The Effects of Stream Incision on Groundwater Quality in a Riparian Zone

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Presentation Outline

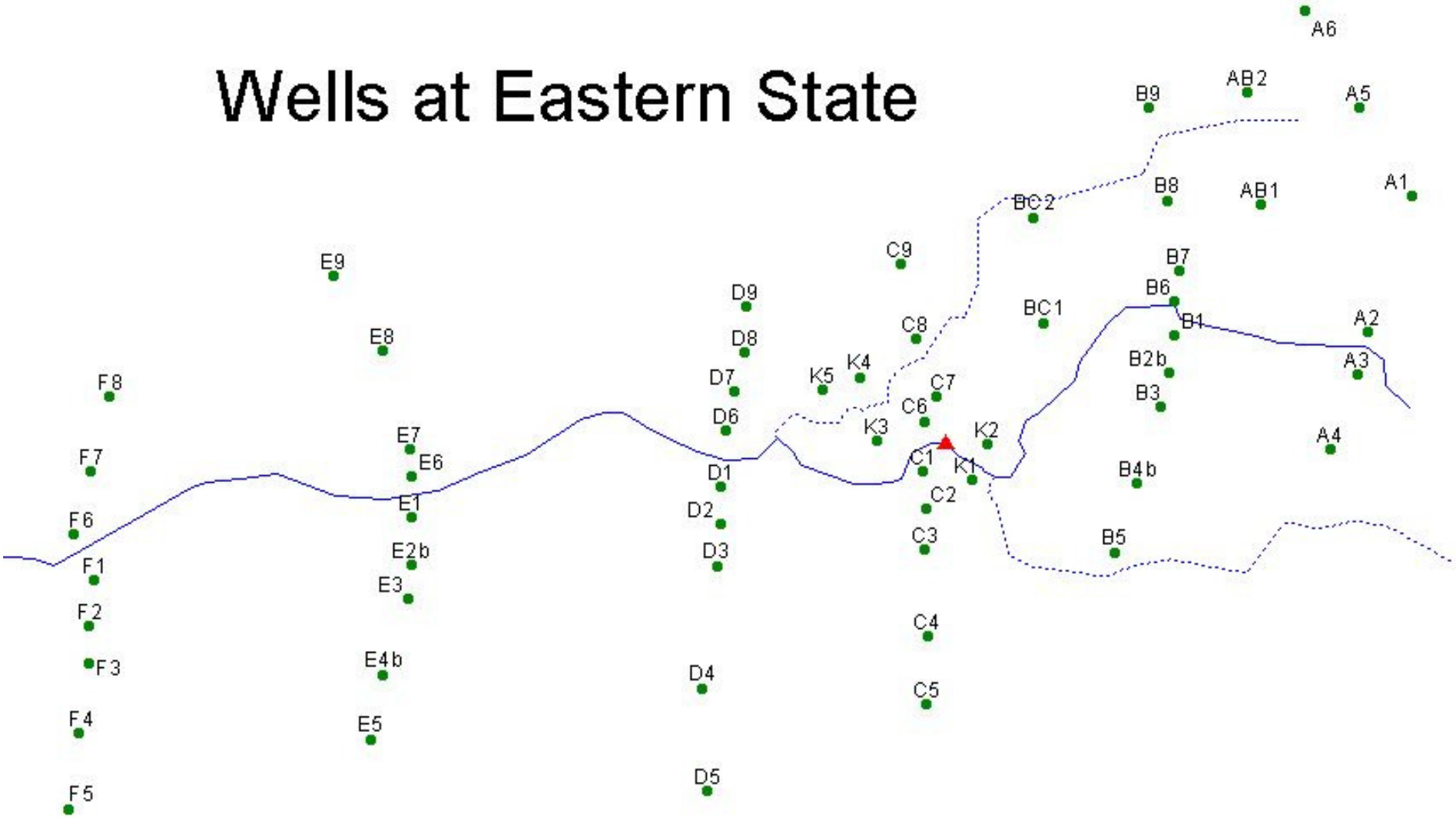
- Introduction
  - Background of terms
  - Related previous studies
- Research Question
- Hypotheses
- Data Collection & Analysis
- Results
- Discussion
  - Meaning of results
- Future Studies

Introduction

- **Stream Incision:** the increased erosion of a stream channel from its natural setting. Characteristics include:
  - a wider and deeper channel
  - increased sediment load
  - lowered water table
  - a common effect of urbanization due to high % of impervious surface
- **Water quality:** the chemical, biological, physical, and radiological characteristics of water
  - AKA – level of purity
- **Riparian Zones:** a buffer zone between uplands and streams
- Previous studies have focused on:
  - soil nutrient concentrations (Galloway 2003, Groffman 2002, Groffman 2003)
  - surface water qualities (Rabalais 2002)
  - groundwater hydrology (Burt 2000, Schilling 2004)

* Lack of research related to groundwater quality associated with stream incision.

Wells at Eastern State



Base map provided by Chris Bowles
College of William & Mary

My Research Question

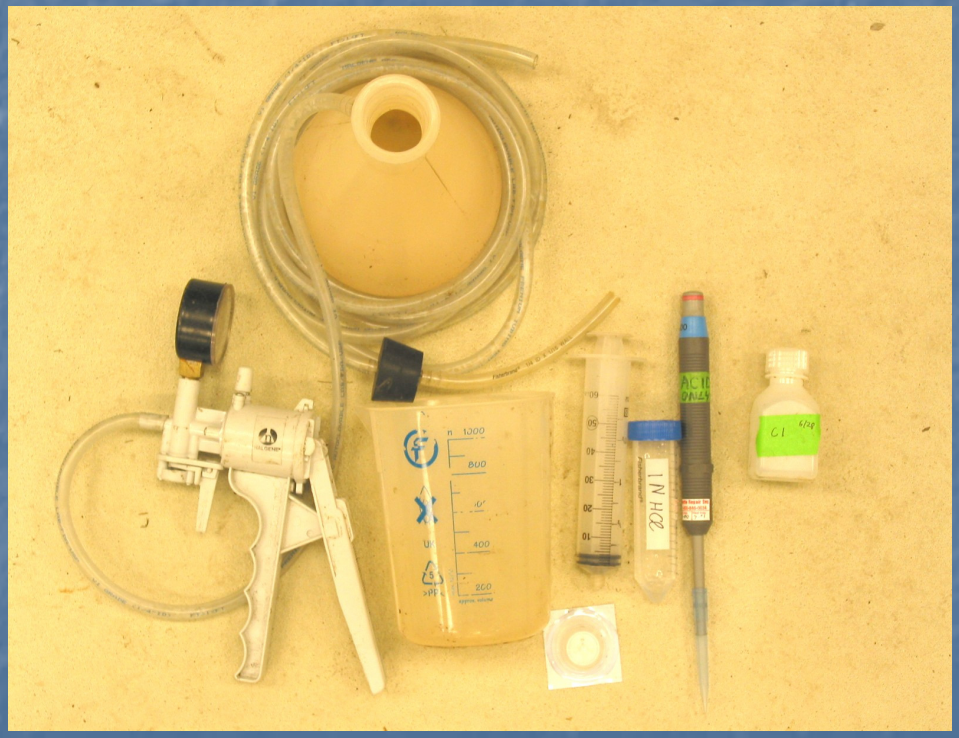
- How does groundwater quality change with respect to stream incision?

Hypotheses

- the water table will lower downstream from the knickpoint causing the water chemistry to alter in several ways:
  - Phosphate (DIP), ferrous iron, ammonium, and hydrogen sulfide concentrations will be higher above the knickpoint
  - Nitrate (NO_3) levels will increase downstream
  - Dissolved oxygen will increase with a lowered water table

Data Collection

- Materials:
  - hand pump capable of reaching the bottom of all the wells
  - at least a 500 mL beaker
  - 60 mL, 5 mL syringes
  - syringe filters
  - 50 mL plastic bottles
  - Conductivity and temperature measuring device



Collecting Method

Photography by Rebecca Lawrence

1) Empty well and allow for recharge
2) Pump again and pour into large beaker
3) Fill the syringe, add filter, and pump into the 50 mL plastic bottles
4) Add 500 uL of HCL^- to prevent Fe from oxidizing
5) Measure the conductivity and temperature of the water in the beaker
6) You're now ready to ANALYZE!

(note to self: wait till excitement dies down before moving on)

Data Analysis

- Colorimetric testing
- Each nutrient is measured separately using different standards and wavelengths
- Plot in Excel and Sigma Plot

Results
Outline

- Difference in nutrient concentrations above and below the knickpoint for:
  - Phosphate
  - Iron
  - Ammonium
  - Hydrogen Sulfide
  - Wait… what about nitrate and nitrite???
- Average concentrations by transect
- The 3 Groups
- Concentrations v. water table elevation/depth

Nutrient concentrations:
Above v. Below knickpoint

- Each nutrient was found to have a significant difference in concentrations between the 2 areas of study

t-Test: Two-Sample Assuming Unequal Variances

Phosphate

	Above Knickpoint	Below Knickpoint
Mean	3.873	1.865
P(T<=t) two-tail	0.0134	

t-Test: Two-Sample Assuming Unequal Variances

Iron

	Above Knickpoint	Below Knickpoint
Mean	27.819	13.038
P(T<=t) two-tail	0.006	

t-Test: Two-Sample Assuming Unequal Variances

Ammonium

	Above Knickpoint	Below Knickpoint
Mean	38.464	10.623
P(T<=t) two-tail	0.0001	

t-Test: Two-Sample Assuming Unequal Variances

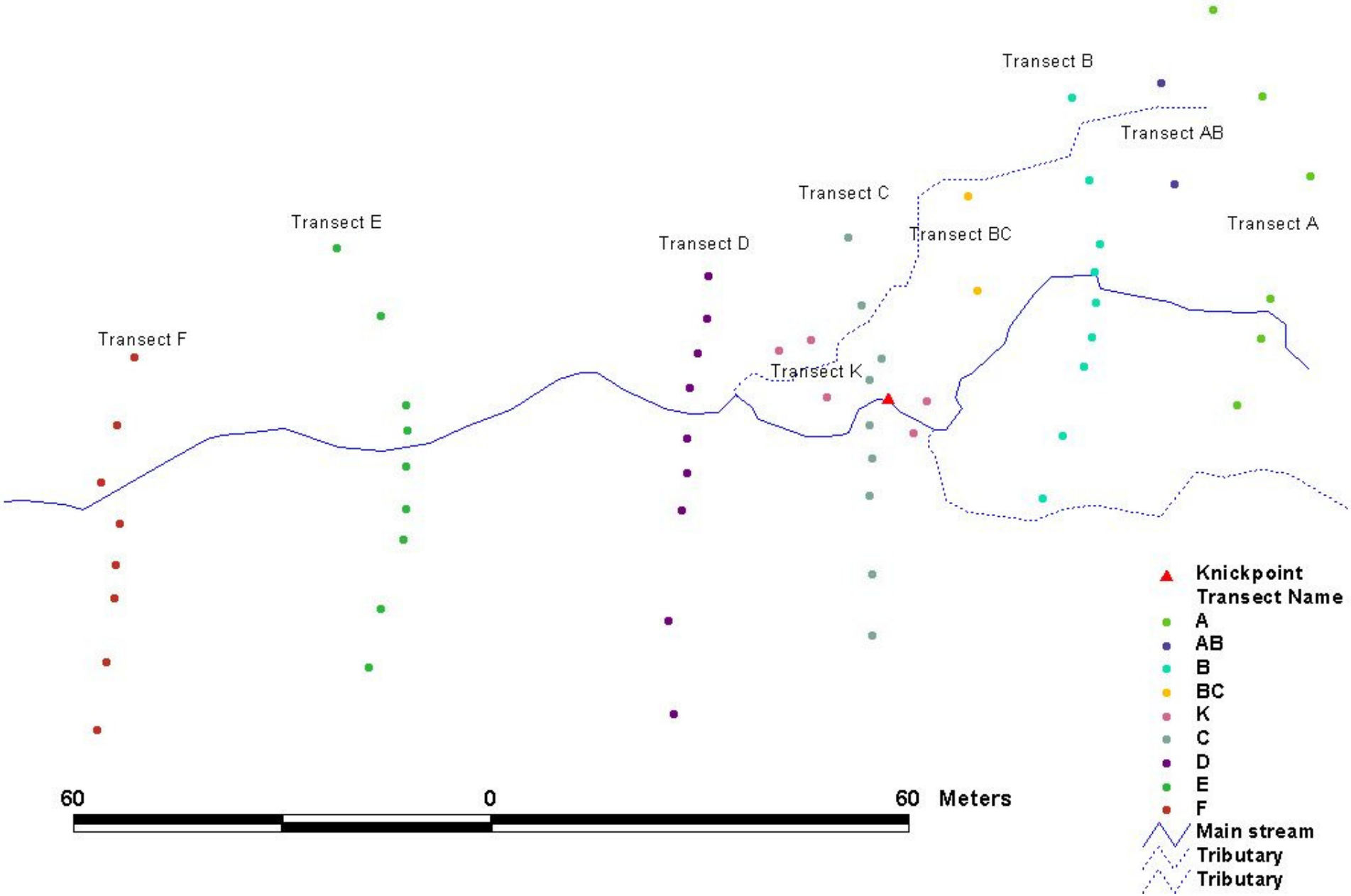
Sulfide

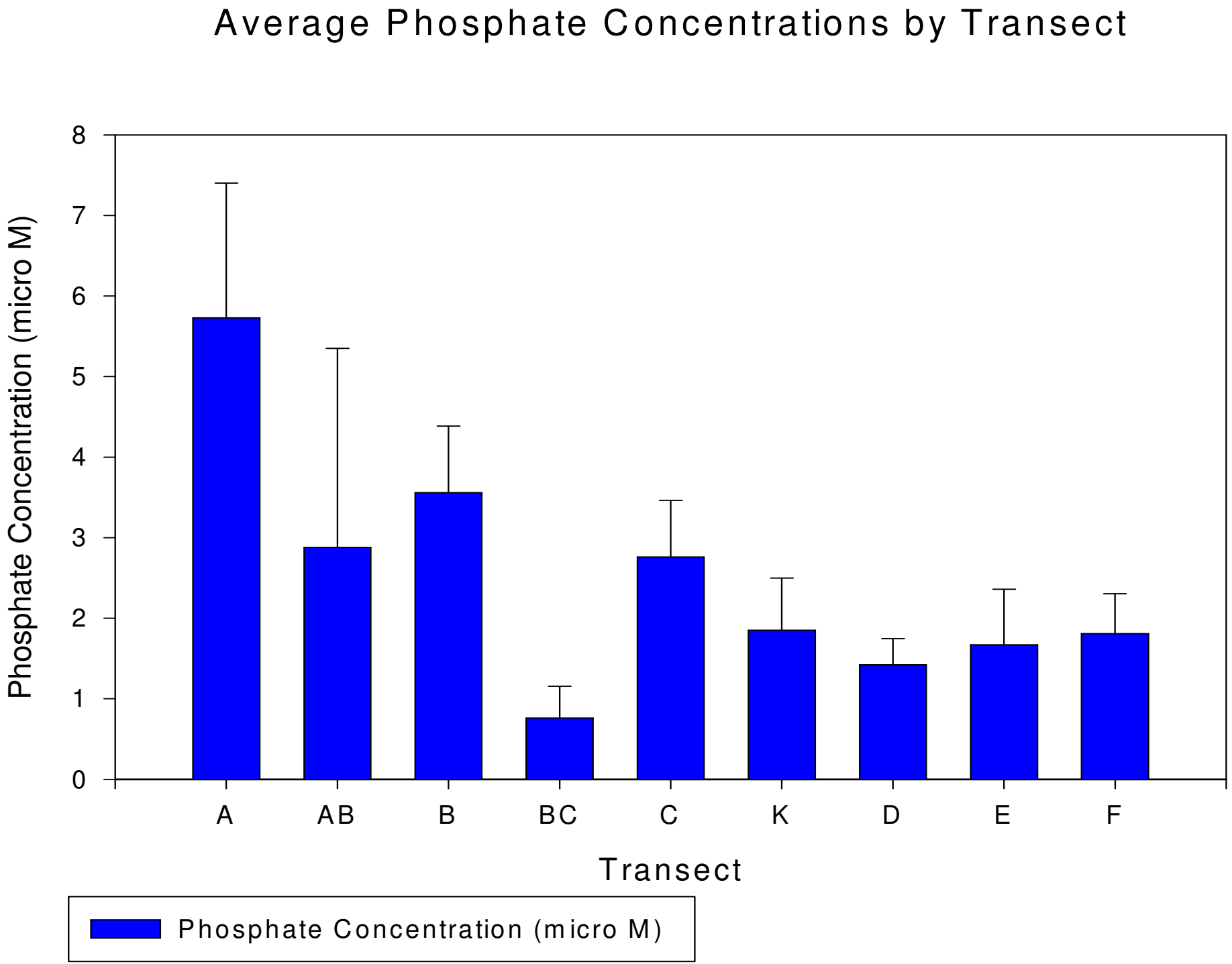
	Above Knickpoint	Below Knickpoint
Mean	2.934	5.480
P(T<=t) two-tail	0.0003	

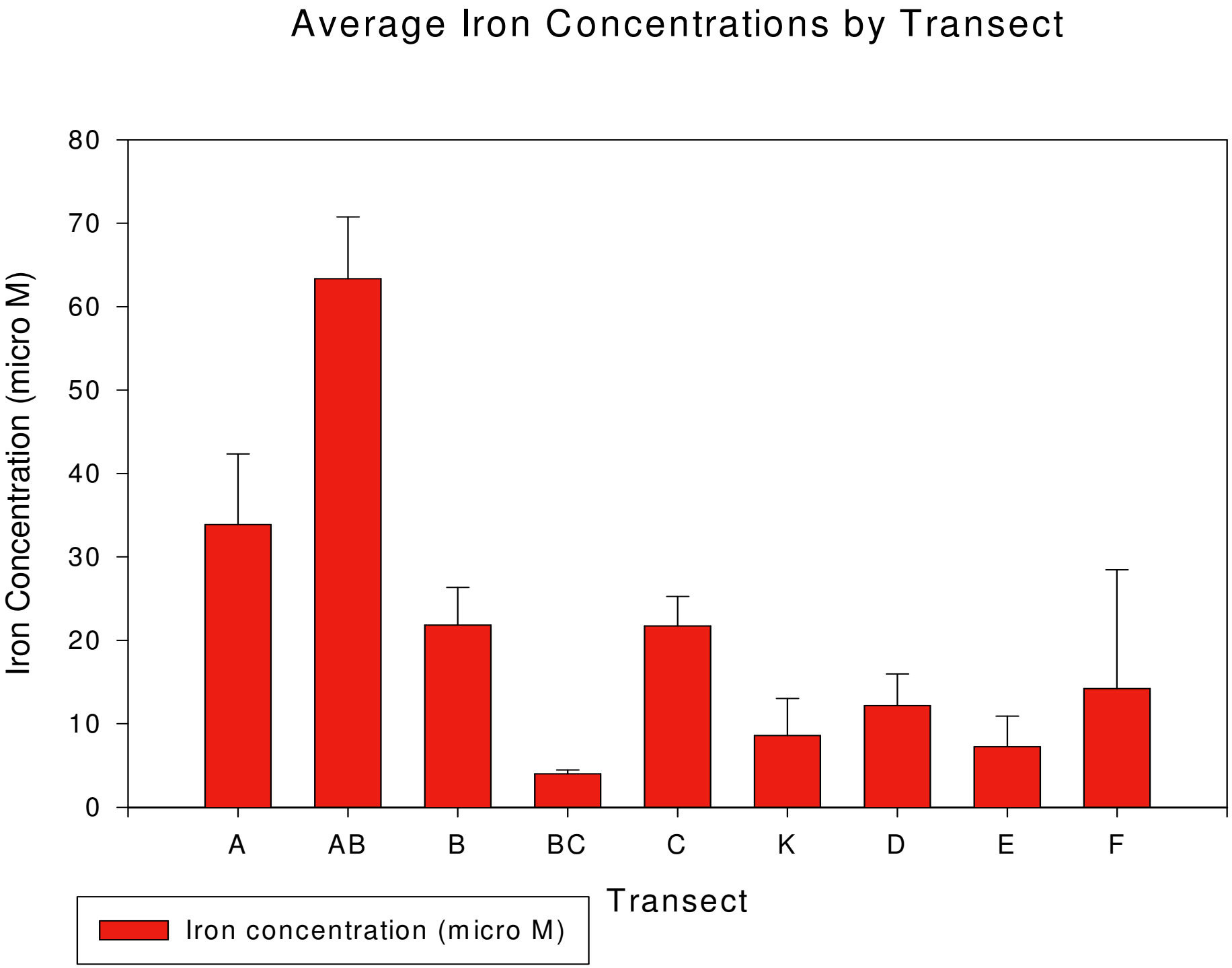
What *about* nitrate/nitrite?

- After testing all the samples, no nitrate was found.
- Groundwater is anoxic

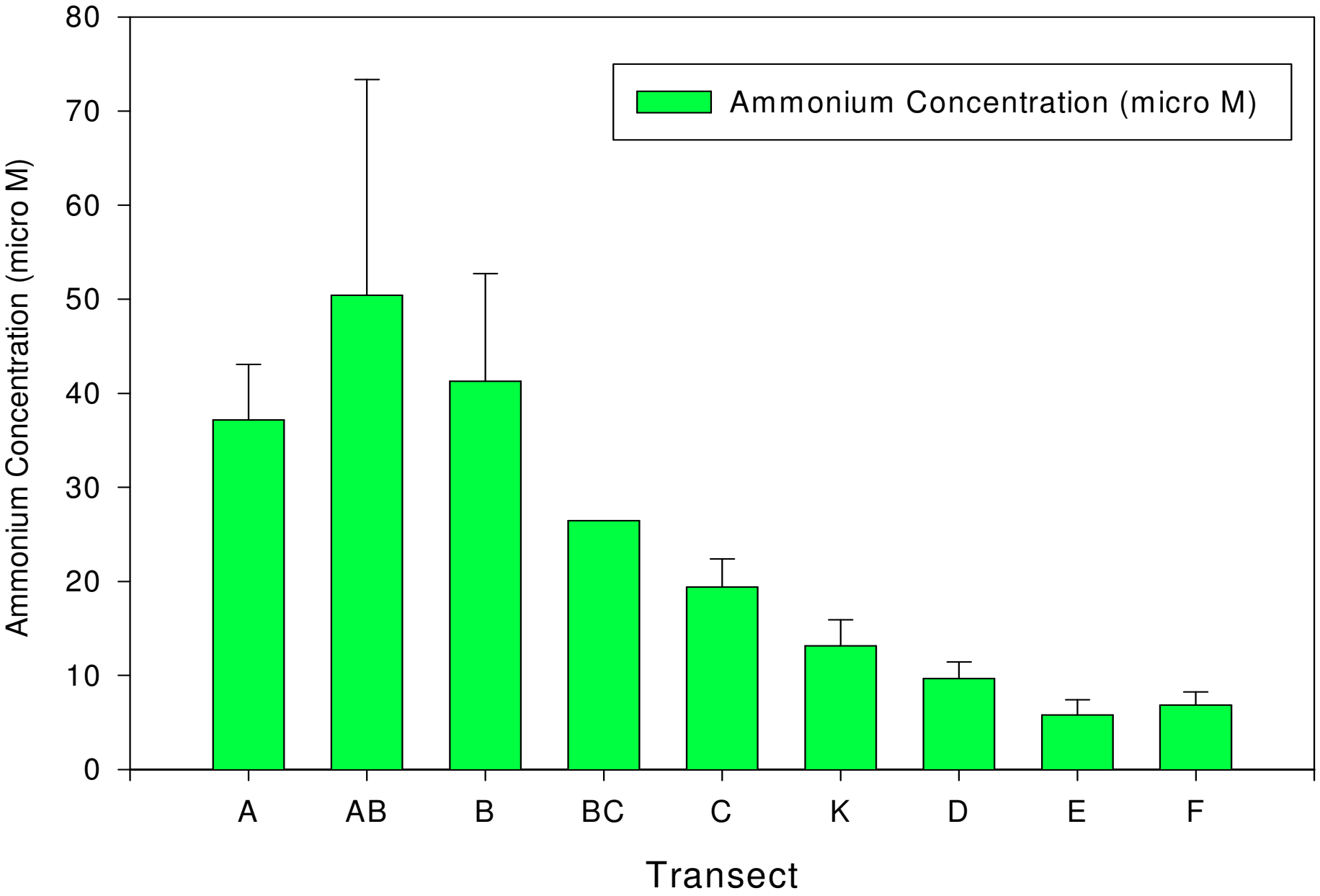
Transect Averages

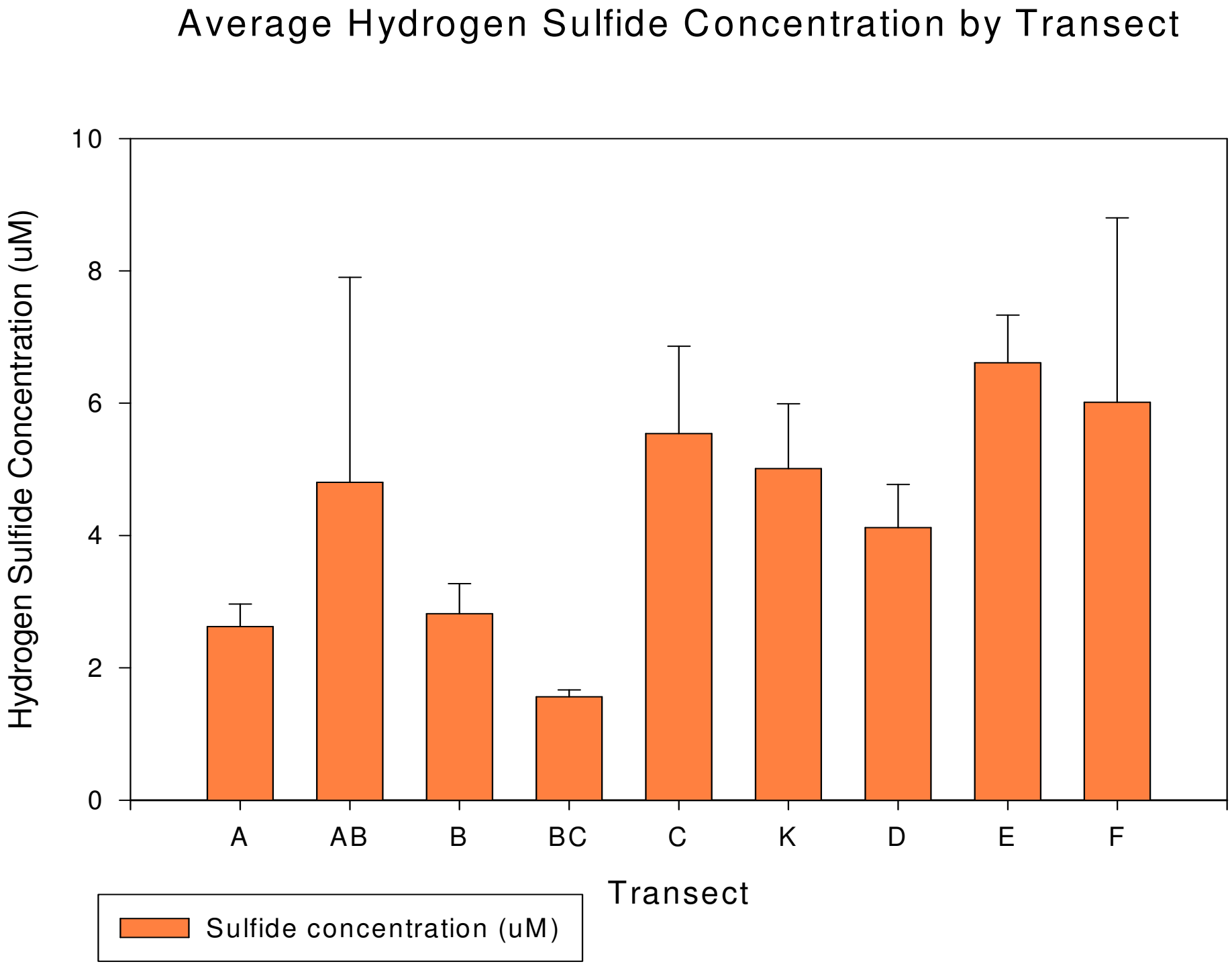



Average Phosphate Concentrations by Transect
Phosphate Concentration (micro M)
8
7
6
5
4
3
2
1
0
A
AB
B
BC
C
K
D
E
F
Transect
Phosphate Concentration (micro M)


Average Iron Concentrations by Transect
Iron Concentration (micro M)
80
70
60
50
40
30
20
10
0
A
AB
B
BC
C
K
D
E
F
Transect
Iron concentration (micro M)

Average Ammonium Concentration by Transect

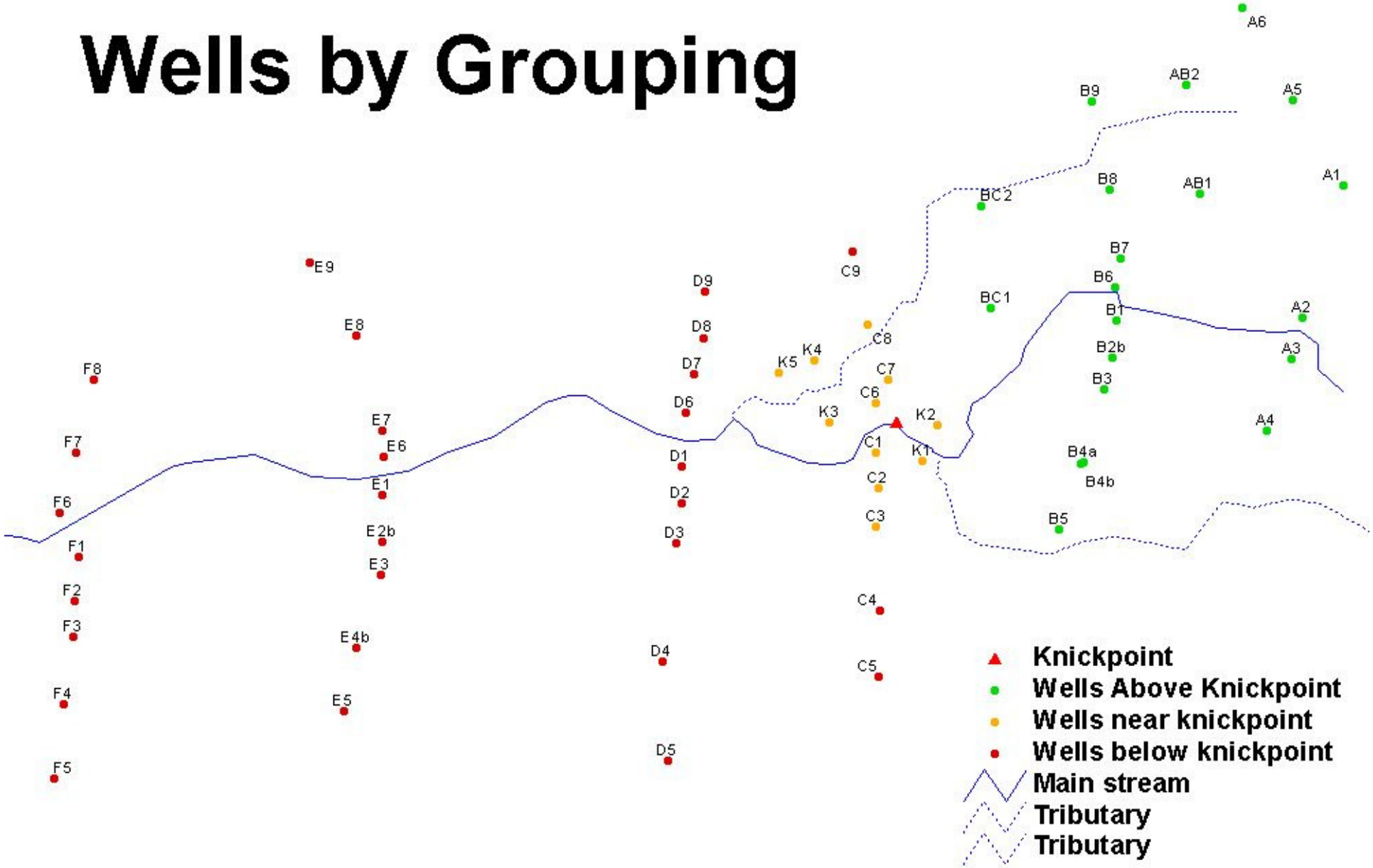



Average Hydrogen Sulfide Concentration by Transect
Hydrogen Sulfide Concentration (uM)
10
8
6
4
2
0
A
AB
B
BC
C
K
D
E
F
Transect
Sulfide concentration (uM)

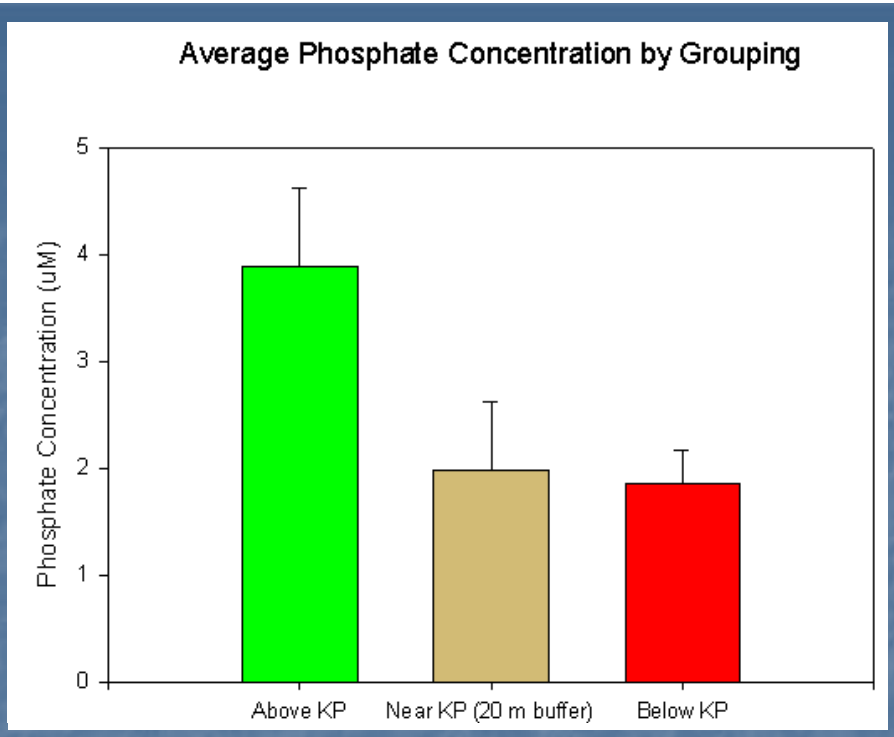
The 3 Groups

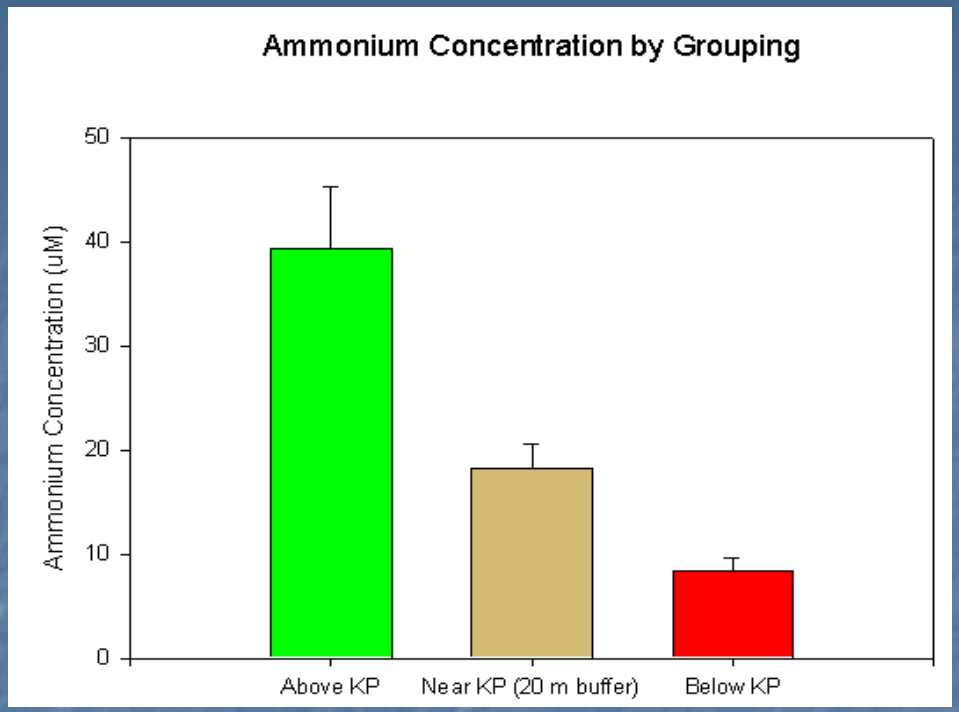
- The wells were grouped into 3 categories:
  - Above the Knickpoint
  - Near the Knickpoint (20m radius)
  - Below the Knickpoint

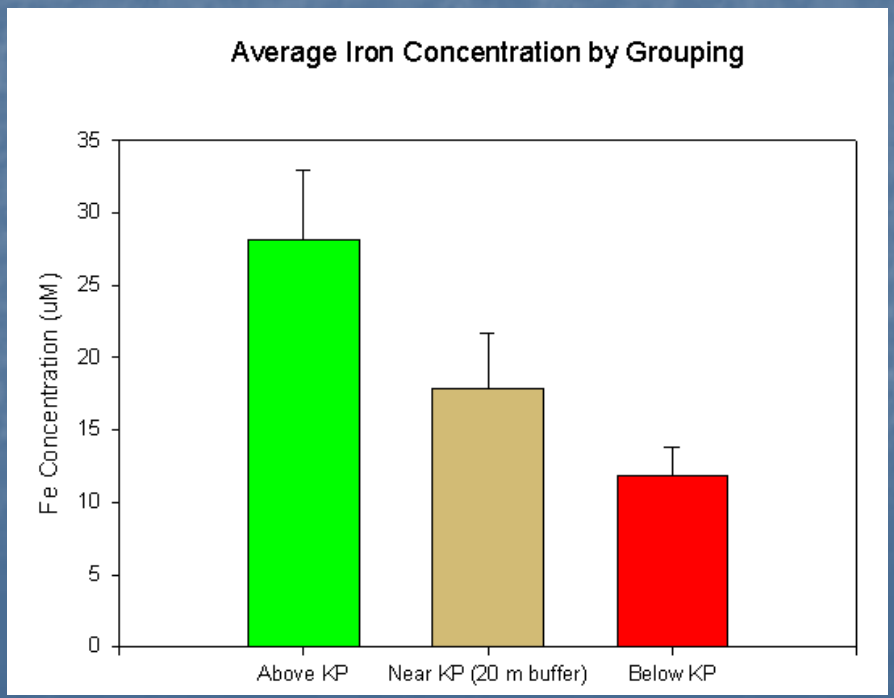
Wells by Grouping

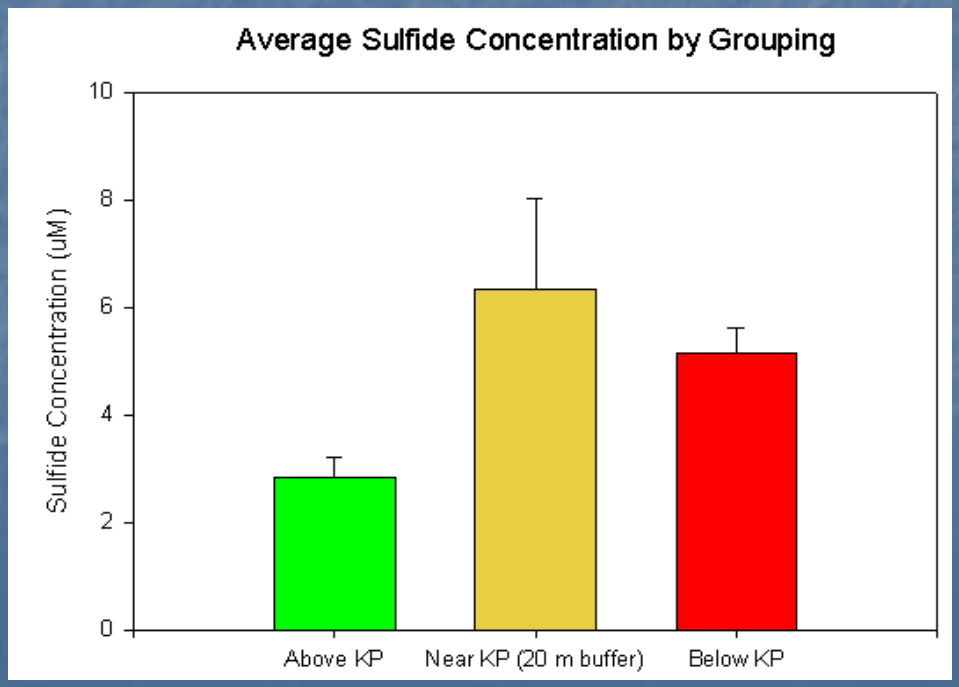


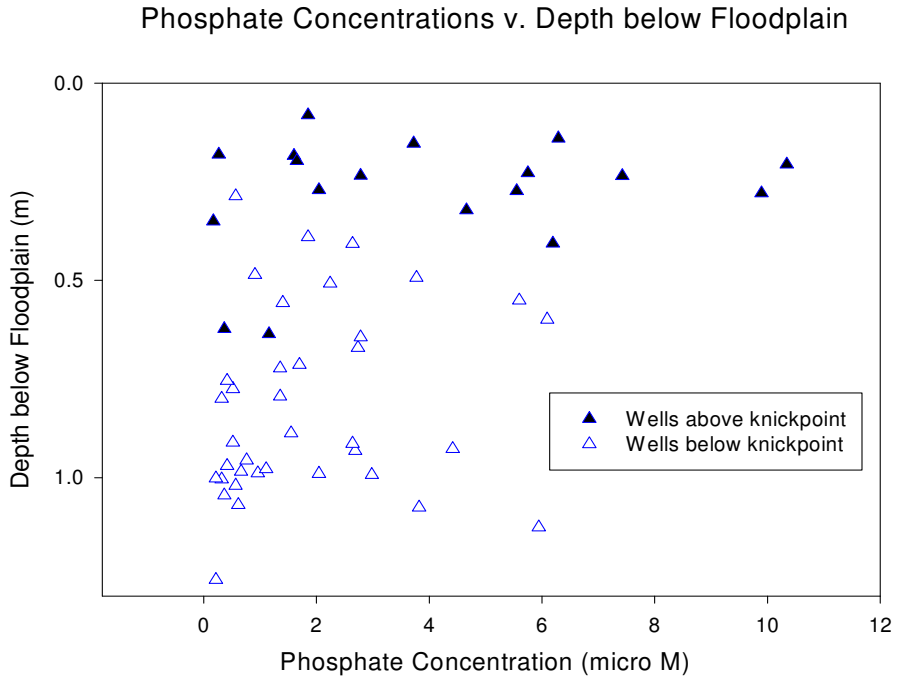
Base map provided by Chris Bowles
Cartography by Logan Reid

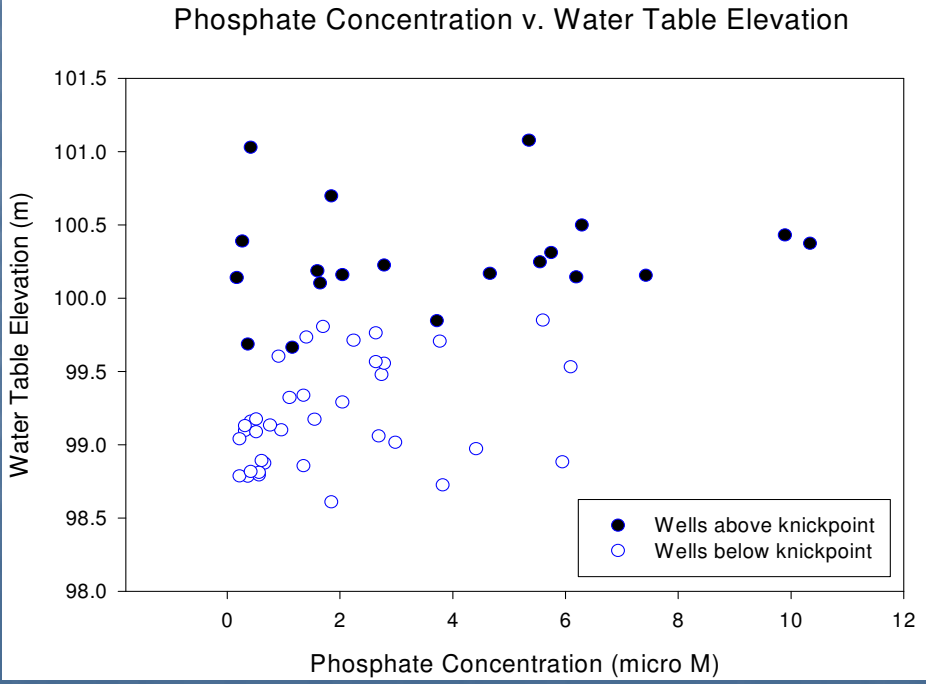

Average Phosphate Concentration by Grouping
Phosphate Concentration (uM)
0
1
2
3
4
5
Above KP
Near KP (20 m buffer)
Below KP


Ammonium Concentration by Grouping
Ammonium Concentration (uM)
0
10
20
30
40
50
Above KP
Near KP (20 m buffer)
Below KP

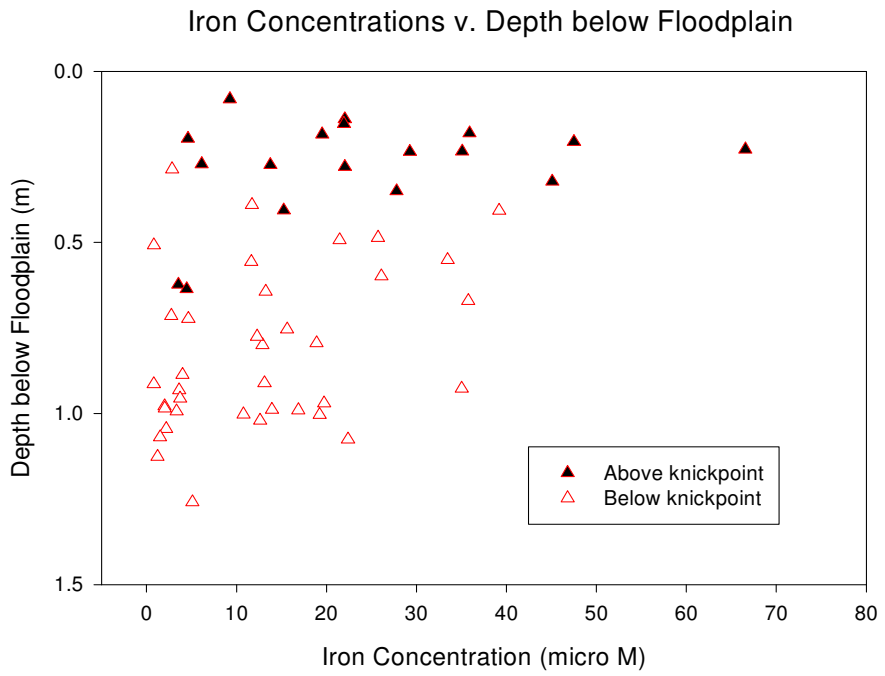

Average Iron Concentration by Grouping
Fe Concentration (uM)
0
5
10
15
20
25
30
35
Above KP
Near KP (20 m buffer)
Below KP

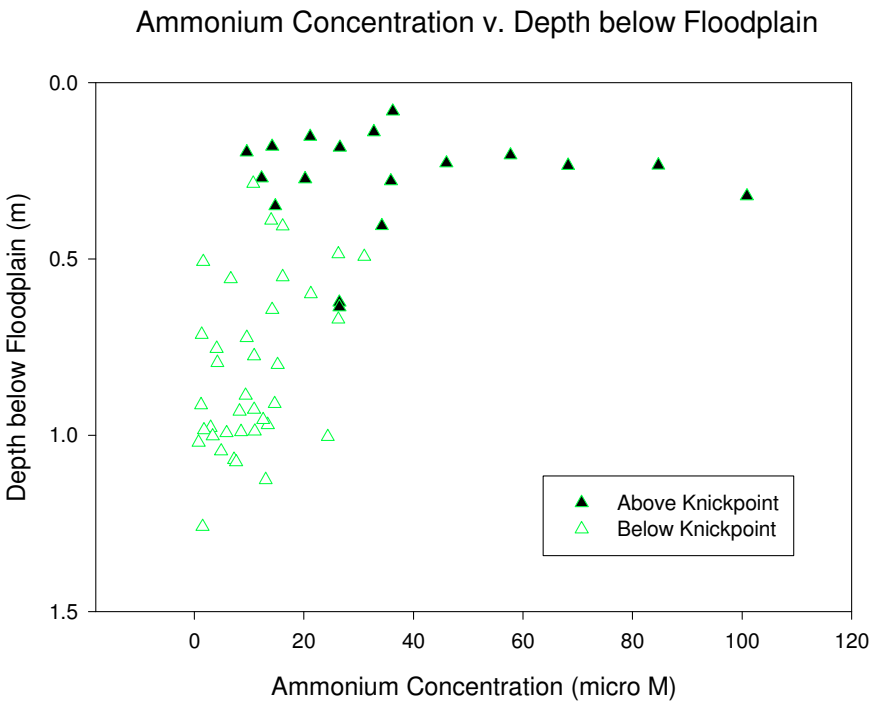

Average Sulfide Concentration by Grouping
Sulfide Concentration (uM)
0
2
4
6
8
10
Above KP
Near KP (20 m buffer)
Below KP

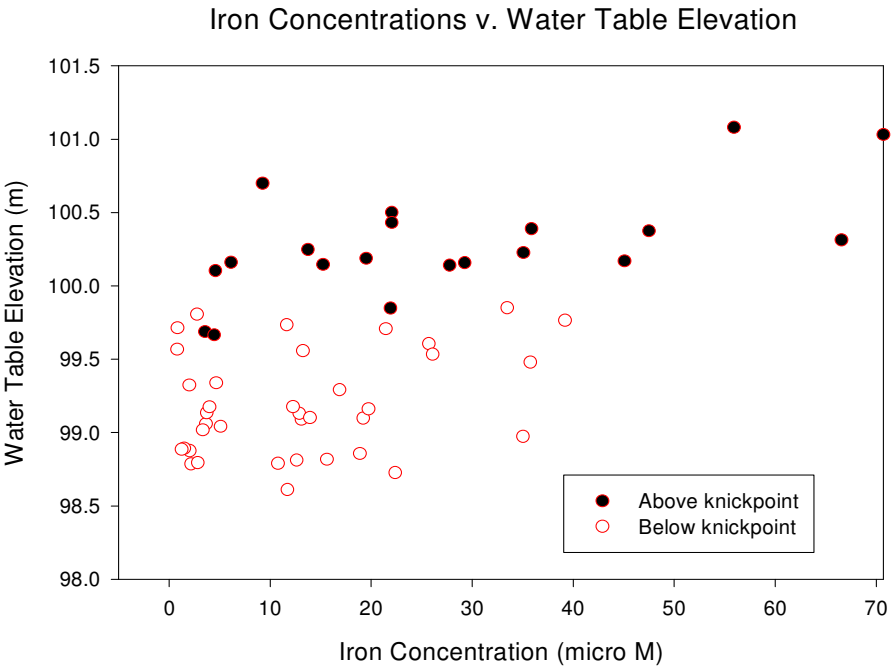


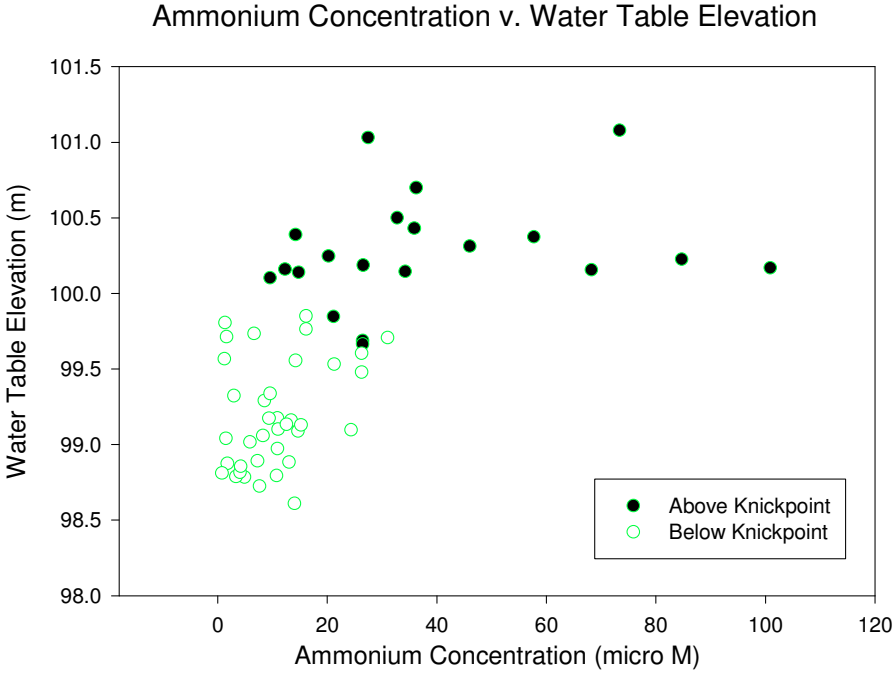


- Above the knickpoint has more variation and is closer to surface
- Below the knickpoint has lower concentrations and is more clustered together

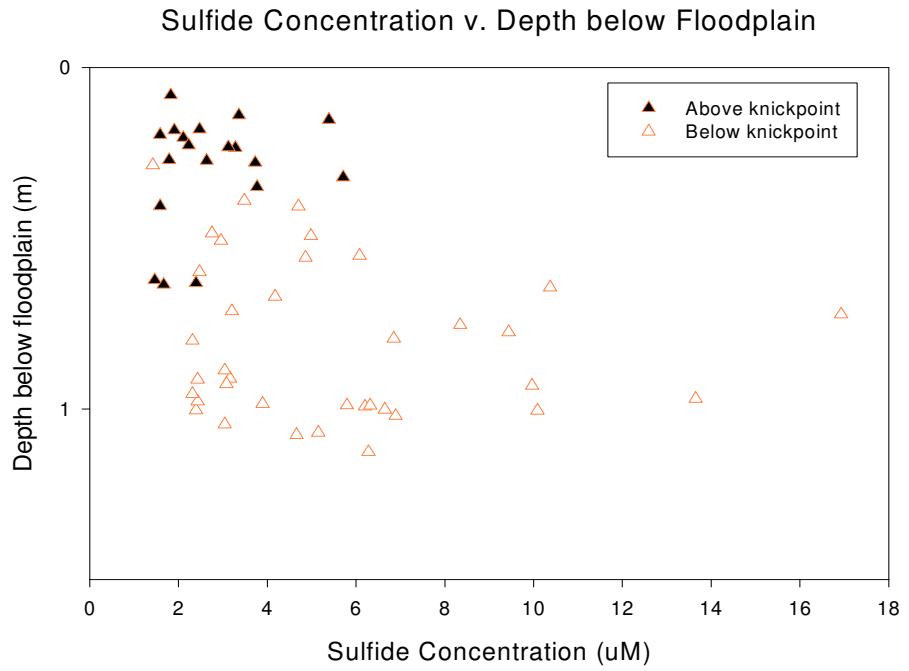

Iron Concentrations v. Depth below Floodplain
Depth below Floodplain (m)
0.0
0.5
1.0
1.5
0
10
20
30
40
50
60
70
80
Iron Concentration (micro M)
Above knickpoint
Below knickpoint

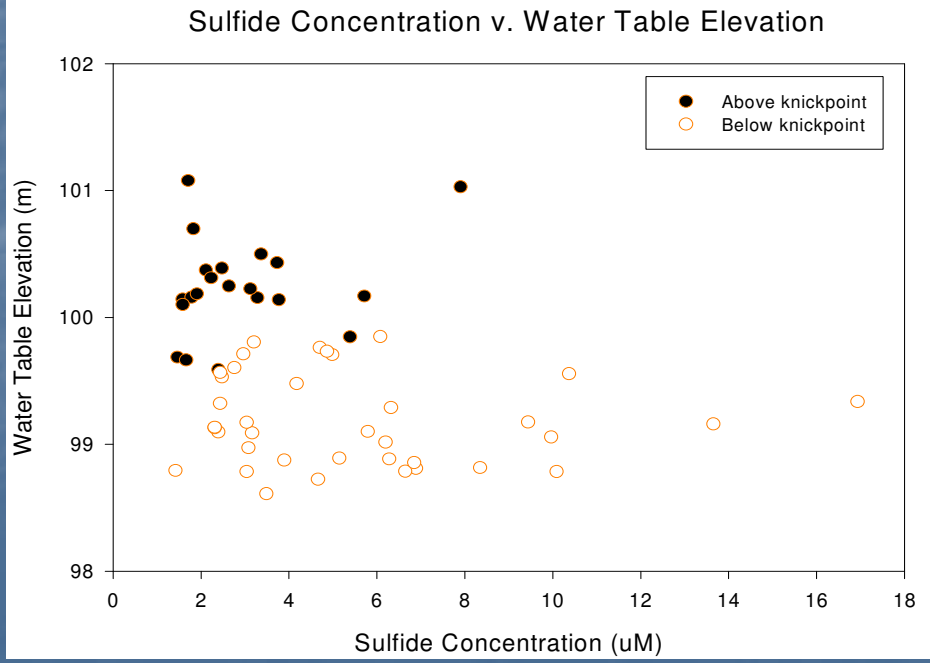

Ammonium Concentration v. Depth below Floodplain
Depth below Floodplain (m)
0.0
0.5
1.0
1.5
0
20
40
60
80
100
120
Ammonium Concentration (micro M)
Above Knickpoint
Below Knickpoint


Iron Concentrations v. Water Table Elevation
Water Table Elevation (m)
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
0
10
20
30
40
50
60
70
Iron Concentration (micro M)
Above knickpoint
Below knickpoint

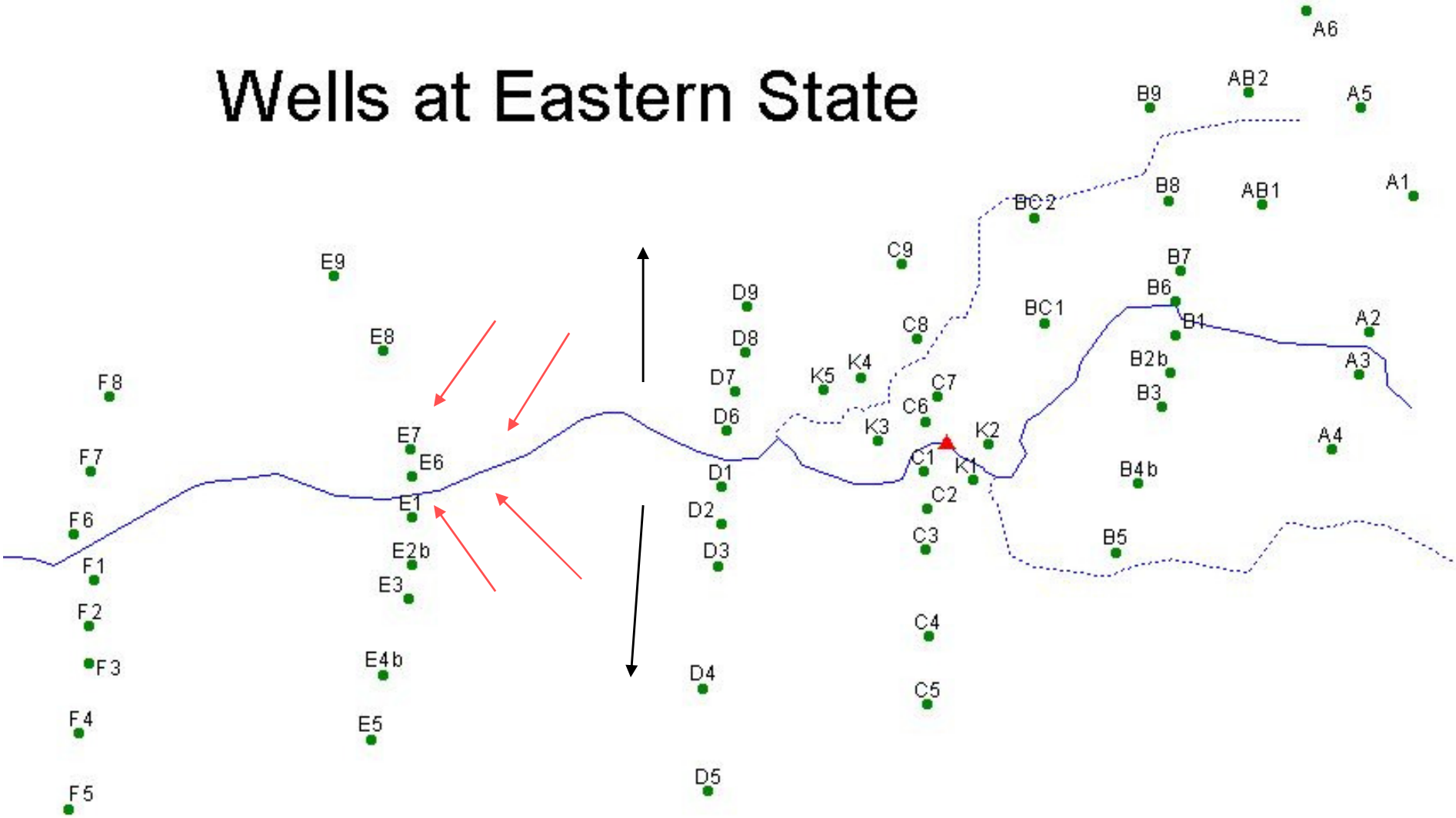

Ammonium Concentration v. Water Table Elevation
Water Table Elevation (m)
101.5
101.0
100.5
100.0
99.5
99.0
98.5
98.0
0
20
40
60
80
100
120
Ammonium Concentration (micro M)
Above Knickpoint
Below Knickpoint

- Above the knickpoint is more clustered with lower concentrations
- Below the knickpoint has greater variation





Wells at Eastern State



Base map provided by Chris Bowles
College of William & Mary

Discussion

In summary:

- Significant difference in nutrient concentrations above the knickpoint v. below it.
- Higher concentrations of nutrients further upstream of the knickpoint (except sulfide) versus closer to it (also seen in 3 groups)
- The higher the water table, the greater variation in concentration
- Hydrogen sulfide was the exception

Meaning:

- Hypothesis correct with respect to the concentrations of DIP, Iron, and Ammonium.
- Hydrogen sulfide found to be the opposite of what was expected
- No nitrate or nitrite found
- No dissolved oxygen

Possible explanations of results:

- Increased vegetation downstream causes increased nutrient absorption
- Possible increase in decaying organic matter downstream explains increase in Sulfide
- Oxidized Iron precipitates into stream
- DIP will bind to Fe+3 ions

Photography by Rebecca Lawrence

Implications of the research:

- Because stream incision occurs as a result of urbanization, this research helps to show the changes in groundwater quality as a result of urbanization.
- With impervious surface continually increasing, stream incision will become more common and significant
- It is important to understand the adverse affects that development is producing in our environment

Further Studies

- To fully explore the groundwater quality at this site, further studies should include:
  - Collecting samples after a rainfall event
  - Continued sample collection spaced throughout the year to look at seasonal variations
  - Monitoring further downstream and upstream to see the whole picture

Acknowledgements

- Randy Chambers for allowing me this opportunity and mentoring me in the way of the scientist
- Timothy Russell for continuous assistance in GIS and other programs
- Catherine Noll, Rebecca Lawrence, and Chris Bowles for helping collect samples and allowing me to use their data in my project

Advantages to this location

- The knickpoint is a natural discontinuity in the landscape, which causes stream incision downstream and has been shown to cause a lowering in the water table.
- Upstream from the knickpoint is a natural and undisturbed environment which provides a control to conduct the experiment, while just a few meters downstream there is stream incision occurring.
- Stream incision often occurs in streams as a result of urbanization and therefore the study in this area can be applied to thousands of environments where urbanization has occurred.
- Often studies of stream incision as a result of urbanization require many years of study to see any differences from a control that may not even be the same area.
- Therefore the knickpoint provides a perfect setting to conduct a relatively short study with a control for comparison.

Resources

- "Water quality." Glossary of Environmental Terms. Natural Resources Defense Council, June 8, 2005. http://www.nrdc.org/reference/glossary/w.asp

- Groffman, Peter M., Bain, Daniel J., Belt, Kenneth T . "Down by the riverside: urban riparian Ecology." Frontiers in Ecology and the Environment 1(6) (2003): 315 -321.

  This article is very helpful in understanding the concept of a riparian zone and how a lowered water table affects the ecology of this environment.

Groffman, Peter M., Boulware, Natalie J., Zipper, Wayne C., Pouyat, Richard V., Band, Lawrence E., Colosimo, Mark F. "Soil Nitrogen Cycle Processes in Urban Riparian Zones." Environmental Science & Technology Vol. 36, No. 21 (2002): 4547 – 4552.

This gave an in depth understanding of how nitrogen is affected in a riparian zone that has undergone stream incision.

Galloway, James N., Aber, John D., Erisman, Jan Willem, Sietzinger, Sybil P., Howarth, Robert H., Cowling, Ellis B., and Cosby, B. Jack. "The Nitrogen Cascade." BioScience Vol. 53, No. 4, (2003) 341–356.

This taught me how nitrogen is used in the environment and the various forms it may have.