Water Quality Trends of the Upper Devils Lake Basin in the Vicinity of Lake Alice National Wildlife Refuge, North Dakota (June 2007–March 2011)

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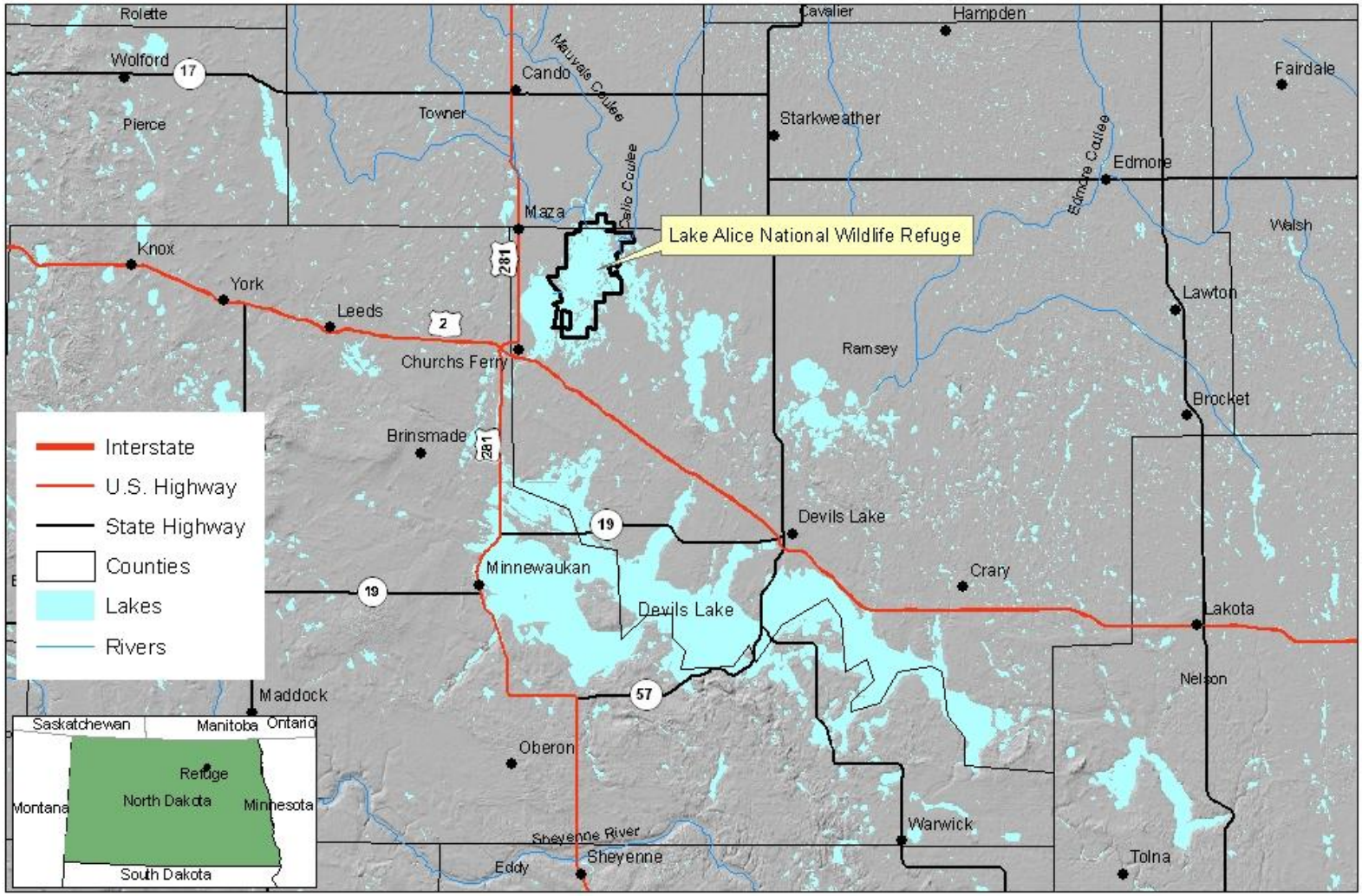
February 29, 2012

Lake Alice National Wildlife Refuge and Study Area



Cartography: Gregory Vandeberg, University of North Dakota
Data: State of North Dakota GIS Hub, ESRI
Date: November 20,2007

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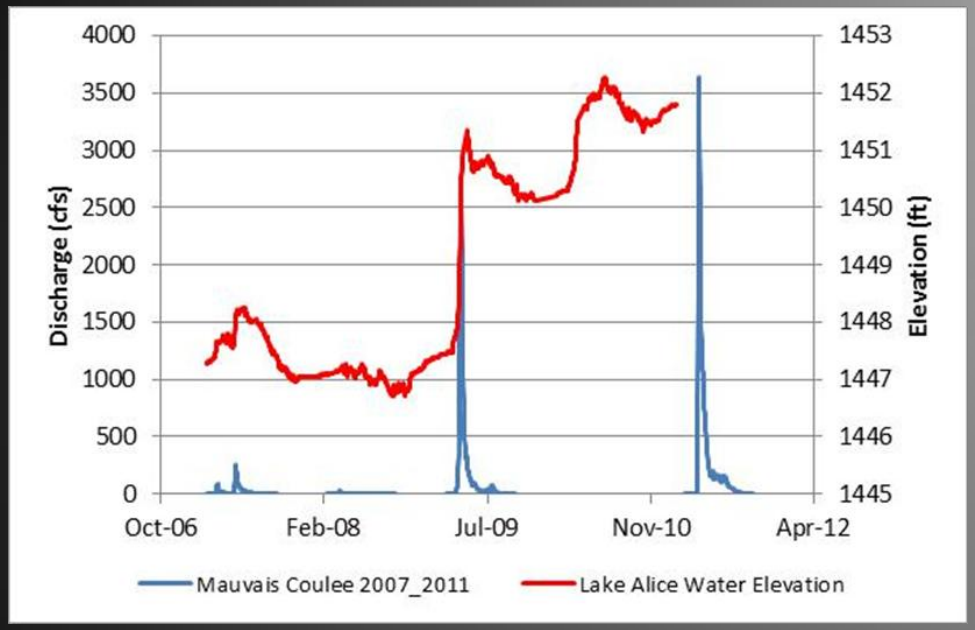
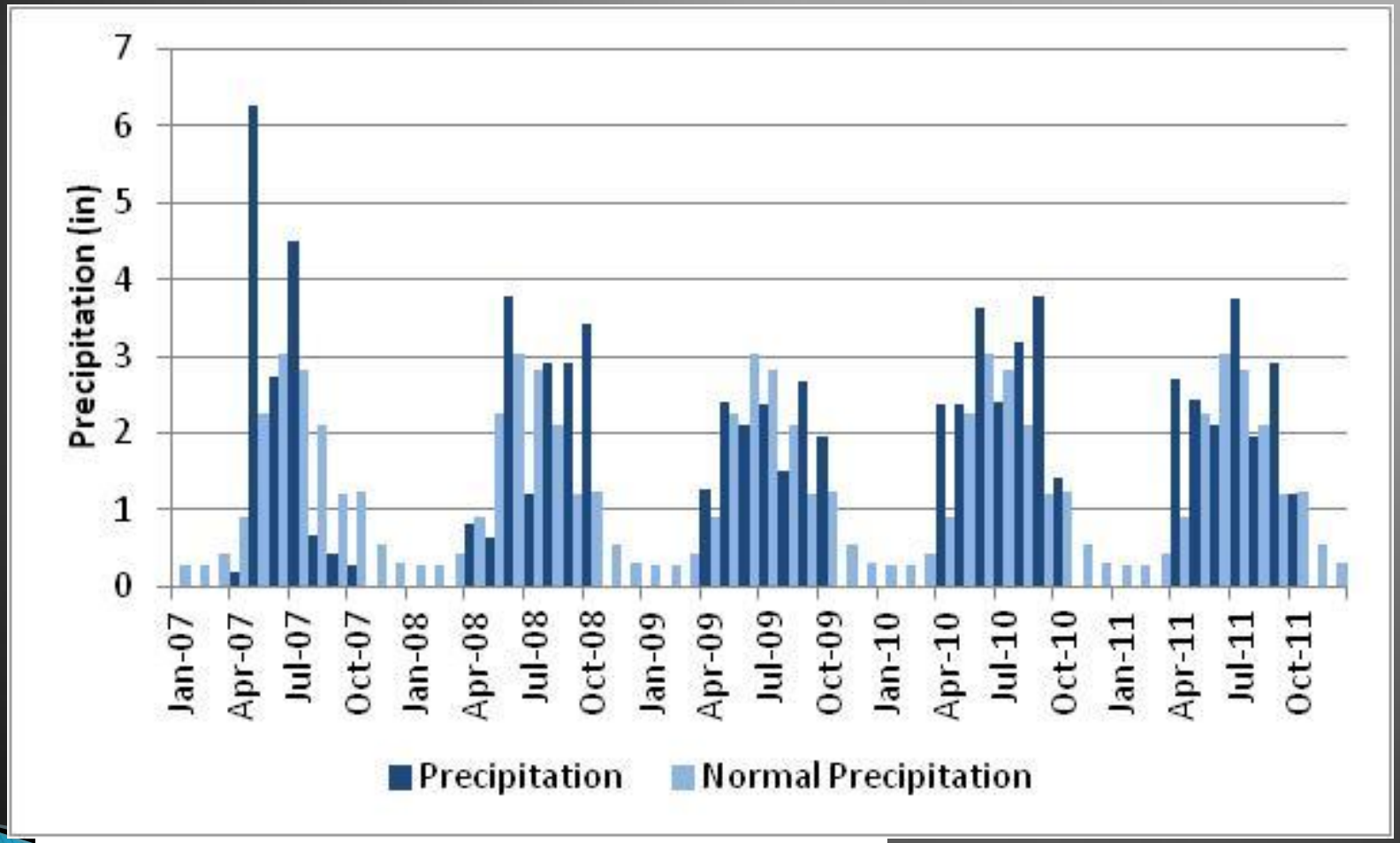
Lake Alice and Devils Lake Rising Water



- Lake Alice-Lake Irvine at1452.32 ft (473.1 m) July 2010
- Lake low 1447.05 ft (471.5 m) Dec 2007 (USGS 2012). Replaced by USGS Big Coulee gage in February 2011.
- Devils Lake was 1454.30 ft on 6/27/2011(USGS 2011)

Precipitation Levels



Concentrated Animal Feeding Operations (CAFO's)

Hog finishing operation near Cando, ND (G. Vandeberg 2006).

- Nutrient Management plan required. NPDES permit only required if permit owner voluntarily indicates there will be a discharge to surface water
- 3 swine CAFO's upstream of Lake Alice (closest within 5.1 km).
- 18,000 nursery pigs, 6594 sows and 20,900 finisher pigs .
- Almost 27 million gallons (101 million liters) waste per year.
- 6,270 acres (2537 hectares) identified for manure application.

Agricultural Chemical Application

(G. Vandeberg 2009).

Modified Channels and Limited Riparian Buffers

(G. Vandeberg 2009)

Flooded Farmsteads, Chemical and Fuel Storage Areas

(G. Vandeberg 2009)

Study Objectives

- Determine seasonal variation of water quality in Lake Alice and vicinity.
- Determine trace element and nutrient concentrations in sediment.
- Compare the results of this study with previous studies.
- Complete a physical and habitat assessment of the lake tributaries.

Methods

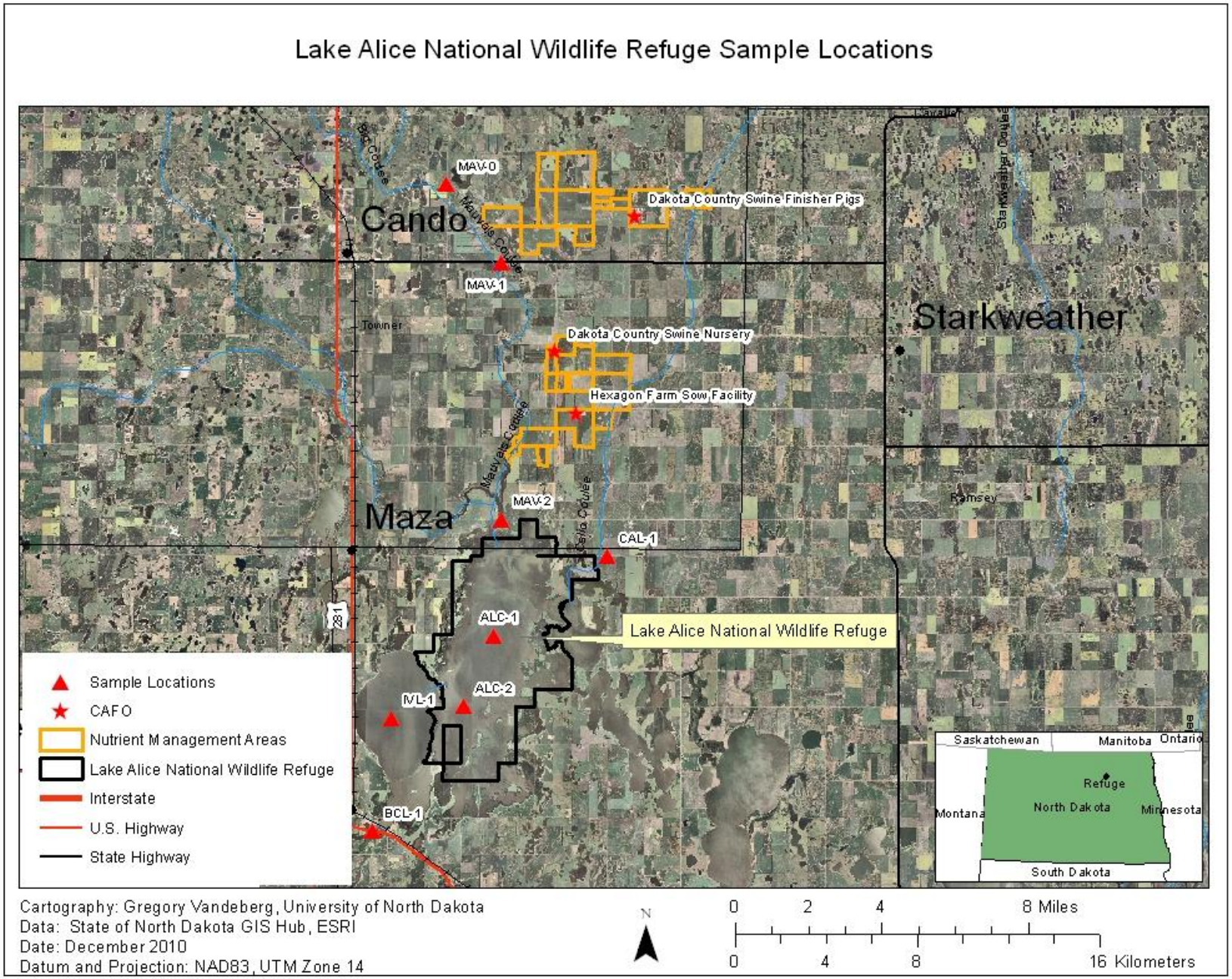
- Water samples and analysis
  - Field measurement of pH, Cond., D.O., temp, Secchi depth, water depth
  - Major ions of Ca, Mg, Na, K, HCO_3, CO_3, Cl, SO_4, Hardness and alkalinity
  - Biological: chlorophyll a and b, E Coli, F Coliform
  - Trace elements (ICP-MS)
  - Nutrients: NH_3, NO_2-NO_3, TKN, P
  - Pesticides
- Sediments
  - pH and ions
  - Trace elements (nitric acid/hydrogen peroxide digest, ICP-MS)
  - Nutrients
  - texture

Mark Blore and Brooks Hansen returning from sampling Lake Alice (G. Vandeberg 2008).

Sampling Dates and Methods

- 2007
  - (Monthly June–October)
- 2008
  - Monthly May–October
- 2009
  - Monthly May–November
- 2010
  - March, May, September
- 2011
  - March

- Stream samples collected as grab samples
- Lake samples
  - Field readings at 3.28 ft (1 m), and integrated depths
  - Collected at 3.28 ft (1 m for 2007)
  - 0–6 ft composite for 2008–2011


Lake Alice National Wildlife Refuge Sample Locations
Cando
Starkweather
Maza
Towner
Ramsey
MAV-0
MAV-1
MAV-2
CAL-1
ALC-1
ALC-2
IVL-1
BCL-1
Dakota Country Swine Finisher Pigs
Dakota Country Swine Nursery
Hexagon Farm Sow Facility
Lake Alice National Wildlife Refuge
281
Sample Locations
CAFO
Nutrient Management Areas
Lake Alice National Wildlife Refuge
Interstate
U.S. Highway
State Highway
Saskatchewan
Manitoba
Ontario
Montana
North Dakota
Minnesota
South Dakota
Refuge
Cartography: Gregory Vandeberg, University of North Dakota
Data: State of North Dakota GIS Hub, ESRI
Date: December 2010
Datum and Projection: NAD83, UTM Zone 14
N
0 2 4 8 Miles
0 4 8 16 Kilometers

Mauvais Coulee (MAV-0)

(G. Vandeberg 2011).

Mauvais Coulee (MAV-2)

(G. Vandeberg 2007).

(G. Vandeberg 2010).

Calio Coulee (CAL-1)

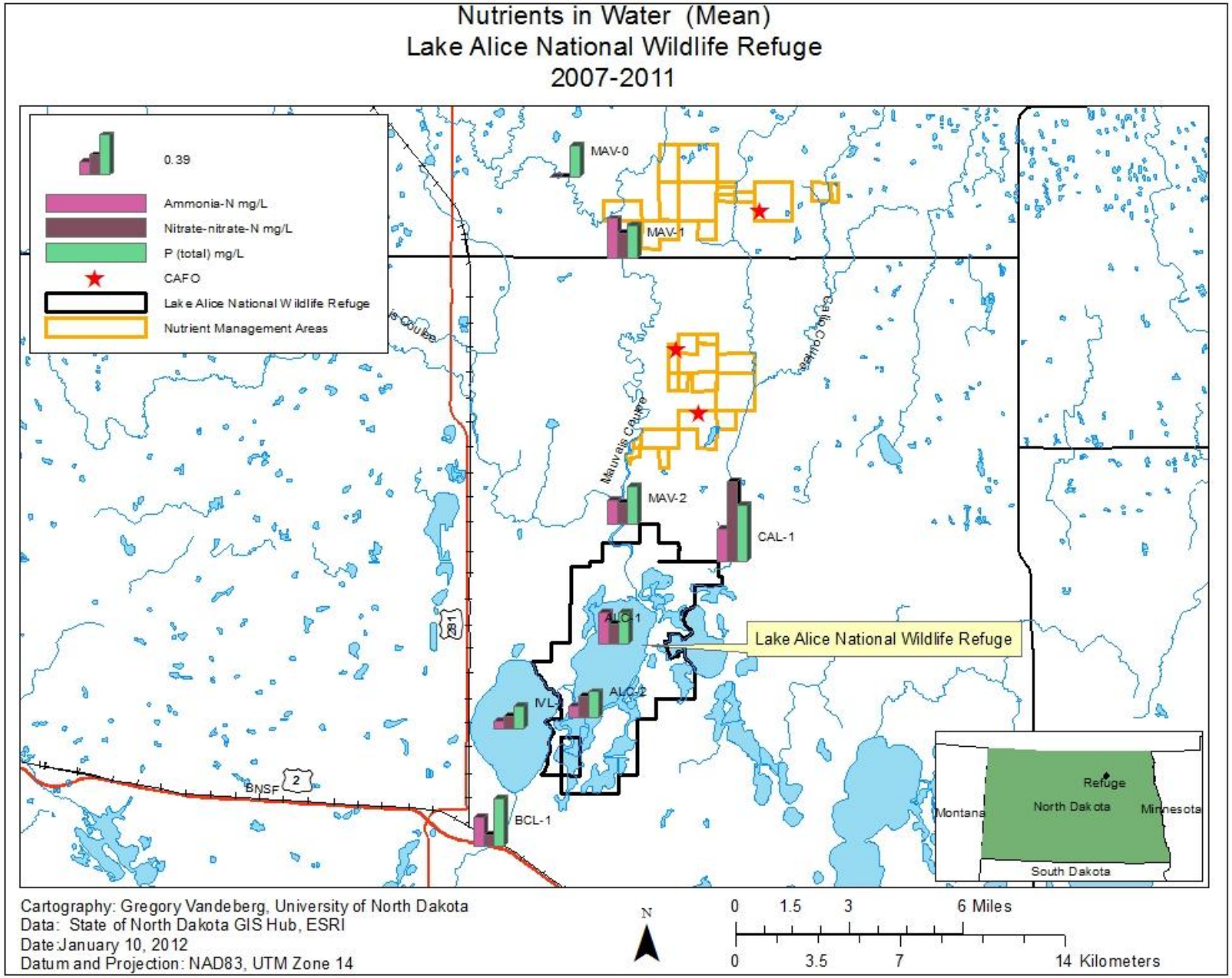
(G. Vandeberg July 30, 2008).

(G. Vandeberg 2010).

Big Coulee (BCL-1)

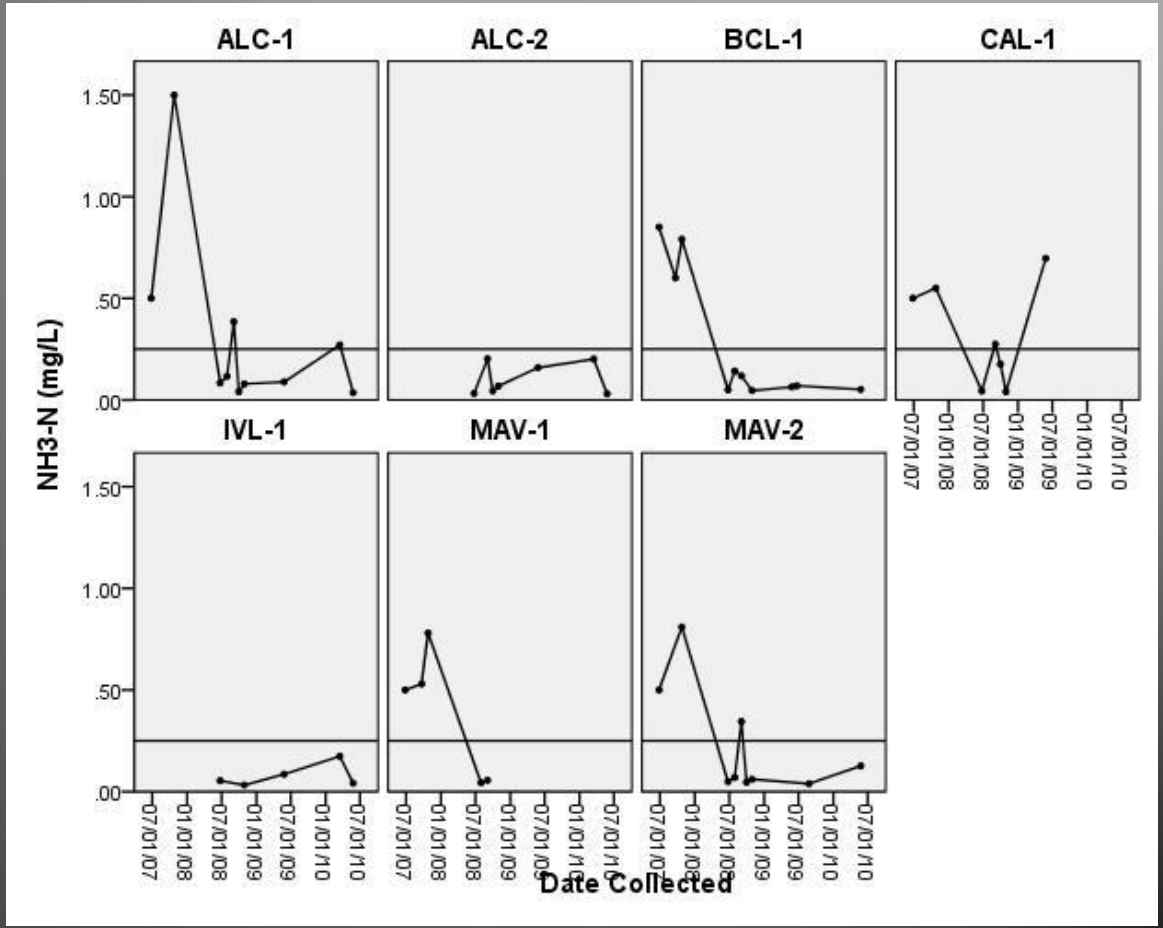
(G. Vandeberg 2007).

(G. Vandeberg 2010).


Nutrients in Water (Mean)
Lake Alice National Wildlife Refuge
2007-2011
0.39
Ammonia-N mg/L
Nitrate-nitrate-N mg/L
P (total) mg/L
CAFO
Lake Alice National Wildlife Refuge
Nutrient Management Areas
MAV-0
MAV-1
MAV-2
CAL-1
ALC-1
ALC-2
IVL-1
BCL-1
Lake Alice National Wildlife Refuge
BNSF
281
2
Refuge
Montana
North Dakota
Minnesota
South Dakota
Cartography: Gregory Vandeberg, University of North Dakota
Data: State of North Dakota GIS Hub, ESRI
Date:January 10, 2012
Datum and Projection: NAD83, UTM Zone 14
N
0 1.5 3 6 Miles
0 3.5 7 14 Kilometers

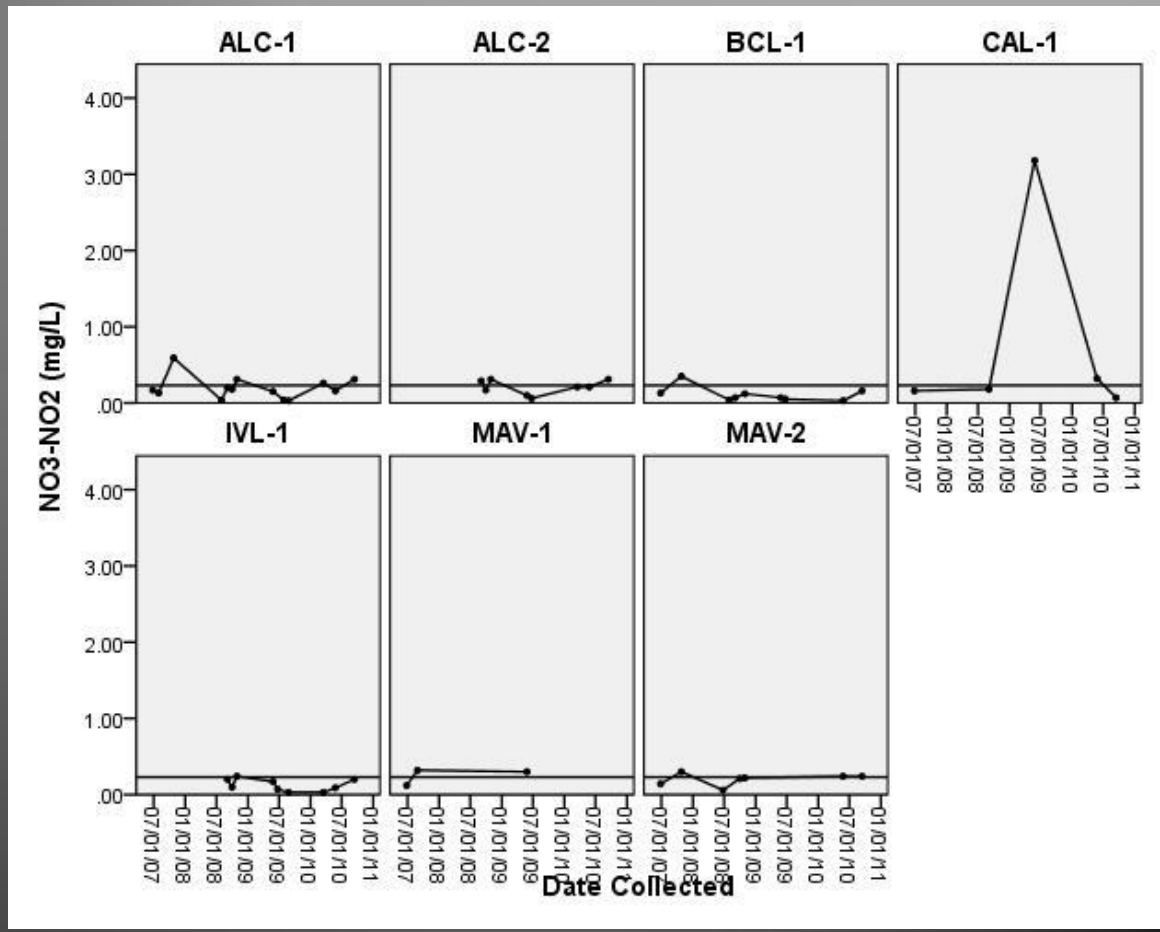
Ammonia as N (total)

- Stats
  - Max 1.5 (ALC-1, 10/25/07)
  - Means (< 0.17 – 0.382 mg/L)
- ND Lake Avg. 0.272 mg/L (Wax 2006)
- 2010-2011 values for Cal-1 and MAV-1 were < 0.03 mg/L
- Ryberg and Vecchia (2006) noted increasing, but not significant ((p=0.05) linear trends for Mauvais Coulee and Big Coulee (dissolved) for 1980-2003



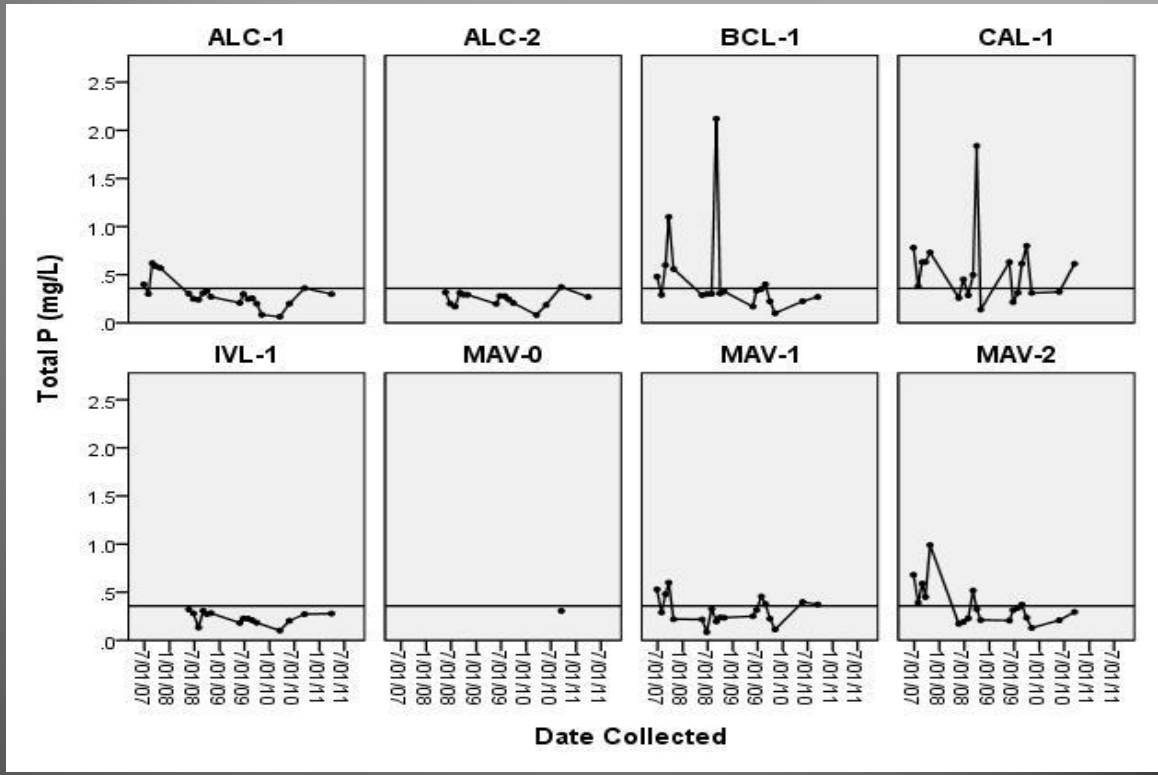
Nitrate-Nitrite as N (total)

- Stats
  - Max 3.18 mg/L (CAL-1) (5/27/09)
  - Means (0.07-0.382 mg/L)
- ND Lake Avg. 0.117 mg/L (Wax 2006)
- ND Standard 1.0 mg/L (diss.) up to 10% may exceed
- Nitrate goal for lakes of 0.25 mg/L
- Ryberg and Vecchia (2006) noted significant (p=0.05) upward trend for Mauvais Coulee (dissolved) from 1980-2003, Lake Alice, Lake Irvine and Big Coulee had no significant upward trends

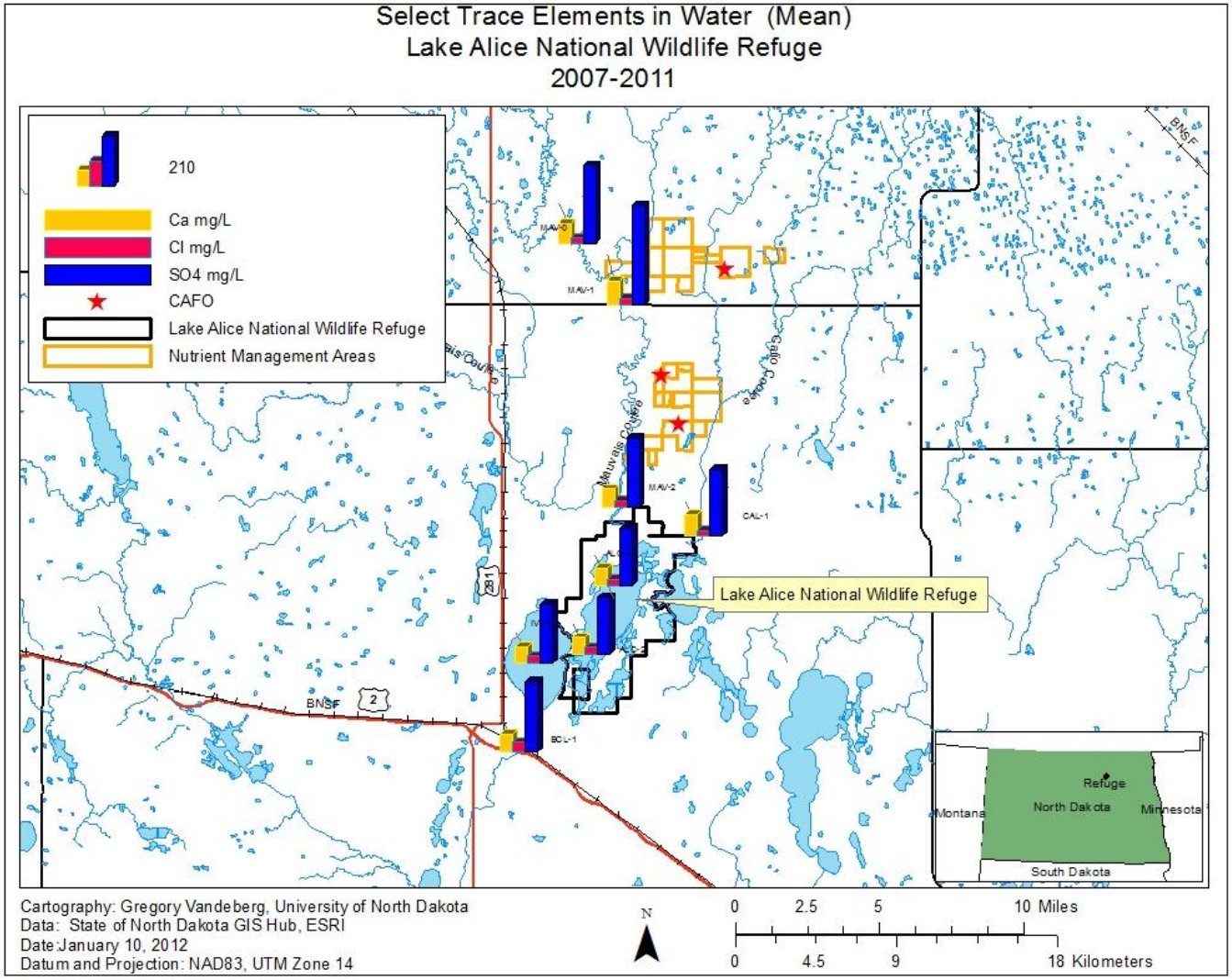


Phosphorus (total)

- Stats
  - Max 2.12 mg/L (BCL-1)
  - Means (0.232-0.549 mg/L)
- ND Lakes avg. 0.152 mg/L (Wax 2006)
- ND Lakes goal 0.02 mg/L
- Ryberg and Vecchia (2006) noted significant ($p<0.05$) upward trend for Mauvais Coulee from 1980-2003

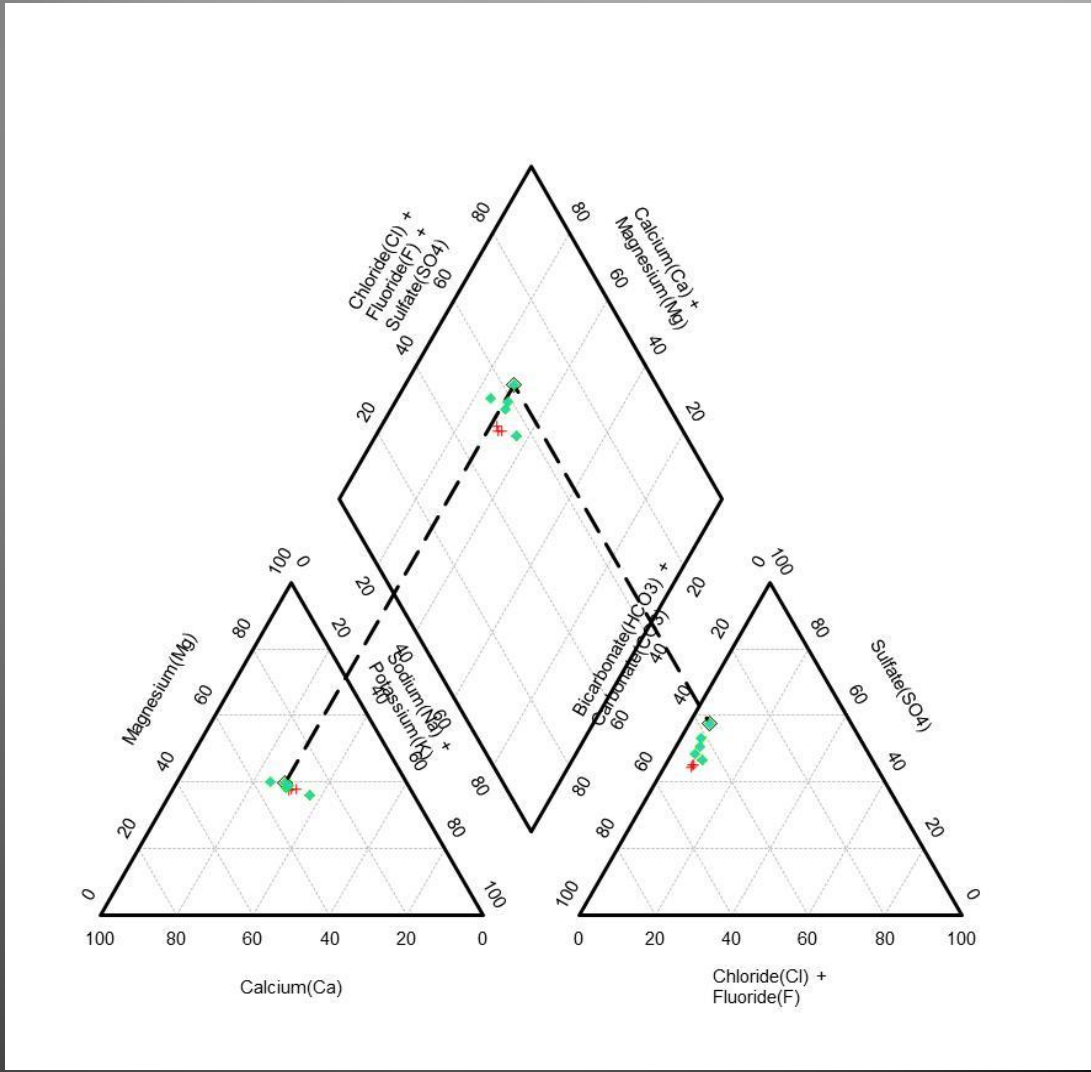


Major Ions in Water



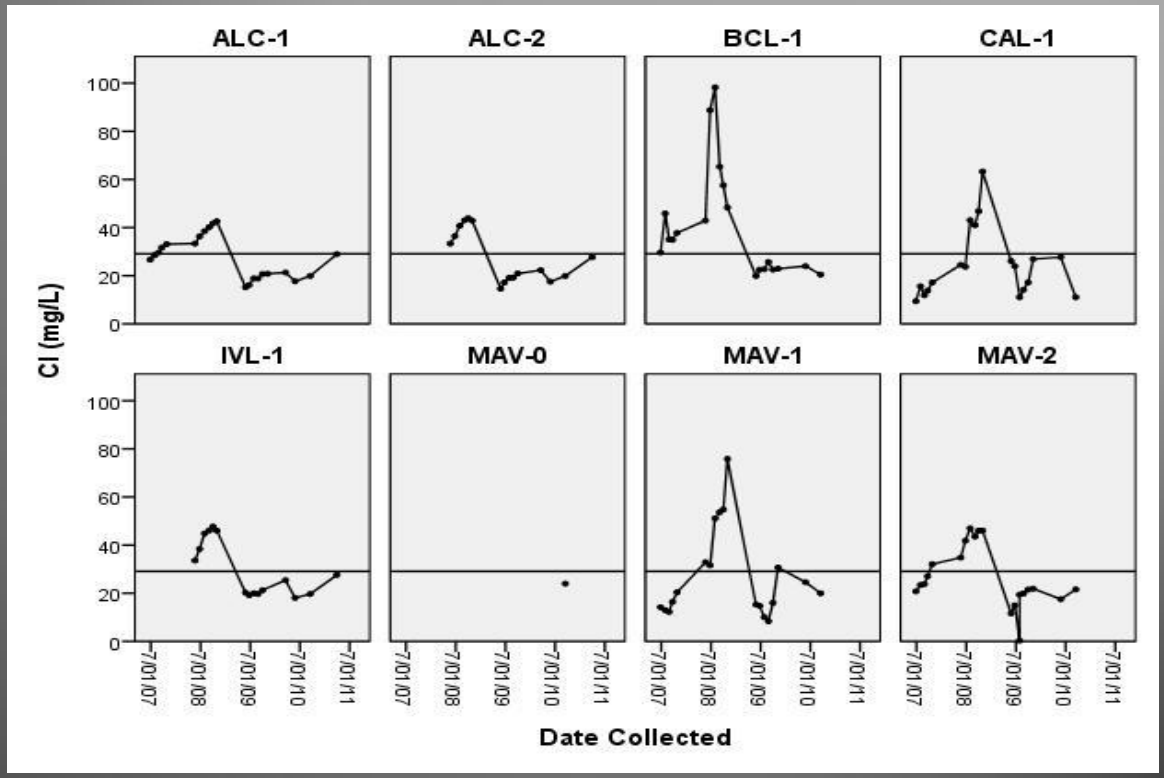
Piper Plot of Mean Concentrations (2007–2011)

- Lake and stream waters similar
- Mixed chemistry dominated by sulfate anion
- Green markers are lake samples, red are stream

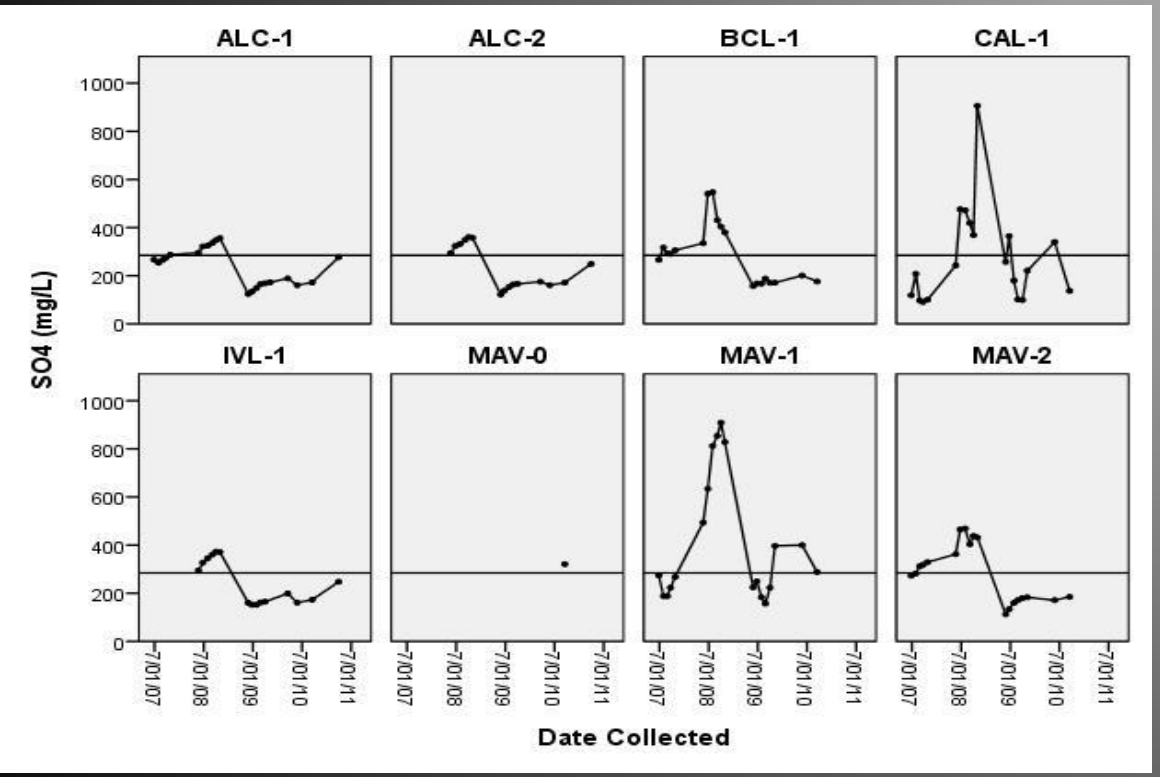


Chloride (total)

- Stats
  - Max 98.3 mg/L Big Coulee (7/30/08)
  - Means (24.0 -40.27 mg/L)
- Less than 100 mg/L 30 day average standard for ND Class I waters
- Ryberg and Vecchia (2006) noted significant ($p<0.05$) linear upward trend for Big Coulee from 1980-2003 (dissolved), not significant for Lake Alice and Irvine, and Mauvais Coulee

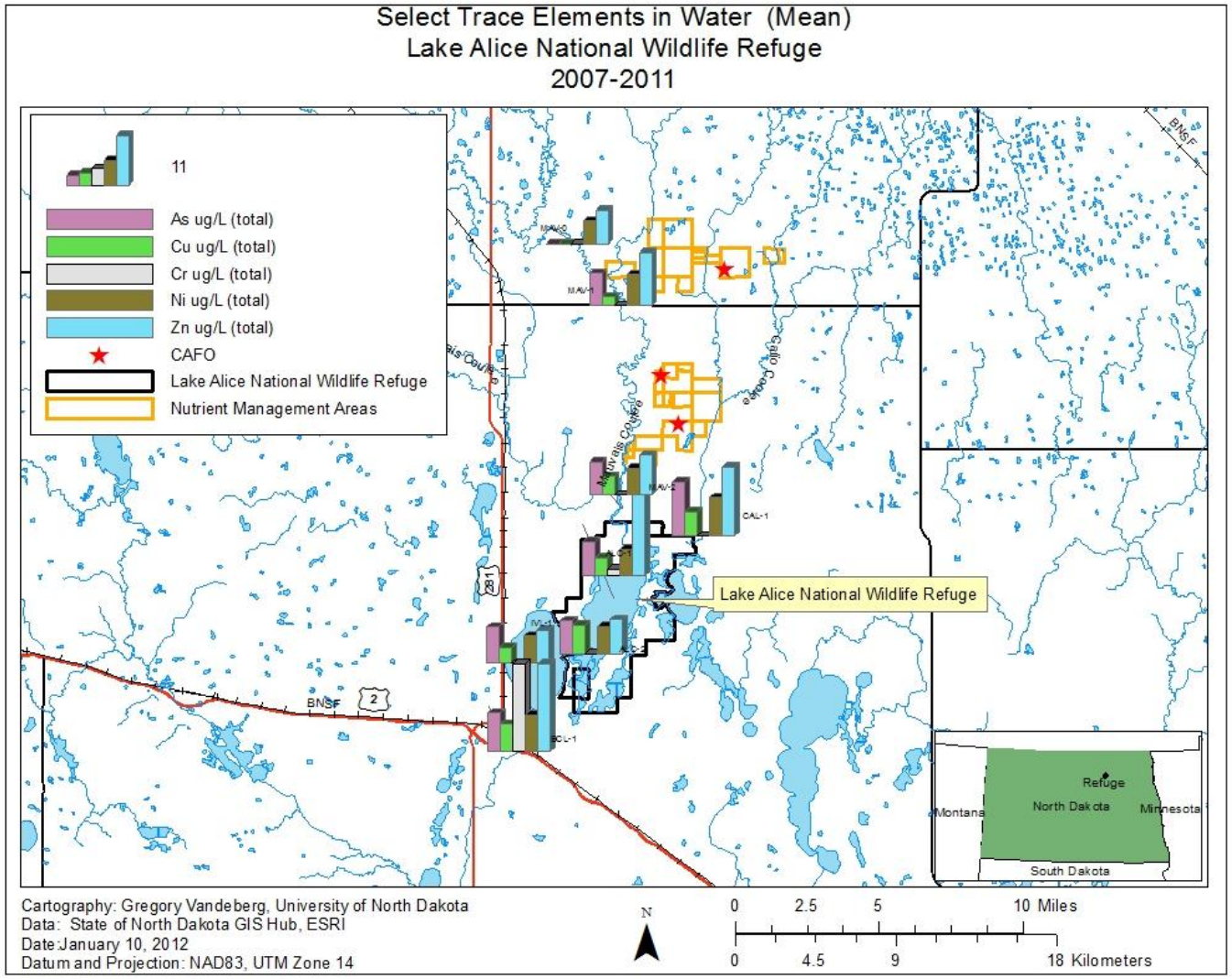


Sulfate (total)



- Stats
  - Max 909 mg/L (MAV-1, 9/30/08)
  - Means (175-321 mg/L)
- ND standard for Class I streams is 450 mg/L (30 day arithmetic mean)
- Ryberg and Vecchia (2006) noted upward but not significant ($p<0.05$) trends for Mauvais Coulee and lakes for 1980-2003 (dissolved)

Trace Elements in Water



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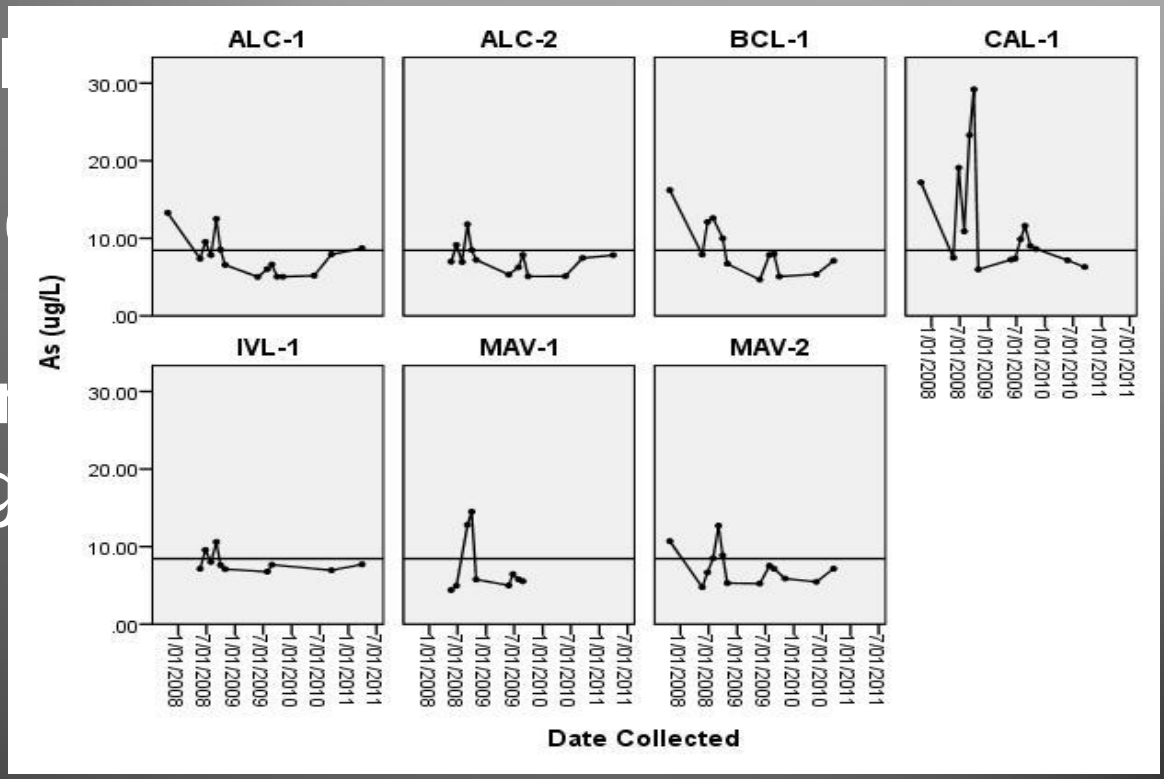
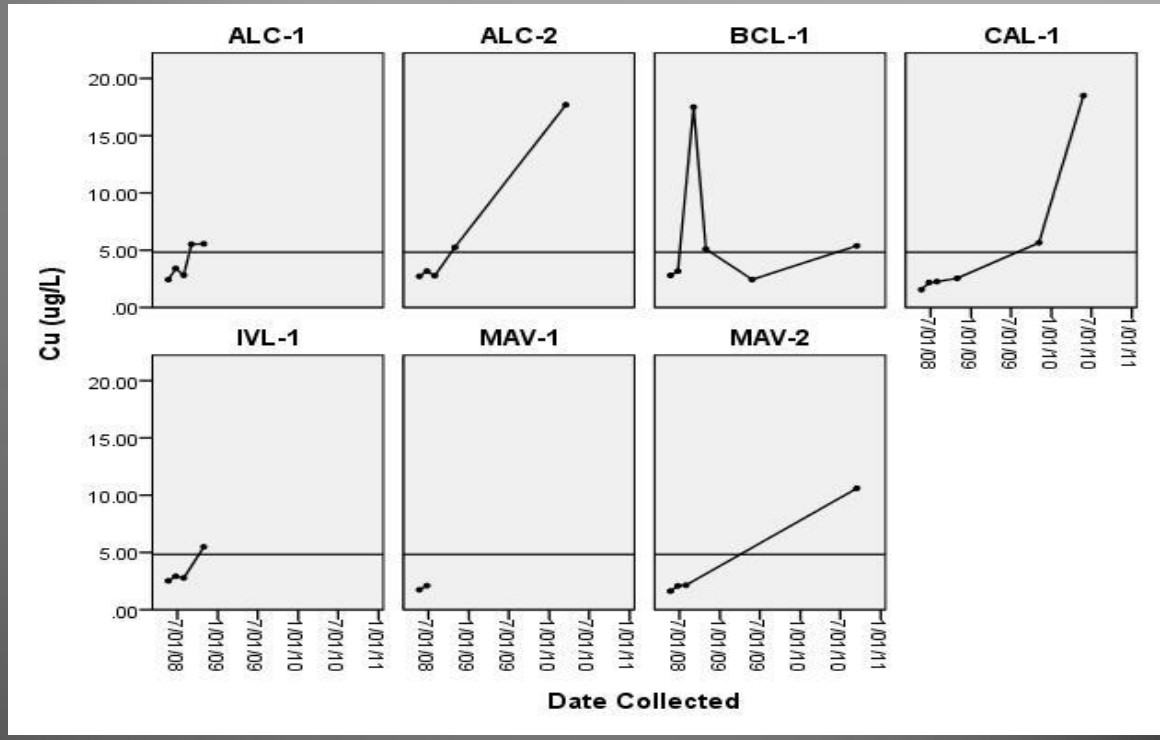
As (total)

- Stats
  - Max 29.2 ug/L Ca
    Coulee (9/30/08)
  - Means (<5.0 – 12.
    ug/L)
- As drinking wate
  standard is 10 ug



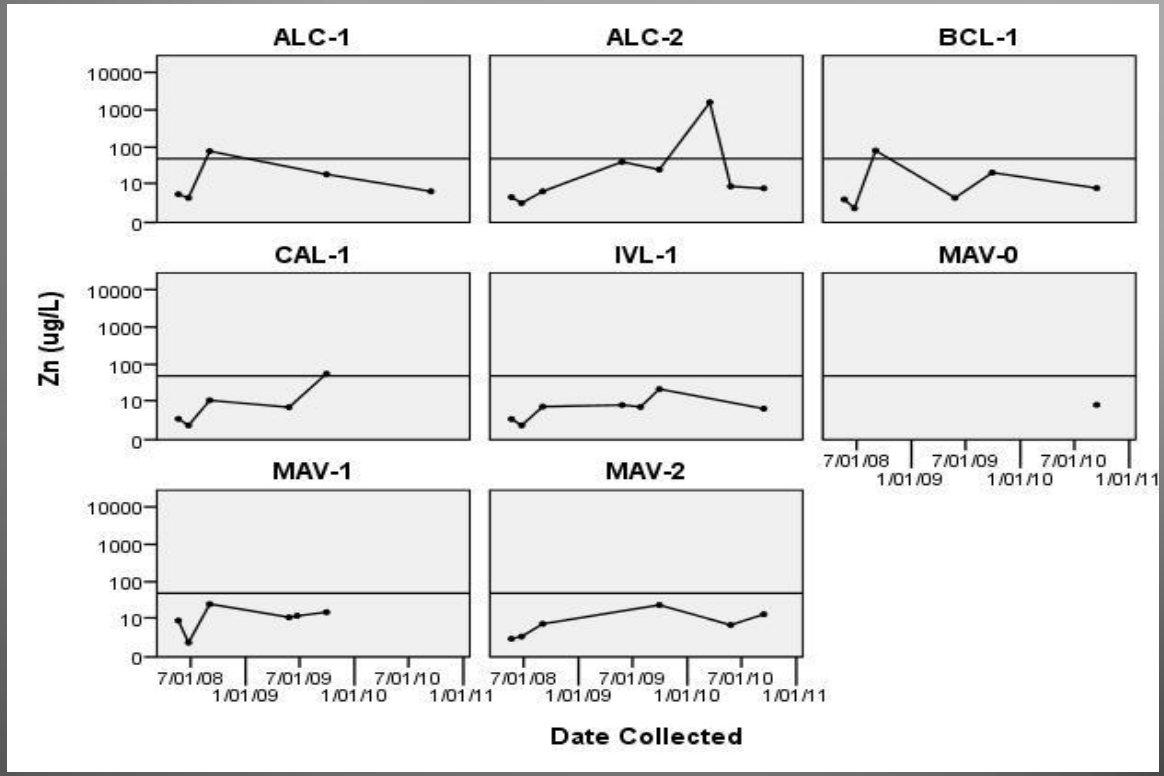
Cu (total)

- Stats
  - Max 18.5 ug/L Calio Coulee (5/26/10)
  - Means (1.92-3.50 ug/L)
  - Missing values nondetect (5.00 ug/L)
- Cu acute aquatic life standard is 55.8 µg/L, and the chronic life standard is 32.7 µg/L based on a $CaCO_3$ hardness of 434 mg/L which is the average for this study



Zn

- Stats
  - Max 1580 ug/L Lake Alice (3/17/10)(dis. 837 ug/L)
  - Means (6.69-120.71 ug/L)
- Similar minimum concentrations in rinse water (contamination or source water?)
- Acute and chronic aquatic life standard is 410 µg/L based on hardness of 427 mg/L



Conclusions

- Nutrients on average highest in Calio Coulee
  - Ammonia trends appear to decrease at ALC-1, BCL-1 and MAV-2
  - Nitrate-nitrate concentrations are similar
  - No clear trend for P, maybe decreasing at MAV-2
- Major Ions (Ca, Cl and SO_4)
  - Similar for all locations
  - Cl appears to have decreased in lakes, wide variation in streams
  - SO_4 appears to have decreased in lakes, wide variation in streams
- Trace elements
  - As mean highest in CAL-1 and BCL-1, trends appear downward or stable
  - Cu concentrations appear to increase, but very near detection concentrations
  - Zn concentrations have no clear trend

Further Work

- Seasonal decomposition of data
  - Seasonal Mann-Kendall or regression
- Discharge decomposition
  - Regression of concentrations vs. lake levels and discharge

Acknowledgements

- Funded in part by:
  - U.S. Fish and Wildlife Service Cooperative Agreement 62580-&-J002
  - ND Department of Health
  - ND EPSCoR Program
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