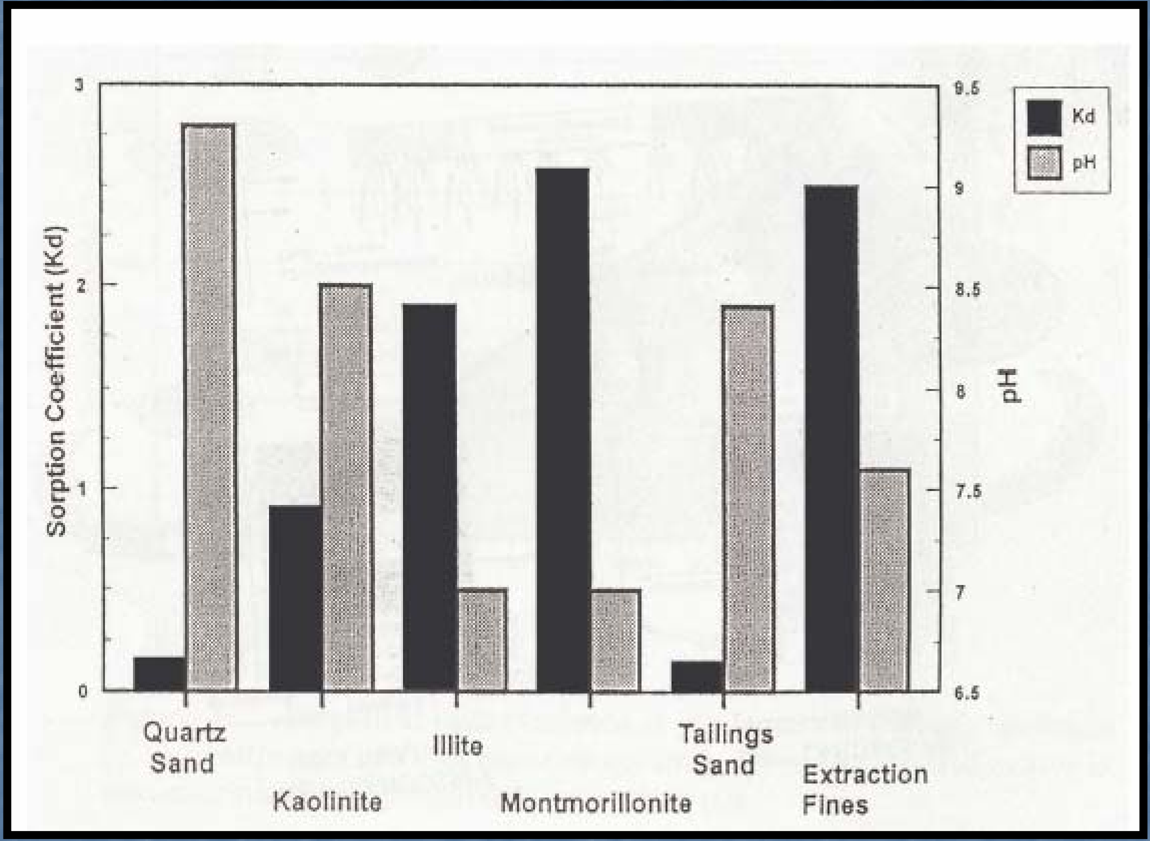
Naphthenic Acids - Attenuation



Naphthenic Acids - Biodegradation



Naphthenic Acids - Sorption

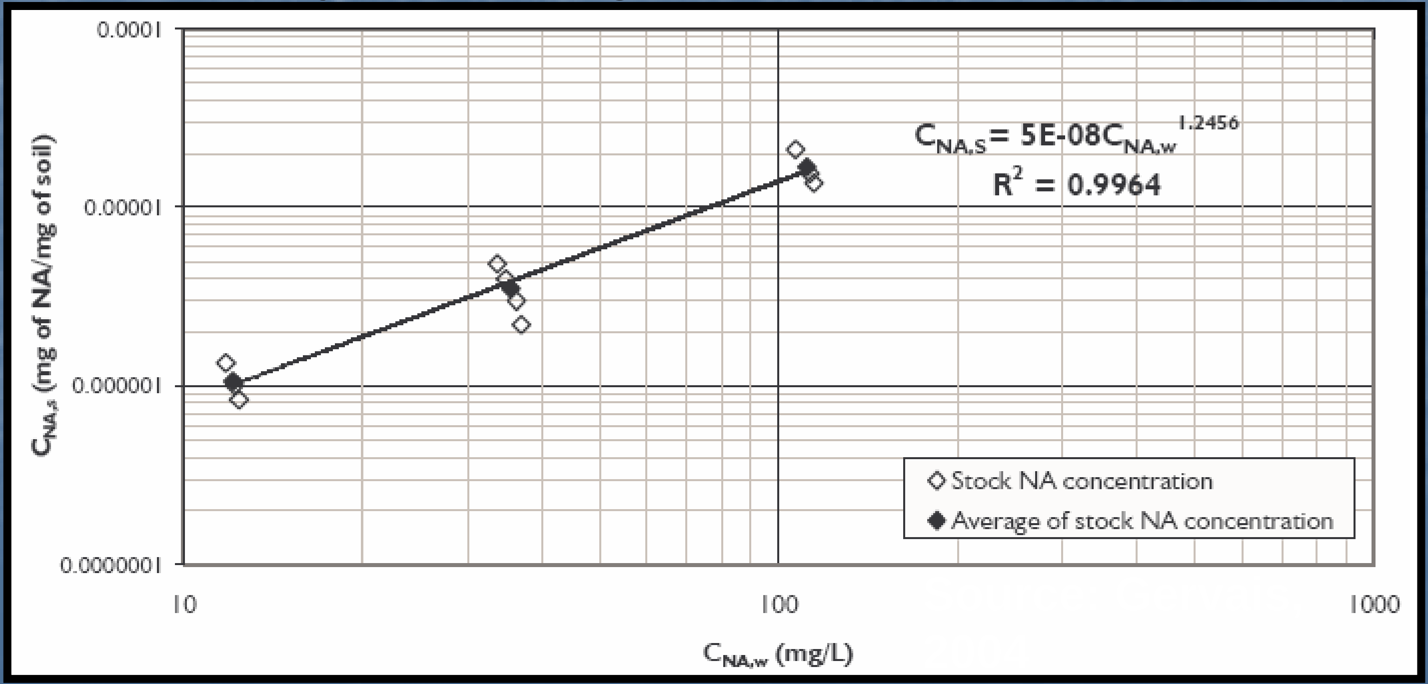


Units: mg/L

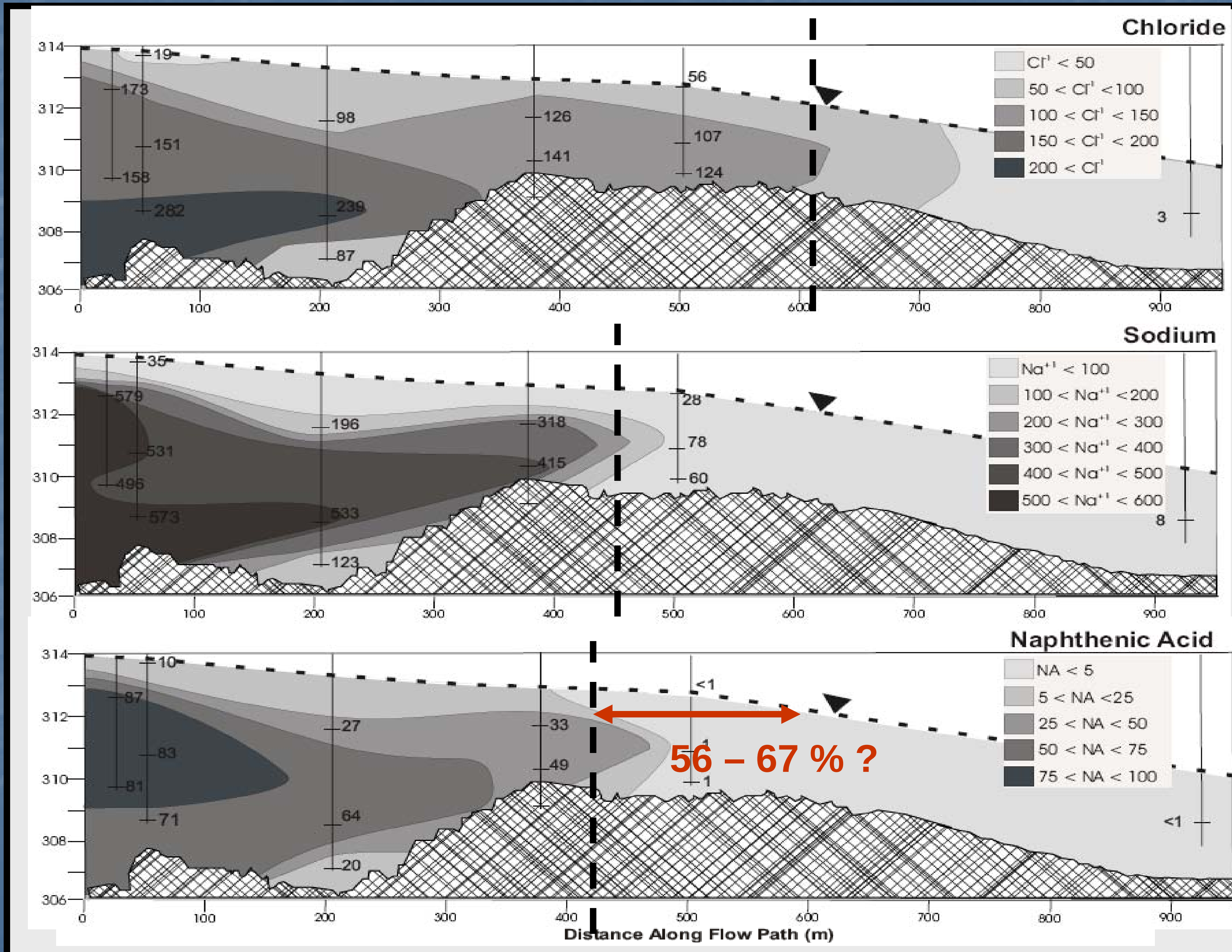
Source: Schramm et al. 2000

Naphthenic Acids - Sorption

- Sand from sand aquifer in Fort McMurray Area
- Naphthenic Acids from tailings water
- Solution TDS of approximately 1,700 mg/L
- pH varied between 7 and 8
- Fraction of Organic Carbon (foc): 1%
- Velocity relative to groundwater: 56 – 67%



Naphthenic Acids - Sorption



Naphthenic Acids - Conclusions

- Overall retardation of Naphthenic Acids is low
- Significant Biodegradation of Naphthenic Acids is not interpreted
- Weak sorption could explain Naphthenic Acid retardation
- Difficult to account for initial conditions → Constant Source?

Trace Metals - Introduction

Element	Oxidizing Conditions	Reducing Conditions
Pb	$Pb(OH)^+$ & Pb^{2+}	$Pb(OH)^+$ & Pb^{2+}
Cu	Cu^{2+} & Cu^+	$Cu_{(s)}$ & Cu^+
Ni	Ni^{2+}	Ni^{2+}
Cd	Cd^{2+}	Cd^{2+}
Co	Co^{2+}	Co^{2+}
Zn	Zn^{2+}	Zn^{2+}
Cr	CrO_4^{2-}	$Cr_2O_{3(s)}$ & $CrOH^{2+}$ & CrO^+
As	$H_2AsO_4^-$ & $HAsO_4^{2-}$	$H_3AsO_3^-$
Se	SeO_4^{2-}	SeO_3^{2-}

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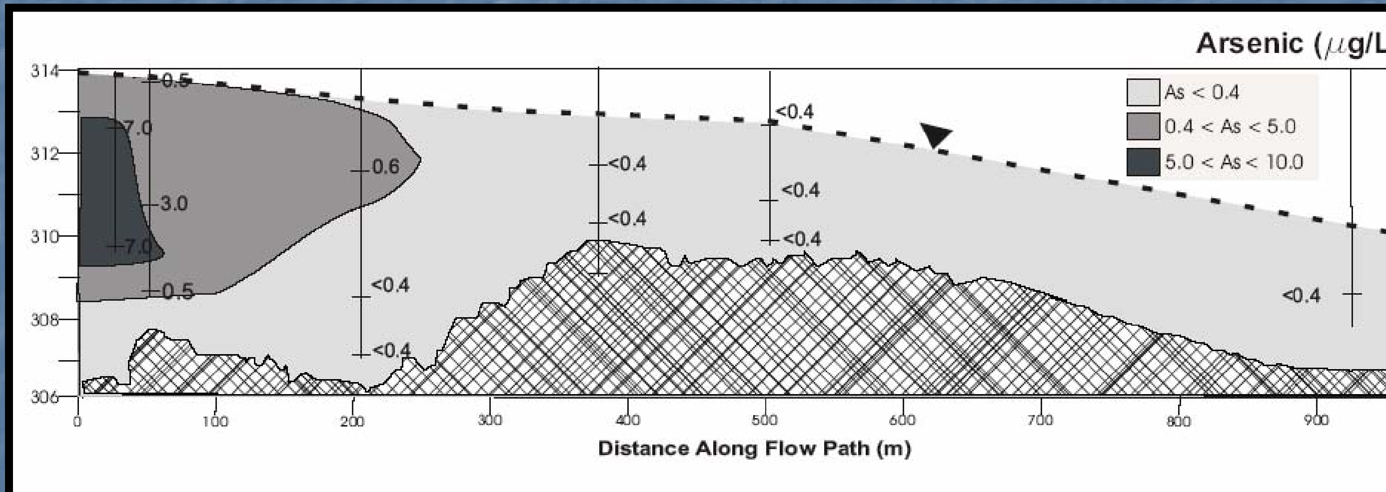
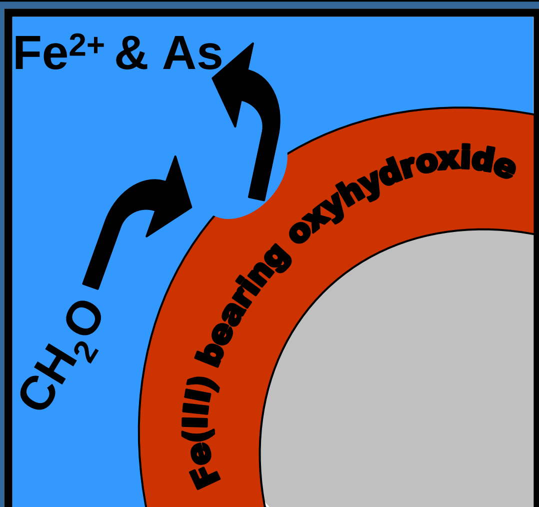
Trace Metals - Dissolved Concentrations

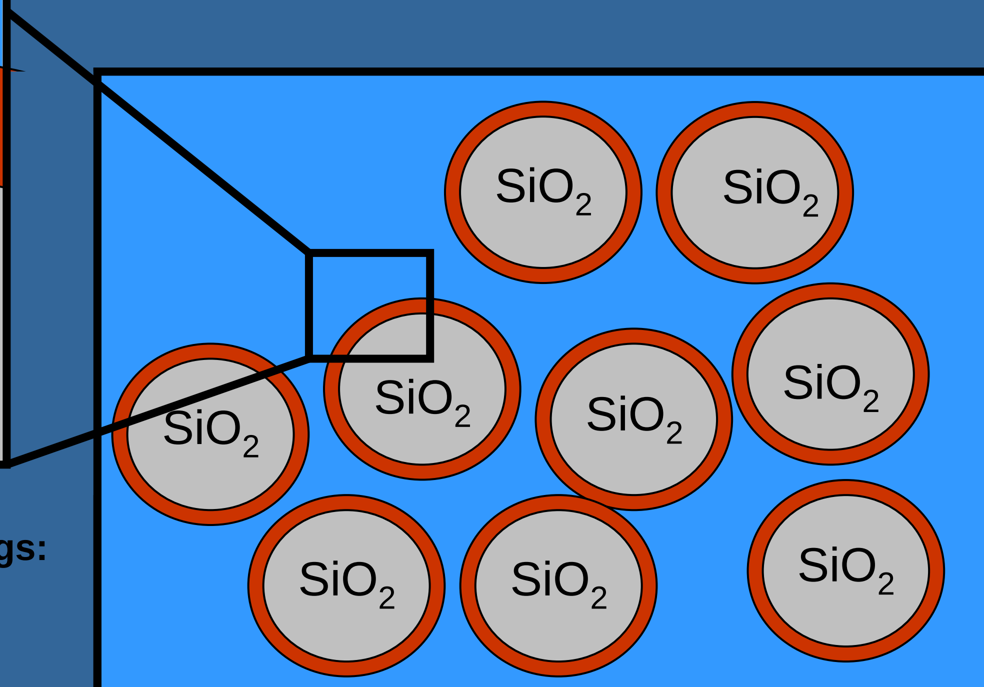
- Dissolved Arsenic Associated with Plume (mg/L)



Trace Metals – Release Mechanisms

$$4FeOOH_{(s)} + CH_2O + 6H^+ \rightarrow CO_3 + 4Fe^{2+} + 6H_2O$$





Some Possible Fe Mineral Phases in Oxidizing Settings:

$Fe(OH)_3$

$FeOOH$

Fe_3O_4

Fe_2O_3

Trace Metals – Controls for Release

- Two Controlling Influences in Trace Metal Release:
  - Trace Metal Content of Aquifer Material
  - Reductive Capacity of the Seepage Waters

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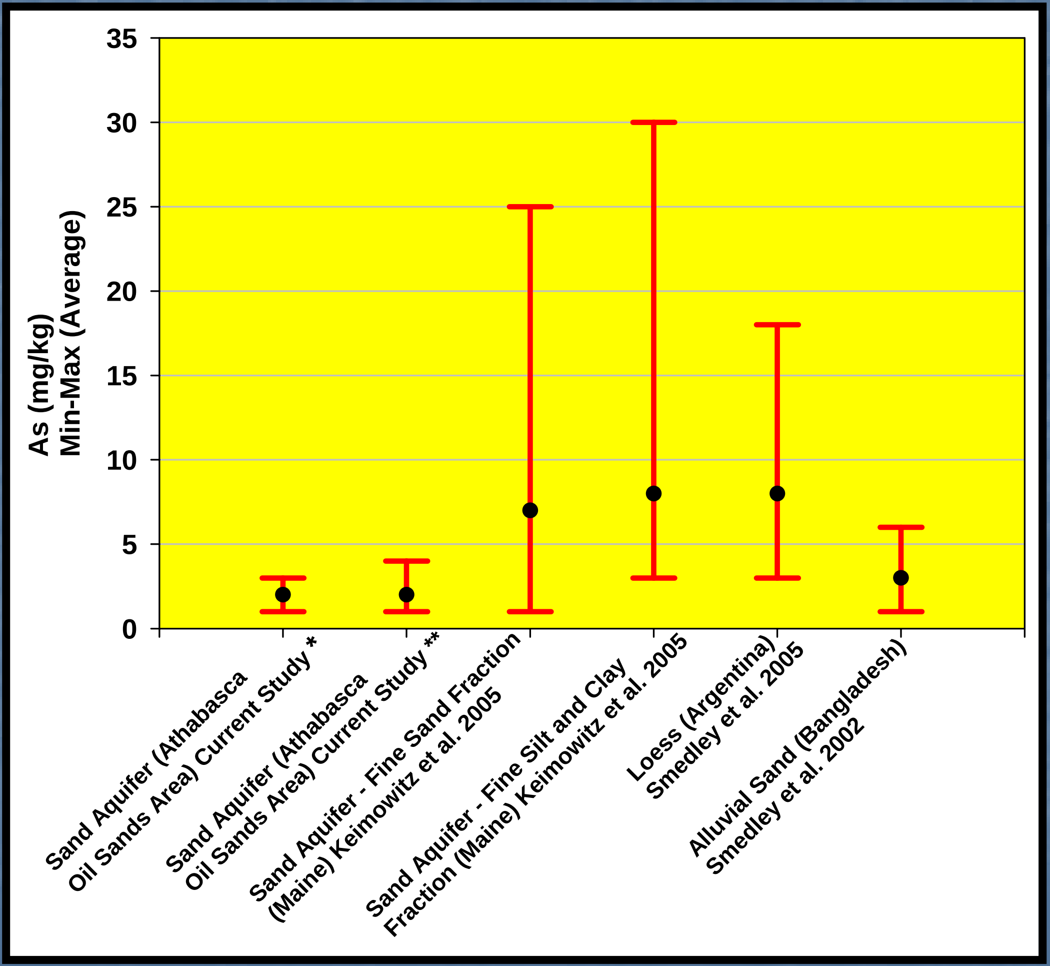
Trace Metals – Solid Phase Content

- As content in solid phase determined using solid phase extractions:

	0.5M HCl	5.0M HCl
Amorphous FeS, Greigite, Mackinawite & Pyrrhotite		
Pyrite & Elemental Sulphur		
Carbonates		
Amorphous Oxyhydroxides		
Poorly crystalline metal oxides, hydroxides, monosufides, adsorbed metals & ion exchangeable metals		
Crystalline Metal Oxides/Oxyhydroxides & Metals bound in Clays		

Trace Metals – Solid Phase Content



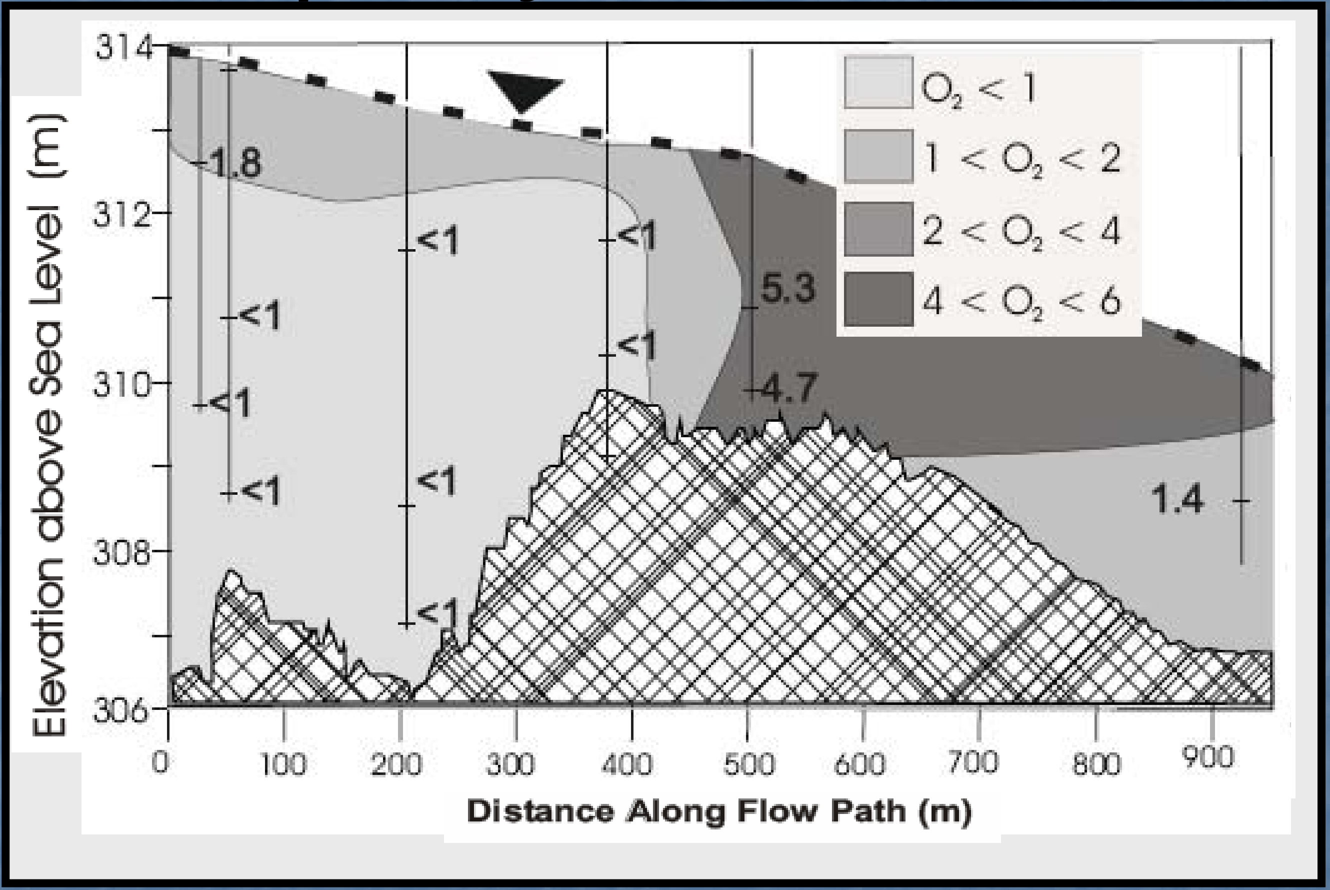
* Extracted using 0.5M HCl for 24 hours

** Extracted using 5.0M HCl for 24 hours

Trace Metals – Controls for Release

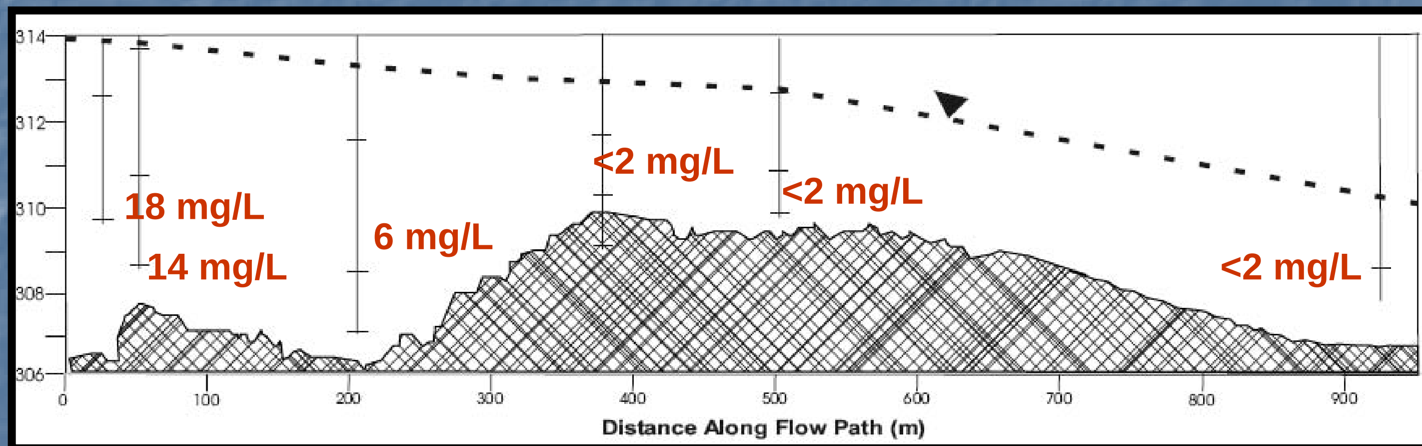
- Two Controlling Influences in Trace Metal Release:
  - Trace Metal Content of Aquifer Material
  - Reductive Capacity of the Seepage Waters

Trace Metals - Reductive Capacity of Plume



Trace Metals - Reductive Capacity of Plume

5 Day Biological Oxygen Demand Tests



- Some uncertainty regarding contribution of Fe, Mn, NH_4 and CH_4(aq) (COD) to biological oxygen demand results
- Contribution of Naphthenic Acids?

Trace Metals - Conclusions

Possible causes for low dissolved As concentrations:

1. Plume is assumed weakly reducing
2. Low As content in solid phase
3. Phase association of As

References

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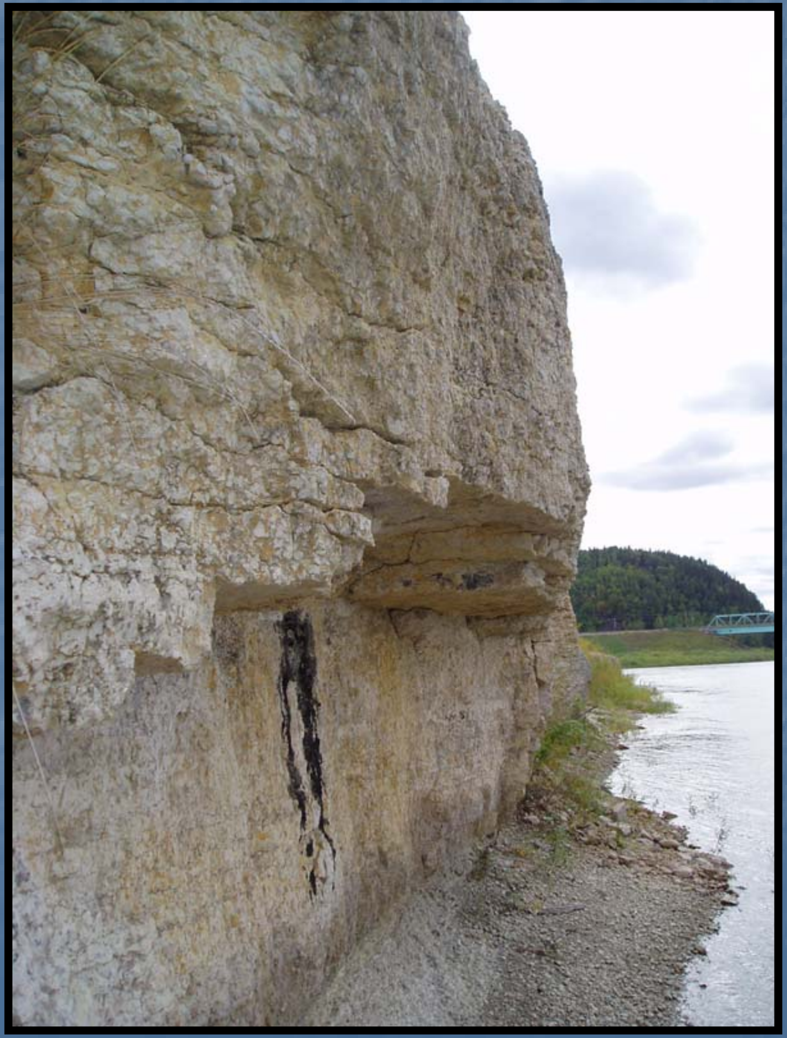
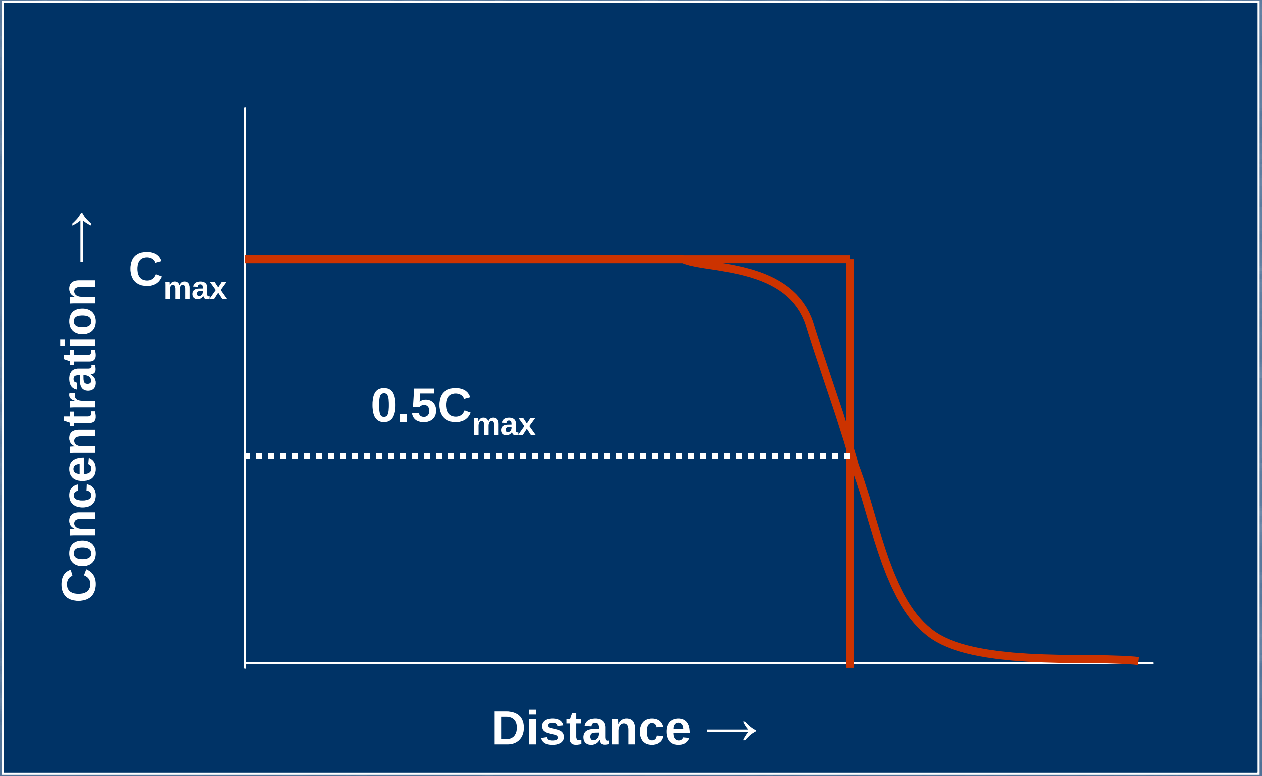
5. Smedley, P.L. and Kinniburgh, D.G. (2002). A review of the source, behavior and distribution of arsenic in natural waters. Appl. Geochem., 17: 517-568.

Questions?

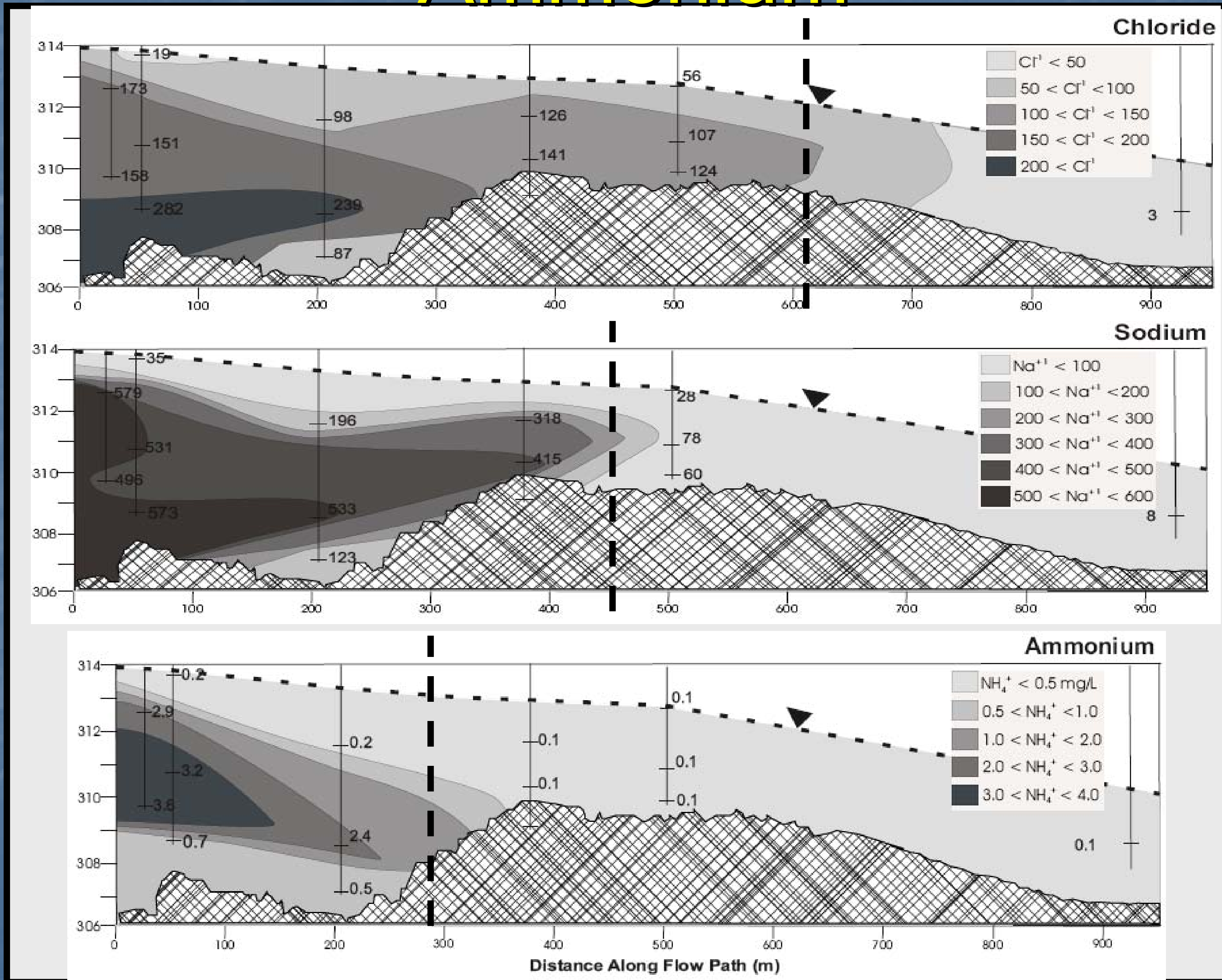


Extra Slides

Advective Front

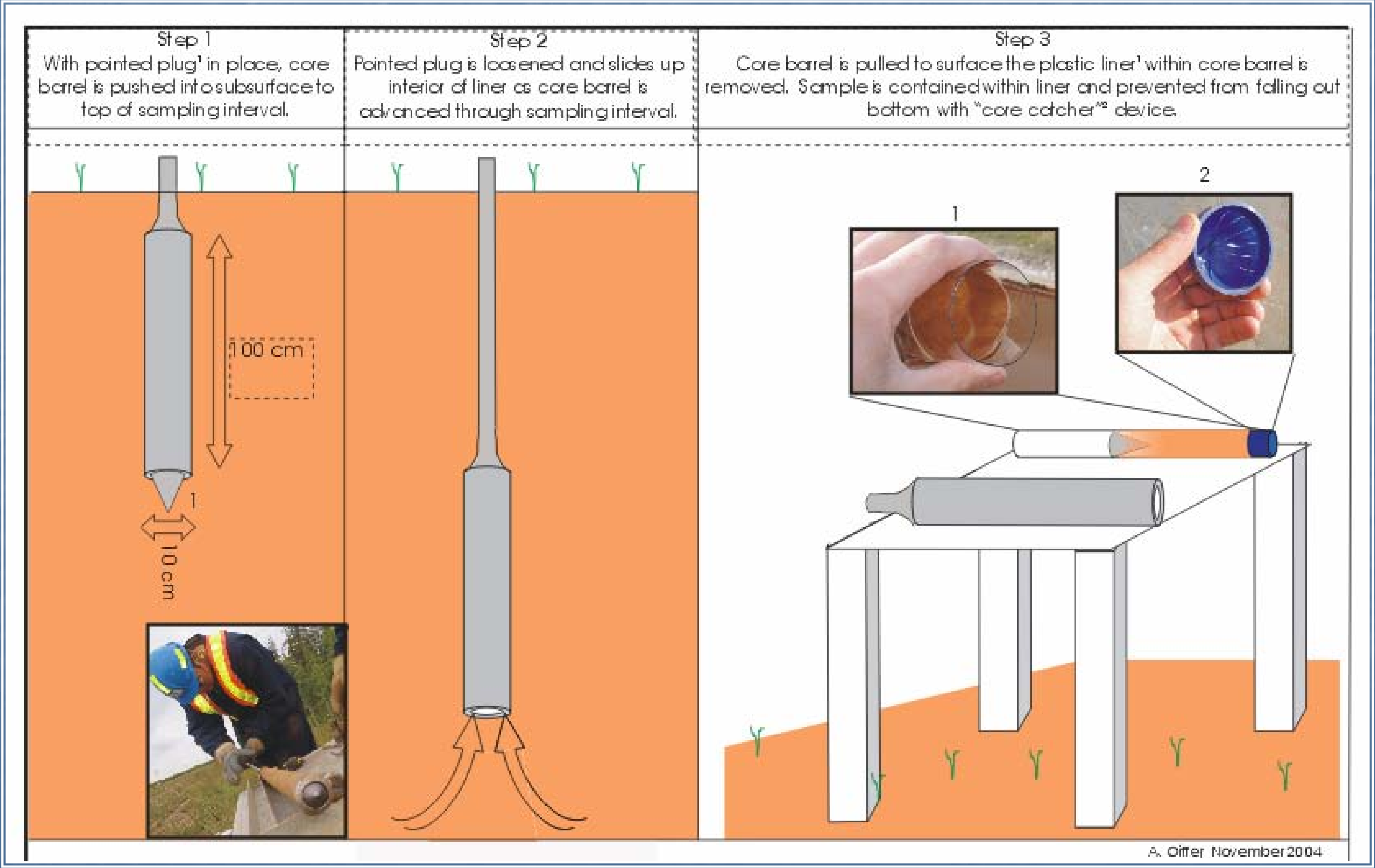


Ammonium



Chloride
Cl⁻ < 50
50 < Cl⁻ < 100
100 < Cl⁻ < 150
150 < Cl⁻ < 200
200 < Cl⁻
Sodium
Na⁺ < 100
100 < Na⁺ < 200
200 < Na⁺ < 300
300 < Na⁺ < 400
400 < Na⁺ < 500
500 < Na⁺ < 600
Ammonium
NH4+ < 0.5 mg/L
0.5 < NH4+ < 1.0
1.0 < NH4+ < 2.0
2.0 < NH4+ < 3.0
3.0 < NH4+ < 4.0
Distance Along Flow Path (m)

Coring


Step 1
With pointed plug[1] in place, core barrel is pushed into subsurface to top of sampling interval.
Step 2
Pointed plug is loosened and slides up interior of liner as core barrel is advanced through sampling interval.
Step 3
Core barrel is pulled to surface the plastic liner[1] within core barrel is removed. Sample is contained within liner and prevented from falling out bottom with "core catcher"[2] device.
100 cm
1
10 cm
1
2
A. Oiffer November 2004