

Pebble Project

Surface Water Quality Program

Streams, Sediments, and Seeps



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Introduction/Discussion Topics

- Stream Program
 - Overview
 - Methodology and QA/QC
 - Results and Discussion
 - Spatial Trends
 - Temporal Trends
- Seeps Program
 - Overview
 - Methods
 - Preliminary Data
- Ongoing Activities



Streams and Sediment Program Objectives

- **Characterize existing surface water conditions and natural variability in streams**
 - Sources and influences on water quality
 - Collect data in support of other disciplines (e.g. fish/aquatic resources)
 - Water quality data to be combined with hydrology and groundwater data for a comprehensive water balance
 - Document natural water quality, including deviations from standards
- **Provide data for consideration during project design for safe engineering and sound environmental practices**



Stream Program Overview

- **Water quality in streams is influenced by:**
 - precipitation,
 - overland runoff,
 - precipitation and re-suspension of sediments, and
 - groundwater



Stream Program Overview

Naturally Occurring Elevations

- **Water quality data can be compared to:**
 - State of Alaska Chronic Aquatic Life Criteria (CALC) (18 AAC 70)
 - EPA Drinking Water Standards (DW)
- **Naturally Occurring Elevated Concentrations**
 - The term “naturally occurring elevated concentrations” is used to indicate concentrations of an analyte that are above water quality criteria
- **All drainages in the study area exhibit some parameters with naturally elevated concentrations.**



Stream Program

Surface Water Field Methodology

- Field Parameter Measurements
 - YSI 556 combination meter; Temp., DO, pH, Cond., ORP
 - Hach 2100P turbidity meter
- Surface Water Field Sampling
 - DH-81 depth-integrated sampler or
 - grab sampling in shallow streams, during freeze-over periods, and turbulent high flows
 - Samples composited and poured into bottles
 - Bottles placed on ice in coolers in the field; transported to field lab



Stream Program

Surface Water Sampling Field Methodology

Field Lab Sample Management

- A field laboratory is maintained to provide clean and efficient handling of field samples
- Dissolved metals filtered at the field lab with 0.45 micron filter
- Samples transferred to laboratories
 - SGS/CT&E Environmental Services (Anchorage, Alaska)
 - North Creek Analytical (Beaverton, Oregon)
 - Columbia Analytical Services (Kelso, Washington)



Stream Program

Water Quality Analytes

Laboratory parameters

- 23 total and dissolved trace metals
- 9 major cations and anions
- pH, TDS, TSS, alkalinity, hardness
- Cyanides (total, weak acid dissociable (WAD), thiocyanate)
- Organics (Semi-volatile Organic Compounds (SVOC), VOC, and pesticides)
- Dissolved Organic Carbon was added in June of 2007
- DRO/GRO/BTEX was conducted in a one time sample at 2 stations each in South Fork Kaktuli, North Fork Kaktuli and Upper Talarik in June, 2007



Stream Program

Sediment Collection Methodology

- Conducted in June from a subset of water quality stations
- Scooped up with a decontaminated stainless spoon or trowel into a stainless steel bowl from up to 5 areas of deposition at each sampling location due to limited amount of sediment,
- Composited one sample/station for placement in glass jars provided by laboratories
- Samples transferred to laboratories – SGS and CAS



Sediment Collection Methodology

Analytes

- Total Metals
- Mercury
- Cyanide
- Chloride
- Fluoride
- Sulfate, Total Sulfur
- Acid Volatile Sulfide and Simultaneously Extracted Metals (AVS-SEM)
- Ammonia



Quality Assurance and Control

- **Pebble Project QAPP - Submitted to ADEC for approval**
- **Field Sampling Plan**
 - Sampling equipment cleaned with Alconox and DI water between sites
 - Clean Hands/Dirty Hands; other clean procedures
- **QA/QC Samples**
 - 10% duplicate and triplicate frequency
 - 5% equipment rinse blanks
 - One DI blank per trip
 - One low-level Hg trip blank per cooler
- **Field Audits (one per year conducted by Shaw Alaska)**



Stream Program



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Stream Program

Overall Field Parameters for Surface Water

- **Temperature**
 - Instantaneous readings -0.20-23.43 °C
 - Daily mean readings 0.21-20.32 °C
 - State water quality criteria < 20 °C
- **Dissolved Oxygen**
 - Range 2.22-26.20 mg/L
 - State water quality criteria 7–17 mg/L



Stream Program

Overall Field Parameters for Surface Water

- **pH**
 - Range 4.39 - 9.27,
 - Most values within state water quality criterion range (6.5 - 8.0)
 - Greater range than previous local studies (6.9 – 8.1) but shows similar predominance of near-neutral values
- **Specific Conductance**
 - Range 0.007 – 0.145
 - Similar to range seen in data of the Lake Clark area



Stream Program

Overall Field Parameters for Surface Water

- **Alkalinity**
 - Range 3.1 – 38 mg/L
 - Alaska water quality criteria >20 mg/L
 - Majority of values throughout the area are < 20 mg/L
 - Indicates generally low buffering capacity throughout the area
- **Hardness**
 - Range 5 – 62
- **TDS**
 - Range 2-126 mg/L
 - Alaska state water quality criteria - 500 mg/L
 - Low dissolved solids indicate that area soil and rock is not easily dissolved.



Stream Program

Nutrient and Cation Results for Surface Water

- **Nutrients**

- Nitrate/nitrite, ammonia and total phosphorus generally in low concentrations
- Most concentrations < MRL and/or detection limit
- No concentrations > Alaska state water quality criteria

- **Major Cations**

- Calcium, sodium, magnesium and potassium present in low concentrations
- Concentrations of cations similar to data from Lake Clark area, but with greater range
- Predominantly in the dissolved fraction



Stream Program

Major Anion Results for Surface Water

- **Major anions**
 - Sulfate
 - Generally low concentrations of < 30 mg/L, some exceptions up to 89.5 mg/L
 - All values < State drinking water criteria of 250 ug/L
 - Fluoride < MRL and/or detection limit
 - Chloride
 - Low concentrations range 0.40 – 1.40 mg/L,
 - State water quality criteria - 230 mg/L
- **Overall water characterization**
 - Predominantly calcium bicarbonate or calcium bicarbonate-sulfate
 - Calcium bicarbonate concentrations are low, but calcium bicarbonate is still the predominant ion at 60 % of the positively charge ions in most stream water samples



Stream Program

Metals Results for Surface Water

- There are naturally elevated concentrations above CALC and/or drinking water criteria for:
 - aluminum
 - lead
 - copper
 - manganese
 - iron
 - zinc
 - silver
 - cadmium
 - antimony



Stream Program

Cyanide Results for Surface Water

- **Cyanide occurs in naturally elevated concentrations on an occasional basis**
 - State of Alaska water quality criterion for cyanide is 0.0052 mg/L free cyanide measured using the WAD cyanide method
 - Majority of results are below detection level
 - Range of naturally elevated concentrations of cyanide:
0.0055 mg/L to 0.0530 mg/L
 - Samples submitted for low level analysis (EPA Method OIA-1677) measures to 0.0005 mg/L- these tests have confirmed results



Stream Program

Spatial Variation

- **The spatial variation in contribution of water sources can vary in proportion and quality dependent on:**

Groundwater contributions by rock chemistry and rock formation

Aquifer characteristics

Macro and micro climate patterns

Surface soil characteristics

Areas where sediments deposit and may be re-suspended



Stream Program Sampling Locations

- **Stream sampling sites were selected in:**
 - **the Kuktuli River (Nushagak watershed)**
 - North Fork – 5 stations - 3 main stem and 2 tributary
 - South Fork – 15 stations - 8 main stem and 7 tributary
 - Mainstem - 1 station
 - **Upper Talarik Creek (Kvichak watershed)**
 - 10 stations - 4 main stem and 6 tributary
 - **Kaskanak Creek (Kvichak watershed)**
 - 1 station
 - Measures the nature and extent of potential inter-basin transfer from South Fork Kuktuli River

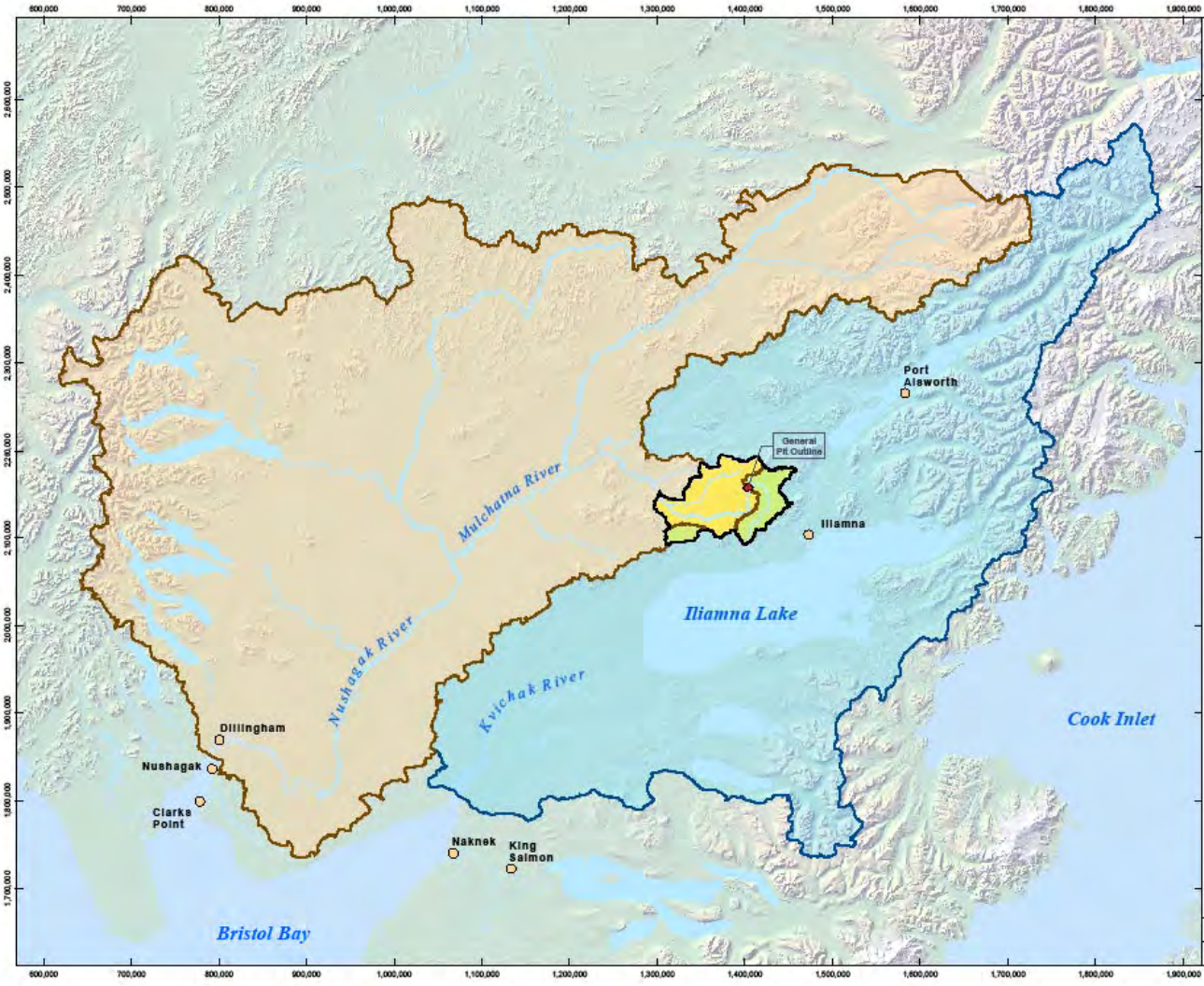


Figure 9.1-1
 Regional Watersheds
 (Mine Study Area)
DRAFT

- Legend**
- Mine Area Drainage
 - Nushagak Watershed
 - Kvichak Watershed
 - Village
 - River
 - Waterbody



0 10 20 30 40 Miles
 0 10 20 30 40 Kilometers
 Scale 1:1,300,000
 Alaska State Plane Zone 5 (units feet)
 1983 North American Datum

File: fig9-1-2_Regional_Watersheds	Date: June 07, 2007
Version:	Author: HDR-LS, JC

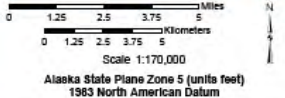
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Figure 9.1-2
Study Area Drainages
(Mine Study Area)

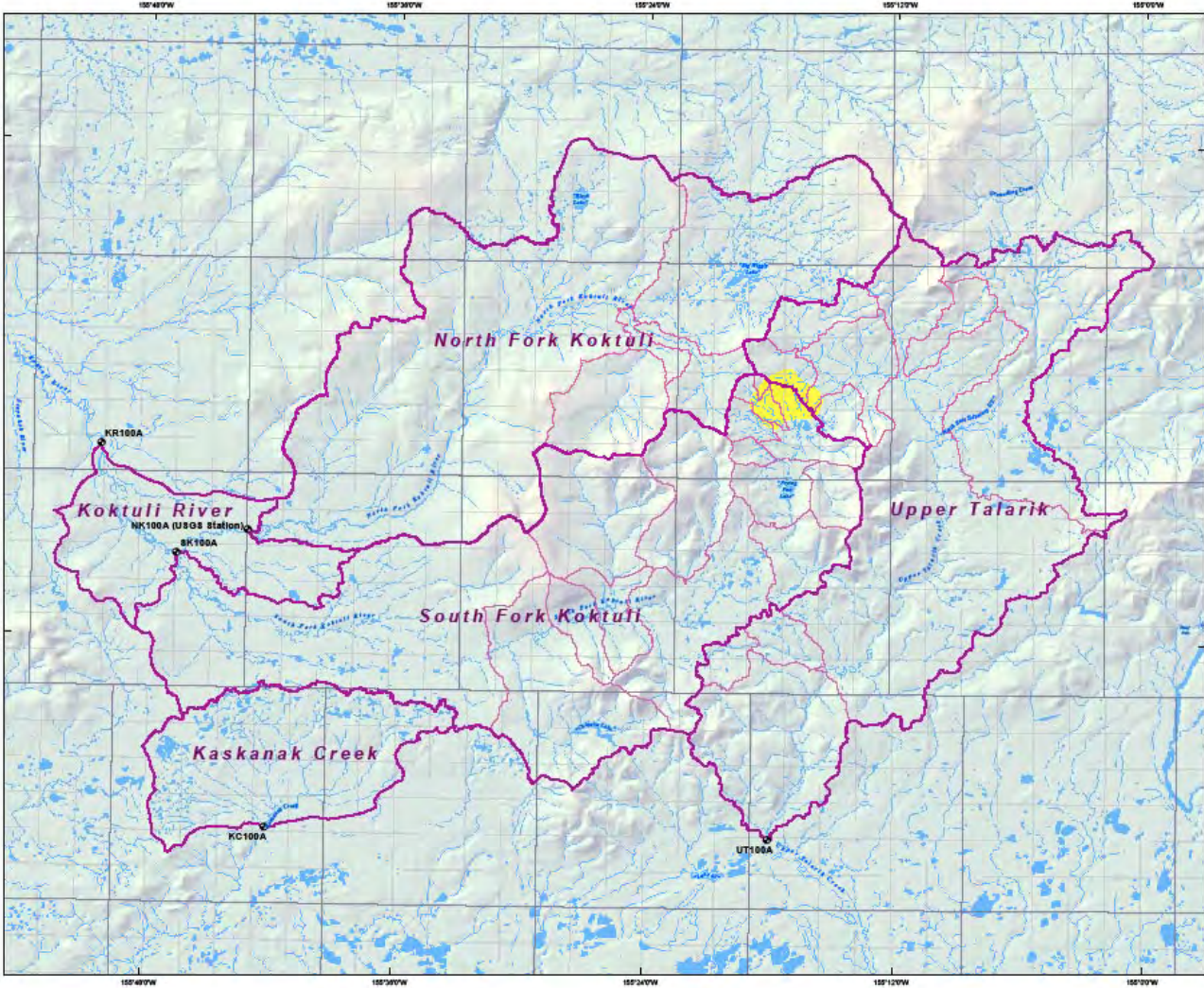
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Legend

- Farthest Downstream Monitoring Station for each Drainage
- Stream
- Water Feature
- General Pit Outline
- Farthest Downstream Monitoring Station Drainage Boundary
- Monitoring Station Drainage Boundary



File: fig 9.1-2_Catchments_for_Monitoring_v01.mxd Date: March 12, 2007
Version: 1 Author: HDR - MC, JC



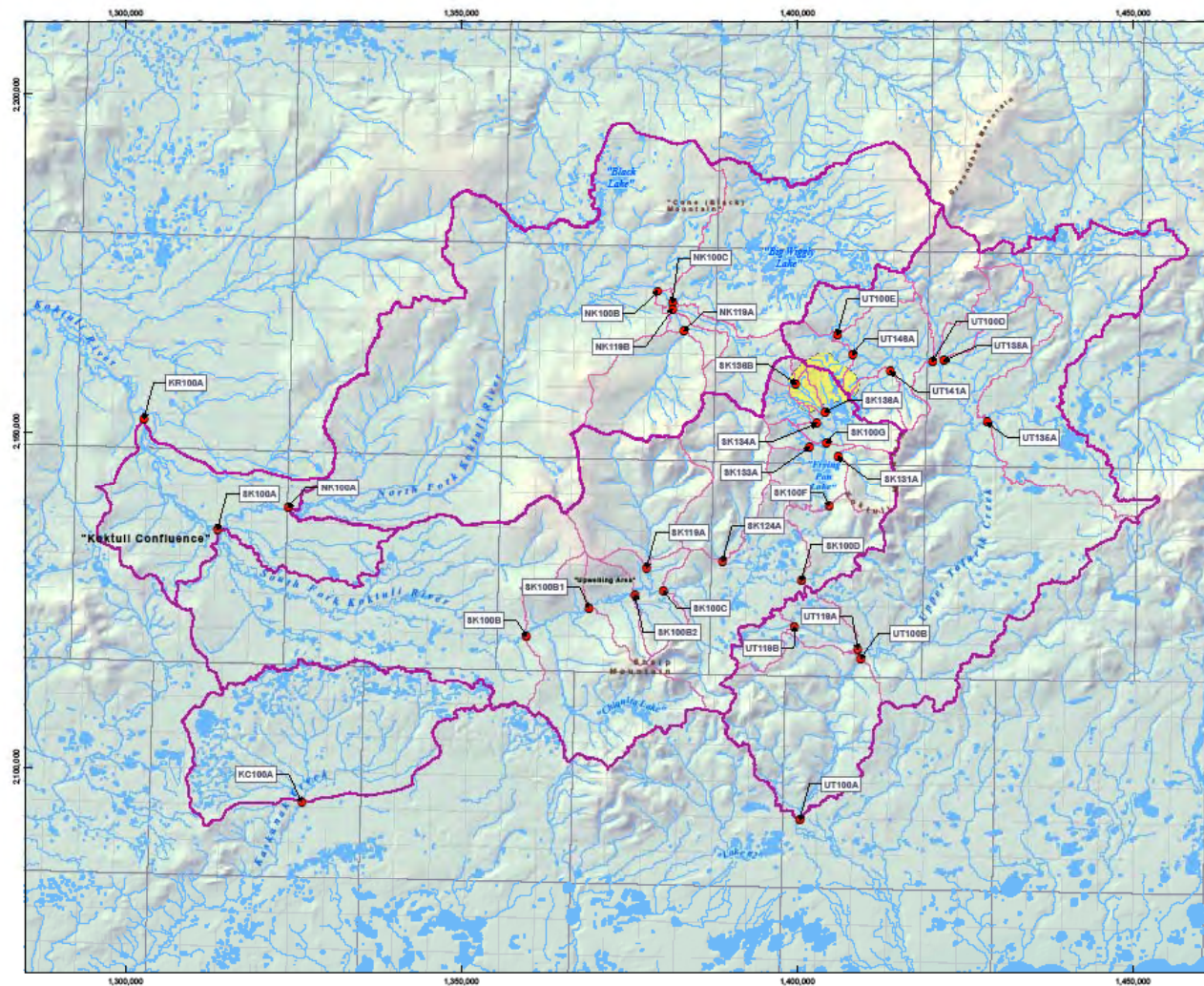
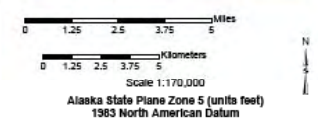


Figure 9.1-3
Baseline Stream Surface -
Water Quality Stations
(Mine Study Area)

DRAFT

Legend

- Baseline Stream Surface - Water Quality Station
- ✦ General Pit Outline
- ⬭ Downstream Drainage Boundary
- ⬭ Drainage Boundary



File: Rp9-1-3_Baseline_Surface_Wa...	Date: February 28, 2007
Version: 1	Author: HDR - MC, JC

Stream Program Sampling Locations

– Sampling Stations were based on the following criteria:

upstream and downstream of the Pebble Ore Deposit

upstream and downstream of potential development concepts

side drainages

sites historically sampled by Cominco,

areas where there is flow gain or loss, and

sites where upwelling is known to occur



Stream Program Sampling Locations

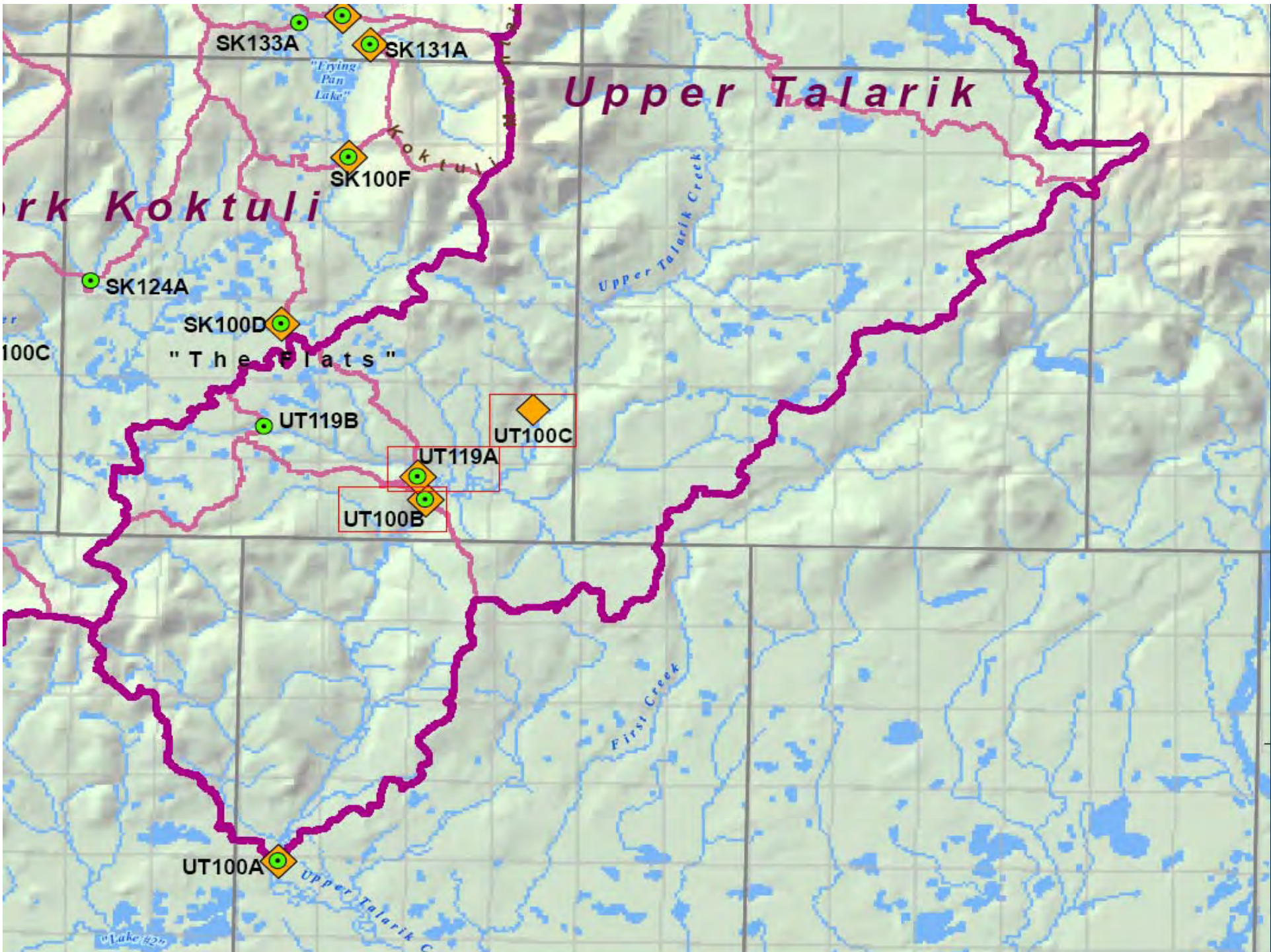
24 Sediment sampling locations

- Sampled at a subset of surface-water stations in June
- Limited sediment material available for collection, sampling at times continued during subsequent sampling events.
- 16 sites/2005; 13 sites/2006; 13 sites/2007
- Sites located in South Fork Koktuli, North Fork Koktuli, and Upper Tilarik



Stream Program Sampling Locations

- Main Stem stations labeled 100 with an alphabetic suffix that increases as you go upstream: 100A, 100B, 100C...
- Tributaries are given increasing numeric values starting at 101 as you move upstream: 102, 103, 104...
- If there are multiple sites within a tributary, they are given an alphabetic suffix which increases as you move upstream: 102A, 102B, 102C ...

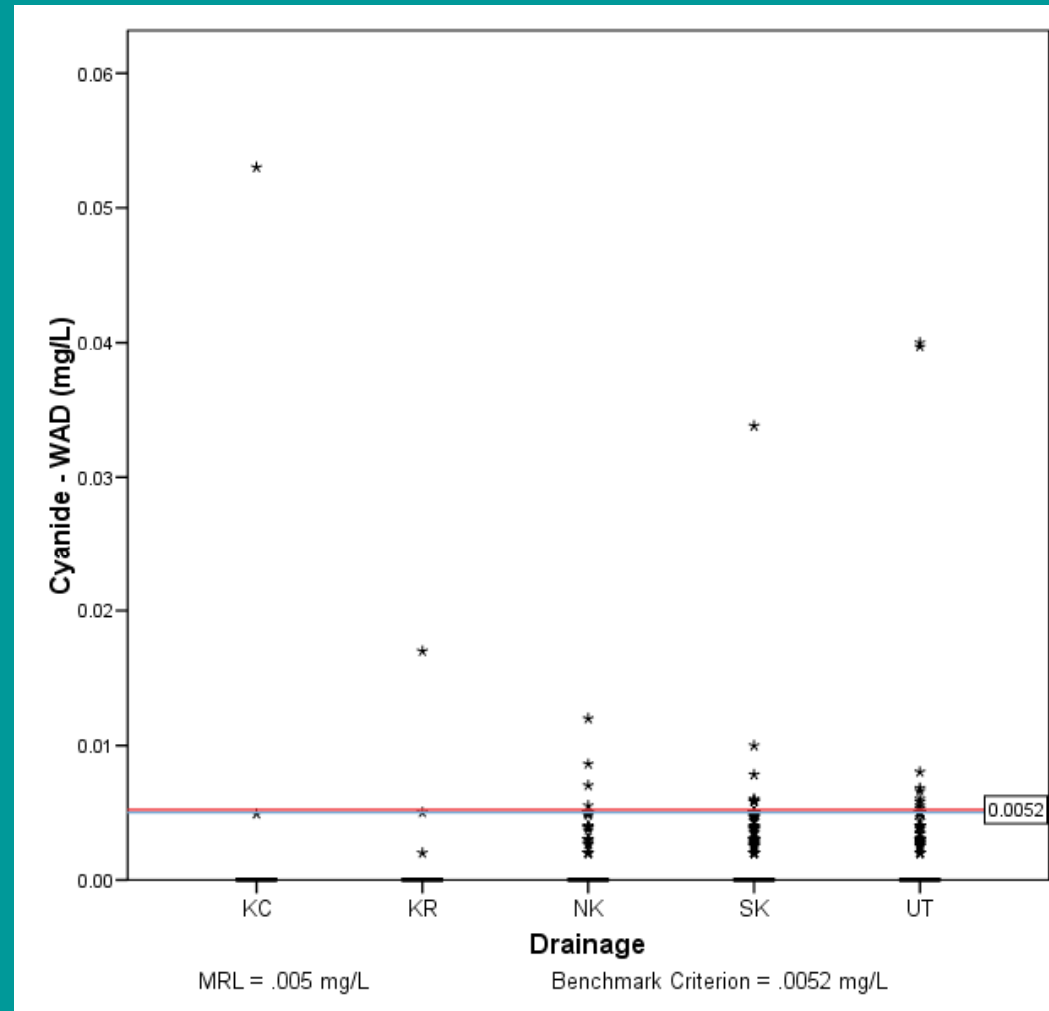


Stream Program

Spatial Consistencies in Data

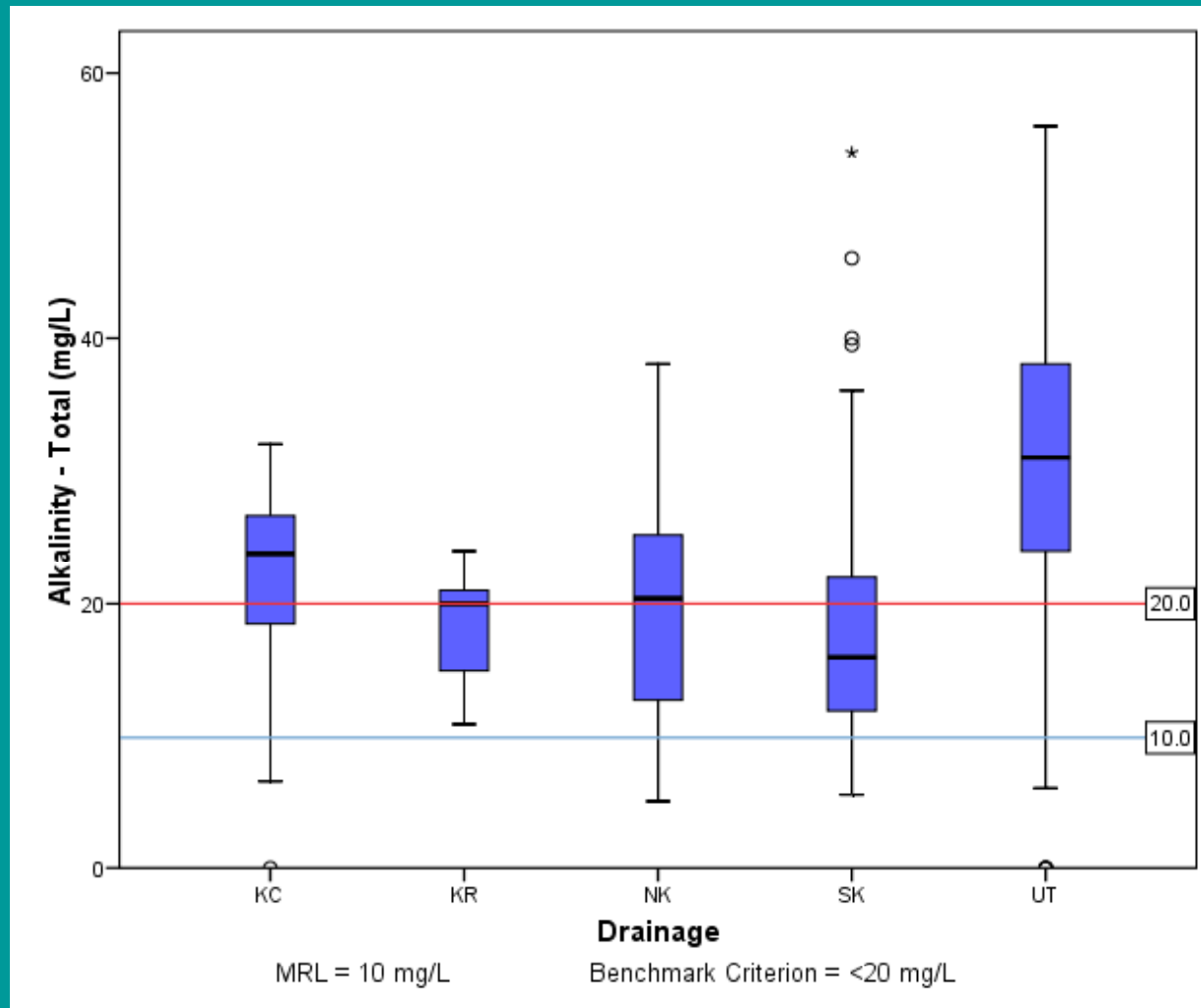
- Ph - near neutral at all sites
- Alkalinity - low at all sites, below minimum criterion
- Hardness - low at all sites, but some spatial variability
- Sulfate - low at all sites, but with spatial variability
- Mercury - predominantly non-detectable at all sites
- CN (total, WAD, thiocyanate) - predominantly non-detectable at all sites, rare readings occur throughout the area
- Little spatial variation:
 - DO, turbidity, water temperature, ammonia, nitrate/nitrite, total phosphorus and zinc (except in North Fork)

Stream Program Spatial Trends in Cyanide



Stream Program

Spatial Trends for Alkalinity



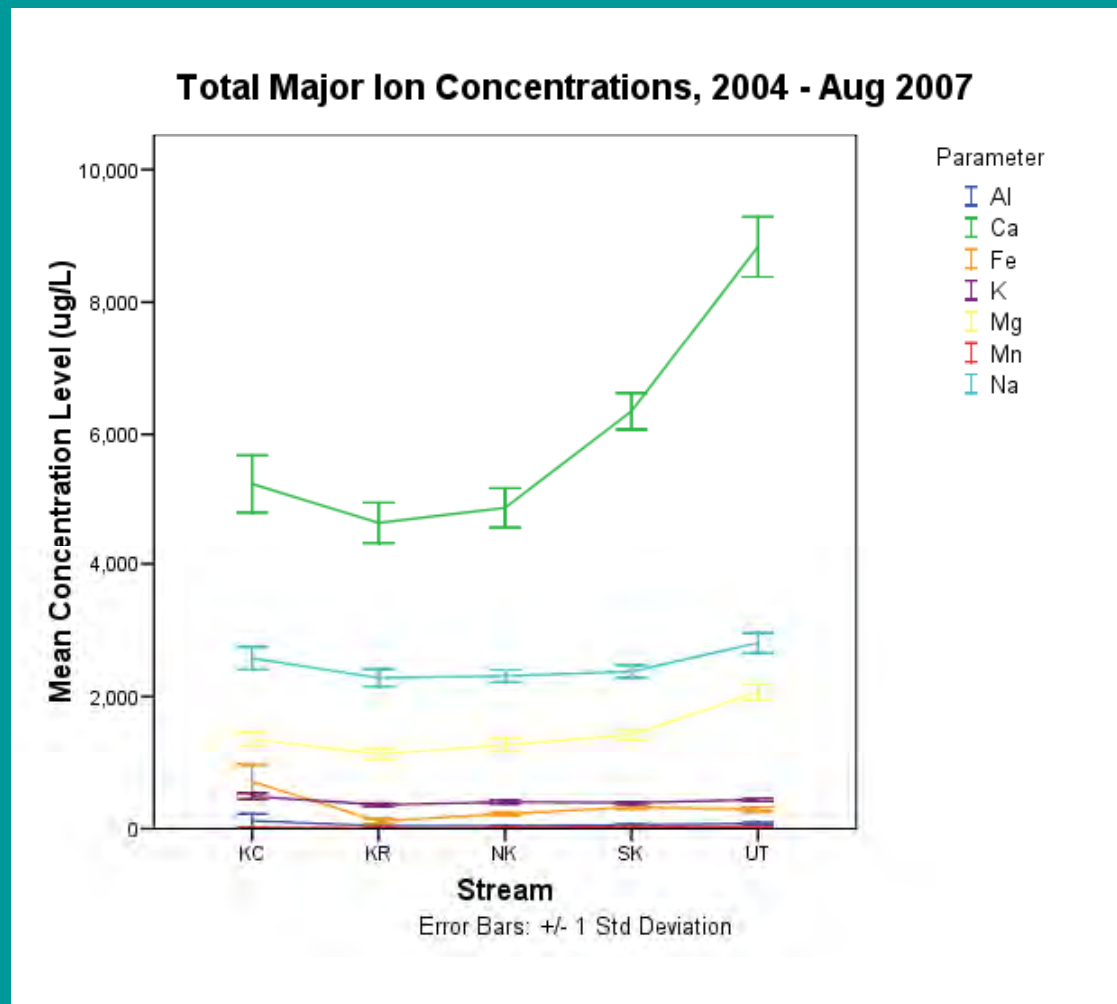
Stream Program

Spatial Trends in Major ions

- Calcium highest in Upper Talarik. lowest in Kaktuli River Mainstem
- Aluminum highest in Kaskanak Creek
- Iron lowest in Kaktuli River Mainstem, highest in Kaskanak Creek

Stream Program

Spatial Trends in Major Ions



Stream Program

Spatial Trends in Trace Elements

- Copper and molybdenum are highest in South Fork Kaktuli
- Nickel is highest in Upper Talarik
- Arsenic is highest in Kaskanak and lowest in Main Stem Kaktuli
- Zinc is highest and most variable in North Fork Kaktuli

Stream Program

Spatial Trends in Naturally Elevated Metals Data

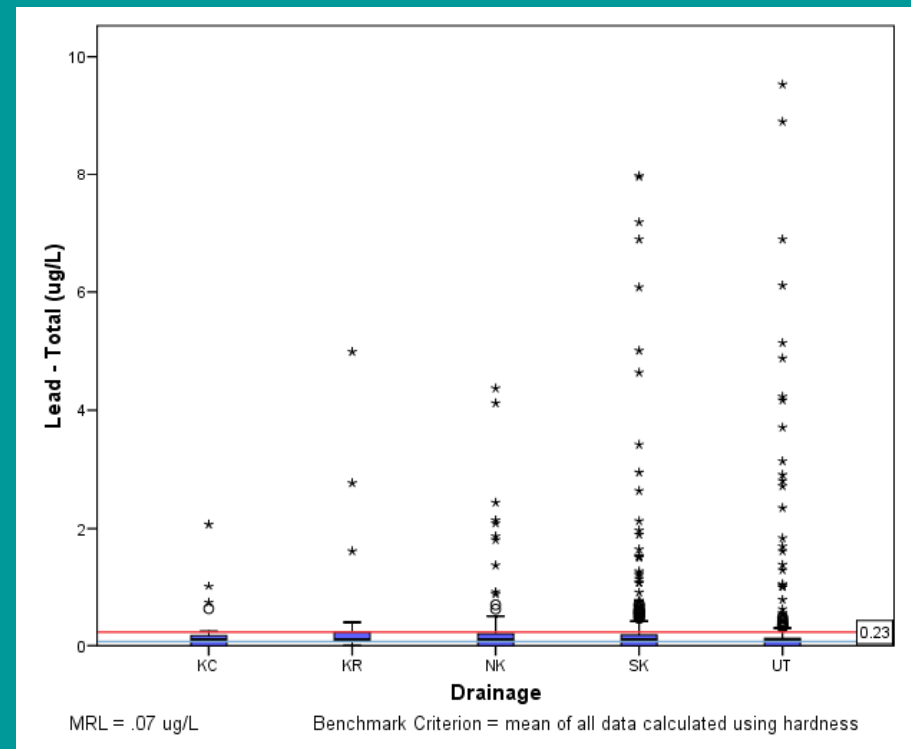
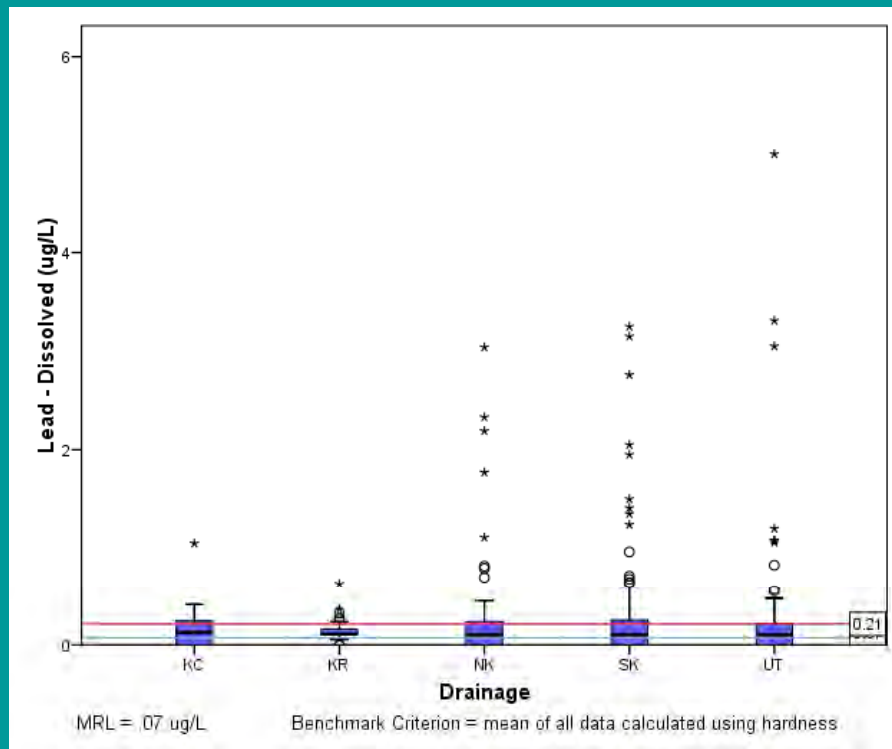
OCCUR IN ALL DRAINAGES

- Lead (dissolved and total)
 - Elevated above CALC at most sites, less frequently in Upper Talarik
 - Generally little variation in concentration between drainages
- Aluminum (total)
 - Elevated above CALC - Occurs more frequently in the upper reaches of South Fork Kaktuli and Upper Talarik, and in Kaskanak Creek.
- Cyanide (WAD)
 - Elevated above CALC (.0052 ug/L) – rare, no spatial trends



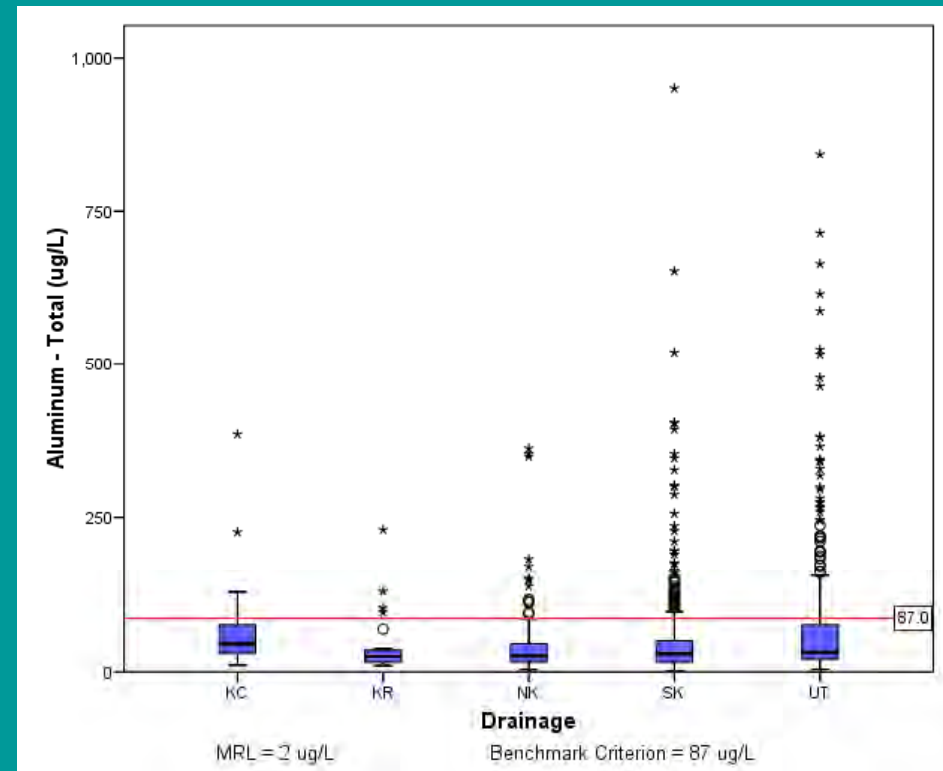
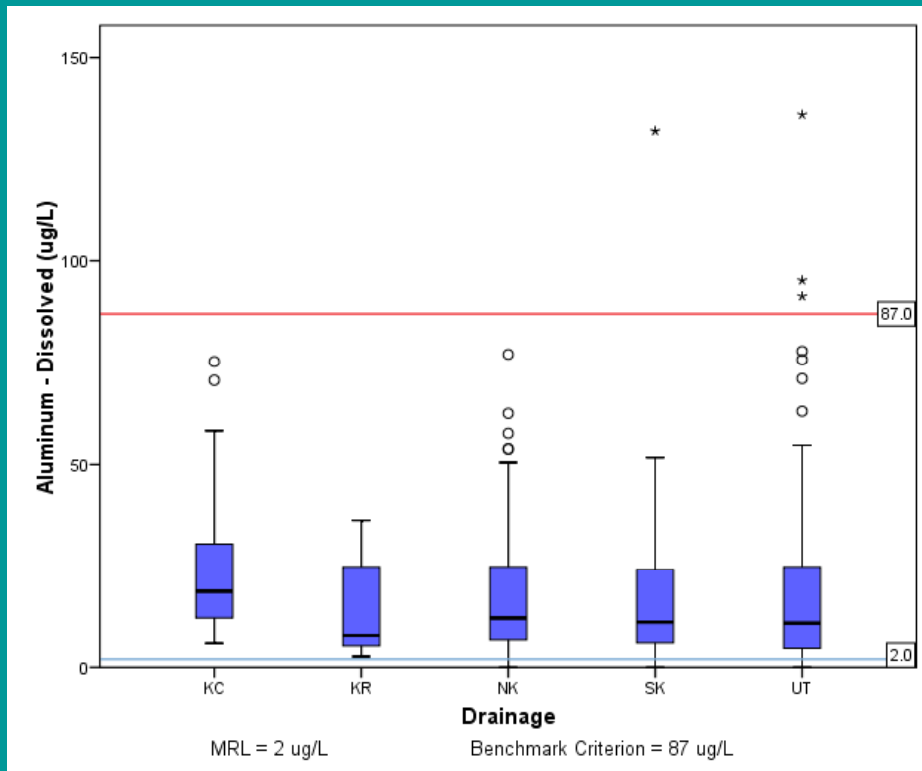
Stream Program

Spatial Trends in Lead Concentrations



Stream Program

Spatial Trends in Aluminum Concentrations



Stream Program

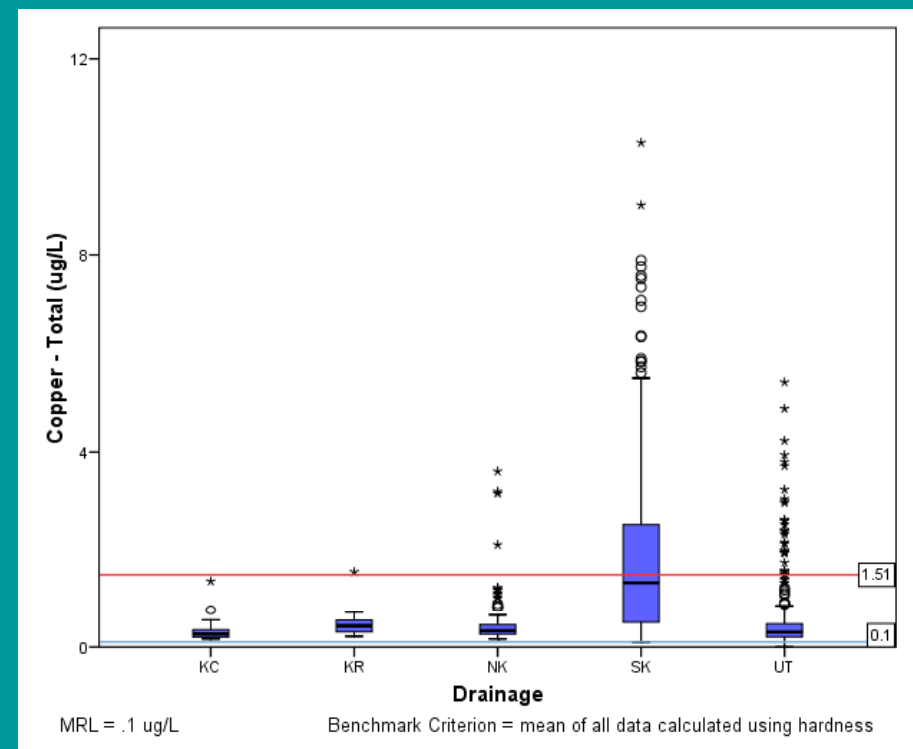
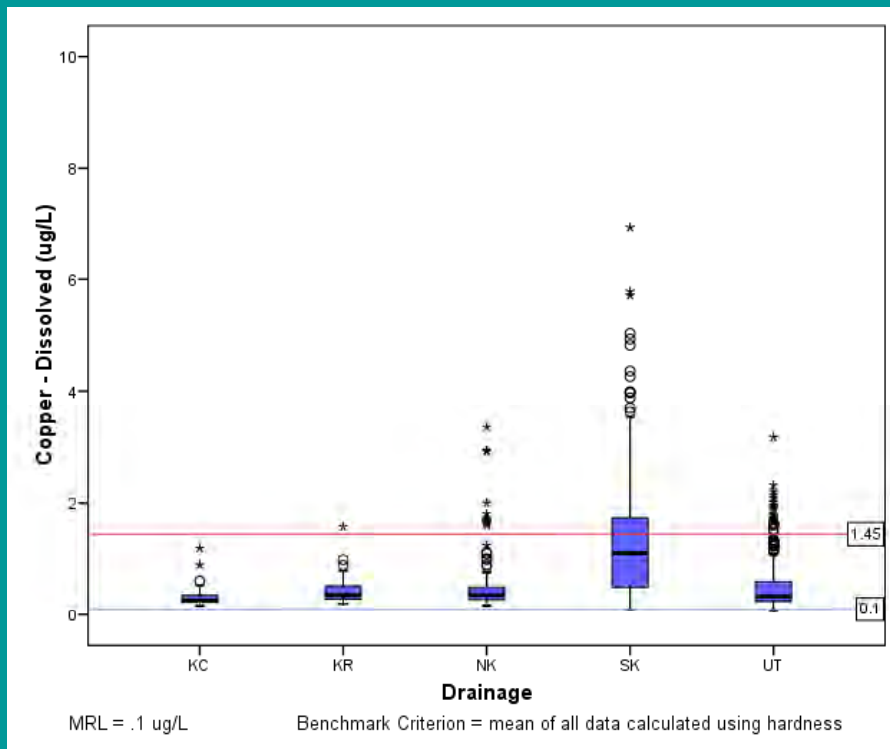
Spatial Trends in Naturally Elevated Metals Data - Continued

OCCUR IN ALL DRAINAGES EXCEPT KASKANAK CREEK

- Copper
 - Elevated above CALC - occurrences rare except South Fork Kaktuli
 - Elevated concentrations occur at 13 out of 15 South Fork Kaktuli stations - at some stations 100% of the time
 - Few elevated concentrations in most side tributaries
- Manganese
 - Elevated above dw criterion – occurrences rare except in upper reaches of South Fork Kaktuli and Upper Talarik
- Zinc (dissolved and/or total zinc)
 - Elevated above CALC (about 20 ug/L) - rare
 - Generally < 10 ug/L throughout the area with little spatial variation

Stream Program

Spatial Trends in Copper Concentrations



Stream Program

Spatial Trends in Naturally Elevated Metals Data - continued

OCCUR IN ALL DRAINAGES EXCEPT KOKTULI RIVER MAINSTEM

- Silver (dissolved and/or total)
 - Elevated above CALC - rare

OCCUR IN ALL DRAINAGES EXCEPT KOKTULI RIVER MAINSTEM, AND UPPER TALARIK

- Iron
 - Elevated above CALC
 - Kaskanak Creek generally had higher iron concentrations
 - Upper reaches South Fork Koktuli had more frequent naturally occurring elevated concentrations

OCCUR ONLY IN UPPER TALARIK AND SOUTH FORK KOKTULI RIVER

- Antimony,
 - Elevated above dw criterion –rare
 - Occurs at low levels throughout the area



Stream Program

Characterization of Drainages



South Fork Kaktuli



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Drainage Characteristics

South Fork Koktuli

- Drains mineral deposit
- Highest of all drainages in:
 - copper,
 - molybdenum,
 - sulfate - especially near mineral deposit (similar trend in Upper Talarik)
 - water temperature at site just downstream of Frying Pan Lake
- Lowest of all drainages for:
 - median pH values <6.5 at mid-stream sites
 - low pH values; uncommon in Alaska but do exist in some streams
- Decrease downstream and with distance from mineral deposit:
 - copper
 - molybdenum
 - nickel
 - magnesium
 - overall ion concentration
 - iron
 - manganese
 - aluminum
 - sulfate



North Fork Koktuli



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Drainage Characteristics

North Fork Kaktuli

- Highest of all drainages in:
zinc – also most variable
- Decrease downstream:
TDS – also lower in tributaries
calcium –also low in tribs
magnesium
iron
nickel
alkalinity
hardness
potassium
lead
iron
- Increases downstream:
zinc

Koktuli River Mainstem



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Drainage Characteristics

Main Stem Koktuli River

- Located below convergence of the North & South Forks of Koktuli River
 - North Fork contribution of zinc is noticeable
 - Lower TDS values from North Fork are also noticeable
 - South Fork contribution of copper and molybdenum is noticeable
- Highest of all drainages for:
 - Flow
- Lowest of all drainages for
 - Metals which are present predominantly in the particulate fraction – iron, manganese, and aluminum
 - Arsenic < MRL on all 52 sampling occasions
- Only one station – no spatial trends for the main stem
- Zinc is the most abundant trace element followed by copper and molybdenum



Upper Talarik Creek



Drainage Characteristics Upper Talarik Creek

- **Drains** a portion of the mineral deposit

- **Highest of all drainages in:**

nickel	pH	hardness
calcium	specific conductance	
magnesium	alkalinity	

- **Decrease downstream and with distance from mineral deposit:**

sodium	magnesium	lead	nickel
potassium	alkalinity	zinc	iron

- **Increase downstream:**

arsenic	molybdenum
---------	------------

Kaskanak Creek



Drainage Characteristics Kaskanak Creek

- **Highest of all drainages in:**
 - iron
 - aluminum
 - Arsenic – still below water quality criteria
- **Lowest of all drainages for:**
 - flow
 - 71% of all lead values were undetected
- **Only one station – no spatial trends within the drainage**

Stream Program Overview

Temporal Trends

The contribution of sources vary in proportion and quality temporally

During open water season (late April-October) stream flow is a combination of groundwater, snowmelt and precipitation

Seasonal high flows may contribute:

- greater dilution from snow melt or precipitation
- greater erosion
- re-suspension of sediment
- flushing of near surface groundwater



Stream Program Overview

Temporal Trends

During freezing conditions stream flow is generally groundwater fed

Iced-over conditions prevent contribution from precipitation, and may lead to increasing concentrations of ions and metals during the formation of ice.

As water freezes, other components are precipitated creating higher concentrations in the underlying liquid portion – particularly in areas of ice dams



Stream Program Overview

Sampling for Temporal Trends

Characterize water chemistry under various hydrologic conditions:

- Spring break-up
- Summer low-flow
- Fall precipitation events
- Winter freeze-over



Samples collected regularly from April 2004 – October 2007

- 2004: 7 events (April-October)
- 2005: 8 events (January, March, May - October)
- 2006: 10 events (February, March, May – December)
- 2007: 12 events (Jan – December) – to be completed

Stream Program Overview

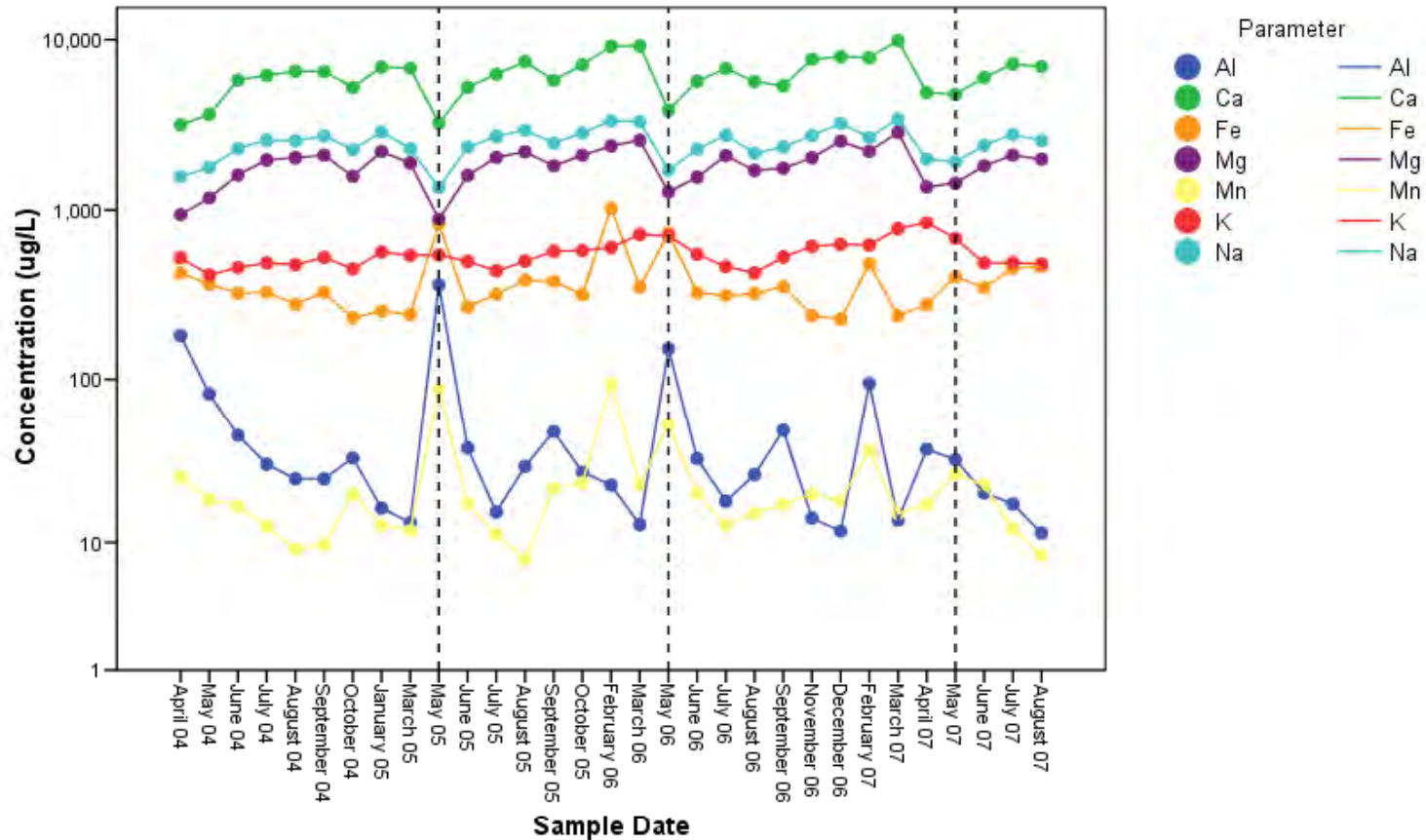
Temporal Trends Associated with Break-up

- Lower pH, alkalinity, specific conductance, hardness
- Lower concentrations of:
 - Calcium
 - Sodium
 - Magnesium
- Higher concentrations of:
 - Iron
 - Aluminum
 - Manganese

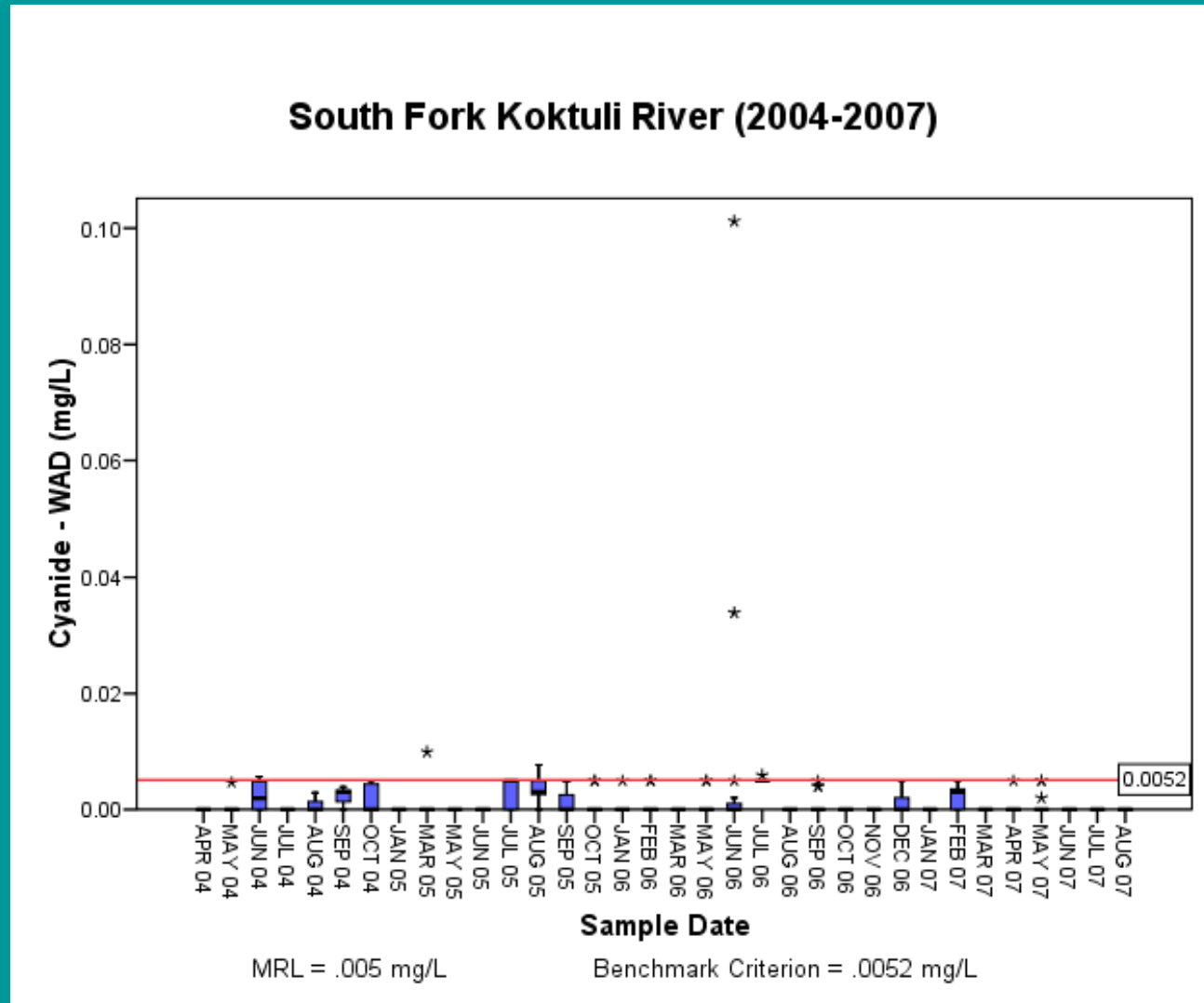


Influence of Break-up North Fork Koktuli River

Total Major Metal Concentration vs Time for Site NK100C

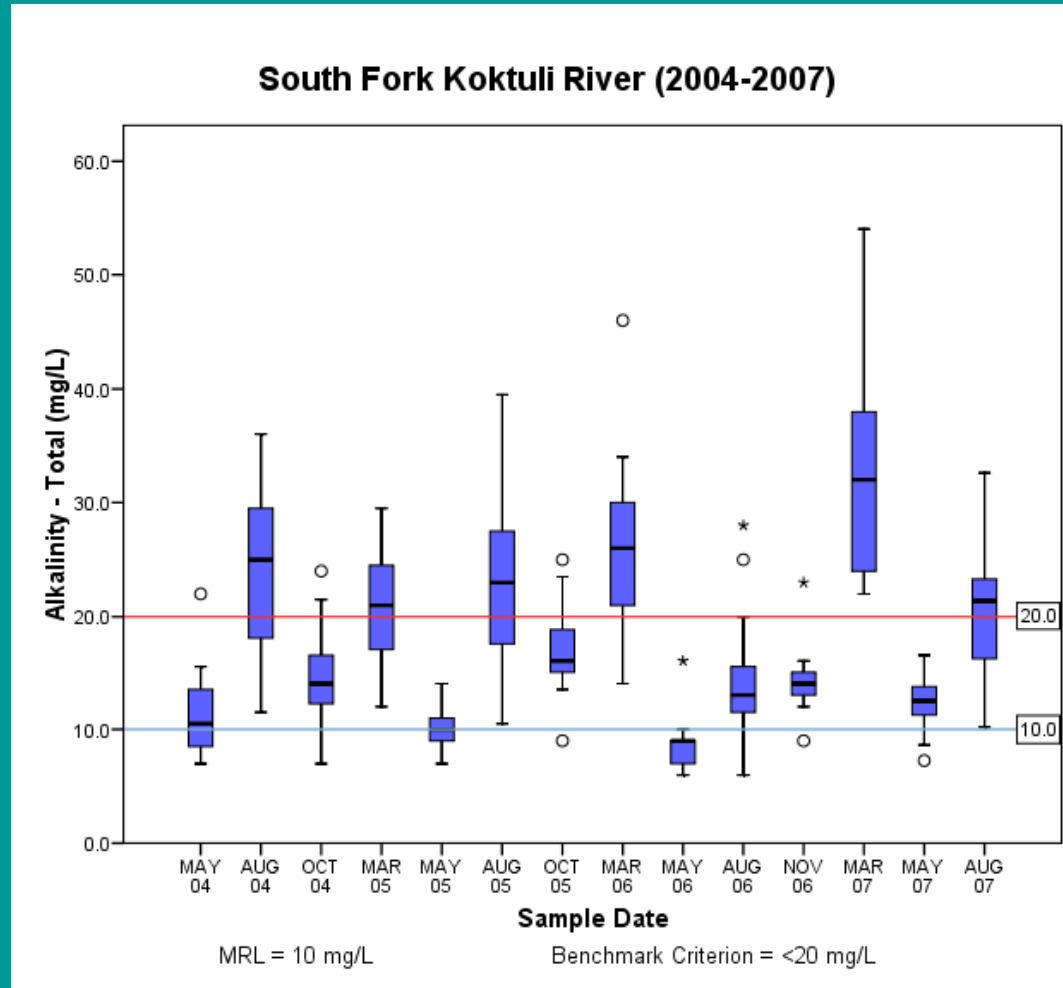


Temporal Trends - Cyanide



No apparent temporal trends

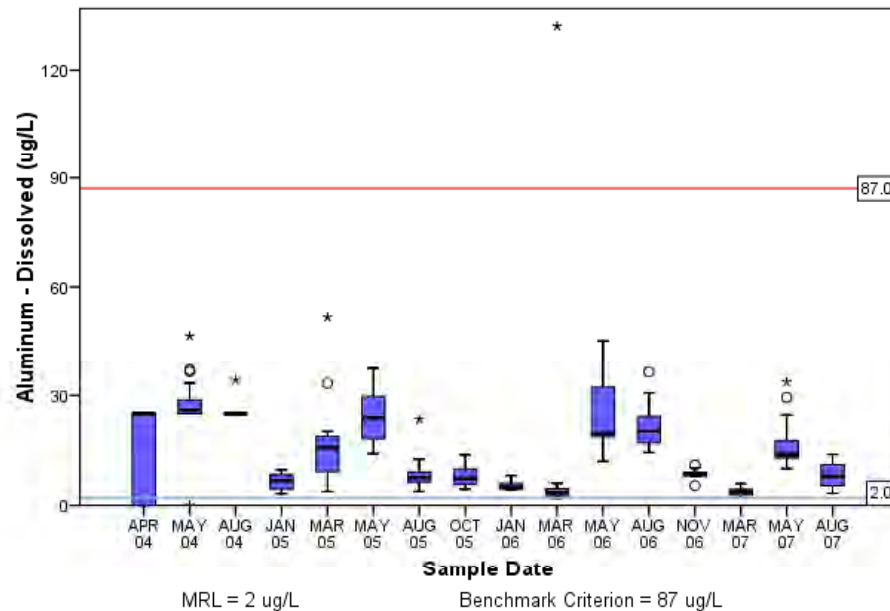
Temporal Trends - Alkalinity



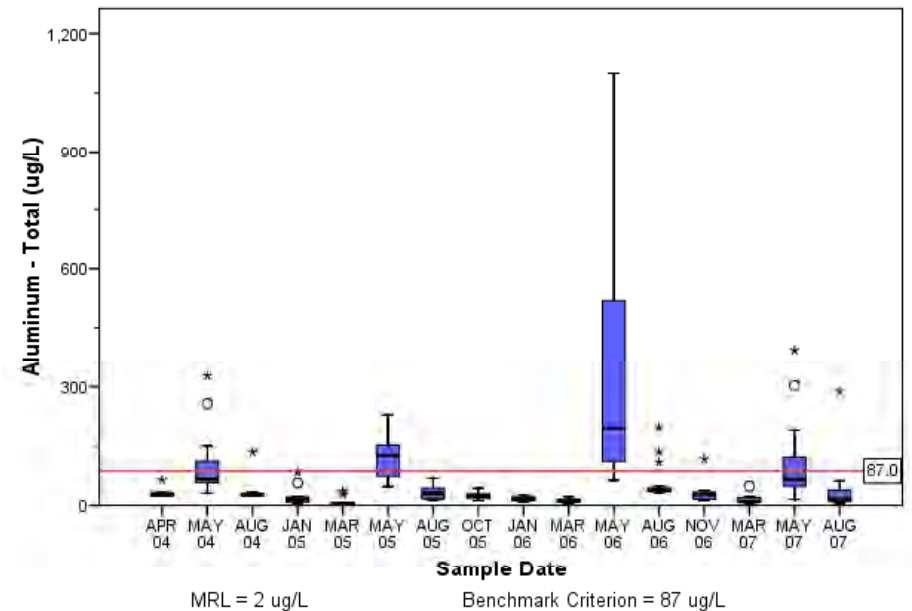
Low concentrations during break-up and fall precipitation events

Temporal Trends – Aluminum South Fork Kaktuli

South Fork Kaktuli River (2004-2007)

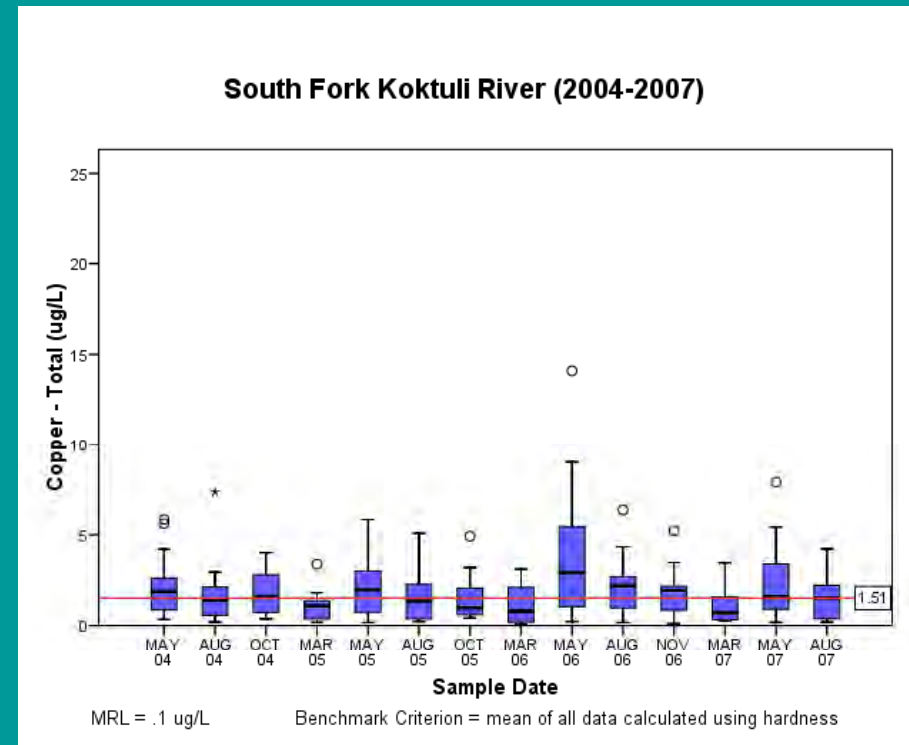
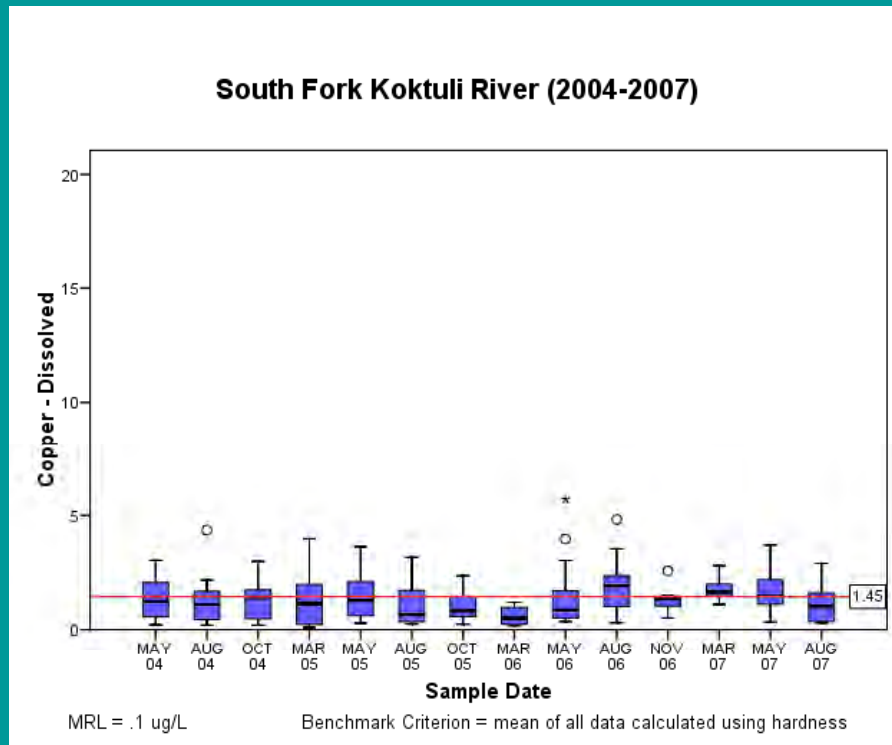


South Fork Kaktuli River (2004-2007)



Higher concentrations at break-up

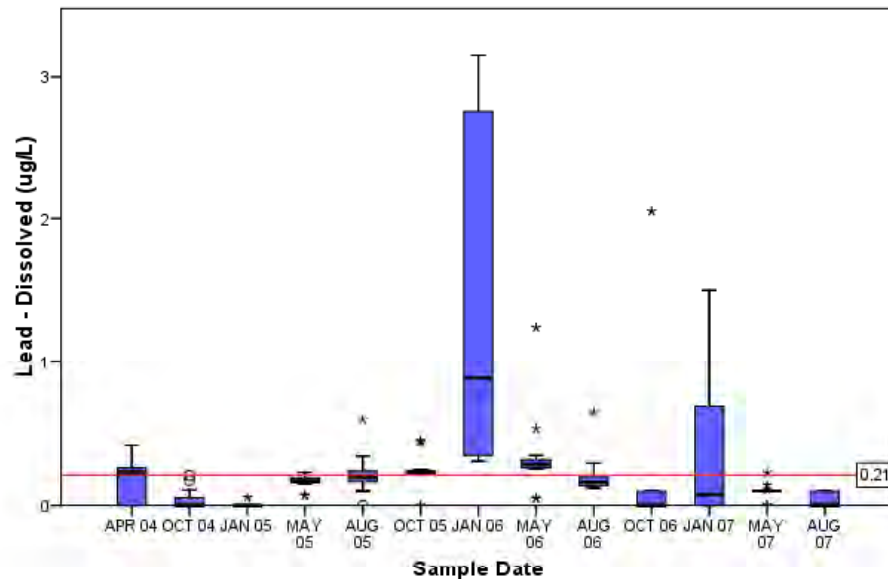
Temporal Trends – Copper



Lower concentrations during winter

Temporal Trends – Lead

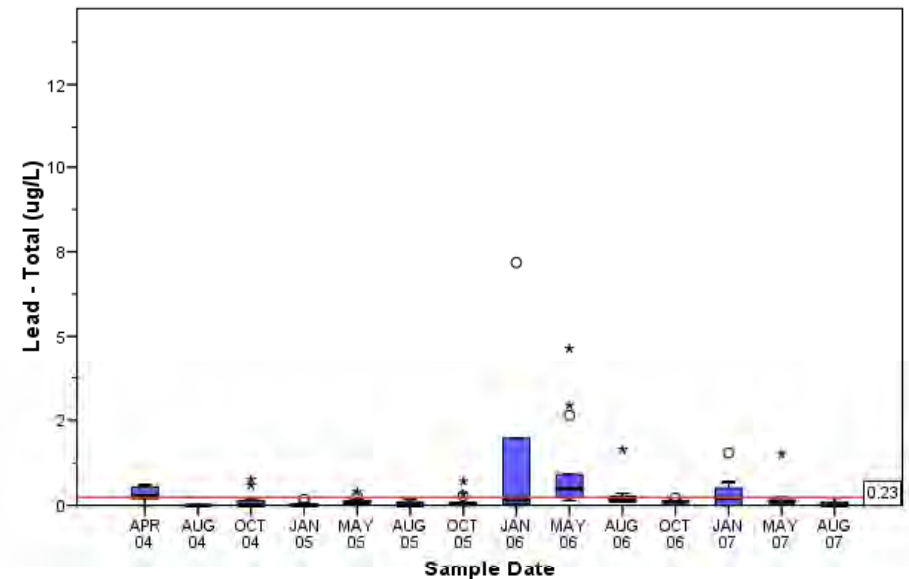
South Fork Koktuli River (2004-2007)



MRL = .07 ug/L

Benchmark Criterion = mean of all data calculated using hardness

South Fork Koktuli River (2004-2007)



MRL = .07 ug/L

Benchmark Criterion = mean of all data calculated using hardness

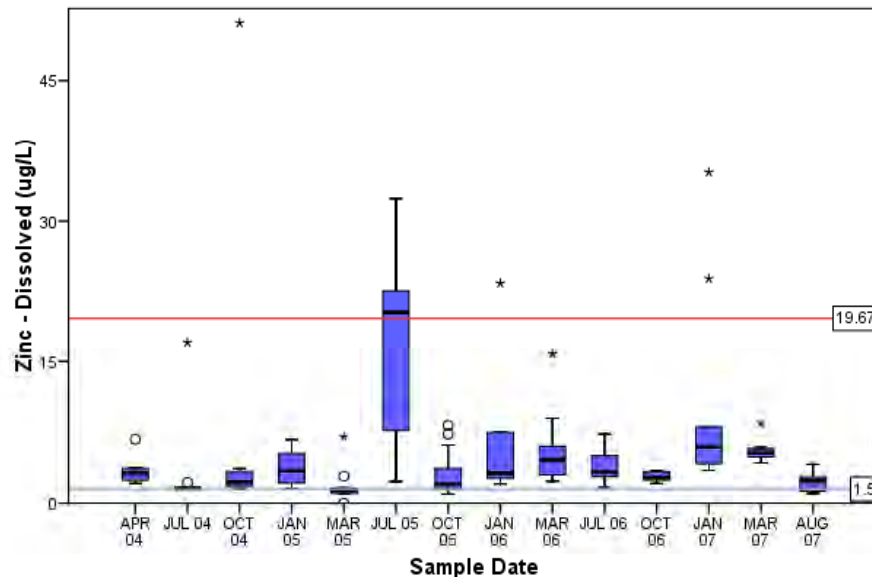
High concentrations some winters



Temporal Trends – Zinc

South Fork Koktuli River and Upper Talarik Creek

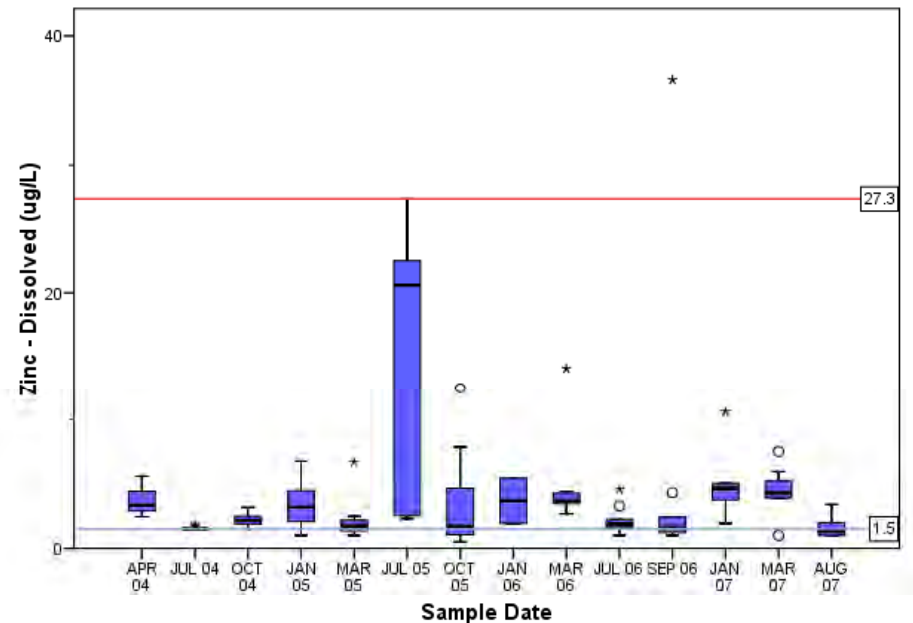
South Fork Koktuli River (2004-2007)



MRL = 1.5 ug/L

Benchmark Criterion = mean of all data calculated using hardness

Upper Talarik Creek (2004-2007)



MRL = 1.5 ug/L

Benchmark Criterion = mean of all data calculated using hardness

No apparent seasonal trend, but shared temporal trend between drainages



Seep Program



Seep Program Objectives

- Better understanding of relationship between surface water and groundwater
- Calibration of groundwater models

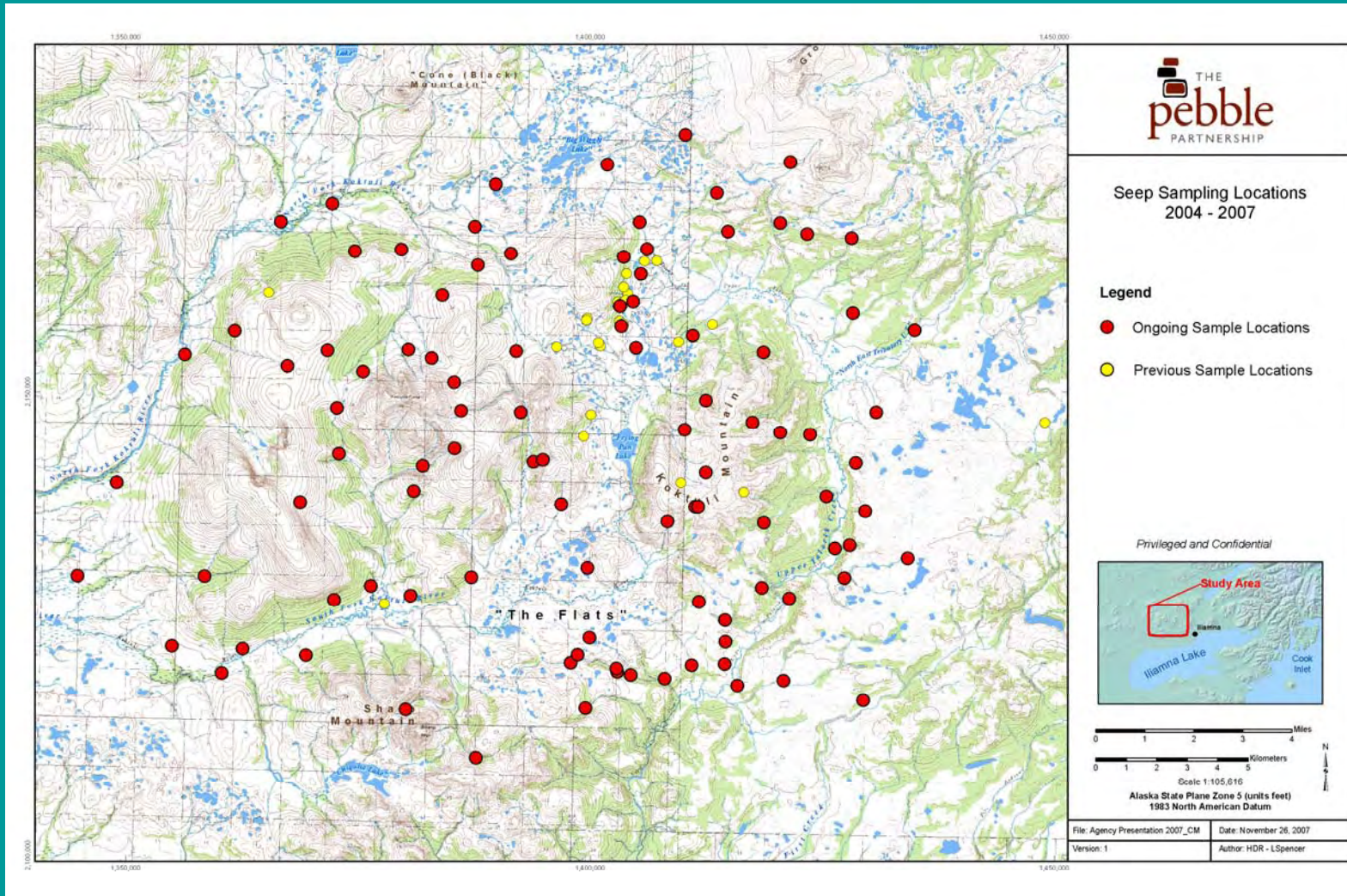


Seeps Program 2005-2007

- Program – 24 sampling sites in 2004
- Additional sites added and discontinued over time
- 99 sites being sampled in 2007
- 5 sampling events per year



Seep Sampling Stations



Seeps Sampling Methods

- Flow measured by 60°, 90° or 120° v-notch weir, or direct catch in small and low flow seeps
- Field parameters measured with YSI and Hach meters
- Water collected via grab sample
- Bottles placed on ice in coolers in the field
- Dissolved metals samples filtered by field team with 0.45 micron filter
- Samples transferred to Shaw for shipping to laboratories
 - Major Ions
 - Total and Dissolved Metals
 - TDS/TSS
 - Nutrients
 - Low Level Mercury
 - Cyanide
 - Organics



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Seeps Program Results

- pH generally near-neutral, range 2.3 – 8.6
- alkalinity range 4 - 70
- Seep temps range 0 – 8.13, usually <5 °C and colder than streams
- DO range 3 - 13 mg/L
- Seeps were generally characterized by low conductivity (0.02 - 0.13 mS/cm)
- Discharge range 0 – 2 cfs
- Measurable flow varies throughout the year
- Response to precip events varied



Seeps Program Results

- A few seeps have naturally elevated levels above the CALC:
 - Lead – 8 sites
 - Aluminum – 7 sites
 - Cadmium – 3 sites
 - Copper – 2 sites
 - Magnesium – 2 sites
 - Zinc – 2 sites
 - Nickel – 1 site



Ongoing Surface Water Program Activities

- Continue monthly stream sampling
- Identify stream segments with similar concentrations of naturally elevated analytes
- Identify time periods with similar concentrations of naturally elevated analytes
- Review seeps sampling program
- Examine water chemistry and data in conjunction with macroinvertebrate, periphyton, fisheries and other data collected at co-located sites
- Continue to make modifications to the program based on incoming data and project design changes



Thank you



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